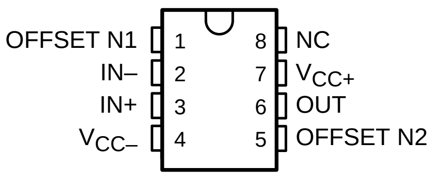
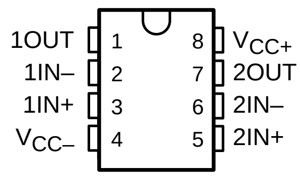
- **Direct Upgrades to TL07x and TL08x BiFET Operational Amplifiers**
- **Faster Slew Rate (20 V/μs Typ) Without Increased Power Consumption**
- **On-Chip Offset-Voltage Trimming for Improved DC Performance and Precision Grades Are Available (1.5 mV, TL051A)**

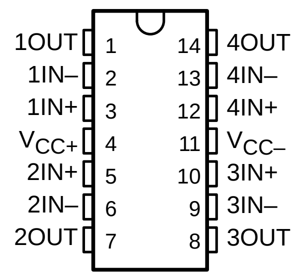
TL051
D OR P PACKAGE
(TOP VIEW)



TL052
D, P, OR PS PACKAGE
(TOP VIEW)



TL054
D, DB, N, OR NS PACKAGE
(TOP VIEW)



description/ordering information

The TL05x series of JFET-input operational amplifiers offers improved dc and ac characteristics over the TL07x and TL08x families of BiFET operational amplifiers. On-chip Zener trimming of offset voltage yields precision grades as low as 1.5 mV (TL051A) for greater accuracy in dc-coupled applications. Texas Instruments improved BiFET process and optimized designs also yield improved bandwidth and slew rate without increased power consumption. The TL05x devices are pin-compatible with the TL07x and TL08x and can be used to upgrade existing circuits or for optimal performance in new designs.

BiFET operational amplifiers offer the inherently higher input impedance of the JFET-input transistors, without sacrificing the output drive associated with bipolar amplifiers. This makes them better suited for interfacing with high-impedance sensors or very low-level ac signals. They also feature inherently better ac response than bipolar or CMOS devices having comparable power consumption.

The TL05x family was designed to offer higher precision and better ac response than the TL08x, with the low noise floor of the TL07x. Designers requiring significantly faster ac response or ensured lower noise should consider the Excalibur TLE208x and TLE207x families of BiFET operational amplifiers.

Because BiFET operational amplifiers are designed for use with dual power supplies, care must be taken to observe common-mode input voltage limits and output swing when operating from a single supply. DC biasing of the input signal is required, and loads should be terminated to a virtual-ground node at mid-supply. Texas Instruments TLE2426 integrated virtual ground generator is useful when operating BiFET amplifiers from single supplies.

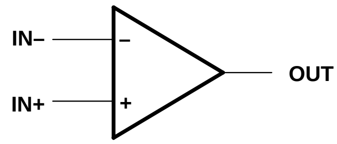
The TL05x are fully specified at ±15 V and ±5 V. For operation in low-voltage and/or single-supply systems, Texas Instruments LinCMOS families of operational amplifiers (TLC-prefix) are recommended. When moving from BiFET to CMOS amplifiers, particular attention should be paid to the slew rate and bandwidth requirements, and also the output loading.

ORDERING INFORMATION

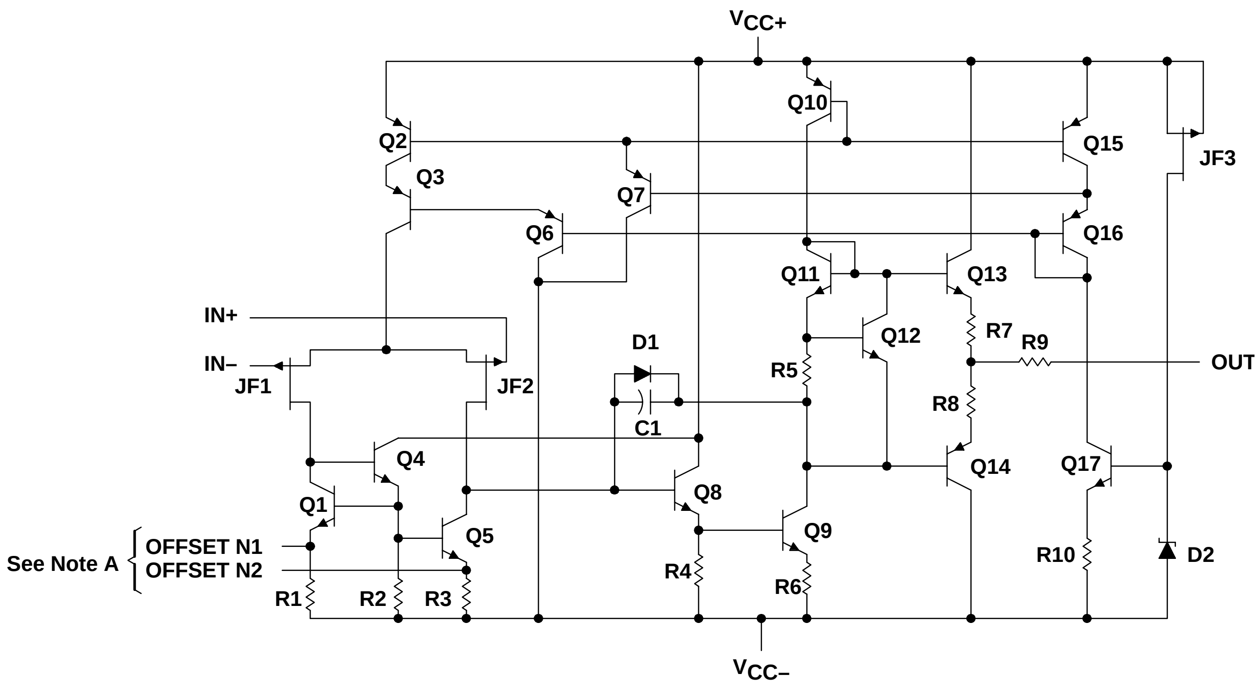
T_A	V_{IO}max AT 25°C	PACKAGE†		ORDERABLE PART NUMBER	TOP-SIDE MARKING
0°C to 70°C	800 µV	PDIP (P)	Tube of 50	TL051ACP	TL051ACP
				TL052ACP	TL052ACP
		SOIC (D)	Tube of 75	TL051ACD	051AC
			Tube of 75	TL052ACD	052AC
			Reel of 2500	TL052ACDR	
	1.5 mV	PDIP (P)	Tube of 50	TL051CP	TL051CP
				TL052CP	TL052CP
		PDIP (N)	Tube of 25	TL054ACN	TL054ACN
		SOIC (D)	Tube of 75	TL051CD	TL051C
			Reel of 2500	TL051CDR	
			Tube of 75	TL052CD	TL052C
			Reel of 2500	TL052CDR	
			Tube of 50	TL054ACD	TL054C
			Reel of 2500	TL054ACDR	
		SOP (PS)	Reel of 2000	TL052CPSR	TL052
		SSOP (DB)	Reel of 2000	TL054CDBR	TL054
	4 mV	PDIP (N)	Tube of 25	TL054CN	TL054CN
		SOIC (D)	Tube of 50	TL054CD	TL054C
			Reel of 2500	TL054CDR	
		SOP (NS)	Reel of 2000	TL054CNSR	TL054
–40°C to 85°C	800 µV	PDIP (P)	Tube of 50	TL052AIP	TL052AI
		SOIC (D)	Tube of 75	TL052AID	052AI
			Reel of 2500	TL052AIDR	
	1.5 mV	PDIP (N)	Tube of 25	TL054AIN	TL054AIN
		PDIP (P)	Tube of 50	TL051IP	TL051IP
				TL052IP	TL052IP
		SOIC (D)	Tube of 75	TL051ID	TL051I
			Tube of 75	TL052ID	TL052I
			Reel of 2500	TL052IDR	
			Tube of 50	TL054AID	TL054AI
			Reel of 2500	TL054AIDR	
	4 mV	PDIP (N)	Tube of 25	TL054IN	TL054IN
		SOIC (D)	Tube of 50	TL054ID	TL054I
			Reel of 2500	TL054IDR	

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

symbol (each amplifier)



equivalent schematic (each amplifier)



NOTE A: OFFSET N1 and OFFSET N2 are available only on the TL051x.

ACTUAL DEVICE COMPONENT COUNT†			
COMPONENT	TL051	TL052	TL054
Transistors	20	34	62
Resistors	10	19	37
Diodes	2	3	5
Capacitors	1	2	4

† These figures include all four amplifiers and all ESD, bias, and trim circuitry.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)†

Supply voltage, V_{CC+} (see Note 1) . . . . 18 V
Supply voltage, V_{CC-} (see Note 1) . . . . –18 V
Differential input voltage (see Note 2) . . . . ±30 V
Input voltage range, V_I (any input, see Notes 1 and 3) . . . . ±15 V
Input current, I_I (each input) . . . . ±1 mA
Output current, I_O (each output) . . . . ±80 mA
Total current into V_{CC+} . . . . 160 mA
Total current out of V_{CC-} . . . . 160 mA
Duration of short-circuit current at (or below) 25°C . . . . Unlimited
Package thermal impedance, θ_{JA} (see Notes 4 and 5): D package (8 pin) . . . . 97°C/W
D package (14 pin) . . . . 86°C/W
DB package (14 pin) . . . . 96°C/W
N package (14 pin) . . . . 80°C/W
NS package (14 pin) . . . . 76°C/W
P package (8 pin) . . . . 85°C/W
PS package (8 pin) . . . . 95°C/W
Operating virtual junction temperature, T_J . . . . 150°C
Lead temperature 1,6 mm (1/16inch) from case for 10 seconds . . . . 260°C
Storage temperature range . . . . –65°C 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, are with respect to the midpoint between V_{CC+} and V_{CC-}.
2. Differential voltages are at IN+ with respect to IN–.
3. The magnitude of the input voltage must never exceed the magnitude of the supply voltage or 15 V, whichever is less.
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 impact reliability.
5. The package thermal impedance is calculated in accordance with JESD 51-7.

recommended operating conditions

			C SUFFIX		I SUFFIX		UNIT
			MIN	MAX	MIN	MAX	
$V_{CC\pm}$	Supply voltage		±5	±15	±5	±15	V
V_{IC}	Common-mode input voltage	$V_{CC\pm}$ = ±5 V	–1	4	–1	4	V
		$V_{CC\pm}$ = ±15 V	–11	11	–11	11	
T_A	Operating free-air temperature		0	70	–40	85	°C

TL051C and TL051AC electrical characteristics at specified free-air temperature

PARAMETER		TEST CONDITIONS		T_A†	TL051C, TL051AC						UNIT
					$V_{CC\pm} = \pm5$ V			$V_{CC\pm} = \pm15$ V			
					MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage	$V_O = 0$, $V_{IC} = 0$, $R_S = 50\ \Omega$	TL051C	25°C		0.75	3.5		0.59	1.5	mV
				Full range			4.5			2.5	
			TL051AC	25°C		0.55	2.8		0.35	0.8	
				Full range			3.8			1.8	
$\alpha_{V_{IO}}$	Temperature coefficient of input offset voltage‡		TL051C	25°C to 70°C		8			8		µV/°C
			TL051AC	25°C to 70°C		8			8	25	
	Input offset-voltage long-term drift§			25°C		0.04			0.04		µV/mo
I_{IO}	Input offset current	$V_O = 0$, $V_{IC} = 0$, See Figure 5		25°C		4	100		5	100	pA
				70°C		0.02	1		0.025	1	nA
I_{IB}	Input bias current	$V_O = 0$, $V_{IC} = 0$, See Figure 5		25°C		20	200		30	200	pA
				70°C		0.15	4		0.2	4	nA
V_{ICR}	Common-mode input voltage range			25°C	–1 to 4	–2.3 to 5.6		–11 to 11	–12.3 to 15.6		V
				Full range	–1 to 4			–11 to 11			
V_{OM+}	Maximum positive peak output voltage swing	$R_L = 10\ k\Omega$		25°C	3	4.2		13	13.9		V
				Full range	3			13			
		$R_L = 2\ k\Omega$		25°C	2.5	3.8		11.5	12.7		
				Full range	2.5			11.5			
V_{OM-}	Maximum negative peak output voltage swing	$R_L = 10\ k\Omega$		25°C	–2.5	–3.5		–12	–13.2		V
				Full range	–2.5			–12			
		$R_L = 2\ k\Omega$		25°C	–2.3	–3.2		–11	–12		
				Full range	–2.3			–11			
A_{VD}	Large-signal differential voltage amplification¶	$R_L = 2\ k\Omega$		25°C	25	59		50	105		V/mV
				0°C	30	65		60	129		
				70°C	20	46		30	85		
r_i	Input resistance			25°C		10^{12}			10^{12}		Ω
c_i	Input capacitance			25°C		10			12		pF
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}$min, $V_O = 0$, $R_S = 50\ \Omega$		25°C	65	85		75	93		dB
				0°C	65	84		75	92		
				70°C	65	84		75	91		
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{CC\pm}/\Delta V_{IO}$)	$V_O = 0$, $R_S = 50\ \Omega$		25°C	75	99		75	99		dB
				0°C	75	98		75	98		
				70°C	75	97		75	97		
I_{CC}	Supply current	$V_O = 0$, No load		25°C		2.6	3.2		2.7	3.2	mA
				0°C		2.7	3.2		2.8	3.2	
				70°C		2.6	3.2		2.7	3.2	

† Full range is 0°C to 70°C.
‡ This parameter is tested on a sample basis for the TL051A. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.
§ Typical values are based on the input offset-voltage shift observed through 168 hours of operating life test at $T_A = 150°C$, extrapolated to $T_A = 25°C$ using the Arrhenius equation, and assuming an activation energy of 0.96 eV.
¶ For $V_{CC\pm} = \pm5$ V, $V_O = \pm2.3$ V, or for $V_{CC\pm} = \pm15$ V, $V_O = \pm10$ V.

TL051C and TL051AC operating characteristics at specified free-air temperature

PARAMETER		TEST CONDITIONS	T_A†	TL051C, TL051AC $V_{CC\pm} = \pm5$ V MIN	TYP	MAX	$V_{CC\pm} = \pm15$ V MIN	TYP	MAX	UNIT
SR+	Positive slew rate at unity gain‡	$R_L = 2$ kΩ, $C_L = 100$ pF, See Figure 1	25°C		16		13	20		V/μs
			Full range		16.4		11	22.6		
SR–	Negative slew rate at unity gain‡		25°C		15		13	18		
			Full range		16		11	19.3		
t_r	Rise time	$V_{I(PP)} = \pm10$ mV, $R_L = 2$ kΩ, $C_L = 100$ pF, See Figures 1 and 2	25°C		55			56		ns
			0°C		54			55		
			70°C		63			63		
t_f	Fall time		25°C		55			57		
			0°C		54			56		
			70°C		62			64		
	Overshoot factor		25°C		24			19		%
			0°C		24			19		
			70°C		24			19		
V_n	Equivalent input noise voltage§	$R_S = 20$ Ω, See Figure 3; f = 10 Hz	25°C		75			75		nV/√Hz
		f = 1 kHz	25°C		18			18	30	
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	f = 10 Hz to 10 kHz	25°C		4			4		μV
I_n	Equivalent input noise current	f = 1 kHz	25°C		0.01			0.01		pA/√Hz
THD	Total harmonic distortion¶	$R_S = 1$ kΩ, $R_L = 2$ kΩ, f = 1 kHz	25°C		0.003			0.003		%
B_1	Unity-gain bandwidth	$V_I = 10$ mV, $R_L = 2$ kΩ, $C_L = 25$ pF, See Figure 4	25°C		3			3.1		MHz
			0°C		3.2			3.3		
			70°C		2.7			2.8		
ϕ_m	Phase margin at unity gain	$V_I = 10$ mV, $R_L = 2$ kΩ, $C_L = 25$ pF, See Figure 4	25°C		59			62		deg
			0°C		58			62		
			70°C		59			62		

† Full range is 0°C to 70°C.
‡ For $V_{CC\pm} = \pm5$ V, $V_{I(PP)} = \pm1$ V; for $V_{CC\pm} = \pm15$ V, $V_{I(PP)} = \pm5$ V.
§ This parameter is tested on a sample basis for the TL051A. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.
¶ For $V_{CC\pm} = \pm5$ V, $V_{O(RMS)} = 1$ V; for $V_{CC\pm} = \pm15$ V, $V_{O(RMS)} = 6$ V.

TL051I and TL051AI electrical characteristics at specified free-air temperature

PARAMETER		TEST CONDITIONS		T_A†	TL051I, TL051AI						UNIT
					$V_{CC\pm} = \pm5$ V			$V_{CC\pm} = \pm15$ V			
					MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage	$V_O = 0$, $V_{IC} = 0$, $R_S = 50\ \Omega$	TL051I	25°C		0.75	3.5		0.59	1.5	mV
				Full range			5.3			3.3	
			TL051AI	25°C		0.55	2.8		0.35	0.8	
				Full range			4.6			2.6	
$\alpha_{V_{IO}}$	Temperature coefficient of input offset voltage‡		TL051I	25°C to 85°C		7			8		µV/°C
			TL051AI	25°C to 85°C		8			8	25	
	Input offset-voltage long-term drift§			25°C		0.04			0.04		µV/mo
I_{IO}	Input offset current	$V_O = 0$, $V_{IC} = 0$, See Figure 5		25°C		4	100		5	100	pA
				85°C		0.06	10		0.07	10	nA
I_{IB}	Input bias current	$V_O = 0$, $V_{IC} = 0$, See Figure 5		25°C		20	200		30	200	pA
				85°C		0.6	20		0.7	20	nA
V_{ICR}	Common-mode input voltage range			25°C	–1 to 4	–2.3 to 5.6		–11 to 11	–12.3 to 15.6		V
				Full range	–1 to 4			–11 to 11			
V_{OM+}	Maximum positive peak output voltage swing	$R_L = 10\ k\Omega$		25°C	3	4.2		13	13.9		V
				Full range	3			13			
		$R_L = 2\ k\Omega$		25°C	2.5	3.8		11.5	12.7		
				Full range	2.5			11.5			
V_{OM-}	Maximum negative peak output voltage swing	$R_L = 10\ k\Omega$		25°C	–2.5	–3.5		–12	–13.2		V
				Full range	–2.5			–12			
		$R_L = 2\ k\Omega$		25°C	–2.3	–3.2		–11	–12		
				Full range	–2.3			–11			
A_{VD}	Large-signal differential voltage amplification¶	$R_L = 2\ k\Omega$		25°C	25	59		50	105		V/mV
				–40°C	30	74		60	145		
				85°C	20	43		30	76		
r_i	Input resistance			25°C		10^{12}			10^{12}		Ω
c_i	Input capacitance			25°C		10			12		pF
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}min$, $V_O = 0$, $R_S = 50\ \Omega$		25°C	65	85		75	93		dB
				–40°C	65	83		75	90		
				85°C	65	84		75	93		
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{CC\pm}/\Delta V_{IO}$)	$V_O = 0$, $R_S = 50\ \Omega$		25°C	75	99		75	99		dB
				–40°C	75	98		75	98		
				85°C	75	99		75	99		
I_{CC}	Supply current	$V_O = 0$, No load		25°C		2.6	3.2		2.7	3.2	mA
				–40°C		2.4	3.2		2.6	3.2	
				85°C		2.5	3.2		2.6	3.2	

† Full range is –40°C to 85°C

‡ This parameter is tested on a sample basis for the TL051A. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

§ Typical values are based on the input offset-voltage shift observed through 168 hours of operating life test at $T_A = 150°C$, extrapolated to $T_A = 25°C$ using the Arrhenius equation, and assuming an activation energy of 0.96 eV.

¶ For $V_{CC\pm} = \pm5$ V, $V_O = \pm2.3$ V, or for $V_{CC\pm} = \pm15$ V, $V_O = \pm10$ V.

TL051I and TL051AI operating characteristics at specified free-air temperature

PARAMETER		TEST CONDITIONS	T_A†	TL051I, TL051AI $V_{CC\pm} = \pm5$ V MIN	TYP	MAX	$V_{CC\pm} = \pm15$ V MIN	TYP	MAX	UNIT
SR+	Positive slew rate at unity gain‡	$R_L = 2$ kΩ, $C_L = 100$ pF, See Figure 1	25°C		16		13	20		V/μs
			Full range				11			
SR–	Negative slew rate at unity gain‡		25°C		15		13	18		
			Full range				11			
t_r	Rise time	$V_{I(PP)} = \pm10$ mV, $R_L = 2$ kΩ, $C_L = 100$ pF, See Figures 1 and 2	25°C		55			56		ns
			–40°C		52			53		
			85°C		64			65		
t_f	Fall time		25°C		55			57		
			–40°C		51			53		
			85°C		64			65		
	Overshoot factor		25°C		24			19		%
			–40°C		24			19		
			85°C		24			19		
V_n	Equivalent input noise voltage§	$R_S = 20$ Ω, See Figure 3; f = 10 Hz	25°C		75			75		nV/√Hz
		f = 1 kHz	25°C		18			18	30	
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	f = 10 Hz to 10 kHz	25°C		4			4		μV
I_n	Equivalent input noise current	f = 1 kHz	25°C		0.01			0.01		pA/√Hz
THD	Total harmonic distortion¶	$R_S = 1$ kΩ, $R_L = 2$ kΩ, f = 1 kHz	25°C		0.003			0.003		%
B_1	Unity-gain bandwidth	$V_I = 10$ mV, $R_L = 2$ kΩ, $C_L = 25$ pF, See Figure 4	25°C		3			3.1		MHz
			–40°C		3.5			3.6		
			85°C		2.6			2.7		
ϕ_m	Phase margin at unity gain	$V_I = 10$ mV, $R_L = 2$ kΩ, $C_L = 25$ pF, See Figure 4	25°C		59			62		deg
			–40°C		58			61		
			85°C		59			62		

† Full range is –40°C to 85°C.
‡ For $V_{CC\pm} = \pm5$ V, $V_{I(PP)} = \pm1$ V; for $V_{CC\pm} = \pm15$ V, $V_{I(PP)} = \pm5$ V.
§ This parameter is tested on a sample basis for the TL051A. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.
¶ For $V_{CC\pm} = \pm5$ V, $V_{O(RMS)} = 1$ V; for $V_{CC\pm} = \pm15$ V, $V_{O(RMS)} = 6$ V.

TL052C and TL052AC electrical characteristics at specified free-air temperature

PARAMETER		TEST CONDITIONS		T_A†	TL052C, TL052AC $V_{CC\pm} = \pm5$ V			TL052C, TL052AC $V_{CC\pm} = \pm15$ V			UNIT
					MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage	$V_O = 0$, $V_{IC} = 0$, $R_S = 50\ \Omega$	TL052C	25°C		0.73	3.5		0.65	1.5	mV
				Full range			4.5			2.5	
			TL052AC	25°C		0.51	2.8		0.4	0.8	
				Full range			3.8			1.8	
$\alpha_{V_{IO}}$	Temperature coefficient of input offset voltage‡		TL052C	25°C to 70°C		8			8		µV/°C
			TL052AC	25°C to 70°C		8			6	25	
	Input offset-voltage long-term drift§	$V_O = 0$, $R_S = 50\ \Omega$	$V_{IC} = 0$,	25°C		0.04			0.04		µV/mo
I_{IO}	Input offset current	$V_O = 0$, See Figure 5	$V_{IC} = 0$,	25°C		4	100		5	100	pA
				70°C		0.02	1		0.025	1	nA
I_{IB}	Input bias current	$V_O = 0$, See Figure 5	$V_{IC} = 0$,	25°C		20	200		30	200	pA
				70°C		0.15	4		0.2	4	nA
V_{ICR}	Common-mode input voltage range			25°C	–1 to 4	–2.3 to 5.6		–11 to 11	–12.3 to 15.6		V
				Full range	–1 to 4			–11 to 11			
V_{OM+}	Maximum positive peak output voltage swing	$R_L = 10\ k\Omega$		25°C	3	4.2		13	13.9		V
				Full range	3			13			
		$R_L = 2\ k\Omega$		25°C	2.5	3.8		11.5	12.7		
				Full range	2.5			11.5			
V_{OM-}	Maximum negative peak output voltage swing	$R_L = 10\ k\Omega$		25°C	–2.5	–3.5		–12	–13.2		V
				Full range	–2.5			–12			
		$R_L = 2\ k\Omega$		25°C	–2.3	–3.2		–11	–12		
				Full range	–2.3			–11			
A_{VD}	Large-signal differential voltage amplification¶	$R_L = 2\ k\Omega$		25°C	25	59		50	105		V/mV
				0°C	30	65		60	129		
				70°C	20	46		30	85		
r_i	Input resistance			25°C		10^{12}			10^{12}		Ω
c_i	Input capacitance			25°C		10			12		pF
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}$min, $V_O = 0$,	$R_S = 50\ \Omega$	25°C	65	85		75	93		dB
				0°C	65	84		75	92		
				70°C	65	84		75	91		

† Full range is 0°C to 70°C.

‡ This parameter is tested on a sample basis. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.

§ Typical values are based on the input offset-voltage shift observed through 168 hours of operating life test at $T_A = 150°C$, extrapolated to $T_A = 25°C$ using the Arrhenius equation, and assuming an activation energy of 0.96 eV.

¶ For $V_{CC\pm} = \pm5$ V, $V_O = \pm2.3$ V; at $V_{CC\pm} = \pm15$ V, $V_O = \pm10$ V.

TL052C and TL052AC electrical characteristics at specified free-air temperature (continued)

PARAMETER		TEST CONDITIONS	T_A	TL052C, TL052AC $V_{CC\pm} = \pm5$ V MIN	TYP	MAX	$V_{CC\pm} = \pm15$ V MIN	TYP	MAX	UNIT
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{CC\pm}/\Delta V_{IO}$)	$V_O = 0$, $R_S = 50\ \Omega$	25°C	75	99		75	99		dB
			0°C	75	98		75	98		
			70°C	75	97		75	97		
I_{CC}	Supply current (two amplifiers)	$V_O = 0$, No load	25°C		4.6	5.6		4.8	5.6	mA
			0°C		4.7	6.4		4.8	6.4	
			70°C		4.4	6.4		4.6	6.4	
V_{O1}/V_{O2}	Crosstalk attenuation	$A_{VD} = 100$	25°C		120			120		dB

TL052C and TL052AC operating characteristics at specified free-air temperature

PARAMETER		TEST CONDITIONS	T_A†	TL052C, TL052AC $V_{CC\pm} = \pm5$ V MIN	TYP	MAX	$V_{CC\pm} = \pm15$ V MIN	TYP	MAX	UNIT
SR+	Slew rate at unity gain	$R_L = 2\ k\Omega$, $C_L = 100$ pF, See Figure 1	25°C		17.8		9	20.7		V/µs
			Full range				8			
SR–	Negative slew rate at unity gain‡		25°C		15.4		9	17.8		
			Full range				8			
t_r	Rise time	$V_{I(PP)} = \pm10$ mV, $R_L = 2\ k\Omega$, $C_L = 100$ pF, See Figures 1 and 2	25°C		55			56		ns
			0°C		54			55		
			70°C		63			63		
t_f	Fall time		25°C		55			57		
			0°C		54			56		
			70°C		62			64		
	Overshoot factor		25°C		24			19		%
			0°C		24			19		
			70°C		24			19		
V_n	Equivalent input noise voltage§	$R_S = 20\ \Omega$, See Figure 3; f = 10 Hz	25°C		71			71		$nV/\sqrt{Hz}$
		$R_S = 20\ \Omega$, See Figure 3; f = 1 kHz	25°C		19			19	30	
$V_{N(PP)}$	Peak-to-peak equivalent input noise current	$R_S = 20\ \Omega$, See Figure 3; f = 10 Hz to 10 kHz	25°C		4			4		µV
I_n	Equivalent input noise current	f = 1 kHz	25°C		0.01			0.01		$pA/\sqrt{Hz}$
THD	Total harmonic distortion¶	$R_S = 1\ k\Omega$, $R_L = 2\ k\Omega$, f = 1 kHz	25°C		0.003			0.003		%
B_1	Unity-gain bandwidth	$V_I = 10$ mV, $R_L = 2\ k\Omega$, $C_L = 25$ pF, See Figure 4	25°C		3			3		MHz
			0°C		3.2			3.2		
			70°C		2.6			2.7		
ϕ_m	Phase margin at unity gain	$V_I = 10$ mV, $R_L = 2\ k\Omega$, $C_L = 25$ pF, See Figure 4	25°C		60			63		deg
			0°C		59			63		
			70°C		60			63		

† Full range is 0°C to 70°C.
‡ For $V_{CC\pm} = \pm5$ V, $V_{I(PP)} = \pm1$ V; for $V_{CC\pm} = \pm15$ V, $V_{I(PP)} = \pm5$ V.
§ This parameter is tested on a sample basis. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.
¶ For $V_{CC\pm} = \pm5$ V, $V_{O(RMS)} = 1$ V; for $V_{CC\pm} = \pm15$ V, $V_{O(RMS)} = 6$ V.

TL052I and TL052AI electrical characteristics at specified free-air temperature

PARAMETER		TEST CONDITIONS		T_A†	TL052I, TL052AI						UNIT
					$V_{CC\pm}$ = ±5 V			$V_{CC\pm}$ = ±15 V			
					MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage	V_O = 0, V_{IC} = 0, R_S = 50 Ω	TL052I	25°C		0.73	3.5		0.65	1.5	mV
				Full range			5.3			3.3	
			TL052AI	25°C		0.51	2.8		0.4	0.8	
				Full range			4.6			2.6	
$\alpha_{V_{IO}}$	Temperature coefficient‡		TL052I	25°C to 85°C		7			6		μV/°C
			TL052AI	25°C to 85°C		6			6	25	
	Input offset-voltage long-term drift§	V_O = 0, R_S = 50 Ω	V_{IC} = 0,	25°C		0.04			0.04		μV/mo
I_{IO}	Input offset current	V_O = 0, See Figure 5	V_{IC} = 0,	25°C		4	100		5	100	pA
				85°C		0.06	10		0.07	10	nA
I_{IB}	Input bias current	V_O = 0, See Figure 5	V_{IC} = 0,	25°C		20	200		30	200	pA
				85°C		0.6	20		0.7	20	nA
V_{ICR}	Common-mode input voltage range			25°C	–1 to 4	–2.3 to 5.6		–11 to 11	–12.3 to 15.6		V
				Full range	–1 to 4			–11 to 11			
V_{OM+}	Maximum positive peak output voltage swing	R_L = 10 kΩ		25°C	3	4.2		13	13.9		V
				Full range	3			13			
		R_L = 2 kΩ		25°C	2.5	3.8		11.5	12.7		
				Full range	2.5			11.5			
V_{OM-}	Maximum negative peak output voltage swing	R_L = 10 kΩ		25°C	–2.5	–3.5		–12	–13.2		V
				Full range	–2.5			–12			
		R_L = 2 kΩ		25°C	–2.3	–3.2		–11	–12		
				Full range	–2.3			–11			
A_{VD}	Large-signal differential voltage amplification¶	R_L = 2 kΩ		25°C	25	59		50	105		V/mV
				–40°C	30	74		60	145		
				85°C	20	43		30	76		
r_i	Input resistance			25°C		10^{12}			10^{12}		Ω
c_i	Input capacitance			25°C		10			12		pF
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}$min, V_O = 0,	R_S = 50 Ω	25°C	65	85		75	93		dB
				–40°C	65	83		75	90		
				85°C	65	84		75	93		

† Full range is –40°C to 85°C.
‡ This parameter is tested on a sample basis. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters
§ Typical values are based on the input offset-voltage shift observed through 168 hours of operating life test at T_A = 150°C, extrapolated to T_A = 25°C using the Arrhenius equation, and assuming an activation energy of 0.96 eV.
¶ At $V_{CC\pm}$ = ±5 V, V_O = ±2.3 V; at $V_{CC\pm}$ = ±15 V, V_O = ±10 V.

TL052I and TL052AI electrical characteristics at specified free-air temperature (continued)

PARAMETER		TEST CONDITIONS		T_A	TL052I, TL052AI						UNIT
					$V_{CC\pm} = \pm5$ V			$V_{CC\pm} = \pm15$ V			
					MIN	TYP	MAX	MIN	TYP	MAX	
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{CC\pm}/\Delta V_{IO}$)	$V_O = 0$,	$R_S = 50\ \Omega$	25°C	75	99		75	99		dB
				–40°C	75	98		75	98		
				85°C	75	99		75	99		
I_{CC}	Supply current (two amplifiers)	$V_O = 0$,	No load	25°C		4.6	5.6		4.8	5.6	mA
				–40°C		4.5	6.4		4.7	6.4	
				85°C		4.4	6.4		4.6	6.4	
V_{O1}/V_{O2}	Crosstalk attenuation	$A_{VD} = 100$		25°C		120			120		dB

TL052I and TL052AI operating characteristics at specified free-air temperature

PARAMETER		TEST CONDITIONS		T_A†	TL052I, TL052AI						UNIT
					$V_{CC\pm} = \pm5$ V			$V_{CC\pm} = \pm15$ V			
					MIN	TYP	MAX	MIN	TYP	MAX	
SR+	Slew rate at unity gain‡	$R_L = 2\ k\Omega$, See Figure 1	$C_L = 100$ pF,	25°C		17.8		9	20.7		V/µs
				Full range				8			
SR–	Negative slew rate at unity gain‡			25°C		15.4		9	17.8		
				Full range				8			
t_r	Rise time	$V_{I(PP)} = \pm10$ mV, $R_L = 2\ k\Omega$, See Figures 1 and 2	$C_L = 100$ pF,	25°C		55			56		ns
				–40°C		52			53		
				85°C		64			65		
t_f	Fall time			25°C		55			57		
				–40°C		51			53		
				85°C		64			65		
	Overshoot factor			25°C		24%			19%		%
				–40°C		24%			19%		
				85°C		24%			19		
V_n	Equivalent input noise voltage§	$R_S = 20\ \Omega$, See Figure 3	f = 10 Hz	25°C		71			71		nV/√Hz
			f = 1 kHz	25°C		19			19	30	
$V_{N(PP)}$	Peak-to-peak equivalent input noise current		f = 10 Hz to 10 kHz	25°C		4			4		µV
I_n	Equivalent input noise current	f = 1 kHz		25°C		0.01			0.01		pA/√Hz
THD	Total harmonic distortion¶	$R_S = 1\ k\Omega$, f = 1 kHz	$R_L = 2\ k\Omega$,	25°C		0.003			0.003		%
B_1	Unity-gain bandwidth	$V_I = 10$ mV, $C_L = 25$ pF,	$R_L = 2\ k\Omega$, See Figure 4	25°C		3			3		MHz
				–40°C		3.5			3.6		
				85°C		2.5			2.6		
ϕ_m	Phase margin at unity gain	$V_I = 10$ mV, $C_L = 25$ pF,	$R_L = 2\ k\Omega$, See Figure 4	25°C		60			63		deg
				–40°C		58			61		
				85°C		60			63		

† Full range is –40°C to 85°C.
‡ For $V_{CC\pm} = \pm5$ V, $V_{I(PP)} = \pm1$ V; for $V_{CC\pm} = \pm15$ V, $V_{I(PP)} = \pm5$ V.
§ This parameter is tested on a sample basis. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.
¶ For $V_{CC\pm} = \pm5$ V, $V_{O(RMS)} = 1$ V; for $V_{CC\pm} = \pm15$ V, $V_{O(RMS)} = 6$ V.

TL054C and TL054AC electrical characteristics at specified free-air temperature

PARAMETER		TEST CONDITIONS		T_A†	TL054C, TL054AC $V_{CC\pm} = \pm5$ V MIN	$V_{CC\pm} = \pm5$ V TYP	$V_{CC\pm} = \pm5$ V MAX	$V_{CC\pm} = \pm15$ V MIN	$V_{CC\pm} = \pm15$ V TYP	$V_{CC\pm} = \pm15$ V MAX	UNIT
V_{IO}	Input offset voltage	$V_O = 0$, $V_{IC} = 0$, $R_S = 50\ \Omega$	TL054C	25°C		0.64	5.5		0.56	4	mV
				Full range			7.7			6.2	
			TL054AC	25°C		0.57	3.5		0.5	1.5	
				Full range			5.7			3.7	
$\alpha_{V_{IO}}$	Temperature coefficient of input offset voltage		TL054C	25°C to 70°C		25			23		µV/°C
			TL054AC	25°C to 70°C		24			23		
	Input offset-voltage long-term drift‡			25°C		0.04			0.04		µV/mo
I_{IO}	Input offset current	$V_O = 0$, $V_{IC} = 0$, See Figure 5		25°C		4	100		5	100	pA
				70°C		0.02	1		0.025	1	nA
I_{IB}	Input bias current	$V_O = 0$, $V_{IC} = 0$, See Figure 5		25°C		20	200		30	200	pA
				70°C		0.15	4		0.2	4	nA
V_{ICR}	Common-mode input voltage range			25°C	–1 to 4	–2.3 to 5.6		–11 to 11	–12.3 to 15.6		V
				Full range	–1 to 4			–11 to 11			
V_{OM+}	Maximum positive peak output voltage swing	$R_L = 10\ k\Omega$		25°C	3	4.2		13	13.9		V
				Full range	3			13			
		$R_L = 2\ k\Omega$		25°C	2.5	3.8		11.5	12.7		
				Full range	2.5			11.5			
V_{OM-}	Maximum negative peak output voltage swing	$R_L = 10\ k\Omega$		25°C	–2.5	–3.5		–12	–13.2		V
				Full range	–2.5			–12			
		$R_L = 2\ k\Omega$		25°C	–2.3	–3.2		–11	–12		
				Full range	–2.3			–11			
A_{VD}	Large-signal differential voltage amplification§	$R_L = 2\ k\Omega$		25°C	25	72		50	133		V/mV
				0°C	30	88		60	173		
				70°C	20	57		30	85		
r_i	Input resistance			25°C		10^{12}			10^{12}		Ω
c_i	Input capacitance			25°C		10			12		pF
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}$min, $V_O = 0$, $R_S = 50\ \Omega$		25°C	65	84		75	92		dB
				0°C	65	84		75	92		
				70°C	65	84		75	93		
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{CC\pm}/\Delta V_{IO}$)	$V_{CC\pm} = \pm5$ V to ±15 V, $V_O = 0$, $R_S = 50\ \Omega$		25°C	75	99		75	99		dB
				0°C	75	99		75	99		
				70°C	75	99		75	99		
I_{CC}	Supply current (four amplifiers)	$V_O = 0$, No load		25°C		8.1	11.2		8.4	11.2	mA
				0°C		8.2	12.8		8.5	12.8	
				70°C		7.9	11.2		8.2	11.2	
V_{O1}/V_{O2}	Crosstalk attenuation	$A_{VD} = 100$		25°C		120			120		dB

† Full range is 0°C to 70°C.
‡ Typical values are based on the input offset-voltage shift observed through 168 hours of operating life test at $T_A = 150°C$, extrapolated to $T_A = 25°C$ using the Arrhenius equation, and assuming an activation energy of 0.96 eV.
§ For $V_{CC\pm} = \pm5$ V, $V_O = \pm2.3$ V, at $V_{CC\pm} = \pm15$ V, $V_O = \pm10$ V.B

TL054C and TL054AC operating characteristics at specified free-air temperature

PARAMETER		TEST CONDITIONS		T_A†	TL054C, TL054C $V_{CC\pm} = \pm5$ V MIN	TYP	MAX	$V_{CC\pm} = \pm15$ V MIN	TYP	MAX	UNIT
SR+	Positive slew rate at unity gain	$R_L = 2$ kΩ, $C_L = 100$ pF, See Figure 1 and Note 7		25°C		15.4		10	17.8		V/μs
				0°C		15.7		8	17.9		
				70°C		14.4		8	17.5		
SR–	Negative slew rate at unity gain‡			25°C		13.9		10	15.9		
				0°C		14.3		8	16.1		
				70°C		13.3		8	15.5		
t_r	Rise time	$V_{I(PP)} = \pm10$ mV, $R_L = 2$ kΩ, $C_L = 100$ pF, See Figures 1 and 2		25°C		55			56		ns
				0°C		54			55		
				70°C		63			63		
t_f	Fall time			25°C		55			57		
				0°C		54			56		
				70°C		62			64		
	Overshoot factor			25°C		24%			19%		%
				0°C		24%			19%		
				70°C		24%			19		
V_n	Equivalent input noise voltage§	$R_S = 20$ Ω, See Figure 3	f = 10 Hz	25°C		75			75		nV/√Hz
			f = 1 kHz	25°C		21			21	45	
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage		f = 10 Hz to 10 kHz	25°C		4			4		μV
I_n	Equivalent input noise current	f = 1 kHz		25°C		0.01			0.01		pA/√Hz
THD	Total harmonic distortion¶	$R_S = 1$ kΩ, $R_L = 2$ kΩ, f = 1 kHz		25°C		0.003			0.003		%
B_1	Unity-gain bandwidth	$V_I = 10$ mV, $R_L = 2$ kΩ, $C_L = 25$ pF, See Figure 4		25°C		2.7			2.7		MHz
				0°C		3			3		
				70°C		2.4			2.4		
ϕ_m	Phase margin at unity gain	$V_I = 10$ mV, $R_L = 2$ kΩ, $C_L = 25$ pF, See Figure 4		25°C		61			64		deg
				0°C		60			64		
				70°C		61			63		

† Full range is 0°C to 70°C.
‡ For $V_{CC\pm} = \pm5$ V, $V_{I(PP)} = \pm1$ V; for $V_{CC\pm} = \pm15$ V, $V_{I(PP)} = \pm5$ V.
§ This parameter is tested on a sample basis. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.
¶ For $V_{CC\pm} = \pm5$ V, $V_{O(RMS)} = 1$ V; for $V_{CC\pm} = \pm15$ V, $V_{O(RMS)} = 6$ V.

TL054I and TL054AI electrical characteristics at specified free-air temperature

PARAMETER		TEST CONDITIONS		T_A†	TL054I, TL054AI						UNIT
					$V_{CC\pm}$ = ±5 V			$V_{CC\pm}$ = ±15 V			
					MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage	V_O = 0, V_{IC} = 0, R_S = 50 Ω	TL054I	25°C		0.64	5.5		0.56	4	mV
				Full range			8.8			7.3	
			TL054AI	25°C		0.57	3.5		0.5	1.5	
				Full range			6.8			4.8	
$\alpha_{V_{IO}}$	Temperature coefficient of input offset voltage		TL054I	25°C to 85°C		25			24		µV/°C
			TL054AI	25°C to 85°C		25			23		
	Input offset voltage long-term drift‡			25°C		0.04			0.04		µV/mo
I_{IO}	Input offset current	V_O = 0, V_{IC} = 0, See Figure 5		25°C		4	100		5	100	pA
				85°C		0.06	10		0.07	10	nA
I_{IB}	Input bias current	V_O = 0, V_{IC} = 0, See Figure 5		25°C		20	200		30	200	pA
				85°C		0.6	20		0.7	20	nA
V_{ICR}	Common-mode input voltage range			25°C	–1 to 4	–2.3 to 5.6		–11 to 11	–12.3 to 15.6		V
				Full range	–1 to 4			–11 to 11			
V_{OM+}	Maximum positive peak output voltage swing	R_L = 10 kΩ		25°C	3	4.2		13	13.9		V
				Full range	3			13			
		R_L = 2 kΩ		25°C	2.5	3.8		11.5	12.7		
				Full range	2.5			11.5			
V_{OM-}	Maximum negative peak output voltage swing	R_L = 10 kΩ		25°C	–2.5	–3.5		–12	–13.2		V
				Full range	–2.5			–12			
		R_L = 2 kΩ		25°C	–2.3	–3.2		–11	–12		
				Full range	–2.3			–11			
A_{VD}	Large-signal differential voltage amplification§	R_L = 2 kΩ		25°C	25	72		50	133		V/mV
				–40°C	30	101		60	212		
				85°C	20	50		30	70		
r_i	Input resistance			25°C		10^{12}			10^{12}		Ω
c_i	Input capacitance			25°C		10			12		pF
CMRR	Common-mode rejection ratio	V_{IC} = V_{ICR}min, V_O = 0, R_S = 50 Ω		25°C	65	84		75	92		dB
				–40°C	65	83		75	92		
				85°C	65	84		75	93		
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{CC\pm}/\Delta V_{IO}$)	$V_{CC\pm}$ = ±5 V to ±15 V, V_O = 0, R_S = 50 Ω		25°C	75	99		75	99		dB
				–40°C	75	98		75	99		
				85°C	75	99		75	99		
I_{CC}	Supply current (four amplifiers)	V_O = 0, No load		25°C		8.1	11.2		8.4	11.2	mA
				–40°C		7.9	12.8		8.2	12.8	
				85°C		7.6	11.2		7.9	11.2	
V_{O1}/V_{O2}	Crosstalk attenuation	A_{VD} = 100		25°C		120			120		dB

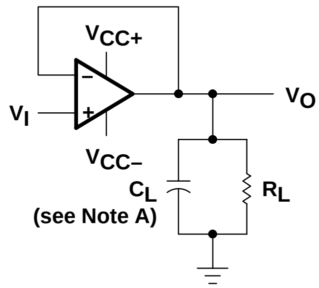
† Full range is –40°C to 85°C.
‡ Typical values are based on the input offset voltage shift observed through 168 hours of operating life test at T_A = 150°C, extrapolated to T_A = 25°C using the Arrhenius equation, and assuming an activation energy of 0.96 eV.
§ For $V_{CC\pm}$ = ±5 V, V_O = ±2.3 V, at $V_{CC\pm}$ = ±15 V, V_O = ±10 V.

TL054I and TL054AI operating characteristics at specified free-air temperature

PARAMETER		TEST CONDITIONS	T_A†	TL054I, TL054AI						UNIT
				$V_{CC\pm} = \pm5$ V			$V_{CC\pm} = \pm15$ V			
				MIN	TYP	MAX	MIN	TYP	MAX	
SR+	Positive slew rate at unity gain	$R_L = 2\ k\Omega$, $C_L = 100$ pF, See Figure 1	25°C		15.4		10	17.8		V/μs
			–40°C		16.4		8	18		
			85°C		14		8	17.3		
SR–	Negative slew rate at unity gain‡		25°C		13.9		10	15.9		
			–40°C		14.7		8	16.1		
			85°C		13		8	15.3		
t_r	Rise time	$V_{I(PP)} = \pm10$ mV, $R_L = 2\ k\Omega$, $C_L = 100$ pF, See Figures 1 and 2	25°C		55			56		ns
			–40°C		52			53		
			85°C		64			65		
t_f	Fall time		25°C		55			57		
			–40°C		51			53		
			85°C		64			65		
	Overshoot factor		25°C		24			19		%
			–40°C		24			19		
			85°C		24			19		
V_n	Equivalent input noise voltage§	$R_S = 20\ \Omega$, See Figure 3; f = 10 Hz	25°C		75			75		$nV/\sqrt{Hz}$
		$R_S = 20\ \Omega$, See Figure 3; f = 1 kHz	25°C		21			21	45	
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	$R_S = 20\ \Omega$, See Figure 3; f = 10 Hz to 10 kHz	25°C		4			4		μV
I_n	Equivalent input noise current	f = 1 kHz	25°C		0.01			0.01		$pA/\sqrt{Hz}$
THD	Total harmonic distortion¶	$R_S = 1\ k\Omega$, $R_L = 2\ k\Omega$, f = 1 kHz	25°C		0.003%			0.003%		%
B_1	Unity-gain bandwidth	$V_I = 10$ mV, $R_L = 2\ k\Omega$, $C_L = 25$ pF, See Figure 4	25°C		2.7			2.7		MHz
			–40°C		3.3			3.3		
			85°C		2.3			2.4		
ϕ_m	Phase margin at unity gain	$V_I = 10$ mV, $R_L = 2\ k\Omega$, $C_L = 25$ pF, See Figure 4	25°C		61			64		deg
			–40°C		59			62		
			85°C		61			64		

† Full range is –40°C to 85°C.
‡ For $V_{CC\pm} = \pm5$ V, $V_{I(PP)} = \pm1$ V; for $V_{CC\pm} = \pm15$ V, $V_{I(PP)} = \pm5$ V.
§ This parameter is tested on a sample basis. For other test requirements, please contact the factory. This statement has no bearing on testing or nontesting of other parameters.
¶ For $V_{CC\pm} = \pm5$ V, $V_{O(RMS)} = 1$ V; for $V_{CC\pm} = \pm15$ V, $V_{O(RMS)} = 6$ V.

PARAMETER MEASUREMENT INFORMATION



NOTE A: C_L includes fixture capacitance.

Figure 1. Slew Rate, Rise/Fall Time, and Overshoot Test Circuit

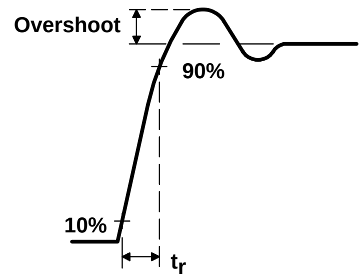


Figure 2. Rise-Time and Overshoot Waveform

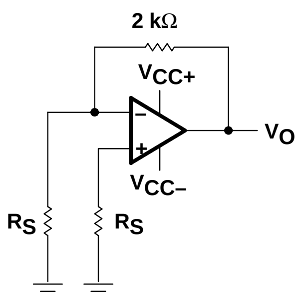
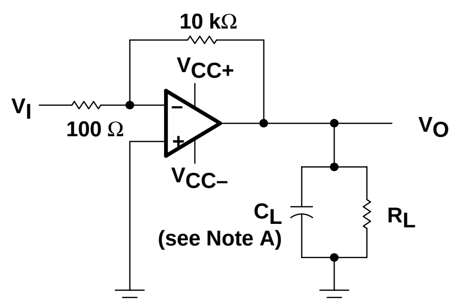


Figure 3. Noise-Voltage Test Circuit



NOTE A: C_L includes fixture capacitance.

Figure 4. Unity-Gain Bandwidth and Phase-Margin Test Circuit

typical values

Typical values, as presented in this data sheet represent the median (50% point) of device parametric performance.

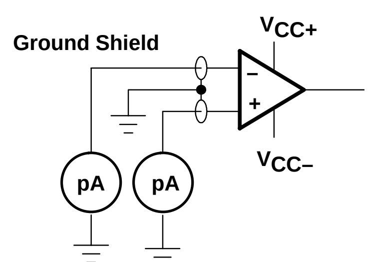


Figure 5. Input-Bias and Offset-Current Test Circuit

input bias and offset current

At the picoamp-bias-current level typical of the TL05x and TL05xA, accurate measurement of the bias current becomes difficult. Not only does this measurement require a picoammeter, but test-socket leakages easily can exceed the actual device bias currents. To accurately measure these small currents, Texas Instruments uses a two-step process. The socket leakage is measured using picoammeters with bias voltages applied, but with no device in the socket. The device then is inserted in the socket, and a second test that measures both the socket leakage and the device input bias current is performed. The two measurements then are subtracted algebraically to determine the bias current of the device.

noise

Because of the increasing emphasis on low noise levels in many of today's applications, the input noise voltage density is sample tested at f = 1 kHz. Texas Instruments also has additional noise-testing capability to meet specific application requirements. Please contact the factory for details.

TYPICAL CHARACTERISTICS

Table of Graphs

			FIGURE
V_{IO}	Input offset voltage	Distribution	6–11
$\alpha_{V_{IO}}$	Temperature coefficient of input offset voltage	Distribution	12, 13, 14
I_{IB}	Input bias current	vs Common-mode input voltage vs Free-air temperature	15 16
I_{IO}	Input offset current	vs Free-air temperature	16
V_{IC}	Common-mode input voltage range limits	vs Supply voltage vs Free-air temperature	17 18
V_O	Output voltage	vs Differential input voltage	19, 20
V_{OM}	Maximum peak output voltage	vs Supply voltage vs Output current vs Free-air temperature	21 25, 26 27, 28
$V_{O(PP)}$	Maximum peak-to-peak output voltage	vs Frequency	22, 23, 24
A_{VD}	Large-signal differential voltage amplification	vs Load resistance vs Frequency vs Free-air temperature	29 30 31, 32, 33
CMRR	Common-mode rejection ratio	vs Frequency vs Free-air temperature	34, 35 36
z_o	Output impedance	vs Frequency	37
k_{SVR}	Supply-voltage rejection ratio	vs Free-air temperature	38
I_{OS}	Short-circuit output current	vs Supply voltage vs Time vs Free-air temperature	39 40 41
I_{CC}	Supply current	vs Supply voltage vs Free-air temperature	42, 43, 44 45, 46, 47
SR	Slew rate	vs Load resistance vs Free-air temperature	48–53 54–59
	Overshoot factor	vs Load capacitance	60
V_n	Equivalent input noise voltage	vs Frequency	61, 62
THD	Total harmonic distortion	vs Frequency	63
B_1	Unity-gain bandwidth	vs Supply voltage vs Free-air temperature	64, 65, 66 67, 68, 69
ϕ_m	Phase margin	vs Supply voltage vs Load capacitance vs Free-air temperature	70, 71, 72 73, 74, 75 76, 77, 78
	Phase shift	vs Frequency	30
	Voltage-follower small-signal pulse response	vs Time	79
	Voltage-follower large-signal pulse response	vs Time	80

TYPICAL CHARACTERISTICS

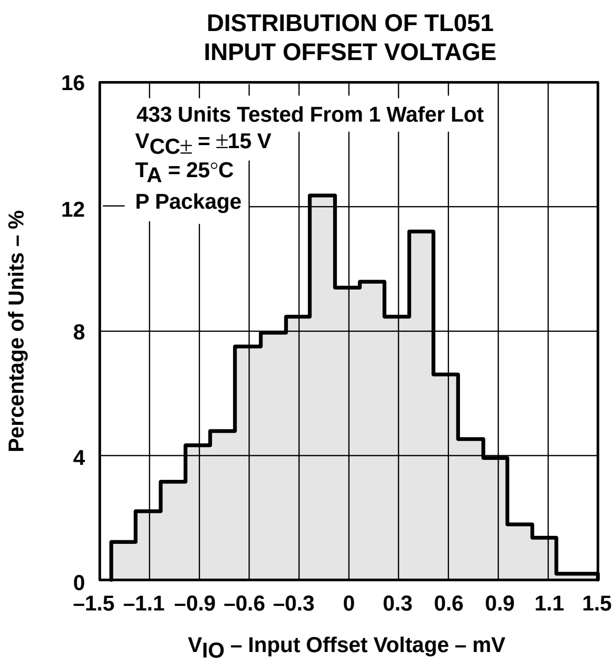


Figure 6

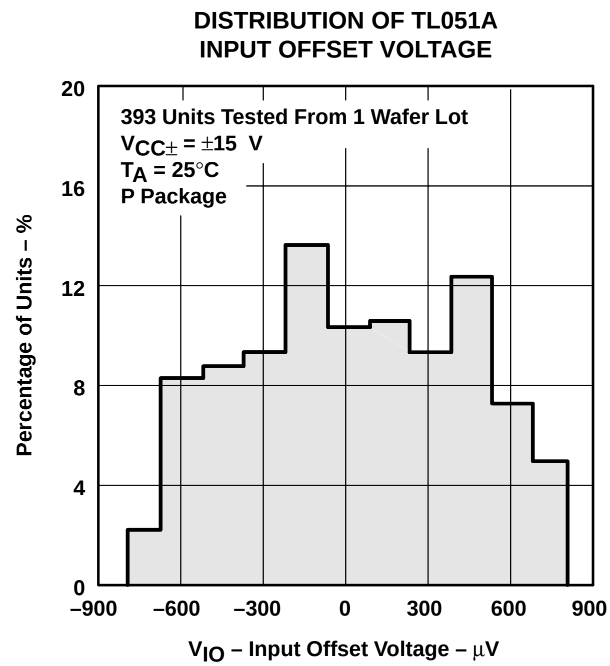


Figure 7

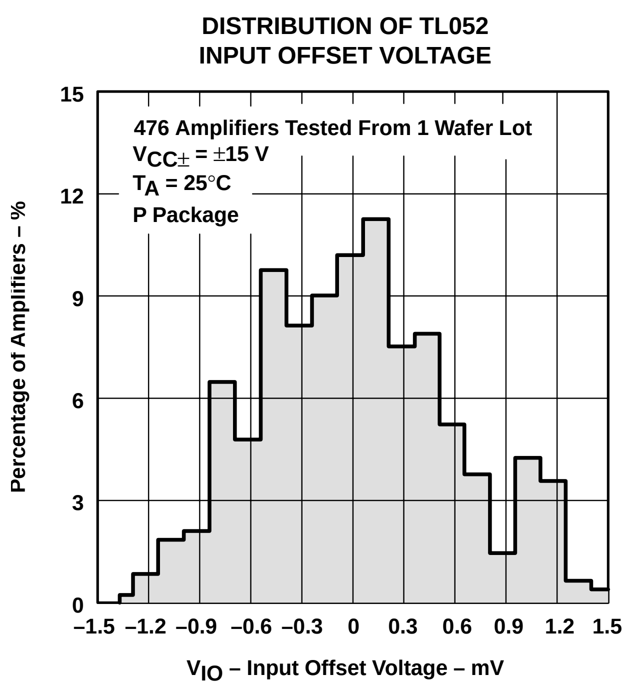


Figure 8

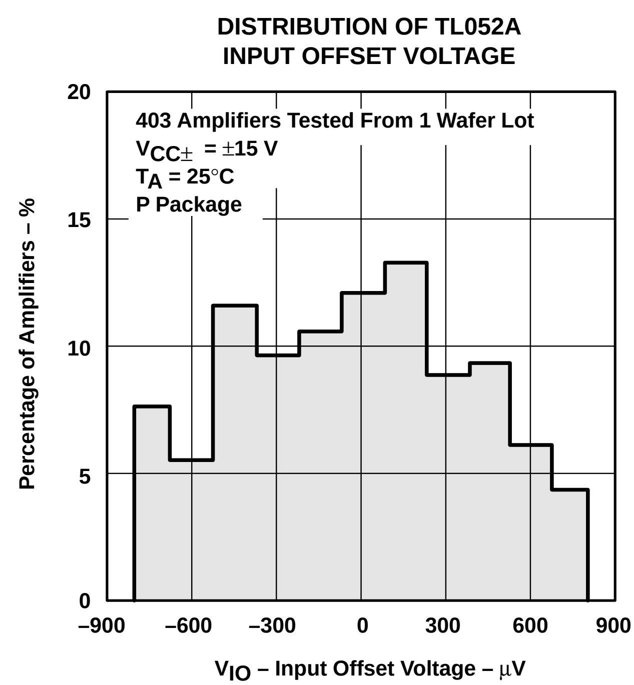


Figure 9

TYPICAL CHARACTERISTICS

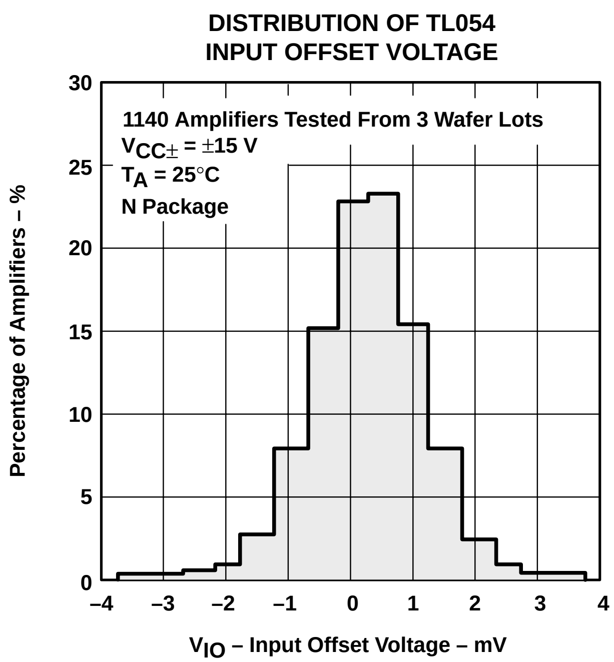


Figure 10

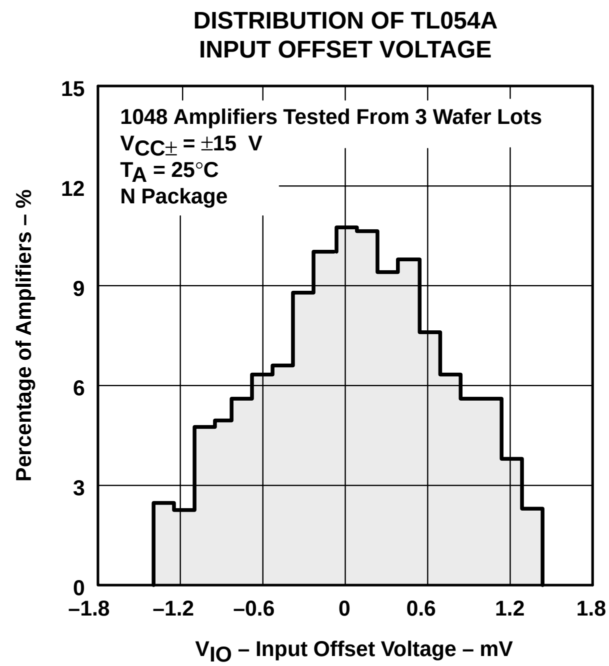


Figure 11

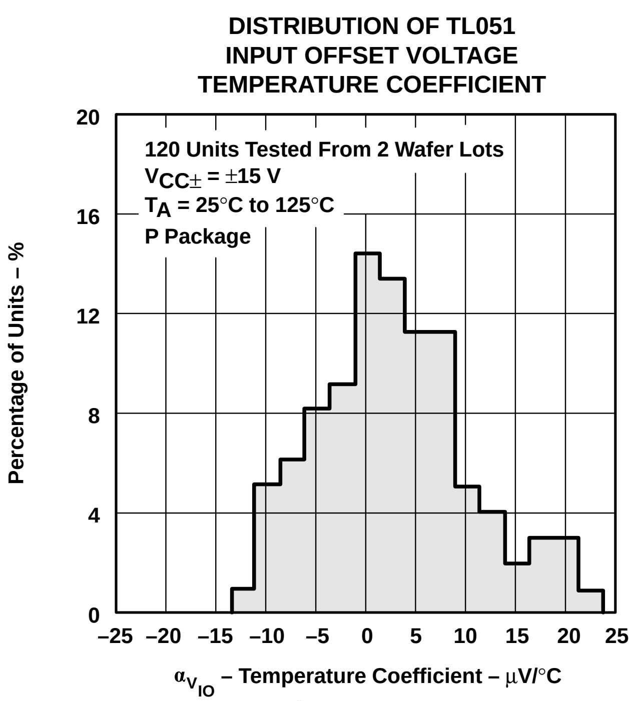


Figure 12

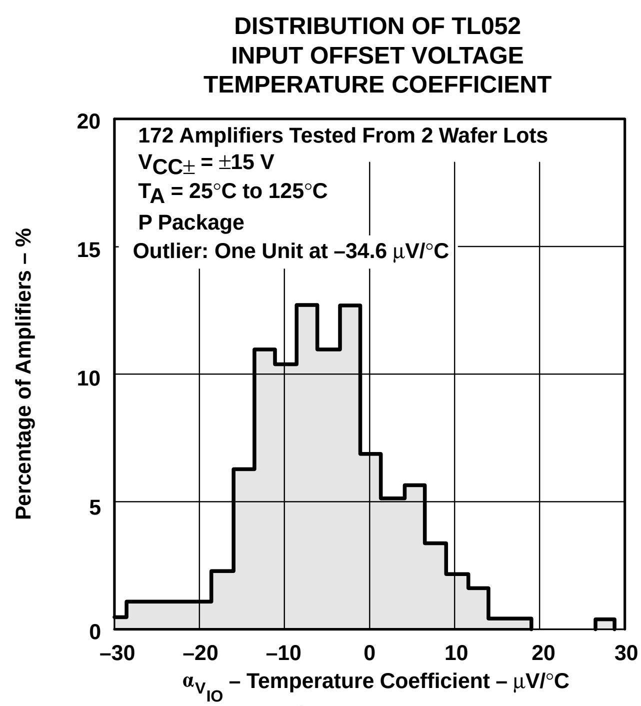


Figure 13

TYPICAL CHARACTERISTICS

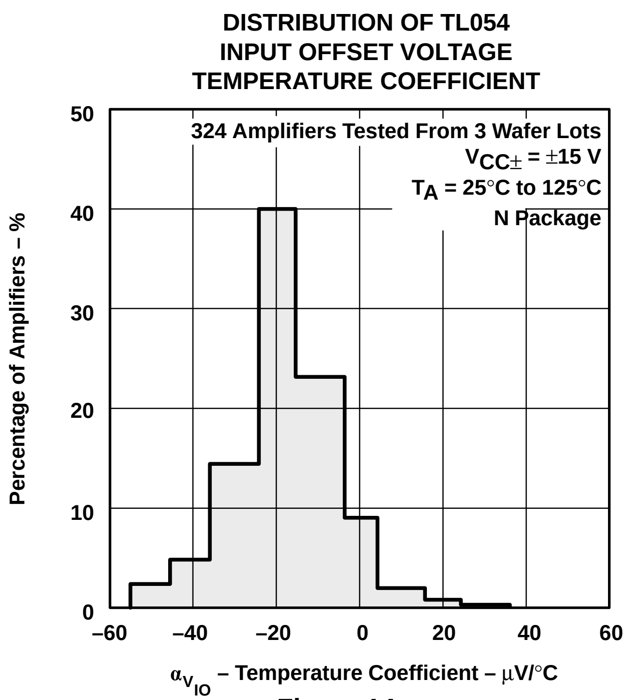


Figure 14

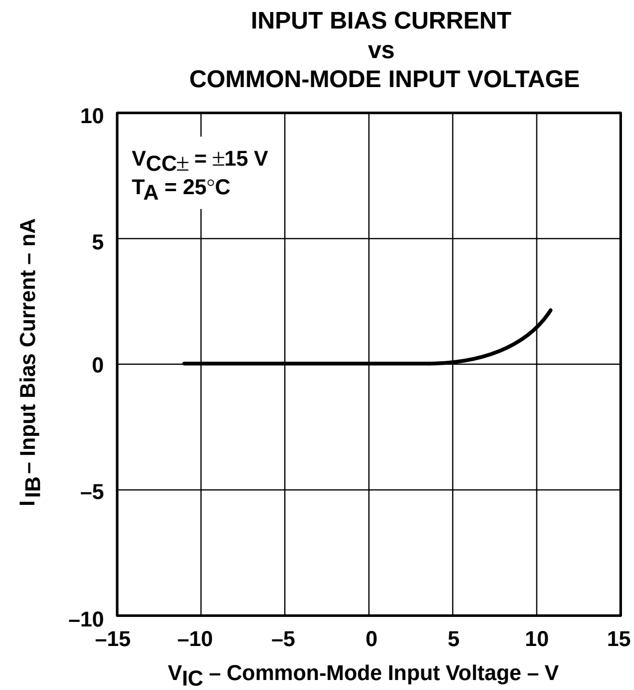


Figure 15

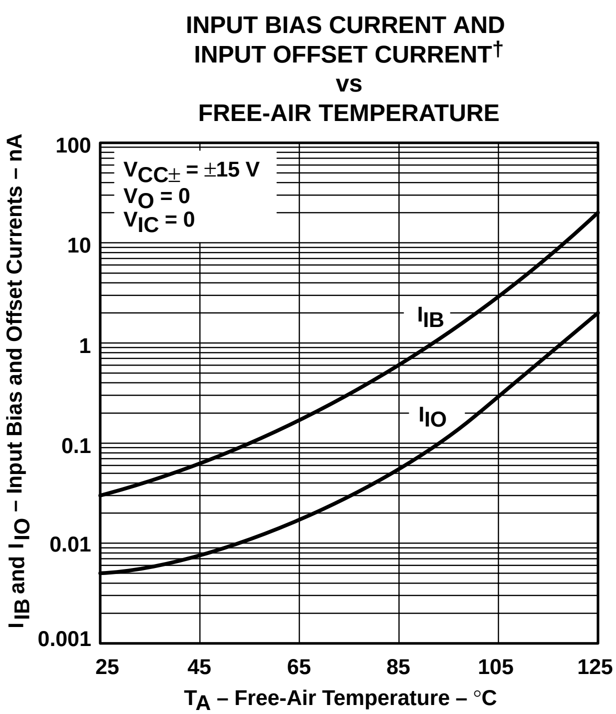


Figure 16

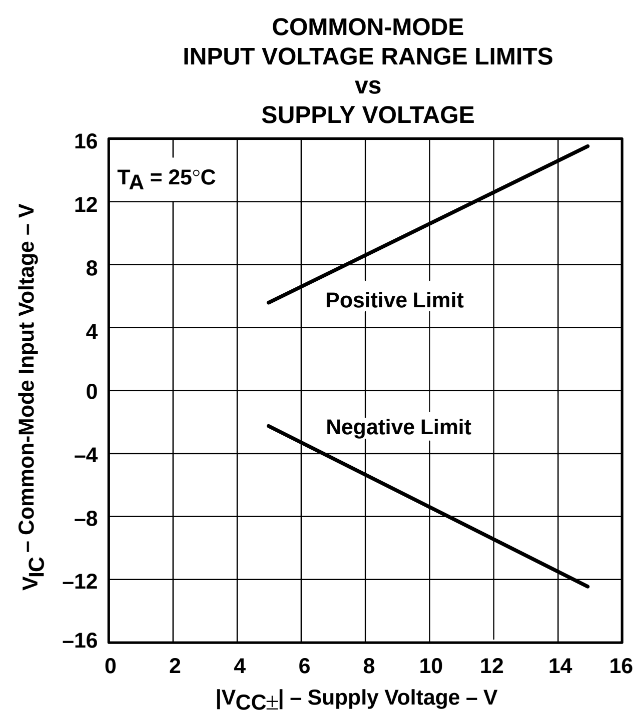


Figure 17

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS

COMMON-MODE INPUT VOLTAGE RANGE LIMITS† vs FREE-AIR TEMPERATURE

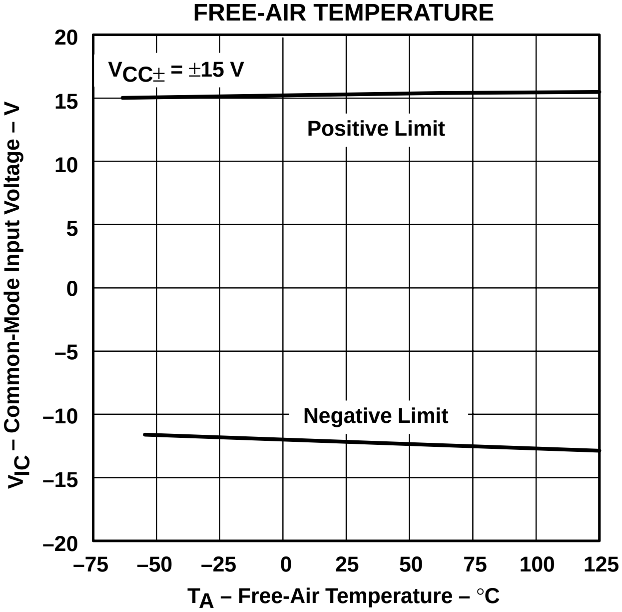


Figure 18

OUTPUT VOLTAGE vs DIFFERENTIAL INPUT VOLTAGE

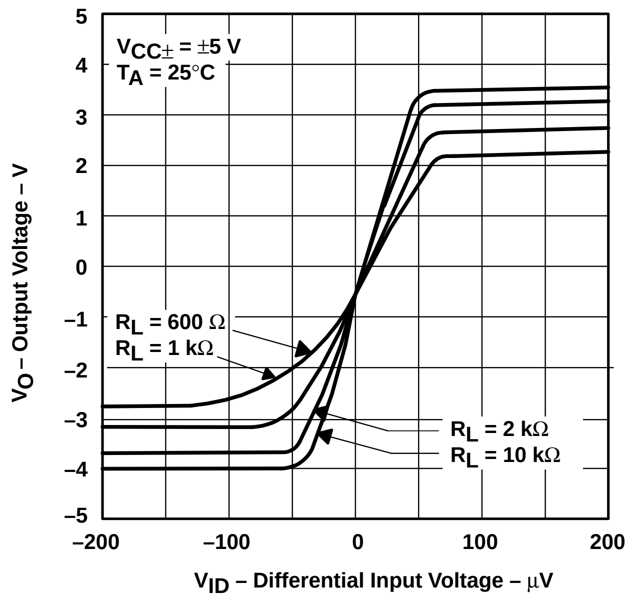


Figure 19

OUTPUT VOLTAGE vs DIFFERENTIAL INPUT VOLTAGE

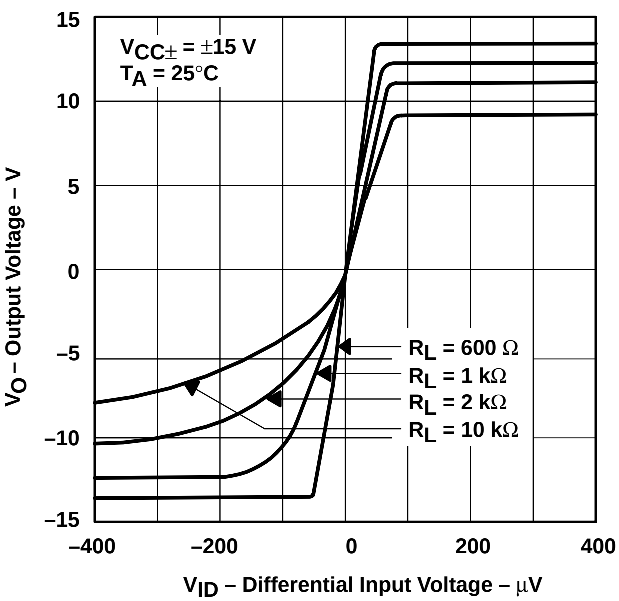


Figure 20

MAXIMUM PEAK OUTPUT VOLTAGE vs SUPPLY VOLTAGE

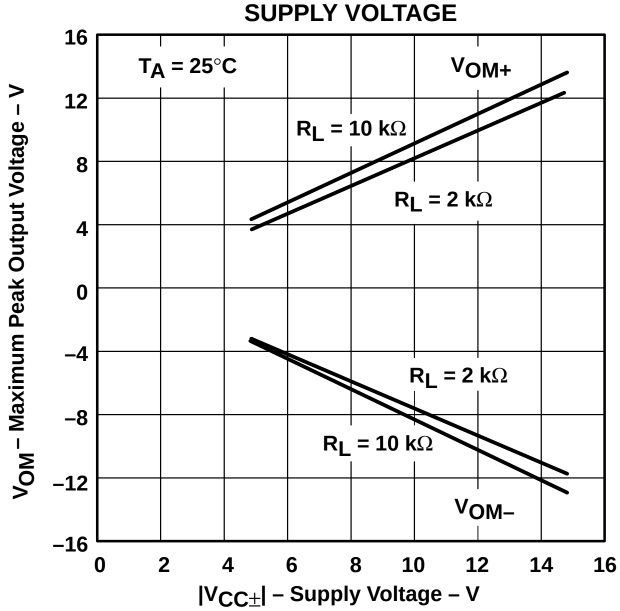


Figure 21

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS

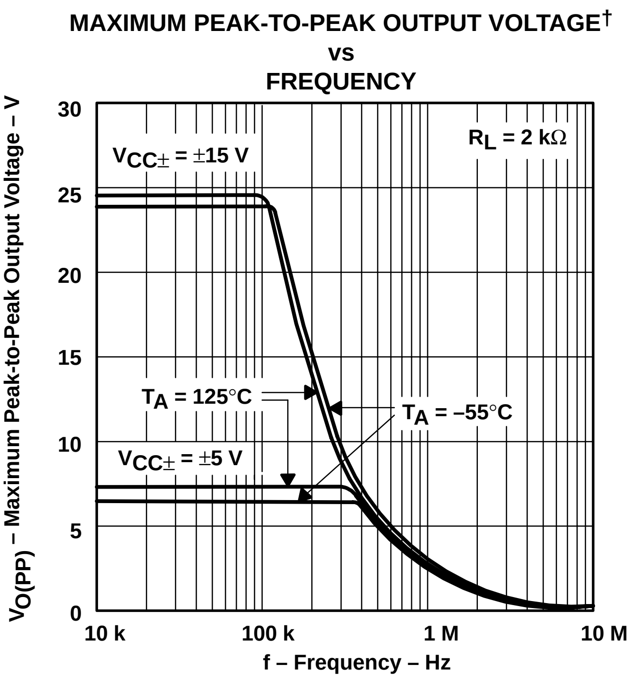


Figure 22

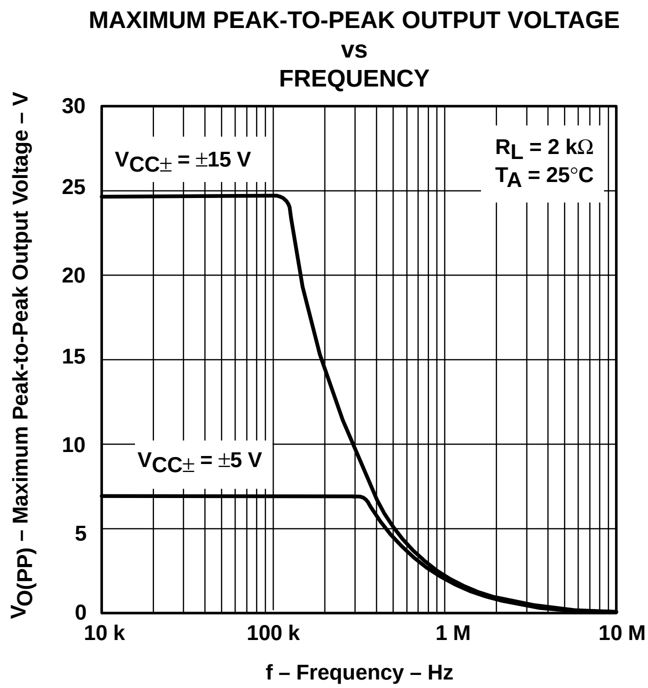


Figure 23

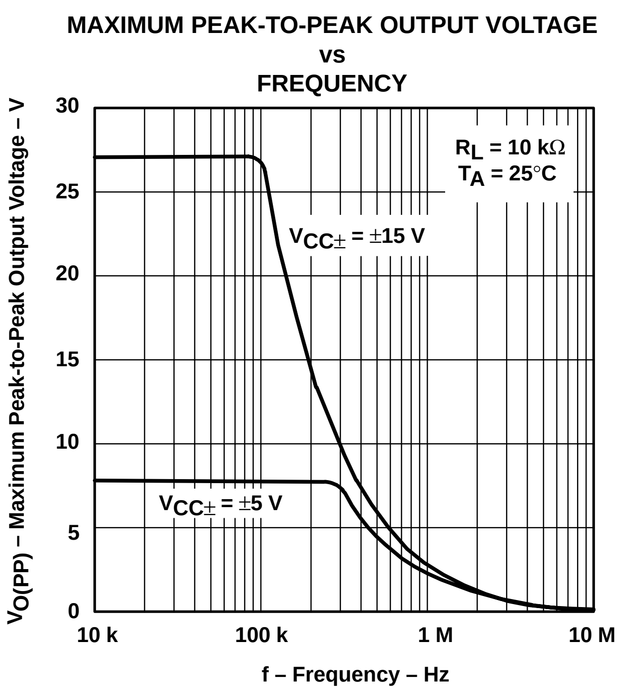


Figure 24

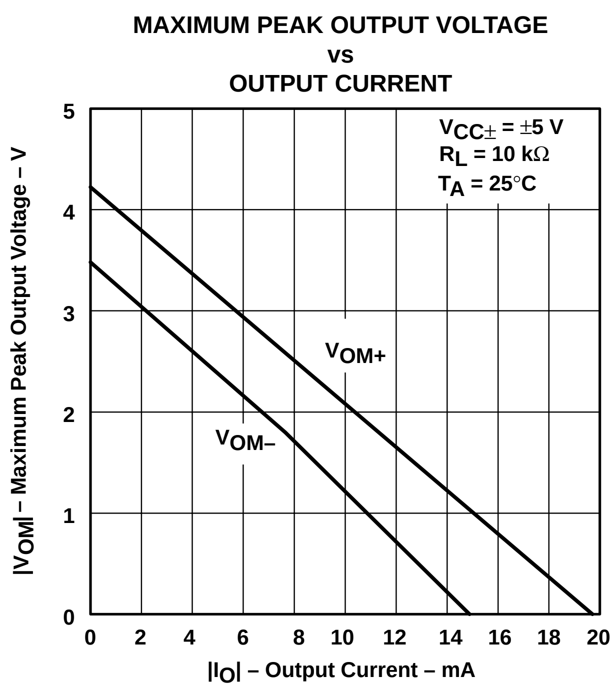


Figure 25

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS

MAXIMUM PEAK OUTPUT VOLTAGE vs OUTPUT CURRENT

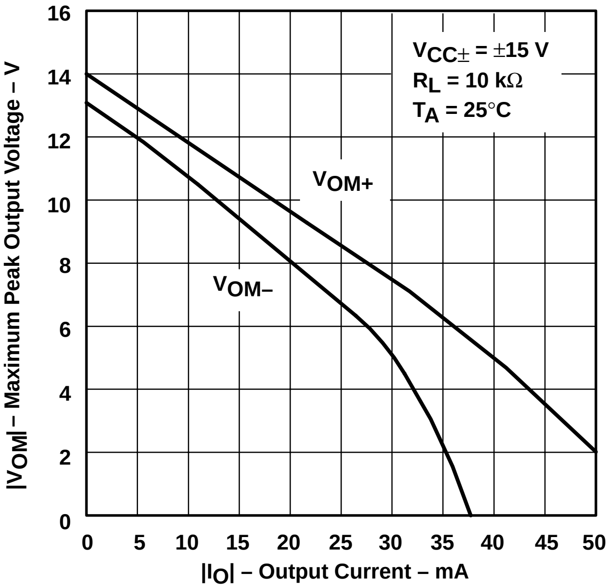


Figure 26

MAXIMUM PEAK OUTPUT VOLTAGE† vs FREE-AIR TEMPERATURE

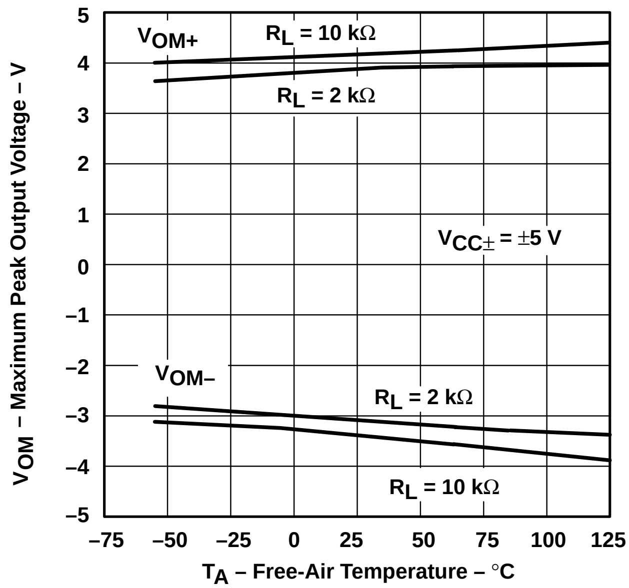


Figure 27

MAXIMUM PEAK OUTPUT VOLTAGE† vs FREE-AIR TEMPERATURE

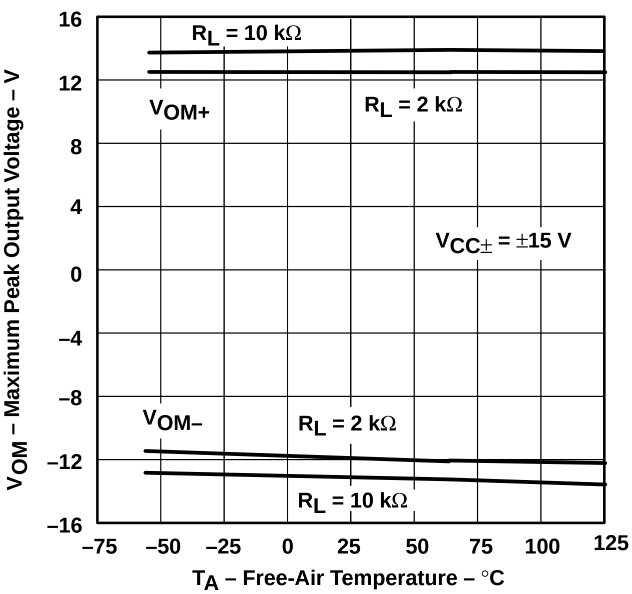


Figure 28

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION vs LOAD RESISTANCE

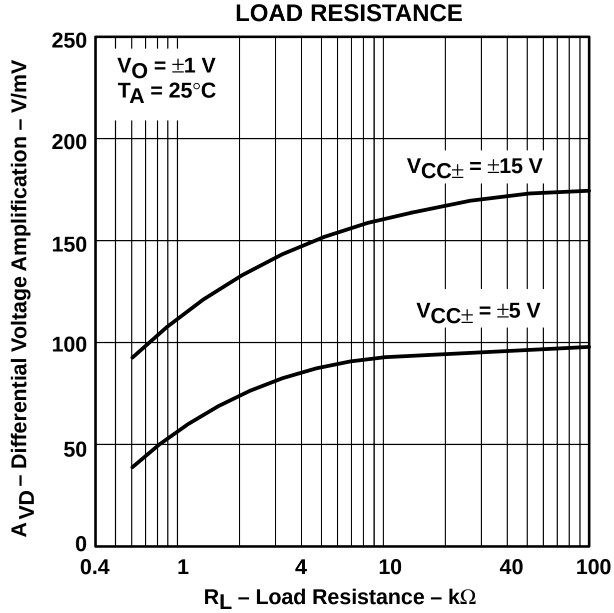


Figure 29

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT vs FREQUENCY

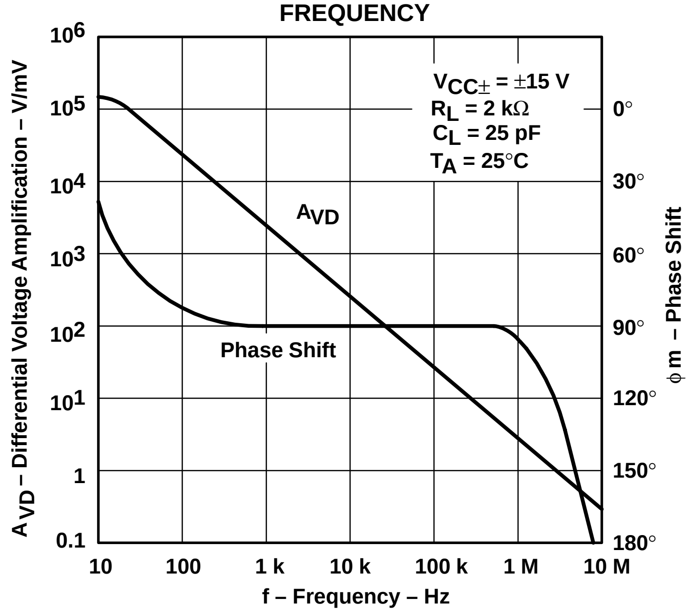


Figure 30

TL051 AND TL052 LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION† vs FREE-AIR TEMPERATURE

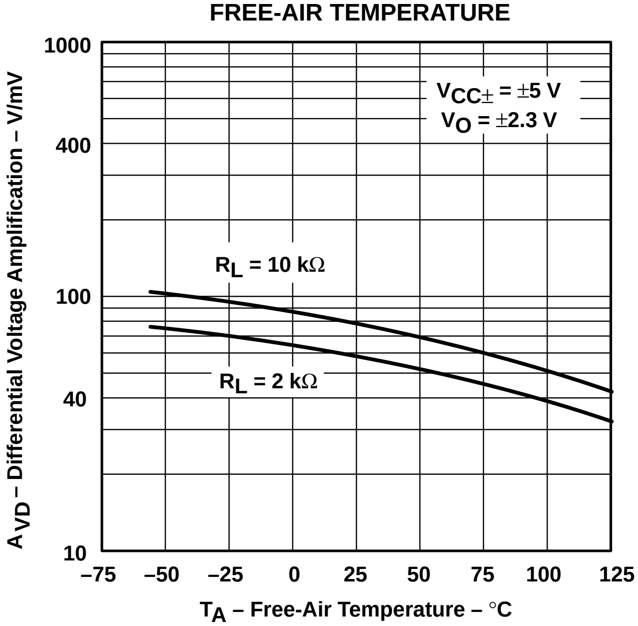


Figure 31

TL054 LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION† vs FREE-AIR TEMPERATURE

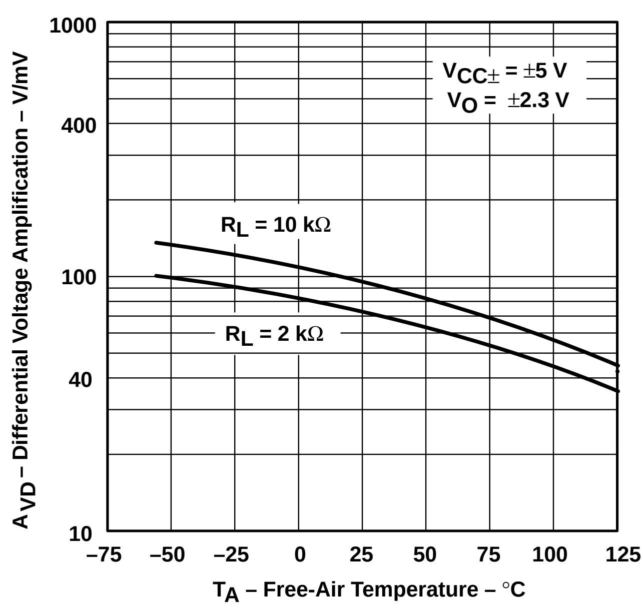


Figure 32

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION† vs FREE-AIR TEMPERATURE

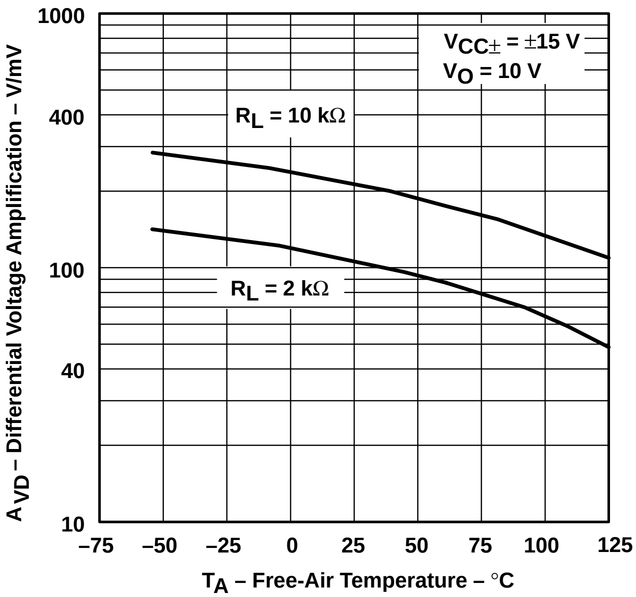


Figure 33

COMMON-MODE REJECTION RATIO vs FREQUENCY

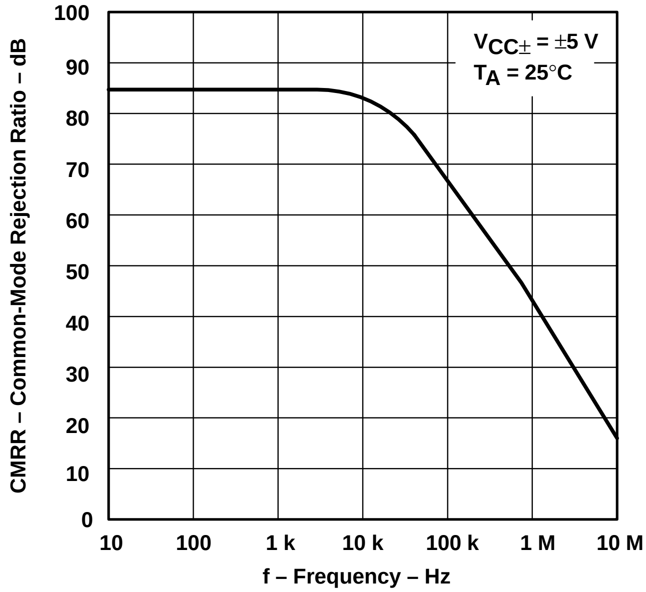


Figure 34

COMMON-MODE REJECTION RATIO vs FREQUENCY

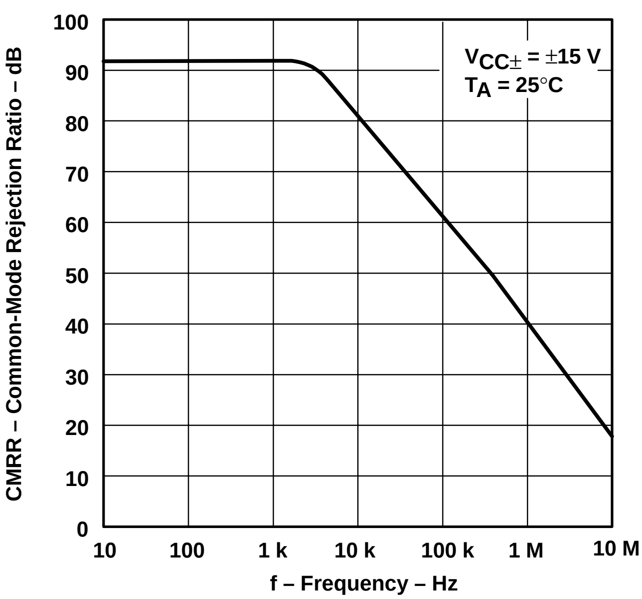


Figure 35

COMMON-MODE REJECTION RATIO† vs FREE-AIR TEMPERATURE

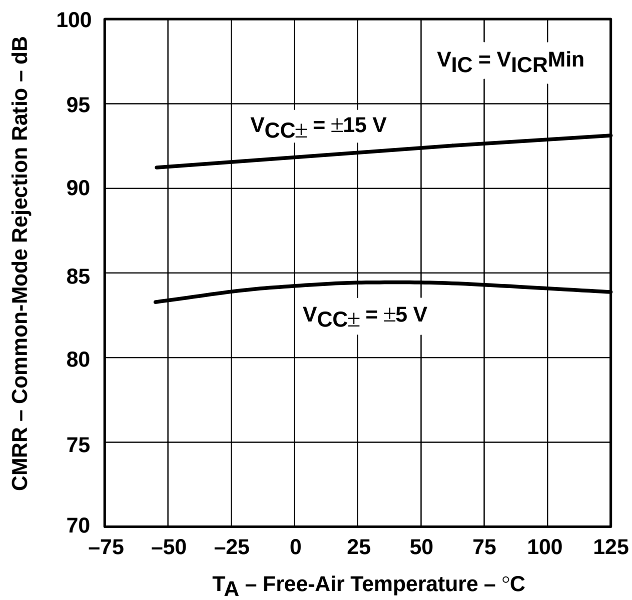


Figure 36

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS

OUTPUT IMPEDANCE vs FREQUENCY

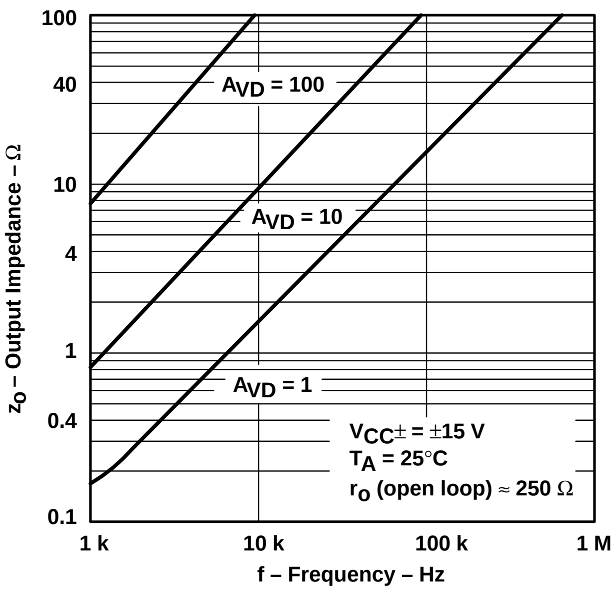


Figure 37

SUPPLY-VOLTAGE REJECTION RATIO† vs FREE-AIR TEMPERATURE

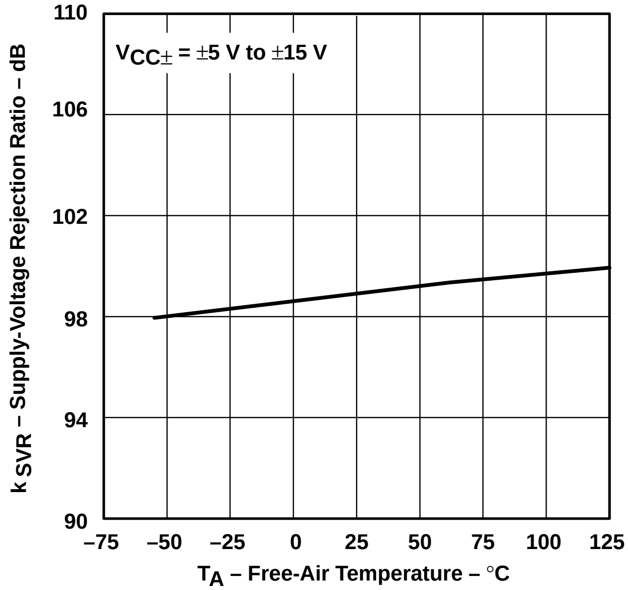


Figure 38

SHORT-CIRCUIT OUTPUT CURRENT vs SUPPLY VOLTAGE

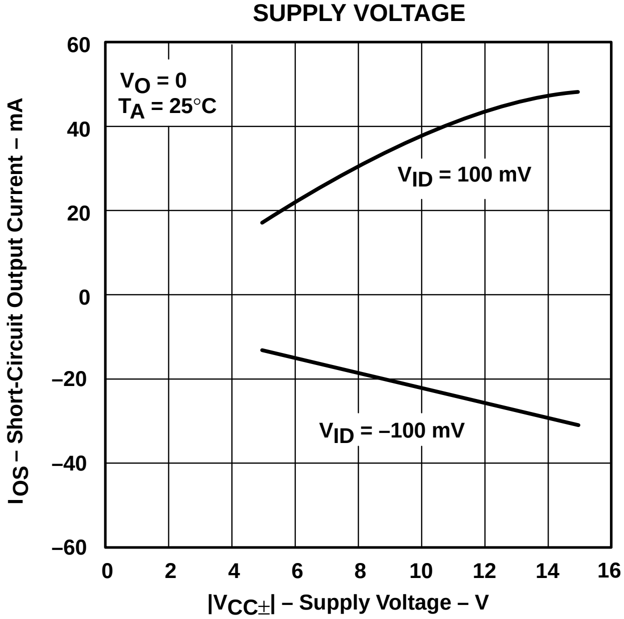


Figure 39

SHORT-CIRCUIT OUTPUT CURRENT vs TIME

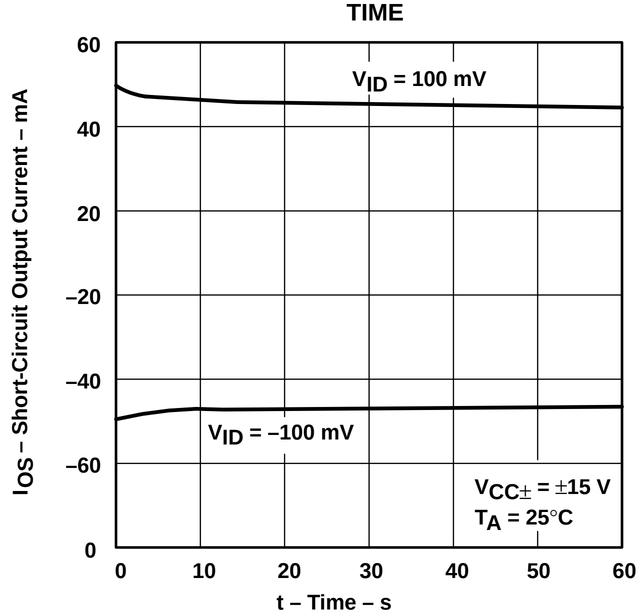


Figure 40

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS

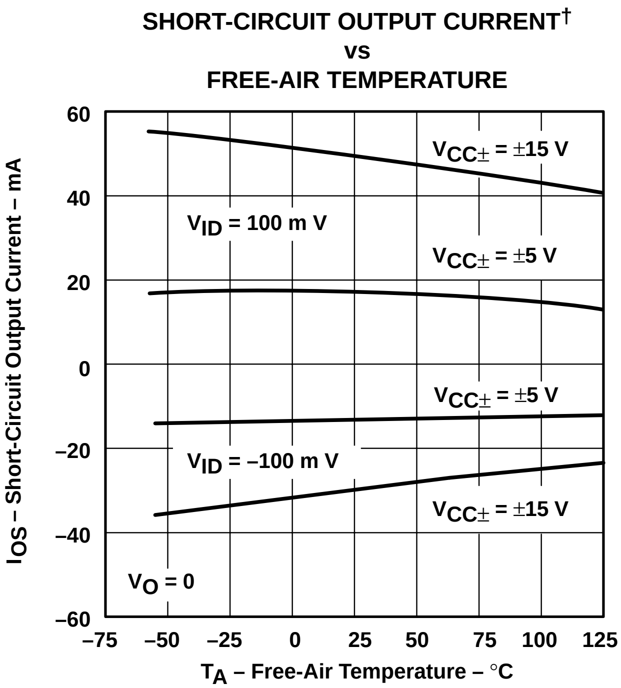


Figure 41

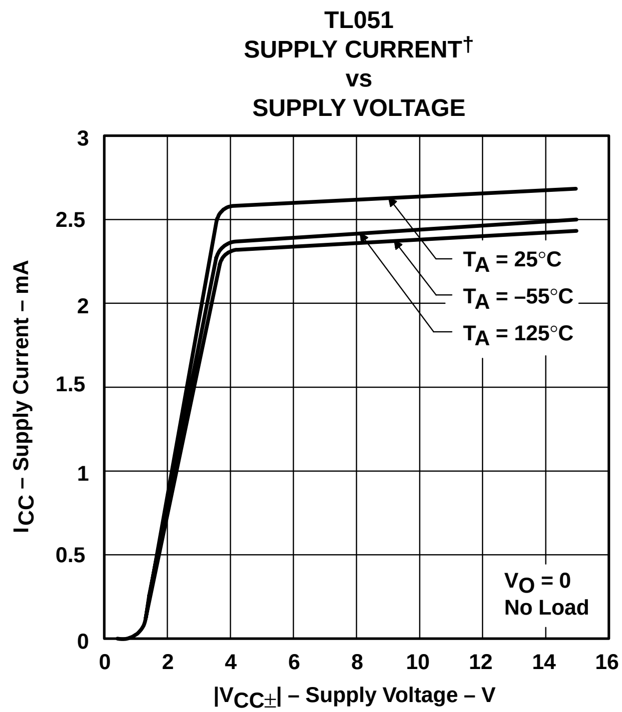


Figure 42

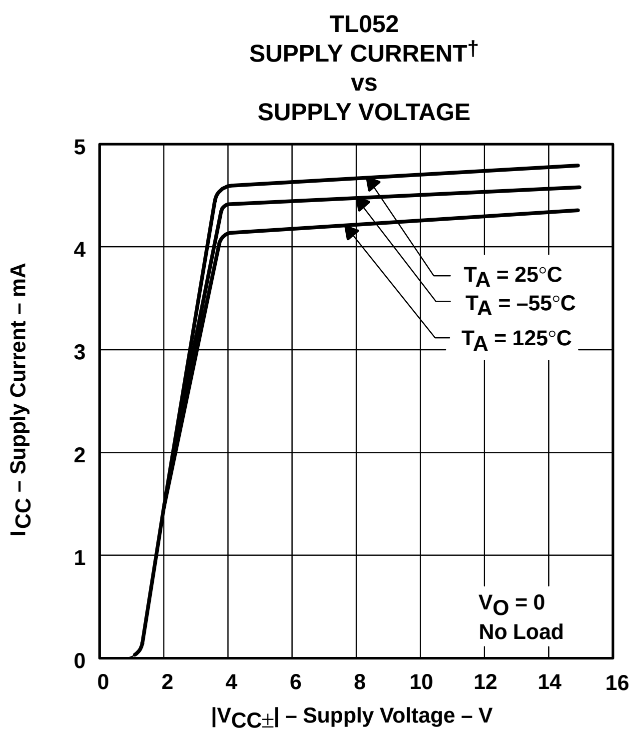


Figure 43

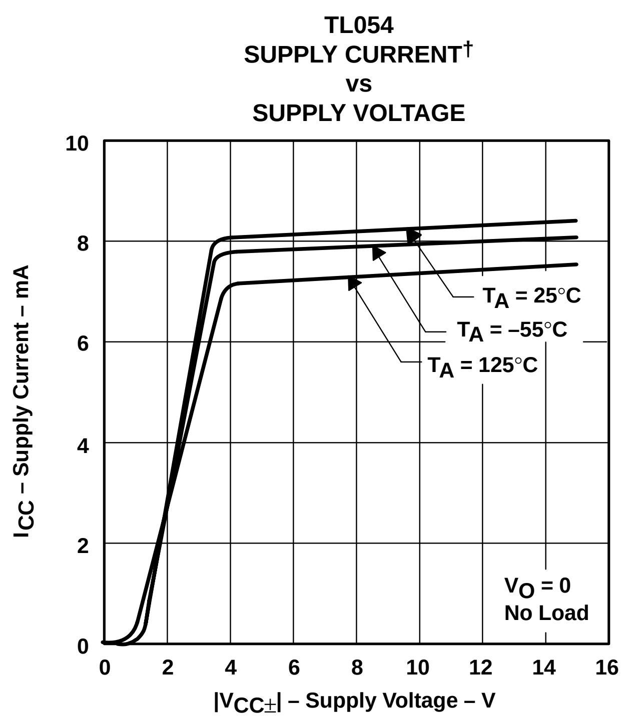


Figure 44

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS

**TL051
SUPPLY CURRENT†
vs
FREE-AIR TEMPERATURE**

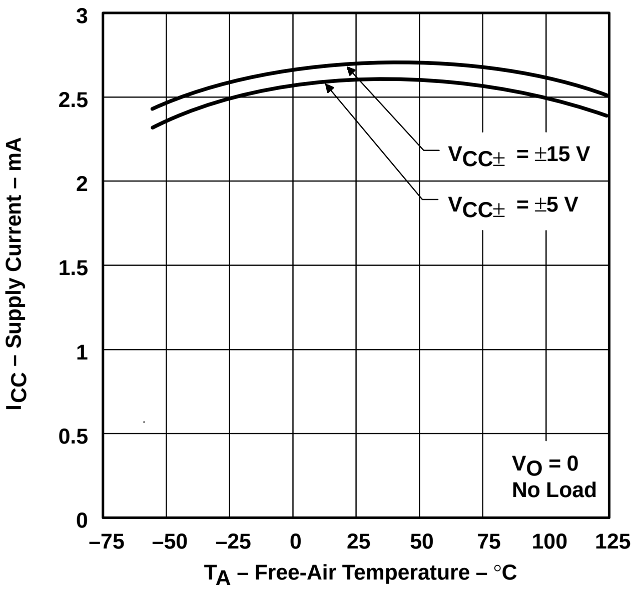


Figure 45

**TL052
SUPPLY CURRENT†
vs
FREE-AIR TEMPERATURE**

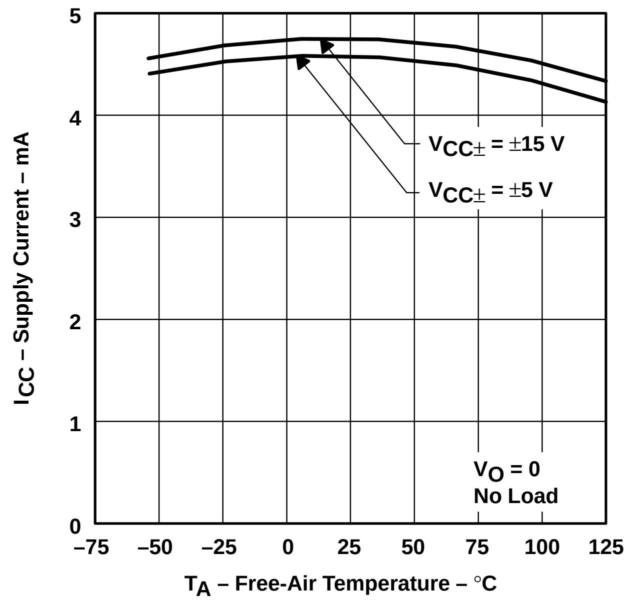


Figure 46

**TL054
SUPPLY CURRENT†
vs
FREE-AIR TEMPERATURE**

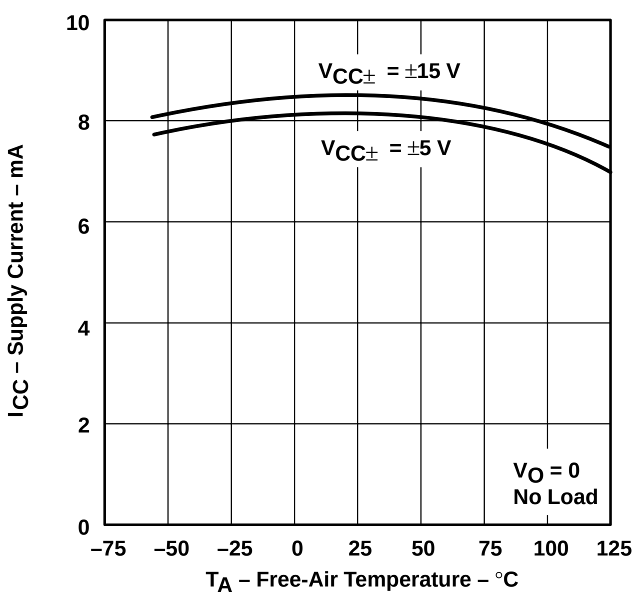


Figure 47

**TL051
SLEW RATE
vs
LOAD RESISTANCE**

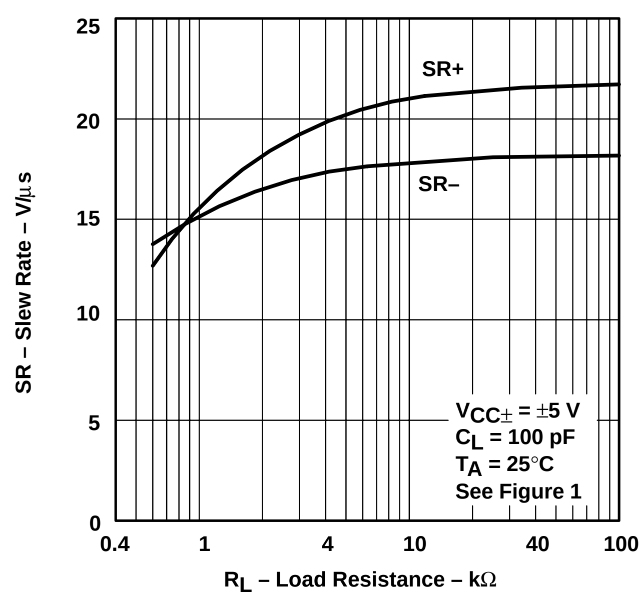


Figure 48

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS

TL052
SLEW RATE
vs
LOAD RESISTANCE

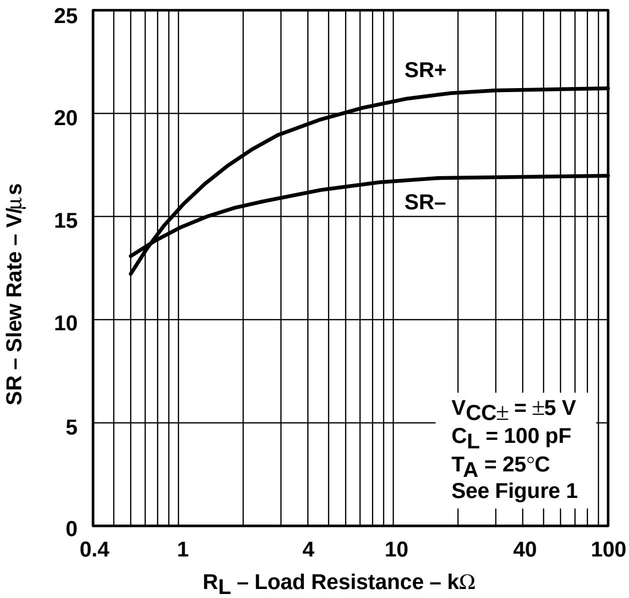


Figure 49

TL054
SLEW RATE
vs
LOAD RESISTANCE

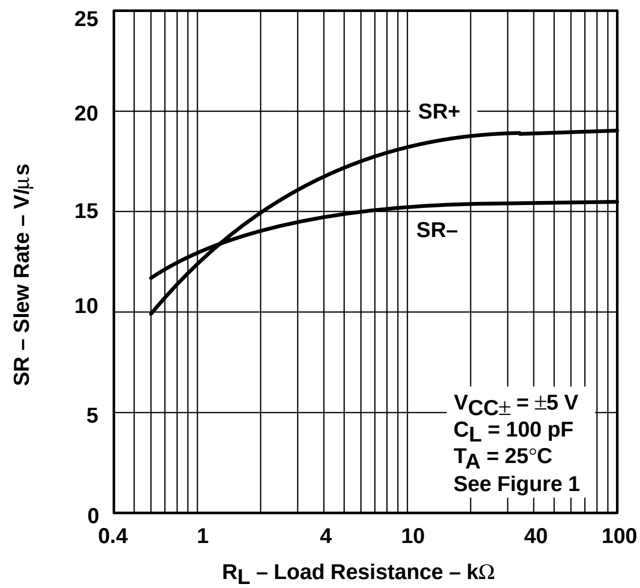


Figure 50

TL051
SLEW RATE
vs
LOAD RESISTANCE

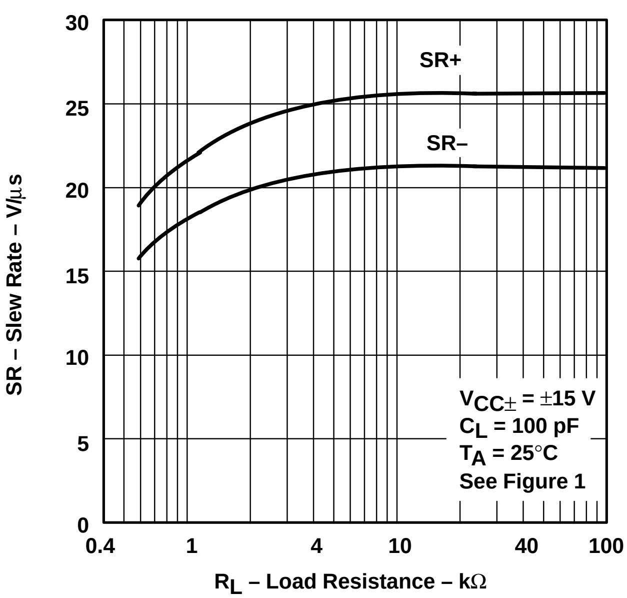


Figure 51

TL052
SLEW RATE
vs
LOAD RESISTANCE

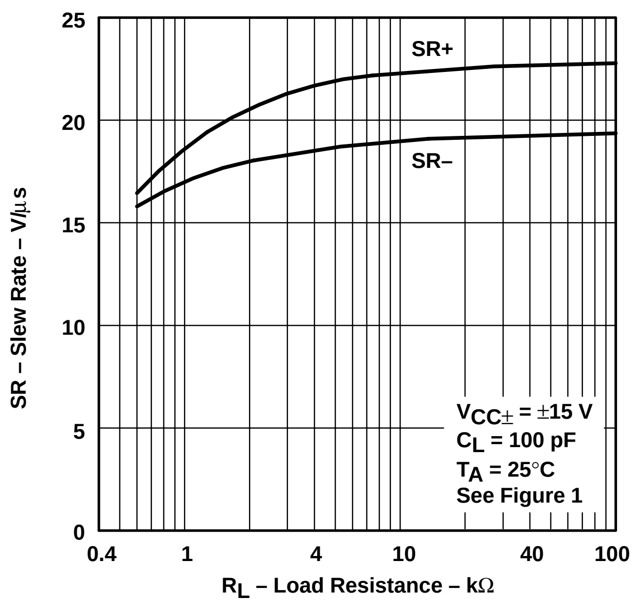


Figure 52

TYPICAL CHARACTERISTICS

**TL054
SLEW RATE
vs
LOAD RESISTANCE**

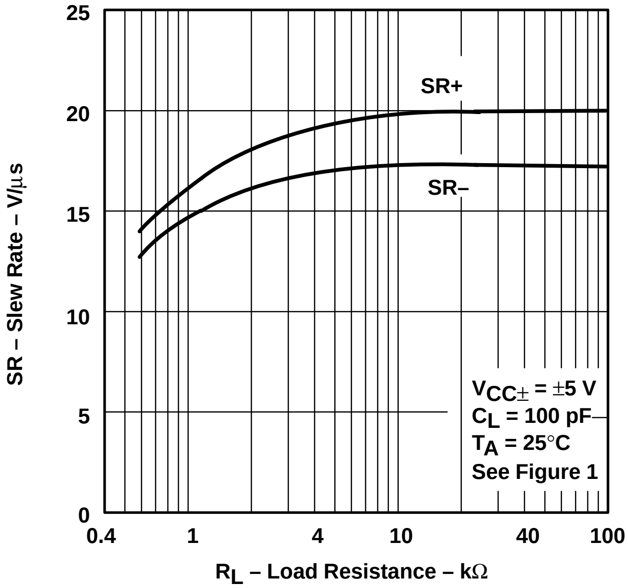


Figure 53

**TL051
SLEW RATE†
vs
FREE-AIR TEMPERATURE**

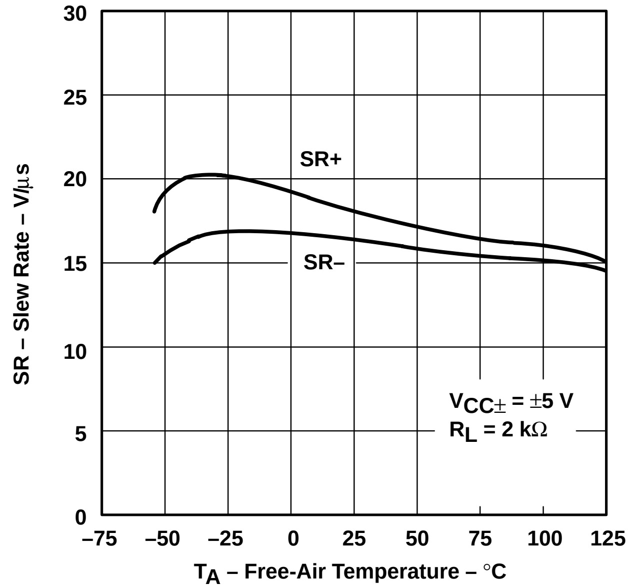


Figure 54

**TL052
SLEW RATE†
vs
FREE-AIR TEMPERATURE**

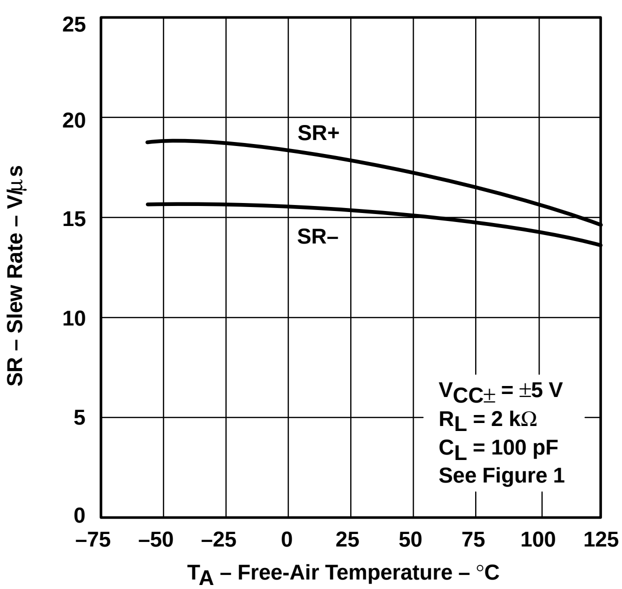


Figure 55

**TL054
SLEW RATE†
vs
FREE-AIR TEMPERATURE**

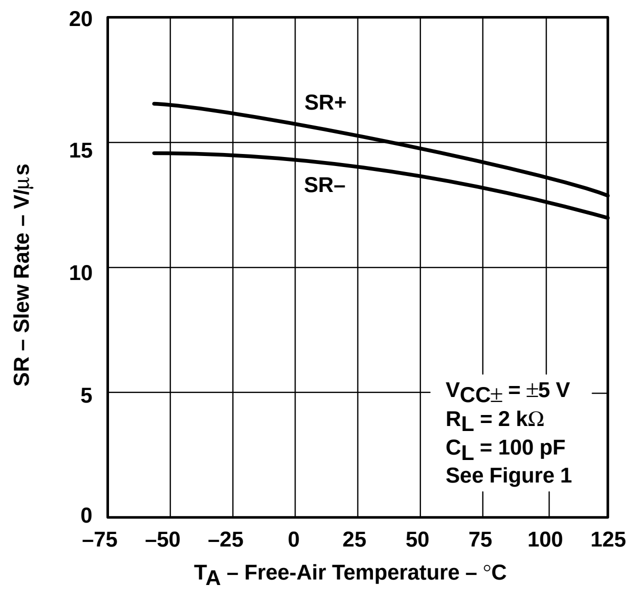


Figure 56

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS

TL051
SLEW RATE†
vs
FREE-AIR TEMPERATURE

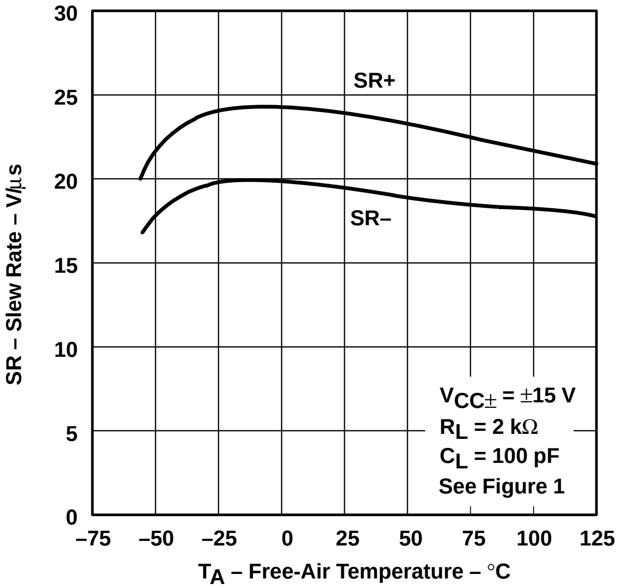


Figure 57

TL052
SLEW RATE†
vs
FREE-AIR TEMPERATURE

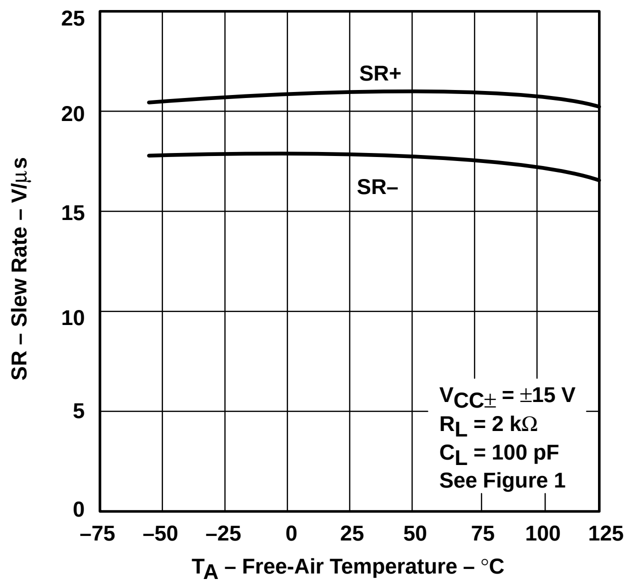


Figure 58

TL054
SLEW RATE†
vs
FREE-AIR TEMPERATURE

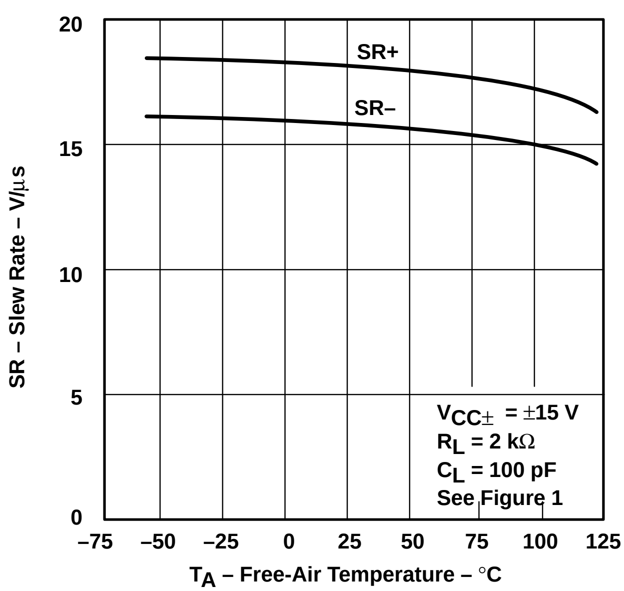


Figure 59

OVERSHOOT FACTOR
vs
LOAD CAPACITANCE

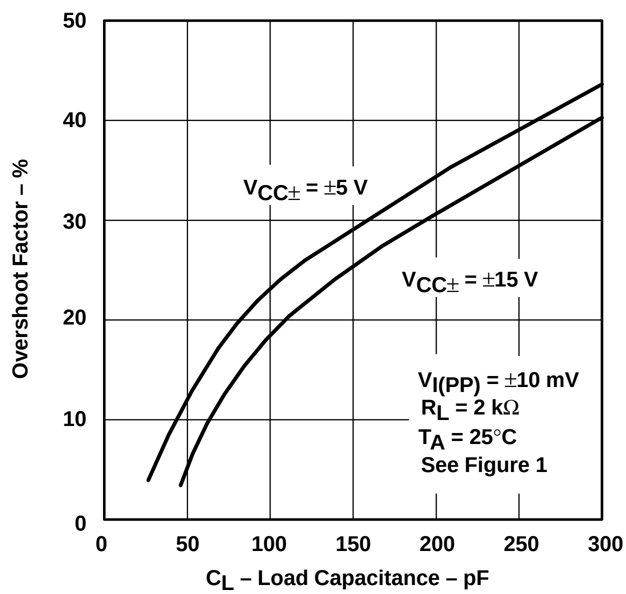


Figure 60

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS

TL051
EQUIVALENT INPUT NOISE VOLTAGE
vs
FREQUENCY

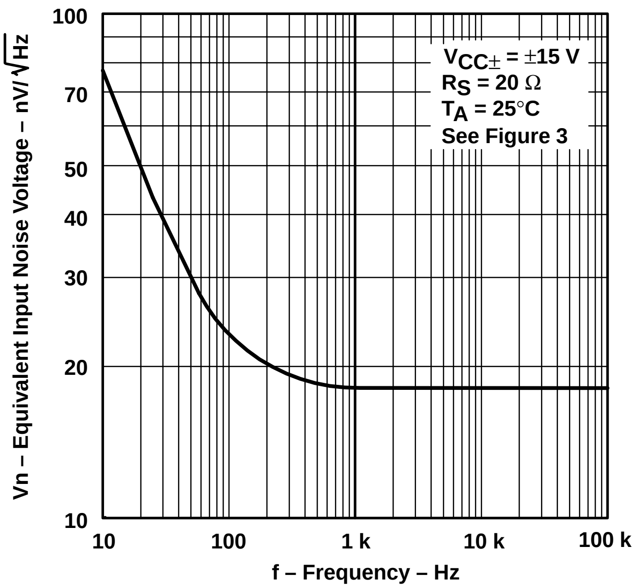


Figure 61

TL052 AND TL054
EQUIVALENT INPUT NOISE VOLTAGE
vs
FREQUENCY

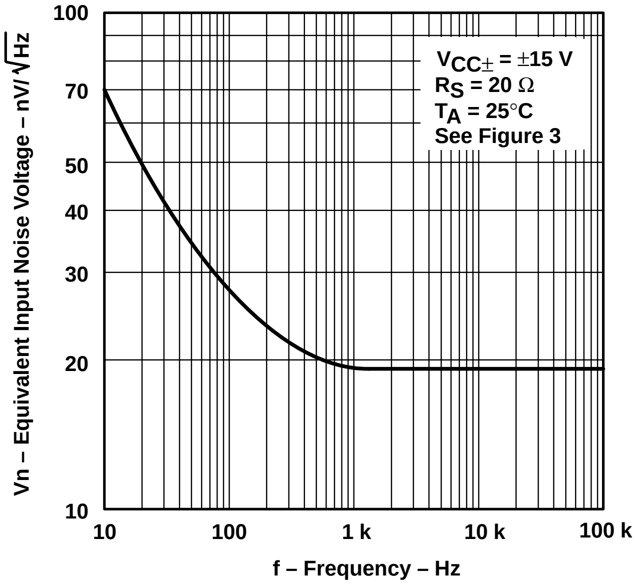


Figure 62

TOTAL HARMONIC DISTORTION
vs
FREQUENCY

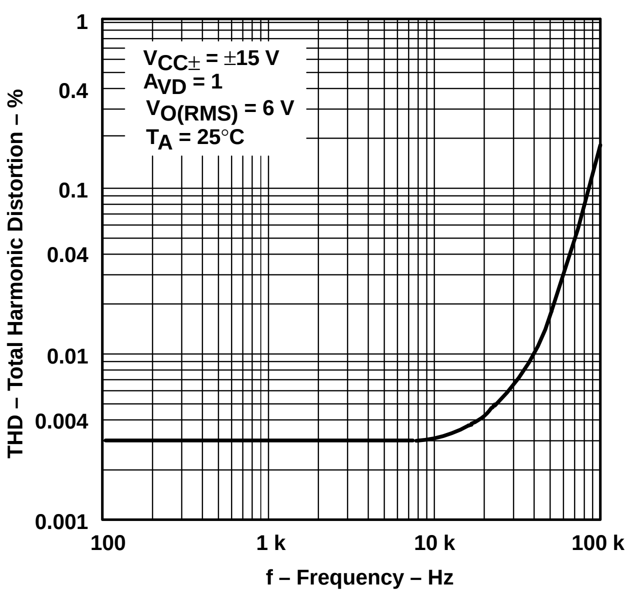


Figure 63

TL051
UNITY-GAIN BANDWIDTH
vs
SUPPLY VOLTAGE

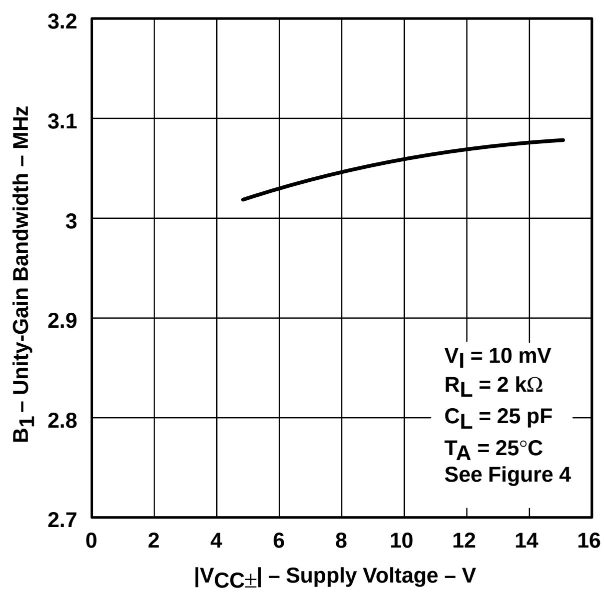


Figure 64

TYPICAL CHARACTERISTICS

TL052
UNITY-GAIN BANDWIDTH
vs
SUPPLY VOLTAGE

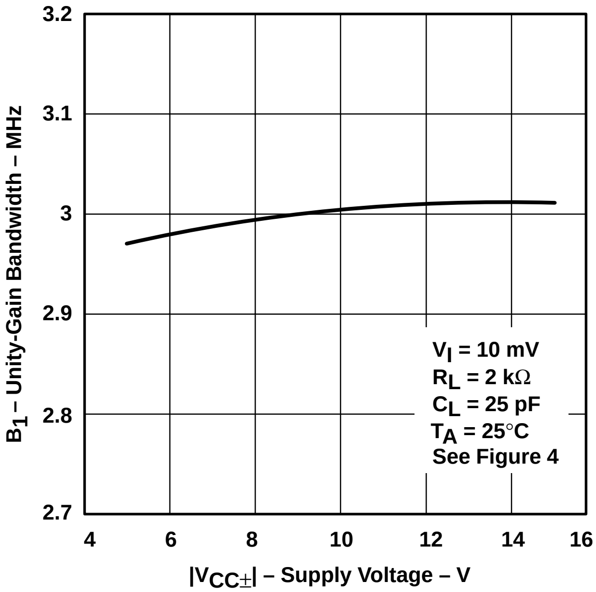


Figure 65

TL054
UNITY-GAIN BANDWIDTH
vs
SUPPLY VOLTAGE

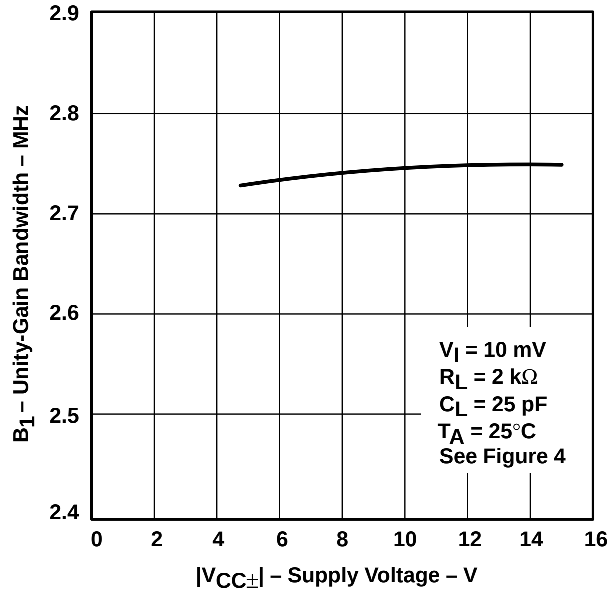


Figure 66

TL051
UNITY-GAIN BANDWIDTH†
vs
FREE-AIR TEMPERATURE

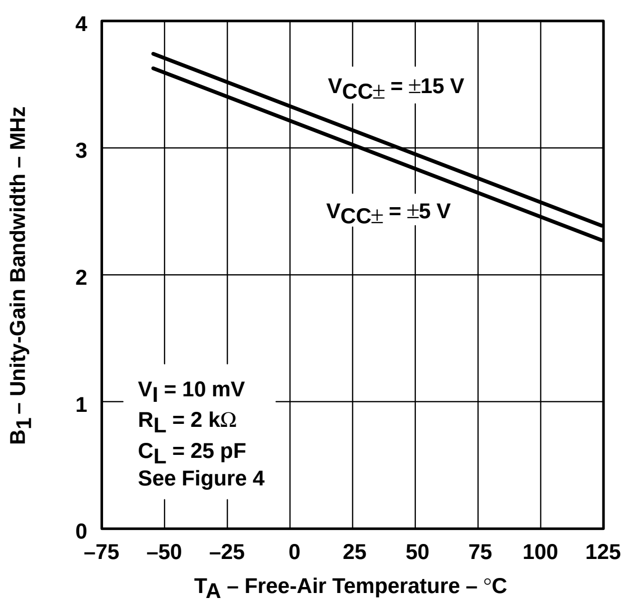


Figure 67

TL052
UNITY-GAIN BANDWIDTH†
vs
FREE-AIR TEMPERATURE

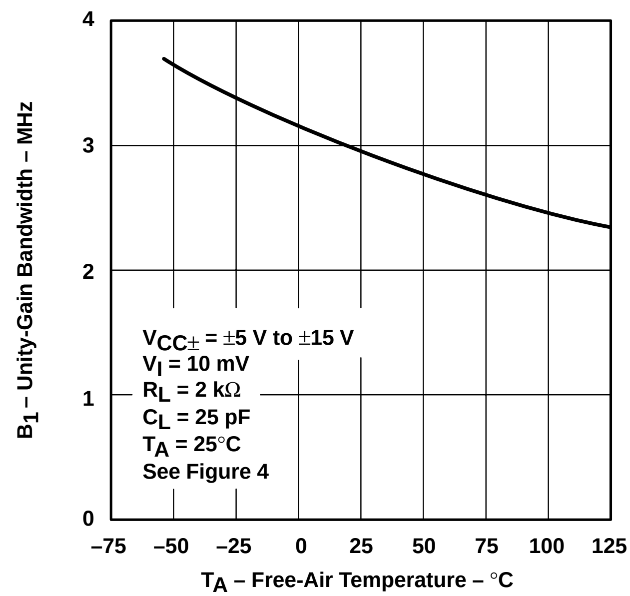


Figure 68

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS

TL054
UNITY-GAIN BANDWIDTH†
vs
FREE-AIR TEMPERATURE

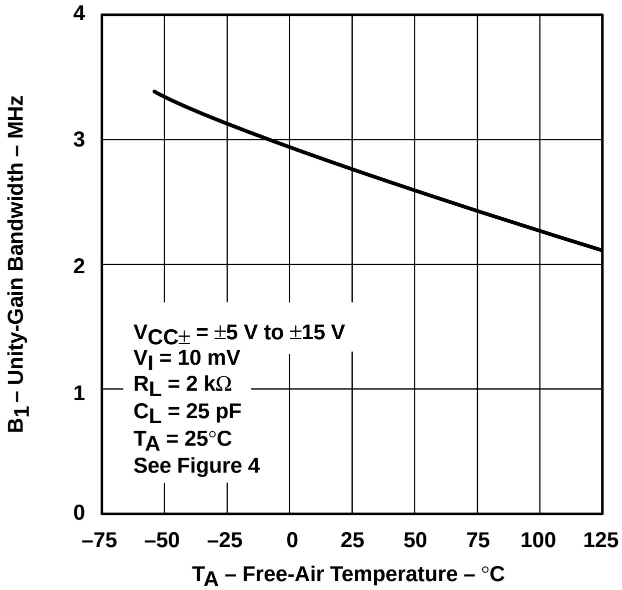


Figure 69

TL051
PHASE MARGIN
vs
SUPPLY VOLTAGE

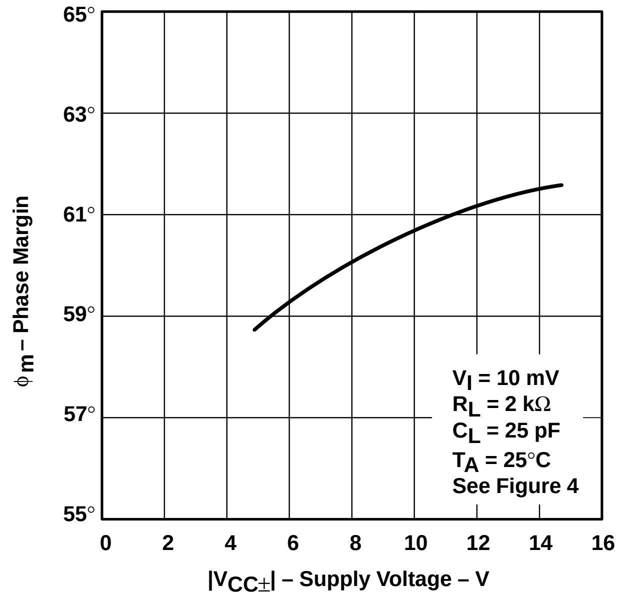


Figure 70

TL052
PHASE MARGIN
vs
SUPPLY VOLTAGE

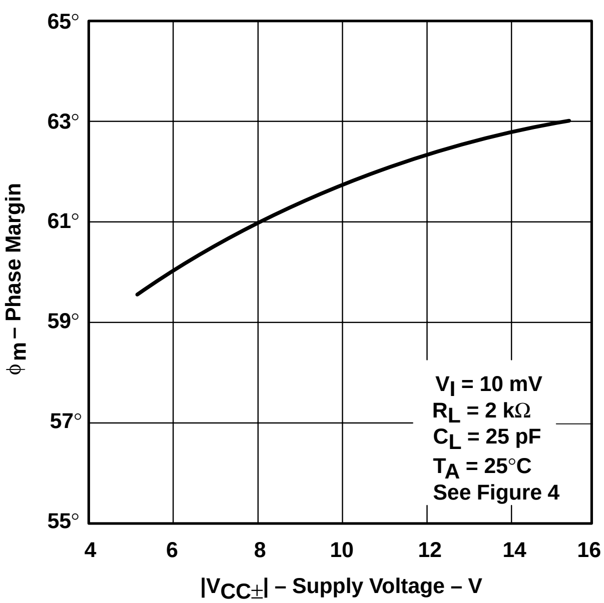


Figure 71

TL054
PHASE MARGIN
vs
SUPPLY VOLTAGE

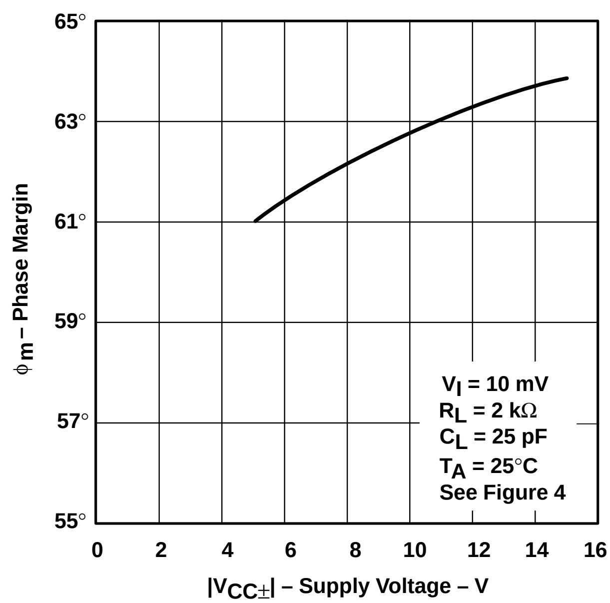


Figure 72

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS

TL051
PHASE MARGIN†
vs
LOAD CAPACITANCE

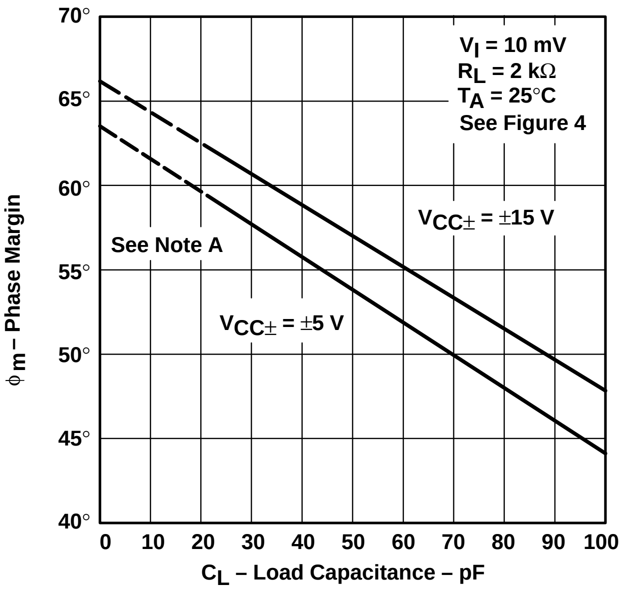


Figure 73

TL052
PHASE MARGIN†
vs
LOAD CAPACITANCE

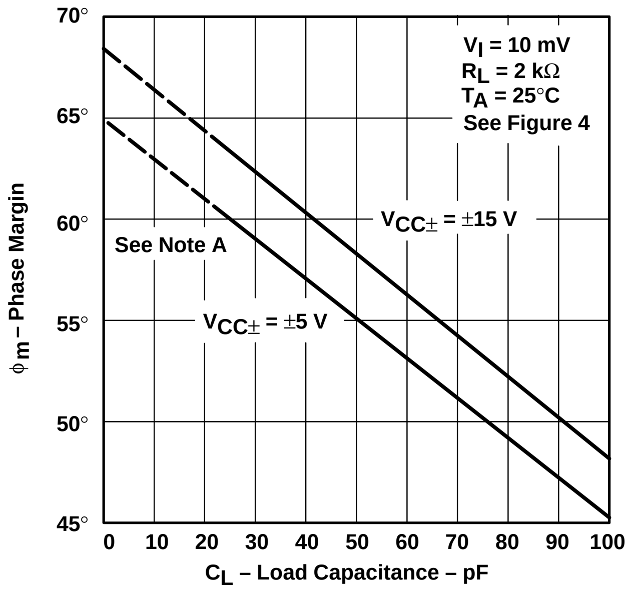


Figure 74

TL054
PHASE MARGIN†
vs
LOAD CAPACITANCE

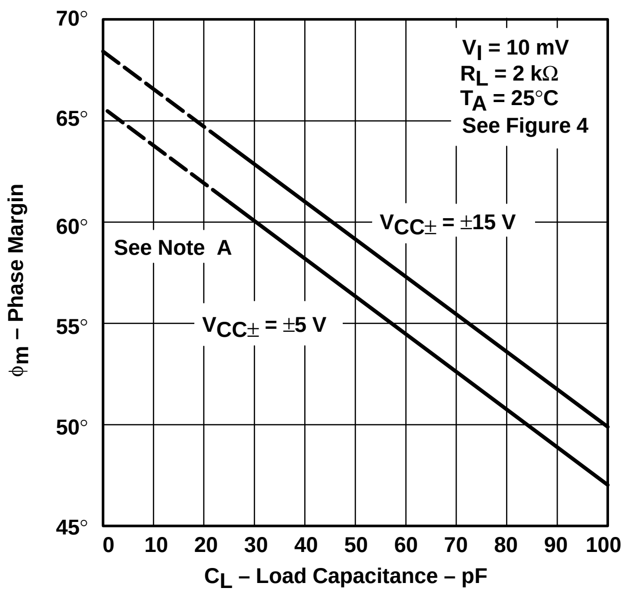


Figure 75

† Values of phase margin below a load capacitance of 25 pF were estimated.

TYPICAL CHARACTERISTICS

TL051
PHASE MARGIN†
vs
FREE-AIR TEMPERATURE

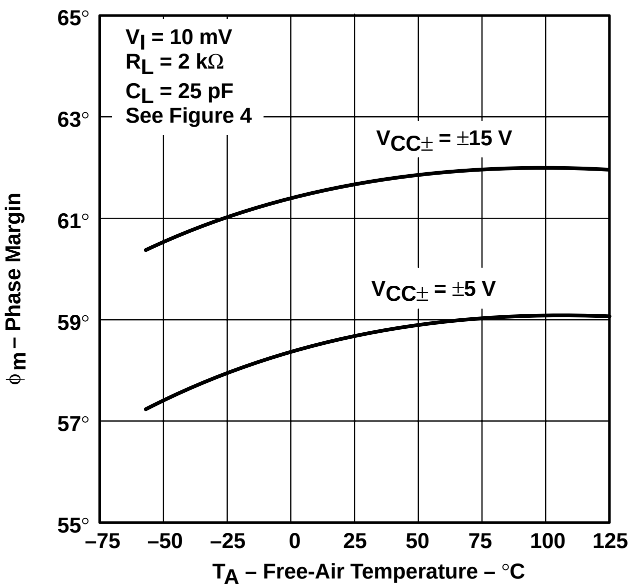


Figure 76

TL052
PHASE MARGIN†
vs
FREE-AIR TEMPERATURE

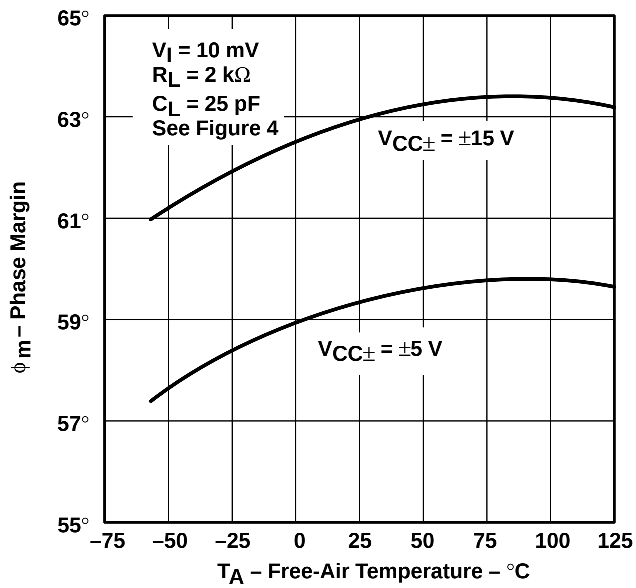


Figure 77

TL054
PHASE MARGIN†
vs
FREE-AIR TEMPERATURE

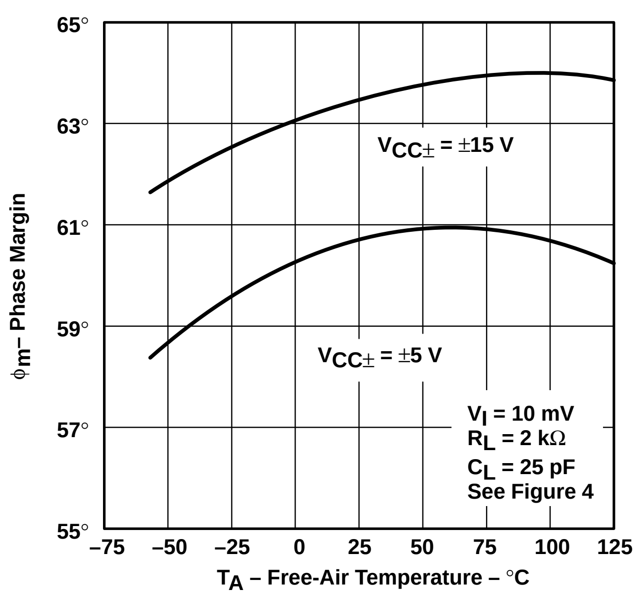


Figure 78

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS

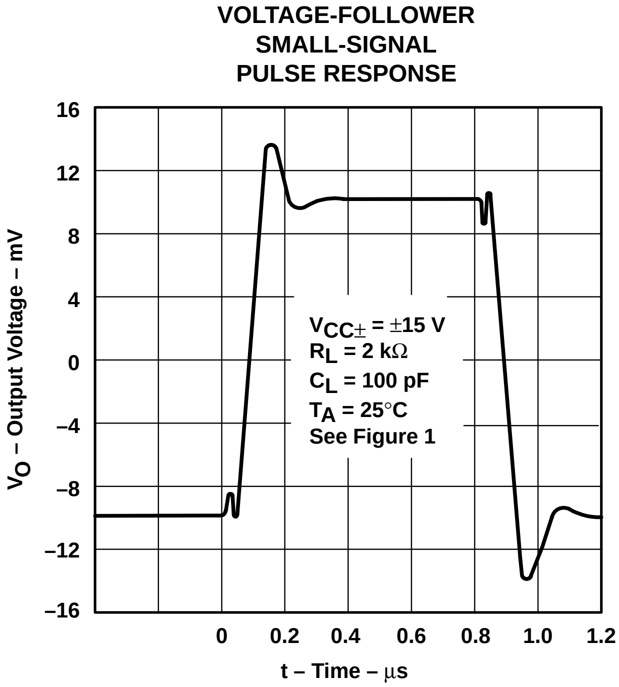


Figure 79

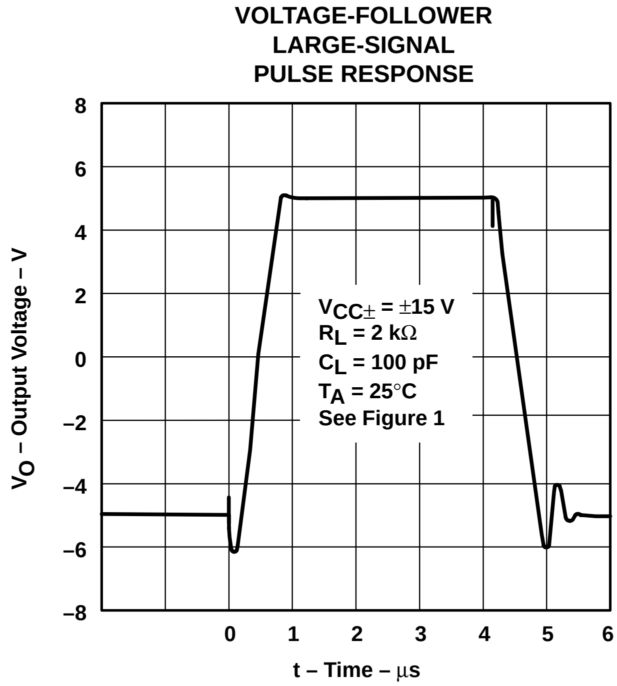


Figure 80

APPLICATION INFORMATION

output characteristics

All operating characteristics (except bandwidth and phase margin) are specified with 100-pF load capacitance. The TL05x and TL05xA drive higher capacitive loads; however, as the load capacitance increases, the resulting response pole occurs at lower frequencies, causing ringing, peaking, or even oscillation. The value of the load capacitance at which oscillation occurs varies with production lots. If an application appears to be sensitive to oscillation due to load capacitance, adding a small resistance in series with the load should alleviate the problem. Capacitive loads of 1000 pF, and larger, may be driven if enough resistance is added in series with the output (see Figure 81 and Figure 82).

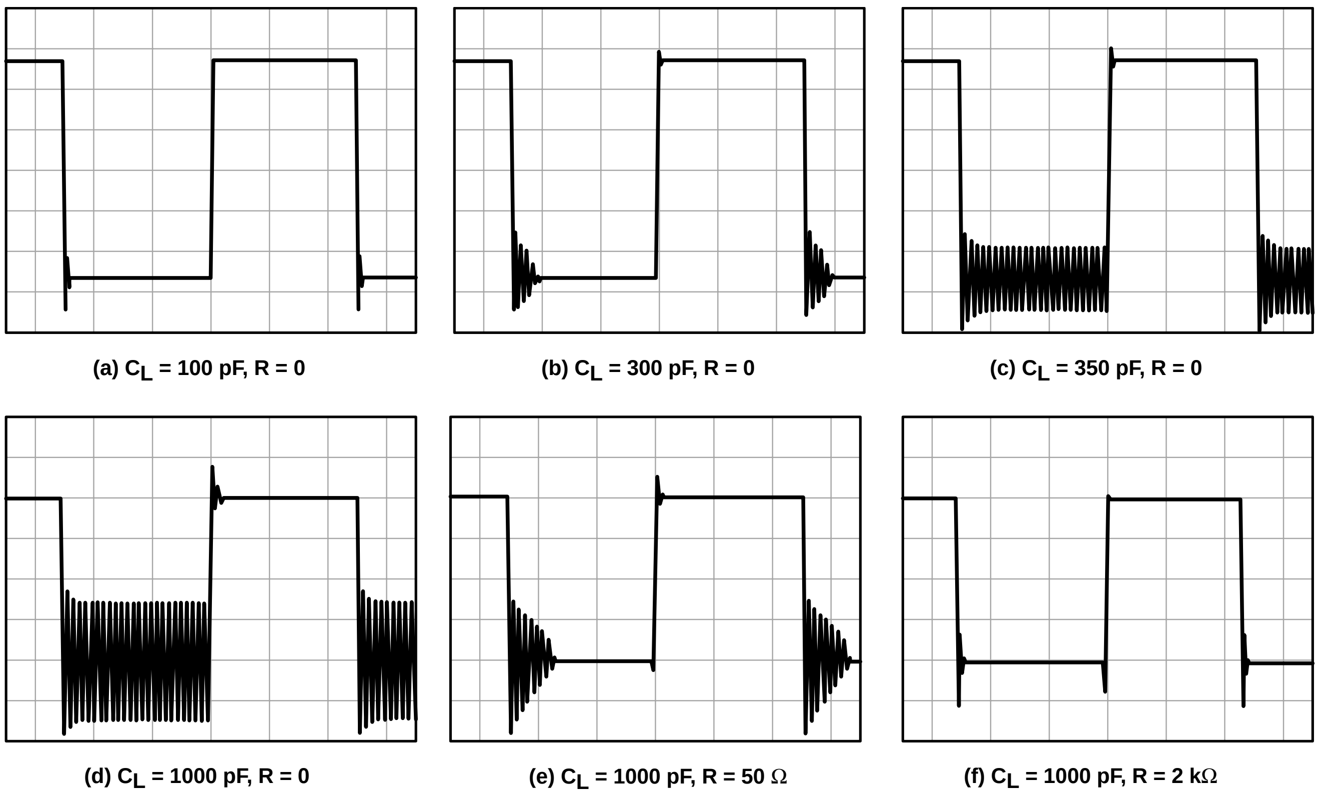
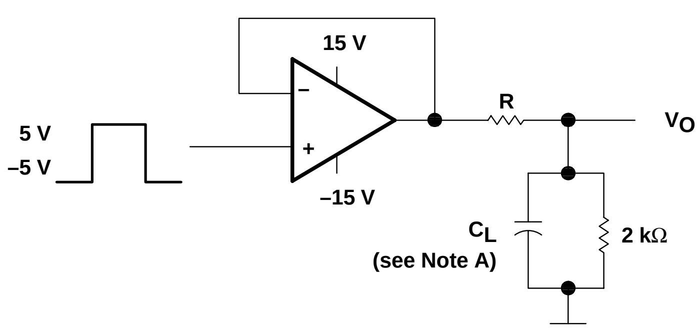


Figure 81. Effect of Capacitive Loads



NOTE A: C_L includes fixture capacitance.

Figure 82. Test Circuit for Output Characteristics

APPLICATION INFORMATION

input characteristics

The TL05x and TL05xA are specified with a minimum and a maximum input voltage that, if exceeded at either input, could cause the device to malfunction.

Because of the extremely high input impedance and resulting low-bias current requirements, the TL05x and TL05xA are well suited for low-level signal processing; however, leakage currents on printed-circuit boards and sockets easily can exceed bias current requirements and cause degradation in system performance. It is good practice to include guard rings around inputs (see Figure 83). These guards should be driven from a low-impedance source at the same voltage level as the common-mode input.

Unused amplifiers should be connected as grounded unity-gain followers to avoid possible oscillation.

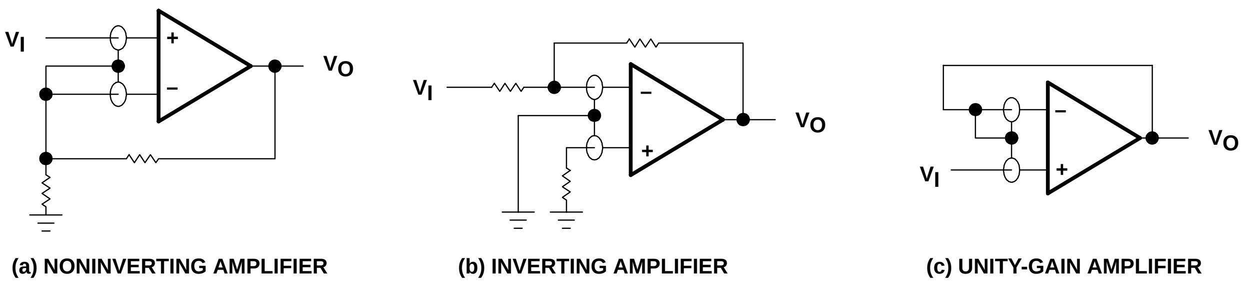


Figure 83. Use of Guard Rings

noise performance

The noise specifications in operational amplifier circuits are greatly dependent on the current in the first-stage differential amplifier. The low input-bias current requirements of the TL05x and TL05xA result in a very low current noise. This feature makes the devices especially favorable over bipolar devices when using values of circuit impedance greater than 50 kΩ.

APPLICATION INFORMATION

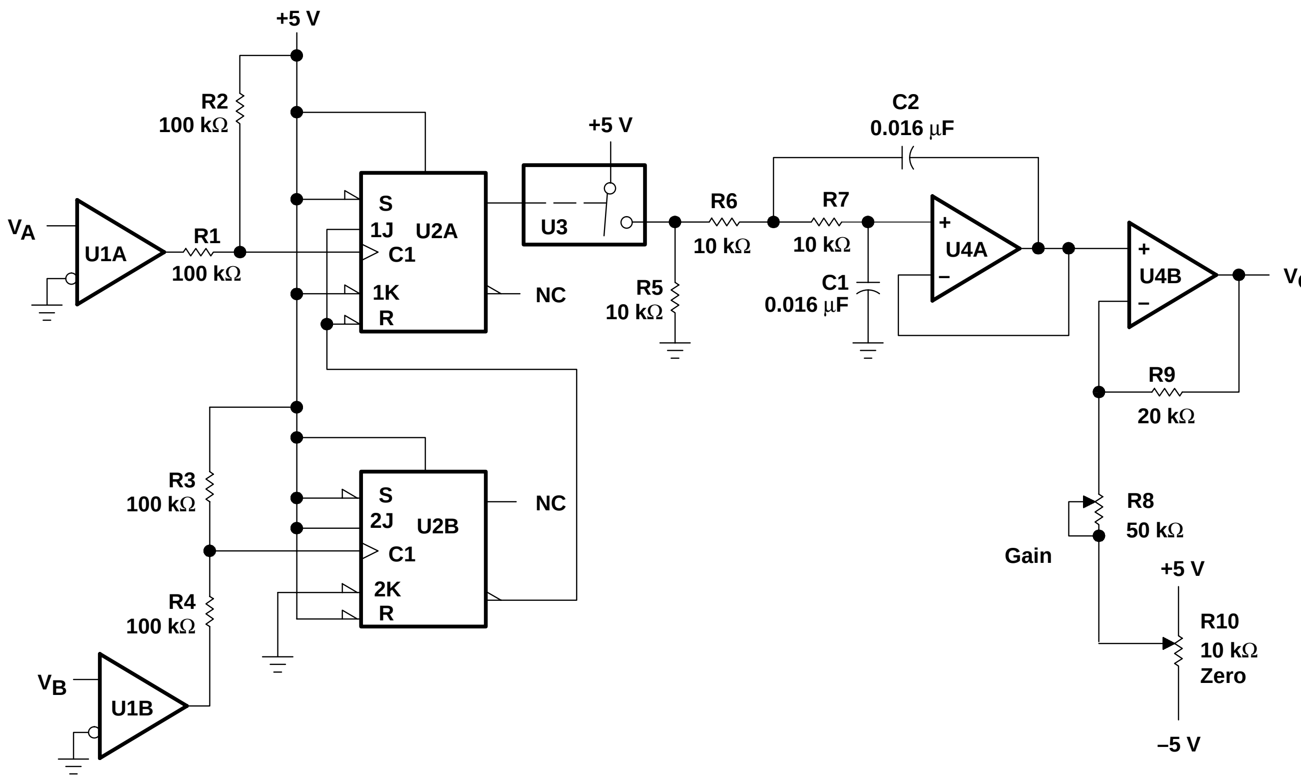
phase meter

The phase meter in Figure 84 produces an output voltage of 10 mV per degree of phase delay between the two input signals V_A and V_B. The reference signal V_A must be the same frequency as V_B. The TLC3702 comparators (U1) convert these two input sine waves into ±5-V square waves. Then, R1 and R4 provide level shifting prior to the SN74HC109 dual J-K flip flops.

Flip-flop U2B is connected as a toggle flip-flop and generates a square wave at one-half the frequency of V_B. Flip-flop U2A also produces a square wave at one-half the input frequency. The pulse duration of U2A varies from zero to one-half the period, where zero corresponds to zero phase delay between V_A and V_B and one-half the period corresponds to V_B lagging V_A by 360 degrees.

The output pulse from U2A causes the TLC4066 (U3) switch to charge the TL05x (U4) integrator capacitors C1 and C2. As the phase delay approaches 360 degrees, the output of U4A approximates a square wave, and U2A has an output of almost 2.5 V. U4B acts as a noninverting amplifier with a gain of 1.44 in order to scale the 0- to 2.5-V integrator output to a 0- to 3.6-V output range.

R8 and R10 provide output gain and zero-level calibration. This circuit operates over a 100-Hz to 10-kHz frequency range.



NOTE A: U1 = TLC3702; $V_{CC\pm}$ = ±5 V
U2 = SN74HC109
U3 = TLC4066
U4, U5 = TL05x; $V_{CC\pm}$ = ±5 V

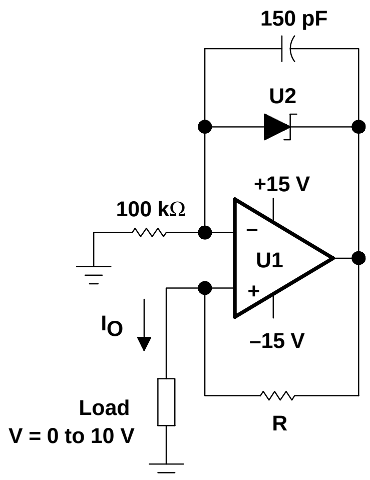
Figure 84. Phase Meter

APPLICATION INFORMATION

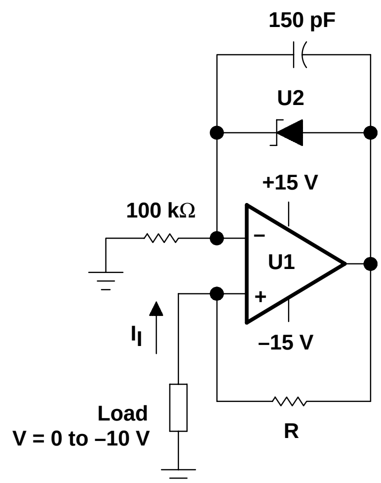
precision constant-current source over temperature

A precision current source (see Figure 85) benefits from the high input impedance and stability of Texas Instruments enhanced-JFET process. A low-current shunt regulator maintains 2.5 V between the inverting input and the output of the TL05x. The negative feedback then forces 2.5 V across the current-setting resistor R; therefore, the current to the load simply is 2.5 V divided by R.

Possible choices for the shunt regulator include the LT1004, LT1009, and LM385. If the regulator's cathode connects to the operational amplifier output, this circuit sources load current. Similarly, if the cathode connects to the inverting input, the circuit sinks current from the load. To minimize output current change with temperature, R should be a metal film resistor with a low temperature coefficient. Also, this circuit must be operated with split-voltage supplies.



(a) SOURCE CURRENT LOAD



(b) SINK CURRENT LOAD

NOTE A: U1 = 1/2 TL05x
U2 = LM385, LT1004, or LT1009 voltage reference
$I = \frac{2.5\ V}{R}$, R = Low-temperature-coefficient metal-film resistor

Figure 85. Precision Constant-Current Source

APPLICATION INFORMATION

instrumentation amplifier with adjustable gain/null

The instrumentation amplifier in Figure 86 benefits greatly from the high input impedance and stable input offset voltage of the TL05xA. Amplifiers U1A, U1B, and U2A form the actual instrumentation amplifier, while U2B provides offset null. Potentiometer R1 provides gain adjustment. With R1 = 2 kΩ, the circuit gain equals 100, while with R1 = 200 kΩ, the circuit gain equals two. The following equation shows the instrumentation amplifier gain as a function of R1:

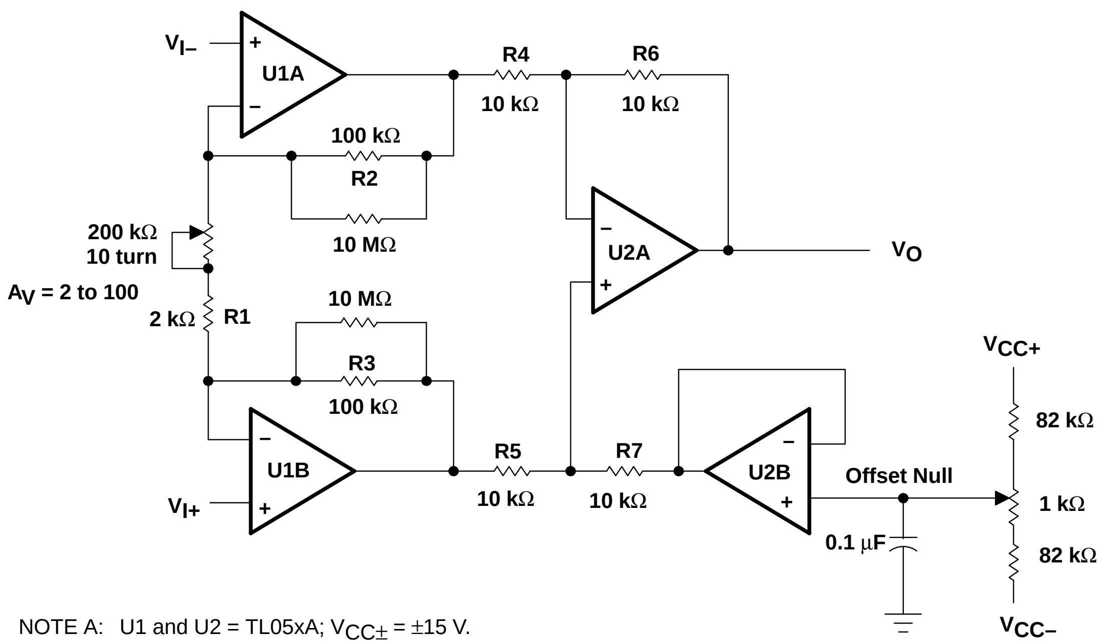
$$A_V = 1 + \left(\frac{R2 + R3}{R1}\right)$$

Readjusting the offset null is necessary when the circuit gain is changed. If U2B is needed for another application, R7 can be terminated at ground. The low input offset voltage of the TL05xA minimizes the dc error of the circuit. For best matching, all resistors should be one-percent tolerance. The matching between R4, R5, R6, and R7 controls the CMRR of this application.

The following equation shows the output voltages when the input voltage equals zero. This dc error can be nulled by adjusting the offset null potentiometer; however, any change in offset voltage over time or temperature also creates an error. To calculate the error from changes in offset, consider the three offset components in the equation as delta offsets, rather than initial offsets. The improved stability of Texas Instruments enhanced JFETs minimizes the error resulting from change in input offset voltage with time. Assuming V_I equals zero, V_O can be shown as a function of the offset voltage:

$$V_O = V_{IO2}\left[\left(1 + \frac{R3}{R1}\right)\left(\frac{R7}{R5 + R7}\right)\left(1 + \frac{R6}{R4}\right) + \frac{R2}{R1}\left(\frac{R6}{R4}\right)\right]$$

$$-V_{IO1}\left[\frac{R3}{R1}\left(\frac{R7}{R5 + R7}\right)\left(1 + \frac{R6}{R4}\right) + \frac{R6}{R4}\left(1 + \frac{R2}{R1}\right)\right] + V_{IO3}\left(1 + \frac{R6}{R4}\right)$$



NOTE A: U1 and U2 = TL05xA; $V_{CC\pm}$ = ±15 V.

Figure 86. Instrumentation Amplifier

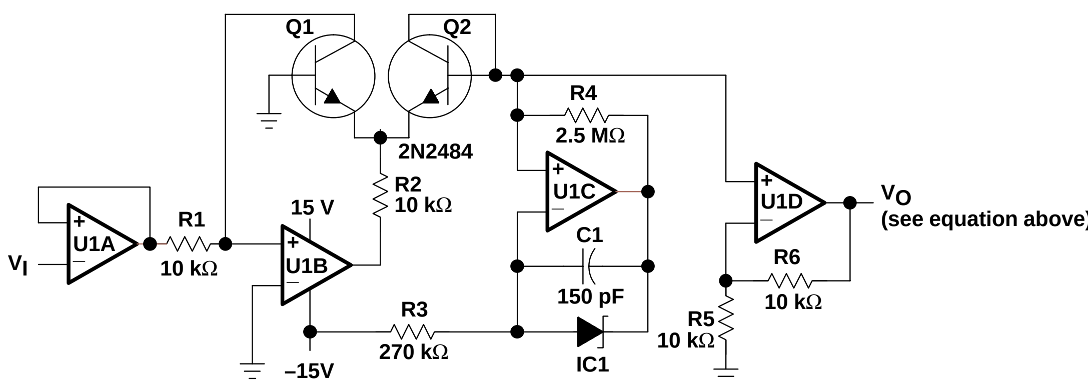
APPLICATION INFORMATION

high input impedance log amplifier

The low input offset voltage and high input impedance of the TL05xA creates a precision log amplifier (see Figure 87). IC1 is a 2.5-V, low-current precision, shunt regulator. Transistors Q1 and Q2 must be a closely matched npn pair. For best performance over temperature, R4 should be a metal-film resistor with a low temperature coefficient.

In this circuit, U1A serves as a high-impedance unity-gain buffer. Amplifier U1B converts the input voltage to a current through R1 and Q1. Amplifier U1C, IC1, and R4 form a 1-μA temperature-stable current source that sets the base-emitter voltage of Q2. U1D amplifies the difference between the base-emitter voltage of Q1 and Q2 (see Figure 88). The output voltage is given by the following equation:

$$V_O = -\left[1 + \frac{R6}{R5}\right]\frac{kT}{q}\left[\ln\frac{V_I}{\left(R1 \times 1 \times 10^{-6}\right)}\right] \text{ where } k = 1.38 \times 10^{-23},\ q = 1.602 \times 10^{-19}, \text{ and T is Kelvin temperature}$$



NOTE A: U1A through U1D = TL05xA. IC1 = LM385, LT1004, or LT1009 voltage reference

Figure 87. Log Amplifier

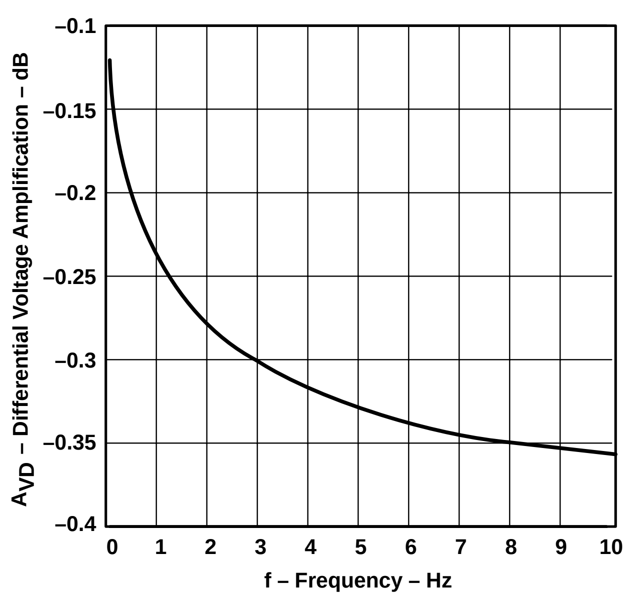


Figure 88. Output Voltage vs Input Voltage for Log Amplifier

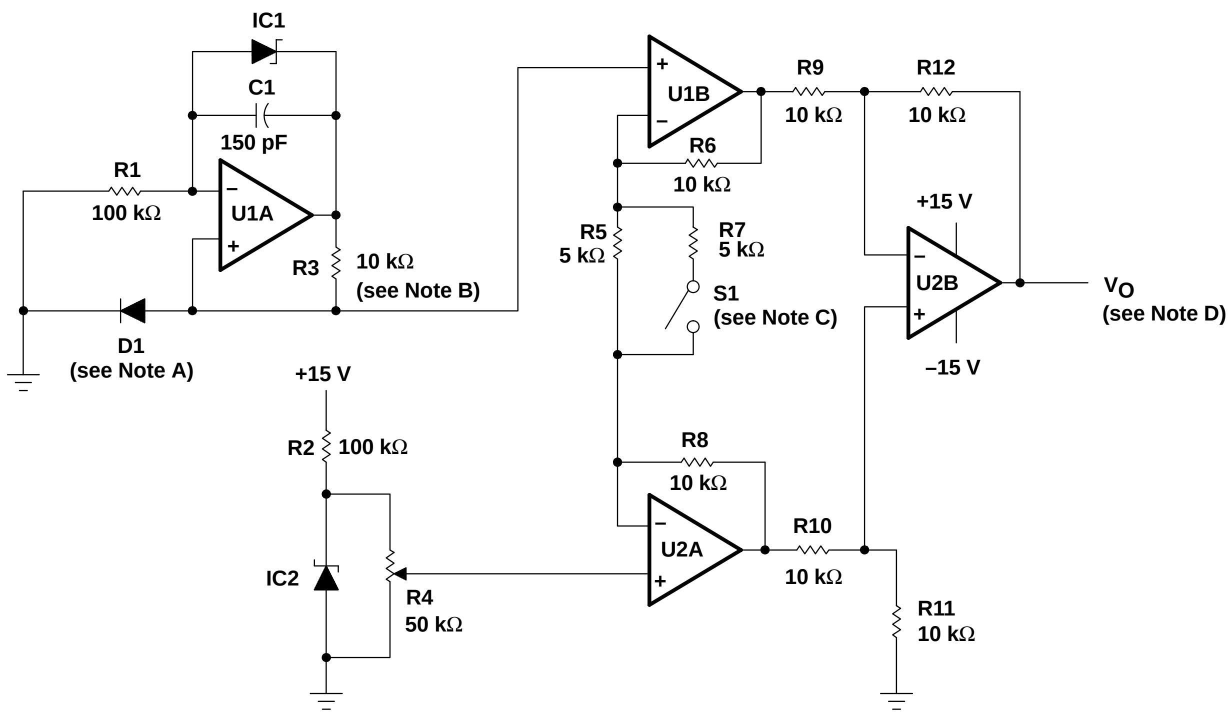
APPLICATION INFORMATION

analog thermometer

By combining a current source that does not vary over temperature with an instrumentation amplifier, a precise analog thermometer can be built (see Figure 89). Amplifier U1A and IC1 establish a constant current through the temperature-sensing diode D1. For this section of the circuit to operate correctly, the TL05x must use split supplies, and R3 must be a metal-film resistor with a low temperature coefficient.

The temperature-sensitive voltage from the diode is compared to a temperature-stable voltage reference set by IC2. R4 should be adjusted to provide the correct output voltage when the diode is at a known temperature. Although this potentiometer resistance varies with temperature, the divider ratio of the potentiometer remains constant.

Amplifiers U1B, U2A, and U2B form the instrumentation amplifier that converts the difference between the diode and reference voltage to a voltage proportional to the temperature. With switch S1 closed, the amplifier gain equals 5 and the output voltage is proportional to temperature in degrees Celsius. With S1 open, the amplifier gain is 9 and the output is proportional to temperature in degrees Fahrenheit. Every time S1 is changed, R4 must be recalibrated. By setting S1 correctly, the output voltage equals 10 mV per degree (C or F).



NOTES: A. Temperature-sensing diode ≈ (–2 mV/°C)
B. Metal-film resistor (low temperature coefficient)
C. Switch open for °F and closed for °C
D. V_O α temperature; 10 mV/°C or 10 mV/°F
E. U1, U2 = TL05x. IC1, IC2 = LM385, LT1004, or LT1009 voltage reference

Figure 89. Analog Thermometer

APPLICATION INFORMATION

voltage-ratio-to-dB converter

The application in Figure 90 measures the amplitude ratio of two signals, then converts the ratio to decibels (see Figure 91). The output voltage provides a resolution of 100 mV/dB. The two inputs can be either dc or sinusoidal ac signals. When using ac signals, both signals should be the same frequency or output glitches will occur. For measuring two input signals of different frequencies, extra filtering should be added after the rectifiers.

The circuit contains three low-offset TL05xA devices. Two of these devices provide the rectification and logarithmic conversion of the inputs. The third TL05xA forms an instrumentation amplifier. The stage performing the logarithmic conversion also requires two well-matched npn transistors.

The input signal first passes through a high-impedance unity-gain buffer U1A (U2A). Then U1B (U2B) rectifies the input signal at a gain of 0.5, and U1C (U2C) provides a noninverting gain of 2, so that the system gain is still one. U1D (U2D), R6 (R13), and Q1 (Q2) perform the logarithmic conversion of the rectified input signal. The instrumentation amplifier formed by U3A, U3B, U3D scales the difference of the two logarithmic voltages by a gain of 33.6. As a result, the output voltage equals 100 mV/dB. The 1-kΩ potentiometer on the input of U3C calibrates the zero-dB reference level. The following equations are used to derive the relationship between the input voltage ratio, expressed in decibels, and the output voltage.

$$X\ dB = 20\ \log\left[\frac{V_A}{V_B}\right] = 20\left[\frac{\ln\left(V_A\right) - \left(V_B\right)}{\ln\ (10)}\right]$$

$$X\ dB = 8.686\left[\ln\left(V_A\right) - \ln\left(V_B\right)\right]$$

$$V_{BE(Q1)} = \frac{kT}{q}\ \ln\left[\frac{V_A}{R \times I_S}\right] \qquad V_{BE(Q2)} = \frac{kT}{q}\ \ln\left[\frac{V_B}{R \times I_S}\right]$$

$$\Delta V_{BE} = V_{BE(Q1)} - V_{BE(Q2)} = \frac{kT}{q}\left[\ln\left(V_A\right) - \ln\left(V_B\right)\right]$$

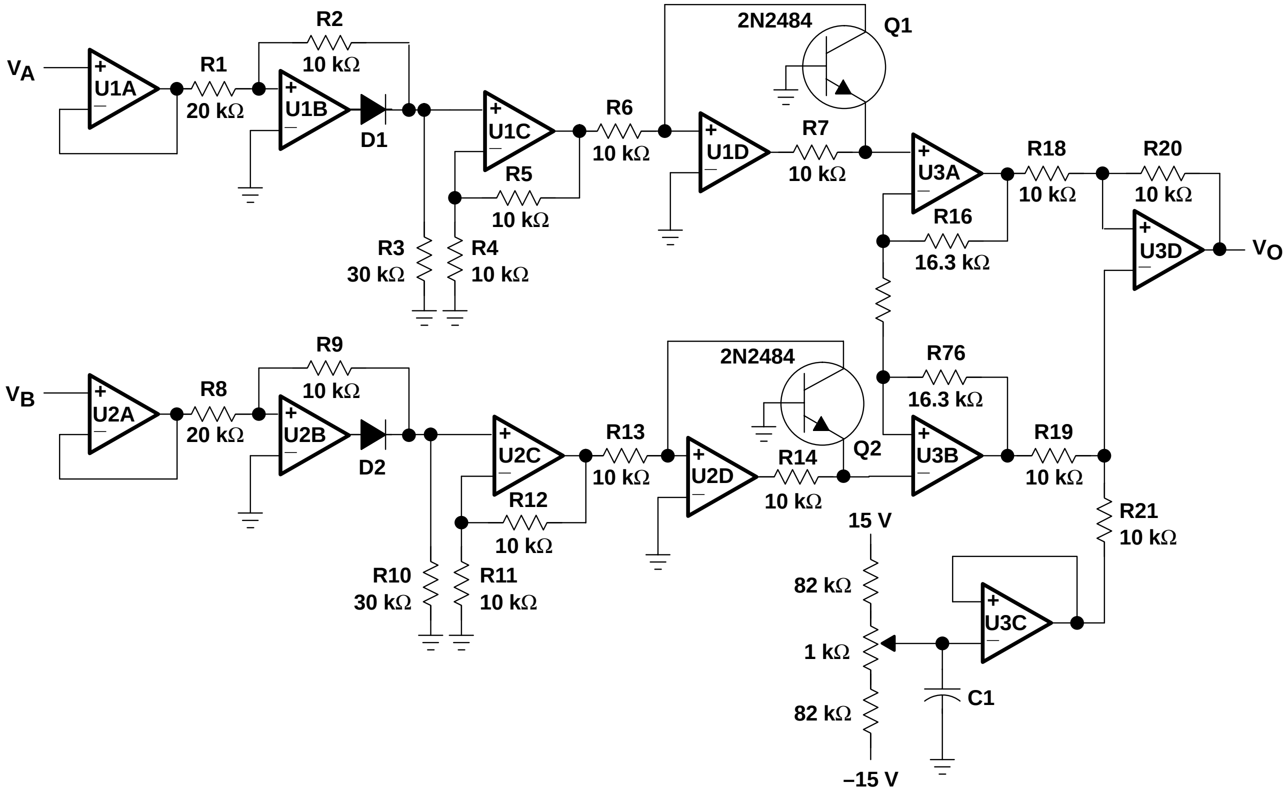
$$X\ dB = \frac{8.686}{kT/q}\left[V_{BE(Q1)} - V_{BE(Q2)}\right] = 336\left[V_{BE(Q1)} - V_{BE(Q2)}\right]\ \text{at}\ 25°C$$

where

$$k = 1.38 \times 10^{-23},\ q = 1.602 \times 10^{-19},\ \text{and T is Kelvin temperature}$$

This gives a resolution of 1 V/dB. Therefore, the gain of the instrumentation amplifier is set at 33.6 to obtain 100 mV/dB.

APPLICATION INFORMATION



NOTE A: U1A through U3D = TL05xA, $V_{CC\pm}$ = ±15 V. D1 and D2 = 1N914.

Figure 90. Voltage Ratio-to-dB Converter

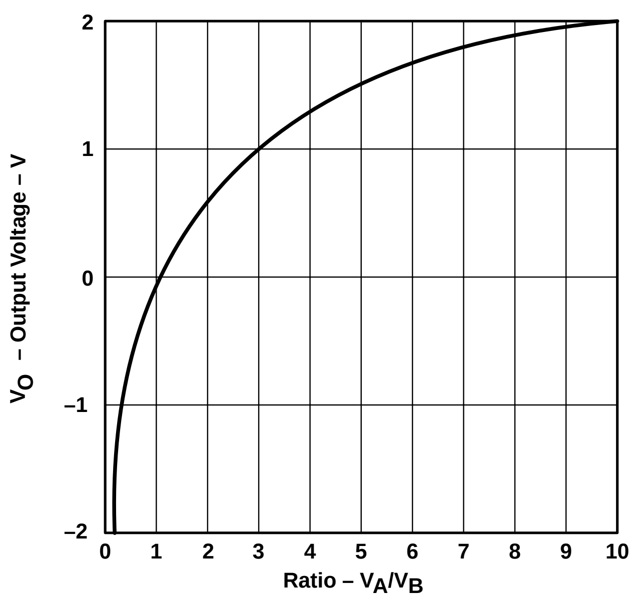


Figure 91. Output Voltage vs the Ratio of the Input Voltages for Voltage-to-dB Converter

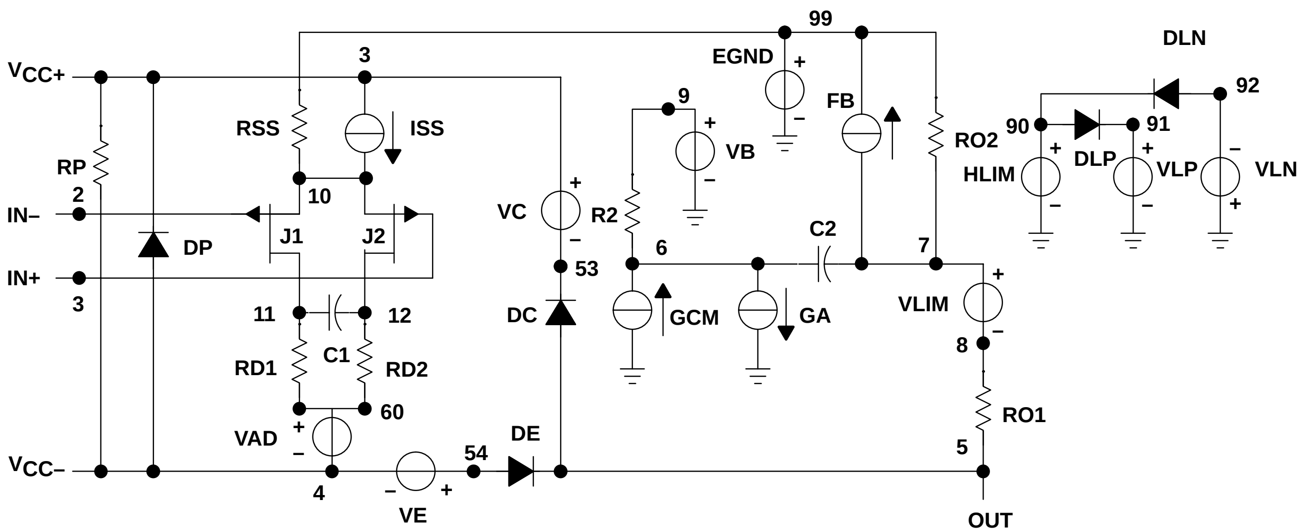
APPLICATION INFORMATION

macromodel information

Macromodel information provided was derived using Microsim *Parts*™, the model-generation software used with Microsim *PSpice*™. The Boyle macromodel (see Note 6 and subcircuit Figure 92) are generated using the TL05x typical electrical and operating characteristics at T_A = 25°C. Using this information, output simulations of the following key parameters can be generated to a tolerance of 20% (in most cases):

- Maximum positive output voltage swing
- Maximum negative output voltage swing
- Slew rate
- Quiescent power dissipation
- Input bias current
- Open-loop voltage amplification
- Unity-gain frequency
- Common-mode rejection ratio
- Phase margin
- DC output resistance
- AC output resistance
- Short-circuit output current limit

NOTE 6: G. R. Boyle, B. M. Cohn, D. O. Pederson, and J. E. Solomon, "Macromodeling of Integrated Circuit Operational Amplifiers", *IEEE Journal of Solid-State Circuits,* SC-9, 353 (1974).

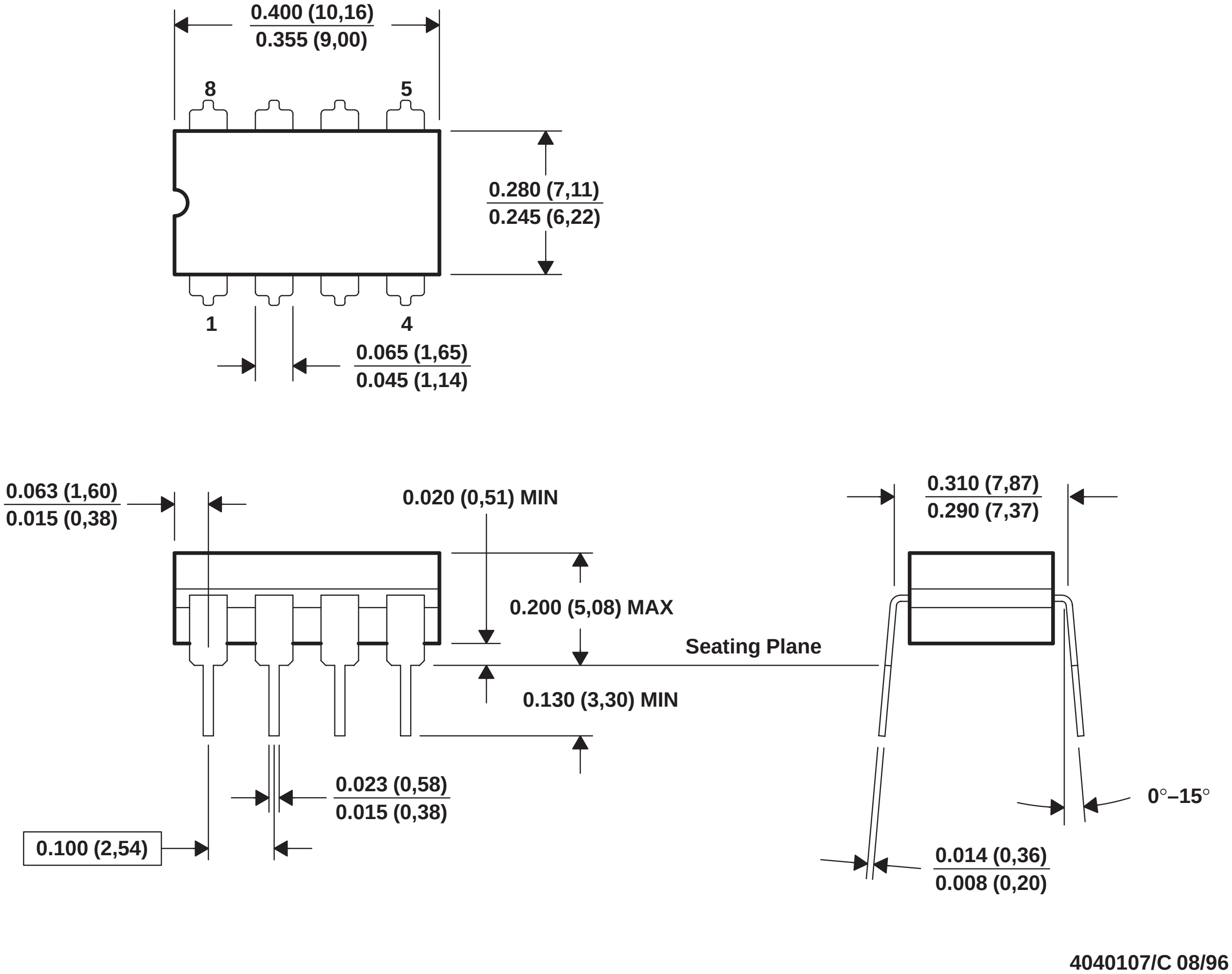



```
.SUBCKT TL05x 1 2 3 4 5
    C1    11   12    3.988E–12
    C2    6    7     15.00E–12
    DC    5    53    DX
    DE    54   5     DX
    DLP   90   91    DX
    DLN   92   90    DX
    DP    4    3     DX
    EGND  99   0     POLY (2) (3,0) (4,0) 0 .5 .5
    FB    7    99    POLY (5) VB VC VE VLP
    + VLN 0 2.875E6 –3E6 3E6 3E6 –3E6
    GA    6    0     11    12 292.2E–6
    GCM   0    6     10    99 6.542E–9
    ISS   3    10    DC 300.0E–6
    HLIM  90   0     VLIM 1K
    J1    11   2     10 JX
    J2    12   1     10 JX
    R2    6    9     100.0E3
RD1   4    11    3.422E3
RD2   4    12    3.422E3
R01   8    5     125
R02   7    99    125
RP    3    4     11.11E3
RSS   10   99    666.7E6
VB    9    0     DC 0
VC    3    53    DC 3
VE    54   4     DC 3.7
VLIM  7    8     DC 0
VLP   91   0     DC 28
VLN   0    92    DC 28
.MODEL DX D (IS=800.0E–18)
.MODEL JX PJF (IS=15.00E–12 BETA=185.2E–6
+ VTO=–.1)
.ENDS
```

Figure 92. Boyle Macromodel and Subcircuit

PSpice and *Parts* are trademarks of MicroSim Corporation.

JG (R-GDIP-T8) CERAMIC DUAL-IN-LINE

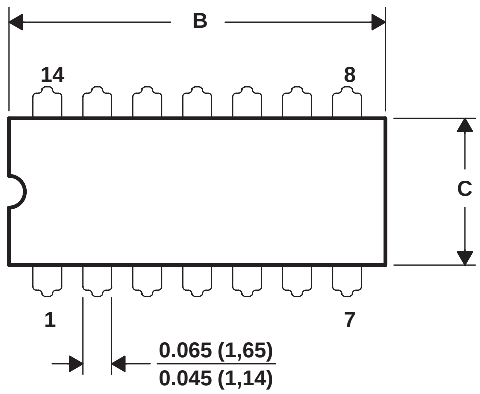


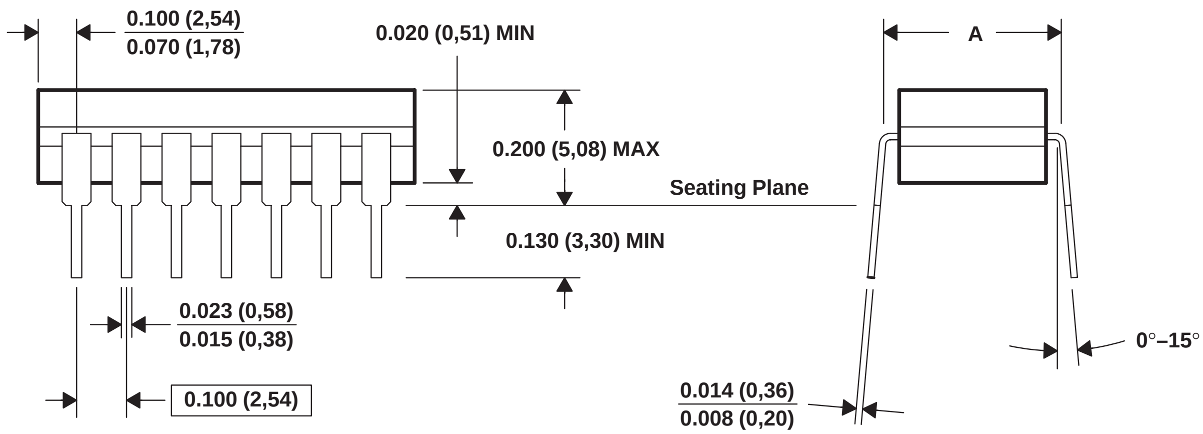
NOTES:
- A. All linear dimensions are in inches (millimeters).
- B. This drawing is subject to change without notice.
- C. This package can be hermetically sealed with a ceramic lid using glass frit.
- D. Index point is provided on cap for terminal identification.
- E. Falls within MIL STD 1835 GDIP1-T8

J (R-GDIP-T**) CERAMIC DUAL-IN-LINE

14 LEADS SHOWN

DIM \ PINS **	14	16	20
A MAX	0.310 (7,87)	0.310 (7,87)	0.310 (7,87)
A MIN	0.290 (7,37)	0.290 (7,37)	0.290 (7,37)
B MAX	0.785 (19,94)	0.785 (19,94)	0.975 (24,77)
B MIN	0.755 (19,18)	0.755 (19,18)	0.930 (23,62)
C MAX	0.300 (7,62)	0.300 (7,62)	0.300 (7,62)
C MIN	0.245 (6,22)	0.245 (6,22)	0.245 (6,22)



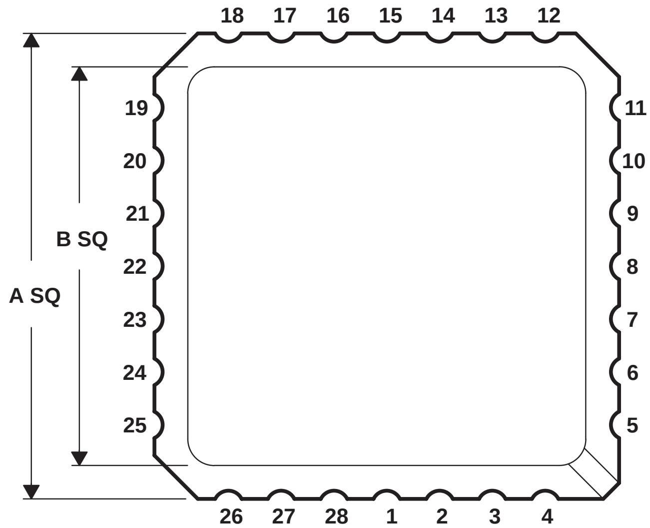


4040083/E 03/99

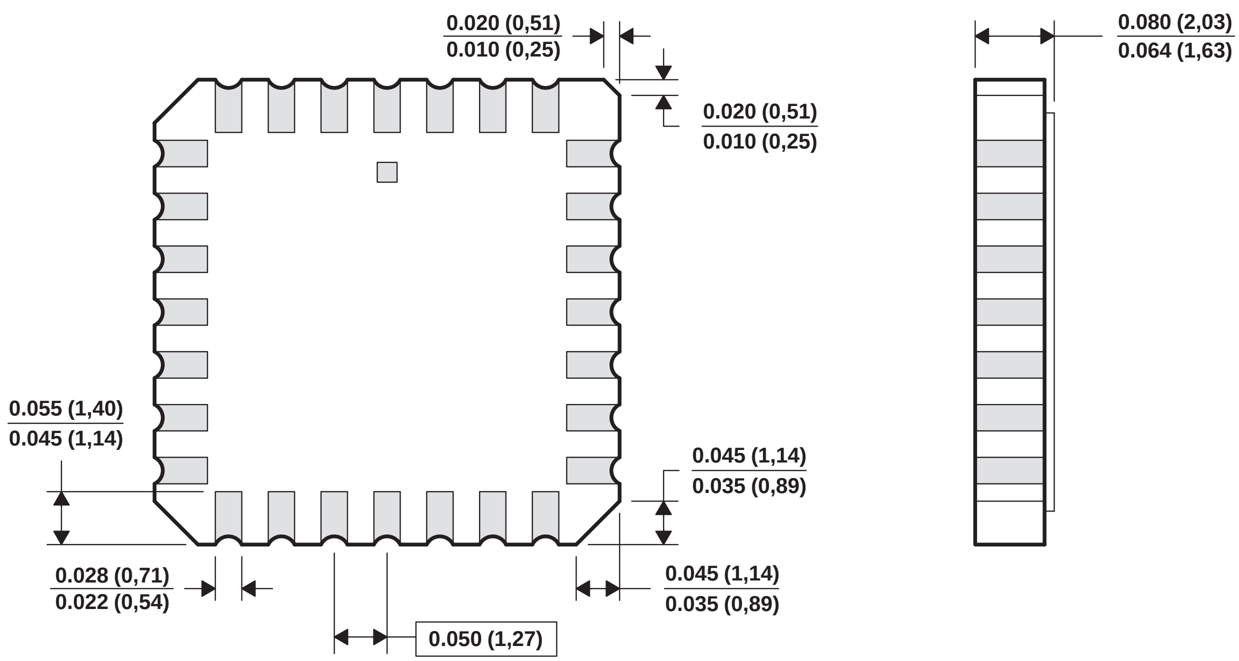
NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. This package is hermetically sealed with a ceramic lid using glass frit.
D. Index point is provided on cap for terminal identification.
E. Falls within MIL STD 1835 GDIP1-T14, GDIP1-T16, and GDIP1-T20

FK (S-CQCC-N)** **LEADLESS CERAMIC CHIP CARRIER**

28 TERMINAL SHOWN



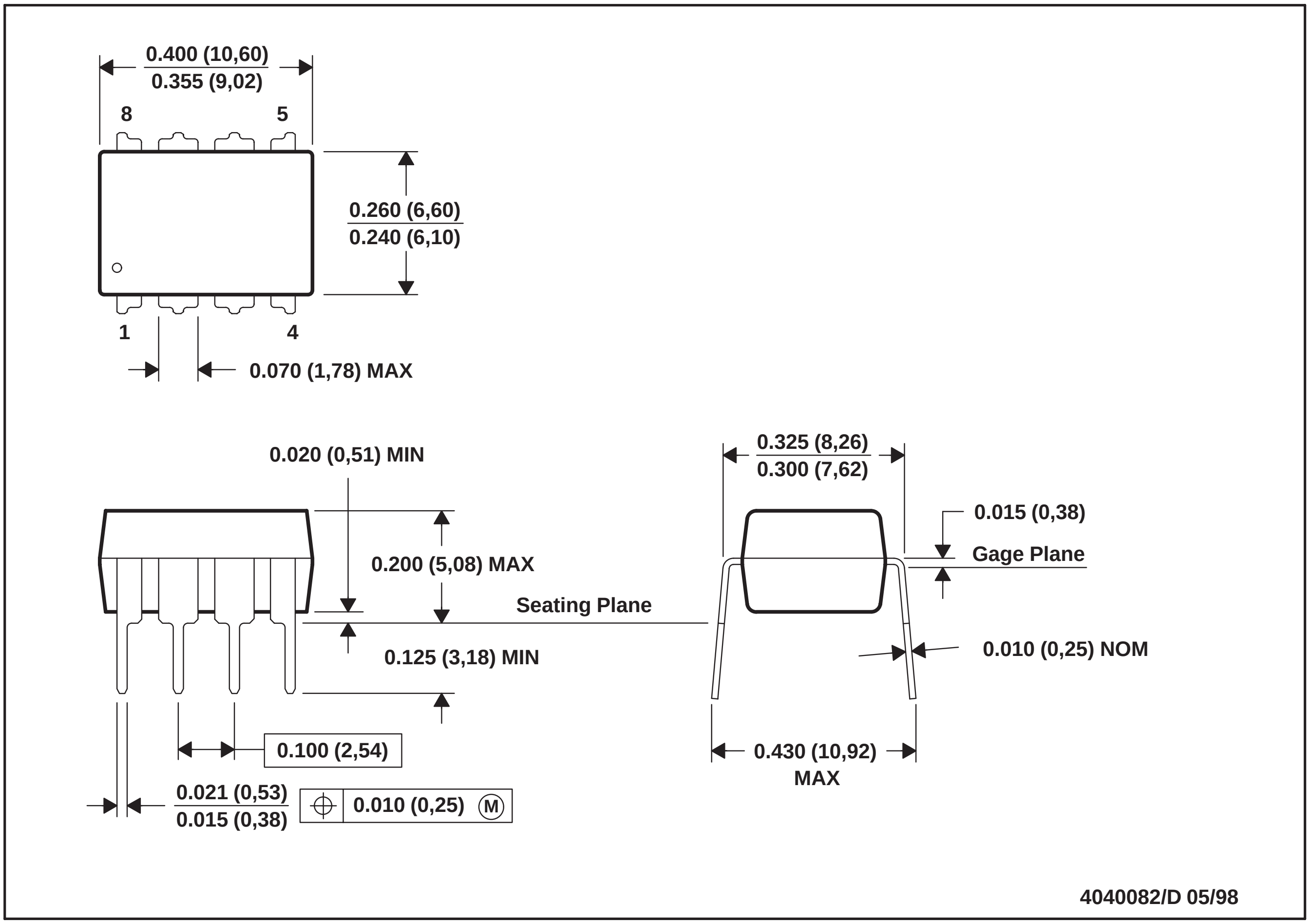
NO. OF TERMINALS **	A		B	
	MIN	MAX	MIN	MAX
20	0.342 (8,69)	0.358 (9,09)	0.307 (7,80)	0.358 (9,09)
28	0.442 (11,23)	0.458 (11,63)	0.406 (10,31)	0.458 (11,63)
44	0.640 (16,26)	0.660 (16,76)	0.495 (12,58)	0.560 (14,22)
52	0.739 (18,78)	0.761 (19,32)	0.495 (12,58)	0.560 (14,22)
68	0.938 (23,83)	0.962 (24,43)	0.850 (21,6)	0.858 (21,8)
84	1.141 (28,99)	1.165 (29,59)	1.047 (26,6)	1.063 (27,0)



4040140 / D 10/96

NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. This package can be hermetically sealed with a metal lid.
D. The terminals are gold plated.
E. Falls within JEDEC MS-004

P (R-PDIP-T8) **PLASTIC DUAL-IN-LINE**



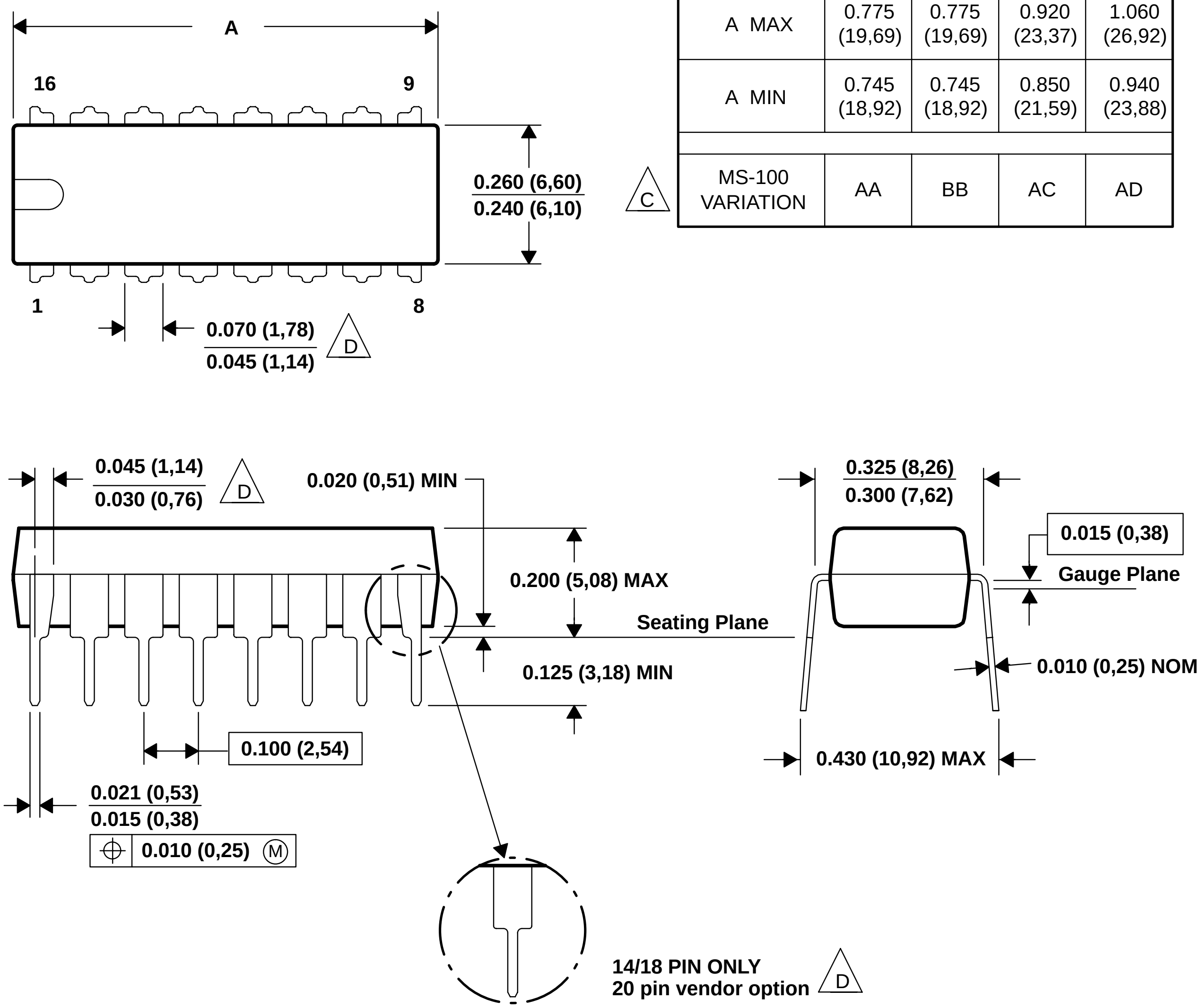
NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Falls within JEDEC MS-001

For the latest package information, go to http://www.ti.com/sc/docs/package/pkg_info.htm

N (R-PDIP-T**) PLASTIC DUAL-IN-LINE PACKAGE

16 PINS SHOWN

DIM \ PINS **	14	16	18	20
A MAX	0.775 (19,69)	0.775 (19,69)	0.920 (23,37)	1.060 (26,92)
A MIN	0.745 (18,92)	0.745 (18,92)	0.850 (21,59)	0.940 (23,88)
MS-100 VARIATION	AA	BB	AC	AD



NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Falls within JEDEC MS-001, except 18 and 20 pin minimum body lrngth (Dim A).
D. The 20 pin end lead shoulder width is a vendor option, either half or full width.

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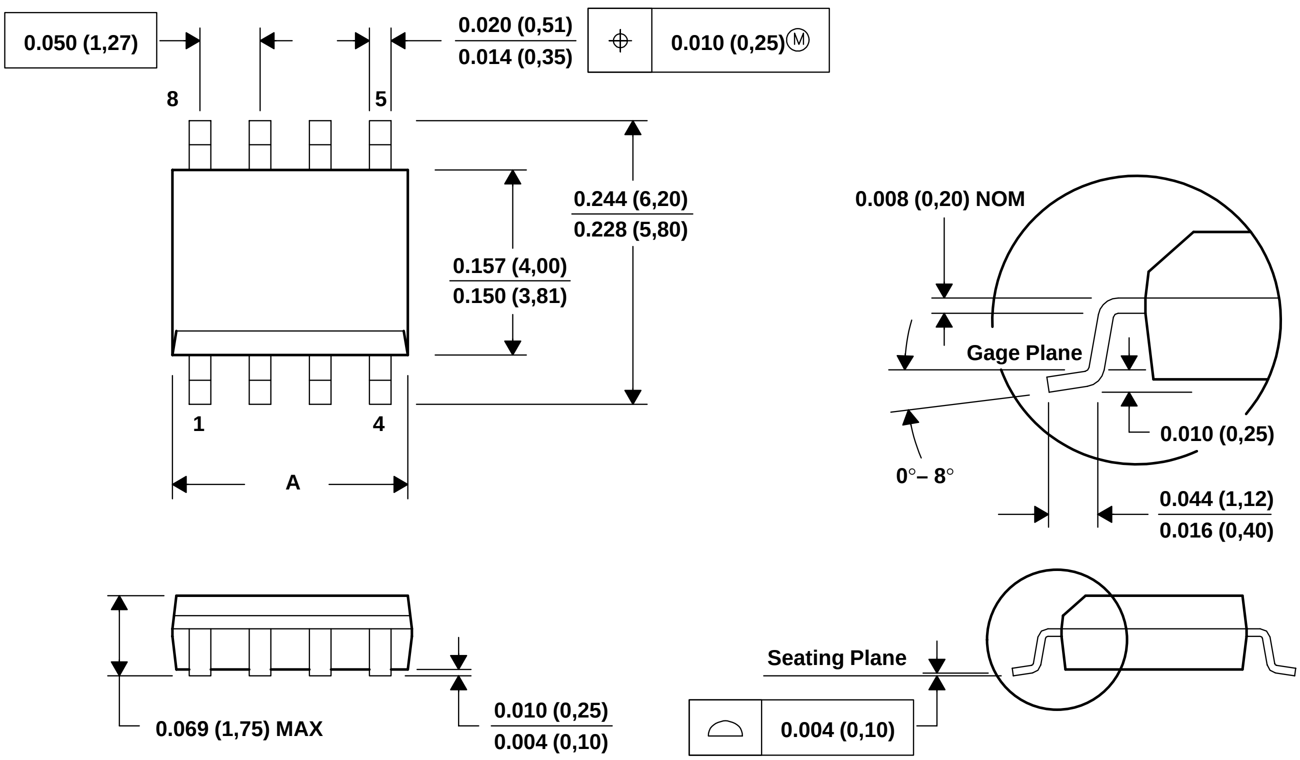
D (R-PDSO-G)** **PLASTIC SMALL-OUTLINE PACKAGE**

8 PINS SHOWN

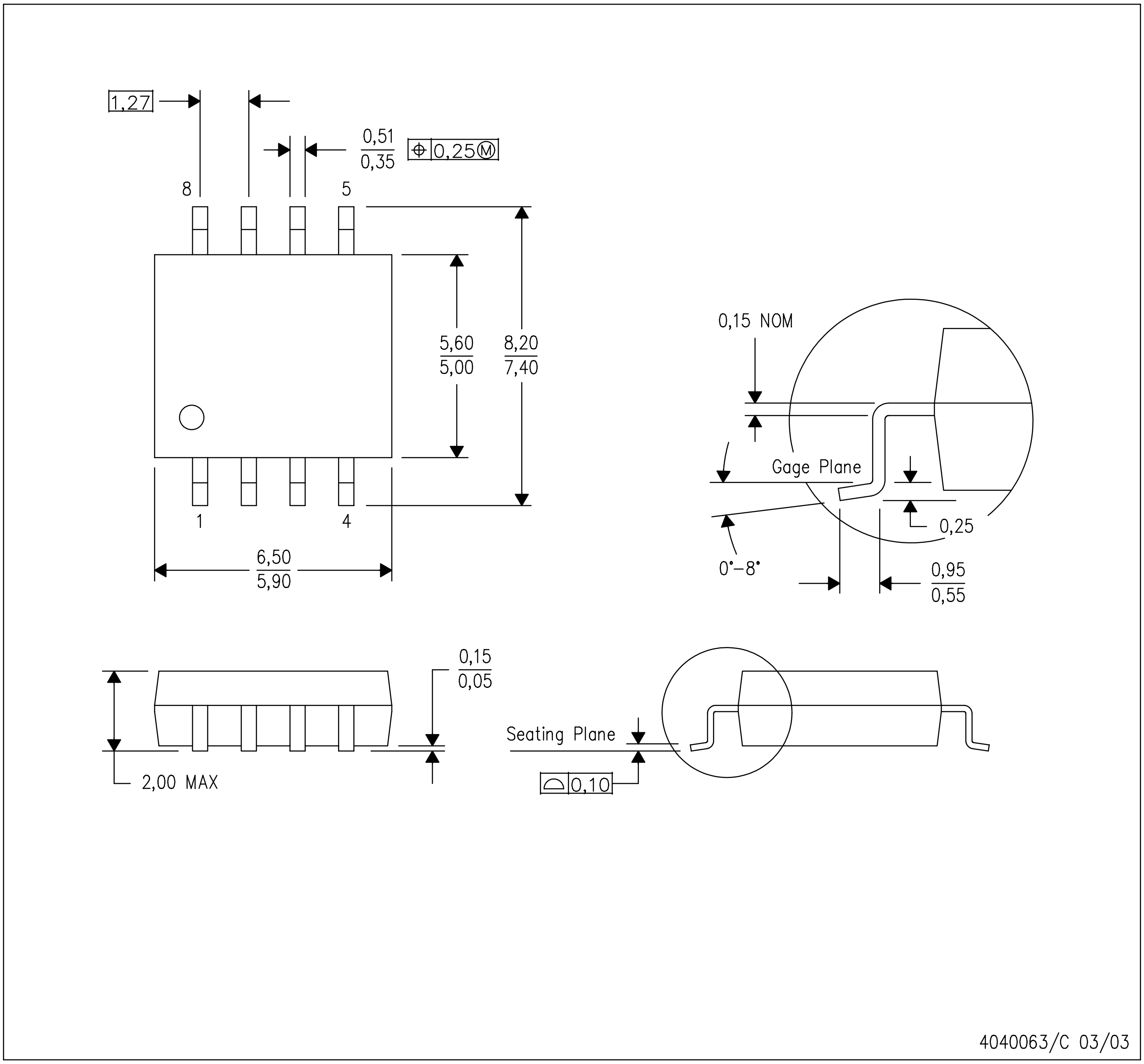


PINS ** / DIM	8	14	16
A MAX	0.197 (5,00)	0.344 (8,75)	0.394 (10,00)
A MIN	0.189 (4,80)	0.337 (8,55)	0.386 (9,80)

4040047/E 09/01

NOTES: A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion, not to exceed 0.006 (0,15).
D. Falls within JEDEC MS-012

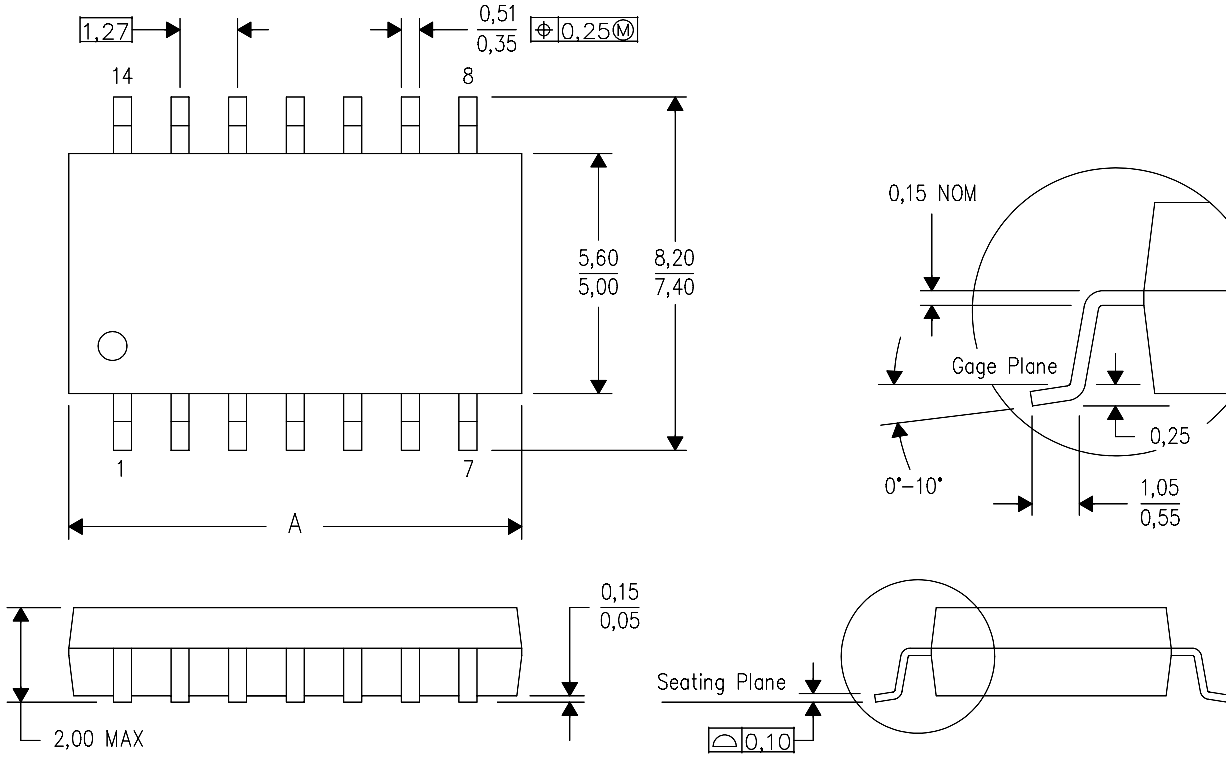
PS (R-PDSO-G8) PLASTIC SMALL-OUTLINE PACKAGE



NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion, not to exceed 0,15.

NS (R-PDSO-G**) PLASTIC SMALL-OUTLINE PACKAGE

14-PIN SHOWN



PINS ** / DIM	14	16	20	24
A MAX	10,50	10,50	12,90	15,30
A MIN	9,90	9,90	12,30	14,70

4040062/C 03/03

NOTES:
A. All linear dimensions are in millimeters.
B. This drawing is subject to change without notice.
C. Body dimensions do not include mold flash or protrusion, not to exceed 0,15.

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