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MC33232

Power Factor Controller

The MC33232 is the monolithic Integrated Circuit using the SMARTMOS® process as the new technology. And is active power factor controller specially design for use as off−line power converter application. This integrated circuit features an internal startup timer for stand−alone application, a one quadrant multiplier for near unity power factor, zero current detector to ensure critical condition operation, transconductance error amplifier, quickstart circuit for enhanced startup, trimmed internal bandgap reference, current sensing comparator, a totem pole output ideally suited for drive a power MOSFET, and a one shot−rigger circuit to eliminate a problem at the light loading.

Also included are protective features consisting of an overvoltage comparator to eliminate runaway output voltage due to removal, and a protect circuit to eliminate thermal runaway. This device is available in dual−in−line and surface mount plastic package.

Features

- One Shot−trigger Circuit to Eliminate a Problem at the Light Loading
- Overvoltage Comparator Eliminates Runaway Output Voltage
- Quickstart Circuit for Enhanced Startup
- Internal Startup Timer
- One Quadrant Multiplier
- Zero Current Detector
- Trimmed 2% Internal Bandgap Reference
- Totem Pole Output with High State Clamp
- Undervoltage Lockout with 6.0 V of Hysteresis
- Low Startup and Operating Current
- These are Pb−Free Devices

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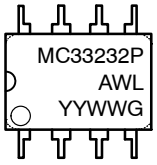
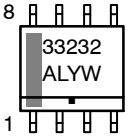
SILICON MONOLITHIC INTEGRATED CIRCUIT

MARKING DIAGRAMS

PDIP−8
P SUFFIX
CASE 626

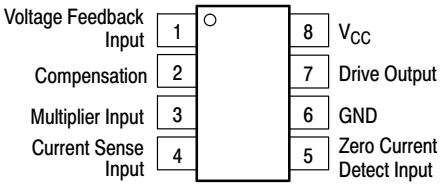


SOIC−8
D SUFFIX
CASE 751



A	=	Assembly Location
WL or L	=	Wafer Lot
Y	=	Year
WW or W	=	Work Week
G or ▪	=	Pb−Free Package

PIN ASSIGNMENT



ORDERING INFORMATION

See detailed ordering and shipping information in the package dimensions section on page 2 of this data sheet.

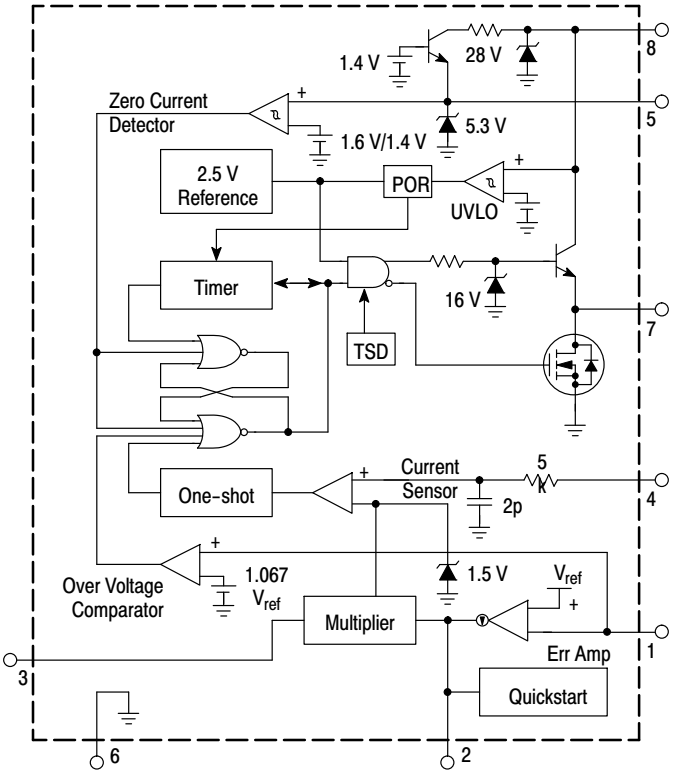


Figure 1. Simplified Block Diagram

ORDERING INFORMATION

Device	Operating Junction Temperature Range	Package	Shipping†
MC33232PG	−40°C to +150°C	PDIP−8 (Pb−Free)	50 Units / Rail
MC33232DG		SOIC−8 (Pb−Free)	98 Units / Rail
MC33232DR2G		SOIC−8 (Pb−Free)	2500 Tape & Reel

†For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specifications Brochure, BRD8011/D.

MAXIMUM RATINGS

Parameter	Symbol	Value	Unit
Total Power Supply and Zener Current	$(I_{CC} + I_Z)$	30	mA
Output Current, Source or Sink (Note 1) Peak Current (Under 0.5 μsec) DC (Continuously Current)	I_O	 750 300	mA
Current Sense, Multiplier and Voltage Feedback Input	V_{in}	−0.3 to 10	V
Zero Current Detect Input High State Forward Current Low State Reverse Current	I_{in}	 50 −10	mA
Power Dissipation and Thermal Characteristic D Suffix, Plastic Package, Case 751 Maximum Power Dissipation @ T_A = 70°C Thermal Resistance, Junction−to−Air P Suffix, Plastic Package, Case 626 Maximum Power Dissipation @ T_A = 70°C Thermal Resistance, Junction−to−Air	 P_D $R_{\theta JA}$ P_D $R_{\theta JA}$	 450 178 800 100	 mW °C/W mW °C/W
Operating Junction Temperature	T_J	+150	°C
Storage Temperature	T_{stg}	−55 to +150	°C

Stresses exceeding Maximum Ratings may damage the device. Maximum Ratings are stress ratings only. Functional operation above the Recommended Operating Conditions is not implied. Extended exposure to stresses above the Recommended Operating Conditions may affect device reliability.

1. Maximum package power dissipation limits must be observed.

RECOMMENDED OPERATING CONDITION (V_{CC} = 12 V and T_A = 25°C unless otherwise noted)

Characteristic	Symbol	Min	Typ	Max	Unit
Operating Frequency (R_{ZCD} = 4.7 kΩ, C_{err} = 0.68 μF)	F				MHz
Normal Loading			0.4		
Under Loading			1.0		
External Resistance for Zero Current Detect Control	R_{ZCD}	−	4.7	−	kΩ
Operating Ambient Temperature	T_A	−20	−	+85	°C

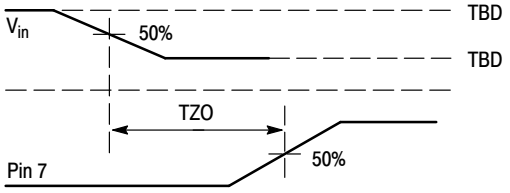
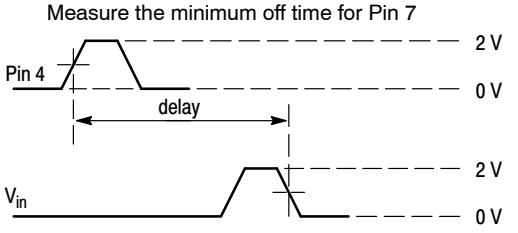
ELECTRICAL CHARACTERISTICS (V_{CC} = 12 V, for typical values T_A = −20°C ~ +85°C, unless otherwise noted)

Characteristic		Symbol	Min	Typ	Max	Unit
ERROR AMPLIFIER						
Voltage Feedback Input Threshold		V_{FB}				V
T_A = 25°C			2.465	2.5	2.535	
T_A = −20°C ~ +85°C (V_{CC} = 12 V ~ 25 V)			2.44	−	2.54	
Line Regulation	(V_{CC} = 12 V ~ 25 V, T_A = 25°C)	Reg_{line}	−	1.0	10	mV
Input Bias Current	(V_{FB} = 0 V)	I_{IB}	−	−0.1	−0.5	μA
Transconductance	(T_A = 25°C)	gm	80	100	130	μmho
Output Current	(V_{CC} = 12 V ~ 28 V, T_A = 25°C)					μA
Source	(V_{FB} = 2.3 V)	I_{source}	−	10	−	
Sink	(V_{FB} = 2.7 V)	I_{sink}	−	10	−	
Output Voltage Swing						V
High State	(V_{FB} = 2.3 V)	$V_{OH(ea)}$	5.8	6.2	−	
Low State	(V_{FB} = 2.7 V)	$V_{OL(ea)}$	−	1.7	2.4	
OVERVOLTAGE COMPARATOR						
Voltage Feedback Input Threshold		V_{TH}	1.04 V_{FB}	1.067 V_{FB}	1.095 V_{FB}	V
OVERTEMPERATURE PROTECT CIRCUIT (This item is just reference value without any specifying)						
Detect Temperature		TSD	120	−	−	°C

ELECTRICAL CHARACTERISTICS (V_{CC} = 12 V, for typical values T_A = −20°C ~ +85°C, unless otherwise noted)

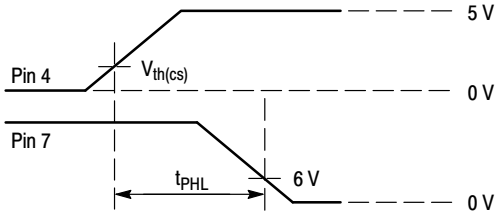
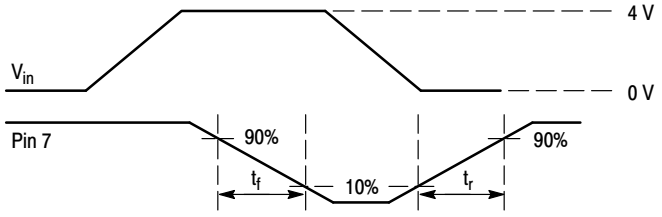
Characteristic		Symbol	Min	Typ	Max	Unit
MULTIPLIER						
Input Threshold	(Pin 2)	V_{thm}	1.05 V_{OL} (ea)	1.2 V_{OL} (ea)	–	V
Dynamic Input Voltage Range						V
Multiplier Input	(Pin 3)	Vpin 3	0 to 2.5	0 to 3.5	–	
Compensation	(Pin 2)	Vpin 2	V_{thm} to V_{thm} + 1.0	V_{thm} to V_{thm} + 1.5	–	
Input Bias Current, Pin 3	(V_{FB} = 0 V)	$I_{IB(mult)}$	–	−0.1	−0.5	μA
Multiplier Gain	(Vpin 3 = 0.5 V, Vpin 2 = V_{FB} + 1.0 V)	K	0.43	0.65	0.87	1/V
ZERO CURRENT DETECTOR						
Input Threshold Voltage (V_{in} Increasing)		$V_{th(ZCD)}$	1.33	1.6	1.87	V
Hysteresis (V_{in} Decreasing)		$V_{H(ZCD)}$	100	200	300	mV
Input Clamp Voltage	High State (I_{DET} = +3.0 mA)	V_{IH}	5.0	5.3	–	V
	Low State (I_{DET} = −3.0 mA)	V_{IL}	0.3	0.7	1.0	
Propagation Delay Time Zero Current Detect to Drive Out						nsec
	R_{ZCD} = 4.7 kΩ	TZO	–	100	200	
ONE SHOT TRIGGER						
Output Minimum Off Time		T_{OS}	500	–	850	nsec
CURRENT SENSE COMPARATOR						
Input Bias Current	(Vpin 4 = 0 V)	$I_{IB(cs)}$	–	−0.15	−1.0	μA
Input Offset Voltage	(Vpin 2 = 1.1 V, Vpin 3 = 0 V)	$V_{io(cs)}$	–	9.0	25	mV
Maximum Current Sense Input Threshold		V_{thmax}	1.3	1.5	1.8	V
Delay to Output		$t_{PHL(in/out)}$	–	100	200	nsec
DRIVE OUTPUT						
Output Voltage (V_{CC} = 12 V)						V
Low State	(I_{sink} = 20 mA)	V_{OL}	–	0.3	0.8	
	(I_{sink} = 200 mA)		–	2.4	3.3	
High State	(I_{source} = 20 mA)	V_{OH}	9.8	10.3	–	V
	(I_{source} = 200 mA)		7.8	8.4	–	
Output Voltage (V_{CC} = 25 V, I_{source} = 20 mA, C_L = 15 pF)		V_O	14	16	18	V
Output Voltage Rise Time	(C_L = 1.0 nF)	t_r	–	50	120	nsec
Output Voltage Fall Time	(C_L = 1.0 nF)	t_f	–	50	120	nsec
Output Voltage with UVLO Active (V_{CC} = 7.0 V, I_{sink} = 1.0 mA)		$V_{O(UVLO)}$	–	0.1	0.5	V
RESTART TIMER						
Restart Time Delay		tDLY	200	900	–	μsec
Restart Time at Startup		POR	0	25	–	μsec
UNDER VOLTAGE LOCKOUT (Metal Option Version)						
Startup Threshold (V_{CC} Increasing)		$V_{th(on)}$	14.4	16	17.6	V
Minimum Operating Voltage After Turn−off (V_{CC} Decreasing)		V_{shut}	9.0	10	11	V
Hysteresis		V_H	3.5	6.0	8.6	V
TOTAL DEVICE						
Power Supply Current	Startup (V_{CC} = 7.0 V)	I_{CC}	–	0.05	0.1	mA
	Operating		–	6.5	12	
	Dynamic Operating (50 KHz, C_L = 1.0 nF)		–	9.0	20	
Power Supply Zener Voltage (I_{CC} = 25 mA)		VZ	26	28	–	V

MEASUREMENT CONDITION Note: Test conditions follow the test circuit diagram unless otherwise noted (See last page)

Item	Condition		Measurement Method
V_{FB}		Pin 1 = Pin 2	Measure Pin 1 voltage when connect Pin 1 and Pin 2
V_{FB2}	SW1 = B		
Regline			Regline = $V_{FB2} - V_{FB}$
$I_{IB(err)}$	Pin 1 = 0 V		Measure Pin 1 current
gm	Pin 2 = 2.0 V Pin 2 current (Ipin2) @ Pin 1 = 2.55 Pin 2 current (Ipin2) @ Pin 1 = 2.45		$gm = \frac{(Ipin2 - I'pin2)}{(2.55 - 2.45)}$
I_{source}	Pin 1 = 2.3 V	SW1 = A&B Pin 2 = 2.0 V	Measure Pin 2 output current
I_{sink}	Pin 1 = 2.7 V		
$V_{OH(ea)}$	Pin 1 = 2.3 V		Measure Pin 2 voltage
$V_{OL(ea)}$	Pin 1 = 2.7 V		
V_{th}	V_{in} = Ref.1 Pin 4 = GND	Pin 2 = 4.0 V Pin 3 = 2.0 V	Measure Pin 1 voltage when Pin 7 switch to low by increasing Pin 1 voltage from 0 V
$V_{th(mult)}$	V_{in} = Ref.1 Pin 1 = 0 V	Pin 4 = 0.015 V Pin 3 = 0.5 V	Measure Pin 2 voltage when Pin 7 switch to low by decreasing Pin 2 voltage from 2.5 V
Vpin3 Vpin2	V_{in} = Ref.1 Pin 2 = $V_{th(mult)}$ Measure Pin 4 voltage when Pin 7 switch to low with each Pin 3 condition A: @ Pin 3 = 0 V B: @ Pin 3 = 1.25 V C: @ Pin 3 = 2.5 V		$\alpha = \frac{C}{A} \times \frac{0.77}{1.67} + A$ $25\% \cdot \left\|\frac{B - \alpha}{C - A}\right\| \times 100$ Measure the A, B and C with the condition and calculate the linearity of the multiplier
$I_{IB(mult)}$	Pin 1, 3 = 0 V	Pin 2 = 1.1 V	Measure Pin 3 current
K	Pin 1 = 0 V Pin 2 = $V_{th(mult)}$ + 1 V	Pin 3 = 0.5 V V_{in} = Ref.1	Measure V_{thp4} as Pin 4 voltage when Pin 7 switch to low by increasing Pin 4 voltage from 0 V and calculate by the following equation. K = V_{thp4} / 0.50
$V_{th(ZCD)}$	V_{in} = Ref.1	Pin 1 = 0 V Pin 2 = 3.0 V Pin 3 = 0.5 V Pin 4 = GND	Measure Pin 5 voltage when Pin 7 switch to low by increasing V_{in} voltage from 0 V
V_H			Measure V_{th2} as Pin 5 voltage when Pin 7 switch to low by increasing V_{in} voltage from 4 V and calculate V_H by the following equation. $V_H = V_{th(zero)} - V_{th2}$
TZO	SW3 = ON		
TZO2	SW2 = B		Measure the propagation delay time from V_{in} to Pin 7 
TOS	V_{in} = Ref.1 Pin 3 = 0.5 V Delay: 500 nSec ~ 700 nSec	Pin 1 = 0 V	Measure the minimum off time for Pin 7 

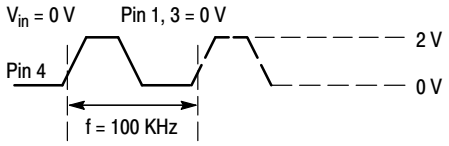
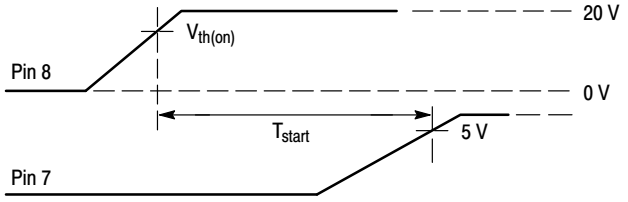
Ref.1: Pin 4 = GND, V_{in} = 4 V return to zero pulse

MEASUREMENT CONDITION

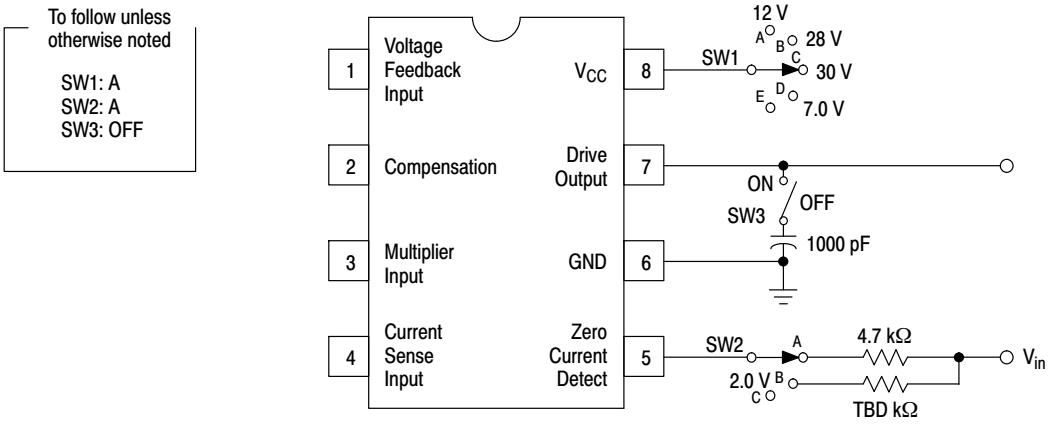
Item	Condition		Measurement Method
$V_{IH(ZCD)}$	Pin 1 = 0 V	Pin 5 = 3 mA	Measure Pin 5 voltage at 3 mA to Pin 5
$V_{IL(ZCD)}$	Pin 2 = 1.1 V	Pin 5 = −3 mA	Measure Pin 5 voltage at −3 mA to Pin 5
$I_{IB(CS)}$		Pin 4 = 0 V	Measure Pin 4 current
$V_{IO(CS)}$		Pin 3 = 0 V V_{in} = Ref.1	Measure Pin 4 voltage when Pin 7 switch to low by increasing Pin 4 voltage from −0.3 V
t_{PHL}	Pin 1 = 0 V Pin 2 = $V_{th(mult)}$ + 0.5 V Pin 3 = 0.5 V Pin 4 = See right figure V_{in} = Ref.1 $V_{th(cs)}$: Threshold voltage of Pin 4 (at Pin 2 = $V_{th(mult)}$ + 0.5 V, Pin 3 = 0.5 V)		
$V_{th(max)}$	Pin 1 = 0 V Pin 2 = 4.0 V	Pin 3 = 3.0 V V_{in} = Ref.1	Measure Pin 4 voltage when Pin 7 switch to low by increasing Pin 4 voltage from 0 V
$V_{OL(OUT)}$	Pin 1 = 0 V SW2 = C	Pin 7 = 20 mA	Measure Pin 7 voltage at 20 mA to Pin 7
		Pin 7 = 200 mA	Measure Pin 7 voltage at 200 mA to Pin 7
$V_{OH(OUT)}$	Pin 1 = 0 V Pin 4 = GND	Pin 7 = −20 mA	Measure Pin 7 voltage at −20 mA to Pin 7
		Pin 7 = −200 mA	Measure Pin 7 voltage at −200 mA to Pin 7
$V_{O(max)}$	V_{in} = Ref.1	SW1 = C Pin 7 = −20 mA	Measure Pin 7 voltage at −20 mA to Pin 7
t_r t_f	Pin 1, 4 = 0 V SW3 = ON V_{in} = See right figure f = 50 KHz		
$V_{O(UVLO)}$	Pin 1 = 0 V SW1 = D	Pin 7 = 1.0 mA	Measure Pin 7 voltage at 10 mA to Pin 7
$V_{th(ON)}$	SW1 = E		Measure Pin 8 voltage when Pin 2 change to over 1 V by increasing Pin 8 voltage from 7 V
V_{shut}	Pin 4 = 0 V		Measure Pin 8 voltage when Pin 2 change to under 1 V by increasing Pin 8 voltage from 15 V
V_H	V_{in} = 0 V		$V_H = V_{th(on)} - V_{shut}$

I_{CC} Startup	Pin 1 = 0 V	SW1 = D	Measure Pin 8 current
Operating			Measure Pin 8 current
Dynamic Operating	Pin 1 = 0 V	Pin 4 = 0 V Pin 2 = 2.5 V SW3 = ON Pin 3 = 0.5 V V_{in}: Low = 0 V, High = 4 V f_{in} = Square Wave @ TBD KHz	

Ref.1: Pin 4 = GND, V_{in} = 4 V return to zero pulse

Item	Condition	Measurement Method
V_Z	SW1 = E Pin 5 = 2.0 V Pin 8 = 25 mA Pin 1, 4 = 0 V	Measure Pin 8 voltage
t_{DLY}		Measure Pin 7 frequency (FPin 7) t_{DLY} = 1 / FPin 7
POR	SW1 = E Pin 4 = 0 V V_{in} = 0 V	 POR = T_{start} – t_{DLY}

TEST CIRCUIT



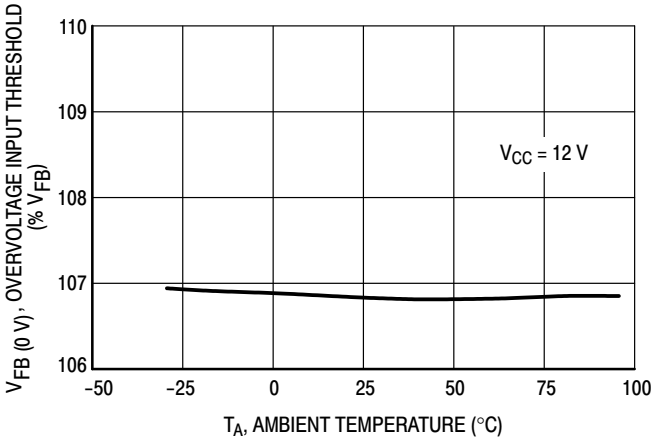


Figure 2. Overvoltage Comparator Input Threshold versus Temperature

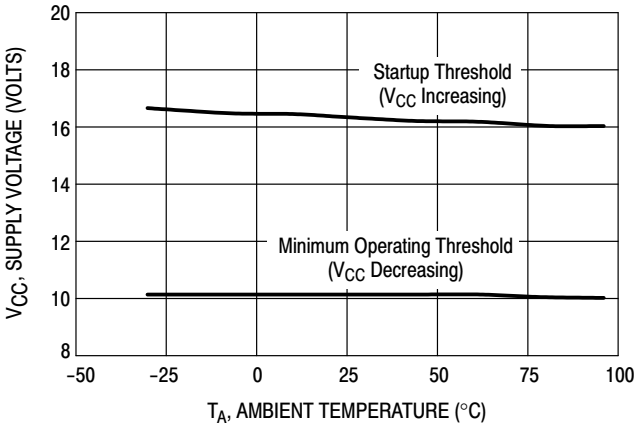


Figure 3. Undervoltage Lockout Thresholds versus Temperature

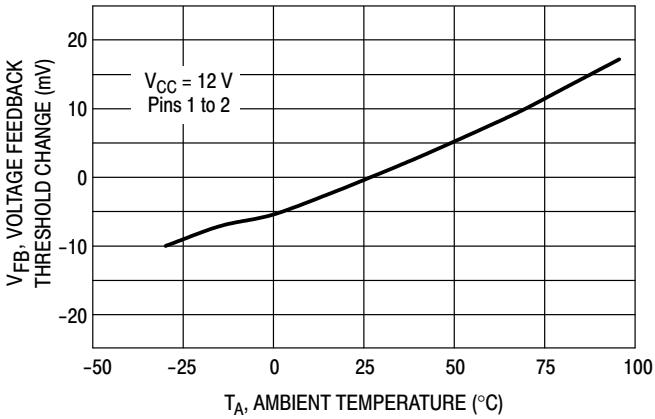


Figure 4. Voltage Feedback Input Threshold Change versus Temperature

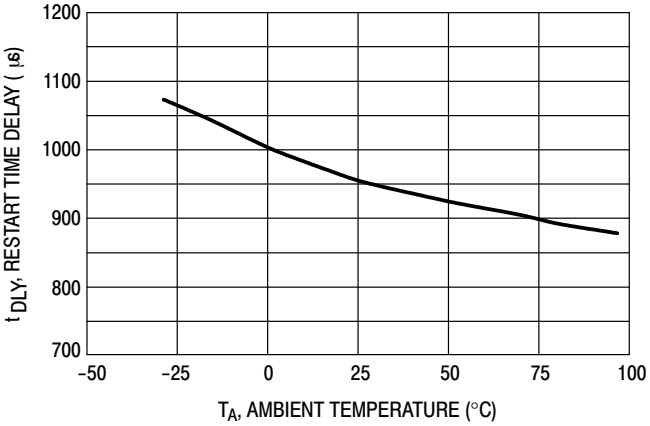


Figure 5. Restart Timer Delay versus Temperature

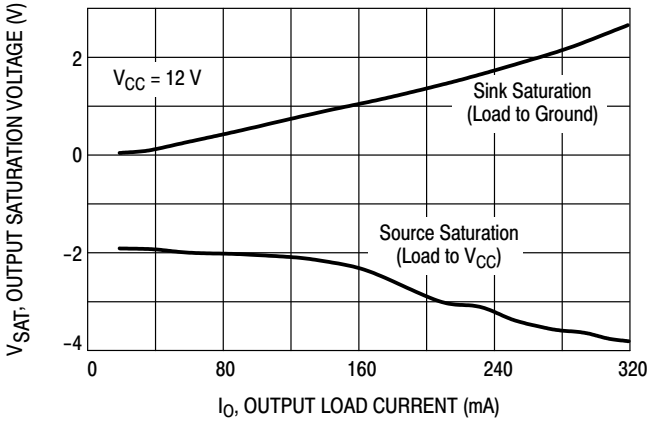


Figure 6. Output Saturation Voltage versus Load Current

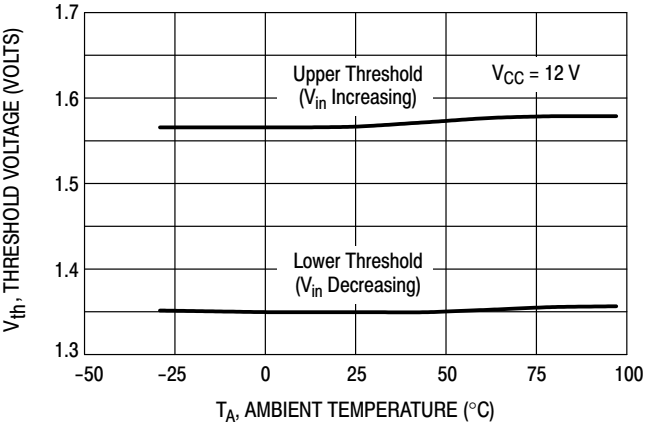


Figure 7. Zero Current Detector Input Threshold versus Temperature

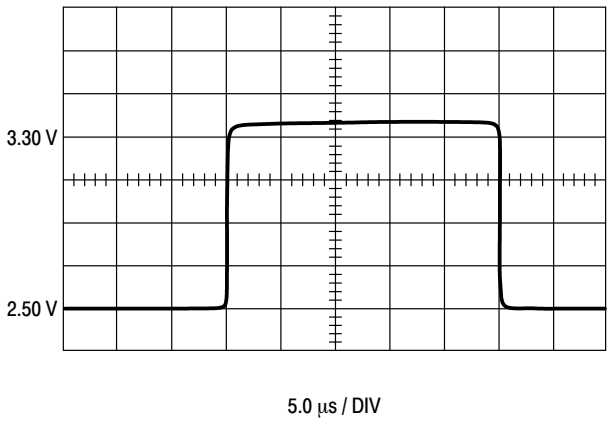


Figure 8. Error Amp Transient Response

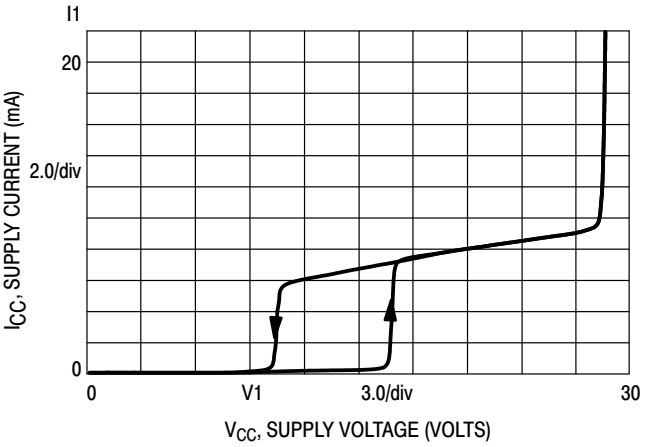


Figure 9. Supply Current versus Supply Voltage

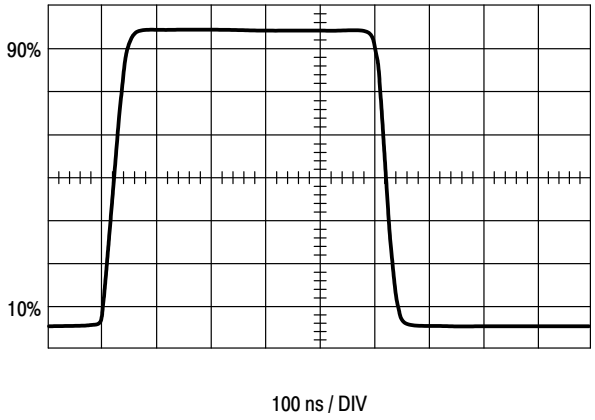


Figure 10. Drive Output Waveform

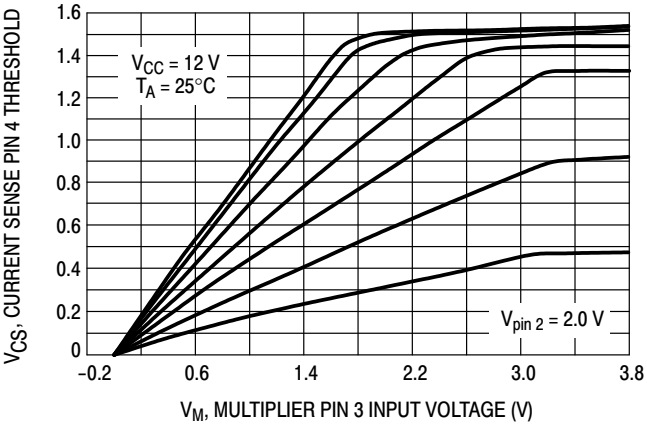


Figure 11. Restart Timer Delay versus Temperature

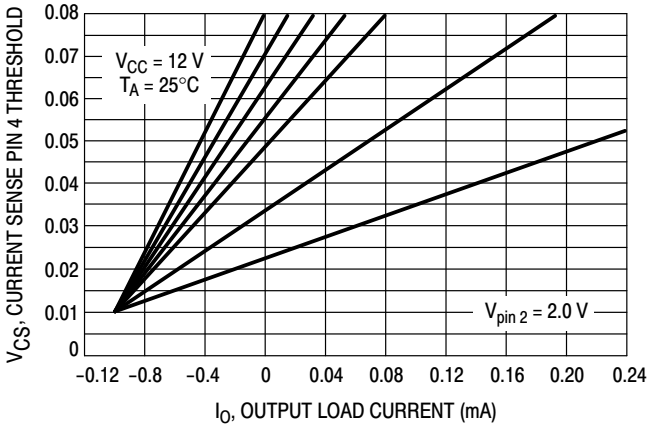
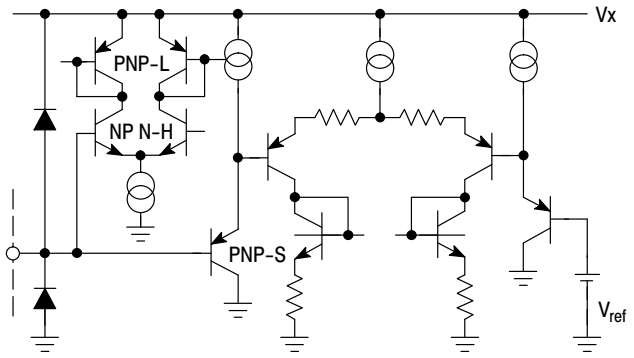
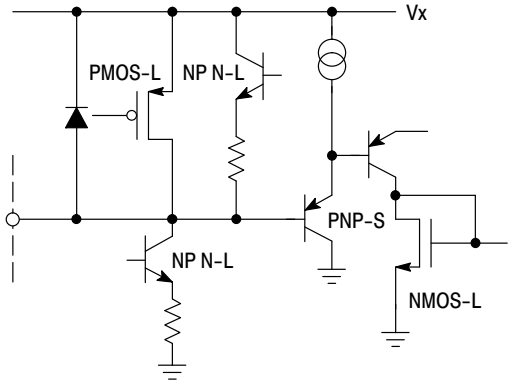
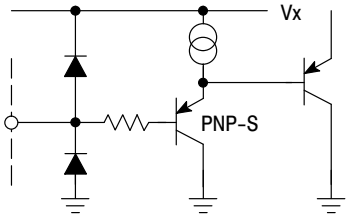
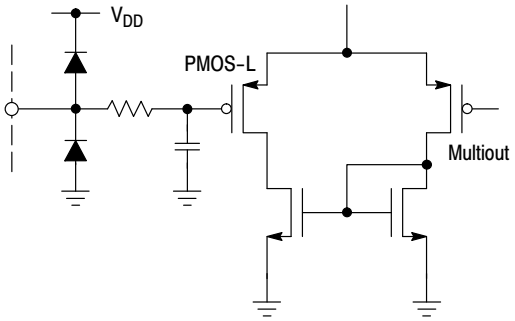
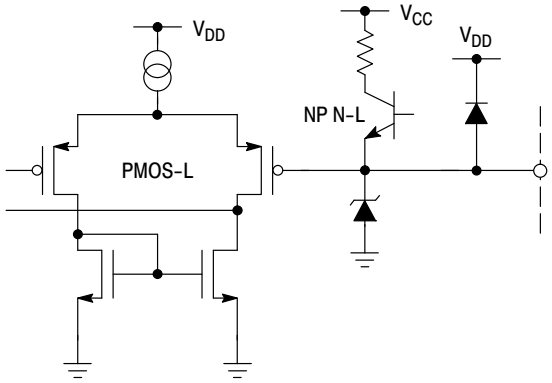
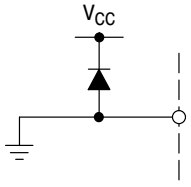
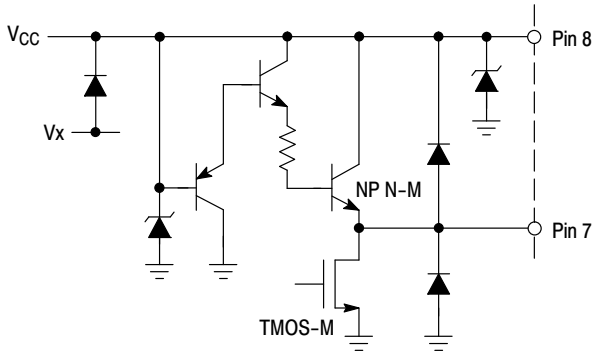


Figure 12. Current Sense Input Threshold versus Multiplier Input (Expanded View)

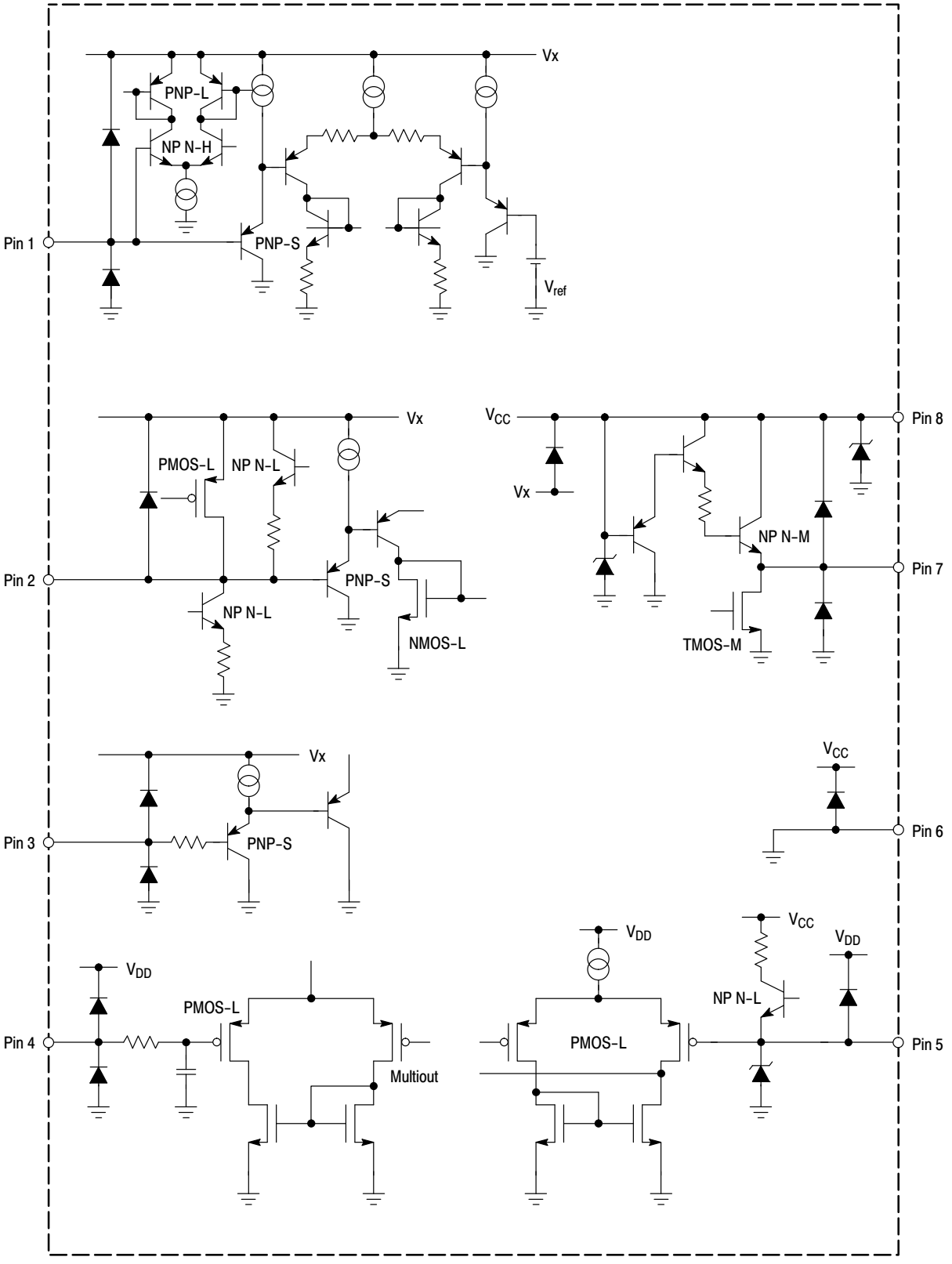
PIN FUNCTION DESCRIPTION

Name	Pin No.	Equivalent Circuit	Function
V_{FB}	1		Voltage Feedback Input This pin is an input for error amplifier to feedback the voltage from the converter output. Have the overvoltage detect circuit to cut off the drive out when the voltage is over 8% from setting value.
COMP	2		Error Amplifier Output/Compensation This pin is an error amplifier output. Can do phase compensation or gain adjustment by this pin.
Mult	3		Multiplier Input Monitor the AC off line voltage using this input.
CS	4		Current Sense Input Control the output voltage by sensing the overcurrent at each cycle. This pin connects the RC filter and 1.5 V clamp diode.

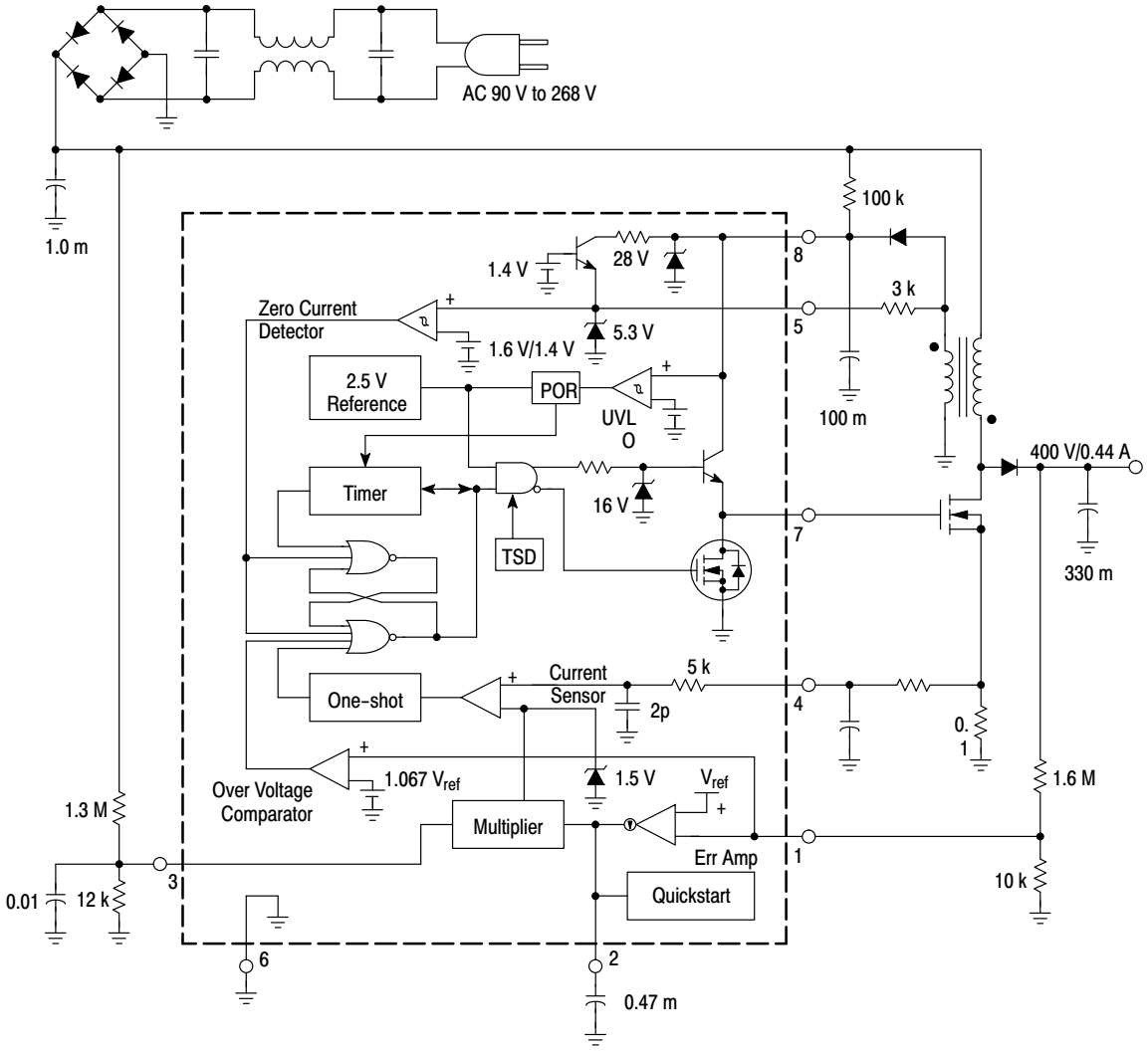
PIN FUNCTION DESCRIPTION

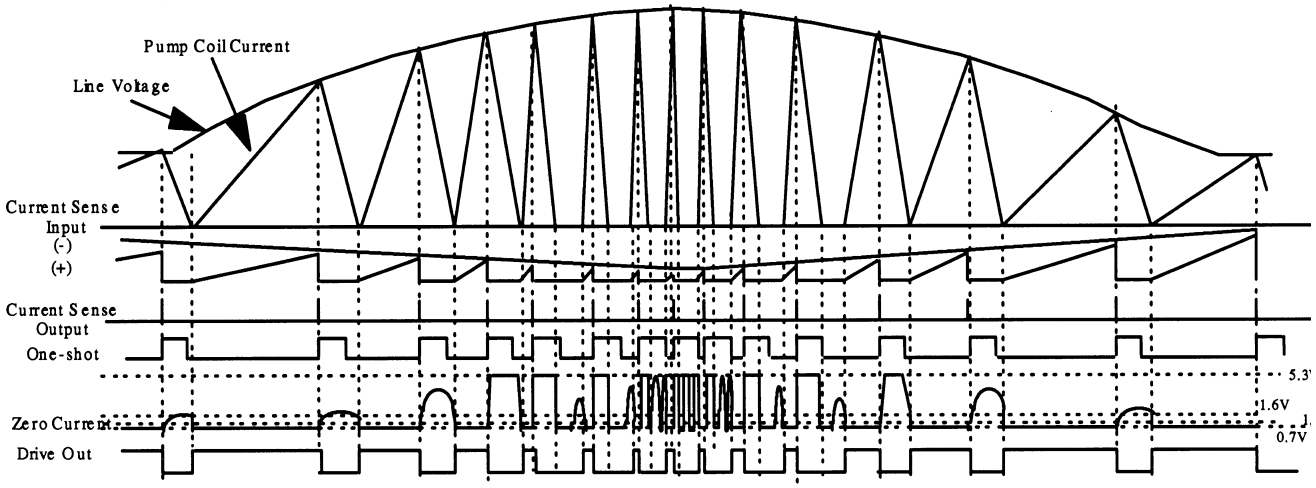
Name	Pin No.	Equivalent Circuit	Function
ZCD	5		Zero Current Detect Input Control the output ON point to detect the zero current point on the coil. This pin has the 0.7 V and 5.3 V clamp diode internal.
GND	6		Ground
Output	7		Drive Out Totem pole output.
V_{CC}	8		Power Supply

INTERNAL EQUIVALENT CIRCUIT



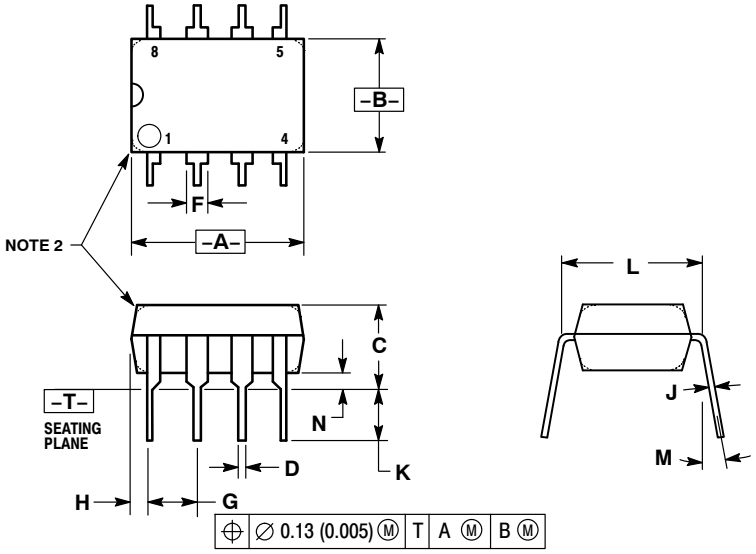
SUGGESTED APPLICATION CIRCUIT





PACKAGE DIMENSIONS

PDIP−8
P SUFFIX
CASE 626−05
ISSUE L

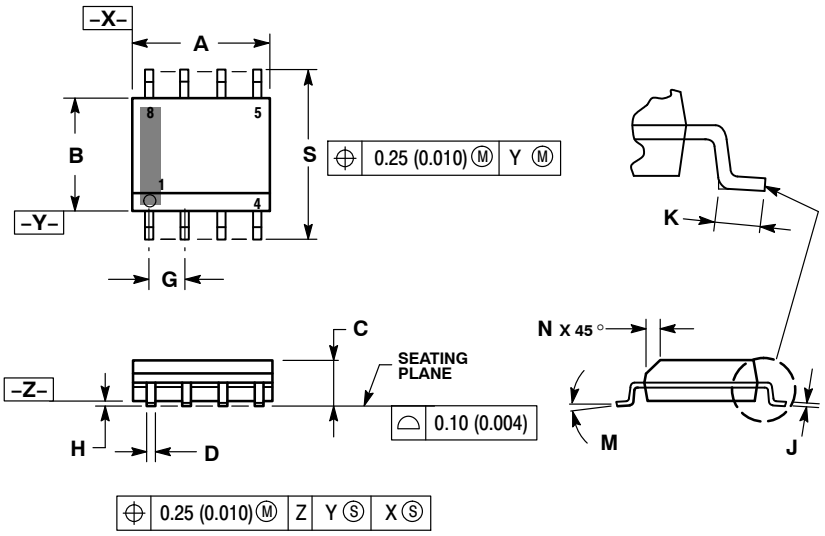


NOTES:
1. DIMENSION L TO CENTER OF LEAD WHEN FORMED PARALLEL.
2. PACKAGE CONTOUR OPTIONAL (ROUND OR SQUARE CORNERS).
3. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.

	MILLIMETERS		INCHES	
DIM	MIN	MAX	MIN	MAX
A	9.40	10.16	0.370	0.400
B	6.10	6.60	0.240	0.260
C	3.94	4.45	0.155	0.175
D	0.38	0.51	0.015	0.020
F	1.02	1.78	0.040	0.070
G	2.54 BSC		0.100 BSC	
H	0.76	1.27	0.030	0.050
J	0.20	0.30	0.008	0.012
K	2.92	3.43	0.115	0.135
L	7.62 BSC		0.300 BSC	
M	---	10°	---	10°
N	0.76	1.01	0.030	0.040

PACKAGE DIMENSIONS

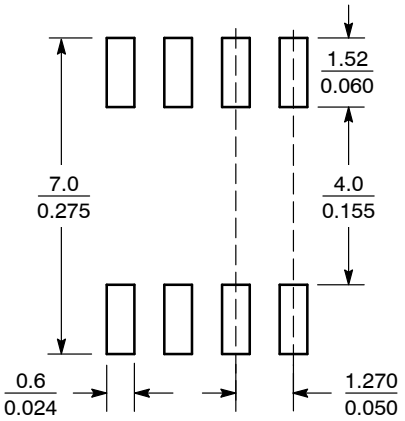
SOIC−8
D SUFFIX
CASE 751−07
ISSUE AJ



NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.
3. DIMENSION A AND B DO NOT INCLUDE MOLD PROTRUSION.
4. MAXIMUM MOLD PROTRUSION 0.15 (0.006) PER SIDE.
5. DIMENSION D DOES NOT INCLUDE DAMBAR PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.127 (0.005) TOTAL IN EXCESS OF THE D DIMENSION AT MAXIMUM MATERIAL CONDITION.
6. 751−01 THRU 751−06 ARE OBSOLETE. NEW STANDARD IS 751−07.

	MILLIMETERS		INCHES	
DIM	MIN	MAX	MIN	MAX
A	4.80	5.00	0.189	0.197
B	3.80	4.00	0.150	0.157
C	1.35	1.75	0.053	0.069
D	0.33	0.51	0.013	0.020
G	1.27 BSC		0.050 BSC	
H	0.10	0.25	0.004	0.010
J	0.19	0.25	0.007	0.010
K	0.40	1.27	0.016	0.050
M	0 °	8 °	0 °	8 °
N	0.25	0.50	0.010	0.020
S	5.80	6.20	0.228	0.244

SOLDERING FOOTPRINT*



SCALE 6:1 $\left(\frac{\text{mm}}{\text{inches}}\right)$

*For additional information on our Pb−Free strategy and soldering details, please download the ON Semiconductor Soldering and Mounting Techniques Reference Manual, SOLDERRM/D.

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