

Dual Low Power Operational Amplifiers

Utilizing the circuit designs perfected for recently introduced Quad Operational Amplifiers, these dual operational amplifiers feature 1) low power drain, 2) a common mode input voltage range extending to ground/ V_{EE} , 3) single supply or split supply operation and 4) pinouts compatible with the popular MC1558 dual operational amplifier. The LM158 series is equivalent to one-half of an LM124.

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.

- 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
- Similar Performance to the Popular MC1558
- ESD Clamps on the Inputs Increase Ruggedness of the Device without Affecting Operation

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

| Rating | Symbol | LM258 LM358 | LM2904 LM2904V | Unit |
|--|------------------------------|----------------|-------------------|------------------|
| Power Supply Voltages Single Supply Split Supplies | V_{CC} V_{CC}, V_{EE} | 32 ± 16 | 26 ± 13 | Vdc |
| Input Differential Voltage Range (Note 1) | V_{IDR} | ± 32 | ± 26 | Vdc |
| Input Common Mode Voltage Range (Note 2) | V_{ICR} | -0.3 to 32 | -0.3 to 26 | Vdc |
| Output Short Circuit Duration | t_{SC} | Continuous | | |
| Junction Temperature | T_J | 150 | | $^\circ\text{C}$ |
| Storage Temperature Range | T_{stg} | -55 to +125 | | $^\circ\text{C}$ |
| Operating Ambient Temperature Range | T_A | | | $^\circ\text{C}$ |
| LM258 | | -25 to +85 | — | |
| LM358 | | 0 to +70 | — | |
| LM2904 | | — | -40 to +105 | |
| LM2904V | | — | -40 to +125 | |

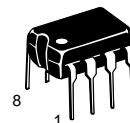
NOTES: 1. Split Power Supplies.

2. For Supply Voltages less than 32 V for the LM258/358 and 26 V for the LM2904, the absolute maximum input voltage is equal to the supply voltage.

LM358, LM258, LM2904, LM2904V

DUAL DIFFERENTIAL INPUT OPERATIONAL AMPLIFIERS

SEMICONDUCTOR TECHNICAL DATA

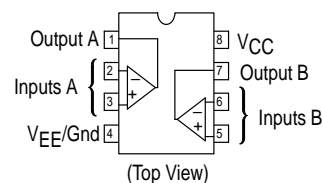


N SUFFIX
PLASTIC PACKAGE
CASE 626



D SUFFIX
PLASTIC PACKAGE
CASE 751
(SO-8)

PIN CONNECTIONS



ORDERING INFORMATION

| Device | Operating Temperature Range | Package |
|----------|---|-------------|
| LM2904D | $T_A = -40^\circ$ to $+105^\circ\text{C}$ | SO-8 |
| LM2904N | | Plastic DIP |
| LM2904VD | $T_A = -40^\circ$ to $+125^\circ\text{C}$ | SO-8 |
| LM2904VN | | Plastic DIP |
| LM258D | $T_A = -25^\circ$ to $+85^\circ\text{C}$ | SO-8 |
| LM258N | | Plastic DIP |
| LM358D | $T_A = 0^\circ$ to $+70^\circ\text{C}$ | SO-8 |
| LM358N | | Plastic DIP |

LM358, LM258, LM2904, LM2904V

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

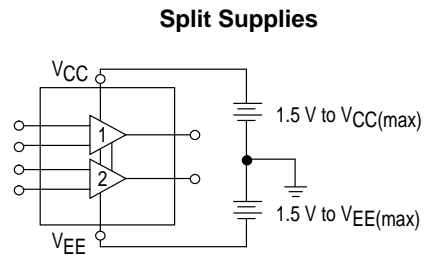
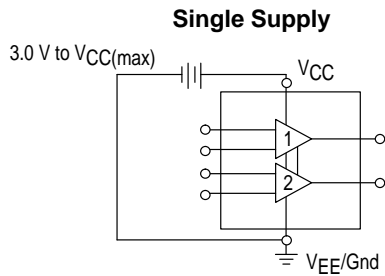
| Characteristic | Symbol | LM258 | | | LM358 | | | LM2904 | | | LM2904V | | | Unit |
|--|----------------------|-------|------|-----------------|-------|------|-----------------|--------|------|-----------------|---------|------|-----------------|-------|
| | | Min | Typ | Max | Min | Typ | Max | Min | Typ | Max | Min | Typ | Max | |
| Input Offset Voltage V _{CC} = 5.0 V to 30 V (26 V for LM2904, 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 1) T _A = T _{low} (Note 1) | V _{IO} | – | 2.0 | 5.0 | – | 2.0 | 7.0 | – | 2.0 | 7.0 | – | – | – | mV |
| | | – | – | 7.0 | – | – | 9.0 | – | – | 10 | – | – | 13 | |
| | | – | – | 2.0 | – | – | 9.0 | – | – | 10 | – | – | 10 | |
| Average Temperature Coefficient of Input Offset Voltage T _A = T _{high} to T _{low} (Note 1) | ΔV _{IO} /ΔT | – | 7.0 | – | – | 7.0 | – | – | 7.0 | – | – | 7.0 | – | μV/°C |
| Input Offset Current T _A = T _{high} to T _{low} (Note 1) | I _{IO} | – | 3.0 | 30 | – | 5.0 | 50 | – | 5.0 | 50 | – | 5.0 | 50 | nA |
| | | – | – | 100 | – | – | 150 | – | 45 | 200 | – | 45 | 200 | |
| Input Bias Current T _A = T _{high} to T _{low} (Note 1) | I _{IB} | – | –45 | –150 | – | –45 | –250 | – | –45 | –250 | – | –45 | –250 | |
| | | – | –50 | –300 | – | –50 | –500 | – | –50 | –500 | – | –50 | –500 | |
| Average Temperature Coefficient of Input Offset Current T _A = T _{high} to T _{low} (Note 1) | ΔI _{IO} /ΔT | – | 10 | – | – | 10 | – | – | 10 | – | – | 10 | – | pA/°C |
| Input Common Mode Voltage Range (Note 2), V _{CC} = 30 V (26 V for LM2904, V) V _{CC} = 30 V (26 V for LM2904, V), T _A = T _{high} to T _{low} | V _{ICR} | 0 | – | 28.3 | 0 | – | 28.3 | 0 | – | 24.3 | 0 | – | 24.3 | V |
| | | 0 | – | 28 | 0 | – | 28 | 0 | – | 24 | 0 | – | 24 | |
| Differential Input Voltage Range | V _{IDR} | – | – | V _{CC} | – | – | 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 1) | A _{VOL} | 50 | 100 | – | 25 | 100 | – | 25 | 100 | – | 25 | 100 | – | V/mV |
| | | 25 | – | – | 15 | – | – | 15 | – | – | 15 | – | – | |
| Channel Separation 1.0 kHz ≤ f ≤ 20 kHz, Input Referenced | CS | – | –120 | – | – | –120 | – | – | –120 | – | – | –120 | – | dB |
| Common Mode Rejection R _S ≤ 10 kΩ | CMR | 70 | 85 | – | 65 | 70 | – | 50 | 70 | – | 50 | 70 | – | dB |
| Power Supply Rejection | PSR | 65 | 100 | – | 65 | 100 | – | 50 | 100 | – | 50 | 100 | – | dB |
| Output Voltage—High Limit (T _A = T _{high} to T _{low}) (Note 1) V _{CC} = 5.0 V, R _L = 2.0 kΩ, T _A = 25°C V _{CC} = 30 V (26 V for LM2904, V), R _L = 2.0 kΩ V _{CC} = 30 V (26 V for LM2904, V), R _L = 10 kΩ | V _{OH} | 3.3 | 3.5 | – | 3.3 | 3.5 | – | 3.3 | 3.5 | – | 3.3 | 3.5 | – | V |
| | | 26 | – | – | 26 | – | – | 22 | – | – | 22 | – | – | |
| | | 27 | 28 | – | 27 | 28 | – | 23 | 24 | – | 23 | 24 | – | |
| Output Voltage—Low Limit V _{CC} = 5.0 V, R _L = 10 kΩ, T _A = T _{high} to T _{low} (Note 1) | V _{OL} | – | 5.0 | 20 | – | 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 | – | 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 | – | 10 | 20 | – | mA |
| | | 12 | 50 | – | 12 | 50 | – | – | – | – | – | – | – | μA |
| Output Short Circuit to Ground (Note 3) | I _{SC} | – | 40 | 60 | – | 40 | 60 | – | 40 | 60 | – | 40 | 60 | mA |
| Power Supply Current (T _A = T _{high} to T _{low}) (Note 1) V _{CC} = 30 V (26 V for LM2904, V), V _O = 0 V, R _L = ∞ V _{CC} = 5 V, V _O = 0 V, R _L = ∞ | I _{CC} | – | 1.5 | 3.0 | – | 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 | – | 0.7 | 1.2 | |

NOTES: 1. T_{low} = –40°C for LM2904
= –40°C for LM2904V
= –25°C for LM258
= 0°C for LM358
T_{high} = +105°C for LM2904
= +125°C for LM2904V
= +85°C for LM258
= +70°C for LM358

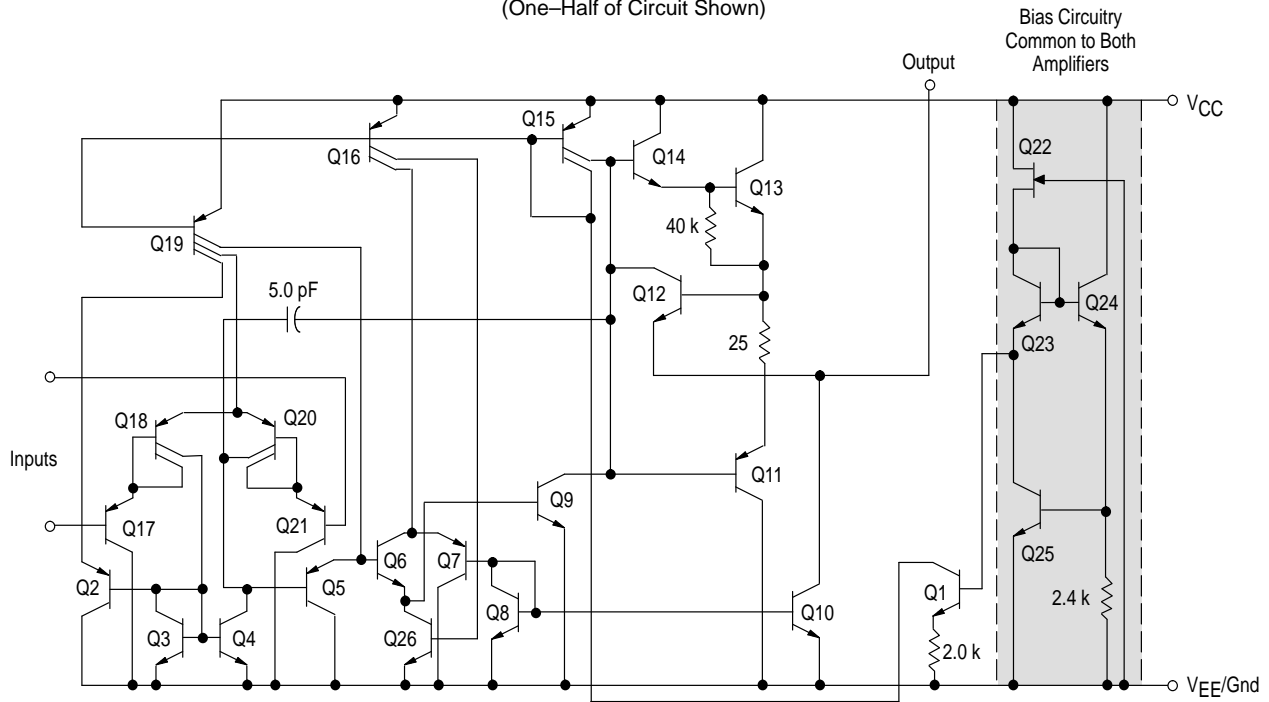
2. The input common mode voltage or either input signal voltage should not be allowed to go negative by more than 0.3 V. The upper end of the common mode voltage range is V_{CC} –1.7 V.

3. 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.

LM358, LM258, LM2904, LM2904V



Representative Schematic Diagram
(One-Half of Circuit Shown)



CIRCUIT DESCRIPTION

The LM258 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.

Large Signal Voltage Follower Response

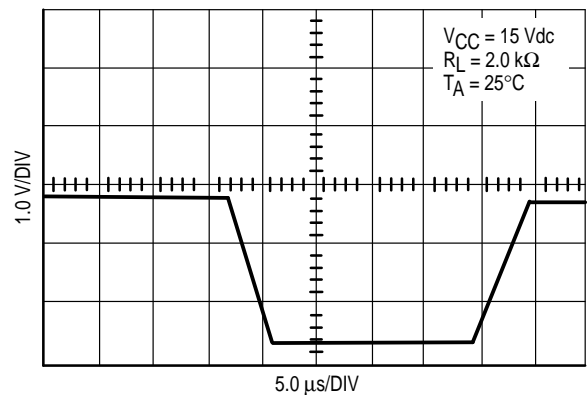


Figure 1. Input Voltage Range

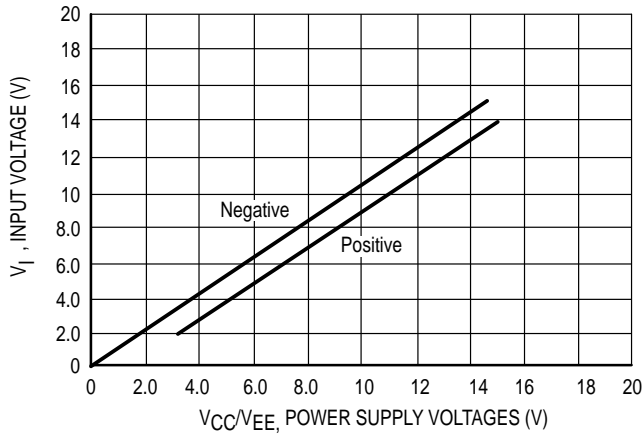


Figure 2. Large-Signal Open Loop Voltage Gain

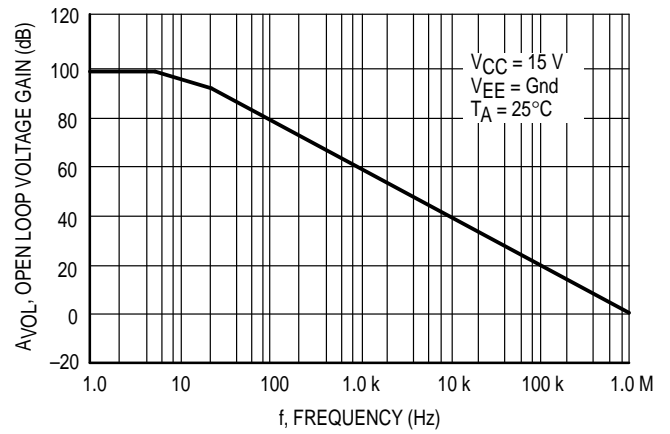


Figure 3. Large-Signal Frequency Response

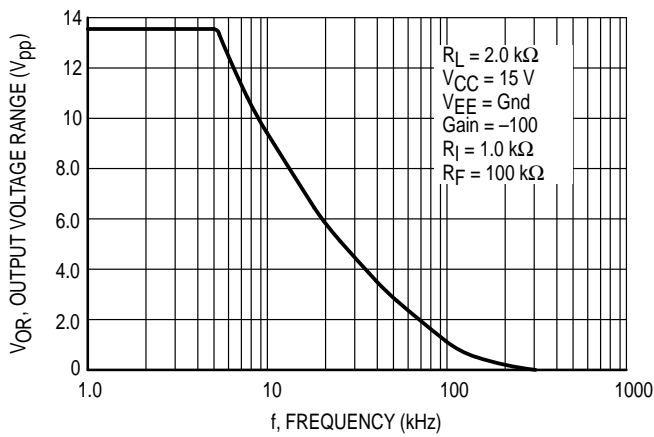


Figure 4. Small Signal Voltage Follower Pulse Response (Noninverting)

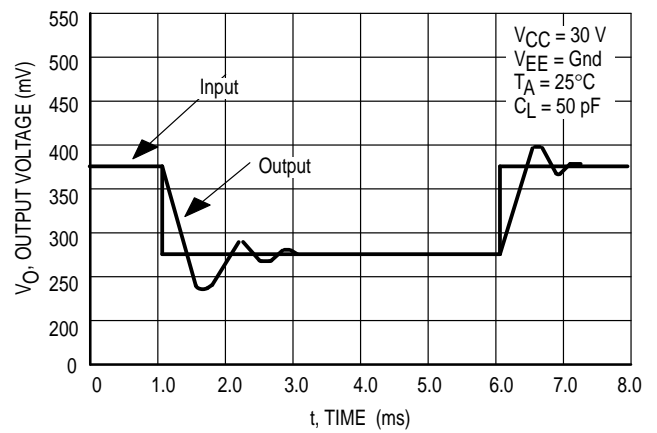


Figure 5. Power Supply Current versus Power Supply Voltage

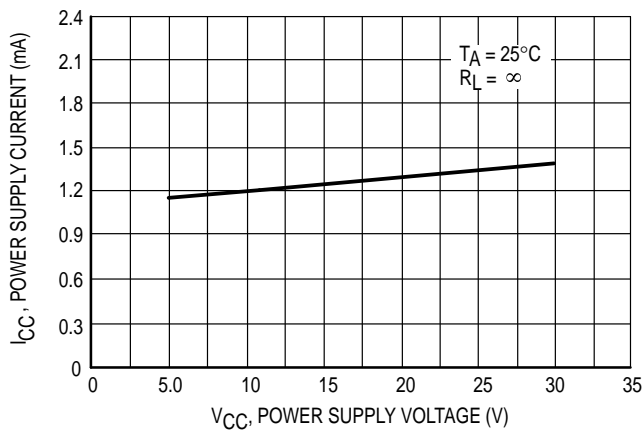
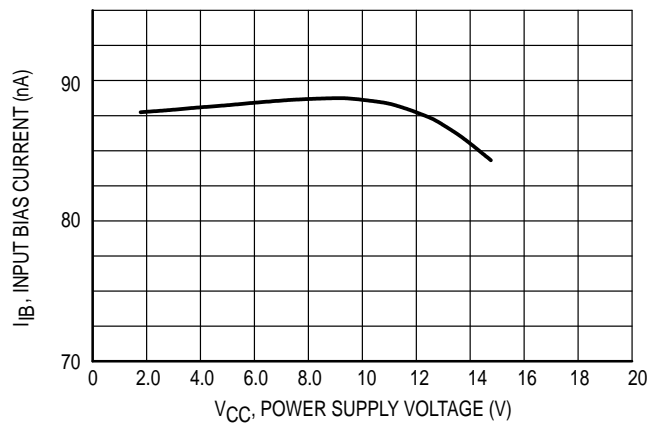


Figure 6. Input Bias Current versus Supply Voltage



LM358, LM258, LM2904, LM2904V

Figure 7. Voltage Reference

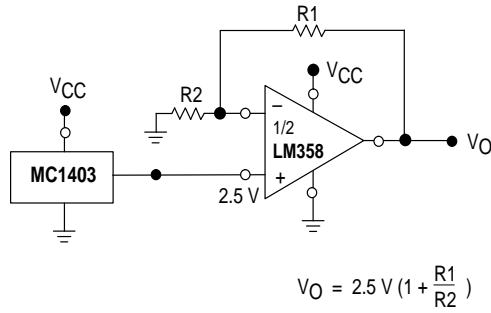


Figure 8. Wien Bridge Oscillator

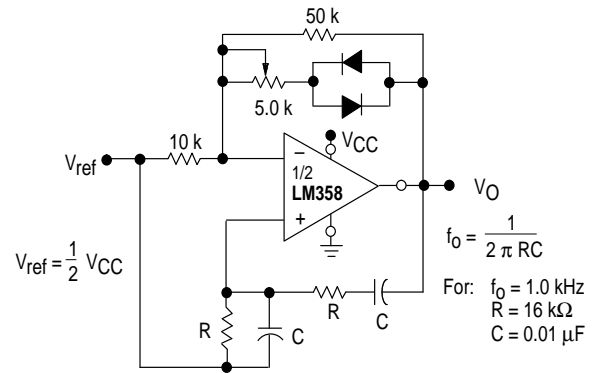


Figure 9. High Impedance Differential Amplifier

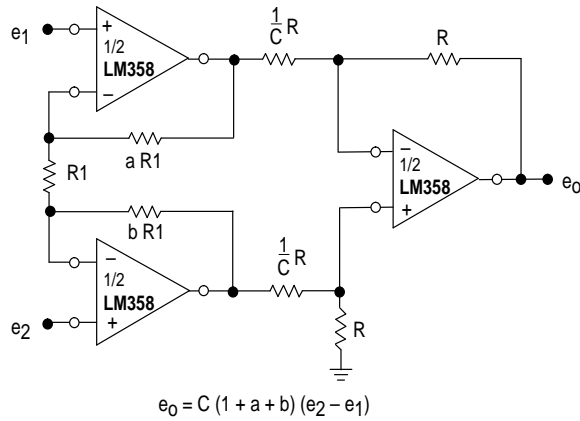


Figure 10. Comparator with Hysteresis

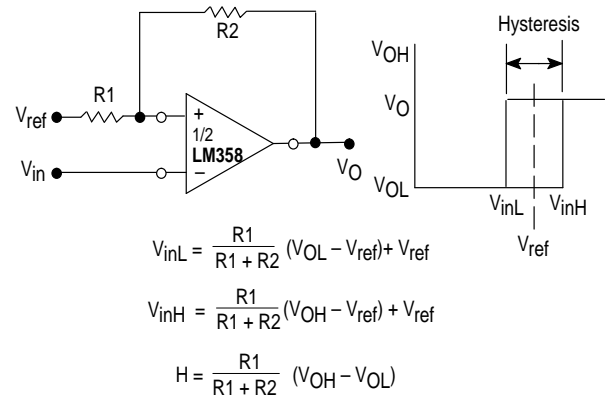


Figure 11. Bi-Quad Filter

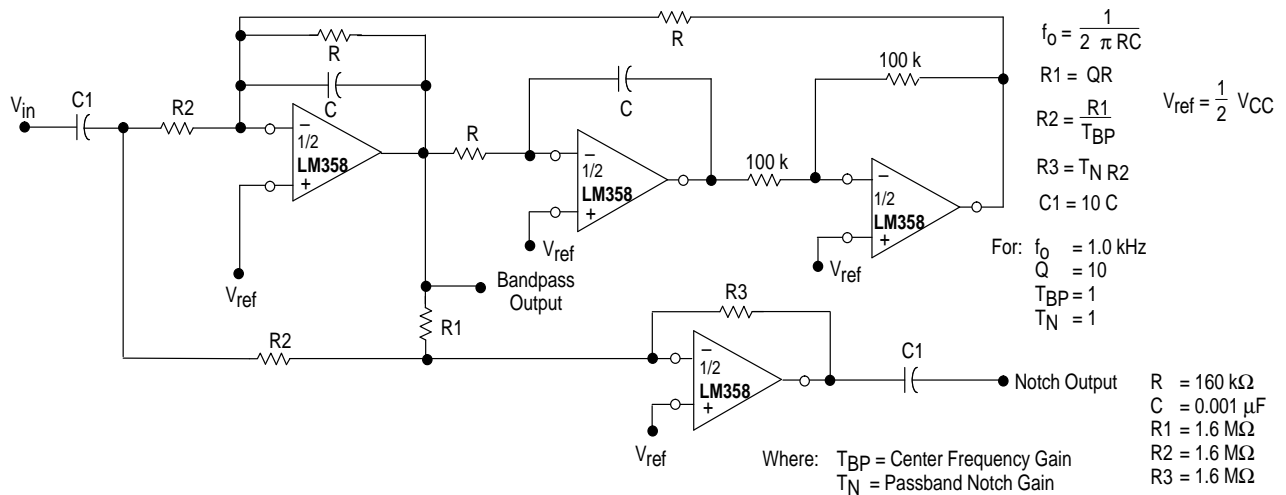


Figure 12. Function Generator

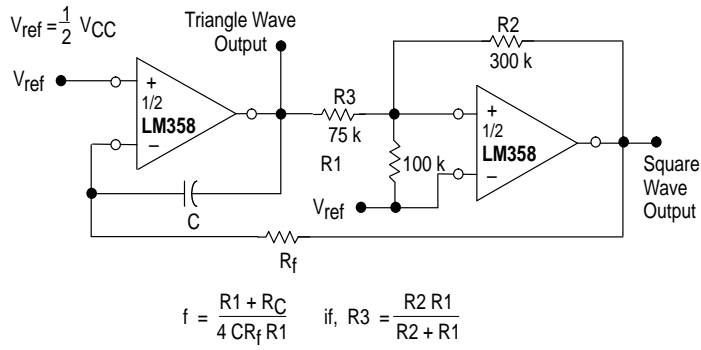
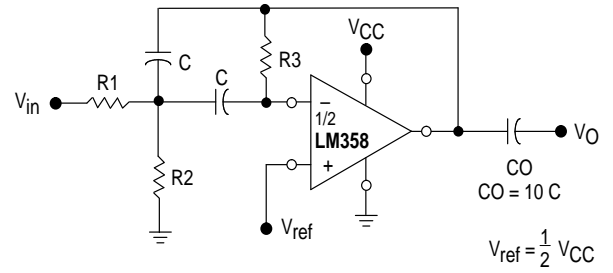


Figure 13. Multiple Feedback Bandpass Filter



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

Choose value f_0 , C

$$\text{Then: } R_3 = \frac{Q}{\pi f_0 C}$$

$$R_1 = \frac{R_3}{2 A(f_0)}$$

$$R_2 = \frac{R_1 R_3}{4 Q^2 R_1 - R_3}$$

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

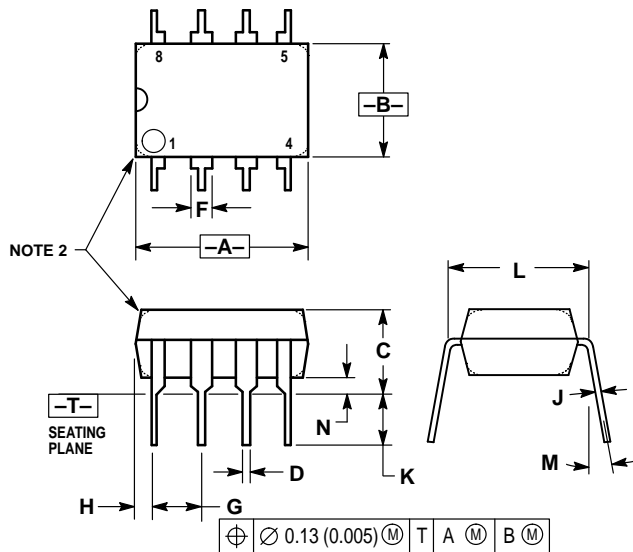
Where f_0 and BW are expressed in Hz.

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

LM358, LM258, LM2904, LM2904V

OUTLINE DIMENSIONS

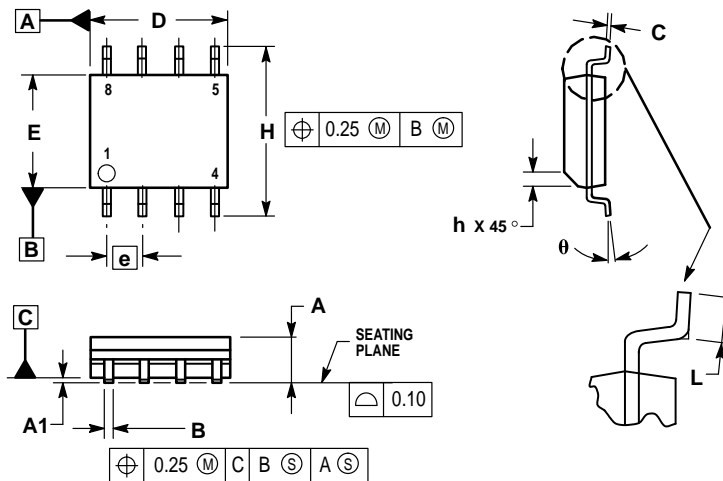
N SUFFIX PLASTIC PACKAGE CASE 626-05 ISSUE K



- 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.

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


D SUFFIX PLASTIC PACKAGE CASE 751-05 (SO-8) ISSUE R



- NOTES:
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
 2. DIMENSIONS ARE IN MILLIMETERS.
 3. DIMENSION D AND E DO NOT INCLUDE MOLD PROTRUSION.
 4. MAXIMUM MOLD PROTRUSION 0.15 PER SIDE.
 5. DIMENSION B DOES NOT INCLUDE MOLD PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.127 TOTAL IN EXCESS OF THE B DIMENSION AT MAXIMUM MATERIAL CONDITION.

| DIM | MILLIMETERS | |
|-----|-------------|------|
| | MIN | MAX |
| A | 1.35 | 1.75 |
| A1 | 0.10 | 0.25 |
| B | 0.35 | 0.49 |
| C | 0.18 | 0.25 |
| D | 4.80 | 5.00 |
| E | 3.80 | 4.00 |
| e | 1.27 BSC | |
| H | 5.80 | 6.20 |
| h | 0.25 | 0.50 |
| L | 0.40 | 1.25 |
| θ | 0° | 7° |

LM358, LM258, LM2904, LM2904V

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LM358/D



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