LM358S, LM2904S

Single Supply Dual Operational Amplifiers

Utilizing the circuit designs perfected for Quad Operational Amplifiers, these dual operational amplifiers feature low power drain, a common mode input voltage range extending to ground/V_{EE}, and single supply or split supply operation. The LM358S and LM2904S are half of the LM324S and LM2902S, respectively.

These amplifiers have several distinct advantages over standard operational amplifier types in single supply applications. The common mode input range includes the negative supply, thereby eliminating the necessity for external biasing components in many applications. The output voltage range also includes the negative power supply voltage.

Features

- Short Circuit Protected Outputs
- True Differential Input Stage
- Single Supply Operation: 3.0 V to 32 V
- Low Input Bias Currents
- Internally Compensated
- Common Mode Range Extends to Negative Supply
- Single and Split Supply Operation
- These Devices are Pb−Free, Halogen Free/BFR Free and are RoHS Compliant

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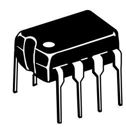
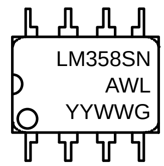
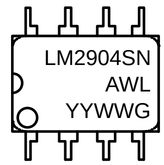
MARKING DIAGRAMS



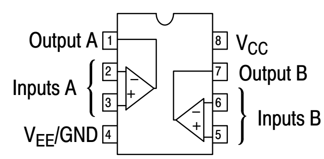
PDIP−8
N SUFFIX
CASE 626





LMxxxx = Specific Device Code
A, AL = Assembly Location
WL = Wafer Lot
Y, YY = Year
W, WW = Work Week
G or ▪ = Pb−Free Package

PIN CONNECTIONS



(Top View)

ORDERING INFORMATION

See detailed ordering and shipping information on page 8 of this data sheet.

Single Supply **Split Supplies**

Figure 1.

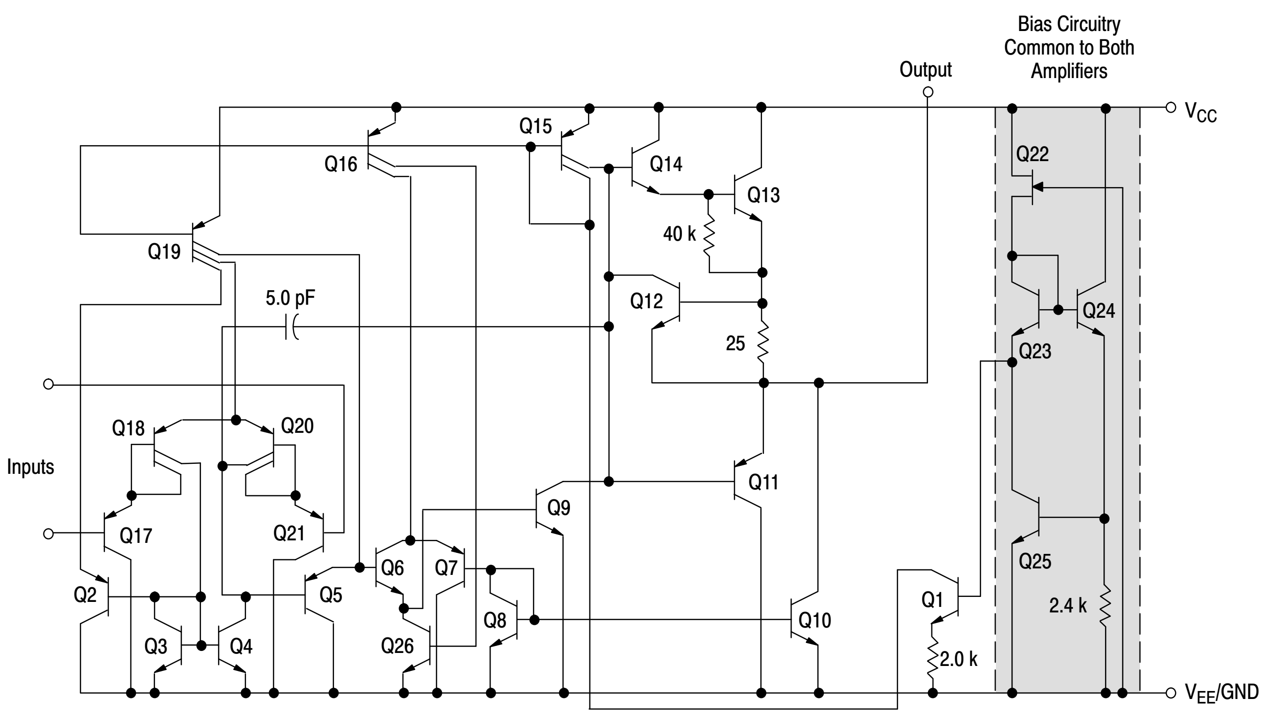


Figure 2. Representative Schematic Diagram
(One−Half of Circuit Shown)

MAXIMUM RATINGS (T_A = +25°C, unless otherwise noted.)

Rating		Symbol	Value	Unit
Power Supply Voltages				Vdc
	Single Supply	V_{CC}	32	
	Split Supplies	V_{CC}, V_{EE}	±16	
Input Differential Voltage Range (Note 1)		V_{IDR}	±32	Vdc
Input Common Mode Voltage Range (Note 2)		V_{ICR}	−0.3 to 32	Vdc
Output Short Circuit Duration		t_{SC}	Continuous	
Junction Temperature		T_J	150	°C
Thermal Resistance, Junction−to−Air (Note 3)	Case 626	$R_{\theta JA}$	161	°C/W
Storage Temperature Range		T_{stg}	−65 to +150	°C
Operating Ambient Temperature Range		T_A		°C
	LM358S		0 to +70	
	LM2904S		−40 to +105	

Stresses exceeding those listed in the Maximum Ratings table may damage the device. If any of these limits are exceeded, device functionality should not be assumed, damage may occur and reliability may be affected.

1. Split Power Supplies.
2. For supply voltages less than 32 V the absolute maximum input voltage is equal to the supply voltage.
3. All $R_{\theta JA}$ measurements made on evaluation board with 1 oz. copper traces of minimum pad size. All device outputs were active.

ELECTRICAL CHARACTERISTICS (V_{CC} = 5.0 V, V_{EE} = GND, T_A = 25°C, unless otherwise noted.)

Characteristic	Symbol	LM358S			Unit
		Min	Typ	Max	
Input Offset Voltage V_{CC} = 5.0 V to 30 V, V_{IC} = 0 V to V_{CC} −1.7 V, $V_O \simeq$ 1.4 V, R_S = 0 Ω	V_{IO}				mV
T_A = 25°C		−	2.0	7.0	
$T_A = T_{high}$ (Note 4)		−	−	9.0	
$T_A = T_{low}$ (Note 4)		−	−	9.0	
Average Temperature Coefficient of Input Offset Voltage $T_A = T_{high}$ to T_{low} (Note 4)	$\Delta V_{IO}/\Delta T$	−	7.0	−	μV/°C
Input Offset Current	I_{IO}	−	5.0	50	nA
$T_A = T_{high}$ to T_{low} (Note 4)		−	−	150	
Input Bias Current	I_{IB}	−	−45	−250	nA
$T_A = T_{high}$ to T_{low} (Note 4)		−	−50	−500	
Average Temperature Coefficient of Input Offset Current $T_A = T_{high}$ to T_{low} (Note 4)	$\Delta I_{IO}/\Delta T$	−	10	−	pA/°C
Input Common Mode Voltage Range (Note 5), V_{CC} = 30 V	V_{ICR}	0	−	28.3	V
V_{CC} = 30 V, $T_A = T_{high}$ to T_{low}		0	−	28	
Differential Input Voltage Range	V_{IDR}	−	−	V_{CC}	V
Large Signal Open Loop Voltage Gain	A_{VOL}				V/mV
R_L = 2.0 kΩ, V_{CC} = 15 V, For Large V_O Swing,		25	100	−	
$T_A = T_{high}$ to T_{low} (Note 4)		15	−	−	
Channel Separation 1.0 kHz ≤ f ≤ 20 kHz, Input Referenced	CS	−	−120	−	dB
Common Mode Rejection R_S ≤ 10 kΩ	CMR	65	70	−	dB
Power Supply Rejection	PSR	65	100	−	dB
Output Voltage−High Limit	V_{OH}				V
V_{CC} = 5.0 V, R_L = 2.0 kΩ, T_A = 25°C		3.3	3.5	−	
V_{CC} = 30 V, R_L = 2.0 kΩ, $T_A = T_{high}$ to T_{low} (Note 4)		26	−	−	
V_{CC} = 30 V, R_L = 10 kΩ, $T_A = T_{high}$ to T_{low} (Note 4)		27	28	−	
Output Voltage−Low Limit V_{CC} = 5.0 V, R_L = 10 kΩ, $T_A = T_{high}$ to T_{low} (Note 4)	V_{OL}	−	5.0	20	mV
Output Source Current	I_O +				mA
V_{ID} = +1.0 V, V_{CC} = 15 V		20	45	−	
Output Sink Current	I_O −				
V_{ID} = −1.0 V, V_{CC} = 15 V		10	30	−	mA
V_{ID} = −1.0 V, V_O = 200 mV		12	40	−	μA
Output Short Circuit to Ground (Note 6)	I_{SC}	−	45	60	mA
Power Supply Current (Total Device) $T_A = T_{high}$ to T_{low} (Note 4)	I_{CC}				mA
V_{CC} = 30 V, V_O = 0 V, R_L = ∞		−	0.5	3.0	
V_{CC} = 5 V, V_O = 0 V, R_L = ∞		−	0.3	1.2	

Product parametric performance is indicated in the Electrical Characteristics for the listed test conditions, unless otherwise noted. Product performance may not be indicated by the Electrical Characteristics if operated under different conditions.

4. LM358S: T_{low} = 0°C, T_{high} = +70°C
   LM2904S: T_{low} = −40°C, T_{high} = +105°C
5. The input common mode voltage or either input signal voltage should not be allowed to go negative by more than 0.3 V. The upper end of the common mode voltage range is V_{CC} − 1.7 V.
6. Short circuits from the output to V_{CC} can cause excessive heating and eventual destruction. Destructive dissipation can result from simultaneous shorts on all amplifiers.

ELECTRICAL CHARACTERISTICS (V_{CC} = 5.0 V, V_{EE} = GND, T_A = 25°C, unless otherwise noted.)

Characteristic	Symbol	LM2904S Min	LM2904S Typ	LM2904S Max	Unit
Input Offset Voltage V_{CC} = 5.0 V to 30 V, V_{IC} = 0 V to V_{CC} −1.7 V, V_O ≃ 1.4 V, R_S = 0 Ω T_A = 25°C T_A = T_{high} (Note 7) T_A = T_{low} (Note 7)	V_{IO}	 – – –	 2.0 – –	 7.0 10 10	mV
Average Temperature Coefficient of Input Offset Voltage T_A = T_{high} to T_{low} (Note 7)	$\Delta V_{IO}/\Delta T$	–	7.0	–	μV/°C
Input Offset Current T_A = T_{high} to T_{low} (Note 7)	I_{IO}	– –	5.0 45	50 200	nA
Input Bias Current T_A = T_{high} to T_{low} (Note 7)	I_{IB}	– –	−45 −50	−250 −500	nA
Average Temperature Coefficient of Input Offset Current T_A = T_{high} to T_{low} (Note 7)	$\Delta I_{IO}/\Delta T$	–	10	–	pA/°C
Input Common Mode Voltage Range (Note 8), V_{CC} = 30 V V_{CC} = 30 V, T_A = T_{high} to T_{low}	V_{ICR}	 0 0	 – –	 28.3 28	V
Differential Input Voltage Range	V_{IDR}	–	–	V_{CC}	V
Large Signal Open Loop Voltage Gain R_L = 2.0 kΩ, V_{CC} = 15 V, For Large V_O Swing, T_A = T_{high} to T_{low} (Note 7)	A_{VOL}	 25 15	 100 –	 – –	V/mV
Channel Separation 1.0 kHz ≤ f ≤ 20 kHz, Input Referenced	CS	–	−120	–	dB
Common Mode Rejection R_S ≤ 10 kΩ	CMR	50	70	–	dB
Power Supply Rejection	PSR	50	100	–	dB
Output Voltage−High Limit V_{CC} = 5.0 V, R_L = 2.0 kΩ, T_A = 25°C V_{CC} = 30 V, R_L = 2.0 kΩ, T_A = T_{high} to T_{low} (Note 7) V_{CC} = 30 V, R_L = 10 kΩ, T_A = T_{high} to T_{low} (Note 7)	V_{OH}	 3.3 26 27	 3.5 – 28	 – – –	V
Output Voltage−Low Limit V_{CC} = 5.0 V, R_L = 10 kΩ, T_A = T_{high} to T_{low} (Note 7)	V_{OL}	–	5.0	20	mV
Output Source Current V_{ID} = +1.0 V, V_{CC} = 15 V	I_{O+}	20	45	–	mA
Output Sink Current V_{ID} = −1.0 V, V_{CC} = 15 V V_{ID} = −1.0 V, V_O = 200 mV	I_{O-}	 10 –	 30 –	 – –	 mA μA
Output Short Circuit to Ground (Note 9)	I_{SC}	–	45	60	mA
Power Supply Current (Total Device) T_A = T_{high} to T_{low} (Note 7) V_{CC} = 30 V, V_O = 0 V, R_L = ∞ V_{CC} = 5 V, V_O = 0 V, R_L = ∞	I_{CC}	 – –	 0.5 0.3	 3.0 1.2	mA

Product parametric performance is indicated in the Electrical Characteristics for the listed test conditions, unless otherwise noted. Product performance may not be indicated by the Electrical Characteristics if operated under different conditions.

7. LM358S: T_{low} = 0°C, T_{high} = +70°C
   LM2904S: T_{low} = −40°C, T_{high} = +105°C
8. The input common mode voltage or either input signal voltage should not be allowed to go negative by more than 0.3 V. The upper end of the common mode voltage range is V_{CC} − 1.7 V.
9. Short circuits from the output to V_{CC} can cause excessive heating and eventual destruction. Destructive dissipation can result from simultaneous shorts on all amplifiers.

CIRCUIT DESCRIPTION

The LM358S and LM2904S are made using two internally compensated, two−stage operational amplifiers. The first stage of each consists of differential input devices Q20 and Q18 with input buffer transistors Q21 and Q17 and the differential to single ended converter Q3 and Q4. The first stage performs not only the first stage gain function but also performs the level shifting and transconductance reduction functions. By reducing the transconductance, a smaller compensation capacitor (only 5.0 pF) can be employed, thus saving chip area. The transconductance reduction is accomplished by splitting the collectors of Q20 and Q18. Another feature of this input stage is that the input common mode range can include the negative supply or ground, in single supply operation, without saturating either the input devices or the differential to single−ended converter. The second stage consists of a standard current source load amplifier stage.

Each amplifier is biased from an internal−voltage regulator which has a low temperature coefficient thus giving each amplifier good temperature characteristics as well as excellent power supply rejection.

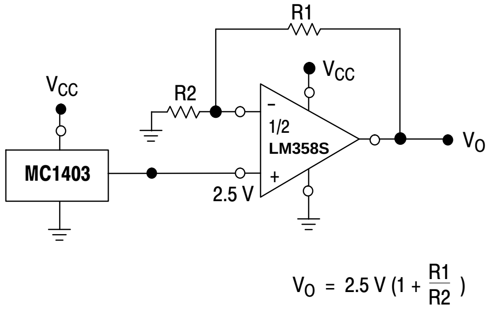


Figure 3. Voltage Reference

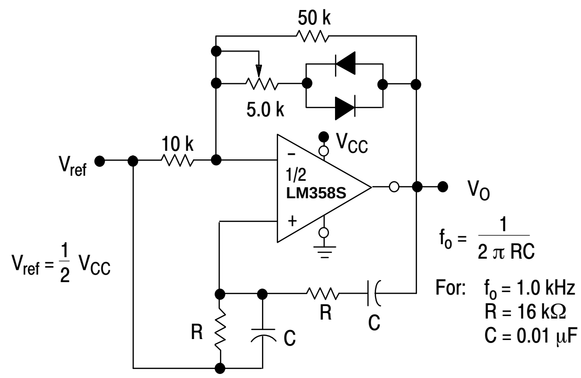


Figure 4. Wien Bridge Oscillator

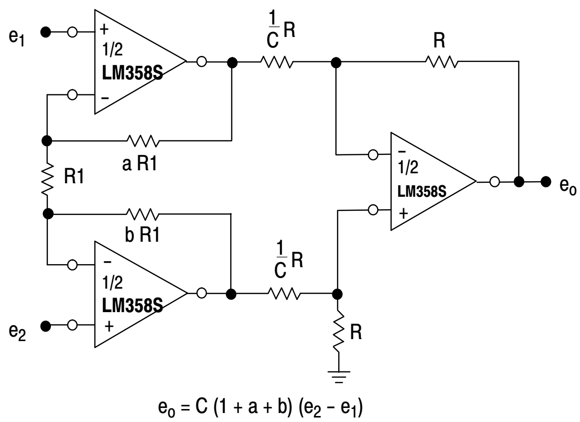


Figure 5. High Impedance Differential Amplifier

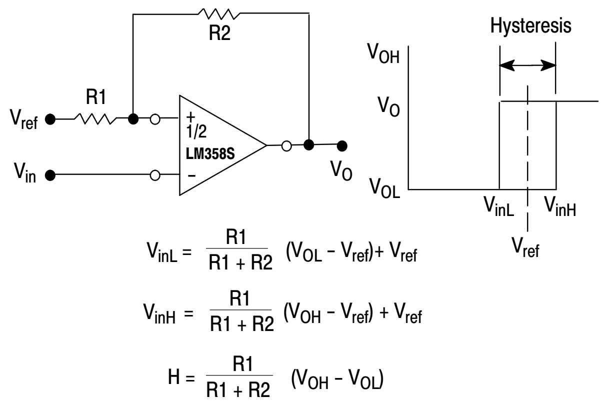


Figure 6. Comparator with Hysteresis

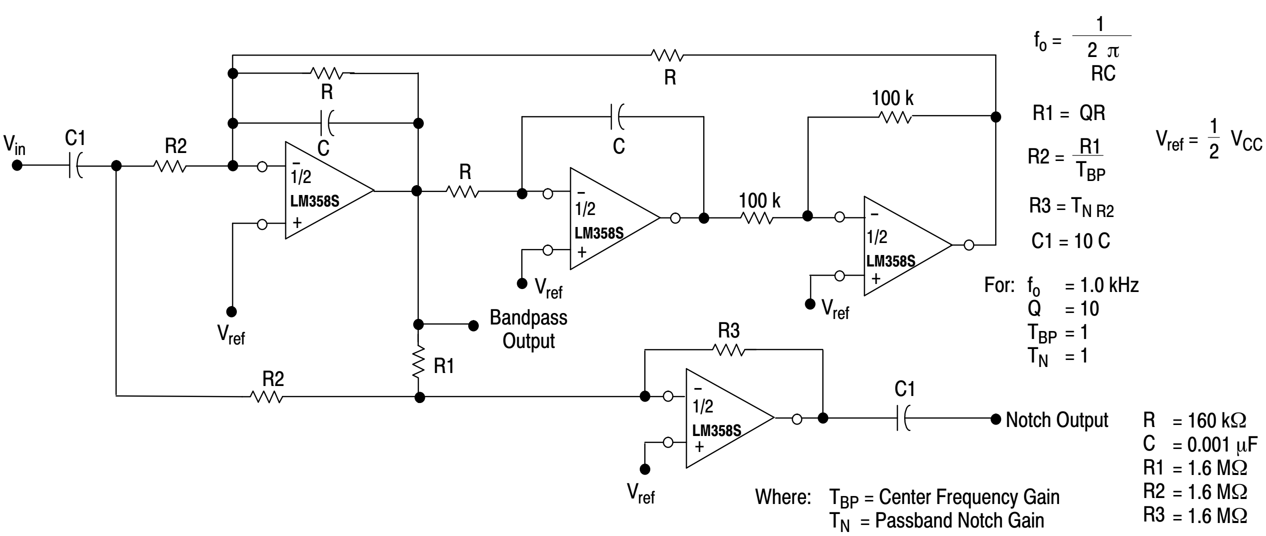
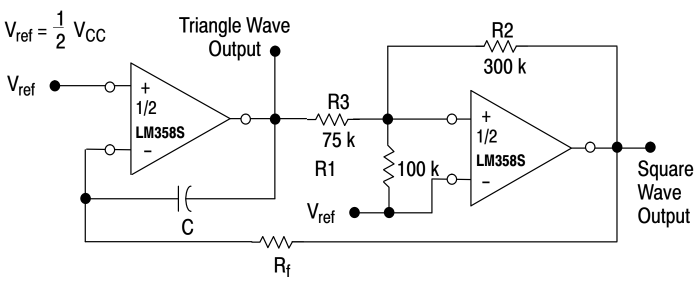
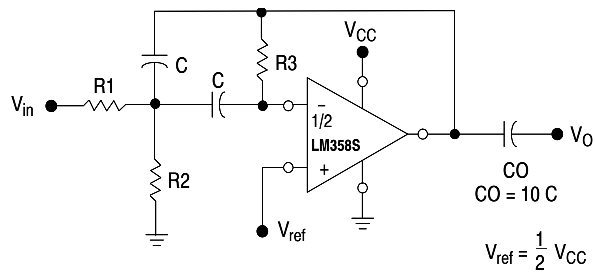


Figure 7. Bi−Quad Filter



$$f = \frac{R1 + R_C}{4\, CR_f\, R1} \qquad \text{if,}\ R3 = \frac{R2\, R1}{R2 + R1}$$

Figure 8. Function Generator



Given: f_o = center frequency
$A(f_o)$ = gain at center frequency

Choose value f_o, C

Then: $R3 = \frac{Q}{\pi f_o C}$

$R1 = \frac{R3}{2\, A(f_o)}$

$R2 = \frac{R1\, R3}{4Q^2 R1 - R3}$

For less than 10% error from operational amplifier. $\frac{Q_o f_o}{BW} < 0.1$

Where f_o and BW are expressed in Hz.

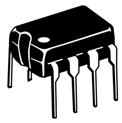
If source impedance varies, filter may be preceded with voltage follower buffer to stabilize filter parameters.

Figure 9. Multiple Feedback Bandpass Filter

ORDERING INFORMATION

Device	Operating Temperature Range	Package	Shipping†
LM358SNG	0°C to +70°C	PDIP−8 (Pb−Free)	50 Units / Rail
LM2904SNG	−40°C to +105°C	PDIP−8 (Pb−Free)	50 Units / Rail

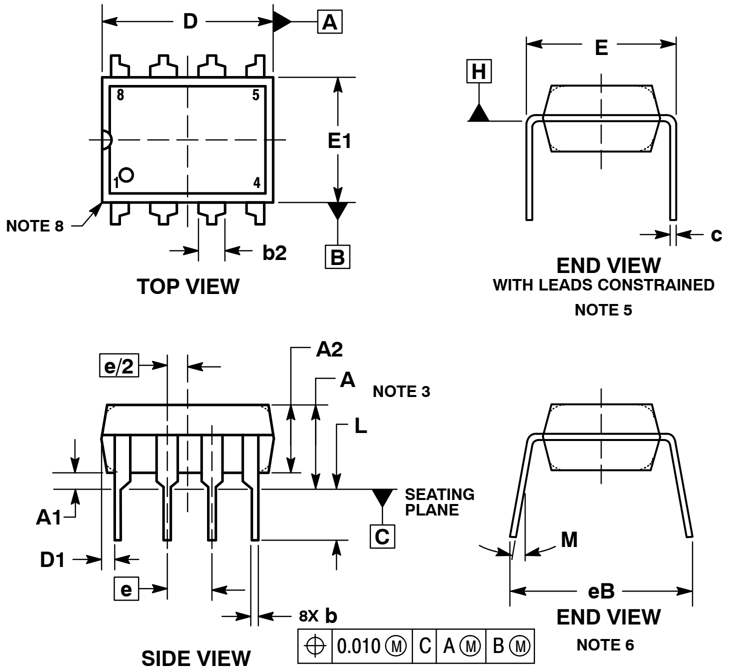
†For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specifications Brochure, BRD8011/D.



SCALE 1:1

PDIP−8
CASE 626−05
ISSUE P

DATE 22 APR 2015

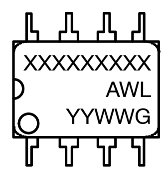


NOTES:
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
2. CONTROLLING DIMENSION: INCHES.
3. DIMENSIONS A, A1 AND L ARE MEASURED WITH THE PACKAGE SEATED IN JEDEC SEATING PLANE GAUGE GS−3.
4. DIMENSIONS D, D1 AND E1 DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS. MOLD FLASH OR PROTRUSIONS ARE NOT TO EXCEED 0.10 INCH.
5. DIMENSION E IS MEASURED AT A POINT 0.015 BELOW DATUM PLANE H WITH THE LEADS CONSTRAINED PERPENDICULAR TO DATUM C.
6. DIMENSION eB IS MEASURED AT THE LEAD TIPS WITH THE LEADS UNCONSTRAINED.
7. DATUM PLANE H IS COINCIDENT WITH THE BOTTOM OF THE LEADS, WHERE THE LEADS EXIT THE BODY.
8. PACKAGE CONTOUR IS OPTIONAL (ROUNDED OR SQUARE CORNERS).

	INCHES		MILLIMETERS	
DIM	MIN	MAX	MIN	MAX
A	----	0.210	---	5.33
A1	0.015	----	0.38	---
A2	0.115	0.195	2.92	4.95
b	0.014	0.022	0.35	0.56
b2	0.060 TYP		1.52 TYP	
C	0.008	0.014	0.20	0.36
D	0.355	0.400	9.02	10.16
D1	0.005	----	0.13	---
E	0.300	0.325	7.62	8.26
E1	0.240	0.280	6.10	7.11
e	0.100 BSC		2.54 BSC	
eB	----	0.430	---	10.92
L	0.115	0.150	2.92	3.81
M	----	10°	---	10°

STYLE 1:
PIN 1. AC IN
2. DC + IN
3. DC − IN
4. AC IN
5. GROUND
6. OUTPUT
7. AUXILIARY
8. V_{CC}

GENERIC MARKING DIAGRAM*



XXXX = Specific Device Code
A = Assembly Location
WL = Wafer Lot
YY = Year
WW = Work Week
G = Pb−Free Package

*This information is generic. Please refer to device data sheet for actual part marking. Pb−Free indicator, “G” or microdot “ ▪”, may or may not be present.

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