MOTOROLA
SEMICONDUCTOR ■
TECHNICAL DATA

2

Dual Low Power Operational Amplifiers

LM158, LM258,
LM358, LM2904

DUAL DIFFERENTIAL INPUT OPERATIONAL AMPLIFIERS

SILICON MONOLITHIC INTEGRATED CIRCUIT

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) pin outs 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

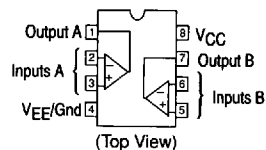**J SUFFIX**
CERAMIC PACKAGE
CASE 693

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	LM158 LM258 LM358	LM2904	Unit
Power Supply Voltages Single Supply Split Supplies	V_{CC} V_{CC}, V_{EE}	32 ±16	26 ±13	Vdc
Input Differential Voltage Range (1)	V_{IDR}	±32	±26	Vdc
Input Common Mode Voltage Range (2)	V_{ICR}	−0.3 to 32	−0.3 to 26	Vdc
Output Short Circuit Duration	t_{SC}	Continuous		
Junction Temperature Ceramic Package Plastic Package	T_J	175 150		°C
Storage Temperature Range Ceramic Package Plastic Package	T_{stg}	−65 to +150 −55 to +125		°C
Operating Ambient Temperature Range LM158 LM258 LM358 LM2904	T_A	−55 to +125 −25 to +85 0 to +70 —	— — — −40 to +105	°C

NOTES: 1. Split Power Supplies.
2. For Supply Voltages less than 32 V for the LM158/258/358 and 26 V for the LM2904, the absolute maximum input voltage is equalt to the supply voltage
3. This input current will only exist when the voltage is negative at any of the input leads. Normal output states will reestablish when the input voltage returns to a voltage greater than −0.3 V.

ORDERING INFORMATION

Device	Temperature Range	Package
LM158J	−55° to +125°C	Ceramic DIP
LM2904D	−40° to +105°C	SO-8
LM2904N		Plastic DIP
LM2904J	−40° to +85°C	Ceramic DIP
LM258D		SO-8
LM258J	−25° to +85°C	Ceramic DIP
LM258N		Plastic DIP
LM358D		SO-8
LM358J	0° to +70°C	Ceramic DIP
LM358N		Plastic DIP

LM158, LM258, LM358, LM2904

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

| Characteristics	Symbol	LM158/LM258 Min	Typ	Max	LM358 Min	Typ	Max	LM2904 Min	Typ	Max	Unit
Input Offset Voltage V_{CC} = 5.0 V to 30 V (26 V for LM2904), V_{IC} = 0 V to V_{CC} −1.7 V, V_O ≈ 14 V, R_S = 0 Ω T_A = 25°C	V_{IO}	—	2.0	5.0	—	2.0	7.0	—	2.0	7.0	mV
T_A = T_{high} to T_{low} (Note 1)		—	—	7.0	—	—	9.0	—	—	10	
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	—	µV/°C
Input Offset Current	I_{IO}	—	3.0	30	—	5.0	50	—	5.0	50	nA
T_A = T_{high} to T_{low} (Note 1)		—	—	100	—	—	150	—	45	200	
Input Bias Current	I_{IB}	—	−45	−150	—	−45	−250	—	−45	−250	
T_A = T_{high} to T_{low} (Note 1)		—	−50	−300	—	−50	−500	—	−50	−500	
Average Temperature Coefficient of Input Offset Current T_A = T_{high} to T_{low} (Note 1)	$\Delta I_{IO}/\Delta T$	—	10	—	—	10	—	—	10	—	pA/°C
Input Common Mode Voltage Range (Note 2) V_{CC} = 30 V (26 V for LM2904)	V_{ICR}	0	—	28.3	0	—	28.3	0	—	24.3	V
V_{CC} = 30 V (26 V for LM2904), T_A = T_{high} to T_{low}		0	—	28	0	—	28	0	—	24	
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,	A_{VOL}	50	100	—	25	100	—	25	100	—	V/mV
T_A = T_{high} to T_{low} (Note 1)		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	—	50	70	—	dB
Power Supply Rejection	PSR	65	100	—	65	100	—	50	100	—	dB
Output Voltage—High Limit (T_A = T_{high} to T_{low}) (Note 1)	V_{OH}										V
V_{CC} = 50 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 (26 V for LM2904), R_L = 2 kΩ		26	—	—	26	—	—	22	—	—	
V_{CC} = 30 V (26 V for LM2904), R_L = 10 kΩ		27	28	—	27	28	—	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	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	I_{O-}	10	20	—	10	20	—	10	20	—	mA
V_{ID} = −1.0 V, V_O = 200 mV		12	50	—	12	50	—	—	—	—	µA
Output Short Circuit to Ground (Note 3)	I_{SC}	—	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_O = 0 V, R_L = ∞	I_{CC}	—	1.5	3.0	—	1.5	3.0	—	1.5	3.0	mA
V_{CC} = 5 V, V_O = 0 V, R_L = ∞		—	0.7	1.2	—	0.7	1.2	—	0.7	1.2	

NOTES: 1. T_{low} = −55°C for LM158 T_{high} = +125°C for LM158
= −40°C for LM2904   = +105°C for LM2904
= −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.
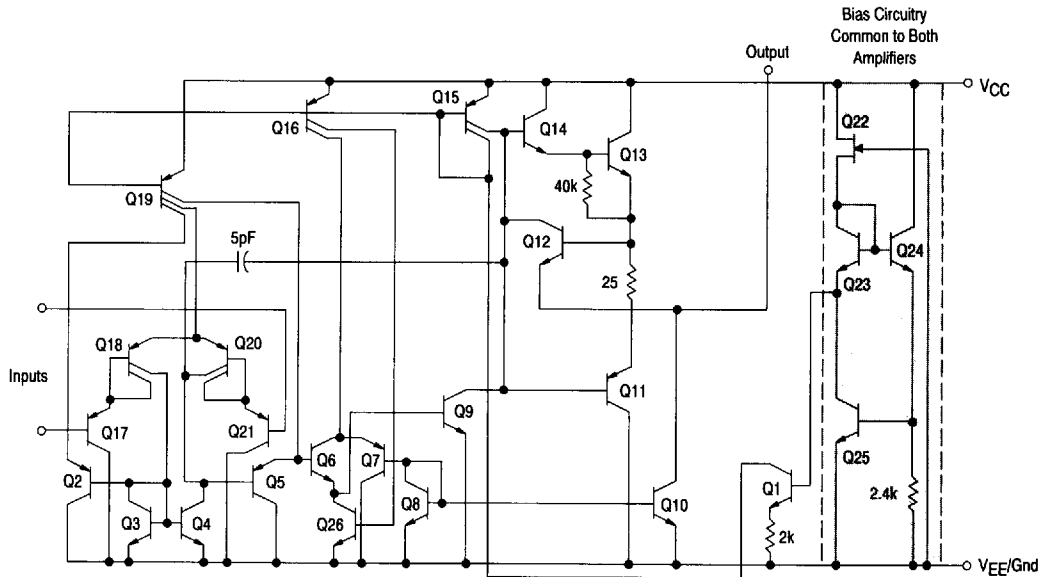
Single Supply

3.0V to V_{CC}(max)

Split Supplies

1.5V to V_{CC}(max)
1.5V to V_{EE}(max)
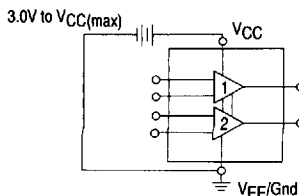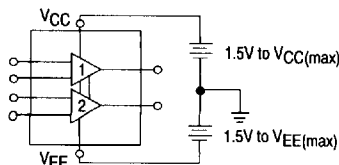
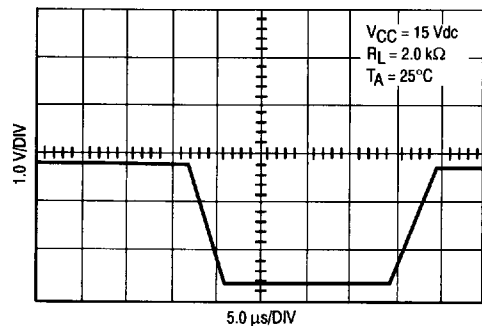# LM158, LM258, LM358, LM2904

Representative Circuit Schematic
(One-Half of Circuit Shown)

CIRCUIT DESCRIPTION

The LM158 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

LM158, LM258, LM358, LM2904

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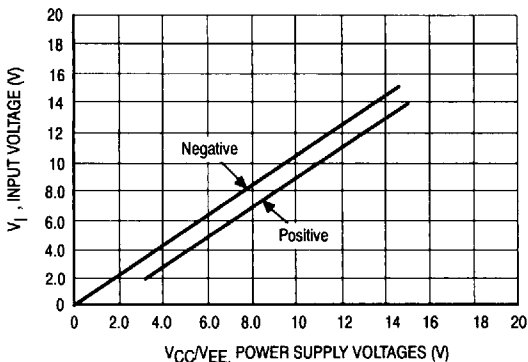
Figure 1. Input Voltage Range

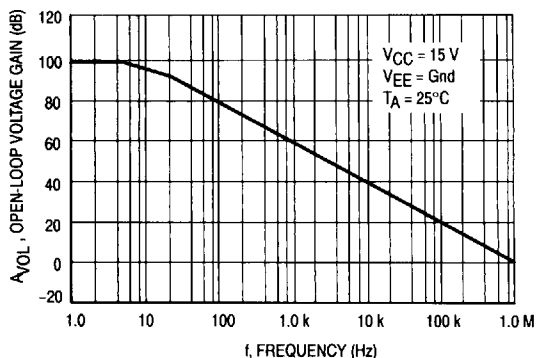**Figure 2. Large-Signal Open-Loop Voltage Gain**

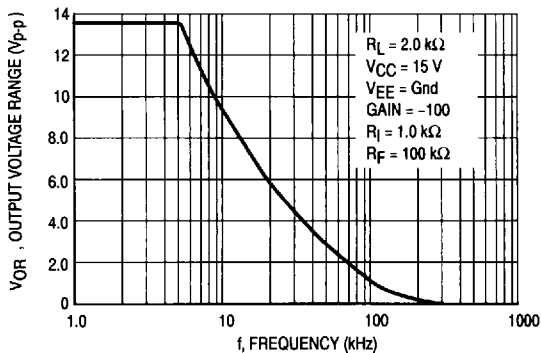

Figure 3. Large-Signal Frequency Response

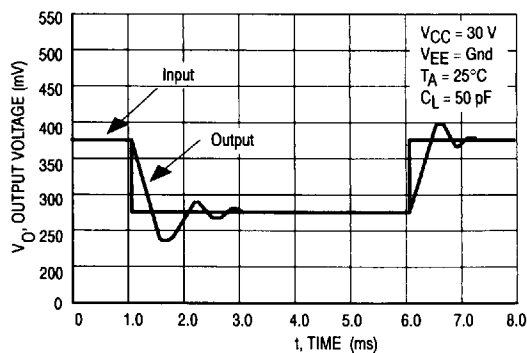**Figure 4. Small Signal Voltage Follower Pulse Response (Noninverting)**

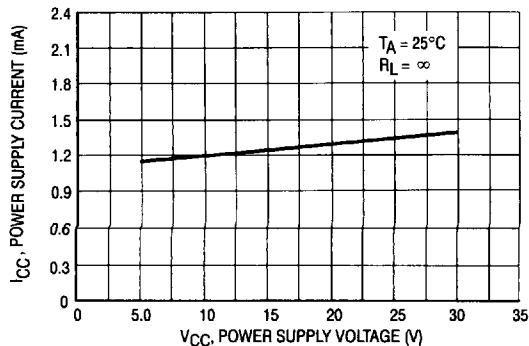**Figure 5. Power Supply Current versus Power Supply Voltage**

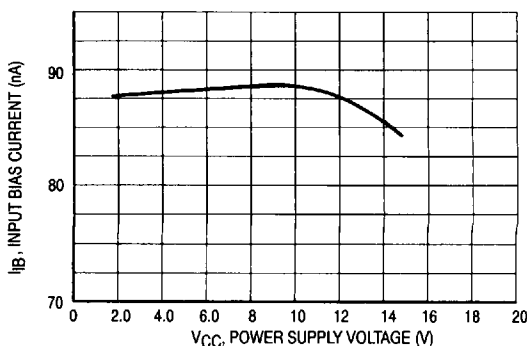**Figure 6. Input Bias Current versus Supply Voltage**

LM158, LM258, LM358, LM2904
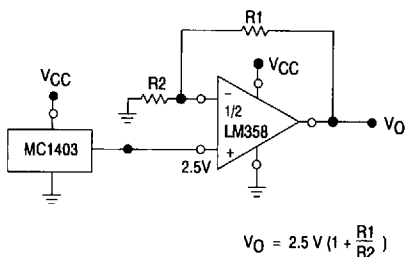
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Figure 7. Voltage Reference

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

Figure 8. Wien Bridge Oscillator

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

$$f_0 = \frac{1}{2\ \pi\ RC}$$

For: f_0 = 1.0 kHz
      R = 16 kΩ
      C = 0.01 μF
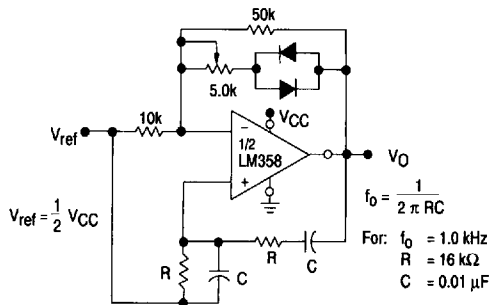
Figure 9. High Impedance Differential Amplifier

$$e_0 = C\ (1 + a + b)\ (e2 - e1)$$
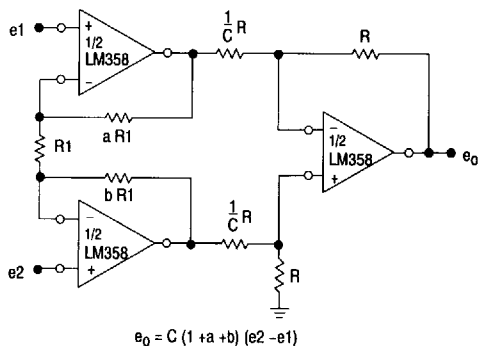
Figure 10. Comparator with Hysteresis

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

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

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

Figure 11. Bi-Quad Filter

$$f_0 = \frac{1}{2\ \pi\ RC}$$

$R1 = QR$

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

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

$R3 = T_N\ R2$

$C1 = 10\ C$

For: f_0 = 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
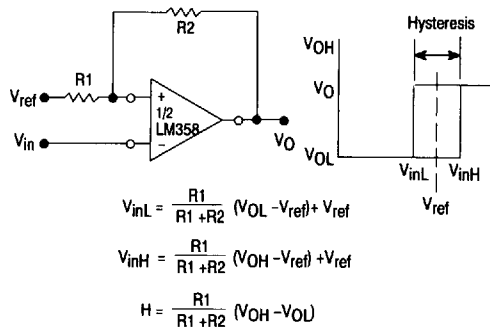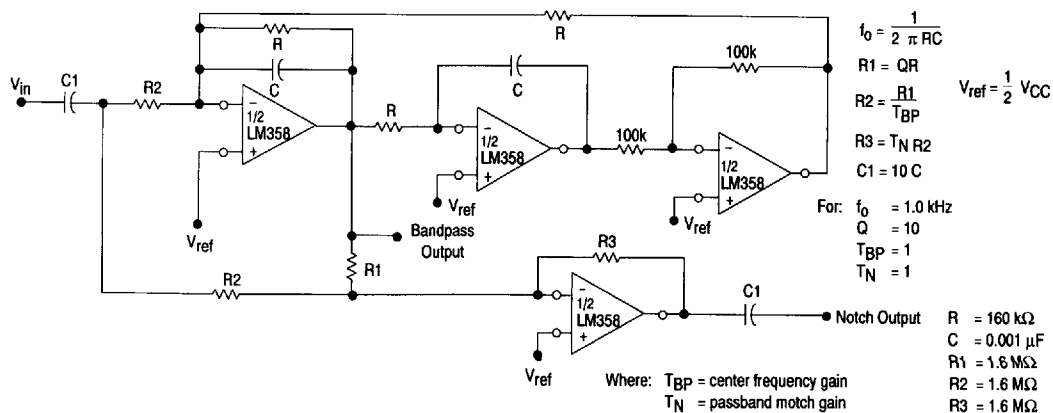
LM158, LM258, LM358, LM2904

Figure 12. Function Generator

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

Triangle Wave Output

V_{ref}

1/2 LM358

R3 75k

R1 100k

V_{ref}

R2 300k

1/2 LM358

Square Wave Output

C

R_f

$$f = \frac{R1 + R_C}{4\,CR_f\,R1} \qquad \text{if, } R3 = \frac{R2\,R1}{R2 + R1}$$
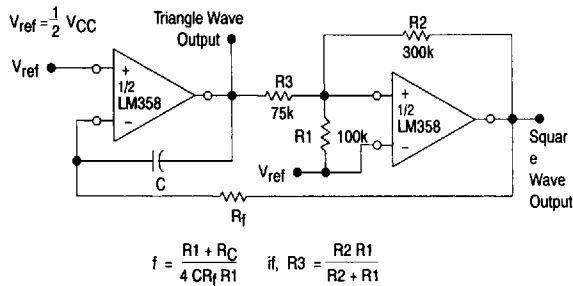
Figure 13. Multiple Feedback Bandpass Filter

V_{in}

R1

C

C

R2

R3

V_{CC}

1/2 LM358

V_{ref}

V_O

C_O

$C_O = 10\,C$

$V_{ref} = \frac{1}{2} V_{CC}$
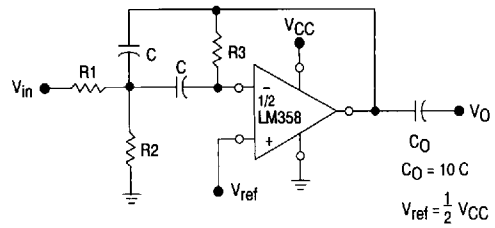
Given: f_0 = center frequency
          $A(f_0)$ = gain at center frequency

Choose value f_0, C
  Then:

$$R3 = \frac{Q}{\pi\,f_0\,C}$$

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

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

For less than 10% error from operational amplifier.

$$\frac{Q_0\,f_0}{BW} < 0.1 \qquad \text{Where } f_0 \text{ and BW are expressed in Hz.}$$

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