Single Supply **Split Supplies**

Figure 1.

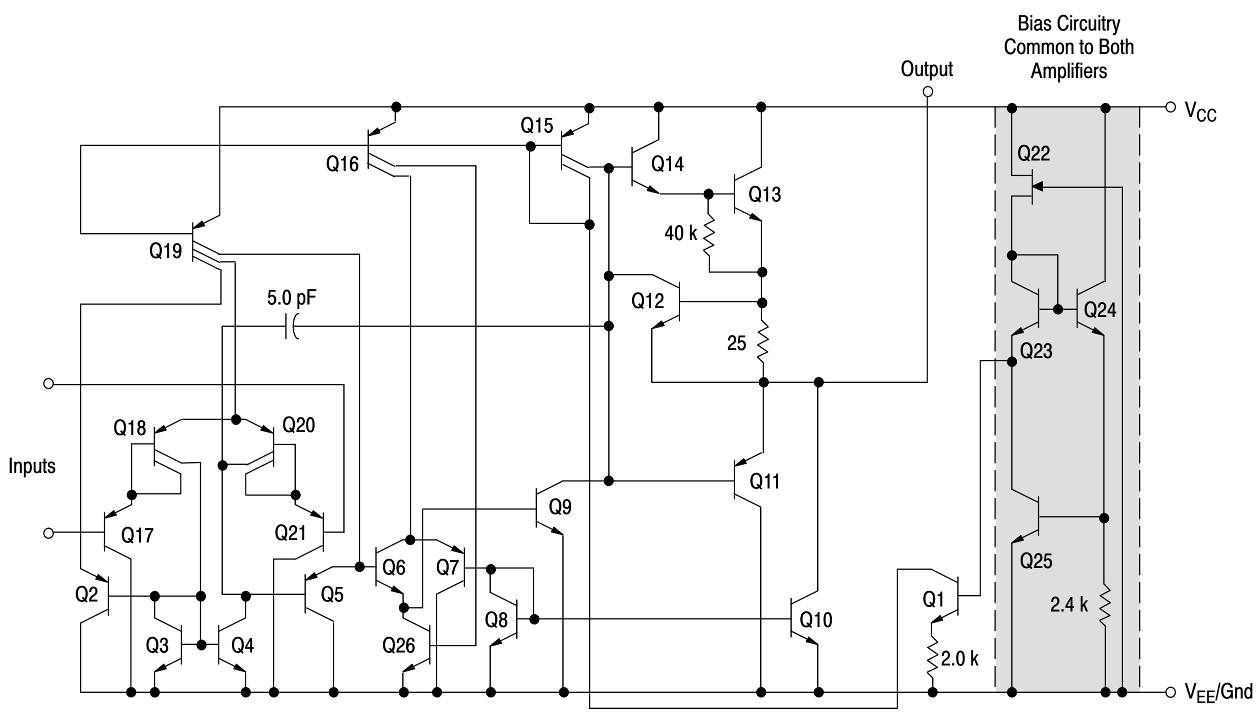


Figure 2. Representative Schematic Diagram
(One−Half of Circuit Shown)

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

Rating	Symbol	Value	Unit
Power Supply Voltages Single Supply Split Supplies	 V_{CC} V_{CC}, V_{EE}	 32 ±16	Vdc
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 846A Case 751 Case 626	$R_{\theta JA}$	238 212 161	°C/W
Storage Temperature Range	T_{stg}	−65 to +150	°C
ESD Protection at any Pin Human Body Model Machine Model	V_{esd}	 2000 200	V
Operating Ambient Temperature Range LM258 LM358, LM358A LM2904/LM2904A LM2904V, NCV2904 (Note 4)	T_A	 −25 to +85 0 to +70 −40 to +105 −40 to +125	°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. 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.
4. *NCV2904 is qualified for automotive use.*

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

Characteristic	Symbol	LM258			LM358			LM358A			Unit
		Min	Typ	Max	Min	Typ	Max	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 ≃ 1.4 V, R_S = 0 Ω	V_{IO}										mV
T_A = 25°C		–	2.0	5.0	–	2.0	7.0	–	2.0	3.0	
T_A = T_{high} (Note 5)		–	–	7.0	–	–	9.0	–	–	5.0	
T_A = T_{low} (Note 5)		–	–	7.0	–	–	9.0	–	–	5.0	
Average Temperature Coefficient of Input Offset Voltage T_A = T_{high} to T_{low} (Note 5)	$\Delta V_{IO}/\Delta T$	–	7.0	–	–	7.0	–	–	7.0	–	μV/°C
Input Offset Current	I_{IO}	–	3.0	30	–	5.0	50	–	5.0	30	nA
T_A = T_{high} to T_{low} (Note 5)		–	–	100	–	–	150	–	–	75	
Input Bias Current	I_{IB}	–	−45	−150	–	−45	−250	–	−45	−100	
T_A = T_{high} to T_{low} (Note 5)		–	−50	−300	–	−50	−500	–	−50	−200	
Average Temperature Coefficient of Input Offset Current T_A = T_{high} to T_{low} (Note 5)	$\Delta I_{IO}/\Delta T$	–	10	–	–	10	–	–	10	–	pA/°C
Input Common Mode Voltage Range (Note 6), V_{CC} = 30 V	V_{ICR}	0	–	28.3	0	–	28.3	0	–	28.5	V
V_{CC} = 30 V, T_A = T_{high} to T_{low}		0	–	28	0	–	28	0	–	28	
Differential Input Voltage Range	V_{IDR}	–	–	V_{CC}	–	–	V_{CC}	–	–	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,		50	100	–	25	100	–	25	100	–	
T_A = T_{high} to T_{low} (Note 5)		25	–	–	15	–	–	15	–	–	
Channel Separation 1.0 kHz ≤ f ≤ 20 kHz, Input Referenced	CS	–	−120	–	–	−120	–	–	−120	–	dB
Common Mode Rejection R_S ≤ 10 kΩ	CMR	70	85	–	65	70	–	65	70	–	dB
Power Supply Rejection	PSR	65	100	–	65	100	–	65	100	–	dB
Output Voltage−High Limit T_A = T_{high} to T_{low} (Note 5)	V_{OH}										V
V_{CC} = 5.0 V, R_L = 2.0 kΩ, T_A = 25°C		3.3	3.5	–	3.3	3.5	–	3.3	3.5	–	
V_{CC} = 30 V, R_L = 2.0 kΩ		26	–	–	26	–	–	26	–	–	
V_{CC} = 30 V, R_L = 10 kΩ		27	28	–	27	28	–	27	28	–	
Output Voltage−Low Limit V_{CC} = 5.0 V, R_L = 10 kΩ, T_A = T_{high} to T_{low} (Note 5)	V_{OL}	–	5.0	20	–	5.0	20	–	5.0	20	mV
Output Source Current	I_{O+}										mA
V_{ID} = +1.0 V, V_{CC} = 15 V		20	40	–	20	40	–	20	40	–	
T_A = T_{high} to T_{low} (LM358A Only)								10	–	–	
Output Sink Current	I_{O-}										
V_{ID} = −1.0 V, V_{CC} = 15 V		10	20	–	10	20	–	10	20	–	mA
T_A = T_{high} to T_{low} (LM358A Only)								5.0	–	–	mA
V_{ID} = −1.0 V, V_O = 200 mV		12	50	–	12	50	–	12	50	–	μA
Output Short Circuit to Ground (Note 7)	I_{SC}	–	40	60	–	40	60	–	40	60	mA
Power Supply Current (Total Device) T_A = T_{high} to T_{low} (Note 5)	I_{CC}										mA
V_{CC} = 30 V, V_O = 0 V, R_L = ∞		–	1.5	3.0	–	1.5	3.0	–	1.5	2.0	
V_{CC} = 5 V, V_O = 0 V, R_L = ∞		–	0.7	1.2	–	0.7	1.2	–	0.7	1.2	

5. LM258: T_{low} = −25°C, T_{high} = +85°C
   LM358, LM358A: T_{low} = 0°C, T_{high} = +70°C
   LM2904/LM2904A: T_{low} = −40°C, T_{high} = +105°C
   LM2904V & NCV2904: T_{low} = −40°C, T_{high} = +125°C
   NCV2904 is qualified for automotive use.
6. 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.
7. 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	LM2904			LM2904A			LM2904V, NCV2904			Unit
		Min	Typ	Max	Min	Typ	Max	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 ≃ 1.4 V, R_S = 0 Ω T_A = 25°C T_A = T_{high} (Note 8) T_A = T_{low} (Note 8)	V_{IO}	 – – –	 2.0 – –	 7.0 10 10	 – – –	 2.0 – –	 7.0 10 10	 – – –	 – – –	 7.0 13 10	mV
Average Temperature Coefficient of Input Offset Voltage T_A = T_{high} to T_{low} (Note 8)	$\Delta V_{IO}/\Delta T$	–	7.0	–	–	7.0	–	–	7.0	–	μV/°C
Input Offset Current T_A = T_{high} to T_{low} (Note 8) Input Bias Current T_A = T_{high} to T_{low} (Note 8)	I_{IO} I_{IB}	– – – –	5.0 45 −45 −50	50 200 −250 −500	– – – –	5.0 45 −45 −50	50 200 −100 −250	– – – –	5.0 45 −45 −50	50 200 −250 −500	nA
Average Temperature Coefficient of Input Offset Current T_A = T_{high} to T_{low} (Note 8)	$\Delta I_{IO}/\Delta T$	–	10	–	–	10	–	–	10	–	pA/°C
Input Common Mode Voltage Range (Note 9), V_{CC} = 30 V V_{CC} = 30 V, T_A = T_{high} to T_{low}	V_{ICR}	0 0	– –	28.3 28	0 0	– –	28.3 28	0 0	– –	28.3 28	V
Differential Input Voltage Range	V_{IDR}	–	–	V_{CC}	–	–	V_{CC}	–	–	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 8)	A_{VOL}	 25 15	 100 –	 – –	 25 15	 100 –	 – –	 25 15	 100 –	 – –	V/mV
Channel Separation 1.0 kHz ≤ f ≤ 20 kHz, Input Referenced	CS	–	−120	–	–	−120	–	–	−120	–	dB
Common Mode Rejection R_S ≤ 10 kΩ	CMR	50	70	–	50	70	–	50	70	–	dB
Power Supply Rejection	PSR	50	100	–	50	100	–	50	100	–	dB
Output Voltage−High Limit T_A = T_{high} to T_{low} (Note 8) V_{CC} = 5.0 V, R_L = 2.0 kΩ, T_A = 25°C V_{CC} = 30 V, R_L = 2.0 kΩ V_{CC} = 30 V, R_L = 10 kΩ	V_{OH}	 3.3 26 27	 3.5 – 28	 – – –	 3.3 26 27	 3.5 – 28	 – – –	 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 8)	V_{OL}	–	5.0	20	–	5.0	20	–	5.0	20	mV
Output Source Current V_{ID} = +1.0 V, V_{CC} = 15 V	I_{O+}	20	40	–	20	40	–	20	40	–	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 –	 20 –	 – –	 10 –	 20 –	 – –	 10 –	 20 –	 – –	 mA μA
Output Short Circuit to Ground (Note 10)	I_{SC}	–	40	60	–	40	60	–	40	60	mA
Power Supply Current (Total Device) T_A = T_{high} to T_{low} (Note 8) V_{CC} = 30 V, V_O = 0 V, R_L = ∞ V_{CC} = 5 V, V_O = 0 V, R_L = ∞	I_{CC}	 – –	 1.5 0.7	 3.0 1.2	 – –	 1.5 0.7	 3.0 1.2	 – –	 1.5 0.7	 3.0 1.2	mA

8. LM258: T_{low} = −25°C, T_{high} = +85°C; LM358, LM358A: T_{low} = 0°C, T_{high} = +70°C
   LM2904/LM2904A: T_{low} = −40°C, T_{high} = +105°C; LM2904V & NCV2904: T_{low} = −40°C, T_{high} = +125°C
   NCV2904 is qualified for automotive use.
9. 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.
10. 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 LM358 series is 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.

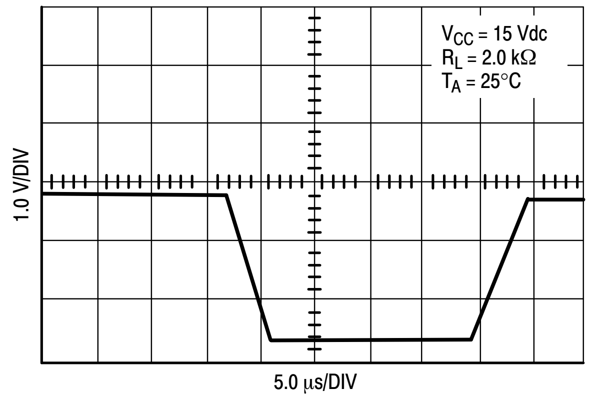


Figure 3. Large Signal Voltage Follower Response

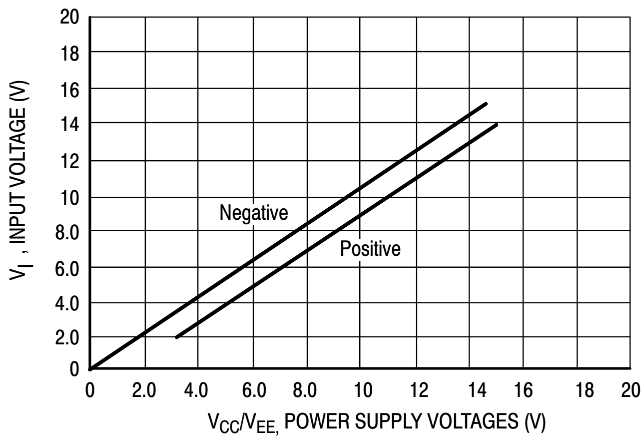


Figure 4. Input Voltage Range

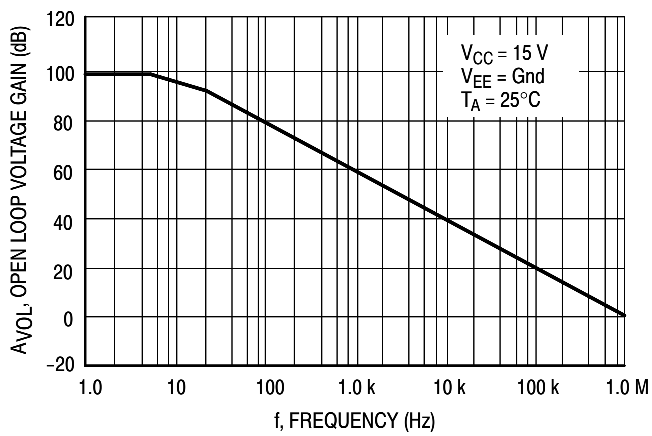


Figure 5. Large−Signal Open Loop Voltage Gain

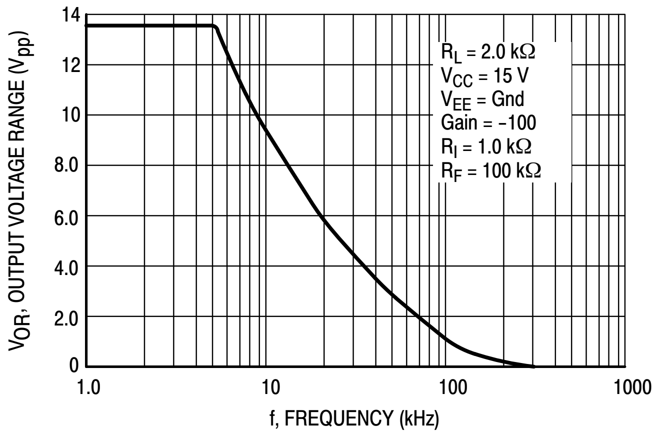


Figure 6. Large−Signal Frequency Response

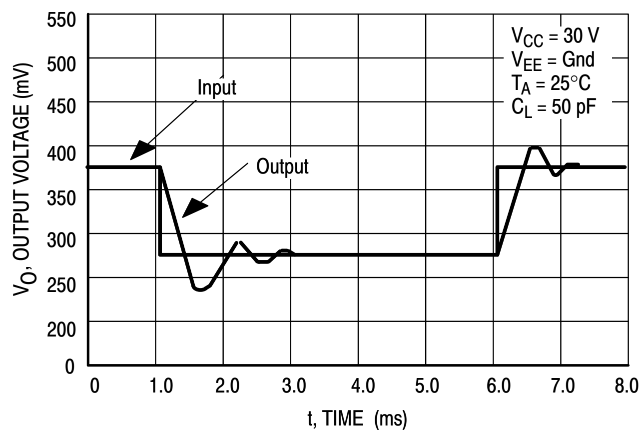


Figure 7. Small Signal Voltage Follower Pulse Response (Noninverting)

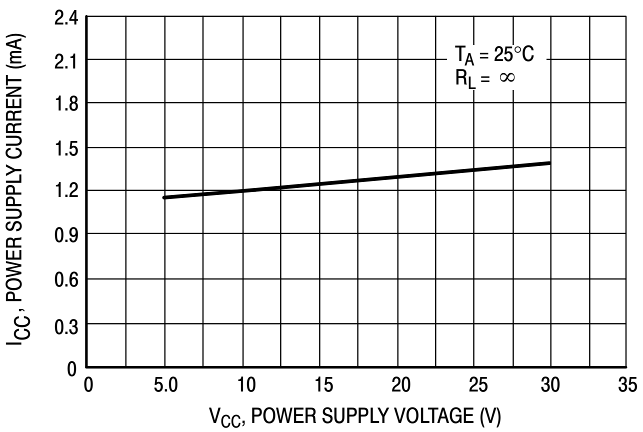


Figure 8. Power Supply Current versus Power Supply Voltage

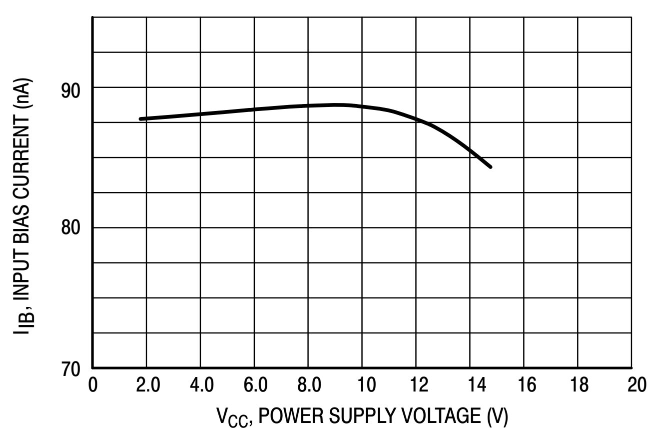
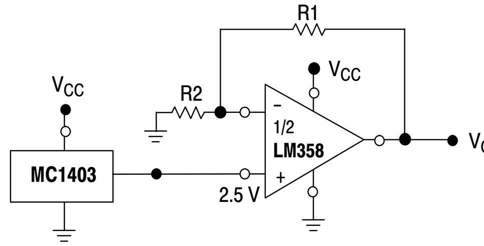


Figure 9. Input Bias Current versus Supply Voltage



$$V_O = 2.5\ V\ (1 + \frac{R1}{R2})$$

Figure 10. Voltage Reference

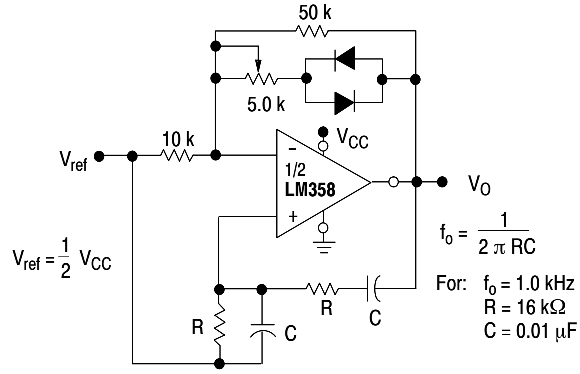
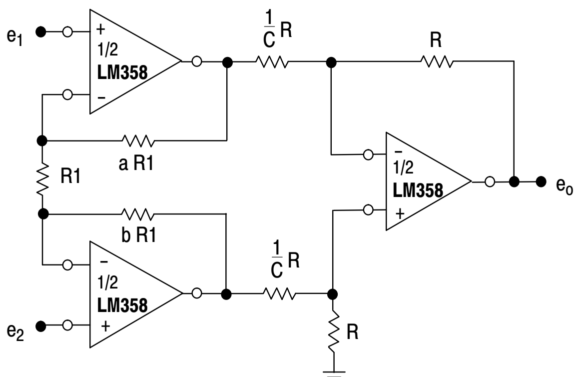
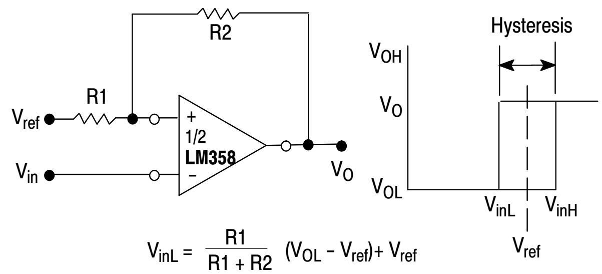


Figure 11. Wien Bridge Oscillator



$$e_o = C\ (1 + a + b)\ (e_2 - e_1)$$

Figure 12. High Impedance Differential Amplifier



$$V_{inL} = \frac{R1}{R1 + R2}\ (V_{OL} - V_{ref}) + V_{ref}$$

$$V_{inH} = \frac{R1}{R1 + R2}\ (V_{OH} - V_{ref}) + V_{ref}$$

$$H = \frac{R1}{R1 + R2}\ (V_{OH} - V_{OL})$$

Figure 13. Comparator with Hysteresis

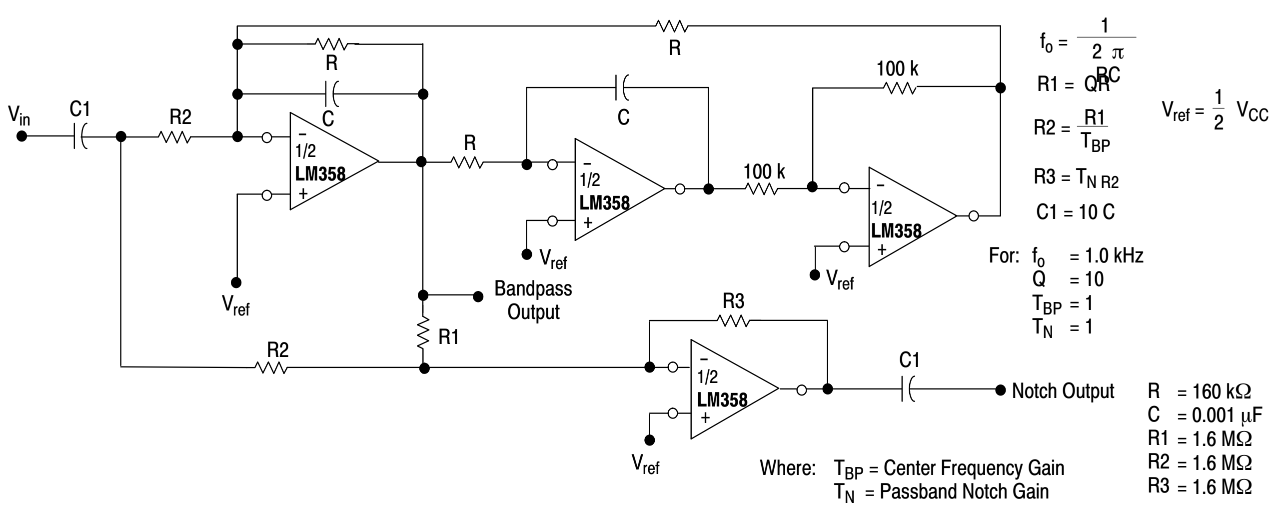
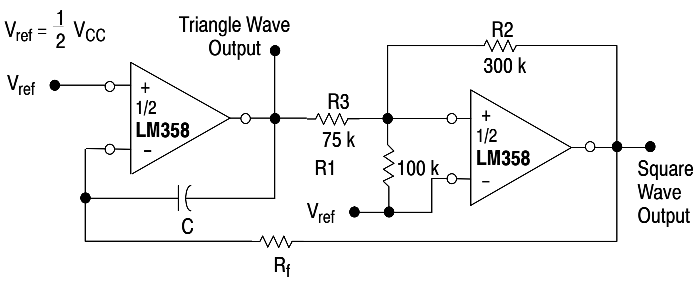
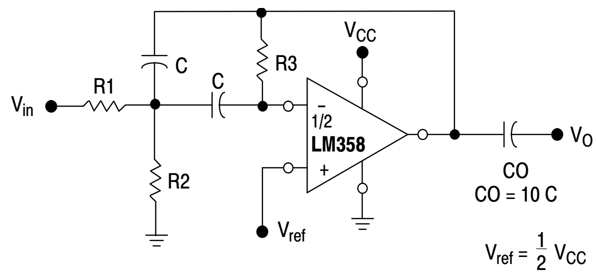


Figure 14. Bi−Quad Filter



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

Figure 15. 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 16. Multiple Feedback Bandpass Filter

ORDERING INFORMATION

Device	Operating Temperature Range	Package	Shipping†
LM358ADR2G	0°C to +70°C	SOIC−8 (Pb−Free)	2500 Tape & Reel
LM358D		SOIC−8	98 Units/Rail
LM358DG		SOIC−8 (Pb−Free)	98 Units/Rail
LM358DR2		SOIC−8	2500 Tape & Reel
LM358DR2G		SOIC−8 (Pb−Free)	2500 Tape & Reel
LM358DMR2		Micro8	4000 Tape & Reel
LM358DMR2G		Micro8 (Pb−Free)	4000 Tape & Reel
LM358N		PDIP−8	50 Units/Rail
LM358NG		PDIP−8 (Pb−Free)	50 Units/Rail
LM258D	−25°C to +85°C	SOIC−8	98 Units/Rail
LM258DG		SOIC−8 (Pb−Free)	98 Units/Rail
LM258DR2		SOIC−8	2500 Tape & Reel
LM258DR2G		SOIC−8 (Pb−Free)	2500 Tape & Reel
LM258DMR2		Micro8	4000 Tape & Reel
LM258DMR2G		Micro8 (Pb−Free)	4000 Tape & Reel
LM258N		PDIP−8	50 Units/Rail
LM258NG		PDIP−8 (Pb−Free)	50 Units/Rail
LM2904D	−40°C to +105°C	SOIC−8	98 Units/Rail
LM2904DG		SOIC−8 (Pb−Free)	98 Units/Rail
LM2904DR2		SOIC−8	2500 Tape & Reel
LM2904DR2G		SOIC−8 (Pb−Free)	2500 Tape & Reel
LM2904DMR2		Micro8	2500 Tape & Reel
LM2904DMR2G		Micro8 (Pb−Free)	2500 Tape & Reel
LM2904N		PDIP−8	50 Units/Rail
LM2904NG		PDIP−8 (Pb−Free)	50 Units/Rail
LM2904ADMG		Micro8 (Pb−Free)	4000 Tape & Reel
LM2904ADMR2		Micro8	4000 Tape & Reel
LM2904ADMR2G		Micro8 (Pb−Free)	4000 Tape & Reel
LM2904AN		PDIP−8	50 Units/Rail
LM2904ANG		PDIP−8 (Pb−Free)	50 Units/Rail

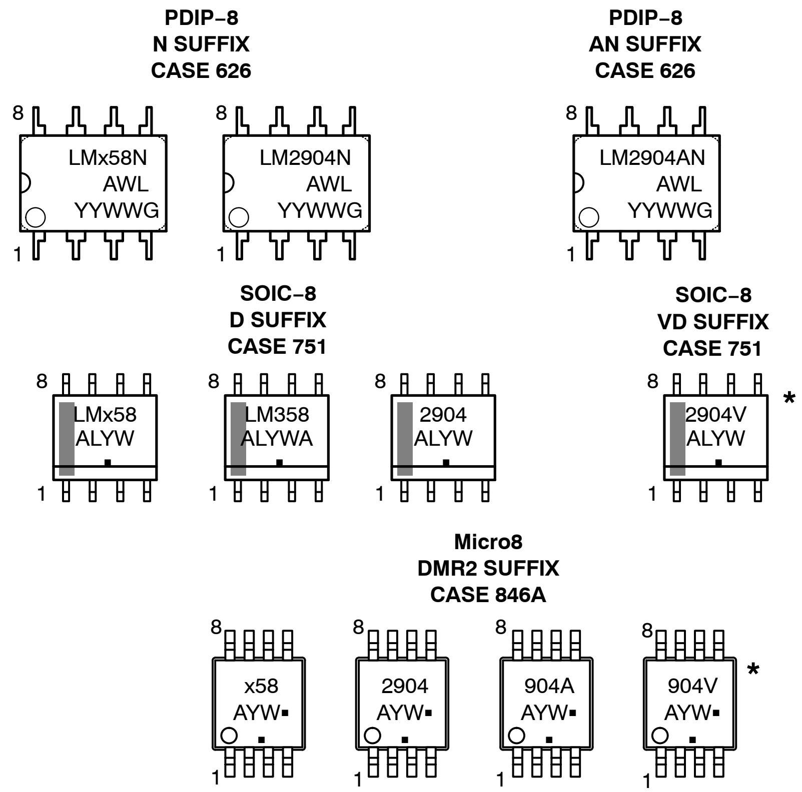
†For information on tape and reel specifications, including part orientation and tape sizes, please refer to our Tape and Reel Packaging Specifications Brochure, BRD8011/D.

ORDERING INFORMATION

Device	Operating Temperature Range	Package	Shipping†
LM2904VD	−40°C to +125°C	SOIC−8	98 Units/Rail
LM2904VDG		SOIC−8 (Pb−Free)	98 Units/Rail
LM2904VDR2		SOIC−8	2500 Tape & Reel
LM2904VDR2G		SOIC−8 (Pb−Free)	2500 Tape & Reel
LM2904VDMR2		Micro8	4000 Tape & Reel
LM2904VDMR2G		Micro8 (Pb−Free)	4000 Tape & Reel
LM2904VN		PDIP−8	50 Units/Rail
LM2904VNG		PDIP−8 (Pb−Free)	50 Units/Rail
NCV2904DR2*		SOIC−8	2500 Tape & Reel
NCV2904DR2G*		SOIC−8 (Pb−Free)	2500 Tape & Reel
NCV2904DMR2*		Micro8	4000 Tape & Reel
NCV2904DMR2G*		Micro8 (Pb−Free)	4000 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.
*NCV2904 is qualified for automotive use.

MARKING DIAGRAMS

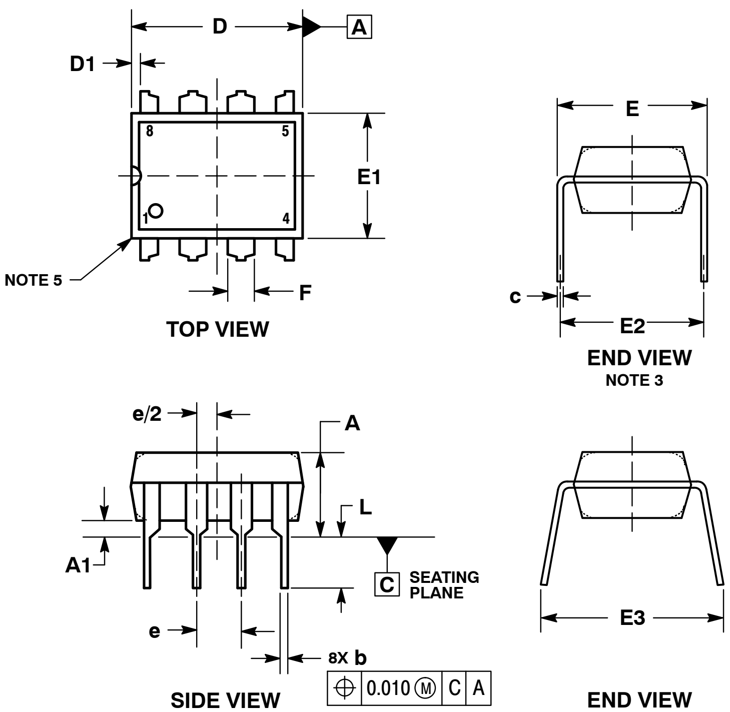


*This diagram also applies to NCV2904

x	= 2 or 3
A	= Assembly Location
WL, L	= Wafer Lot
YY, Y	= Year
WW, W	= Work Week
G	= Pb−Free Package
▪	= Pb−Free Package − (Note: Microdot may be in either location)

PACKAGE DIMENSIONS

PDIP−8
N, AN, VN SUFFIX
CASE 626−05
ISSUE M

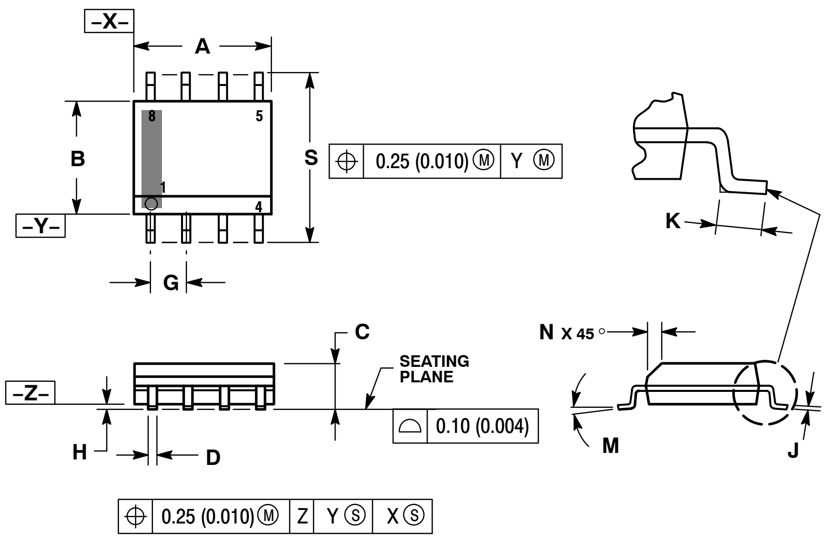


NOTES:
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
2. CONTROLLING DIMENSION: INCHES.
3. DIMENSION E IS MEASURED WITH THE LEADS RESTRAINED PARALLEL AT WIDTH E2.
4. DIMENSION E1 DOES NOT INCLUDE MOLD FLASH.
5. ROUNDED CORNERS OPTIONAL.

	INCHES			MILLIMETERS		
DIM	MIN	NOM	MAX	MIN	NOM	MAX
A	----	----	0.210	----	----	5.33
A1	0.015	----	----	0.38	----	----
b	0.014	0.018	0.022	0.35	0.46	0.56
C	0.008	0.010	0.014	0.20	0.25	0.36
D	0.355	0.365	0.400	9.02	9.27	10.02
D1	0.005	----	----	0.13	----	----
E	0.300	0.310	0.325	7.62	7.87	8.26
E1	0.240	0.250	0.280	6.10	6.35	7.11
E2	0.300 BSC			7.62 BSC		
E3	----	----	0.430	----	----	10.92
e	0.100 BSC			2.54 BSC		
L	0.115	0.130	0.150	2.92	3.30	3.81

PACKAGE DIMENSIONS

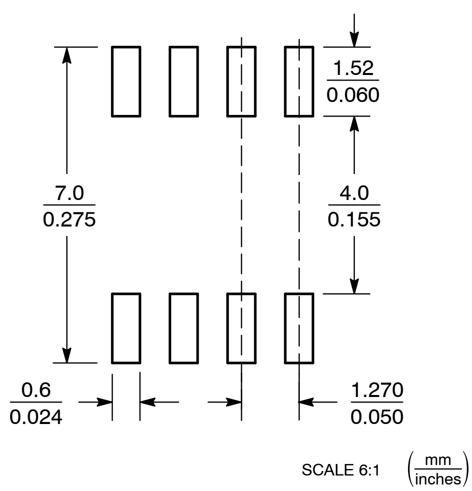
SOIC−8 NB
CASE 751−07
ISSUE AJ



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

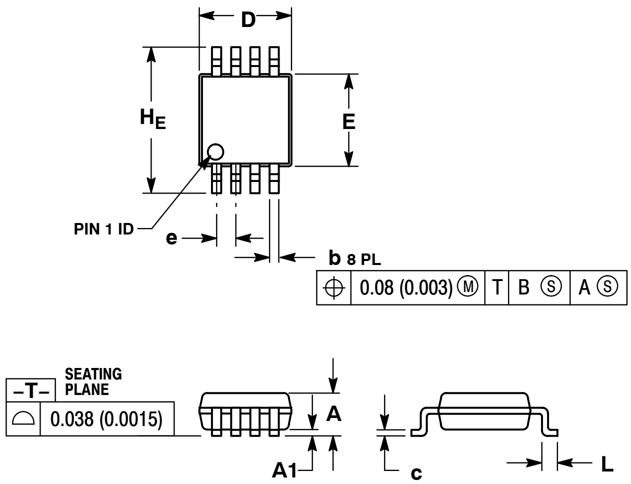
SOLDERING FOOTPRINT*



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

PACKAGE DIMENSIONS

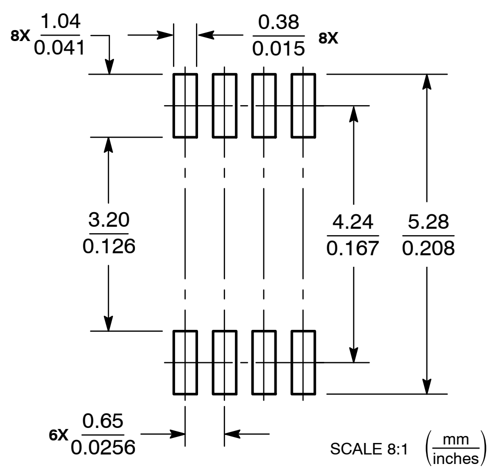
Micro8™
CASE 846A−02
ISSUE G



NOTES:
1. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.
2. CONTROLLING DIMENSION: MILLIMETER.
3. DIMENSION A DOES NOT INCLUDE MOLD FLASH, PROTRUSIONS OR GATE BURRS. MOLD FLASH, PROTRUSIONS OR GATE BURRS SHALL NOT EXCEED 0.15 (0.006) PER SIDE.
4. DIMENSION B DOES NOT INCLUDE INTERLEAD FLASH OR PROTRUSION. INTERLEAD FLASH OR PROTRUSION SHALL NOT EXCEED 0.25 (0.010) PER SIDE.
5. 846A-01 OBSOLETE, NEW STANDARD 846A-02.

	MILLIMETERS			INCHES		
DIM	MIN	NOM	MAX	MIN	NOM	MAX
A	−−	−−	1.10	−−	−−	0.043
A1	0.05	0.08	0.15	0.002	0.003	0.006
b	0.25	0.33	0.40	0.010	0.013	0.016
c	0.13	0.18	0.23	0.005	0.007	0.009
D	2.90	3.00	3.10	0.114	0.118	0.122
E	2.90	3.00	3.10	0.114	0.118	0.122
e	0.65 BSC			0.026 BSC		
L	0.40	0.55	0.70	0.016	0.021	0.028
H_E	4.75	4.90	5.05	0.187	0.193	0.199

SOLDERING FOOTPRINT*



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