

## 1. DESCRIPTION

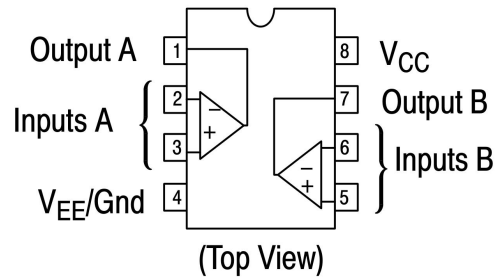
Utilizing the circuit designs perfected for Quad Operational Amplifiers, these dual operational amplifiers feature low power drain, a common mode input voltage range extending to ground/VEE, and single supply or split supply operation.

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.

## 2. 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

### 3. PIN CONFIGURATIONS



### 4. LOGIC DIAGRAM



Figure 1.

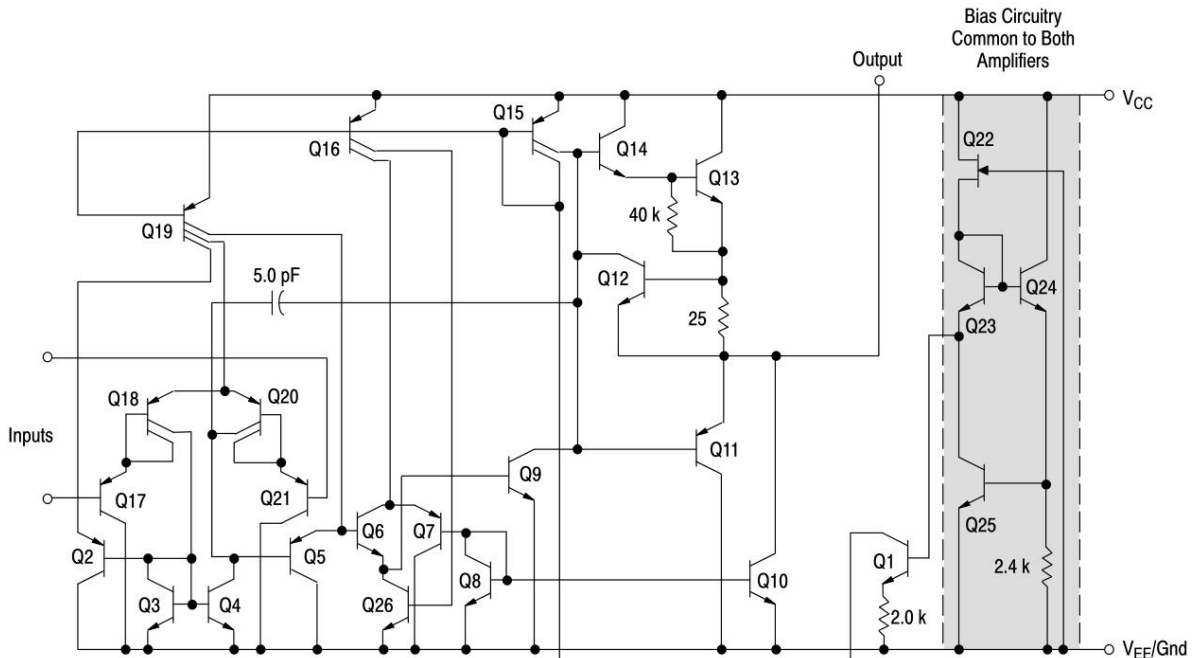


Figure 2. Representative Schematic Diagram  
(One-Half of Circuit Shown)

## 5. SPECIFICATIONS

### 5.1 Maximum Ratings (T<sub>A</sub> = +25°C, unless otherwise noted.)

Rating	Symbol	Value	Unit
Power Supply Voltages Single Supply	V <sub>CC</sub> V <sub>CC</sub> , V <sub>EE</sub>	32 ±16	Vdc
Split Supplies			
Input Differential Voltage Range (Note 1)	V <sub>IDR</sub>	±32	Vdc
Input Common Mode Voltage Range (Note 2)	V <sub>ICR</sub>	-0.3 to 32	Vdc
Output Short Circuit Duration	t <sub>SC</sub>	Continuous	
Junction Temperature	T <sub>J</sub>	150	°C
Thermal Resistance, Junction-to-Air (Note 3)	Case 846A Case 751 Case 626	R <sub>θJA</sub> 238 212 161	°C/W
Storage Temperature Range	T <sub>stg</sub>	-65 to +150	°C
ESD Protection at any Pin Human Body Model Machine Model	V <sub>esd</sub>	2000 200	V
Operating Ambient Temperature Range	T <sub>A</sub>	258 358 2904 -40 to +85	°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<sub>θJA</sub> measurements made on evaluation board with 1 oz. copper traces of minimum pad size. All device outputs were active.

**5.2 Electrical Characteristics**( $V_{CC} = 5.0\text{ V}$ ,  $V_{EE} = \text{GND}$ ,  $T_A = 25^\circ\text{C}$ , unless otherwise noted.)

Characteristic	Symbol	258			358		
		Min	Typ	Max	Min	Typ	Max
Input Offset Voltage $V_{CC} = 5.0\text{ V}$ to $30\text{ V}$ , $V_{IC} = 0\text{ V}$ to $V_{CC} - 1.7\text{ V}$ , $V_O = 1.4\text{ V}$ , $R_S = 0\ \Omega$ $T_A = 25^\circ\text{C}$ $T_A = T_{\text{high}}$ (Note 5) $T_A = T_{\text{low}}$ (Note 5)	$V_{IO}$	–	2.0	5.0	–	2.0	7.0
Average Temperature Coefficient of Input Offset Voltage $T_A = T_{\text{high}}$ to $T_{\text{low}}$ (Note 5)	$\Delta V_{IO}/\Delta T$	–	7.0	–	–	7.0	–
Input Offset Current $T_A = T_{\text{high}}$ to $T_{\text{low}}$ (Note 5) Input	$I_{IO}$	–	3.0	30	–	5.0	50
Bias Current $T_A = T_{\text{high}}$ to $T_{\text{low}}$ (Note 5)	$I_{IB}$	–	–45	–150	–	–45	–250
Average Temperature Coefficient of Input Offset Current $T_A = T_{\text{high}}$ to $T_{\text{low}}$ (Note 5)	$\Delta I_{IO}/\Delta T$	–	10	–	–	10	–
Input Common Mode Voltage Range (Note 6), $V_{CC} = 30\text{ V}$ $V_{CC} = 30\text{ V}$ , $T_A = T_{\text{high}}$ to $T_{\text{low}}$	$V_{ICR}$	0	–	28.3	0	–	28.3
Differential Input Voltage Range	$V_{IDR}$	–	–	$V_{CC}$	–	–	$V_{CC}$
Large Signal Open Loop Voltage Gain $R_L = 2.0\text{ k}\Omega$ , $V_{CC} = 15\text{ V}$ , For Large $V_O$ Swing, $T_A = T_{\text{high}}$ to $T_{\text{low}}$ (Note 5)	$A_{VOL}$	50	100	–	25	100	–
Channel Separation $1.0\text{ kHz} \leq f \leq 20\text{ kHz}$ , Input Referenced	CS	–	–120	–	–	–120	–
Common Mode Rejection $R_S \leq 10\text{ k}\Omega$	CMR	70	85	–	65	70	–
Power Supply Rejection	PSR	65	100	–	65	100	–
Output Voltage–High Limit $T_A = T_{\text{high}}$ to $T_{\text{low}}$ (Note 5) $V_{CC} = 5.0\text{ V}$ , $R_L = 2.0\text{ k}\Omega$ , $T_A = 25^\circ\text{C}$ $V_{CC} = 30\text{ V}$ , $R_L = 2.0\text{ k}\Omega$ $V_{CC} = 30\text{ V}$ , $R_L = 10\text{ k}\Omega$	$V_{OH}$	3.3	3.5	–	3.3	3.5	–
Output Voltage–Low Limit $V_{CC} = 5.0\text{ V}$ , $R_L = 10\text{ k}\Omega$ , $T_A = T_{\text{high}}$ to $T_{\text{low}}$ (Note 5)	$V_{OL}$	–	5.0	20	–	5.0	20
Output Source Current $V_{ID} = +1.0\text{ V}$ , $V_{CC} = 15\text{ V}$ $T_A = T_{\text{high}}$ to $T_{\text{low}}$ (LM358A Only)	$I_{O+}$	20	40	–	20	40	–
Output Sink Current $V_{ID} = -1.0\text{ V}$ , $V_{CC} = 15\text{ V}$ $T_A = T_{\text{high}}$ to $T_{\text{low}}$ (LM358A Only) $V_{ID} = -1.0\text{ V}$ , $V_O = 200\text{ mV}$	$I_{O-}$	10	20	–	10	20	–
Output Short Circuit to Ground (Note 7)	$I_{SC}$	–	40	60	–	40	60
Power Supply Current (Total Device) $T_A = T_{\text{high}}$ to $T_{\text{low}}$ (Note 5) $V_{CC} = 30\text{ V}$ , $V_O = 0\text{ V}$ , $R_L = \infty$ $V_{CC} = 5\text{ V}$ , $V_O = 0\text{ V}$ , $R_L = \infty$	$I_{CC}$	–	1.5	3.0	–	1.5	3.0
		–	0.7	1.2	–	0.7	1.2

4. 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  $V_{CC} - 1.7\text{ V}$ .

5. Short circuits from the output to  $V_{CC}$  can cause excessive heating and eventual destruction. Destructive dissipation can result from

### 5.3 Electrical Characteristics (V<sub>CC</sub> = 5.0 V, V<sub>EE</sub> = Gnd, T<sub>A</sub> = 25°C, unless otherwise noted.)

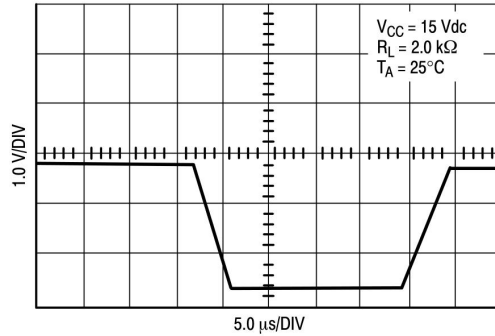
Characteristic	Symbol	2904		
		Min	Typ	Max
Input Offset Voltage V <sub>CC</sub> = 5.0 V to 30 V, V <sub>IC</sub> = 0 V to V <sub>CC</sub> - 1.7 V, V <sub>O</sub> = 1.4 V, R <sub>S</sub> = 0 Ω T <sub>A</sub> = 25°C T <sub>A</sub> = T <sub>high</sub> (Note 8) T <sub>A</sub> = T <sub>low</sub> (Note 8)	V <sub>IO</sub>	-	2.0	7.0
Average Temperature Coefficient of Input Offset Voltage T <sub>A</sub> = T <sub>high</sub> to T <sub>low</sub> (Note 8)	ΔV <sub>IO</sub> /ΔT	-	7.0	-
Input Offset Current T <sub>A</sub> = T <sub>high</sub> to T <sub>low</sub> (Note 8)	I <sub>IO</sub>	-	5.0	50
Input Bias Current T <sub>A</sub> = T <sub>high</sub> to T <sub>low</sub> (Note 8)	I <sub>IB</sub>	-	-45	-250
Average Temperature Coefficient of Input Offset Current T <sub>A</sub> = T <sub>high</sub> to T <sub>low</sub> (Note 8)	ΔI <sub>IO</sub> /ΔT	-	10	-
Input Common Mode Voltage Range (Note 9), V <sub>CC</sub> = 30 V V <sub>CC</sub> = 30 V, T <sub>A</sub> = T <sub>high</sub> to T <sub>low</sub>	V <sub>ICR</sub>	0	-	28.3
Differential Input Voltage Range	V <sub>IDR</sub>	-	-	V <sub>CC</sub>
Large Signal Open Loop Voltage Gain R <sub>L</sub> = 2.0 kΩ, V <sub>CC</sub> = 15 V, For Large V <sub>O</sub> Swing, T <sub>A</sub> = T <sub>high</sub> to T <sub>low</sub> (Note 8)	A <sub>VOL</sub>	25 15	100	- -
Channel Separation 1.0 kHz ≤ f ≤ 20 kHz, Input Referenced	CS	-	-120	-
Common Mode Rejection R <sub>S</sub> ≤ 10 kΩ	CMR	50	70	-
Power Supply Rejection	PSR	50	100	-
Output Voltage—High Limit T <sub>A</sub> = T <sub>high</sub> to T <sub>low</sub> (Note 8) V <sub>CC</sub> = 5.0 V, R <sub>L</sub> = 2.0 kΩ, T <sub>A</sub> = 25°C V <sub>CC</sub> = 30 V, R <sub>L</sub> = 2.0 kΩ V <sub>CC</sub> = 30 V, R <sub>L</sub> = 10 kΩ	V <sub>OH</sub>	3.3 26 27	3.5	- - -
Output Voltage—Low Limit V <sub>CC</sub> = 5.0 V, R <sub>L</sub> = 10 kΩ, T <sub>A</sub> = T <sub>high</sub> to T <sub>low</sub> (Note 8)	V <sub>OL</sub>	-	5.0	20
Output Source Current V <sub>ID</sub> = +1.0 V, V <sub>CC</sub> = 15 V	I <sub>O+</sub>	20	40	-
Output Sink Current V <sub>ID</sub> = -1.0 V, V <sub>CC</sub> = 15 V V <sub>ID</sub> = -1.0 V, V <sub>O</sub> = 200 mV	I <sub>O-</sub>	10 -	20	- -
Output Short Circuit to Ground (Note 10)	I <sub>SC</sub>	-	40	60
Power Supply Current (Total Device) T <sub>A</sub> = T <sub>high</sub> to T <sub>low</sub> (Note 8) V <sub>CC</sub> = 30 V, V <sub>O</sub> = 0 V, R <sub>L</sub> = ∞ V <sub>CC</sub> = 5 V, V <sub>O</sub> = 0 V, R <sub>L</sub> = ∞	I <sub>CC</sub>	- -	1.5 0.7	3.0 1.2

- 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<sub>CC</sub> - 1.7 V.
- Short circuits from the output to V<sub>CC</sub> can cause excessive heating and eventual destruction. Destructive dissipation can result from.

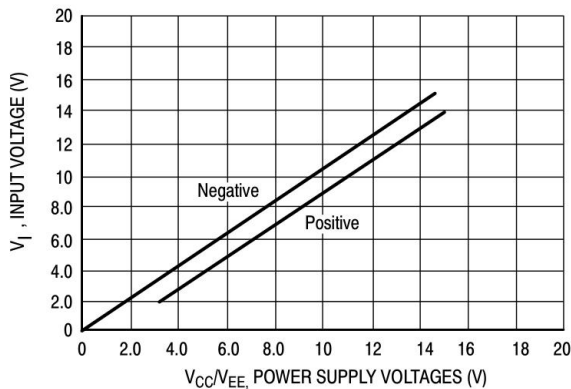
## 6. CIRCUITDESCRIPTION

The 358 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.

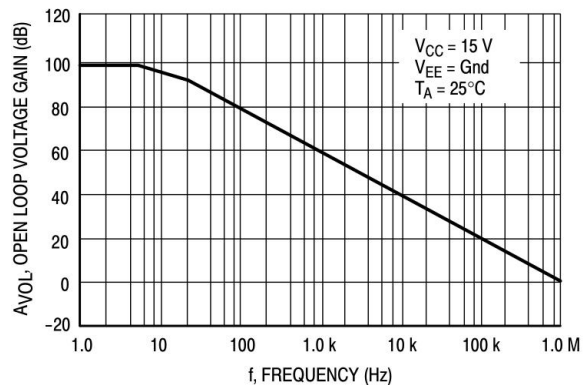
Each amplifier is biased from an internal-voltage regulator which has a low temperature coefficient thus giving each amplifier good temperature characteristics as well as excellent power supply rejection.



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



**Figure 4. Input Voltage Range**



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

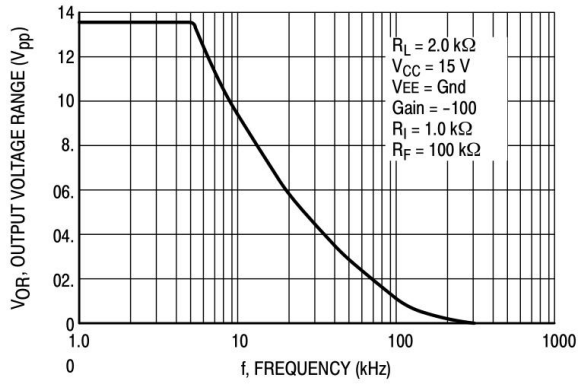


Figure 6. Large-Signal Frequency Response

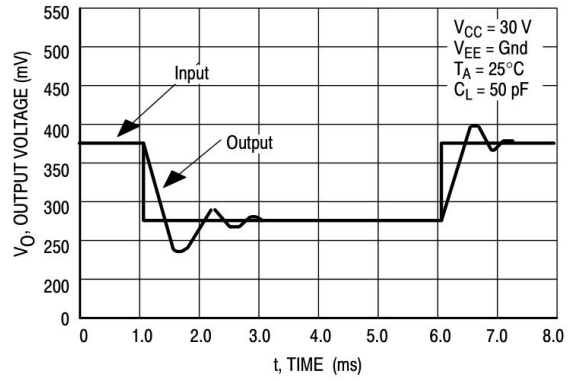


Figure 7. Small Signal Voltage Follower Pulse Response (Noninverting)

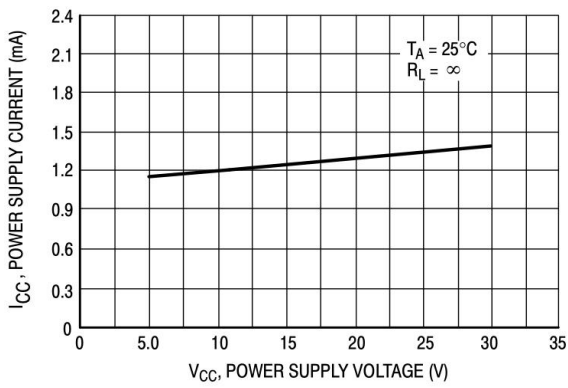


Figure 8. Power Supply Current versus Power Supply Voltage

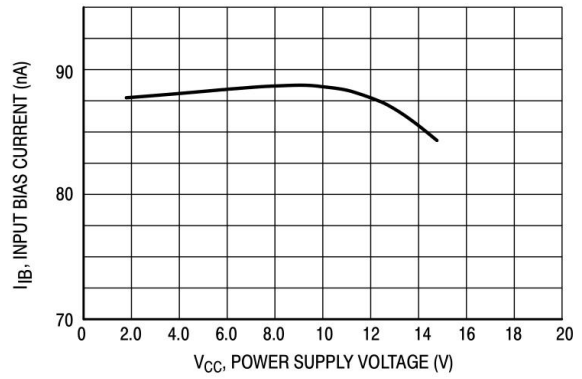


Figure 9. Input Bias Current versus Power Supply Voltage

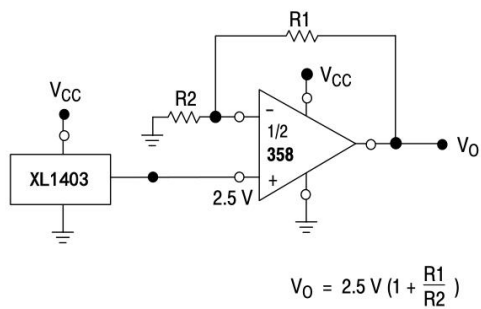


Figure 10. Voltage Reference

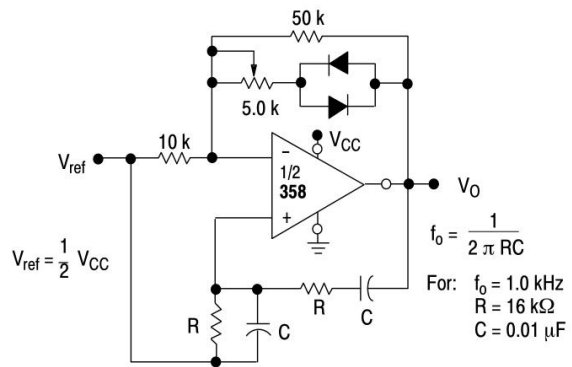


Figure 11. Wien Bridge Oscillator

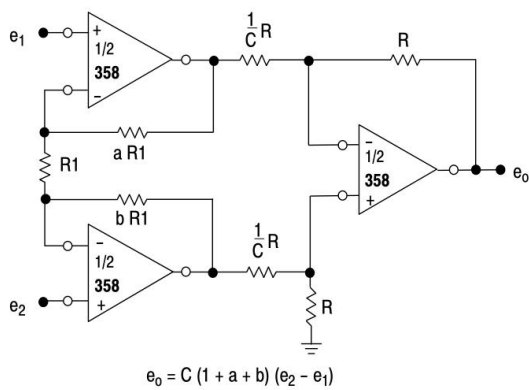


Figure 12. High Impedance Differential Amplifier

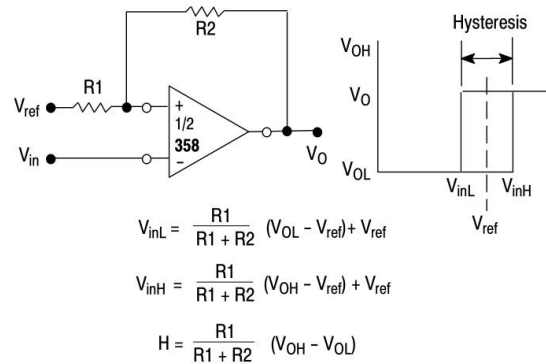


Figure 13. Comparator with Hysteresis

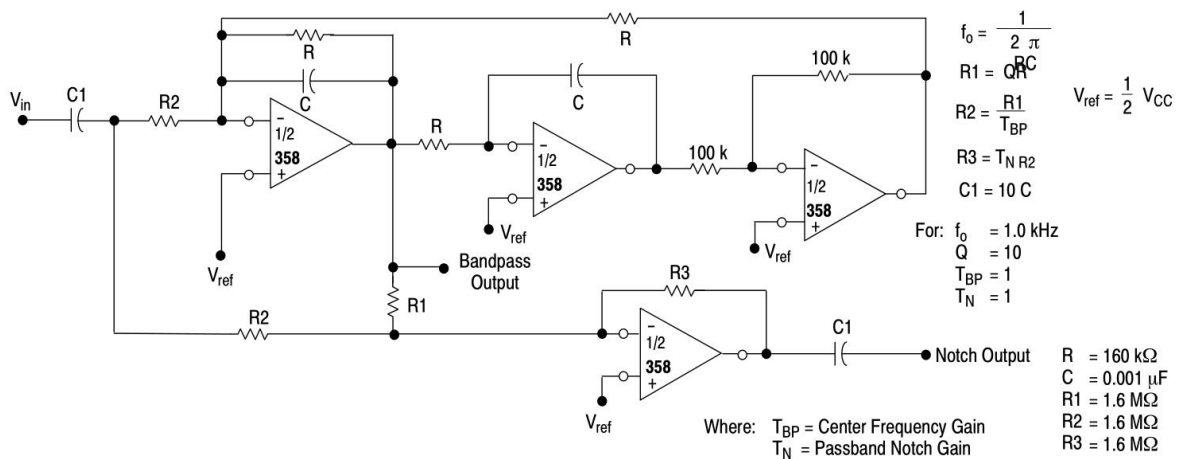
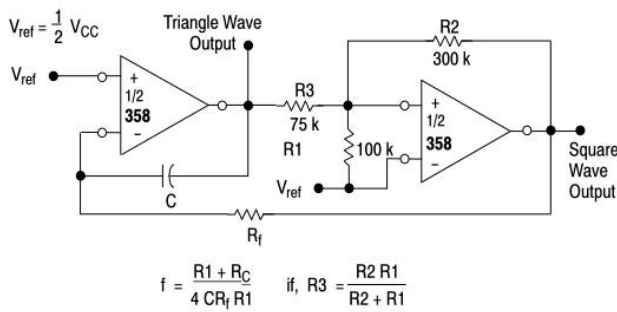
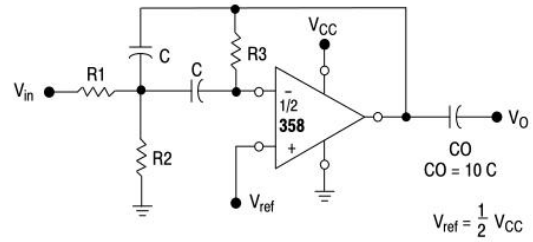


Figure 14. Bi-Quad Filter





**Figure 15. Function Generator**



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

Choose value  $f_0, C$

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

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

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

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.

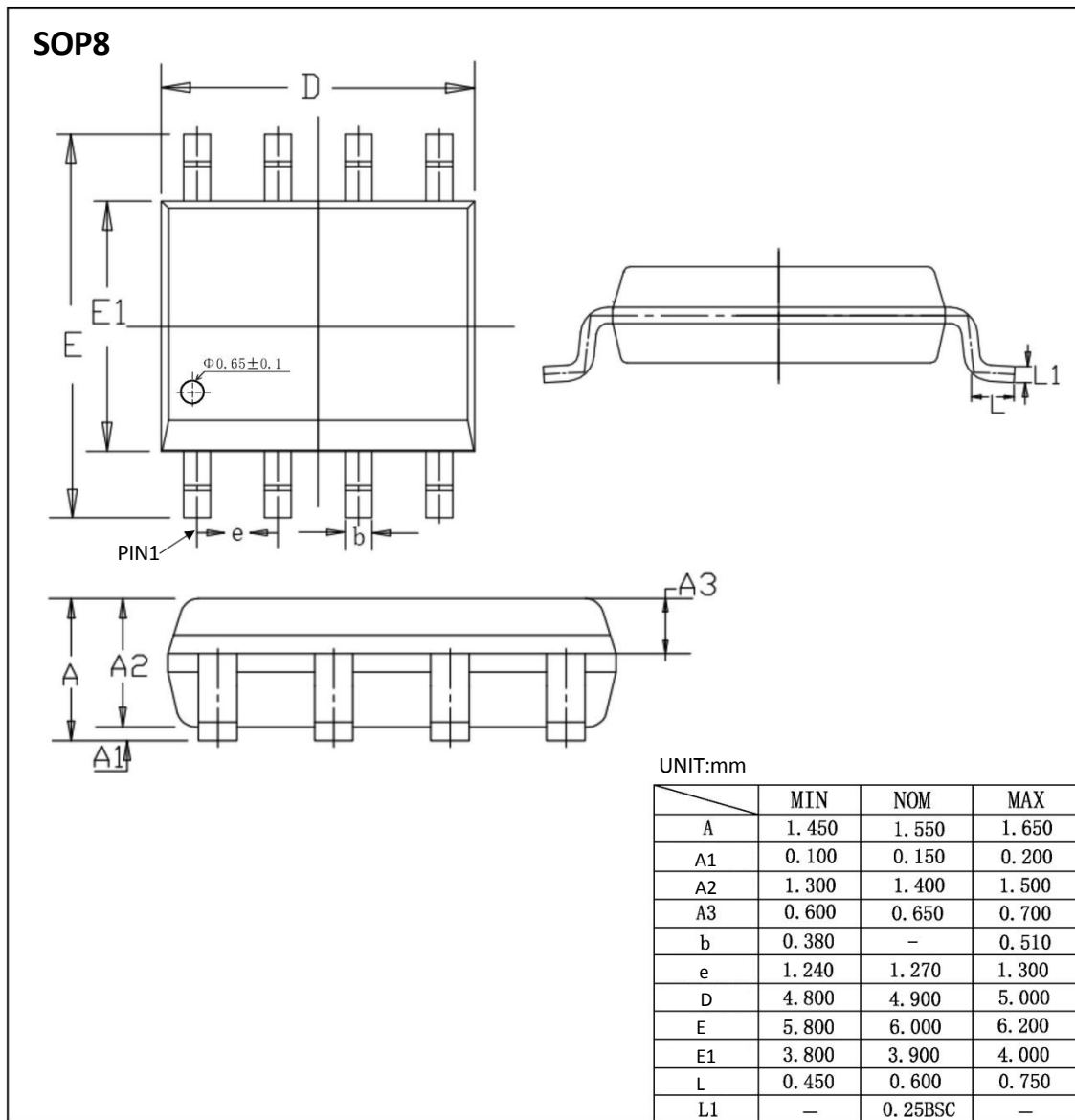
**Figure 16. Multiple Feedback Bandpass Filter**

## 7. ORDERING INFORMATION

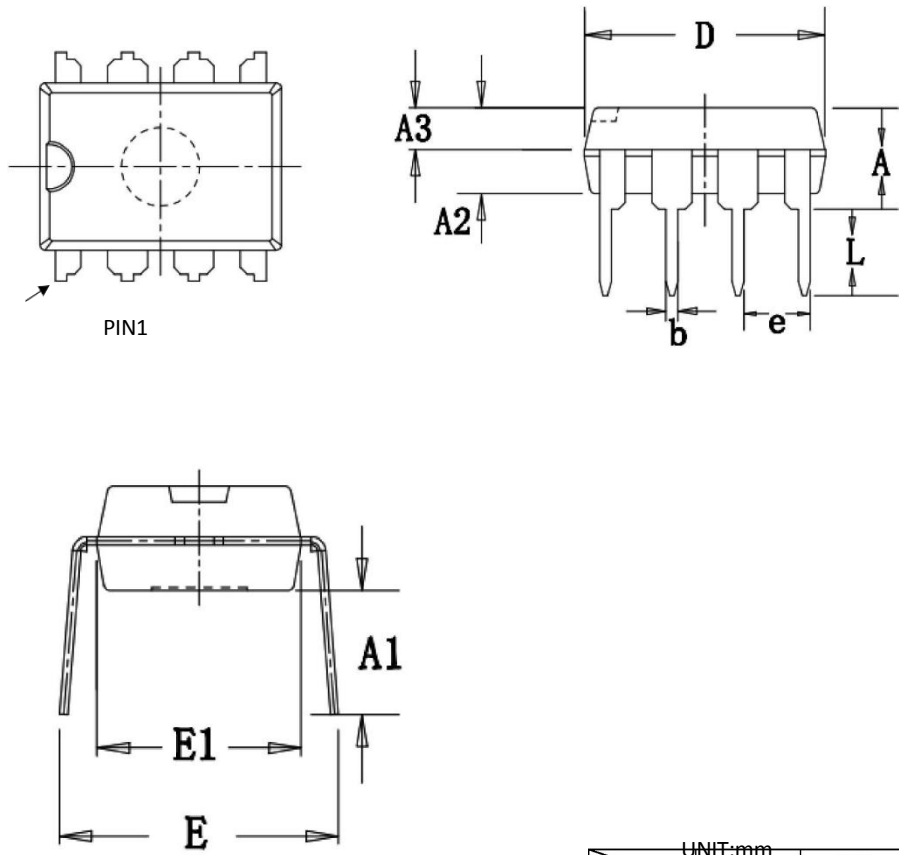
Ordering Information

Part Number	Device Marking	Package Type	Body size (mm)	Temperature (°C)	MSL	Transport Media	Package Quantity
XL258-KR	XL258-KR	VSSOP8	3.30 * 3.0	-40 to 85	MSL3	T&R	2500
XL258	XL258	SOP8	4.9 * 3.9	-40 to 85	MSL3	T&R	2500
XD258	XD258	DIP8	9.25 * 6.38	-40 to 85	MSL3	Tube 50	2000
XL358-KR	XL258-KR	VSSOP8	3.30 * 3.0	-40 to 85	MSL3	T&R	2500
XL358D	XL258D	SOP8	4.9 * 3.9	-40 to 85	MSL3	T&R	2500
XD358	XD258	DIP8	9.25 * 6.38	-40 to 85	MSL3	Tube 50	2000
XL2904-KR	XL2904-KR	VSSOP8	3.30 * 3.0	-40 to 85	MSL3	T&R	2500
XL2904D	XL2904D	SOP8	4.9 * 3.9	-40 to 85	MSL3	T&R	2500
XD2904	XD2904	DIP8	9.25 * 6.38	-40 to 85	MSL3	Tube 50	2000

## 8. DIMENSIONAL DRAWINGS

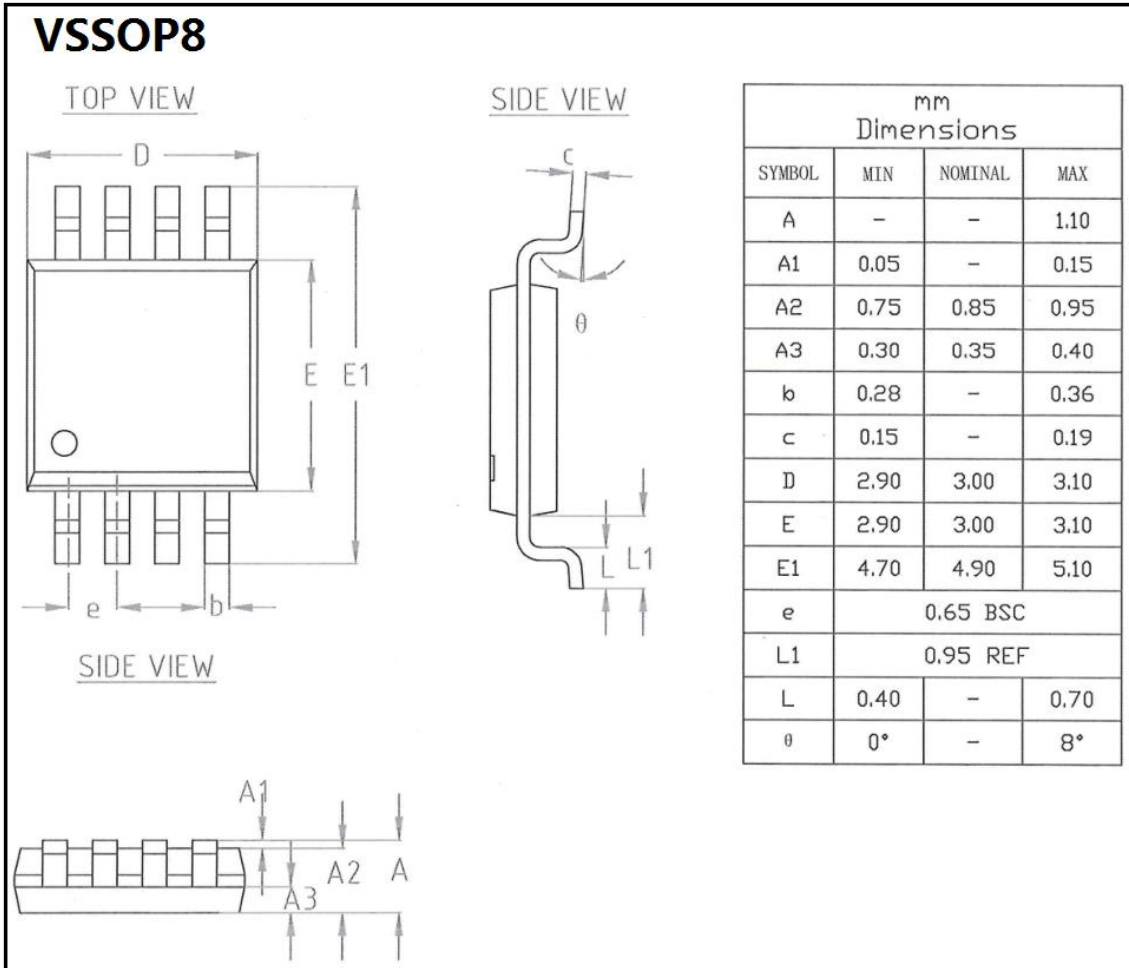


**DIP8**



	UNIT:mm		
	MIN	NOM	MAX
A	3.600	3.800	4.000
	3.786	3.886	3.986
	3.200	3.300	3.400
A3	1.550	1.600	1.650
b	0.440	—	0.490
	2.510	2.540	2.570
	9.150	9.250	9.350
	7.800	8.500	9.200
	6.280	6.380	6.480
	3.000	—	—

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