

# LM258, LM358, LM358A, LM2904, LM2904A, LM2904V, NCV2904, NCV2904V

## 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 LM358 series is equivalent to one-half of an LM324.

These amplifiers have several distinct advantages over standard operational amplifier types in single supply applications. They can operate at supply voltages as low as 3.0 V or as high as 32 V, with quiescent currents about one-fifth of those associated with the MC1741 (on a per amplifier basis). 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.

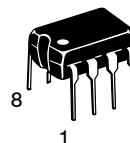
### Features

- 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
- ESD Clamps on the Inputs Increase Ruggedness of the Device without Affecting Operation
- NCV Prefix for Automotive and Other Applications Requiring Site and Control Changes
- These Devices are Pb-Free, Halogen Free/BFR Free and are RoHS Compliant



ON Semiconductor®

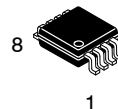
<http://onsemi.com>



PDIP-8  
N, AN, VN SUFFIX  
CASE 626

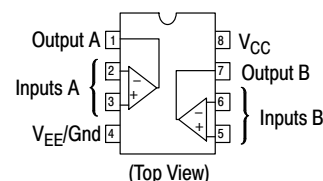


SOIC-8  
D, VD SUFFIX  
CASE 751



Micro8™  
DMR2 SUFFIX  
CASE 846A

### PIN CONNECTIONS



### ORDERING INFORMATION

See detailed ordering and shipping information in the package dimensions section on page 10 of this data sheet.

### DEVICE MARKING INFORMATION

See general marking information in the device marking section on page 11 of this data sheet.

# LM258, LM358, LM358A, LM2904, LM2904A, LM2904V, NCV2904, NCV2904V



Figure 1.

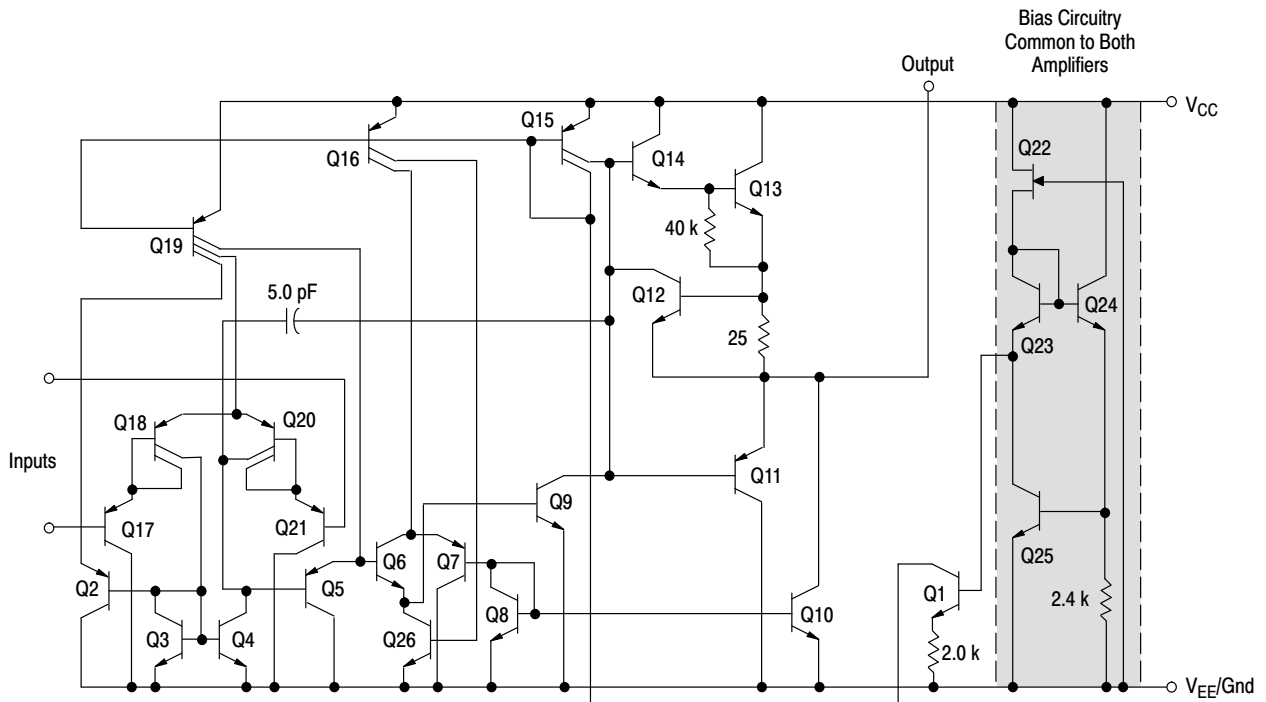


Figure 2. Representative Schematic Diagram  
(One-Half of Circuit Shown)

# LM258, LM358, LM358A, LM2904, LM2904A, LM2904V, NCV2904, NCV2904V

## MAXIMUM RATINGS ( $T_A = +25^{\circ}\text{C}$ , unless otherwise noted.)

| Rating                                                         | Symbol                       | Value                                                               | Unit                 |
|----------------------------------------------------------------|------------------------------|---------------------------------------------------------------------|----------------------|
| Power Supply Voltages<br>Single Supply<br>Split Supplies       | $V_{CC}$<br>$V_{CC}, V_{EE}$ | 32<br>$\pm 16$                                                      | Vdc                  |
| Input Differential Voltage Range (Note 1)                      | $V_{IDR}$                    | $\pm 32$                                                            | 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                                                                 | $^{\circ}\text{C}$   |
| Thermal Resistance, Junction-to-Air (Note 3)                   | $R_{\theta JA}$              | 238<br>212<br>161                                                   | $^{\circ}\text{C/W}$ |
| Storage Temperature Range                                      | $T_{stg}$                    | -65 to +150                                                         | $^{\circ}\text{C}$   |
| ESD Protection at any Pin<br>Human Body Model<br>Machine Model | $V_{esd}$                    | 2000<br>200                                                         | V                    |
| Operating Ambient Temperature Range                            | $T_A$                        | -25 to +85<br>0 to +70<br>-40 to +105<br>-40 to +125<br>-40 to +150 | $^{\circ}\text{C}$   |

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 and NCV2904V are qualified for automotive use.*

# LM258, LM358, LM358A, LM2904, LM2904A, LM2904V, NCV2904, NCV2904V

## ELECTRICAL CHARACTERISTICS ( $V_{CC} = 5.0\text{ V}$ , $V_{EE} = \text{GND}$ , $T_A = 25^\circ\text{C}$ , unless otherwise noted.)

| Characteristic                                                                                                                                                                                                                                                                    | Symbol                   | LM258 |      |          | LM358 |      |          | LM358A |      |          | Unit                         |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|-------|------|----------|-------|------|----------|--------|------|----------|------------------------------|
|                                                                                                                                                                                                                                                                                   |                          | Min   | Typ  | Max      | Min   | Typ  | Max      | Min    | Typ  | Max      |                              |
| Input Offset Voltage<br>$V_{CC} = 5.0\text{ V}$ to $30\text{ V}$ , $V_{IC} = 0\text{ V}$ to $V_{CC} - 1.7\text{ V}$ ,<br>$V_O \approx 1.4\text{ V}$ , $R_S = 0\ \Omega$<br>$T_A = 25^\circ\text{C}$<br>$T_A = T_{\text{high}}$ (Note 5)<br>$T_A = T_{\text{low}}$ (Note 5)        | $V_{IO}$                 | –     | 2.0  | 5.0      | –     | 2.0  | 7.0      | –      | 2.0  | 3.0      | mV                           |
|                                                                                                                                                                                                                                                                                   |                          | –     | –    | 7.0      | –     | –    | 9.0      | –      | –    | 5.0      |                              |
|                                                                                                                                                                                                                                                                                   |                          | –     | –    | 7.0      | –     | –    | 9.0      | –      | –    | 5.0      |                              |
| Average Temperature Coefficient of Input Offset Voltage<br>$T_A = T_{\text{high}}$ to $T_{\text{low}}$ (Note 5)                                                                                                                                                                   | $\Delta V_{IO}/\Delta T$ | –     | 7.0  | –        | –     | 7.0  | –        | –      | 7.0  | –        | $\mu\text{V}/^\circ\text{C}$ |
| Input Offset Current<br>$T_A = T_{\text{high}}$ to $T_{\text{low}}$ (Note 5)                                                                                                                                                                                                      | $I_{IO}$                 | –     | 3.0  | 30       | –     | 5.0  | 50       | –      | 5.0  | 30       | nA                           |
|                                                                                                                                                                                                                                                                                   |                          | –     | –    | 100      | –     | –    | 150      | –      | –    | 75       |                              |
| Input Bias Current<br>$T_A = T_{\text{high}}$ to $T_{\text{low}}$ (Note 5)                                                                                                                                                                                                        | $I_{IB}$                 | –     | –45  | –150     | –     | –45  | –250     | –      | –45  | –100     |                              |
|                                                                                                                                                                                                                                                                                   |                          | –     | –50  | –300     | –     | –50  | –500     | –      | –50  | –200     |                              |
| Average Temperature Coefficient of Input Offset Current<br>$T_A = T_{\text{high}}$ to $T_{\text{low}}$ (Note 5)                                                                                                                                                                   | $\Delta I_{IO}/\Delta T$ | –     | 10   | –        | –     | 10   | –        | –      | 10   | –        | $\text{pA}/^\circ\text{C}$   |
| Input Common Mode Voltage Range (Note 6),<br>$V_{CC} = 30\text{ V}$<br>$V_{CC} = 30\text{ V}$ , $T_A = T_{\text{high}}$ to $T_{\text{low}}$                                                                                                                                       | $V_{ICR}$                | 0     | –    | 28.3     | 0     | –    | 28.3     | 0      | –    | 28.5     | V                            |
|                                                                                                                                                                                                                                                                                   |                          | 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<br>$R_L = 2.0\text{ k}\Omega$ , $V_{CC} = 15\text{ V}$ , For Large $V_O$ Swing,<br>$T_A = T_{\text{high}}$ to $T_{\text{low}}$ (Note 5)                                                                                                       | $A_{VOL}$                | 50    | 100  | –        | 25    | 100  | –        | 25     | 100  | –        | V/mV                         |
|                                                                                                                                                                                                                                                                                   |                          | 25    | –    | –        | 15    | –    | –        | 15     | –    | –        |                              |
| Channel Separation<br>$1.0\text{ kHz} \leq f \leq 20\text{ kHz}$ , Input Referenced                                                                                                                                                                                               | CS                       | –     | –120 | –        | –     | –120 | –        | –      | –120 | –        | dB                           |
| Common Mode Rejection<br>$R_S \leq 10\text{ k}\Omega$                                                                                                                                                                                                                             | CMR                      | 70    | 85   | –        | 65    | 70   | –        | 65     | 70   | –        | dB                           |
| Power Supply Rejection                                                                                                                                                                                                                                                            | PSR                      | 65    | 100  | –        | 65    | 100  | –        | 65     | 100  | –        | dB                           |
| Output Voltage–High Limit<br>$T_A = T_{\text{high}}$ to $T_{\text{low}}$ (Note 5)<br>$V_{CC} = 5.0\text{ V}$ , $R_L = 2.0\text{ k}\Omega$ , $T_A = 25^\circ\text{C}$<br>$V_{CC} = 30\text{ V}$ , $R_L = 2.0\text{ k}\Omega$<br>$V_{CC} = 30\text{ V}$ , $R_L = 10\text{ k}\Omega$ | $V_{OH}$                 | 3.3   | 3.5  | –        | 3.3   | 3.5  | –        | 3.3    | 3.5  | –        | V                            |
|                                                                                                                                                                                                                                                                                   |                          | 26    | –    | –        | 26    | –    | –        | 26     | –    | –        |                              |
|                                                                                                                                                                                                                                                                                   |                          | 27    | 28   | –        | 27    | 28   | –        | 27     | 28   | –        |                              |
| Output Voltage–Low Limit<br>$V_{CC} = 5.0\text{ V}$ , $R_L = 10\text{ k}\Omega$ ,<br>$T_A = T_{\text{high}}$ to $T_{\text{low}}$ (Note 5)                                                                                                                                         | $V_{OL}$                 | –     | 5.0  | 20       | –     | 5.0  | 20       | –      | 5.0  | 20       | mV                           |
| Output Source Current<br>$V_{ID} = +1.0\text{ V}$ , $V_{CC} = 15\text{ V}$<br>$T_A = T_{\text{high}}$ to $T_{\text{low}}$ (LM358A Only)                                                                                                                                           | $I_{O+}$                 | 20    | 40   | –        | 20    | 40   | –        | 20     | 40   | –        | mA                           |
|                                                                                                                                                                                                                                                                                   |                          |       |      |          |       |      |          | 10     | –    | –        |                              |
| Output Sink Current<br>$V_{ID} = -1.0\text{ V}$ , $V_{CC} = 15\text{ V}$<br>$T_A = T_{\text{high}}$ to $T_{\text{low}}$ (LM358A Only)<br>$V_{ID} = -1.0\text{ V}$ , $V_O = 200\text{ mV}$                                                                                         | $I_{O-}$                 | 10    | 20   | –        | 10    | 20   | –        | 10     | 20   | –        | mA                           |
|                                                                                                                                                                                                                                                                                   |                          |       |      |          |       |      |          | 5.0    | –    | –        | mA                           |
|                                                                                                                                                                                                                                                                                   |                          | 12    | 50   | –        | 12    | 50   | –        | 12     | 50   | –        | $\mu\text{A}$                |
| Output Short Circuit to Ground (Note 7)                                                                                                                                                                                                                                           | $I_{SC}$                 | –     | 40   | 60       | –     | 40   | 60       | –      | 40   | 60       | mA                           |
| Power Supply Current (Total Device)<br>$T_A = T_{\text{high}}$ to $T_{\text{low}}$ (Note 5)<br>$V_{CC} = 30\text{ V}$ , $V_O = 0\text{ V}$ , $R_L = \infty$<br>$V_{CC} = 5\text{ V}$ , $V_O = 0\text{ V}$ , $R_L = \infty$                                                        | $I_{CC}$                 | –     | 1.5  | 3.0      | –     | 1.5  | 3.0      | –      | 1.5  | 2.0      | mA                           |
|                                                                                                                                                                                                                                                                                   |                          | –     | 0.7  | 1.2      | –     | 0.7  | 1.2      | –      | 0.7  | 1.2      |                              |

5. LM258:  $T_{\text{low}} = -25^\circ\text{C}$ ,  $T_{\text{high}} = +85^\circ\text{C}$

LM2904/LM2904A:  $T_{\text{low}} = -40^\circ\text{C}$ ,  $T_{\text{high}} = +105^\circ\text{C}$

NCV2904 and NCV2904V are qualified for automotive use.

LM358, LM358A:  $T_{\text{low}} = 0^\circ\text{C}$ ,  $T_{\text{high}} = +70^\circ\text{C}$

LM2904V & NCV2904:  $T_{\text{low}} = -40^\circ\text{C}$ ,  $T_{\text{high}} = +125^\circ\text{C}$

NCV2904V:  $T_{\text{low}} = -40^\circ\text{C}$ ,  $T_{\text{high}} = +150^\circ\text{C}$

6. The input common mode voltage or either input signal voltage should not be allowed to go negative by more than  $0.3\text{ V}$ . The upper end of the common mode voltage range is  $V_{CC} - 1.7\text{ V}$ .

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.

# LM258, LM358, LM358A, LM2904, LM2904A, LM2904V, NCV2904, NCV2904V

## ELECTRICAL CHARACTERISTICS ( $V_{CC} = 5.0\text{ V}$ , $V_{EE} = \text{Gnd}$ , $T_A = 25^\circ\text{C}$ , unless otherwise noted.)

| Characteristic                                                                                                                                                                                                                                                                    | Symbol                   | LM2904 |      |          | LM2904A |      |          | LM2904V, NCV2904<br>NCV2904V |      |          | Unit                         |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|--------|------|----------|---------|------|----------|------------------------------|------|----------|------------------------------|
|                                                                                                                                                                                                                                                                                   |                          | Min    | Typ  | Max      | Min     | Typ  | Max      | Min                          | Typ  | Max      |                              |
| Input Offset Voltage<br>$V_{CC} = 5.0\text{ V}$ to $30\text{ V}$ , $V_{IC} = 0\text{ V}$ to $V_{CC} - 1.7\text{ V}$ ,<br>$V_O \approx 1.4\text{ V}$ , $R_S = 0\ \Omega$<br>$T_A = 25^\circ\text{C}$<br>$T_A = T_{\text{high}}$ (Note 8)<br>$T_A = T_{\text{low}}$ (Note 8)        | $V_{IO}$                 | –      | 2.0  | 7.0      | –       | 2.0  | 7.0      | –                            | –    | 7.0      | mV                           |
| Average Temperature Coefficient of Input Offset Voltage<br>$T_A = T_{\text{high}}$ to $T_{\text{low}}$ (Note 8)                                                                                                                                                                   | $\Delta V_{IO}/\Delta T$ | –      | 7.0  | –        | –       | 7.0  | –        | –                            | 7.0  | –        | $\mu\text{V}/^\circ\text{C}$ |
| Input Offset Current<br>$T_A = T_{\text{high}}$ to $T_{\text{low}}$ (Note 8)                                                                                                                                                                                                      | $I_{IO}$                 | –      | 5.0  | 50       | –       | 5.0  | 50       | –                            | 5.0  | 50       | nA                           |
| Input Bias Current<br>$T_A = T_{\text{high}}$ to $T_{\text{low}}$ (Note 8)                                                                                                                                                                                                        | $I_{IB}$                 | –      | 45   | 200      | –       | 45   | 200      | –                            | 45   | 200      | nA                           |
| Average Temperature Coefficient of Input Offset Current<br>$T_A = T_{\text{high}}$ to $T_{\text{low}}$ (Note 8)                                                                                                                                                                   | $\Delta I_{IO}/\Delta T$ | –      | –45  | –250     | –       | –45  | –100     | –                            | –45  | –250     | pA/ $^\circ\text{C}$         |
| Input Common Mode Voltage Range (Note 9),<br>$V_{CC} = 30\text{ V}$<br>$V_{CC} = 30\text{ V}$ , $T_A = T_{\text{high}}$ to $T_{\text{low}}$                                                                                                                                       | $V_{ICR}$                | –      | –50  | –500     | –       | –50  | –250     | –                            | –50  | –500     |                              |
| Differential Input Voltage Range                                                                                                                                                                                                                                                  | $V_{IDR}$                | 0      | –    | 28.3     | 0       | –    | 28.3     | 0                            | –    | 28.3     | V                            |
| Large Signal Open Loop Voltage Gain<br>$R_L = 2.0\text{ k}\Omega$ , $V_{CC} = 15\text{ V}$ , For Large $V_O$ Swing,<br>$T_A = T_{\text{high}}$ to $T_{\text{low}}$ (Note 8)                                                                                                       | $A_{VOL}$                | 0      | –    | 28       | 0       | –    | 28       | 0                            | –    | 28       | V                            |
| Channel Separation<br>$1.0\text{ kHz} \leq f \leq 20\text{ kHz}$ , Input Referenced                                                                                                                                                                                               | CS                       | –      | –    | $V_{CC}$ | –       | –    | $V_{CC}$ | –                            | –    | $V_{CC}$ | V                            |
| Common Mode Rejection<br>$R_S \leq 10\text{ k}\Omega$                                                                                                                                                                                                                             | CMR                      | 25     | 100  | –        | 25      | 100  | –        | 25                           | 100  | –        | V/mV                         |
| Power Supply Rejection                                                                                                                                                                                                                                                            | PSR                      | 15     | –    | –        | 15      | –    | –        | 15                           | –    | –        |                              |
| Output Voltage–High Limit<br>$T_A = T_{\text{high}}$ to $T_{\text{low}}$ (Note 8)<br>$V_{CC} = 5.0\text{ V}$ , $R_L = 2.0\text{ k}\Omega$ , $T_A = 25^\circ\text{C}$<br>$V_{CC} = 30\text{ V}$ , $R_L = 2.0\text{ k}\Omega$<br>$V_{CC} = 30\text{ V}$ , $R_L = 10\text{ k}\Omega$ | $V_{OH}$                 | –      | –120 | –        | –       | –120 | –        | –                            | –120 | –        | dB                           |
| Output Voltage–Low Limit<br>$V_{CC} = 5.0\text{ V}$ , $R_L = 10\text{ k}\Omega$ ,<br>$T_A = T_{\text{high}}$ to $T_{\text{low}}$ (Note 8)                                                                                                                                         | $V_{OL}$                 | 50     | 70   | –        | 50      | 70   | –        | 50                           | 70   | –        | dB                           |
| Output Source Current<br>$V_{ID} = +1.0\text{ V}$ , $V_{CC} = 15\text{ V}$                                                                                                                                                                                                        | $I_{O+}$                 | 50     | 100  | –        | 50      | 100  | –        | 50                           | 100  | –        | dB                           |
| Output Sink Current<br>$V_{ID} = -1.0\text{ V}$ , $V_{CC} = 15\text{ V}$<br>$V_{ID} = -1.0\text{ V}$ , $V_O = 200\text{ mV}$                                                                                                                                                      | $I_{O-}$                 | 3.3    | 3.5  | –        | 3.3     | 3.5  | –        | 3.3                          | 3.5  | –        | V                            |
| Output Short Circuit to Ground (Note 10)                                                                                                                                                                                                                                          | $I_{SC}$                 | 26     | –    | –        | 26      | –    | –        | 26                           | –    | –        |                              |
| Power Supply Current (Total Device)<br>$T_A = T_{\text{high}}$ to $T_{\text{low}}$ (Note 8)<br>$V_{CC} = 30\text{ V}$ , $V_O = 0\text{ V}$ , $R_L = \infty$<br>$V_{CC} = 5\text{ V}$ , $V_O = 0\text{ V}$ , $R_L = \infty$                                                        | $I_{CC}$                 | 27     | 28   | –        | 27      | 28   | –        | 27                           | 28   | –        |                              |
|                                                                                                                                                                                                                                                                                   |                          | –      | 5.0  | 20       | –       | 5.0  | 20       | –                            | 5.0  | 20       | mV                           |
|                                                                                                                                                                                                                                                                                   |                          | 20     | 40   | –        | 20      | 40   | –        | 20                           | 40   | –        | mA                           |
|                                                                                                                                                                                                                                                                                   |                          | 10     | 20   | –        | 10      | 20   | –        | 10                           | 20   | –        | mA                           |
|                                                                                                                                                                                                                                                                                   |                          | –      | –    | –        | –       | –    | –        | –                            | –    | –        | $\mu\text{A}$                |
|                                                                                                                                                                                                                                                                                   |                          | –      | 40   | 60       | –       | 40   | 60       | –                            | 40   | 60       | mA                           |
|                                                                                                                                                                                                                                                                                   |                          | –      | 1.5  | 3.0      | –       | 1.5  | 3.0      | –                            | 1.5  | 3.0      | mA                           |
|                                                                                                                                                                                                                                                                                   |                          | –      | 0.7  | 1.2      | –       | 0.7  | 1.2      | –                            | 0.7  | 1.2      |                              |

8. LM258:  $T_{\text{low}} = -25^\circ\text{C}$ ,  $T_{\text{high}} = +85^\circ\text{C}$

LM2904/LM2904A:  $T_{\text{low}} = -40^\circ\text{C}$ ,  $T_{\text{high}} = +105^\circ\text{C}$

LM358, LM358A:  $T_{\text{low}} = 0^\circ\text{C}$ ,  $T_{\text{high}} = +70^\circ\text{C}$

LM2904V & NCV2904:  $T_{\text{low}} = -40^\circ\text{C}$ ,  $T_{\text{high}} = +125^\circ\text{C}$

NCV2904 and NCV2904V are qualified for automotive use. NCV2904V:  $T_{\text{low}} = -40^\circ\text{C}$ ,  $T_{\text{high}} = +150^\circ\text{C}$

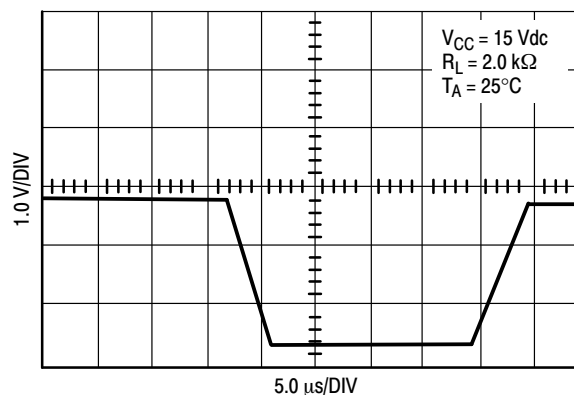
9. The input common mode voltage or either input signal voltage should not be allowed to go negative by more than 0.3 V. The upper end of the common mode voltage range is  $V_{CC} - 1.7\text{ V}$ .

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.

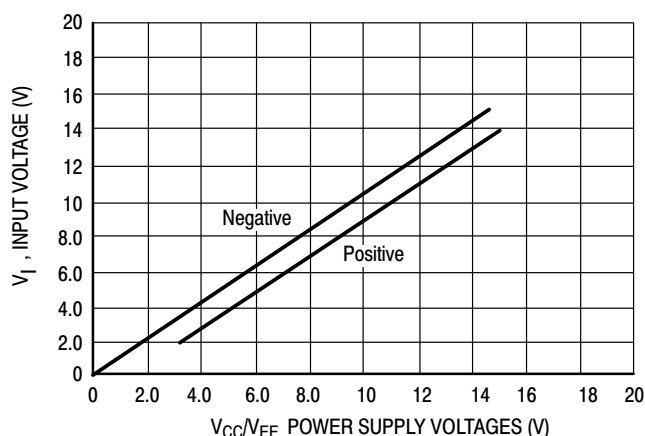
## CIRCUIT DESCRIPTION

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.

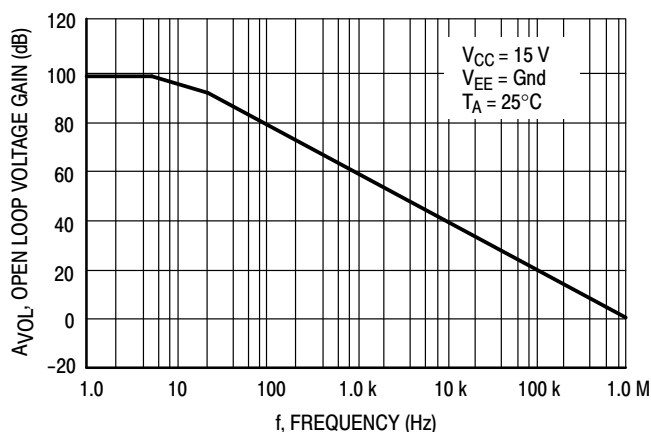
Each amplifier is biased from an internal-voltage regulator which has a low temperature coefficient thus giving each amplifier good temperature characteristics as well as excellent power supply rejection.



**Figure 3. Large Signal Voltage Follower Response**



**Figure 4. Input Voltage Range**



**Figure 5. Large-Signal Open Loop Voltage Gain**

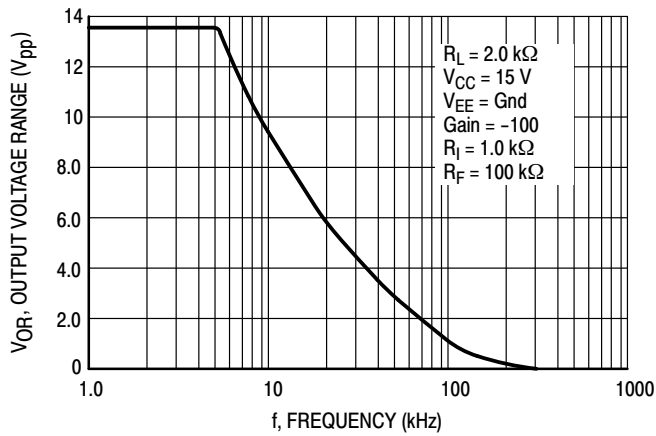


Figure 6. Large-Signal Frequency Response

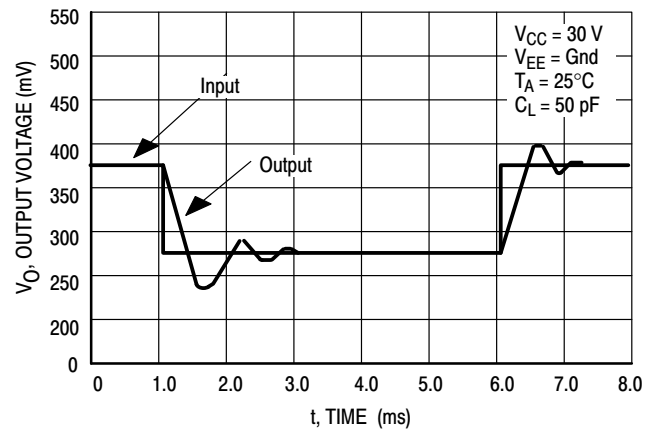


Figure 7. Small Signal Voltage Follower Pulse Response (Noninverting)

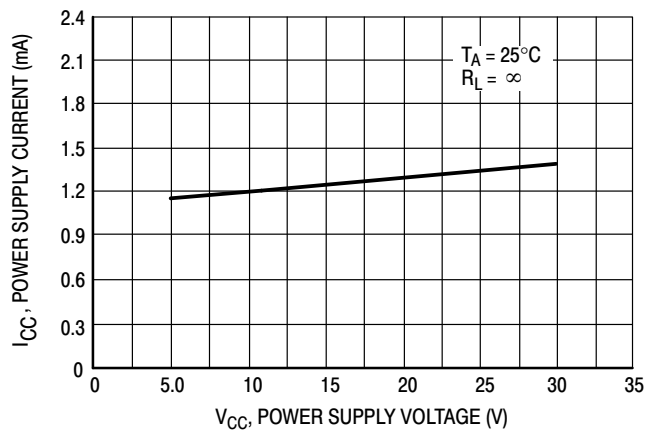


Figure 8. Power Supply Current versus Power Supply Voltage

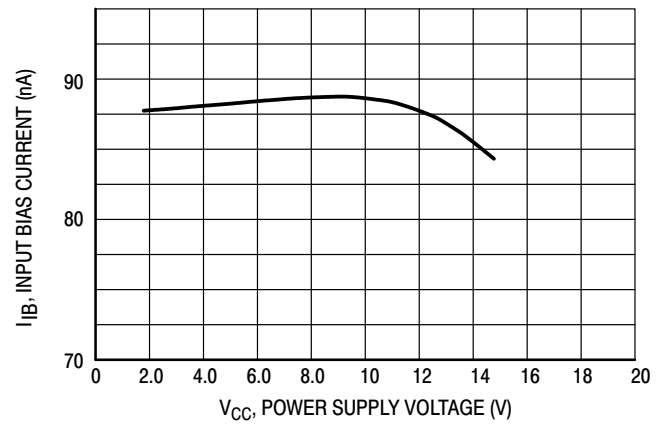


Figure 9. Input Bias Current versus Supply Voltage

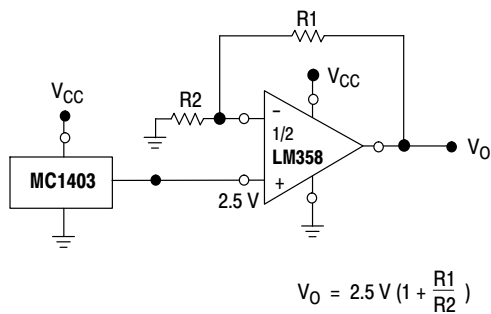


Figure 10. Voltage Reference

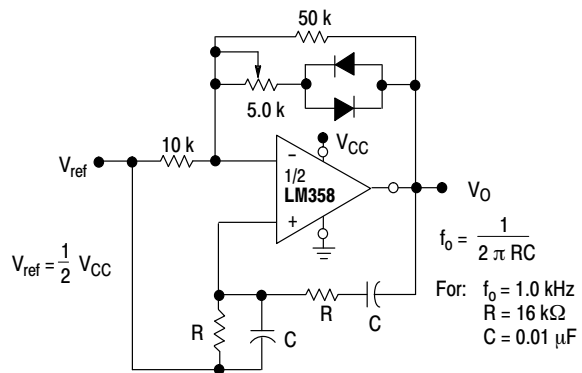


Figure 11. Wien Bridge Oscillator

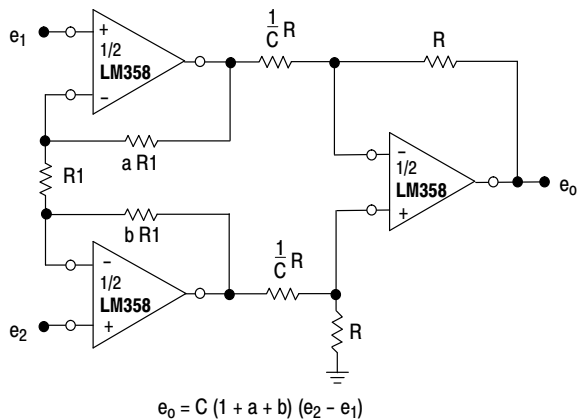


Figure 12. High Impedance Differential Amplifier

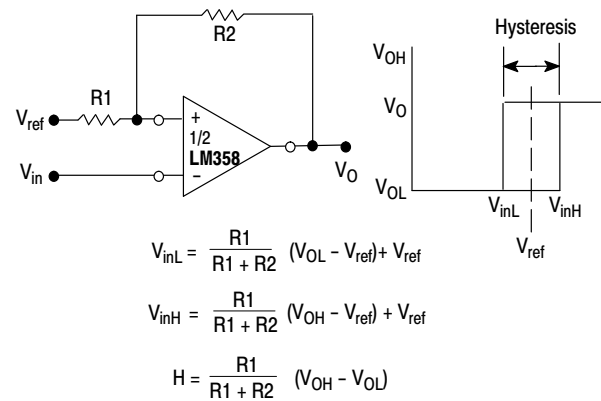


Figure 13. Comparator with Hysteresis

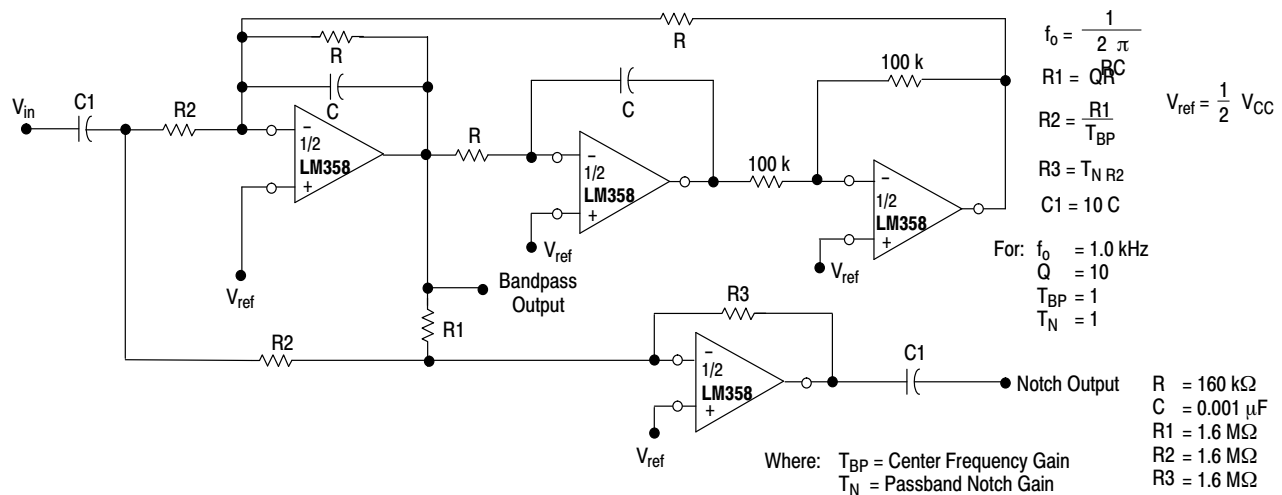


Figure 14. Bi-Quad Filter

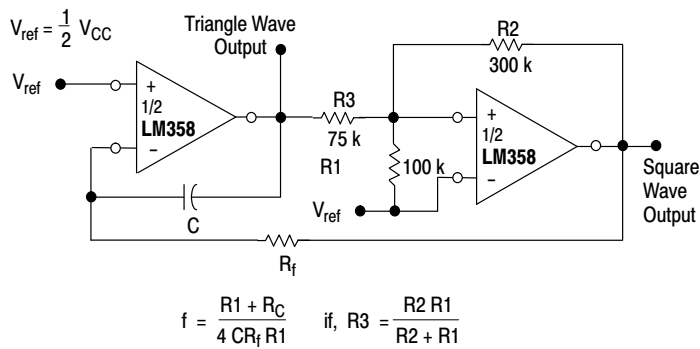
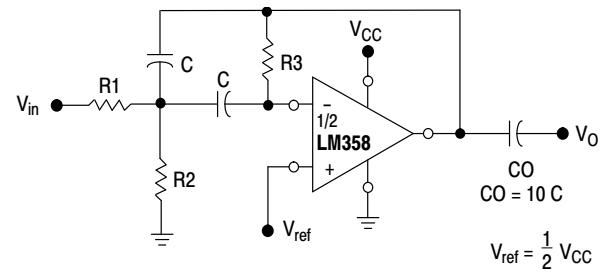


Figure 15. Function Generator



Given:  $f_0$  = center frequency  
 $A(f_0)$  = gain at center frequency

Choose value  $f_0, C$

$$\text{Then: } R3 = \frac{Q}{\pi f_0 C}$$

$$R1 = \frac{R3}{2 A(f_0)}$$

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

For less than 10% error from operational amplifier.  $\frac{Q_0 f_0}{BW} < 0.1$

Where  $f_0$  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

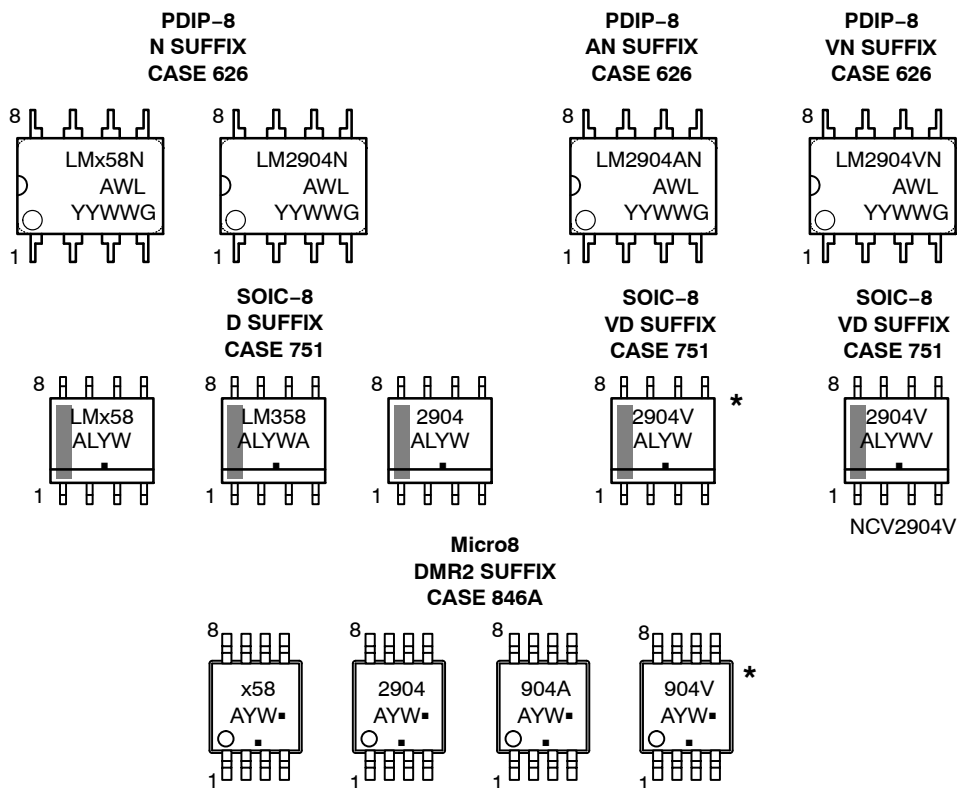
# LM258, LM358, LM358A, LM2904, LM2904A, LM2904V, NCV2904, NCV2904V

## ORDERING INFORMATION

| Device       | Operating Temperature Range | Package             | Shipping <sup>†</sup> |
|--------------|-----------------------------|---------------------|-----------------------|
| LM358ADR2G   | 0°C to +70°C                | SOIC-8<br>(Pb-Free) | 2500 / Tape & Reel    |
| LM358DG      |                             |                     | 98 Units / Rail       |
| LM358DR2G    |                             |                     | 2500 / Tape & Reel    |
| LM358DMR2G   |                             | Micro8<br>(Pb-Free) | 4000 / Tape & Reel    |
| LM358NG      |                             | PDIP-8<br>(Pb-Free) | 50 Units / Rail       |
| LM258DG      | -25°C to +85°C              | SOIC-8<br>(Pb-Free) | 98 Units / Rail       |
| LM258DR2G    |                             |                     | 2500 / Tape & Reel    |
| LM258DMR2G   |                             | Micro8<br>(Pb-Free) | 4000 / Tape & Reel    |
| LM258NG      |                             | PDIP-8<br>(Pb-Free) | 50 Units / Rail       |
| LM2904DG     | -40°C to +105°C             | SOIC-8<br>(Pb-Free) | 98 Units / Rail       |
| LM2904DR2G   |                             |                     | 2500 / Tape & Reel    |
| LM2904DMR2G  |                             | Micro8<br>(Pb-Free) | 2500 / Tape & Reel    |
| LM2904NG     |                             | PDIP-8<br>(Pb-Free) | 50 Units / Rail       |
| LM2904ADMG   |                             | Micro8<br>(Pb-Free) | 4000 / Tape & Reel    |
| LM2904ADMR2G |                             |                     | 4000 / Tape & Reel    |
| LM2904ANG    |                             | PDIP-8<br>(Pb-Free) | 50 Units / Rail       |
| LM2904VDG    | -40°C to +125°C             | SOIC-8<br>(Pb-Free) | 98 Units / Rail       |
| LM2904VDR2G  |                             |                     | 2500 / Tape & Reel    |
| LM2904VDMR2G |                             | Micro8<br>(Pb-Free) | 4000 / Tape & Reel    |
| LM2904VNG    |                             | PDIP-8<br>(Pb-Free) | 50 Units / Rail       |
| NCV2904DR2G  |                             | SOIC-8<br>(Pb-Free) | 2500 / Tape & Reel    |
| NCV2904DMR2G |                             | Micro8<br>(Pb-Free) | 4000 / Tape & Reel    |
| NCV2904VDR2G | -40°C to +150°C             | SOIC-8<br>(Pb-Free) | 2500 / Tape & Reel    |

<sup>†</sup>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.

MARKING DIAGRAMS

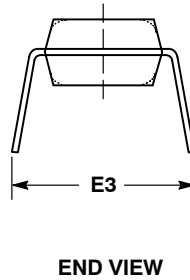
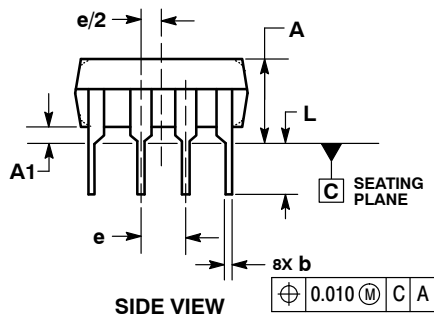
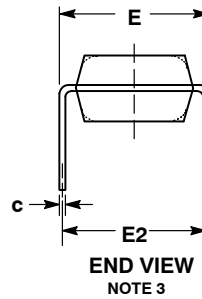
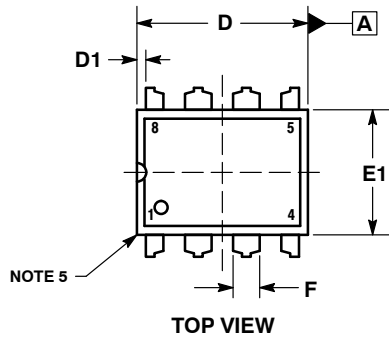


x = 2 or 3  
A = Assembly Location  
WL, L = Wafer Lot  
YY, Y = Year  
WW, W = Work Week  
G = Pb-Free Package  
▪ = Pb-Free Package – (Note: Microdot may be in either location)

\*This diagram also applies to NCV2904

PACKAGE DIMENSIONS

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



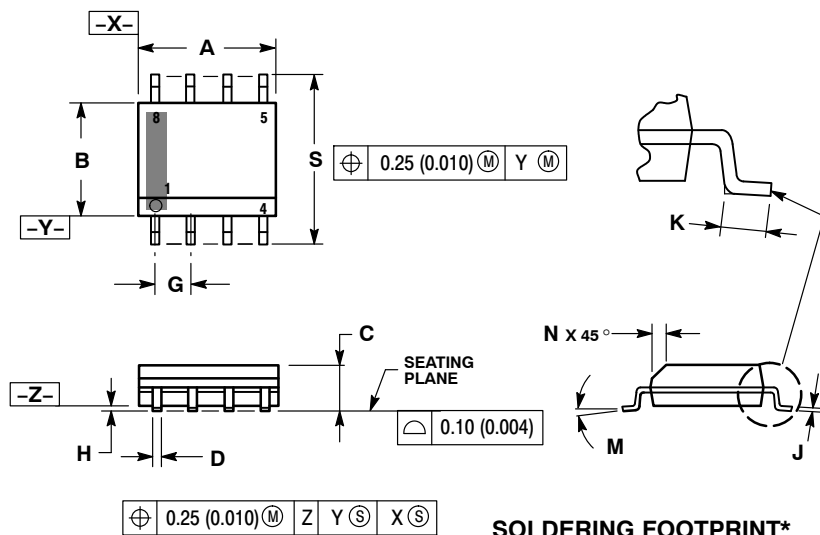
NOTES:

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.

| DIM | INCHES    |       |       | MILLIMETERS |      |       |
|-----|-----------|-------|-------|-------------|------|-------|
|     | 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 AK

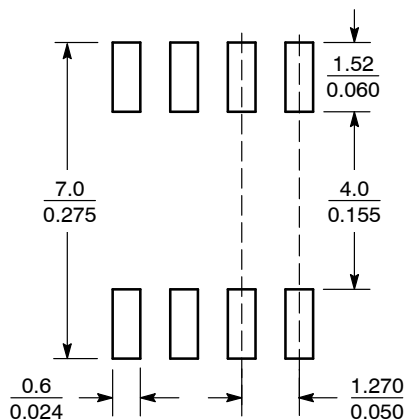


### NOTES:

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.

| DIM | MILLIMETERS |      | INCHES    |       |
|-----|-------------|------|-----------|-------|
|     | 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 |

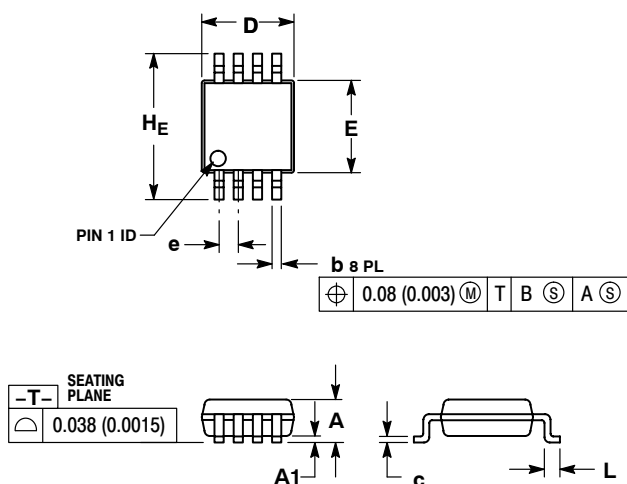
### SOLDERING FOOTPRINT\*



SCALE 6:1 (mm/inches)

\*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

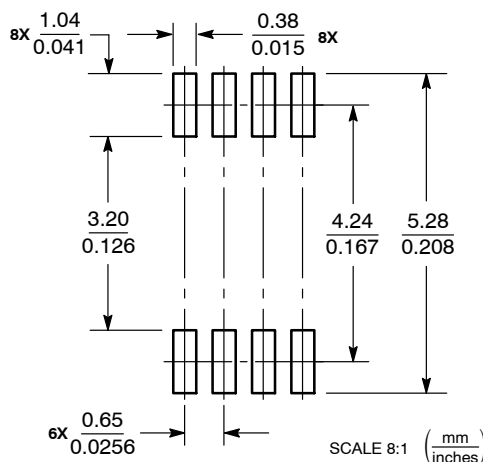
Micro8™  
CASE 846A-02  
ISSUE H

## 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.

| DIM | MILLIMETERS |      |      | INCHES |       |       |
|-----|-------------|------|------|--------|-------|-------|
|     | MIN         | NOM  | MAX  | MIN    | NOM   | MAX   |
| A   | 0.05        | 0.08 | 0.15 | 0.002  | 0.003 | 0.006 |
| A1  | 0.25        | 0.33 | 0.40 | 0.010  | 0.013 | 0.016 |
| b   | 0.13        | 0.18 | 0.23 | 0.005  | 0.007 | 0.009 |
| c   | 2.90        | 3.00 | 3.10 | 0.114  | 0.118 | 0.122 |
| D   | 2.90        | 3.00 | 3.10 | 0.114  | 0.118 | 0.122 |
| E   | 0.40        | 0.55 | 0.70 | 0.016  | 0.021 | 0.028 |
| HE  | 4.75        | 4.90 | 5.05 | 0.187  | 0.193 | 0.199 |

## 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.

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