XL158 SOP8 XL258 SOP8 XL358D SOP8 XD358 DIP8 XL2904D SOP8 XD2904 DIP8

1 Features

- Wide Supply Ranges
  - Single Supply: 3 V to 32 V (26 V for XL2904)
  - Dual Supplies: ±1.5 V to ±16 V (±13 V for XL2904)
- Low Supply-Current Drain, Independent of Supply Voltage: 0.7 mA Typical
- Wide Unity Gain Bandwidth: 0.7 MHz
- Common-Mode Input Voltage Range Includes Ground, Allowing Direct Sensing Near Ground
- Low Input Bias and Offset Parameters
  - Input Offset Voltage: 3 mV Typical
    A Versions: 2 mV Typical
  - Input Offset Current: 2 nA Typical
  - Input Bias Current: 20 nA Typical
    A Versions: 15 nA Typical
- Differential Input Voltage Range Equal to Maximum-Rated Supply Voltage: 32 V (26 V for XL2904)
- Open-Loop Differential Voltage Gain: 100 dB Typical
- Internal Frequency Compensation
- On Products Compliant to MIL-PRF-38535, All Parameters are Tested Unless Otherwise Noted. On All Other Products, Production Processing Does Not Necessarily Include Testing of All Parameters.

2 Applications

- Blu-ray Players and Home Theaters
- Chemical and Gas Sensors
- DVD Recorder and Players
- Digital Multimeter: Bench and Systems
- Digital Multimeter: Handhelds
- Field Transmitter: Temperature Sensors
- Motor Control: AC Induction, Brushed DC, Brushless DC, High-Voltage, Low-Voltage, Permanent Magnet, and Stepper Motor
- Oscilloscopes
- TV: LCD and Digital
- Temperature Sensors or Controllers Using Modbus
- Weigh Scales

3 Description

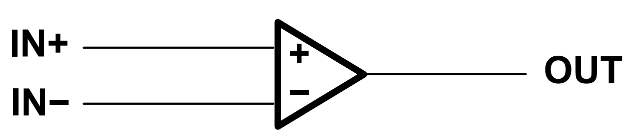
These devices consist of two independent, high-gain frequency-compensated operational amplifiers designed to operate from a single supply or split supply over a wide range of voltages.

4 Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
158 258 358 2904	VSSOP (8)	3.00 mm × 3.00 mm
	SOIC (8)	4.90 mm × 3.90 mm
	SO (8)	5.20 mm × 5.30 mm
	TSSOP (8)	3.00 mm × 4.40 mm
	PDIP (8)	9.81 mm × 6.35 mm
X58 2904	CDIP (8)	9.60 mm × 6.67 mm
	LCCC (20)	8.89 mm × 8.89 mm

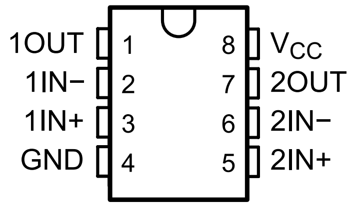
(1) For all available packages, see the orderable addendum at the end of the data sheet.

Symbol (Each Amplifier)

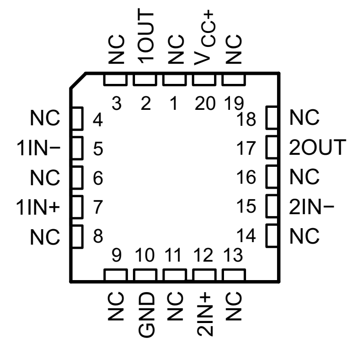


5 Pin Configuration and Functions

D, DGK, P, PS, PW and JG Package
8-Pin SOIC, VSSOP, PDIP, SO, TSSOP and CDIP
(Top View)



FK Package
20-Pin LCCC
(Top View)



NC - No internal connection

Pin Functions

PIN			I/O	DESCRIPTION
NAME	LCCC NO.	SOIC, SSOP, CDIP, PDIP SO, TSSOP, CFP NO.		
1IN–	5	2	I	Negative input
1IN+	7	3	I	Positive input
1OUT	2	1	O	Output
2IN–	15	6	I	Negative input
2IN+	12	5	I	Positive input
2OUT	17	7	O	Output
GND	10	4	—	Ground
NC	1	—	—	Do not connect
	3			
	4			
	6			
	8			
	9			
	11			
	13			
	14			
	16			
	18			
	19			
V_{CC}	—	8	—	Power supply
V_{CC+}	20	—	—	Power supply

6 Specifications

6.1 Absolute Maximum Ratings

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

				XLx58, XLx58x, XL2904		XL2904		UNIT
				MIN	MAX	MIN	MAX	
V_{CC}		Supply voltage[2]		–0.3	±16 or 32	–0.3	±13 or 26	V
V_{ID}		Differential input voltage[3]		–32	32	–26	26	V
V_I	either input	Input voltage		–0.3	32	–0.3	26	V
		Duration of output short circuit (one amplifier) to ground at (or below) T_A = 25°C, V_{CC} ≤ 15 V[4]			Unlimited		Unlimited	s
T_A		Operating free air temperature	XL158	–55	125			°C
			XL258	–25	85			
			XL358	0	70			
			XL2904	–40	125	–40	125	
T_J		Operating virtual junction temperature			150		150	°C
		Case temperature for 60 seconds	FK package		260			°C
		Lead temperature 1.6 mm (1/16 inch) from case for 60 seconds	JG package		300		300	°C
T_{stg}		Storage temperature		–65	150	–65	150	°C

(1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) All voltage values (except differential voltages and V_{CC} specified for the measurement of I_{OS}) are with respect to the network GND.
(3) Differential voltages are at IN+, with respect to IN−.
(4) Short circuits from outputs to V_{CC} can cause excessive heating and eventual destruction.

6.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human-body model (HBM), per ANSI/ESDA/JEDEC JS-001[1]	±500	V
		Charged-device model (CDM), per JEDEC specification JESD22-C101	±1000	

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

6.3 Recommended Operating Conditions

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

			XLx58, XLx58x, XL2904		XL2904		UNIT
			MIN	MAX	MIN	MAX	
V_{CC}	Supply voltage		3	30	3	26	V
V_{CM}	Common-mode voltage		0	V_{CC} – 2	0	V_{CC} – 2	V
T_A	Operating free air temperature	XL158	–55	125			°C
		XL2904	–40	125	–40	125	
		XL358	0	70			
		XL258	–25	85			

6.4 Thermal Information

THERMAL METRIC(1)		XLx58, XLx58x, XL2904					XLx58, XLx58x, XL2904 V	XLx58, XLx58x, XL2904 V	UNIT
		D (SOIC)	DGK (VSSOP)	P (PDIP)	PS (SO)	PW (TSSOP)	FK (LCCC)	JG (CDIP)	
		8 PINS	8 PINS	8 PINS	8 PINS	8 PINS	20 PINS	8 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance	97	172	85	95	149	—	—	°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	72.2	—	—	—	—	5.61	14.5	°C/W

(1) For more information about traditional and new thermal metrics, see the *IC Package Thermal Metrics* application report, SPRA953.

6.5 Electrical Characteristics for XLx58

at specified free-air temperature, V_{CC} = 5 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS(1)		T_A(2)	XL158 XL258			XL358			UNIT
					MIN	TYP(3)	MAX	MIN	TYP(3)	MAX	
V_{IO}	Input offset voltage	V_{CC} = 5 V to MAX, $V_{IC} = V_{ICR(min)}$, V_O = 1.4 V		25°C		3	5		3	7	mV
				Full range			7			9	
αV_{IO}	Average temperature coefficient of input offset voltage			Full range		7			7		μV/°C
I_{IO}	Input offset current	V_O = 1.4 V		25°C		2	30		2	50	nA
				Full range			100			150	
αI_{IO}	Average temperature coefficient of input offset current			Full range		10			10		pA/°C
I_{IB}	Input bias current	V_O = 1.4 V		25°C		–20	–150		–20	–250	nA
				Full range			–300			–500	
V_{ICR}	Common-mode input voltage range	V_{CC} = 5 V to MAX		25°C	0 to V_{CC} – 1.5			0 to V_{CC} – 1.5			V
				Full range	0 to V_{CC} – 2			0 to V_{CC} – 2			
V_{OH}	High-level output voltage	R_L ≥ 2 kΩ		25°C	V_{CC} – 1.5			V_{CC} – 1.5			V
		R_L ≥ 10 kΩ		25°C							
		V_{CC} = MAX	R_L = 2 kΩ	Full range	26			26			
			R_L ≥ 10 kΩ	Full range	27	28		27	28		
V_{OL}	Low-level output voltage	R_L ≤ 10 kΩ		Full range		5	20		5	20	mV
A_{VD}	Large-signal differential voltage amplification	V_{CC} = 15 V, V_O = 1 V to 11 V, R_L ≥ 2 kΩ		25°C	50	100		25	100		V/mV
				Full range	25			15			
CMRR	Common-mode rejection ratio	V_{CC}= 5 V to MAX, $V_{IC} = V_{ICR(min)}$		25°C	70	80		65	80		dB
k_{SVR}	Supply-voltage rejection ratio (ΔV_{DD} /ΔV_{IO})	V_{CC} = 5 V to MAX		25°C	65	100		65	100		dB
V_{O1}/ V_{O2}	Crosstalk attenuation	f = 1 kHz to 20 kHz		25°C		120			120		dB
I_O	Output current	V_{CC} = 15 V, V_{ID} = 1 V, V_O = 0	Source	25°C	–20	–30		–20	–30		mA
				Full range	–10			–10			
		V_{CC} = 15 V, V_{ID} = –1 V, V_O = 15 V	Sink	25°C	10	20		10	20		
				Full range	5			5			
		V_{ID} = –1 V, V_O = 200 mV		25°C	12	30		12	30		μA
I_{OS}	Short-circuit output current	V_{CC} at 5 V, GND at –5 V, V_O = 0		25°C		±40	±60		±40	±60	mA
I_{CC}	Supply current (two amplifiers)	V_O = 2.5 V, No load		Full range		0.7	1.2		0.7	1.2	mA
		V_{CC} = MAX, V_O = 0.5 V_{CC}, No load		Full range		1	2		1	2	

(1) All characteristics are measured under open-loop conditions, with zero common-mode input voltage, unless otherwise specified. MAX V_{CC} for testing purposes is 26 V for XL2902 and 30 V for the others.
(2) Full range is –55°C to 125°C for XL158, –25°C to 85°C for LM258, and 0°C to 70°C for XL358, and –40°C to 125°C for XL2904.
(3) All typical values are at T_A = 25°C

6.6 Electrical Characteristics for XL2904

at specified free-air temperature, V_{CC} = 5 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS[1]		T_A[2]	XL2904 MIN	XL2904 TYP[3]	XL2904 MAX	UNIT
V_{IO}	Input offset voltage	V_{CC} = 5 V to MAX, $V_{IC} = V_{ICR(min)}$, V_O = 1.4 V	Non-A-suffix devices	25°C		3	7	mV
				Full range			10	
			A-suffix devices	25°C		1	2	
				Full range			4	
αV_{IO}	Average temperature coefficient of input offset voltage			Full range		7		μV/°C
I_{IO}	Input offset current	V_O = 1.4 V	Non-V device	25°C		2	50	nA
				Full range			300	
			V-suffix device	25°C		2	50	
				Full range			150	
αI_{IO}	Average temperature coefficient of input offset current			Full range		10		pA/°C
I_{IB}	Input bias current	V_O = 1.4 V		25°C		–20	–250	nA
				Full range			–500	
V_{ICR}	Common-mode input voltage range	V_{CC} = 5 V to MAX		25°C	0 to V_{CC} – 1.5			V
				Full range	0 to V_{CC} – 2			
V_{OH}	High-level output voltage	R_L ≥ 10 kΩ		25°C	V_{CC} – 1.5			V
		V_{CC} = MAX, Non-V device	R_L = 2 kΩ	Full range	22			
			R_L ≥ 10 kΩ	Full range	23	24		
		V_{CC} = MAX V-suffix device	R_L = 2 kΩ	Full range	26			
			R_L ≥ 10 kΩ	Full range	27	28		
V_{OL}	Low-level output voltage	R_L ≤ 10 kΩ		Full range		5	20	mV
A_{VD}	Large-signal differential voltage amplification	V_{CC} = 15 V, V_O = 1 V to 11 V, R_L ≥ 2 kΩ		25°C	25	100		V/mV
				Full range	15			
CMRR	Common-mode rejection ratio	V_{CC} = 5V to MAX, $V_{IC} = V_{ICR(min)}$	Non-V device	25°C	50	80		dB
			V-suffix device	25°C	65	80		
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{CC}/\Delta V_{IO}$)	V_{CC} = 5 V to MAX		25°C	65	100		dB
V_{O1}/V_{O2}	Crosstalk attenuation	f = 1 kHz to 20 kHz		25°C		120		dB
I_O	Output current	V_{CC} = 15 V, V_{ID} = 1 V, V_O = 0	Source	25°C	–20	–30		mA
				Full range	–10			
		V_{CC} = 15 V, V_{ID} = –1 V, V_O = 15 V	Sink	25°C	10	20		
				Full range	5			
		V_{ID} = –1 V, V_O = 200 mV	Non-V device	25°C		30		μA
			V-suffix device	25°C	12	40		
I_{OS}	Short-circuit output current	V_{CC} at 5 V, V_O = 0, GND at −5 V		25°C		±40	±60	mA
I_{CC}	Supply current (four amplifiers)	V_O = 2.5 V, No load		Full range		0.7	1.2	mA
		V_{CC} = MAX, V_O = 0.5 V_{CC}, No load		Full range		1	2	

(1) All characteristics are measured under open-loop conditions, with zero common-mode input voltage, unless otherwise specified. MAX V_{CC} for testing purposes is 26 V for XL2904 and 32 V for XD2904
(2) Full range is –55°C to 125°C for XL158 –25°C to 85°C for XL258, 0°C to 70°C for XL358, and –40°C to 125°C for XL2904.
(3) All typical values are at T_A = 25°C.

6.7 Electrical Characteristics for XL158 and XL258

at specified free-air temperature, V_{CC} = 5 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS[1]	T_A[1]	XL158 MIN	XL158 TYP[2]	XL158 MAX	XL258 MIN	XL258 TYP[2]	XL258 MAX	UNIT
V_{IO}	Input offset voltage	V_{CC} = 5 V to 30 V, $V_{IC} = V_{ICR(min)}$, V_O = 1.4 V	25°C			2		2	3	mV
			Full range			4			4	

(1) All characteristics are measured under open-loop conditions, with zero common-mode input voltage, unless otherwise specified. MAX V_{CC} for testing purposes is 26 V for XL2904 and 30 V for others.
(2) All typical values are at T_A = 25°C.

Electrical Characteristics for XL158 and XL258 (continued)

at specified free-air temperature, V_{CC} = 5 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS(1)		T_A(1)	XL158			XL258			UNIT
					MIN	TYP(2)	MAX	MIN	TYP(2)	MAX	
αV_{IO}	Average temperature coefficient of input offset voltage			Full range		7	15(3)		7	15	μA/°C
I_{IO}	Input offset current	V_O = 1.4 V		25°C		2	10		2	15	nA
				Full range			30			30	
αI_{IO}	Average temperature coefficient of input offset current			Full range		10	200		10	200	pA/°C
I_{IB}	Input bias current	V_O = 1.4 V		25°C		–15	–50		–15	–80	nA
				Full range			–100			–100	
V_{ICR}	Common-mode input voltage range	V_{CC} = 30 V		25°C	0 to V_{CC} – 1.5			0 to V_{CC} – 1.5			V
				Full range	0 to V_{CC} – 2			0 to V_{CC} – 2			
V_{OH}	High-level output voltage	R_L ≥ 2 kΩ		25°C	V_{CC} – 1.5			V_{CC} – 1.5			V
		V_{CC} = 30 V	R_L= 2kΩ	Full range	26			26			
			R_L≥ 10kΩ	Full range	27	28		27	28		
V_{OL}	Low-level output voltage	R_L ≤ 10 kΩ		Full range		5	20		5	20	mV
A_{VD}	Large-signal differential voltage amplification	V_{CC} = 15 V, V_O = 1 V to 11 V, R_L ≥ 2 kΩ		25°C	50	100		50	100		V/mV
				Full range	25			25			
CMRR	Common-mode rejection ratio			25°C	70	80		70	80		dB
k_{SVR}	Supply-voltage rejection ratio (ΔV_D /ΔV_{IO})			25°C	65	100		65	100		dB
V_{O1}/ V_{O2}	Crosstalk attenuation	f = 1 kHz to 20 kHz		25°C		120			120		dB
I_O	Output current	V_{CC} = 15 V, V_{ID} = 1 V, V_O = 0	Source	25°C	–20	–30	–60	–20	–30	−60	mA
				Full range	–10			–10			
		V_{CC} = 15 V, V_{ID} = –1 V, V_O = 15 V	Sink	25°C	10	20		10	20		
				Full range	5			5			
		V_{ID} = −1 V, V_O = 200 mV		25°C	12	30		12	30		μA
I_{OS}	Short-circuit output current	V_{CC} at 5 V, GND at –5 V, V_O = 0		25°C		±40	±60		±40	±60	mA
I_{CC}	Supply current (four amplifiers)	V_O = 2.5 V, No load		Full range		0.7	1.2		0.7	1.2	mA
		V_{CC} = MAX V, V_O = 0.5 V, No load		Full range		1	2		1	2	

(3) On products compliant to MIL-PRF-38535, this parameter is not production tested.

6.8 Electrical Characteristics for XL358

at specified free-air temperature, V_{CC} = 5 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS(1)	T_A(2)	XL358			UNIT
				MIN	TYP(3)	MAX	
V_{IO}	Input offset voltage	V_{CC} = 5 V to 30 V, V_{IC} = $V_{ICR(min)}$, V_O = 1.4 V	25°C		2	3	mV
			Full range			5	
αV_{IO}	Average temperature coefficient of input offset voltage		Full range		7	20	μA/°C
I_{IO}	Input offset current	V_O = 1.4 V	25°C		2	30	nA
			Full range			75	
αI_{IO}	Average temperature coefficient of input offset current		Full range		10	300	pA/°C

(1) All characteristics are measured under open-loop conditions, with zero common-mode input voltage, unless otherwise specified. MAX V_{CC} for testing purposes is 26 V for XL2904 and 30 V for others.
(2) All characteristics are measured under open-loop conditions, with zero common-mode input voltage, unless otherwise specified. MAX V_{CC} for testing purposes is 26 V for XL2904 and 30 V for others.
(3) All typical values are at T_A = 25°C.

Electrical Characteristics for XL358 (continued)

at specified free-air temperature, V_{CC} = 5 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS[1]		T_A[2]	XL358 MIN	XL358 TYP[3]	XL358 MAX	UNIT
I_{IB}	Input bias current	V_O = 1.4 V		25°C		–15	–100	nA
				Full range			–200	
V_{ICR}	Common-mode input voltage range	V_{CC} = 30 V		25°C	0 to V_{CC} – 1.5			V
				Full range	0 to V_{CC} – 2			
V_{OH}	High-level output voltage	R_L ≥ 2 kΩ		25°C	V_{CC} – 1.5			V
		V_{CC} = 30 V	R_L = 2kΩ	Full range	26			
			R_L ≥ 10kΩ	Full range	27	28		
V_{OL}	Low-level output voltage	R_L ≤ 10 kΩ		Full range		5	20	mV
A_{VD}	Large-signal differential voltage amplification	V_{CC} = 15 V, V_O = 1 V to 11 V, R_L ≥ 2 kΩ		25°C	25	100		V/mV
				Full range	15			
CMRR	Common-mode rejection ratio			25°C	65	80		dB
k_{SVR}	Supply-voltage rejection ratio (ΔV_{DD} /ΔV_{IO})			25°C	65	100		dB
V_{O1}/ V_{O2}	Crosstalk attenuation	f = 1 kHz to 20 kHz		25°C		120		dB
I_O	Output current	V_{CC} = 15 V, V_{ID} = 1 V, V_O = 0	Source	25°C	–20	–30	−60	mA
				Full range	–10			
		V_{CC} = 15 V, V_{ID} = –1 V, V_O = 15 V	Sink	25°C	10	20		
				Full range	5			
		V_{ID} = –1 V, V_O = 200 mV		25°C		30		μA
I_{OS}	Short-circuit output current	V_{CC} at 5 V, GND at –5 V, V_O = 0		25°C		±40	±60	mA
I_{CC}	Supply current (four amplifiers)	V_O = 2.5 V, No load		Full range		0.7	1.2	mA
		V_{CC} = MAX V, V_O = 0.5 V, No load		Full range		1	2	

6.9 Operating Conditions

V_{CC} = ±15 V, T_A = 25°C

PARAMETER		TEST CONDITIONS	TYP	UNIT
SR	Slew rate at unity gain	R_L = 1 MΩ, C_L = 30 pF, V_I = ±10 V (see Figure 11)	0.3	V/μs
B_1	Unity-gain bandwidth	R_L = 1 MΩ, C_L = 20 pF (see Figure 11)	0.7	MHz
V_n	Equivalent input noise voltage	R_S = 100 Ω, V_I = 0 V, f = 1 kHz (see Figure 12)	40	nV/√Hz

6.10 Typical Characteristics

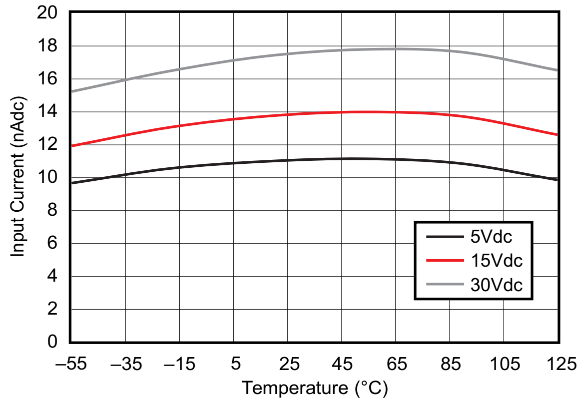


Figure 1. Input Current vs. Temperature

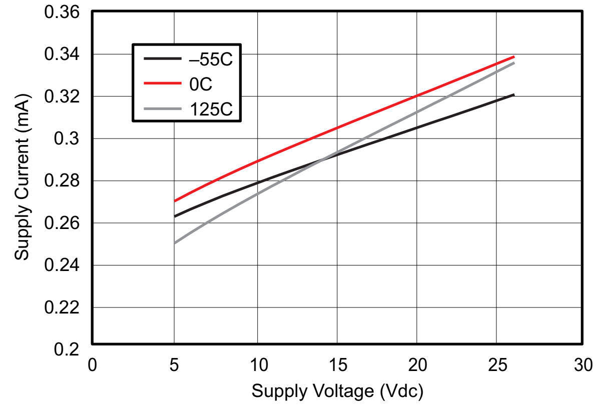


Figure 2. Supply Current vs. Supply Voltage

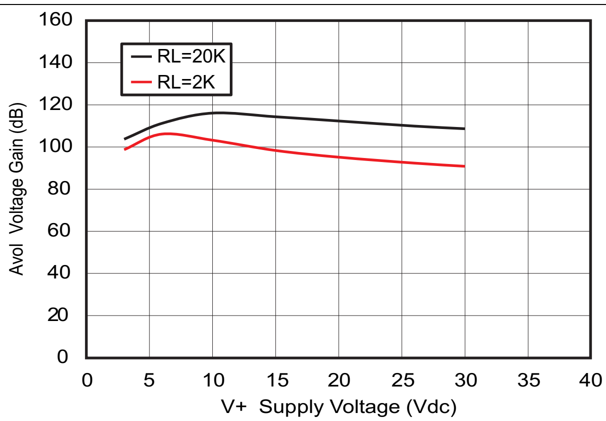


Figure 3. Voltage Gain vs. Supply Voltage

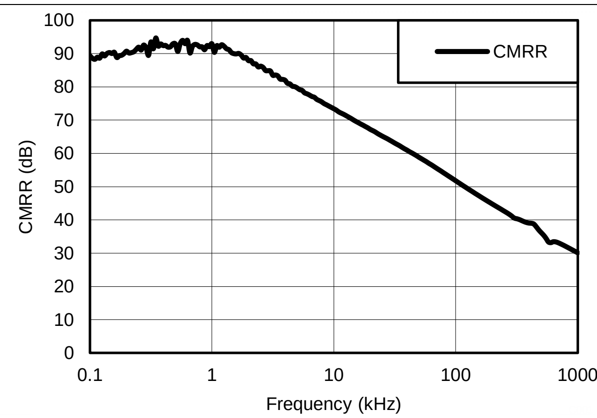


Figure 4. Common-mode Rejection Ratio vs. Frequency

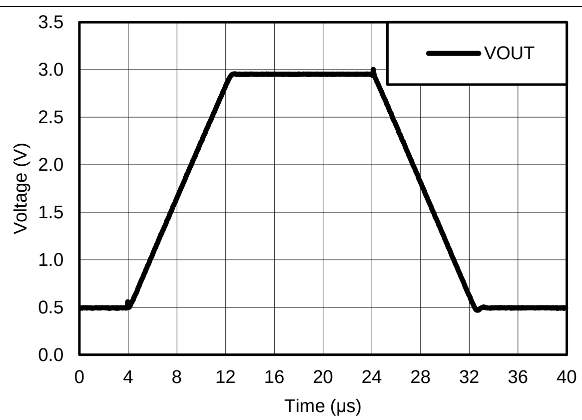


Figure 5. Voltage Follower Large Signal Response (50 pF)

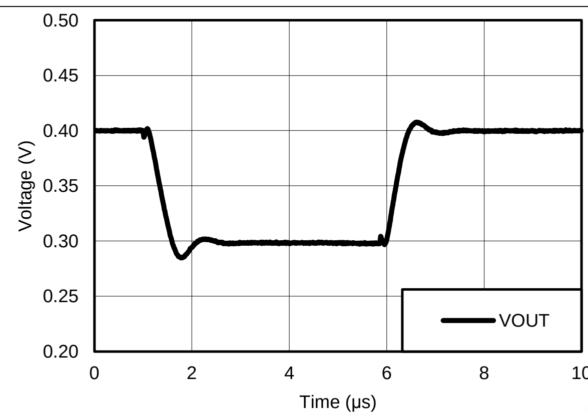


Figure 6. Voltage Follower Small Signal Response (50 pF)

Typical Characteristics (continued)

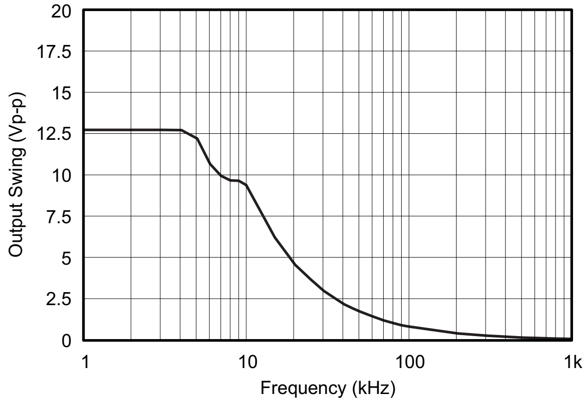


Figure 7. Maximum Output Swing vs. Frequency (V_{CC} = 15 V)

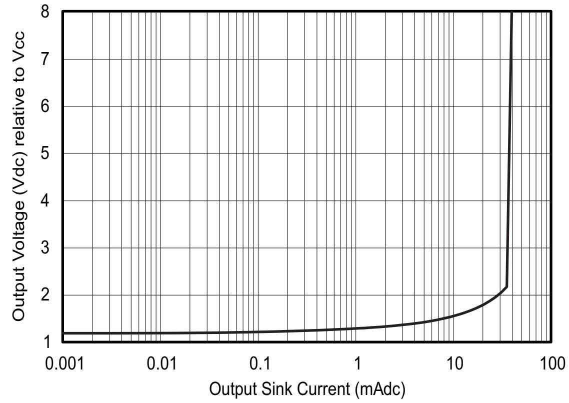


Figure 8. Output Sourcing Characteristics

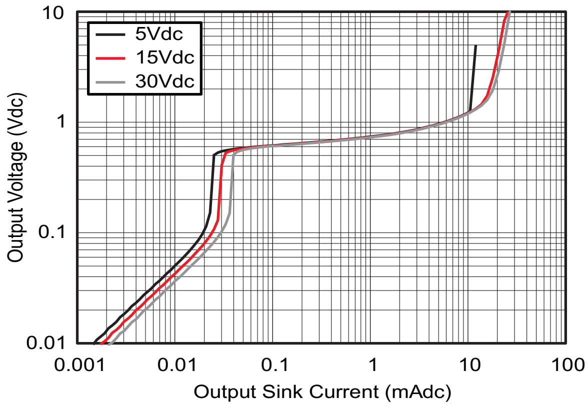


Figure 9. Output Sinking Characteristics

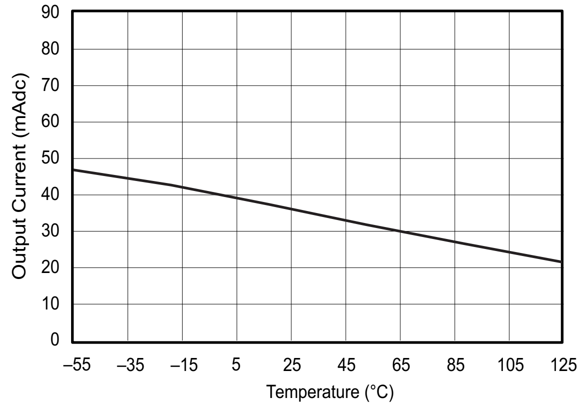


Figure 10. Source Current Limiting

7 Parameter Measurement Information

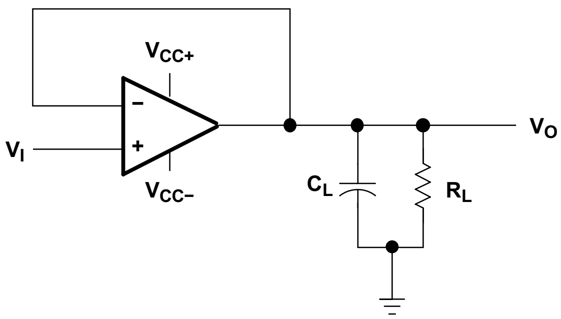


Figure 11. Unity-Gain Amplifier

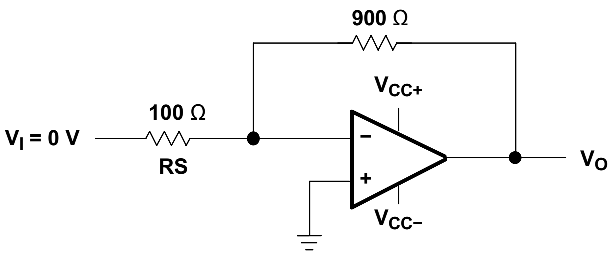


Figure 12. Noise-Test Circuit

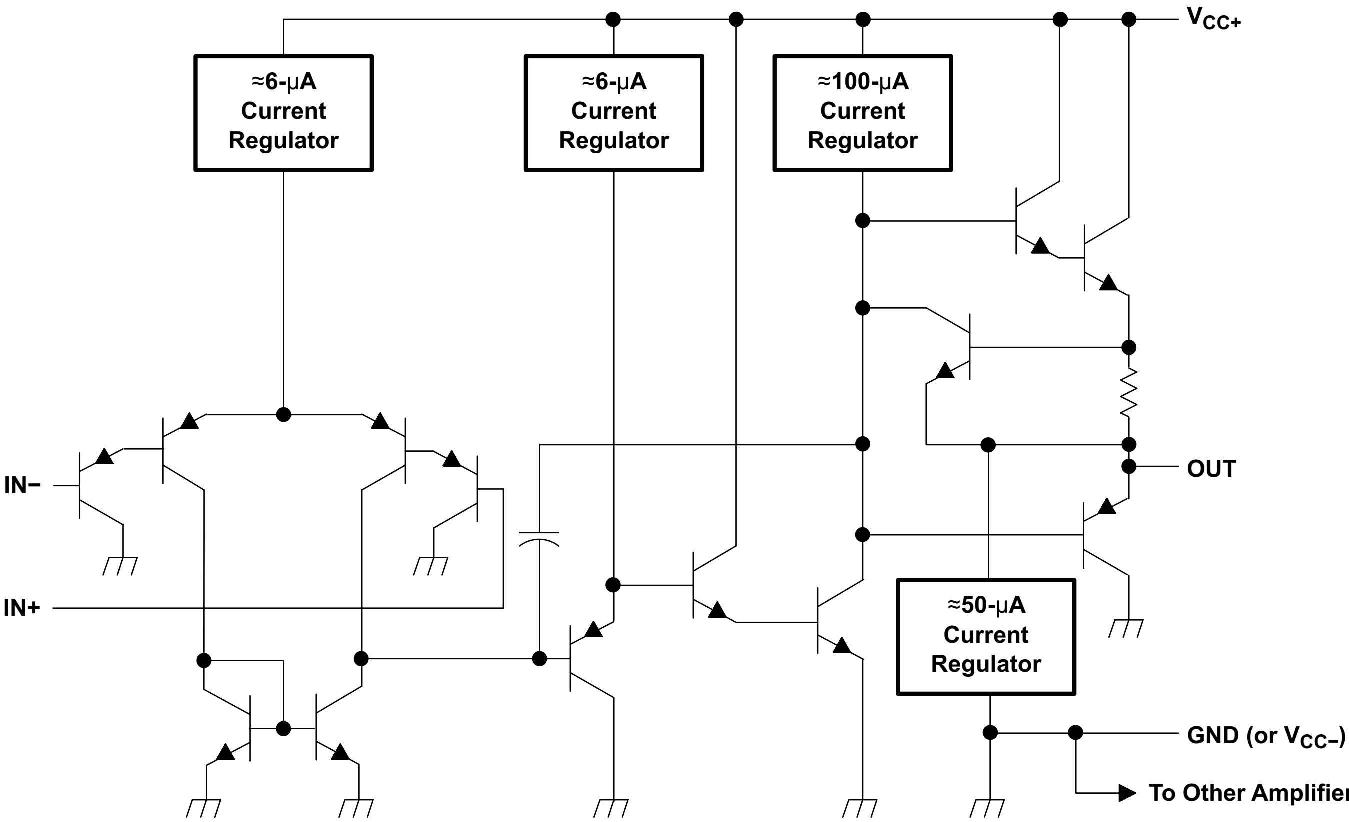
8 Detailed Description

8.1 Overview

These devices consist of two independent, high-gain frequency-compensated operational amplifiers designed to operate from a single supply over a wide range of voltages. Operation from split supplies also is possible if the difference between the two supplies is 3 V to 32 V (3 V to 26 V for the XL2904 device), and V_{CC} is at least 1.5 V more positive than the input common-mode voltage. The low supply-current drain is independent of the magnitude of the supply voltage.

Applications include transducer amplifiers, DC amplification blocks, and all the conventional operational amplifier circuits that now can be implemented more easily in single-supply-voltage systems. For example, these devices can be operated directly from the standard 5-V supply used in digital systems and easily can provide the required interface electronics without additional ±5-V supplies.

8.2 Functional Block Diagram



COMPONENT COUNT	
Epi-FET	1
Diodes	2
Resistors	7
Transistors	51
Capacitors	2

8.3 Feature Description

8.3.1 Unity-Gain Bandwidth

The unity-gain bandwidth is the frequency up to which an amplifier with a unity gain may be operated without greatly distorting the signal. These devices have a 0.7-MHz unity-gain bandwidth.

8.3.2 Slew Rate

The slew rate is the rate at which an operational amplifier can change its output when there is a change on the input. These devices have a 0.3-V/μs slew rate.

8.3.3 Input Common Mode Range

The valid common mode range is from device ground to V_{CC} - 1.5 V (V_{CC} - 2 V across temperature). Inputs may exceed V_{CC} up to the maximum V_{CC} without device damage. At least one input must be in the valid input common mode range for output to be correct phase. If both inputs exceed valid range then output phase is undefined. If either input is less than -0.3 V then input current should be limited to 1mA and output phase is undefined.

8.4 Device Functional Modes

These devices are powered on when the supply is connected. This device can be operated as a single supply operational amplifier or dual supply amplifier depending on the application.

9 Application and Implementation

9.1 Application Information

The XLx58 and XL2904 operational amplifiers are useful in a wide range of signal conditioning applications. Inputs can be powered before V_{CC} for flexibility in multiple supply circuits.

9.2 Typical Application

A typical application for an operational amplifier in an inverting amplifier. This amplifier takes a positive voltage on the input, and makes it a negative voltage of the same magnitude. In the same manner, it also makes negative voltages positive.

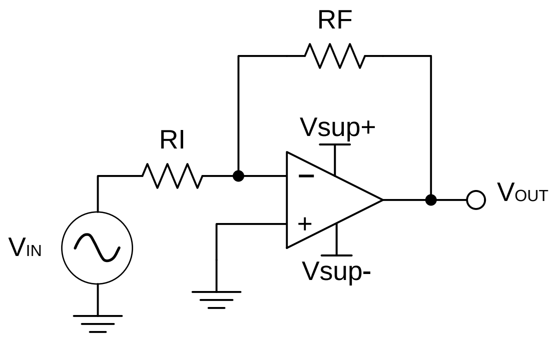


Figure 13. Application Schematic

9.2.1 Design Requirements

The supply voltage must be chosen such that it is larger than the input voltage range and output range. For instance, this application will scale a signal of ±0.5 V to ±1.8 V. Setting the supply at ±12 V is sufficient to accommodate this application.

9.2.2 Detailed Design Procedure

Determine the gain required by the inverting amplifier using Equation 1 and Equation 2:

$$A_v = \frac{VOUT}{VIN} \tag{1}$$

$$A_v = \frac{1.8}{-0.5} = -3.6 \tag{2}$$

Once the desired gain is determined, choose a value for RI or RF. Choosing a value in the kilohm range is desirable because the amplifier circuit will use currents in the milliamp range. This ensures the part will not draw too much current. This example will choose 10 kΩ for RI which means 36 kΩ will be used for RF. This was determined by Equation 3.

$$A_v = -\frac{RF}{RI} \tag{3}$$

Typical Application (continued)

9.2.3 Application Curve

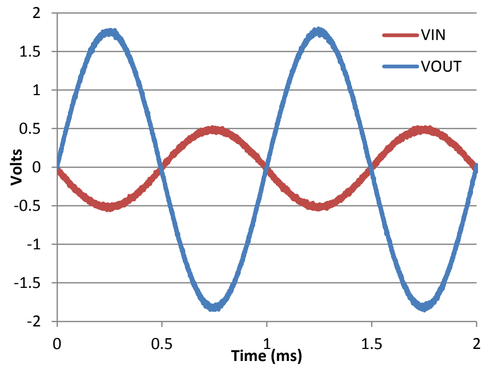


Figure 14. Input and Output Voltages of the Inverting Amplifier

10 Power Supply Recommendations

CAUTION

Supply voltages larger than 32 V for a single supply (26 V for the XL2904), or outside the range of ±16 V for a dual supply (±13 V for the LM2904) can permanently damage the device (see the *Absolute Maximum Ratings*).

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, refer to the *Layout*.

11 Layout

11.1 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, as well as the operational amplifier. 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-effective methods 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 it is not possible to keep them separate, it is much better to cross the sensitive trace perpendicular as opposed to in parallel with the noisy trace.
- Place the external components as close to the device as possible. Keeping RF and RG close to the inverting input minimizes parasitic capacitance, as shown in *Layout Examples*.
- 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.

11.2 Layout Examples

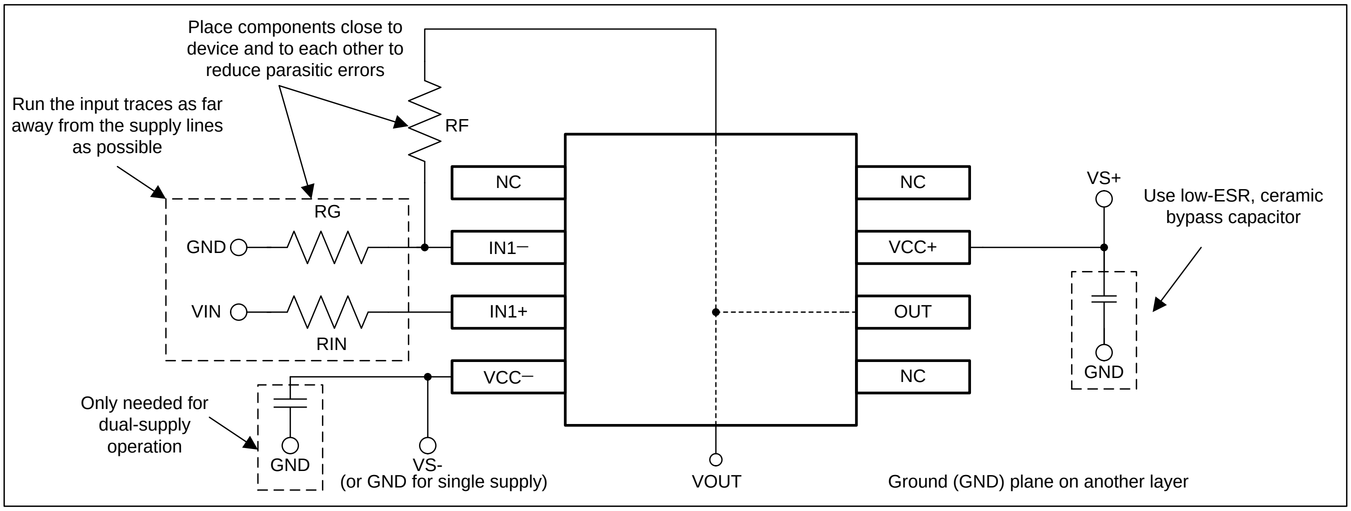


Figure 15. Operational Amplifier Board Layout for Noninverting Configuration

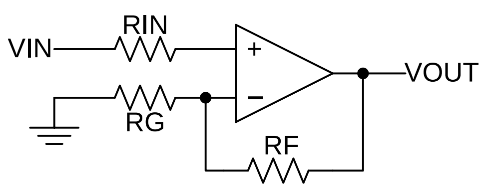


Figure 16. Operational Amplifier Schematic for Noninverting Configuration