1. DESCRIPTION

The XL277 series offer improved noise, wider output voltage swing, and are twice as fast with half the quiescent current than XL177 series. Features include ultra-low offset voltage and drift, low bias current, high common mode rejection, and high power supply rejection.

The XL277 operate from ±2-V to ±18-V supplies with excellent performance. Unlike most op amps that are specified at only one supply voltage, the XL277 series is specified for real-world applications; a single limit applies over the ±5-V (10-V) to ±15-V (30-V) supply range. High performance is maintained as the amplifiers swing to the specified limits. Because the initial offset voltage (±40 μV, maximum) is so low, user adjustment is usually not required.

The XL277 are easy to use and free from phase inversion and the overload problems found in some other op amps. These devices are unity-gain stable and provide excellent dynamic behavior over a wide range of load conditions.

2. FEATURES

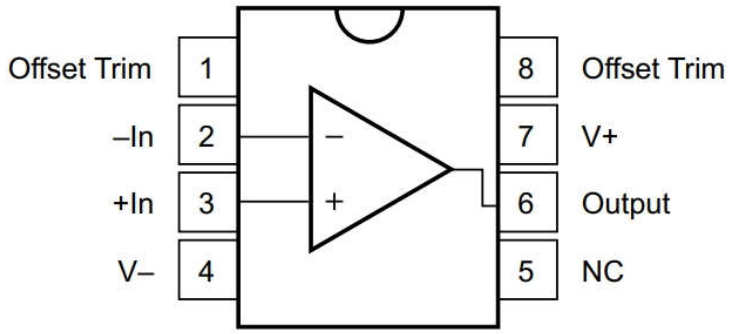
- Ultra-low offset voltage: 20 μV (Typical)
- Ultra-low drift: ±0.3 μV/°C (Typical)
- High open-loop gain: 120 dB
- High common-mode rejection: 130 dB
- High power-supply rejection: 130 dB
- Low bias current: 6-nA maximum
- Wide supply range: ±2 V to ±18 V
- Low quiescent current

3. Applications

- Analog input module
- Weigh scale
- Temperature transmitter ,Pressure transmitter
- Data acquisition (DAQ)
- Lab and field instrumentation
- Battery test

4. PIN CONFIGURATIONS AND FUNCTIONS

XL227P
XL277UA



(TOP VIEW)

Pin Functions

PIN		TYPE	DESCRIPION
NAME	NO.		
–In	2	Input	Inverting input
+In	3	Input	Noninverting input
NC	5	—	No internal connection (can be left floating)
Offset Trim	1	—	Input offset voltage trim (leave floating if not used)
Offset Trim	8	—	Input offset voltage trim (leave floating if not used)
Output	6	Output	Output
V–	4	—	Negative (lowest) power supply
V+	7	—	Positive (highest) power supply

5. SPECIFICATIONS

5.1. Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)(1)

		MIN	MAX	UNIT
V_S	Supply voltage, VS = (V+) – (V–)		36	V
	Input voltage(2)	(V–) – 0.7	(V+) + 0.7	V
I_{SC}	Output short circuit(3)	Continuous		
T_J	Junction temperature		150	°C
T_{STG}	Storage temperature	–55	125	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) Limit input signals that can swing more than 0.7 V beyond the supply rails to 10 mA or less.
(3) Short-circuit to ground.

5.2. ESD Rating

			VALUE	UNIT
V(ESD)	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001(1)	±1000	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101(2)	±300	V

(1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.
(2) JEDEC document JEP157 states that 250-V CDM allows safe manufacturing with a standard ESD control process.

5.3. Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

			MIN	NOM	MAX	UNIT
Vs	Supply voltage, V_S = (V+) – (V–)	Single supply	4	30	36	V
		Dual supply	±2	±15	±18	
TA	Ambient temperature		-40		85	°C

5.4. Thermal Information (Typical Value)

THERMAL METRIC		XL277UA SOP 8 PINS	XL277P DIP 8 PINS	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	115	53	°C/W
$R_{\theta JC(top)}$	Junction-to-case(top) thermal resistance	55	45	°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	56	32	°C/W
ψ_{JT}	Junction-to-top characterization parameter	15	20	°C/W
ψ_{JB}	Junction-to-board characterization parameter	58	30	°C/W
$R_{\theta JC(bot)}$	Junction-to-case(bottom) thermal resistance	N/A	N/A	°C/W

5.5. Electrical Characteristics

at T_A = 25°C, V_S = 10 V to 30 V, V_{CM} = V_{OUT} = V_S / 2, and R_L = 2 kΩ connected to V_S / 2 (unless otherwise noted)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
OPEN-LOOP GAIN							
V_{OS}	Input offset voltage				±20	±40	µV
		T_A = –40°C to +85°C				±50	
dV_{OS}/dT	Input offset voltage drift	T_A = –40°C to +85°C			±0.3	±1.0	µV/°C
	Long-term drift				0.4		µV/mo
PSRR	Power-supply rejection ratio	VS = ±2 V to ±18 V			±0.3	±0.5	
		VS = ±2 V to ±18 V, T_A = –40°C to +85°C			±0.6		µV/V
	Channel separation	dc			0.1		µV/V
INPUT BIAS CURRENT							
IB	Input bias current				±3	±6	nA
		T_A = –40°C to +85°C				±10	
IOS	Input offset current				±2	±7	nA
		T_A = –40°C to +85°C				±10	
NOISE							
	Input voltage noise	f = 0.1 Hz to 10 Hz			0.4		µVPP
en	Input voltage noise density	f = 10 Hz			20		nV/√Hz
		f = 100 Hz			15		
		f = 1 kHz			15		
		f = 10 kHz			15		
i_n	Input current noise density	f = 1 kHz			3		pA/√Hz
INPUT VOLTAGE							
V_{CM}	Common-mode voltage range			(V–) + 2		(V+) – 2	V
CMRR	Common-mode rejection ratio	V_{CM} = (V–) + 2 V to (V+) – 2 V		120	130		dB
		V_{CM} = (V–) + 2 V to (V+) – 2 V, T_A = –40°C to +85°C		110			
INPUT IMPEDANCE							
ZID	Differential				100 || 3		MΩ||pF
ZIC	Common-mode	V_{CM} = (V–) + 2 V to (V+) – 2 V			200 || 3		GΩ||pF
OPEN-LOOP GAIN							
AOL	Open-loop voltage gain	V_O = (V–) + 0.5 V to (V+) – 1.2 V, RL = 10 kΩ			130		dB
		V_O = (V–) + 1.5 V to (V+) – 1.5 V, RL = 2 kΩ		115	120		
			T_A = –40°C to +85°C	100			
FREQUENCY RESPONSE							
GBW	Gain-bandwidth product				0.7		MHz
SR	Slew rate				0.5		V/µs
ts	Settling time	V_S = ±15 V, G = 1, 10-V step	To 0.1%		20		µs
			To 0.01%		25		
tOR	Overload recovery time	V_{IN} × G = VS			10		µs
THD+N	Total harmonic distortion + noise	G = 1, f = 1 kHz, V_O = 3.5 VRMS			0.006%		
OUTPUT							
VO	Voltage output	R_L = 10 kΩ		(V–) + 1		(V+) – 1	V
			T_A = –40°C to +85°C	(V–) + 1		(V+) – 1	
		R_L = 2 kΩ		(V–) + 2		(V+) – 2	
			T_A = –40°C to +85°C	(V–) + 2		(V+) – 2	
ISC	Short-circuit current				±30		mA
CL	Capacitive load drive				See Typical Characteristics Curve		
Z_O	Open-loop Output impedance	f = 1 MHz			35		Ω
POWER SUPPLY							
IQ	Quiescent current	IO = 0 A			1.2	2.5	mA
			T_A = –40°C to +85°C			3.5	

5.6. Typical Characteristics Curve （FYI only）

At TA = 25°C, VS = ±15 V, and RL = 2 kΩ, unless otherwise noted.

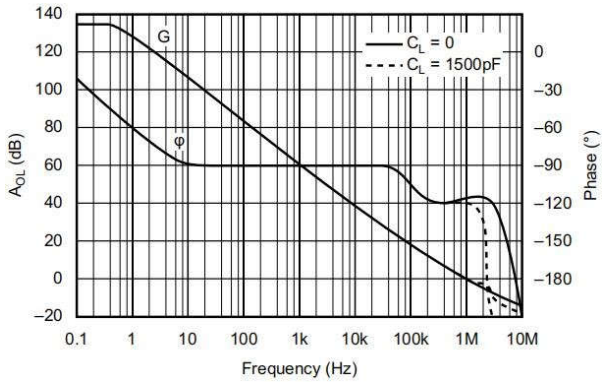


Figure 5-1. Open-Loop Gain and Phase vs Frequency

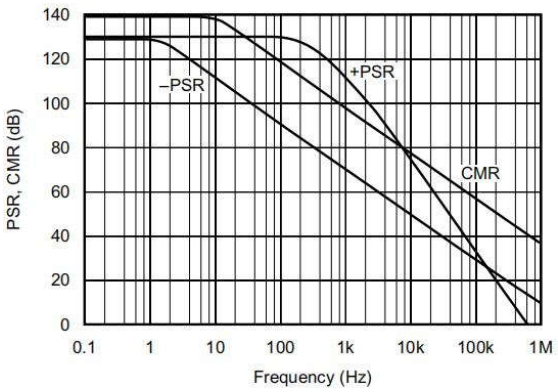


Figure 5-2. Power Supply and Common-Mode Rejection vs Frequency

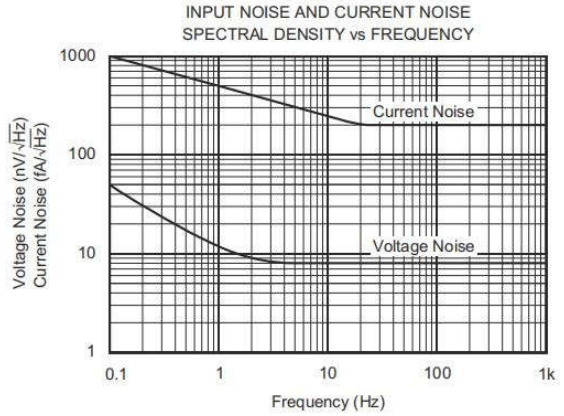


Figure 5-3. Input Noise and Current Noise Spectral Density vs Frequency

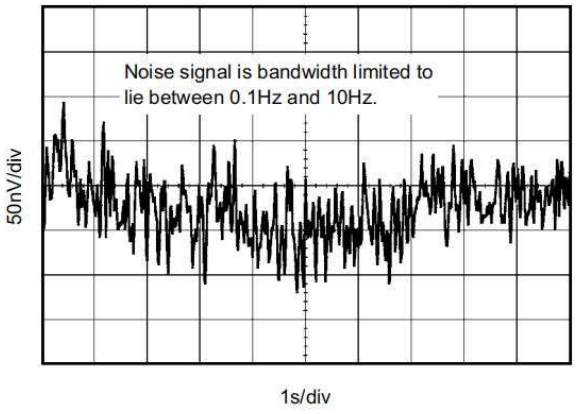


Figure 5-4. Input Noise Voltage vs Time

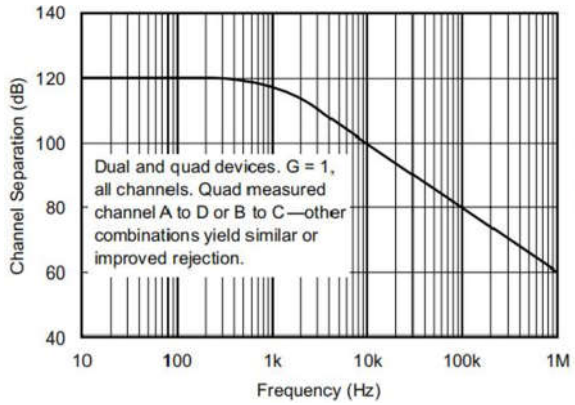


Figure 5-5. Channel Separation vs Frequency

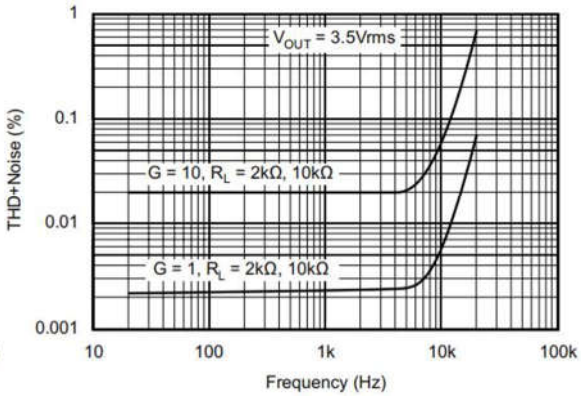


Figure 5-5.Channel Separation vs Frequency

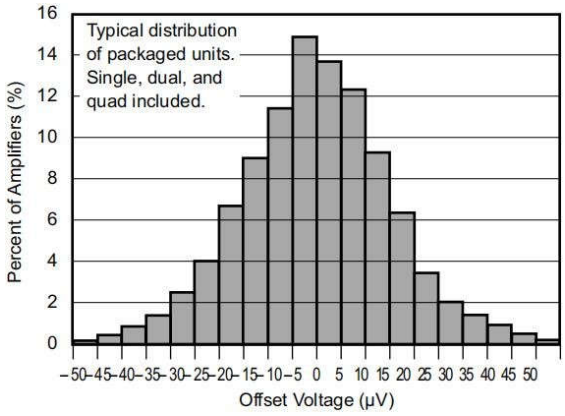


Figure 5-7. Offset Voltage Production Distribution

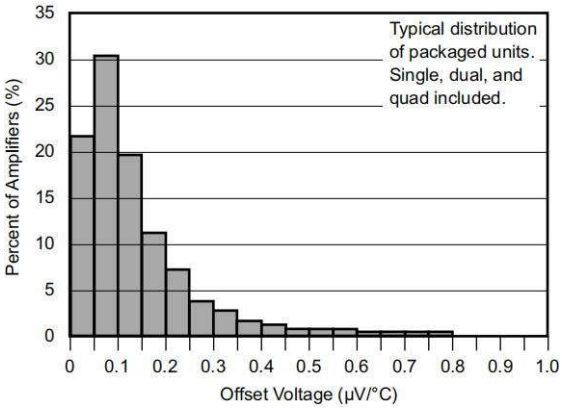


Figure 5-8. Offset Voltage Drift Production Distribution

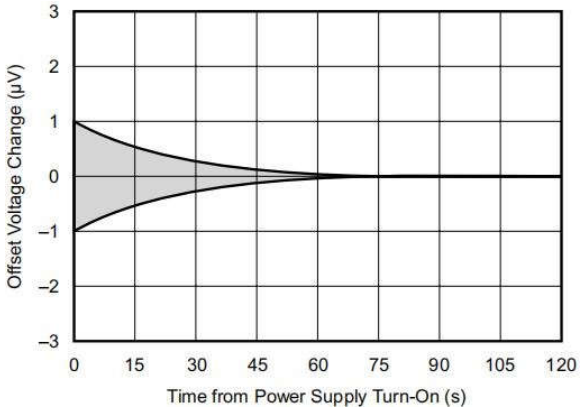


Figure 5-9. Warm-Up Offset Voltage Drift

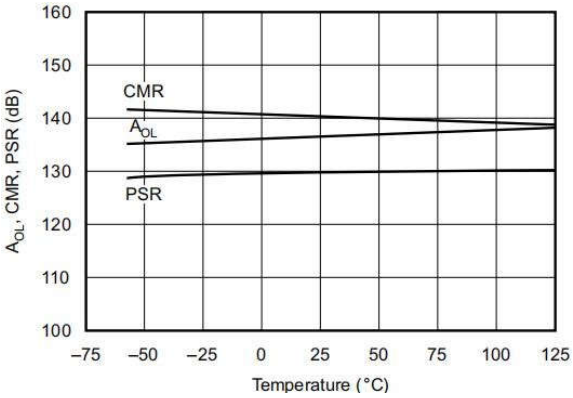


Figure 5-10. AOL, CMR, PSR vs Temperature

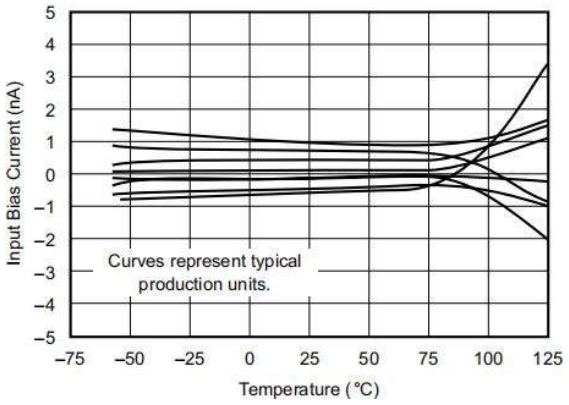


Figure 5-11. Input Bias Current vs Temperature

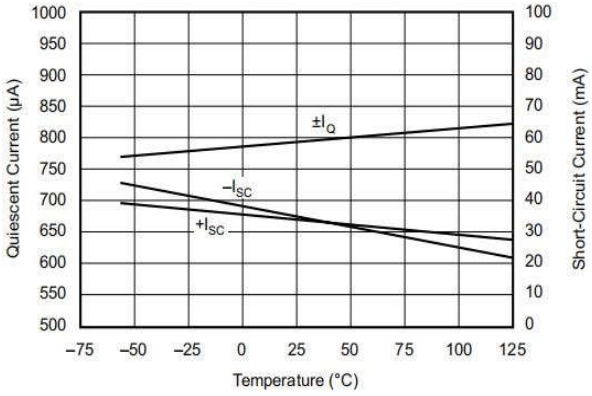


Figure 5-12. Quiescent Current and Short-Circuit Current vs Temperature

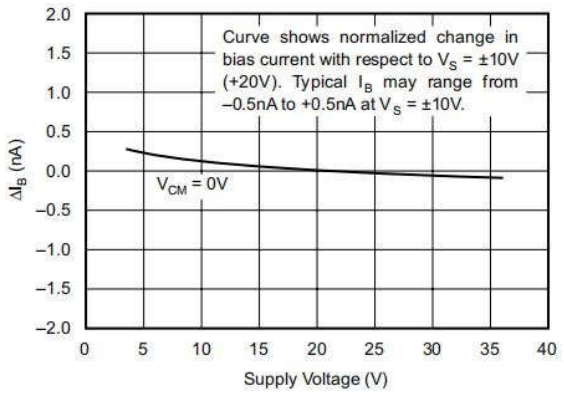


Figure 6-13. Change in Input Bias Current vs Power-Supply Voltage

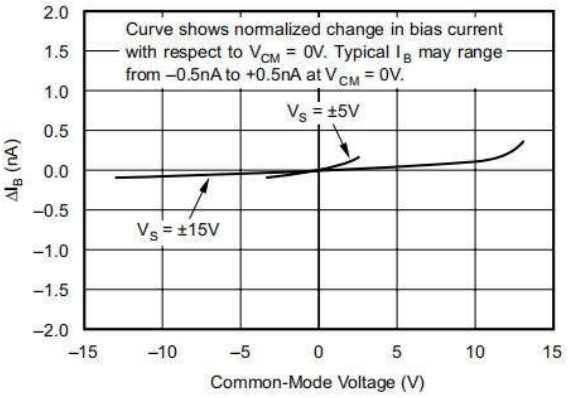


Figure 6-14. Change in Input Bias Current vs Common-Mode Voltage

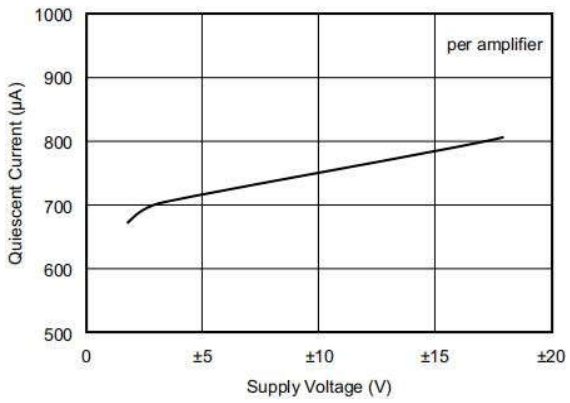


Figure 5-15. Quiescent Current vs Supply Voltage

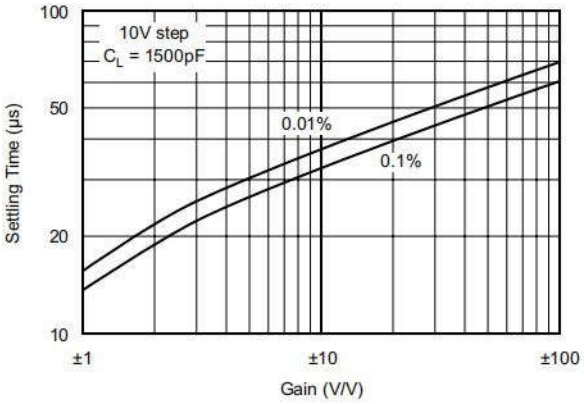


Figure 5-16. Settling Time vs Closed-Loop Gain

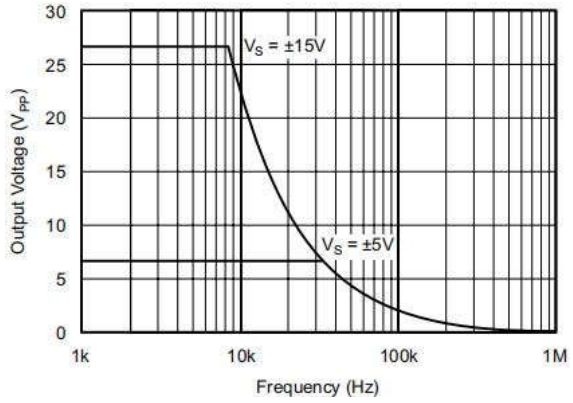


Figure 5-17. Maximum Output Voltage vs Frequency

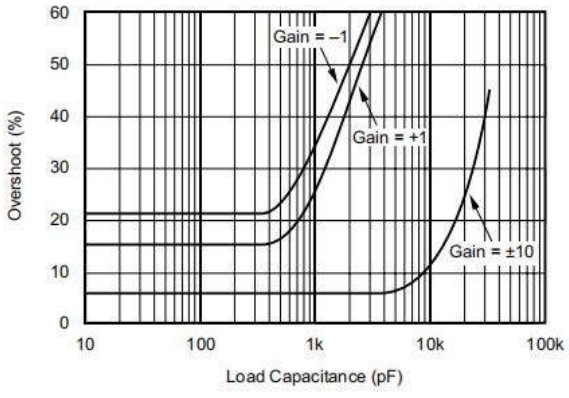


Figure 5-18. Small-Signal Overshoot vs Load Capacitance

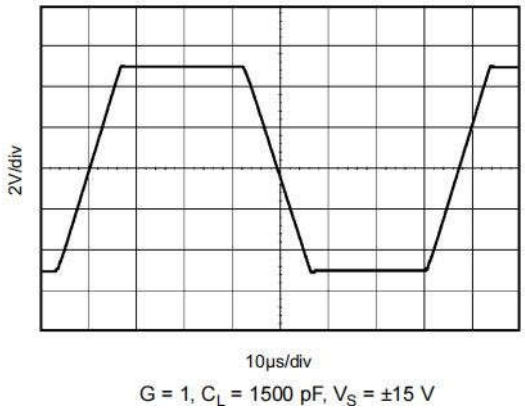


Figure 5-19. Large-Signal Step Response

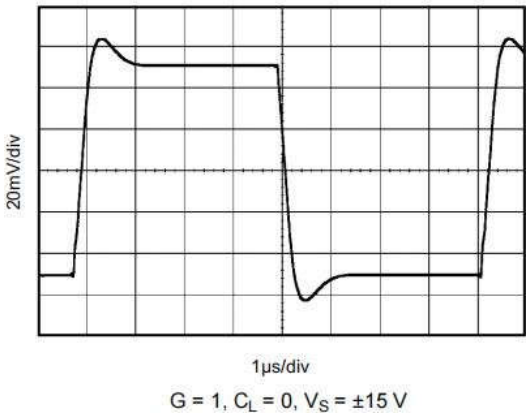


Figure 5-20. Small-Signal Step Response

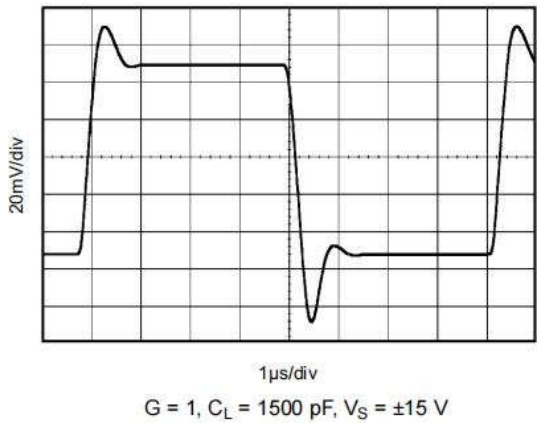


Figure 5-21. Small-Signal Step Response

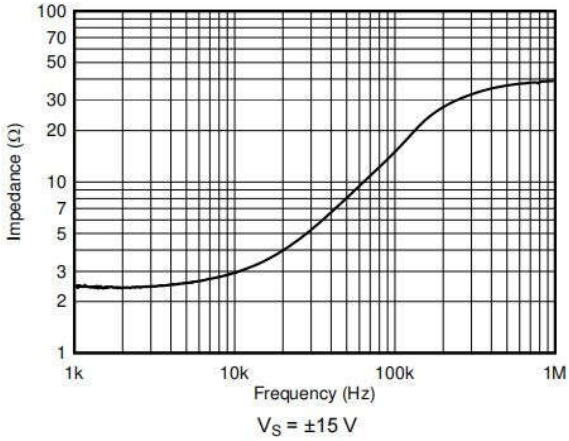


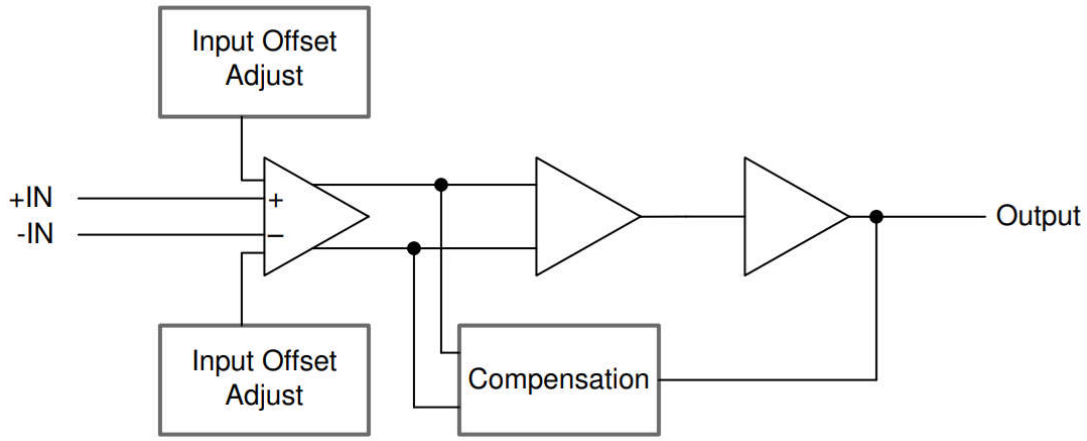
Figure 5-22. Open-Loop Output Impedance

6. DETAILED DESCRIPTION

6.1. Overview

The XL277 series precision operational amplifiers offer improved noise, wider output voltage swing, and are twice as fast with half the quiescent current. Features include ultra-low offset voltage and drift, low bias current, high common-mode rejection, and high power-supply rejection.

6.2. Functional Block Diagram



6.3. Feature Description

The XL277 series is unity-gain stable and free from unexpected output phase reversal, making these devices easy to use in a wide range of applications. Applications with noisy or high-impedance power supplies can require decoupling capacitors close to the device pins. In most cases 0.1-µF capacitors are adequate.

The XL277 series has low offset voltage and drift. To achieve highest performance, optimize the circuit layout and mechanical conditions. Offset voltage and drift can be degraded by small thermoelectric potentials at the operational amplifier inputs. Connections of dissimilar metals generate thermal potential, which can degrade the ultimate performance of the XL277 series. To cancel these thermal potentials, make sure that the thermal potentials are equal in both input pins.

- Keep the thermal mass of the connections to the two input pins similar
- Locate heat sources as far as possible from the critical input circuitry
- Shield operational amplifier and input circuitry from air currents, such as cooling fans

6.3.1. Operating Voltage

The XL277 series of operational amplifiers operate from ±2-V to ±18-V supplies with excellent performance. Unlike most operational amplifiers, which are specified at only one supply voltage, the XL277 series is specified for real-world applications; a single limit applies over the ±5-V to ±15-V supply range. This single limit allows a customer operating at VS = ±10 V to have the same specified performance as a customer using ±15-V supplies. In addition, key parameters are specified over the specified temperature range of –40°C to +85°C. Most behavior remains unchanged through the full operating voltage range of ±2 V to ±18 V.

6.3.2. Offset Voltage Adjustment

The XL277 series is laser-trimmed for low offset voltage and drift, so most circuits do not require external adjustment. However, for the XL277, offset voltage trim connections are provided on pins 1 and 8. Figure 6 -1 shows how the offset voltage can be adjusted by connecting a potentiometer. Only use this adjustment to null the offset of the operational amplifier. Do not use this adjustment to compensate for offsets created elsewhere in a system, because additional temperature drift can be introduced.

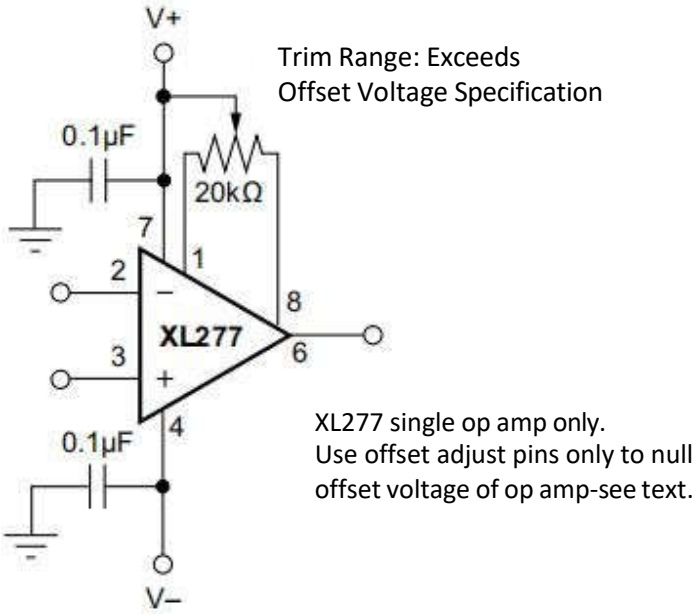


Figure 6-1. XL277 Offset Voltage Trim Circuit

6.3.3. Input Protection

The inputs of the XL277 devices protected with 1-kΩ series input resistors and diode clamps. The inputs can withstand ±30-V differential inputs without damage. The protection diodes conduct current when the inputs are overdriven. This conducted current can disturb the slewing behavior of unity-gain follower applications, but does not damage the operational amplifier.

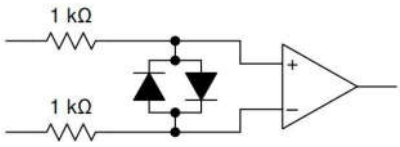
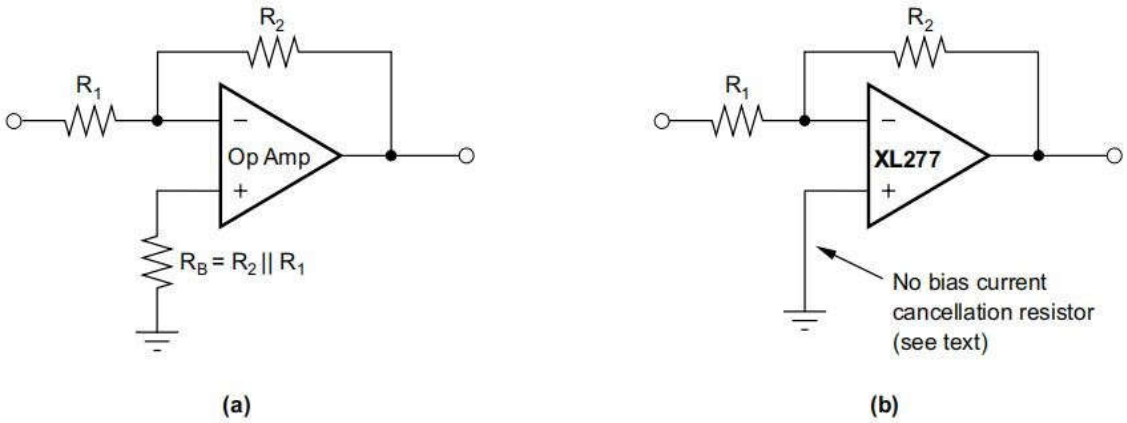


Figure 6-2. XL277 Input Protection

6.3.4. Input Bias Current Cancellation

The input stage base current of the XL277 series is internally compensated with an equal and opposite cancellation circuit. The resulting input bias current is the difference between the input stage base current and the cancellation current. This residual input bias current can be positive or negative.

When the bias current is canceled in this manner, the input bias current and input offset current are approximately the same magnitude. As a result, a bias current cancellation resistor is not necessary, as is often done with other operational amplifiers. Figure 6-3 shows a conventional op amp with external bias current cancellation resistor compared to the XL277 with no external bias current cancellation resistor. A resistor added to cancel input bias current errors can actually increase offset voltage and noise.



Conventional op amp with external bias current cancellation resistor.

XL277 with no external bias current cancellation resistor.

Figure 6-3. Input Bias Current Cancellation

6.3.5. EMI Rejection Ratio (EMIRR)

The electromagnetic interference (EMI) rejection ratio, or EMIRR, describes the EMI immunity of operational amplifiers. An adverse effect that is common to many operational amplifiers is a change in the offset voltage as a result of RF signal rectification. An operational amplifier that is more efficient at rejecting this change in offset as a result of EMI has a higher EMIRR and is quantified by a decibel value. Measuring EMIRR can be performed in many ways, but this report provides the EMIRR IN+, which specifically describes the EMIRR performance when the RF signal is applied to the noninverting input pin of the operational amplifier. In general, only the noninverting input is tested for EMIRR for the following three reasons:

1. Operational amplifier input pins are known to be the most sensitive to EMI, and typically rectify RF signals better than the supply or output pins.
2. The noninverting and inverting operational amplifier inputs have symmetrical physical layouts and exhibit nearly matching EMIRR performance.
3. EMIRR is easier to measure on noninverting pins than on other pins because the noninverting input terminal can be isolated on a printed circuit board (PCB). This isolation allows the RF signal to be applied directly to the noninverting input terminal with no complex interactions from other components or connecting PCB traces.

Figure 6-4 shows the EMIRR IN+ of the XL277 plotted versus frequency.

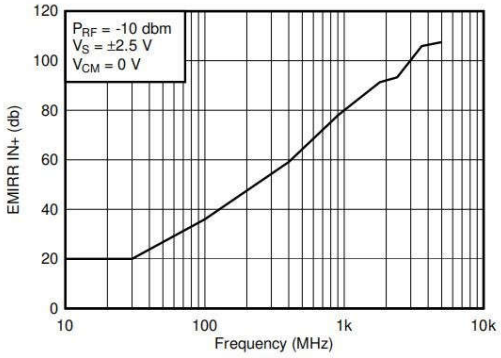


Figure 6-4. XL277 EMIRR IN+ vs Frequency

If available, any dual and quad operational amplifier device versions have nearly similar EMIRR IN+ performance. The XL277 unity-gain bandwidth is 1 MHz. EMIRR performance below this frequency denotes interfering signals that fall within the operational amplifier bandwidth.

Table 6-1 shows the EMIRR IN+ values (typical) for the XL277 at particular frequencies commonly encountered in real-world applications. Applications listed in Table 6-1 can be centered on or operated near the particular frequency shown.

Table 6-1. XL77 EMIRR IN+ for Frequencies of Interest

FREQUENCY	APPLICATION/ALLOCATION	EMIRR IN+
400 MHz	Mobile radio, mobile satellite-space operation, weather, radar, UHF	55 dB
900 MHz	GSM, radio com-nav-GPS (to 1.6 GHz), ISM, aeronautical mobile, UHF	70 dB
1.8 GHz	GSM, mobile personal comm. broadband, satellite, L-band	85 dB
2.4 GHz	802.11b/g/n, Bluetooth®, mobile personal comm, ISM, amateur radio-satellite, S-band	88 dB
3.6 GHz	Radiolocation, aero comm-nav, satellite, mobile, S-band	100 dB
5.0 GHz	802.11a/n, aero comm-nav, mobile comm, space-satellite operation, C-band	103 dB

6.3.5.1. EMIRR IN+ Test Configuration

Figure 6-5 shows the circuit configuration for testing the EMIRR IN+. An RF source is connected to the operational amplifier noninverting input terminal using a transmission line. The operational amplifier is configured in a unity-gain buffer topology with the output connected to a low-pass filter (LPF) and a digital multimeter (DMM). A large impedance mismatch at the operational amplifier input causes a voltage reflection; however, this effect is characterized and accounted for when determining the EMIRR IN+. The resulting dc offset voltage is sampled and measured by the multimeter. The LPF isolates the multimeter from residual RF signals that can interfere with multimeter accuracy.

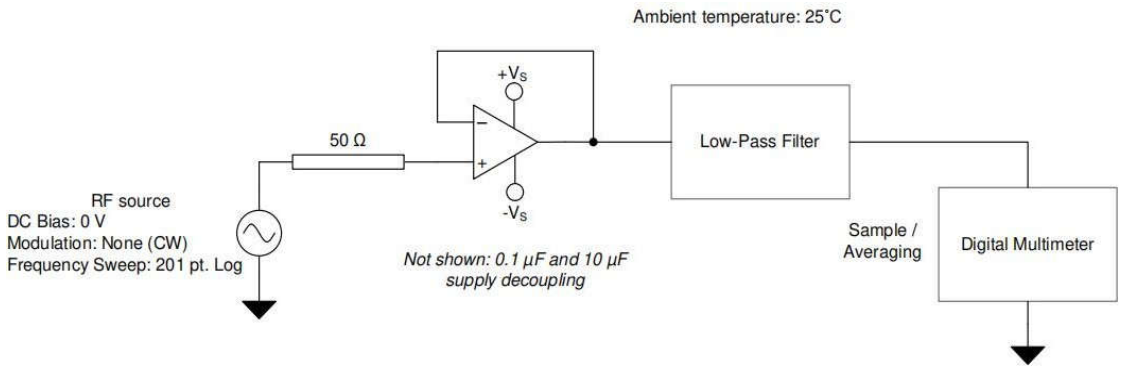


Figure 6-5. EMIRR IN+ Test Configuration Schematic

6.4. Device Functional Modes

The XL277 has a single functional mode and is operational when the power-supply voltage is greater than 4 V (±2 V). The maximum power supply voltage for the XL277 is 36 V (±18 V).

7. Application and Implementation

7.1. Application Information

The XL277 family offers outstanding dc precision and ac performance. These devices operate up to 36-V supply rails and offer ultralow offset voltage and offset voltage drift, as well as 1-MHz bandwidth and high capacitive load drive. These features make the XL277 a robust, high-performance operational amplifier for high-voltage industrial applications.

7.2. Typical Applications

7.2.1. Second-Order, Low-Pass Filter

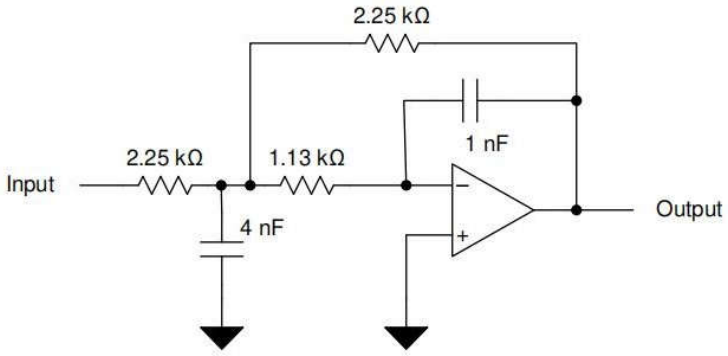


Figure 7-1. Second-Order, Low-Pass Filter

7.2.1.1. Design Requirements

- Gain = 1 V/V
- Low-pass cutoff frequency = 50 kHz
- –40 db/dec filter response
- Maintain less than 3-dB gain peaking in the gain versus frequency response

7.2.1.2. Application Curve

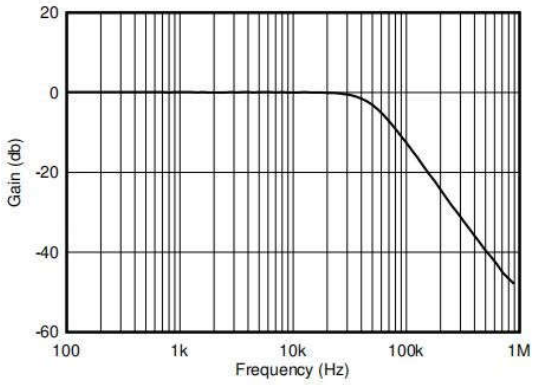


Figure 7-2. XL277 Second-Order, 50-kHz, Low-Pass Filter

7.3. Power Supply Recommendations

The XL277 is specified for operation from 4 V to 36 V (±2 V to ±18 V); many specifications apply from –40°C to 85°C. Parameters that can exhibit significant variance with regard to operating voltage or temperature are presented in Section 5.8.

NOTE: Supply voltages larger than 36 V can permanently damage the device! see Section 6.1.

Place 0.1-µF bypass capacitors close to the power-supply pins to reduce errors coupling in from noisy or high-impedance power supplies. For more detailed information on bypass capacitor placement, see Section 7.4.1.

7.4. Layout

7.4.1. Layout Guidelines

For best operational performance of the device, use good PCB layout practices, including:

- Noise can propagate into analog circuitry through the power pins of the circuit as a whole and operational amplifier itself. Bypass capacitors are used to reduce the coupled noise by providing low-impedance power sources local to the analog circuitry.
  - Connect low-ESR, 0.1-µF ceramic bypass capacitors between each supply pin and ground, placed as close to the device as possible. A single bypass capacitor from V+ to ground is applicable for single- supply applications.
- Separate grounding for analog and digital portions of circuitry is one of the simplest and most-effectivemethods of noise suppression. One or more layers on multilayer PCBs are usually devoted to ground planes. A ground plane helps distribute heat and reduces EMI noise pickup. Make sure to physically separate digital and analog grounds paying attention to the flow of the ground current.
- To reduce parasitic coupling, run the input traces as far away from the supply or output traces as possible. If these traces cannot be kept separate, crossing the sensitive trace perpendicular is much better as opposed to in parallel with the noisy trace.
- Place the external components as close to the device as possible. As shown in Section 7.4.2, keeping RF and RG close to the inverting input minimizes parasitic capacitance.
- Keep the length of input traces as short as possible. Always remember that the input traces are the most sensitive part of the circuit.
- Consider a driven, low-impedance guard ring around the critical traces. A guard ring can significantly reduce leakage currents from nearby traces that are at different potentials.
- Cleaning the PCB following board assembly is recommended for best performance.
- Any precision integrated circuit can experience performance shifts due to moisture ingress into the plastic package. Following any aqueous PCB cleaning process, baking the PCB assembly is recommended to remove moisture introduced into the device packaging during the cleaning process. A low temperature, post cleaning bake at 85°C for 30 minutes is sufficient for most circumstances.

7.4.2. Layout Example

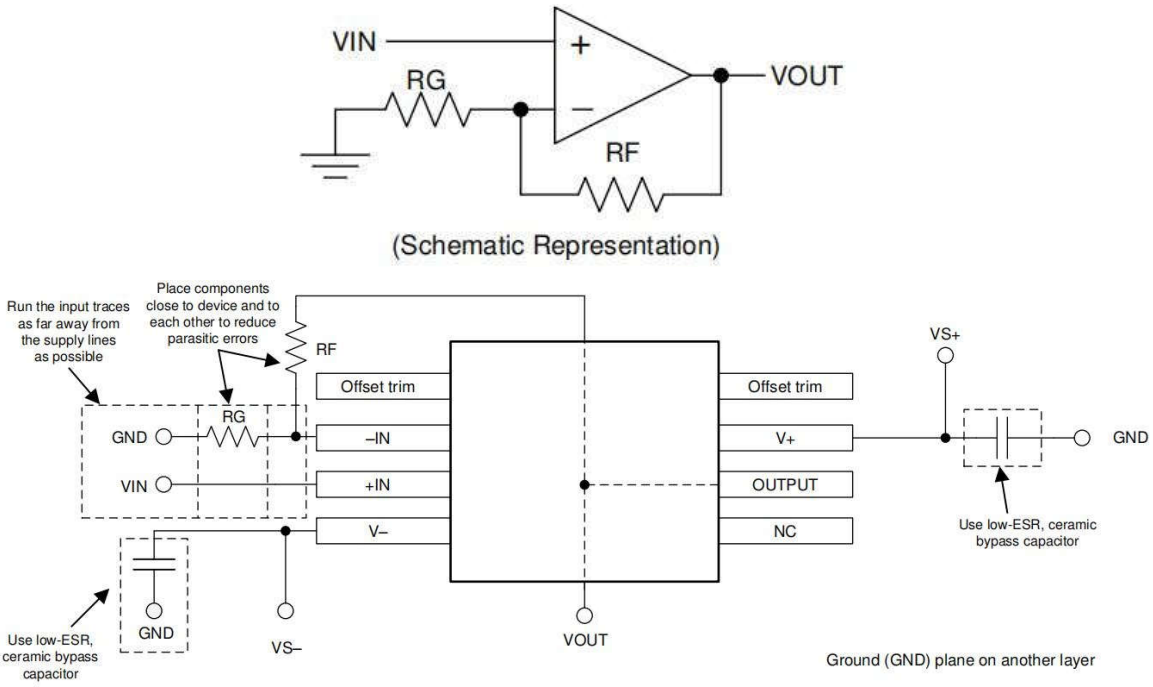


Figure 7-3. XL277 Layout Example for the Noninverting Configuration

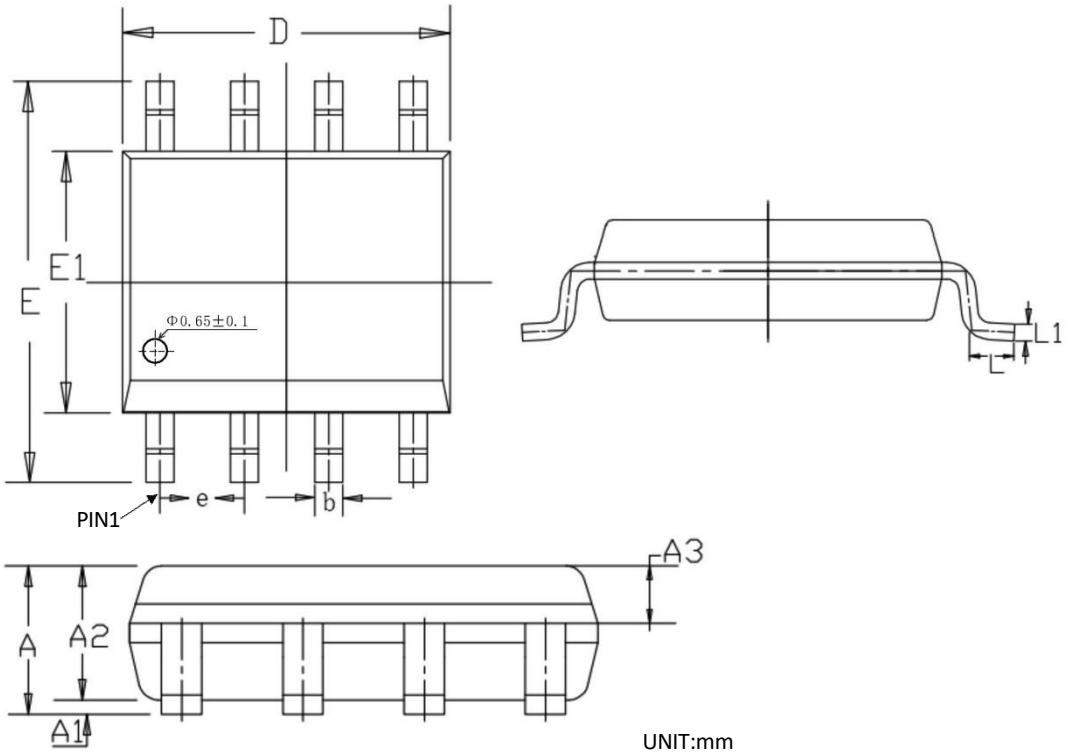
8. ORDERING INFORMATION

Ordering Information

Part Number	Device Marking	Package Type	Body size (mm)	Temperature (°C)	MSL	Transport Media	Package Quantity
XL277P	XL277P	DIP8	9.25 * 6.38	- 40 to 85	MSL3	Tube 50	2000
XL277UA	XL277U	SOP8	4.90 * 3.90	- 40 to 85	MSL3	T&R	2500

9. DIMENSIONAL DRAWINGS

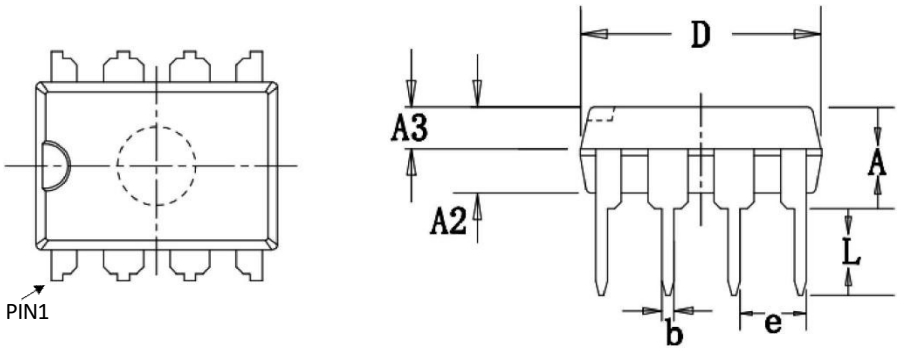
SOP8

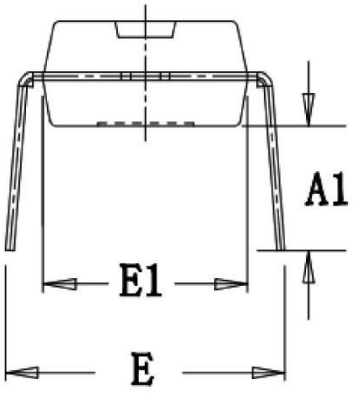


UNIT:mm

	MIN	NOM	MAX
A	1.450	1.550	1.650
A1	0.100	0.150	0.200
A2	1.300	1.400	1.500
A3	0.600	0.650	0.700
b	0.380	–	0.510
e	1.240	1.270	1.300
D	4.800	4.900	5.000
E	5.800	6.000	6.200
E1	3.800	3.900	4.000
L	0.450	0.600	0.750
L1	—	0.25BSC	—

DIP8





UNIT:mm

	MIN	NOM	MAX
A	3.600	3.800	4.000
A1	3.786	3.886	3.986
A2	3.200	3.300	3.400
A3	1.550	1.600	1.650
b	0.440	—	0.490
e	2.510	2.540	2.570
D	9.150	9.250	9.350
E	7.800	8.500	9.200
E1	6.280	6.380	6.480
L	3.000	—	—