

LM158, LM158A, LM258, LM258A LM358, LM358A, LM2904, LM2904Q DUAL OPERATIONAL AMPLIFIERS

SLOS068E – JUNE 1976 – REVISED SEPTEMBER 2002

- **Wide Range of Supply Voltages:**
 - Single Supply . . . 3 V to 30 V
(LM2904 and LM2904Q . . . 3 V to 26 V) or
 - Dual Supplies
- **Low Supply-Current Drain Independent of Supply Voltage . . . 0.7 mA Typ**
- **Common-Mode Input Voltage Range Includes Ground, Allowing Direct Sensing Near Ground**
- **Low Input Bias and Offset Parameters:**
 - Input Offset Voltage . . . 3 mV Typ
A Versions . . . 2 mV Typ
 - Input Offset Current . . . 2 nA Typ
 - Input Bias Current . . . 20 nA Typ
A Versions . . . 15 nA Typ
- **Differential Input Voltage Range Equal to Maximum-Rated Supply Voltage . . . ± 32 V (LM2904 and LM2904Q . . . ± 26 V)**
- **Open-Loop Differential Voltage Amplification . . . 100 V/mV Typ**
- **Internal Frequency Compensation**

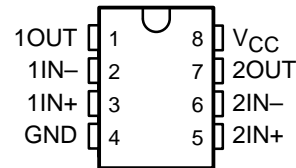
description/ordering information

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 30 V (3 V to 26 V for the LM2904 and LM2904Q), 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.

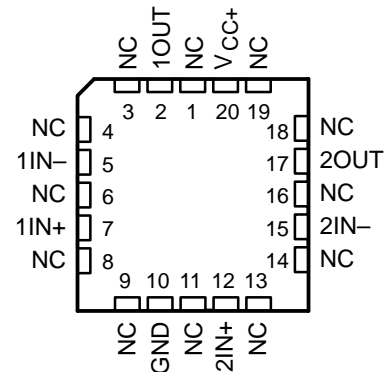
Applications include transducer amplifiers, dc amplification blocks, and all the conventional operational amplifier circuits that now can be implemented more easily in single-supply-voltage systems. For example, these devices can be operated directly from the standard 5-V supply used in digital systems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

The LM2904Q is manufactured to demanding automotive requirements.

LM158, LM158A . . . JG PACKAGE
LM258 . . . D OR P PACKAGE
LM258A . . . P PACKAGE
LM358 . . . D, P, PS, OR PW PACKAGE
LM358A . . . D OR P PACKAGE
LM2904 . . . D, P, PS, OR PW PACKAGE
LM2904Q . . . D PACKAGE
(TOP VIEW)



LM158, LM158A . . . FK PACKAGE
(TOP VIEW)



NC – No internal connection



Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

PRODUCTION DATA information is current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

 **TEXAS
INSTRUMENTS**

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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.

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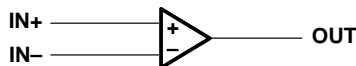
description/ordering information (continued)

ORDERING INFORMATION

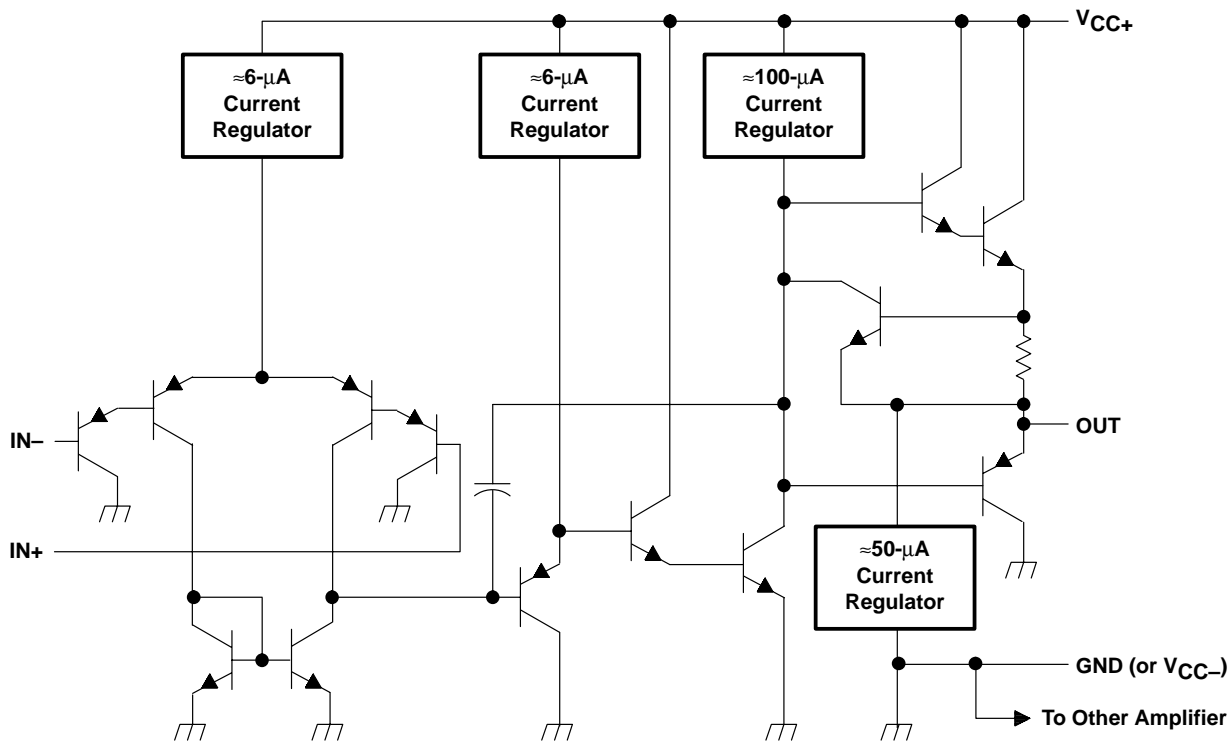
T_A	V_{IO}max AT 25°C	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING
0°C to 70°C	7 mV	PDIP (P)	Tube	LM358P	LM358P
		SOIC (D)	Tube	LM358D	LM358
			Tape and reel	LM358DR	
		SOP (PS)	Tape and reel	LM358PSR	L358
	TSSOP (PW)	Tape and reel	LM358PWR	L358	
	3 mV	PDIP (P)	Tube	LM358AP	LM358AP
		SOIC (D)	Tube	LM358AD	LM358A
			Tape and reel	LM358ADR	
-25°C to 85°C	5 mV	PDIP (P)	Tube	LM258P	LM258P
		SOIC (D)	Tube	LM258D	LM258
	Tape and reel		LM258DR		
	3 mV	PDIP (P)	Tube	LM258AP	LM258AP
-40°C to 125°C	7 mV	PDIP (P)	Tube	LM2904P	LM2904P
		SOIC (D)	Tube	LM2904D	LM2904
			Tape and reel	LM2904DR	
			Tube	LM2904QD	2904Q
			Tape and reel	LM2904QDR	
		SOP (PS)	Tape and reel	LM2904PSR	L2904
	TSSOP (PW)	Tape and reel	LM2904PWR	L2904	
-55°C to 125°C	5 mV	CDIP (JG)	Tube	LM158JG	LM158JG
			Tube	LM158JGB	LM158JGB
		LCCC (FK)	Tube	LM158FKB	LM158FKB
	2 mV	CDIP (JG)	Tube	LM158AJG	LM158AJG
			Tube	LM158AJGB	LM158AJGB
		LCCC (FK)	Tube	LM158AFKB	LM158AFKB

† Package drawings, standard packing quantities, thermal data, symbolization, and PCB design guidelines are available at www.ti.com/sc/package.

symbol (each amplifier)



schematic (each amplifier)



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

**LM158, LM158A, LM258, LM258A
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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

		LM158, LM158A LM258, LM258A LM358, LM358A	LM2904 LM2904Q	UNIT
Supply voltage, V_{CC} (see Note 1)		32	26	V
Differential input voltage, V_{ID} (see Note 2)		±32	±26	V
Input voltage, V_I (either input)		-0.3 to 32	-0.3 to 26	V
Duration of output short circuit (one amplifier) to ground at (or below) 25°C free-air temperature ($V_{CC} \leq 15$ V) (see Note 3)		Unlimited	Unlimited	
Operating virtual junction temperature, T_J		150	150	°C
Package thermal impedance, θ_{JA} (see Notes 4 and 5)	D package	97	97	°C/W
	P package	85	85	
	PS package	95	95	
	PW package	149	149	
Package thermal impedance, θ_{JC} (see Notes 6 and 7)	FK package	5.61		°C/W
	JG package	14.5		
Operating free-air temperature range, T_A	LM158, LM158A	-55 to 125		°C
	LM258, LM258A	-25 to 85		
	LM358, LM358A	0 to 70		
	LM2904, LM2904Q		-40 to 125	
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
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	P package	260	260	°C
Storage temperature range, T_{stg}		-65 to 150	-65 to 150	°C

† 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.

- NOTES:
1. All voltage values, except differential voltages and V_{CC} specified for measurement of I_{OS} , are with respect to the network ground terminal.
 2. Differential voltages are at $IN+$ with respect to $IN-$.
 3. Short circuits from outputs to V_{CC} can cause excessive heating and eventual destruction.
 4. Maximum power dissipation is a function of $T_J(max)$, θ_{JA} , and T_A . The maximum allowable power dissipation at any allowable ambient temperature is $P_D = (T_J(max) - T_A)/\theta_{JA}$. Operating at the absolute maximum T_J of 150°C can affect reliability.
 5. The package thermal impedance is calculated in accordance with JESD 51-7.
 6. Maximum power dissipation is a function of $T_J(max)$, θ_{JC} , and T_C . The maximum allowable power dissipation at any allowable case temperature is $P_D = (T_J(max) - T_C)/\theta_{JC}$. Operating at the absolute maximum T_J of 150°C can affect reliability.
 7. The package thermal impedance is calculated in accordance with MIL-STD-883.



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electrical characteristics at specified free-air temperature, $V_{CC} = 5\text{ V}$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS†	T_A ‡	LM158 LM258			LM358			UNIT
			MIN	TYP§	MAX	MIN	TYP§	MAX	
V_{IO} Input offset voltage	$V_{CC} = 5\text{ V to MAX}$, $V_{IC} = V_{ICR(\text{min})}$, $V_O = 1.4\text{ V}$	25°C	3	5		3	7	mV	
		Full range			7		9		
$\alpha_{V_{IO}}$ Average temperature coefficient of input offset voltage		Full range	7			7		$\mu\text{V}/^\circ\text{C}$	
I_{IO} Input offset current	$V_O = 1.4\text{ V}$	25°C	2	30		2	50	nA	
		Full range			100		150		
$\alpha_{I_{IO}}$ Average temperature coefficient of input offset current		Full range	10			10		$\text{pA}/^\circ\text{C}$	
I_{IB} Input bias current	$V_O = 1.4\text{ V}$	25°C	-20	-150		-20	-250	nA	
		Full range			-300		-500		
V_{ICR} Common-mode input voltage range	$V_{CC} = 5\text{ V to MAX}$	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	$R_L \geq 2\text{ k}\Omega$	25°C	$V_{CC}-1.5$			$V_{CC}-1.5$		V	
		25°C							
		Full range	$R_L = 2\text{ k}\Omega$	26			26		
			$R_L \geq 10\text{ k}\Omega$	27	28		27		28
V_{OL} Low-level output voltage	$R_L \leq 10\text{ k}\Omega$	Full range	5	20		5	20	mV	
A_{VD} Large-signal differential voltage amplification	$V_{CC} = 15\text{ V}$, $V_O = 1\text{ V to }11\text{ V}$, $R_L = \geq 2\text{ k}\Omega$	25°C	50	100		25	100	V/mV	
		Full range	25			15			
CMRR Common-mode rejection ratio	$V_{CC} = 5\text{ V to MAX}$, $V_{IC} = V_{ICR(\text{min})}$	25°C	70	80		65	80	dB	
k_{SVR} Supply-voltage rejection ratio ($\Delta V_{DD}/\Delta V_{IO}$)	$V_{CC} = 5\text{ V to MAX}$	25°C	65	100		65	100	dB	
V_{O1}/V_{O2} Crosstalk attenuation	$f = 1\text{ kHz to }20\text{ kHz}$	25°C		120			120	dB	
I_O Output current	$V_{CC} = 15\text{ V}$, $V_{ID} = 1\text{ V}$, $V_O = 0$	25°C	-20	-30		-20	-30	mA	
		Full range	-10			-10			
		25°C	10	20		10	20		
		Full range	5			5			
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	
		Full range	0.7	1.2		0.7	1.2		
I_{CC} Supply current (two amplifiers)	$V_O = 2.5\text{ V}$, No load	Full range	0.7	1.2		0.7	1.2	mA	
	$V_{CC} = \text{MAX}$, $V_O = 0.5\text{ V}$, No load	Full range	1	2		1	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 the LM2904 and 30 V for others.

‡ Full range is -55°C to 125°C for LM158, -25°C to 85°C for LM258, 0°C to 70°C for LM358, and -40°C to 125°C for LM2904 and LM2904Q.

§ All typical values are at $T_A = 25^\circ\text{C}$.



**LM158, LM158A, LM258, LM258A
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electrical characteristics at specified free-air temperature, $V_{CC} = 5\text{ V}$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS†	T_A ‡	LM2904 LM2904Q			UNIT	
			MIN	TYP§	MAX		
V_{IO} Input offset voltage	$V_{CC} = 5\text{ V to MAX}$, $V_{IC} = V_{ICR(min)}$, $V_O = 1.4\text{ V}$	25°C	3	7		mV	
		Full range			10		
$\alpha_{V_{IO}}$ Average temperature coefficient of input offset voltage		Full range	7			$\mu\text{V}/^\circ\text{C}$	
I_{IO} Input offset current	$V_O = 1.4\text{ V}$	25°C	2	50		nA	
		Full range			300		
$\alpha_{I_{IO}}$ Average temperature coefficient of input offset current		Full range	10			$\text{pA}/^\circ\text{C}$	
I_{IB} Input bias current	$V_O = 1.4\text{ V}$	25°C	-20	-250		nA	
		Full range			-500		
V_{ICR} Common-mode input voltage range	$V_{CC} = 5\text{ V to MAX}$	25°C	0 to $V_{CC}-1.5$			V	
		Full range	0 to $V_{CC}-2$				
V_{OH} High-level output voltage	$R_L \geq 2\text{ k}\Omega$	25°C				V	
	$R_L \geq 10\text{ k}\Omega$	25°C	$V_{CC}-1.5$				
	$V_{CC} = \text{MAX}$	$R_L = 2\text{ k}\Omega$	Full range	26			
		$R_L \geq 10\text{ k}\Omega$	Full range	23	24		
V_{OL} Low-level output voltage	$R_L \leq 10\text{ k}\Omega$	Full range	5	20		mV	
A_{VD} Large-signal differential voltage amplification	$V_{CC} = 15\text{ V}$, $V_O = 1\text{ V to }11\text{ V}$, $R_L \geq 2\text{ k}\Omega$	25°C	25	100		V/mV	
		Full range	15				
CMRR Common-mode rejection ratio	$V_{CC} = 5\text{ V to MAX}$, $V_{IC} = V_{ICR(min)}$	25°C	50	80		dB	
k_{SVR} Supply-voltage rejection ratio ($\Delta V_{DD}/\Delta V_{IO}$)	$V_{CC} = 5\text{ V to MAX}$	25°C	65	100		dB	
V_{O1}/V_{O2} Crosstalk attenuation	$f = 1\text{ kHz to }20\text{ kHz}$	25°C		120		dB	
I_O Output current	$V_{CC} = 15\text{ V}$, $V_{ID} = 1\text{ V}$, $V_O = 0$	25°C	-20	-30		mA	
		Full range	-10				
	$V_{CC} = 15\text{ V}$, $V_{ID} = -1\text{ V}$, $V_O = 15\text{ V}$	25°C	10	20			
		Full range	5				
$V_{ID} = -1\text{ V}$, $V_O = 200\text{ mV}$	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 (two amplifiers)	$V_O = 2.5\text{ V}$, No load	Full range	0.7	1.2		mA	
	$V_{CC} = \text{MAX}$, $V_O = 0.5\text{ V}$, No load	Full range	1	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 the LM2904 and 30 V for others.

‡ Full range is -55°C to 125°C for LM158, -25°C to 85°C for LM258, 0°C to 70°C for LM358, and -40°C to 125°C for LM2904 and LM2904Q.

§ All typical values are at $T_A = 25^\circ\text{C}$.



LM158, LM158A, LM258, LM258A
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electrical characteristics at specified free-air temperature, $V_{CC} = 5\text{ V}$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS†	T_A ‡	LM158A			LM258A			UNIT
			MIN	TYP§	MAX	MIN	TYP§	MAX	
V_{IO} Input offset voltage	$V_{CC} = 5\text{ V to }30\text{ V}$, $V_{IC} = V_{ICR}(\text{min})$, $V_O = 1.4\text{ V}$	25°C	2			2	3		mV
		Full range	4			4			
$\alpha_{V_{IO}}$ Average temperature coefficient of input offset voltage		Full range	7 15*			7 15			$\mu\text{V}/^\circ\text{C}$
I_{IO} Input offset current	$V_O = 1.4\text{ V}$	25°C	2		10		2 15		nA
		Full range	30			30			
$\alpha_{I_{IO}}$ Average temperature coefficient of input offset current		Full range	10 200			10 200			$\text{pA}/^\circ\text{C}$
I_{IB} Input bias current	$V_O = 1.4\text{ V}$	25°C	-15		-50		-15 -80		nA
		Full range	-100			-100			
V_{ICR} Common-mode input voltage range	$V_{CC} = 30\text{ V}$	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	$R_L \geq 2\text{ k}\Omega$ $V_{CC} = 30\text{ V}$	25°C	$V_{CC}-1.5$			$V_{CC}-1.5$			V
		Full range	$R_L = 2\text{ k}\Omega$	26		26			
			$R_L \geq 10\text{ k}\Omega$	27	28		27	28	
V_{OL} Low-level output voltage	$R_L \leq 10\text{ k}\Omega$	Full range	5 20			5 20			mV
A_{VD} Large-signal differential voltage amplification	$V_{CC} = 15\text{ V}$, $V_O = 1\text{ V to }11\text{ V}$, $R_L \geq 2\text{ k}\Omega$	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 ($\Delta V_{DD}/\Delta V_{IO}$)		25°C	65 100		65 100				dB
V_{O1}/V_{O2} Crosstalk attenuation	$f = 1\text{ kHz to }20\text{ kHz}$	25°C	120			120			dB
I_O Output current	$V_{CC} = 15\text{ V}$, $V_{ID} = 1\text{ V}$, $V_O = 0$	25°C	-20 -30 -60			-20 -30 -60			mA
		Full range	-10			-10			
	$V_{CC} = 15\text{ V}$, $V_{ID} = -1\text{ V}$, $V_O = 15$	25°C	10 20		10 20				
		Full range	5			5			
	$V_{ID} = -1\text{ V}$, $V_O = 200\text{ mV}$	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)	$V_O = 2.5\text{ V}$, No load	Full range	0.7 1.2		0.7 1.2				mA
	$V_{CC} = \text{MAX}$, $V_O = 0.5\text{ V}$, No load	Full range	1 2		1 2				

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

† 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 LM2904 and 30 V for others.

‡ Full range is -55°C to 125°C for LM158A, -25°C to 85°C for LM258A, and 0°C to 70°C for LM358A.

§ All typical values are at $T_A = 25^\circ\text{C}$.



**LM158, LM158A, LM258, LM258A
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electrical characteristics at specified free-air temperature, $V_{CC} = 5\text{ V}$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS†	T_A ‡	LM358A			UNIT
			MIN	TYP§	MAX	
V_{IO} Input offset voltage	$V_{CC} = 5\text{ V to }30\text{ V}$, $V_{IC} = V_{ICR(\text{min})}$, $V_O = 1.4\text{ V}$	25°C	2	3		mV
		Full range			5	
$\alpha_{V_{IO}}$ Average temperature coefficient of input offset voltage		Full range	7	20		$\mu\text{V}/^\circ\text{C}$
I_{IO} Input offset current	$V_O = 1.4\text{ V}$	25°C	2	30		nA
		Full range			75	
$\alpha_{I_{IO}}$ Average temperature coefficient of input offset current		Full range	10	300		$\text{pA}/^\circ\text{C}$
I_{IB} Input bias current	$V_O = 1.4\text{ V}$	25°C	-15	-100		nA
		Full range			-200	
V_{ICR} Common-mode input voltage range	$V_{CC} = 30\text{ V}$	25°C	0 to $V_{CC}-1.5$			V
		Full range	0 to $V_{CC}-2$			
V_{OH} High-level output voltage	$R_L \geq 2\text{ k}\Omega$	25°C	$V_{CC}-1.5$			V
	$V_{CC} = 30\text{ V}$	$R_L = 2\text{ k}\Omega$	Full range		26	
		$R_L \geq 10\text{ k}\Omega$	Full range		27 28	
V_{OL} Low-level output voltage	$R_L \leq 10\text{ k}\Omega$	Full range	5	20		mV
A_{VD} Large-signal differential voltage amplification	$V_{CC} = 15\text{ V}$, $V_O = 1\text{ V to }11\text{ V}$, $R_L = \geq 2\text{ k}\Omega$	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 ($\Delta V_{DD}/\Delta V_{IO}$)		25°C	65	100		dB
V_{O1}/V_{O2} Crosstalk attenuation	$f = 1\text{ kHz to }20\text{ kHz}$	25°C	120			dB
I_O Output current	$V_{CC} = 15\text{ V}$, $V_{ID} = 1\text{ V}$, $V_O = 0$	25°C	-20	-30	-60	mA
		Full range	-10			
	$V_{CC} = 15\text{ V}$, $V_{ID} = -1\text{ V}$, $V_O = 15\text{ V}$	25°C	10	20		
		Full range	5			
	$V_{ID} = -1\text{ V}$, $V_O = 200\text{ mV}$	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 (two amplifiers)	$V_O = 2.5\text{ V}$, No load	Full range	0.7	1.2		mA
	$V_{CC} = \text{MAX}$, $V_O = 0.5\text{ V}$ No load	Full range	1	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 LM2904 and 30 V for others.

‡ Full range is -55°C to 125°C for LM158A, -25°C to 85°C for LM258A, and 0°C to 70°C for LM358A.

§ All typical values are at $T_A = 25^\circ\text{C}$.



operating conditions, $V_{CC} = \pm 15\text{ V}$, $T_A = 25^\circ\text{C}$

PARAMETER		TEST CONDITIONS	TYP	UNIT
SR	Slew rate at unity gain	$R_L = 1\text{ M}\Omega$, $C_L = 30\text{ pF}$, $V_I = \pm 10\text{ V}$ (see Figure 1)	0.3	$\text{V}/\mu\text{s}$
B_1	Unity-gain bandwidth	$R_L = 1\text{ M}\Omega$, $C_L = 20\text{ pF}$ (see Figure 1)	0.7	MHz
V_n	Equivalent input noise voltage	$R_S = 100\ \Omega$, $V_I = 0\text{ V}$, $f = 1\text{ kHz}$ (see Figure 2)	40	$\text{nV}/\sqrt{\text{Hz}}$

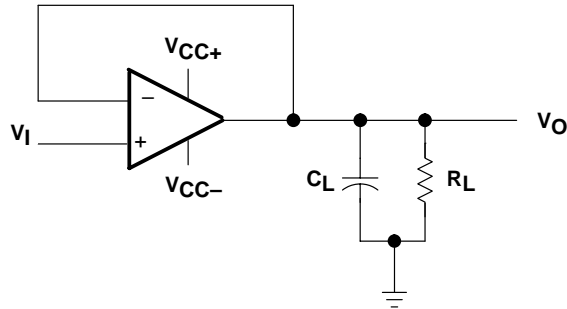


Figure 1. Unity-Gain Amplifier

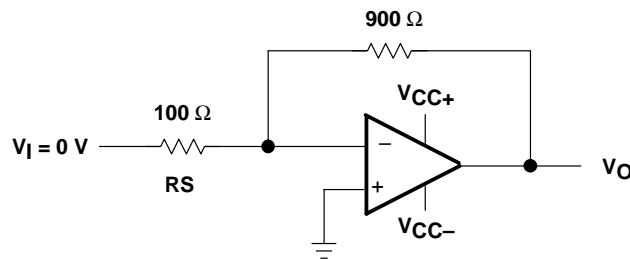


Figure 2. Noise-Test Circuit

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