MOTOROLA

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
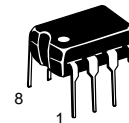- ESD Clamps on the Inputs Increase Ruggedness of the Device without Affecting Operation

N SUFFIX
PLASTIC PACKAGE
CASE 626

D SUFFIX
PLASTIC PACKAGE
CASE 751
(SO–8)

PIN CONNECTIONS

Output A [1]   [8] V_{CC}
Inputs A { [2] + [7] Output B
         [3] − [6] } Inputs B
V_{EE}/Gnd [4]   [5]

(Top View)

MAXIMUM RATINGS (T_A = +25°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		°C
Storage Temperature Range	T_{stg}	−55 to +125		°C

Operating Ambient Temperature Range
  LM258
  LM358
  LM2904
  LM2904V
	T_A	
		−25 to +85
		0 to +70
		−
		−
			
			−
			−
			−40 to +105
			−40 to +125
				°C

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.

ORDERING INFORMATION

Device	Operating Temperature Range	Package
LM2904D	T_A = −40° to +105°C	SO–8
LM2904N		Plastic DIP
LM2904VD	T_A = −40° to +125°C	SO–8
LM2904VN		Plastic DIP
LM258D	T_A = −25° to +85°C	SO–8
LM258N		Plastic DIP
LM358D	T_A = 0° to +70°C	SO–8
LM358N		Plastic DIP

Rev 2

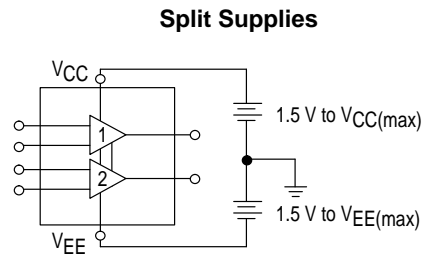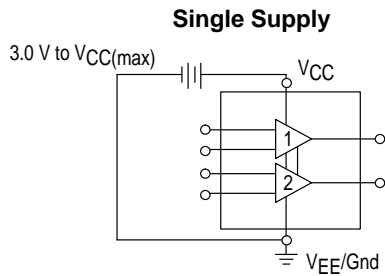# LM358, LM258, LM2904, LM2904V

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

Characteristic	Symbol	LM258 Min	LM258 Typ	LM258 Max	LM358 Min	LM358 Typ	LM358 Max	LM2904 Min	LM2904 Typ	LM2904 Max	LM2904V Min	LM2904V Typ	LM2904V Max	Unit
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, $V_O \simeq$ 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 7.0 2.0	− − −	2.0 − −	7.0 9.0 9.0	− − −	2.0 − −	7.0 10 10	− − −	− − −	− 13 10	mV
Average Temperature Coefficient of Input Offset Voltage $T_A = T_{high}$ to T_{low} (Note 1)	$\Delta V_{IO}/\Delta T$	−	7.0	−	−	7.0	−	−	7.0	−	−	7.0	−	µV/°C
Input Offset Current $T_A = T_{high}$ to T_{low} (Note 1) Input Bias Current $T_A = T_{high}$ to T_{low} (Note 1)	I_{IO} I_{IB}	− − − −	3.0 − −45 −50	30 100 −150 −300	− − − −	5.0 − −45 −50	50 150 −250 −500	− − − −	5.0 45 −45 −50	50 200 −250 −500	− − − −	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 1)	$\Delta I_{IO}/\Delta T$	−	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 0	− −	28.3 28	0 0	− −	28.3 28	0 0	− −	24.3 24	0 0	− −	24.3 24	V
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 25	100 −	− −	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	−	−	−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 26 27	3.5 − 28	− − −	3.3 26 27	3.5 − 28	− − −	3.3 22 23	3.5 − 24	− − −	3.3 22 23	3.5 − 24	− − −	V
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 12	20 50	− −	10 12	20 50	− −	10 −	20 −	− −	10 −	20 −	− −	mA 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, $R_L = \infty$ V_{CC} = 5 V, V_O = 0 V, $R_L = \infty$	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	− −	1.5 0.7	3.0 1.2	mA

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

Single Supply

3.0 V to $V_{CC(max)}$

V_{CC}

V_{EE}/Gnd

Split Supplies

V_{CC}

V_{EE}

1.5 V to $V_{CC(max)}$

1.5 V to $V_{EE(max)}$

Representative Schematic Diagram
(One–Half of Circuit Shown)

Bias Circuitry Common to Both Amplifiers

Output

V_{CC}

Q15, Q16, Q19, Q14, Q13, Q12, Q22, Q24, Q23, Q25

5.0 pF

40 k

25

Q18, Q20, Q17, Q21, Q2, Q3, Q4, Q5, Q6, Q7, Q8, Q26, Q9, Q11, Q10, Q1

Inputs

2.0 k

2.4 k

V_{EE}/Gnd
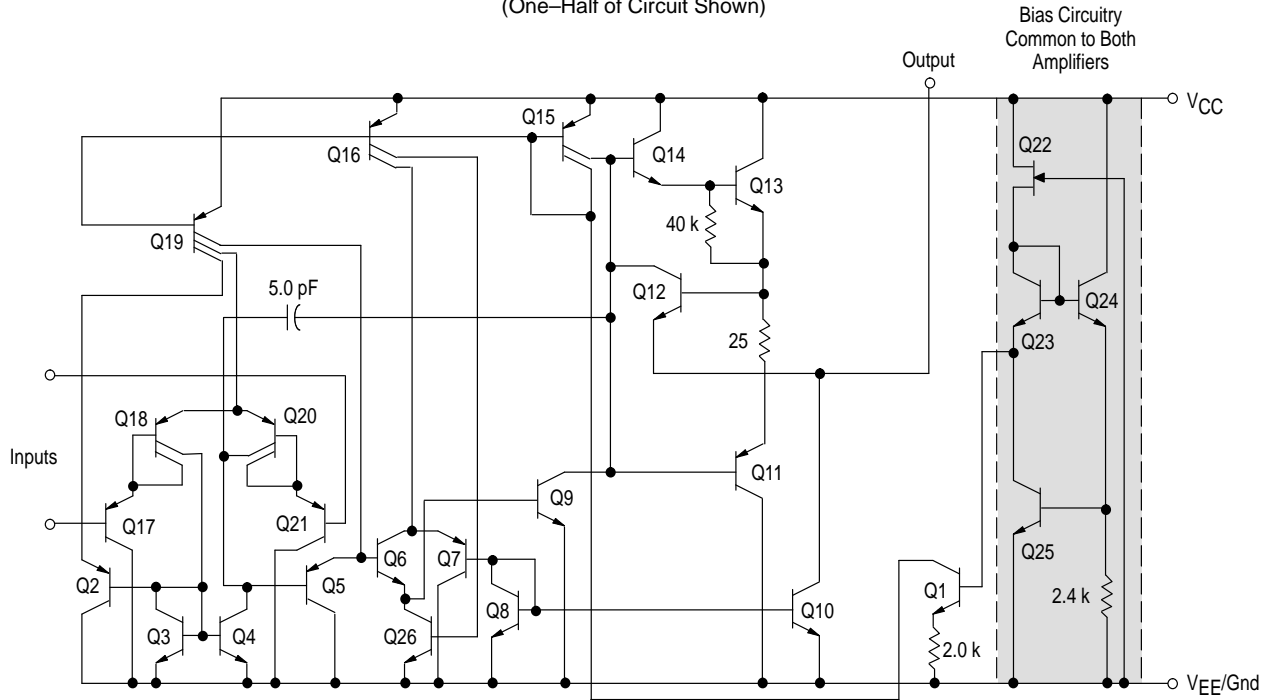
CIRCUIT DESCRIPTION

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

V_{CC} = 15 Vdc
R_L = 2.0 kΩ
T_A = 25°C

1.0 V/DIV

5.0 μs/DIV

MOTOROLA ANALOG IC DEVICE DATA   **3**

LM358, LM258, LM2904, LM2904V
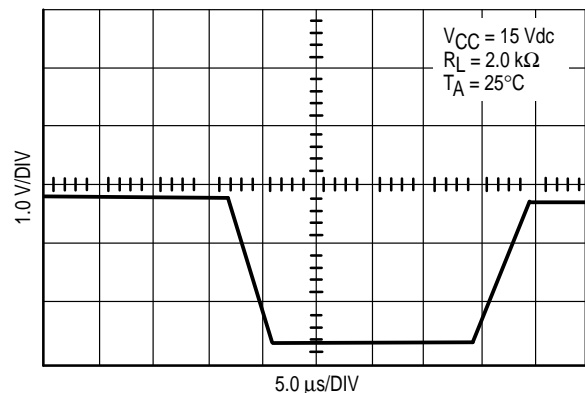
Figure 1. Input Voltage Range
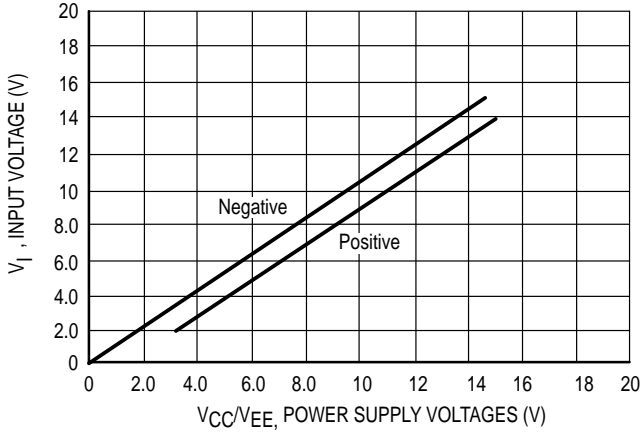
Figure 2. Large–Signal Open Loop Voltage Gain

$V_{CC} = 15$ V
$V_{EE} = $ Gnd
$T_A = 25°C$
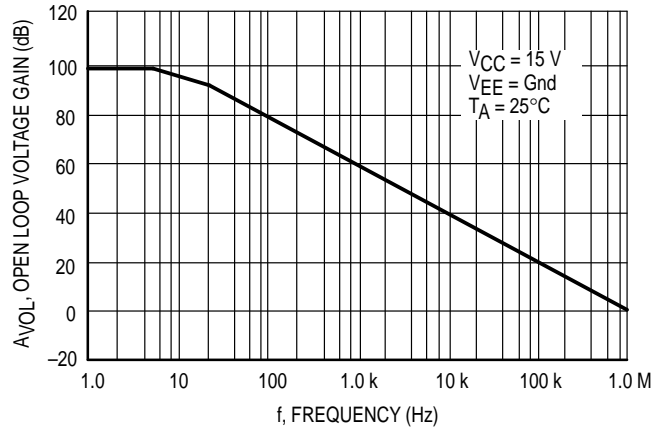
Figure 3. Large–Signal Frequency Response

$R_L = 2.0$ kΩ
$V_{CC} = 15$ V
$V_{EE} = $ Gnd
Gain = –100
$R_I = 1.0$ kΩ
$R_F = 100$ kΩ
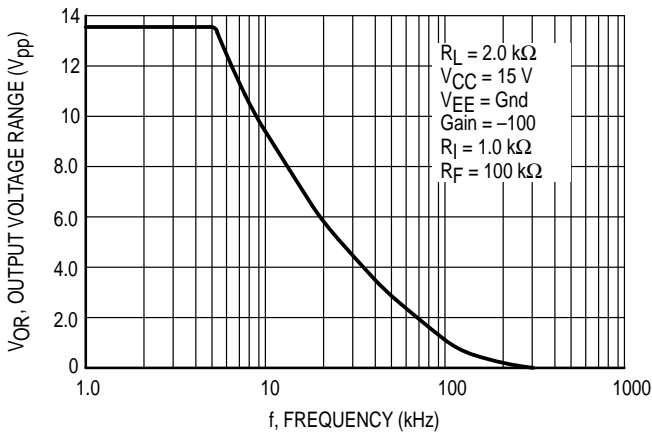
Figure 4. Small Signal Voltage Follower Pulse Response (Noninverting)

$V_{CC} = 30$ V
$V_{EE} = $ Gnd
$T_A = 25°C$
$C_L = 50$ pF

Input

Output
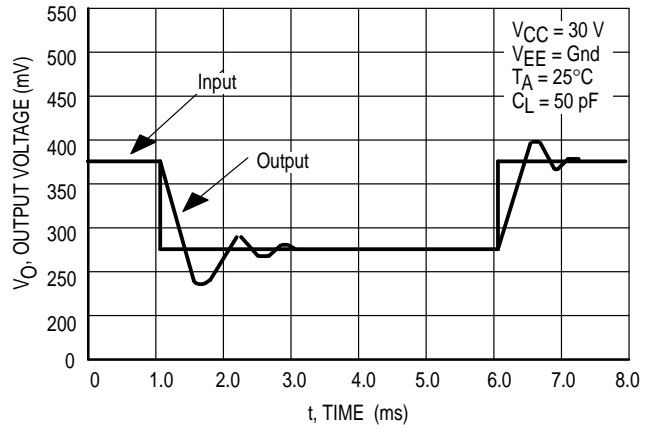
Figure 5. Power Supply Current versus Power Supply Voltage

$T_A = 25°C$
$R_L = \infty$
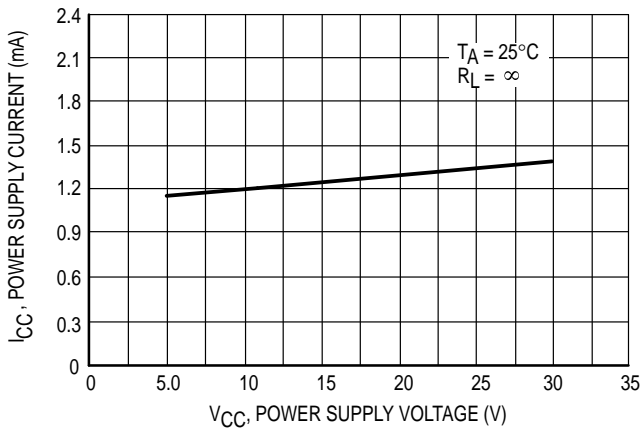
Figure 6. Input Bias Current versus Supply Voltage
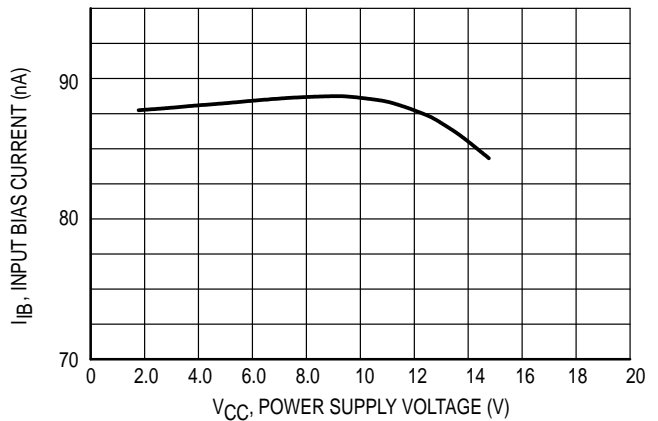
LM358, LM258, LM2904, LM2904V

Figure 7. Voltage Reference

$$V_O = 2.5 \text{ V} \left(1 + \frac{R1}{R2}\right)$$
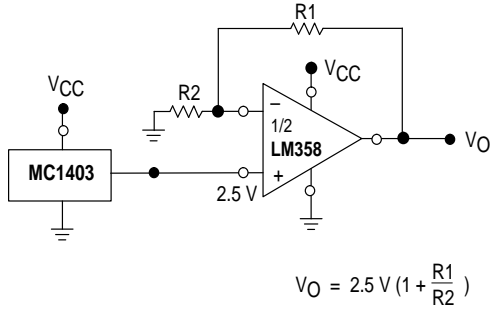
Figure 8. Wien Bridge Oscillator

$$V_{ref} = \frac{1}{2} V_{CC}$$

$$f_O = \frac{1}{2 \pi RC}$$

For: $f_O = 1.0$ kHz
$R = 16$ kΩ
$C = 0.01$ μF
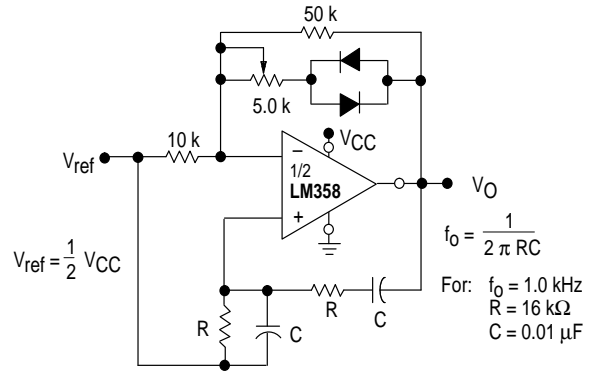
Figure 9. High Impedance Differential Amplifier

$$e_O = C (1 + a + b) (e_2 - e_1)$$
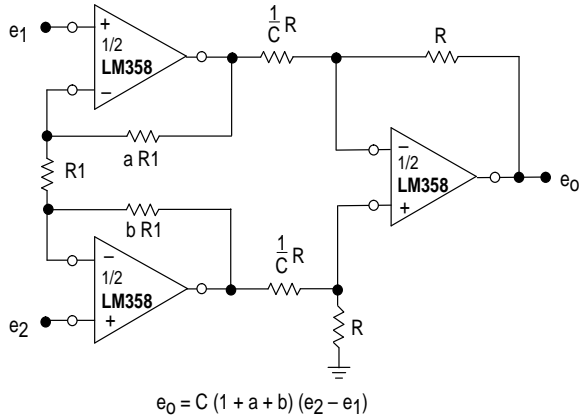
Figure 10. Comparator with Hysteresis

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

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

$$H = \frac{R1}{R1 + R2} (V_{OH} - V_{OL})$$
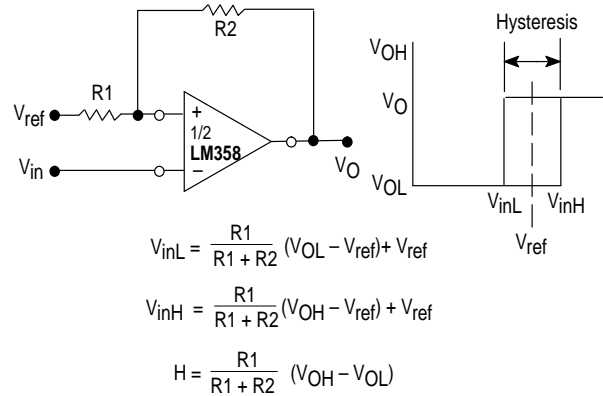
Figure 11. Bi–Quad Filter

$$f_O = \frac{1}{2 \pi RC}$$

$$R1 = QR$$

$$R2 = \frac{R1}{T_{BP}}$$

$$R3 = T_N R2$$

$$C1 = 10 C$$

$$V_{ref} = \frac{1}{2} V_{CC}$$

For: $f_O = 1.0$ kHz
$Q = 10$
$T_{BP} = 1$
$T_N = 1$

$R = 160$ kΩ
$C = 0.001$ μF
$R1 = 1.6$ MΩ
$R2 = 1.6$ MΩ
$R3 = 1.6$ MΩ

Where: T_{BP} = Center Frequency Gain
T_N = Passband Notch Gain

LM358, LM258, LM2904, LM2904V
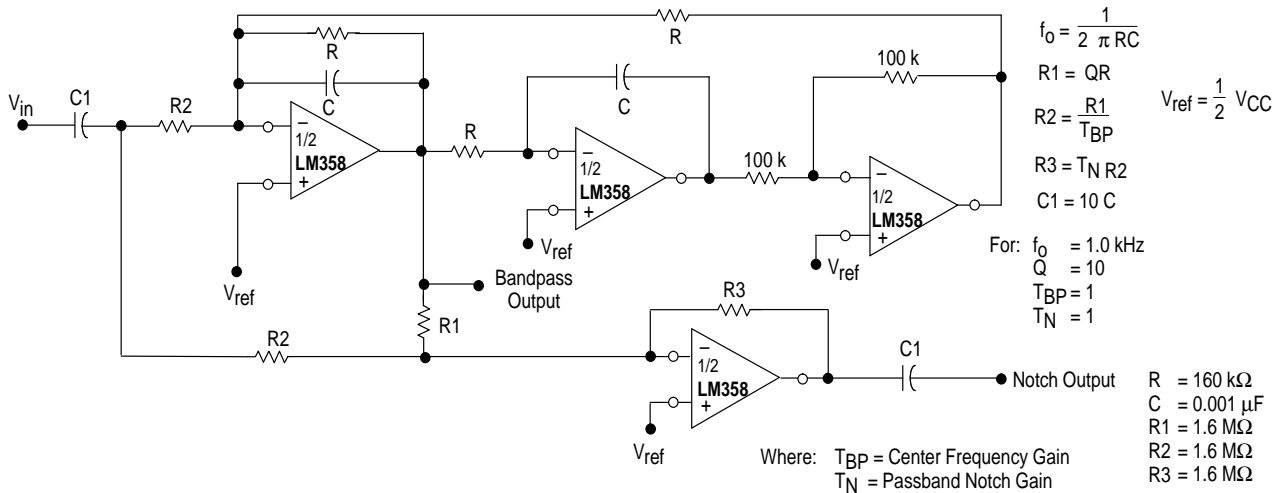
Figure 12. Function Generator

$V_{ref} = \frac{1}{2} V_{CC}$

Triangle Wave Output

V_{ref}

+
1/2
LM358
−

R3
75 k

R1

100 k

V_{ref}

+
1/2
LM358
−

R2
300 k

Square Wave Output

C

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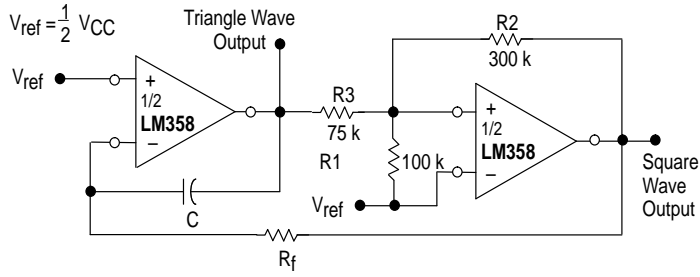
$$f = \frac{R1 + R_C}{4 \, CR_f \, R1} \quad \text{if,} \quad R3 = \frac{R2 \, R1}{R2 + R1}$$

Figure 13. Multiple Feedback Bandpass Filter

V_{in}

R1

C

C

R3

V_{CC}

−
1/2
LM358
+

V_{ref}

R2

CO
CO = 10 C

V_O

$V_{ref} = \frac{1}{2} V_{CC}$
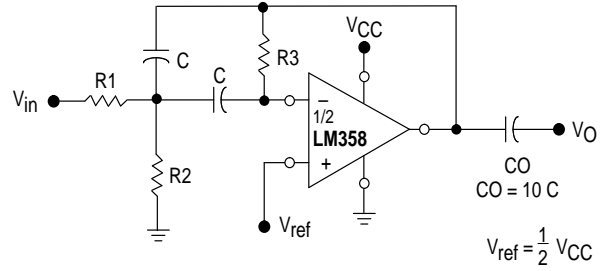
Given: f_O = center frequency
$A(f_O)$ = gain at center frequency

Choose value f_O, C

Then: $R3 = \dfrac{Q}{\pi \, f_O \, C}$

$R1 = \dfrac{R3}{2 \, A(f_O)}$

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

For less than 10% error from operational amplifier. $\dfrac{Q_O \, f_O}{BW} < 0.1$

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.

LM358, LM258, LM2904, LM2904V

OUTLINE DIMENSIONS

N SUFFIX
PLASTIC PACKAGE
CASE 626–05
ISSUE K

NOTE 2

–B–

–A–

F

L

C

–T–
SEATING
PLANE

J

N

D

K

M

H

G

⊕ | ⌀ 0.13 (0.005) Ⓜ | T | A Ⓜ | B Ⓜ
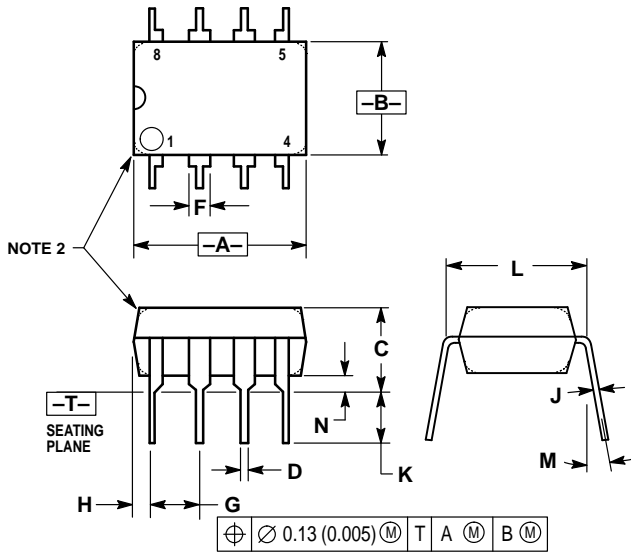
NOTES:
1. DIMENSION L TO CENTER OF LEAD WHEN FORMED PARALLEL.
2. PACKAGE CONTOUR OPTIONAL (ROUND OR SQUARE CORNERS).
3. DIMENSIONING AND TOLERANCING PER ANSI Y14.5M, 1982.

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

A

D

E

H

⊕ | 0.25 Ⓜ | B Ⓜ

B

e

C

A

C

SEATING
PLANE

⌓ | 0.10

A1

B

⊕ | 0.25 Ⓜ | C | B Ⓢ | A Ⓢ

h X 45°

θ

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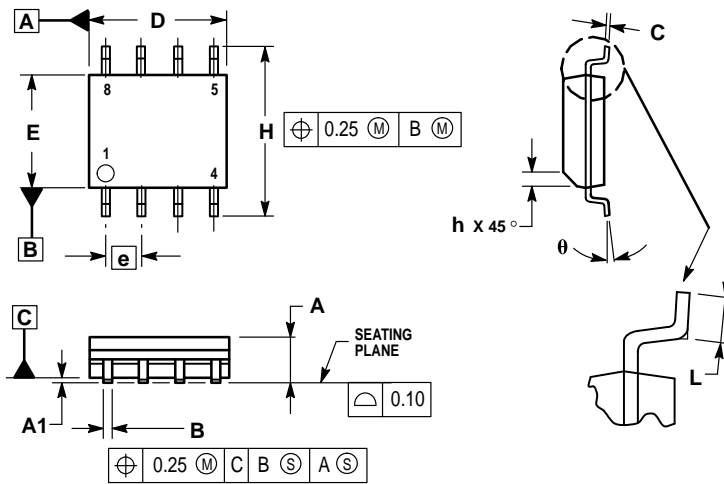
NOTES:
1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M, 1994.
2. DIMENSIONS ARE IN MILLIMETERS.
3. DIMENSION D AND E DO NOT INCLUDE MOLD PROTRUSION.
4. MAXIMUM MOLD PROTRUSION 0.15 PER SIDE.
5. DIMENSION B DOES NOT INCLUDE MOLD PROTRUSION. ALLOWABLE DAMBAR PROTRUSION SHALL BE 0.127 TOTAL IN EXCESS OF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

Ⓜ **MOTOROLA**   ◊

LM358/D