

T-79-10

**MOTOROLA**

Specifications and Applications Information

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) 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 Volts or as high as 32 Volts 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 to 32 Volts
- Low Input Bias Currents
- Internally Compensated
- Common Mode Range Extends to Negative Supply
- Single and Split Supply Operation
- Similar Performance to the Popular MC1558

MAXIMUM RATINGS ($T_A = +25^\circ\text{C}$ 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
Input Forward Current (3) ($V_I < -0.3\text{ V}$)	I_{IF}	50	—	mA
Output Short Circuit Duration	t_S	Continuous		
Junction Temperature Ceramic and Metal Packages Plastic Package	T_J	175 150		$^\circ\text{C}$
Storage Temperature Range Ceramic and Metal Packages Plastic Package	T_{stg}	-65 to +150 -55 to +125		$^\circ\text{C}$
Operating Ambient Temperature Range LM158 LM258 LM358 LM2904	T_A	-55 to +125 -25 to +85 0 to +70 —	— — — -40 to +85	$^\circ\text{C}$

(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 equal 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.

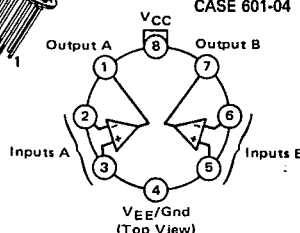
LM158, LM258, LM358, LM2904

DUAL DIFFERENTIAL INPUT OPERATIONAL AMPLIFIERS

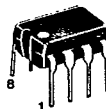
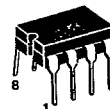
SILICON MONOLITHIC INTEGRATED CIRCUIT



H SUFFIX
METAL PACKAGE
CASE 601-04

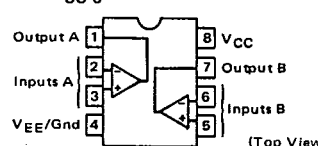


J SUFFIX
CERAMIC PACKAGE
CASE 693-02



N SUFFIX
PLASTIC PACKAGE
CASE 626-05

D SUFFIX
PLASTIC PACKAGE
CASE 751-02
SO-8



ORDERING INFORMATION

Device	Temperature Range	Package
LM158H	-55 to +125 $^\circ\text{C}$	Metal Can
LM158J		Ceramic DIP
LM2904D		SO-8
LM2904H		Metal Can
LM2904J	-40 to +85 $^\circ\text{C}$	Ceramic DIP
LM2904N		Plastic DIP
LM258D		SO-8
LM258H		Metal Can
LM258J	-25 to +85 $^\circ\text{C}$	Ceramic DIP
LM258N		Plastic DIP
LM358D		SO-8
LM358H		Metal Can
LM358J	0 to +70 $^\circ\text{C}$	Ceramic DIP
LM358N		Plastic DIP

LM158, LM258, LM358, LM2904

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

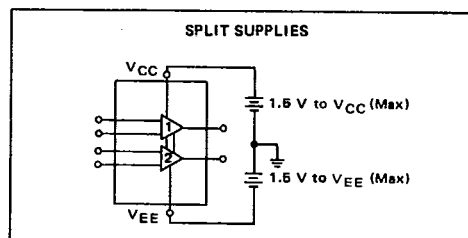
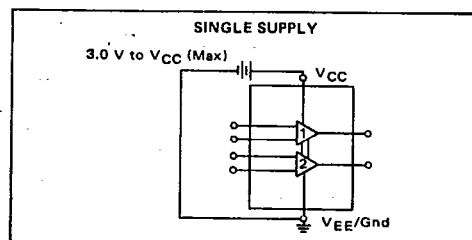
Characteristic	Symbol	LM158/LM258			LM358			LM2904			Unit
		Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage $V_{CC} = 5.0$ V to 30 V (26 V for LM2904), $V_{IC} = 0$ V to $V_{CC} - 1.7$ V, $V_O = 1.4$ V, $R_S = 0$ Ω $T_A = 25^\circ\text{C}$ $T_A = T_{\text{high}}$ to T_{low} (Note 1)	V_{IO}	—	2.0	5.0	—	2.0	7.0	—	2.0	7.0	mV
Average Temperature Coefficient of Input Offset Voltage $T_A = T_{\text{high}}$ to T_{low} (Note 1)	$\Delta V_{IO}/\Delta T$	—	7.0	—	—	7.0	—	—	7.0	—	$\mu\text{V}/^\circ\text{C}$
Input Offset Current $T_A = T_{\text{high}}$ to T_{low} (Note 1)	I_{IO}	—	3.0	30	—	5.0	50	—	5.0	50	nA
Average Temperature Coefficient of Input Offset Current $T_A = T_{\text{high}}$ to T_{low} (Note 1)	$\Delta I_{IO}/\Delta T$	—	10	—	—	10	—	—	10	—	$\text{pA}/^\circ\text{C}$
Input Bias Current $T_A = T_{\text{high}}$ to T_{low} (Note 1)	I_{IB}	—	-45	-150	—	-45	-250	—	-45	-250	nA
Input Common-Mode Voltage Range (Note 2) $V_{CC} = 30$ V (26 V for LM2904) $V_{CC} = 30$ V (26 V for LM2904), $T_A = T_{\text{high}}$ to T_{low}	V_{ICR}	0	—	28.3	0	—	28.3	0	—	24.3	V
Differential Input Voltage Range	V_{IDR}	—	—	V_{CC}	—	—	V_{CC}	—	—	V_{CC}	V
Large Signal Open-Loop Voltage Gain $R_L = 2.0$ k Ω , $V_{CC} = 15$ V, For Large V_O Swing, $T_A = T_{\text{high}}$ to T_{low} (Note 1)	A_{VOL}	50	100	—	25	100	—	—	100	—	V/mV
Channel Separation 1.0 kHz $\leq f \leq 20$ kHz, Input Referenced	—	—	-120	—	—	-120	—	—	-120	—	dB
Common-Mode Rejection Ratio $R_S \leq 10$ k Ω	CMRR	70	85	—	65	70	—	50	70	—	dB
Power Supply Rejection Ratio	PSRR	65	100	—	65	100	—	50	100	—	dB
Output Voltage Range $R_L = 2$ k Ω ($R_L \geq 10$ k Ω for LM2904)	V_{OR}	0	—	3.3	0	—	3.3	0	—	3.3	V
Output Voltage—High Limit ($T_A = T_{\text{high}}$ to T_{low}) (Note 1) $V_{CC} = 30$ V (26 V for LM2904), $R_L = 2$ k Ω $V_{CC} = 30$ V (26 V for LM2904), $R_L = 10$ k Ω	V_{OH}	26	—	—	26	—	—	22	—	—	V
		27	28	—	27	28	—	23	24	—	
Output Voltage—Low Limit $V_{CC} = 5.0$ V, $R_L = 10$ k Ω , $T_A = T_{\text{high}}$ 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 $V_{ID} = -1.0$ V, $V_O = 200$ mV	I_{O-}	10	20	—	10	20	—	10	20	—	mA
		12	50	—	12	50	—	—	—	—	μA
Output Short Circuit to Ground (Note 3)	I_{OS}	—	40	60	—	40	60	—	40	60	mA
Power Supply Current ($T_A = T_{\text{high}}$ to T_{low}) (Note 1) $V_{CC} = 30$ V (26 V for LM2904), $V_O = 0$ V, $R_L = \infty$ $V_{CC} = 5$ V, $V_O = 0$ V, $R_L = \infty$	I_{CC}	—	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	

NOTES:

- (1) $T_{\text{low}} = -55^\circ\text{C}$ for LM158 $T_{\text{high}} = +125^\circ\text{C}$ for LM158
 $= -40^\circ\text{C}$ for LM2904 $= +85^\circ\text{C}$ for LM2904
 $= -25^\circ\text{C}$ for LM258 and LM258
 $= 0^\circ\text{C}$ for LM358 $= +70^\circ\text{C}$ for LM358
- (2) The input common-mode voltage or either input signal voltage should not be allowed to go negative by more than

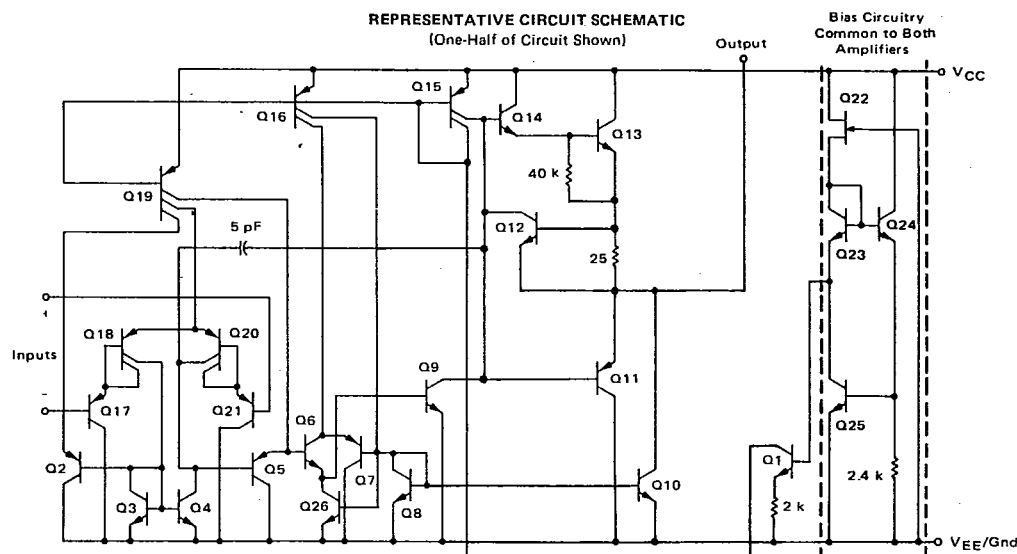
0.3 V. The upper end of the common-mode voltage range is $V_{CC} - 1.7$ V, but either or both inputs can go to $+32$ V without damage ($+26$ V for LM2904).

- (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.

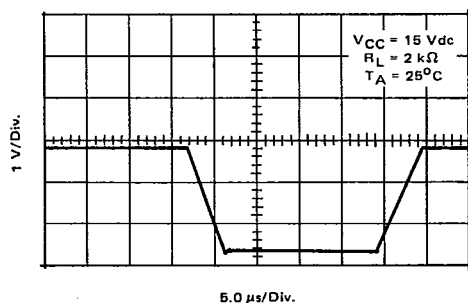


LM158, LM258, LM358, LM2904

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**LARGE SIGNAL VOLTAGE
FOLLOWER RESPONSE**

**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 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.

LM158, LM258, LM358, LM2904

TYPICAL PERFORMANCE CURVES

FIGURE 1 - INPUT VOLTAGE RANGE

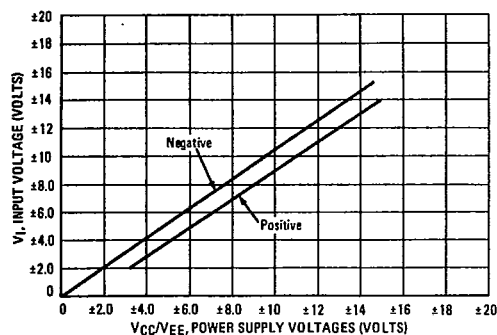


FIGURE 2 - OPEN LOOP FREQUENCY

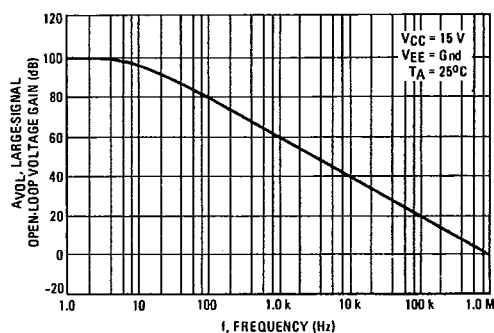


FIGURE 3 - LARGE-SIGNAL FREQUENCY RESPONSE

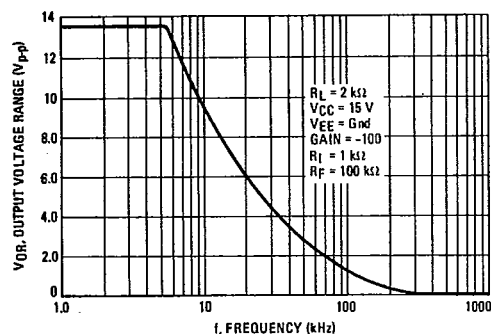


FIGURE 4 - SMALL-SIGNAL VOLTAGE FOLLOWER PULSE RESPONSE (Non-Inverting)

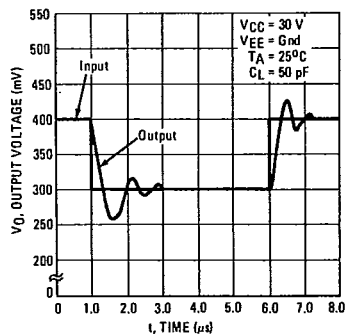


FIGURE 5 - POWER SUPPLY CURRENT versus POWER SUPPLY VOLTAGE

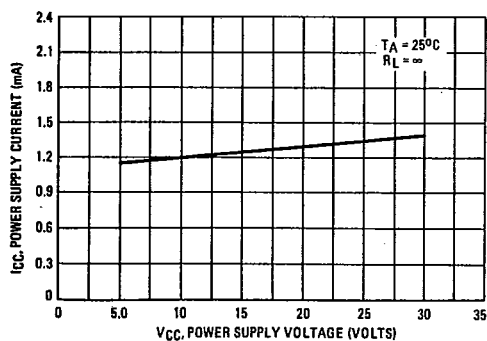
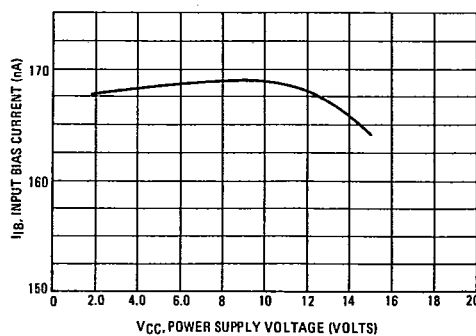


FIGURE 6 - INPUT BIAS CURRENT versus SUPPLY VOLTAGE



LM158, LM258, LM358, LM2904

APPLICATIONS INFORMATION

FIGURE 7 - VOLTAGE REFERENCE

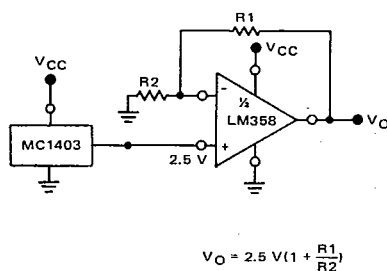
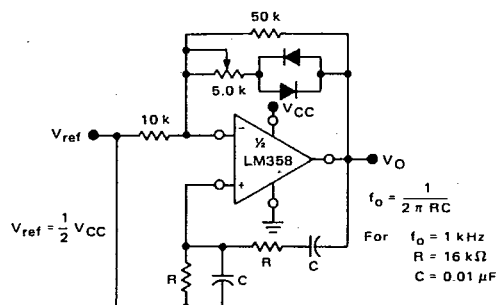


FIGURE 8 - WIEN BRIDGE OSCILLATOR



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FIGURE 9 - HIGH IMPEDANCE DIFFERENTIAL AMPLIFIER

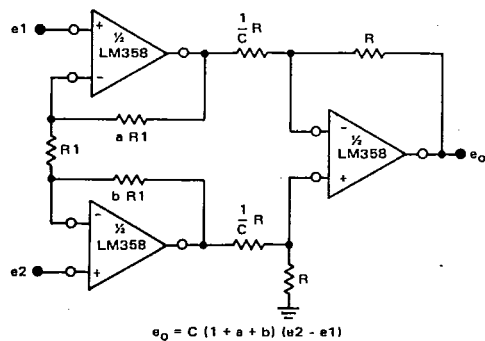


FIGURE 10 - COMPARATOR WITH HYSTERESIS

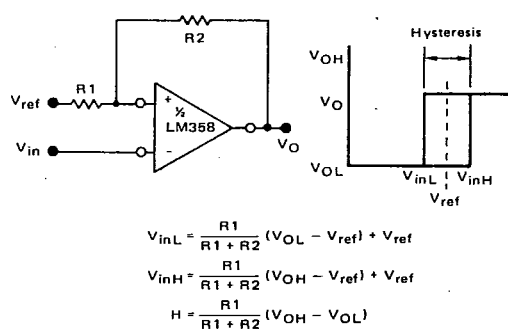
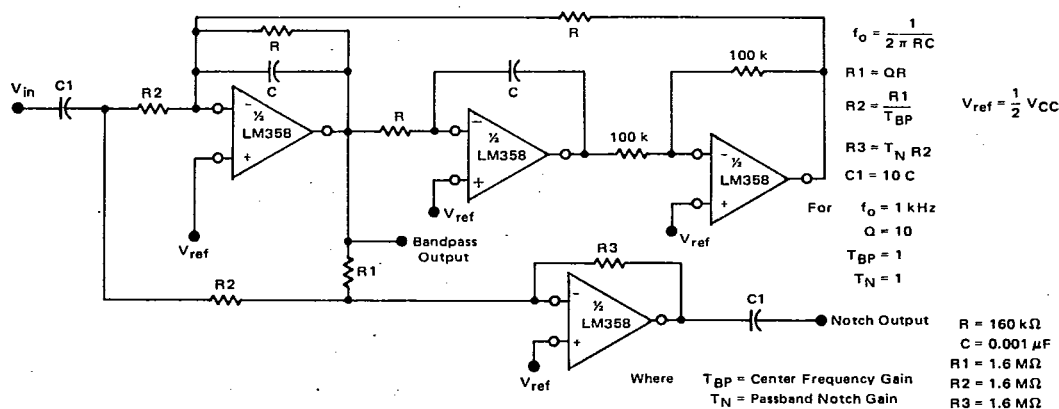


FIGURE 11 - BI-QUAD FILTER



LM158, LM258, LM358, LM2904

APPLICATIONS INFORMATION (continued)

FIGURE 12 - FUNCTION GENERATOR

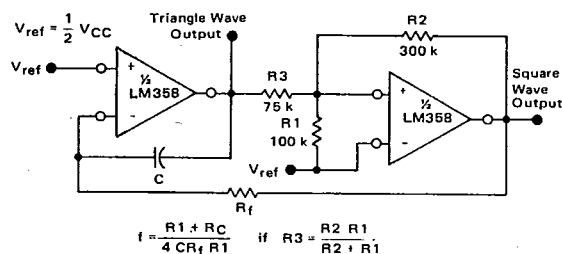
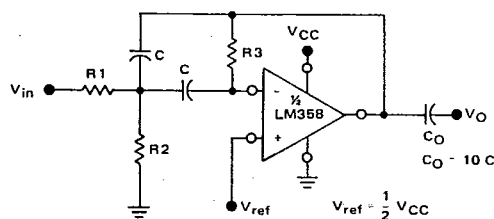


FIGURE 13 - MULTIPLE FEEDBACK BANDPASS FILTER



Given f_o = Center Frequency
 $A(f_o)$ = Gain at Center Frequency

Choose Value f_o , C

Then:

$$R3 = \frac{Q}{\pi f_o C}$$

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

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

For less than 10% error from operational amplifier

$$\frac{Q_o f_o}{BW} < 0.1 \quad \text{Where } f_o \text{ and BW are expressed in Hz.}$$

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