THE DATASHEET OF

TLE2024AQDWRQ1

- **Qualified for Automotive Applications**
- **ESD Protection Exceeds 1000 V Per MIL-STD-883, Method 3015; Exceeds 200 V Using Machine Model (C = 200 pF, R = 0)**
- **Supply Current . . . 300 μA Max**
- **High Unity-Gain Bandwidth . . . 2 MHz Typ**
- **High Slew Rate . . . 0.45 V/μs Min**
- **Supply-Current Change Over Full Temp Range . . . 10 μA Typ at $V_{CC\pm} = \pm 15$ V**
- **Specified for Both 5-V Single-Supply and ±15-V Operation**
- **Phase-Reversal Protection**
- **High Open-Loop Gain . . . 6.5 V/μV (136 dB) Typ**
- **Low Offset Voltage . . . 100 μV Max**
- **Offset Voltage Drift With Time 0.005 μV/mo Typ**
- **Low Input Bias Current . . . 50 nA Max**
- **Low Noise Voltage . . . 19 nV/√Hz Typ**

description

The TLE202x and TLE202xA devices are precision, high-speed, low-power operational amplifiers using a new Texas Instruments Excalibur process. These devices combine the best features of the OP21 with highly improved slew rate and unity-gain bandwidth.

The complementary bipolar Excalibur process utilizes isolated vertical pnp transistors that yield dramatic improvement in unity-gain bandwidth and slew rate over similar devices.

The addition of a bias circuit in conjunction with this process results in extremely stable parameters with both time and temperature. This means that a precision device remains a precision device even with changes in temperature and over years of use.

This combination of excellent dc performance with a common-mode input voltage range that includes the negative rail makes these devices the ideal choice for low-level signal conditioning applications in either single-supply or split-supply configurations. In addition, these devices offer phase-reversal protection circuitry that eliminates an unexpected change in output states when one of the inputs goes below the negative supply rail.

A variety of available options includes small-outline versions for high-density systems applications.

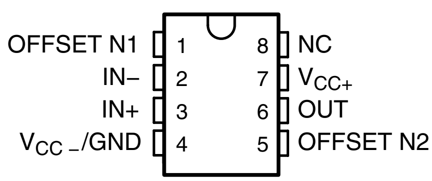
The Q-suffix devices are characterized for operation over the full automotive temperature range of −40°C to 125°C.

ORDERING INFORMATION†

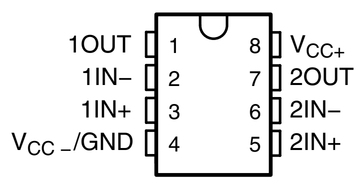
T_A	V_{IO}max AT 25°C	PACKAGE‡		ORDERABLE PART NUMBER	TOP-SIDE MARKING
−40°C to 125°C	200 µV	SOIC (D)	Tape and reel	TLE2021AQDRQ1	2021AQ
		TSSOP (PW)	Tape and reel	TLE2021AQPWRQ1§	2021AQ
	500 µV	SOIC (D)	Tape and reel	TLE2021QDRQ1	2021Q1
		TSSOP (PW)	Tape and reel	TLE2021QPWRQ1§	2021Q1
−40°C to 125°C	300 µV	SOIC (D)	Tape and reel	TLE2022AQDRQ1	2021AQ
		TSSOP (PW)	Tape and reel	TLE2022AQPWRQ1§	2022AQ1
	500 µV	SOIC (D)	Tape and reel	TLE2022QDRQ1	2022Q1
		TSSOP (PW)	Tape and reel	TLE2022QPWRQ1§	2022Q1
−40°C to 125°C	750 µV	SOP (DW)	Tape and reel	TLE2024AQDWRQ1	2024AQ1
	1000 µV	SOP (DW)	Tape and reel	TLE2024QDWRQ1	2024Q1

† For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI web site at http://www.ti.com.
‡ Package drawings, thermal data, and symbolization are available at http://www.ti.com/packaging.
§ Product preview

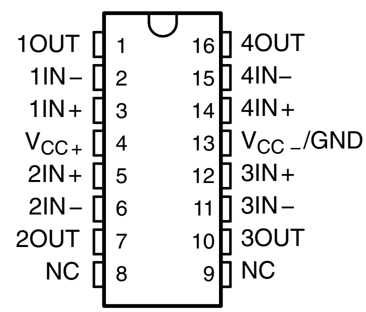
TLE2021
D OR PW PACKAGE
(TOP VIEW)



TLE2022
D OR PW PACKAGE
(TOP VIEW)

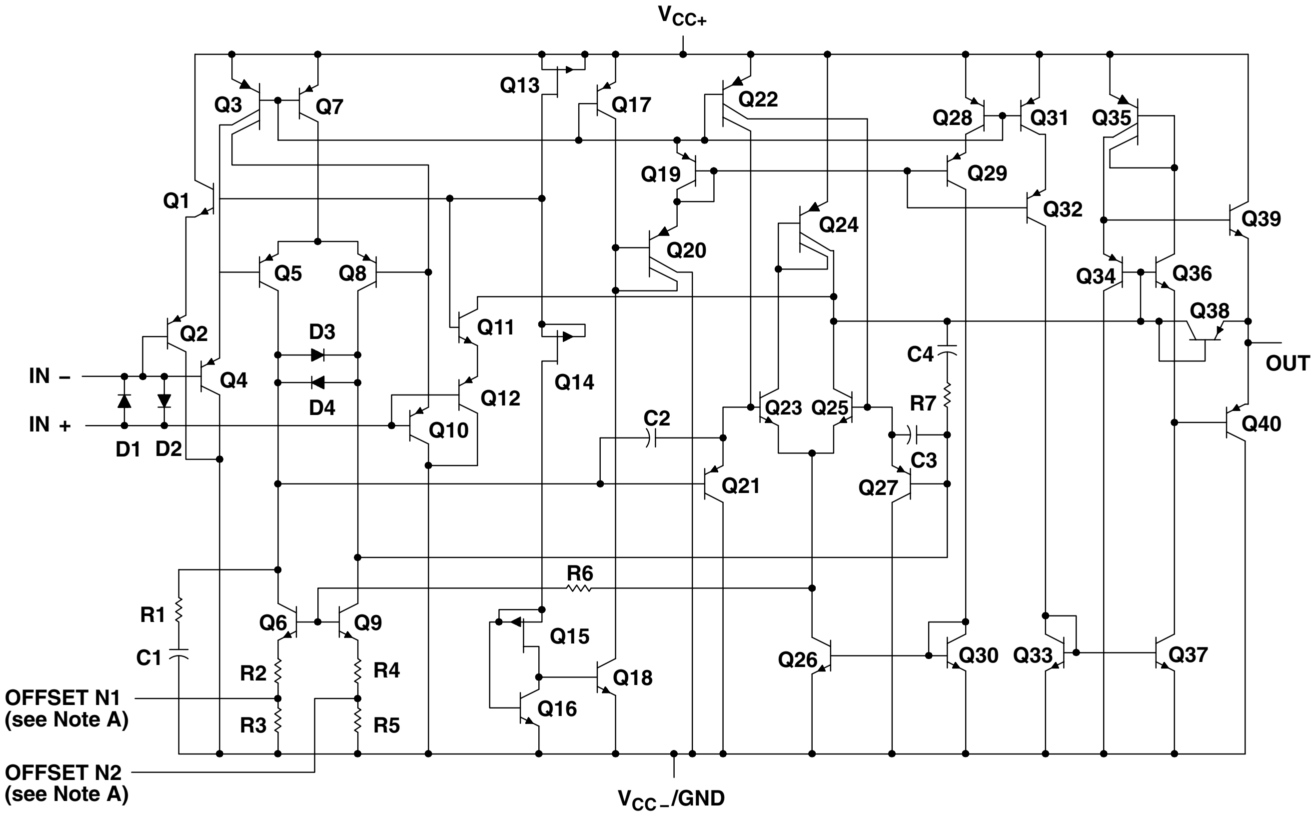


TLE2024
DW PACKAGE
(TOP VIEW)



NC – No internal connection

equivalent schematic (each amplifier)



ACTUAL DEVICE COMPONENT COUNT			
COMPONENT	TLE2021	TLE2022	TLE2024
Transistors	40	80	160
Resistors	7	14	28
Diodes	4	8	16
Capacitors	4	8	16

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

Supply voltage, V_{CC+} (see Note 1) . . . 20 V
Supply voltage, V_{CC-} (see Note 1) . . . –20 V
Differential input voltage, V_{ID} (see Note 2) . . . ±0.6 V
Input voltage range, V_I (any input, see Note 1) . . . $\pm V_{CC}$
Input current, I_I (each input) . . . ±1 mA
Output current, I_O (each output): TLE2021 . . . ±20 mA
TLE2022 . . . ±30 mA
TLE2024 . . . ±40 mA
Total current into V_{CC+} . . . 80 mA
Total current out of V_{CC-} . . . 80 mA
Duration of short-circuit current at (or below) 25°C (see Note 3) . . . unlimited
Operating free-air temperature range, T_A: Q suffix . . . –40°C to 125°C
Operating virtual junction temperature, T_J . . . 150°C
Package thermal impedance, $R_{\theta JA}$ (see Notes 4 and 5): D (8 pin) . . . 97°C/W
DW (16 pin) . . . 57°C/W
PW (8 pin) . . . 149°C/W
PW (14 pin) . . . 113°C/W
Storage temperature range, T_{stg} . . . –65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 3 seconds: D or PW package . . . 300°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–. Excessive current flows if a differential input voltage in excess of approximately ±600 mV is applied between the inputs unless some limiting resistance is used.
3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation rating is not exceeded.
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 $P_D = (T_J(max) - T_A)/\theta_{JA}$. Selecting the maximum of 150°C can affect reliability.
5. The package thermal impedance is calculated in accordance with JESD 51-7.

recommended operating conditions

		MIN	MAX	UNIT
Supply voltage, V_{CC}		±2	±20	V
Common-mode input voltage, V_{IC}	V_{CC} = ± 5 V	0	3.2	V
	$V_{CC\pm}$ = ±15 V	–15	13.2	
Operating free-air temperature, T_A		–40	125	°C

TLE2021 electrical characteristics at specified free-air temperature, V_{CC} = 5 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_A†	TLE2021-Q1 MIN	TLE2021-Q1 TYP	TLE2021-Q1 MAX	TLE2021A-Q1 MIN	TLE2021A-Q1 TYP	TLE2021A-Q1 MAX	UNIT
V_{IO}	Input offset voltage	V_{IC} = 0, R_S = 50 Ω	25°C		120	600		100	400	μV
			Full range			800			550	
α_{VIO}	Temperature coefficient of input offset voltage		Full range		2			2		μV/°C
	Input offset voltage long-term drift (see Note 4)		25°C		0.005			0.005		μV/mo
I_{IO}	Input offset current		25°C		0.2	6		0.2	6	nA
			Full range			10			10	
I_{IB}	Input bias current		25°C		25	70		25	70	nA
			Full range			90			90	
V_{ICR}	Common-mode input voltage range	R_S = 50 Ω	25°C	0 to 3.5	−0.3 to 4		0 to 3.5	−0.3 to 4		V
			Full range	0 to 3.2			0 to 3.2			
V_{OH}	High-level output voltage	R_L = 10 kΩ	25°C	4	4.3		4	4.3		V
			Full range	3.8			3.8			
V_{OL}	Low-level output voltage		25°C		0.7	0.8		0.7	0.8	V
			Full range			0.95			0.95	
A_{VD}	Large-signal differential voltage amplification	V_O = 1.4 V to 4 V, R_L = 10 kΩ	25°C	0.3	1.5		0.3	1.5		V/μV
			Full range	0.1			0.1			
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}$min, R_S = 50 Ω	25°C	85	110		85	110		dB
			Full range	80			80			
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{CC\pm}/\Delta V_{IO}$)	V_{CC} = 5 V to 30 V	25°C	105	120		105	120		dB
			Full range	100			100			
I_{CC}	Supply current	V_O = 2.5 V, No load	25°C		170	300		170	300	μA
			Full range			300			300	
ΔI_{CC}	Supply current change over operating temperature range		Full range		9			9		μA

† Full range is −40°C to 125°C.

NOTE 4: 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.

TLE2021 electrical characteristics at specified free-air temperature, $V_{CC} = \pm 15$ V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_A†	TLE2021-Q1 MIN	TLE2021-Q1 TYP	TLE2021-Q1 MAX	TLE2021A-Q1 MIN	TLE2021A-Q1 TYP	TLE2021A-Q1 MAX	UNIT
V_{IO}	Input offset voltage	$V_{IC} = 0$, $R_S = 50\ \Omega$	25°C		120	500		80	300	µV
			Full range			700			450	
α_{VIO}	Temperature coefficient of input offset voltage		Full range		2			2		µV/°C
	Input offset voltage long-term drift (see Note 4)		25°C		0.006			0.006		µV/mo
I_{IO}	Input offset current		25°C		0.2	6		0.2	6	nA
			Full range			10			10	
I_{IB}	Input bias current		25°C		25	70		25	70	nA
			Full range			90			90	
V_{ICR}	Common-mode input voltage range	$R_S = 50\ \Omega$	25°C	–15 to 13.5	–15.3 to 14		–15 to 13.5	–15.3 to 14		V
			Full range	–15 to 13.2			–15 to 13.2			
V_{OM+}	Maximum positive peak output voltage swing	$R_L = 10\ k\Omega$	25°C	14	14.3		14	14.3		V
			Full range	13.8			13.8			
V_{OM-}	Maximum negative peak output voltage swing		25°C	–13.7	–14.1		–13.7	–14.1		V
			Full range	–13.6			–13.6			
A_{VD}	Large-signal differential voltage amplification	$V_O = \pm 10$ V, $R_L = 10\ k\Omega$	25°C	1	6.5		1	6.5		V/µV
			Full range	0.5			0.5			
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}$min, $R_S = 50\ \Omega$	25°C	100	115		100	115		dB
			Full range	96			96			
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{CC\pm}/\Delta V_{IO}$)	$V_{CC\pm} = \pm 2.5$ V to ± 15 V	25°C	105	120		105	120		dB
			Full range	100			100			
I_{CC}	Supply current	$V_O = 0$, No load	25°C		200	350		200	350	µA
			Full range			350			350	
ΔI_{CC}	Supply current change over operating temperature range		Full range		10			10		µA

† Full range is –40°C to 125°C.

NOTE 4: 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.

TLE2022 electrical characteristics at specified free-air temperature, V_{CC} = 5 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_A†	TLE2022-Q1			TLE2022A-Q1			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage	V_{IC} = 0, R_S = 50 Ω	25°C			600			400	μV
			Full range			800			550	
α_{VIO}	Temperature coefficient of input offset voltage		Full range		2			2		μV/°C
	Input offset voltage long-term drift (see Note 4)		25°C		0.005			0.005		μV/mo
I_{IO}	Input offset current		25°C		0.5	6		0.4	6	nA
			Full range			10			10	
I_{IB}	Input bias current		25°C		35	70		33	70	nA
			Full range			90			90	
V_{ICR}	Common-mode input voltage range	R_S = 50 Ω	25°C	0 to 3.5	–0.3 to 4		0 to 3.5	–0.3 to 4		V
			Full range	0 to 3.2			0 to 3.2			
V_{OH}	High-level output voltage	R_L = 10 kΩ	25°C	4	4.3		4	4.3		V
			Full range	3.8			3.8			
V_{OL}	Low-level output voltage		25°C		0.7	0.8		0.7	0.8	V
			Full range			0.95			0.95	
A_{VD}	Large-signal differential voltage amplification	V_O = 1.4 V to 4 V, R_L = 10 kΩ	25°C	0.3	1.5		0.4	1.5		V/μV
			Full range	0.1			0.1			
CMRR	Common-mode rejection ratio	V_{IC} = V_{ICR}min, R_S = 50 Ω	25°C	85	100		87	102		dB
			Full range	80			82			
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{CC\pm}/\Delta V_{IO}$)	V_{CC} = 5 V to 30 V	25°C	100	115		103	118		dB
			Full range	95			98			
I_{CC}	Supply current	V_O = 2.5 V, No load	25°C		450	600		450	600	μA
			Full range			600			600	
ΔI_{CC}	Supply current change over operating temperature range		Full range		37			37		μA

† Full range is –40°C to 125°C.

NOTE 4: 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.

TLE2022 electrical characteristics at specified free-air temperature, V_{CC} = ±15 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_A†	TLE2022-Q1 MIN	TLE2022-Q1 TYP	TLE2022-Q1 MAX	TLE2022A-Q1 MIN	TLE2022A-Q1 TYP	TLE2022A-Q1 MAX	UNIT
V_{IO}	Input offset voltage	V_{IC} = 0, R_S = 50 Ω	25°C		150	500		120	300	μV
			Full range			700			450	
α_{VIO}	Temperature coefficient of input offset voltage		Full range		2			2		μV/°C
	Input offset voltage long-term drift (see Note 4)		25°C		0.006			0.006		μV/mo
I_{IO}	Input offset current		25°C		0.5	6		0.4	6	nA
			Full range			10			10	
I_{IB}	Input bias current		25°C		35	70		33	70	nA
			Full range			90			90	
V_{ICR}	Common-mode input voltage range	R_S = 50 Ω	25°C	–15 to 13.5	–15.3 to 14		–15 to 13.5	–15.3 to 14		V
			Full range	–15 to 13.2			–15 to 13.2			
V_{OM+}	Maximum positive peak output voltage swing	R_L = 10 kΩ	25°C	14	14.3		14	14.3		V
			Full range	13.8			13.8			
V_{OM-}	Maximum negative peak output voltage swing		25°C	–13.7	–14.1		–13.7	–14.1		V
			Full range	–13.6			–13.6			
A_{VD}	Large-signal differential voltage amplification	V_O = ±10 V, R_L = 10 kΩ	25°C	0.8	4		1	7		V/μV
			Full range	0.8			1			
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}$min, R_S = 50 Ω	25°C	95	106		97	109		dB
			Full range	91			93			
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{CC\pm}/\Delta V_{IO}$)	$V_{CC\pm}$ = ±2.5 V to ±15 V	25°C	100	115		103	118		dB
			Full range	95			98			
I_{CC}	Supply current	V_O = 0, No load	25°C		550	700		550	700	μA
			Full range			700			700	
ΔI_{CC}	Supply current change over operating temperature range		Full range		60			60		μA

† Full range is –40°C to 125°C.

NOTE 4: 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.

TLE2024 electrical characteristics at specified free-air temperature, V_{CC} = 5 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_A†	TLE2024-Q1			TLE2024A-Q1			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage	V_{IC} = 0, R_S = 50 Ω	25°C			1100			850	μV
			Full range			1300			1050	
α_{VIO}	Temperature coefficient of input offset voltage		Full range		2			2		μV/°C
	Input offset voltage long-term drift (see Note 4)		25°C		0.005			0.005		μV/mo
I_{IO}	Input offset current		25°C		0.6	6		0.5	6	nA
			Full range			10			10	
I_{IB}	Input bias current		25°C		45	70		40	70	nA
			Full range			90			90	
V_{ICR}	Common-mode input voltage range	R_S = 50 Ω	25°C	0 to 3.5	–0.3 to 4		0 to 3.5	–0.3 to 4		V
			Full range	0 to 3.2			0 to 3.2			
V_{OH}	High-level output voltage	R_L = 10 kΩ	25°C	3.9	4.2		3.9	4.2		V
			Full range	3.7			3.7			
V_{OL}	Low-level output voltage		25°C		0.7	0.8		0.7	0.8	V
			Full range			0.95			0.95	
A_{VD}	Large-signal differential voltage amplification	V_O = 1.4 V to 4 V, R_L = 10 kΩ	25°C	0.2	1.5		0.3	1.5		V/μV
			Full range	0.1			0.1			
CMRR	Common-mode rejection ratio	V_{IC} = V_{ICR}min, R_S = 50 Ω	25°C	80	90		82	92		dB
			Full range	80			82			
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{CC\pm}/\Delta V_{IO}$)	$V_{CC\pm}$ = ±2.5 V to ±15 V	25°C	98	112		100	115		dB
			Full range	93			95			
I_{CC}	Supply current	V_O = 0, No load	25°C		800	1200		800	1200	μA
			Full range			1200			1200	
ΔI_{CC}	Supply current change over operating temperature range		Full range		50			50		μA

† Full range is –40°C to 125°C.

NOTE 4: 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.

TLE2024 electrical characteristics at specified free-air temperature, V_{CC} = ±15 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_A†	TLE2024-Q1			TLE2024A-Q1			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage	V_{IC} = 0, R_S = 50 Ω	25°C			1000			750	μV
			Full range			1200			950	
α_{VIO}	Temperature coefficient of input offset voltage		Full range		2			2		μV/°C
	Input offset voltage long-term drift (see Note 4)		25°C		0.006			0.006		μV/mo
I_{IO}	Input offset current		25°C		0.6	6		0.2	6	nA
			Full range			10			10	
I_{IB}	Input bias current		25°C		50	70		45	70	nA
			Full range			90			90	
V_{ICR}	Common-mode input voltage range	R_S = 50 Ω	25°C	–15 to 13.5	–15.3 to 14		–15 to 13.5	–15.3 to 14		V
			Full range	–15 to 13.2			–15 to 13.2			
V_{OM+}	Maximum positive peak output voltage swing	R_L = 10 kΩ	25°C	13.8	14.1		13.8	14.2		V
			Full range	13.7			13.7			
V_{OM-}	Maximum negative peak output voltage swing		25°C	–13.7	–14.1		–13.7	–14.1		V
			Full range	–13.6			–13.6			
A_{VD}	Large-signal differential voltage amplification	V_O = ±10 V, R_L = 10 kΩ	25°C	0.4	2		0.8	4		V/μV
			Full range	0.4			0.8			
CMRR	Common-mode rejection ratio	V_{IC} = V_{ICR}min, R_S = 50 Ω	25°C	92	102		94	105		dB
			Full range	88			90			
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{CC\pm}/\Delta V_{IO}$)	$V_{CC\pm}$ = ±2.5 V to ±15 V	25°C	98	112		100	115		dB
			Full range	93			95			
I_{CC}	Supply current	V_O = 0, No load	25°C		1050	1400		1050	1400	μA
			Full range			1400			1400	
ΔI_{CC}	Supply current change over operating temperature range		Full range		85			85		μA

† Full range is –40°C to 125°C.

NOTE 4: 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.

TLE2021 operating characteristics, V_{CC} = 5 V, T_A = 25°C

PARAMETER		TEST CONDITIONS	T_A	MIN	TYP	MAX	UNIT
SR	Slew rate at unity gain	V_O = 1 V to 3 V, See Figure 1	25°C		0.5		V/µs
V_n	Equivalent input noise voltage (see Figure 2)	f = 10 Hz	25°C		21		nV/Hz
		f = 1 kHz	25°C		17		
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	f = 0.1 to 1 Hz	25°C		0.16		µV
		f = 0.1 to 10 Hz	25°C		0.47		
I_n	Equivalent input noise current		25°C		0.9		pA/Hz
B_1	Unity-gain bandwidth	See Figure 3	25°C		1.2		MHz
ϕ_m	Phase margin at unity gain	See Figure 3	25°C		42°		

TLE2021 operating characteristics at specified free-air temperature, V_{CC} = ±15 V

PARAMETER		TEST CONDITIONS	T_A†	MIN	TYP	MAX	UNIT
SR	Slew rate at unity gain	V_O = ±10 V, See Figure 1	25°C	0.45	0.65		V/µs
			Full range	0.4			
V_n	Equivalent input noise voltage (see Figure 2)	f = 10 Hz	25°C		19		nV/Hz
		f = 1 kHz	25°C		15		
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	f = 0.1 to 1 Hz	25°C		0.16		µV
		f = 0.1 to 10 Hz	25°C		0.47		
I_n	Equivalent input noise current		25°C		0.09		pA/Hz
B_1	Unity-gain bandwidth	See Figure 3	25°C		2		MHz
ϕ_m	Phase margin at unity gain	See Figure 3	25°C		46°		

† Full range is –40°C to 125°C for the Q-suffix devices.

TLE2022 operating characteristics, V_{CC} = 5 V, T_A = 25°C

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
SR	Slew rate at unity gain	V_O = 1 V to 3 V, See Figure 1		0.5		V/µs
V_n	Equivalent input noise voltage (see Figure 2)	f = 10 Hz		21		$nV/\sqrt{Hz}$
		f = 1 kHz		17		
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	f = 0.1 to 1 Hz		0.16		µV
		f = 0.1 to 10 Hz		0.47		
I_n	Equivalent input noise current			0.1		$pA/\sqrt{Hz}$
B_1	Unity-gain bandwidth	See Figure 3		1.7		MHz
ϕ_m	Phase margin at unity gain	See Figure 3		47°		

TLE2022 operating characteristics at specified free-air temperature, V_{CC} = ±15 V

PARAMETER		TEST CONDITIONS	T_A†	MIN	TYP	MAX	UNIT
SR	Slew rate at unity gain	V_O = ±10 V, See Figure 1	25°C	0.45	0.65		V/μs
			Full range	0.4			
V_n	Equivalent input noise voltage (see Figure 2)	f = 10 Hz	25°C		19		nV/√Hz
		f = 1 kHz	25°C		15		
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	f = 0.1 to 1 Hz	25°C		0.16		μV
		f = 0.1 to 10 Hz	25°C		0.47		
I_n	Equivalent input noise current		25°C		0.1		pA/√Hz
B_1	Unity-gain bandwidth	See Figure 3	25°C		2.8		MHz
ϕ_m	Phase margin at unity gain	See Figure 3	25°C		52°		

† Full range is –40°C to 125°C.

TLE2024 operating characteristics, V_{CC} = 5 V, T_A = 25°C

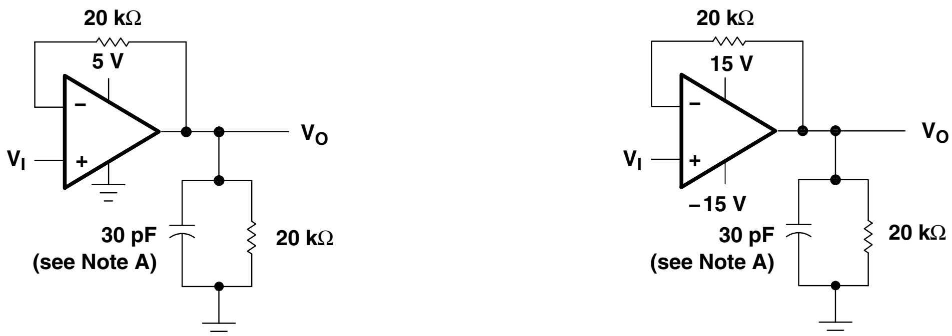
PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
SR	Slew rate at unity gain	V_O = 1 V to 3 V, See Figure 1		0.5		V/μs
V_n	Equivalent input noise voltage (see Figure 2)	f = 10 Hz		21		nV/√Hz
		f = 1 kHz		17		
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	f = 0.1 to 1 Hz		0.16		μV
		f = 0.1 to 10 Hz		0.47		
I_n	Equivalent input noise current			0.1		pA/√Hz
B_1	Unity-gain bandwidth	See Figure 3		1.7		MHz
ϕ_m	Phase margin at unity gain	See Figure 3		47°		

TLE2024 operating characteristics at specified free-air temperature, V_{CC} = ±15 V (unless otherwise noted)

PARAMETER		TEST CONDITIONS	T_A†	MIN	TYP	MAX	UNIT
SR	Slew rate at unity gain	V_O = ±10 V, See Figure 1	25°C	0.45	0.7		V/μs
			Full range	0.4			
V_n	Equivalent input noise voltage (see Figure 2)	f = 10 Hz	25°C		19		nV/√Hz
		f = 1 kHz	25°C		15		
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	f = 0.1 to 1 Hz	25°C		0.16		μV
		f = 0.1 to 10 Hz	25°C		0.47		
I_n	Equivalent input noise current		25°C		0.1		pA/√Hz
B_1	Unity-gain bandwidth	See Figure 3	25°C		2.8		MHz
ϕ_m	Phase margin at unity gain	See Figure 3	25°C		52°		

† Full range is –40°C to 125°C.

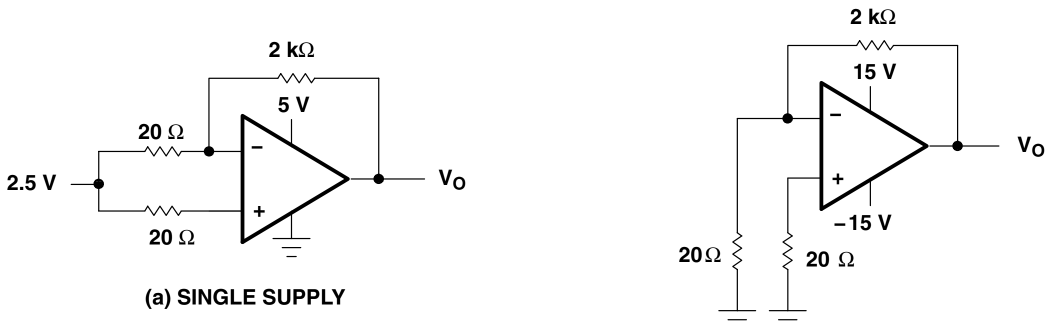
PARAMETER MEASUREMENT INFORMATION



(a) SINGLE SUPPLY (b) SPLIT SUPPLY

NOTE A: C_L includes fixture capacitance.

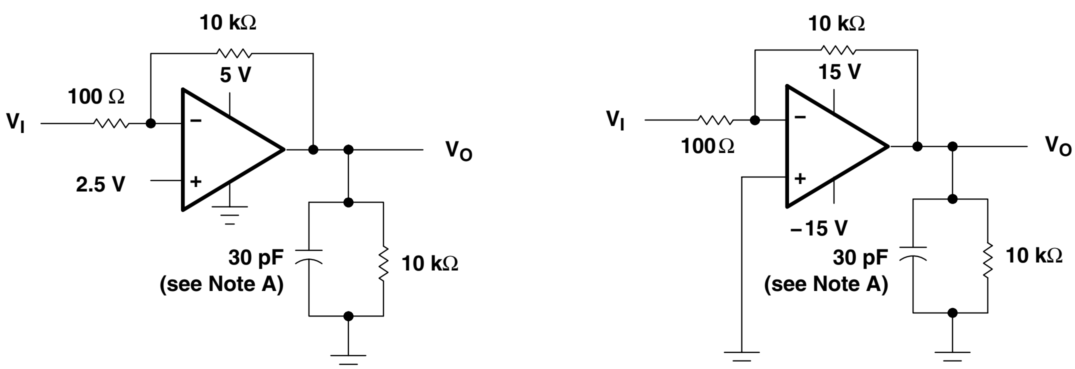
Figure 1. Slew-Rate Test Circuit



(a) SINGLE SUPPLY

(b) SPLIT SUPPLY

Figure 2. Noise-Voltage Test Circuit

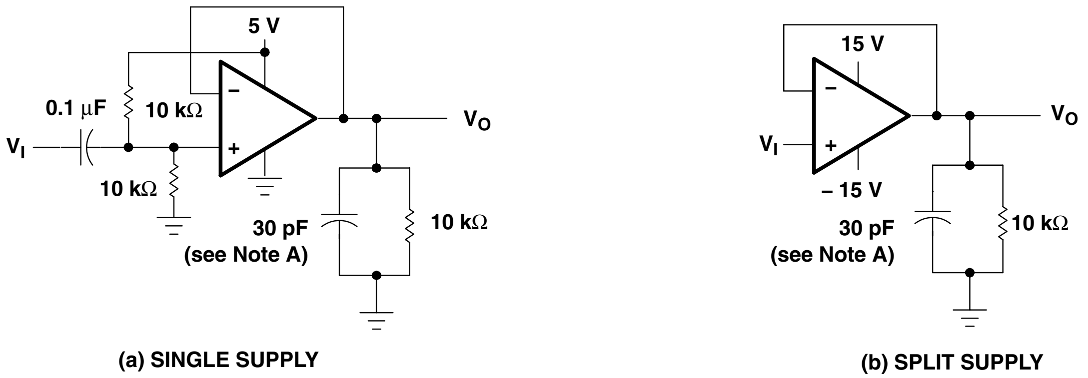


(a) SINGLE SUPPLY (b) SPLIT SUPPLY

NOTE A: C_L includes fixture capacitance.

Figure 3. Unity-Gain Bandwidth and Phase-Margin Test Circuit

PARAMETER MEASUREMENT INFORMATION



NOTE A: C_L includes fixture capacitance.

Figure 4. Small-Signal Pulse-Response Test Circuit

typical values

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

TYPICAL CHARACTERISTICS

Table of Graphs

			FIGURE
V_{IO}	Input offset voltage	Distribution	5, 6, 7
I_{IB}	Input bias current	vs Common-mode input voltage vs Free-air temperature	8, 9, 10 11, 12, 13
I_I	Input current	vs Differential input voltage	14
V_{OM}	Maximum peak output voltage	vs Output current vs Free-air temperature	15, 16, 17 18
V_{OH}	High-level output voltage	vs High-level output current vs Free-air temperature	19, 20 21
V_{OL}	Low-level output voltage	vs Low-level output current vs Free-air temperature	22 23
$V_{O(PP)}$	Maximum peak-to-peak output voltage	vs Frequency	24, 25
A_{VD}	Large-signal differential voltage amplification	vs Frequency vs Free-air temperature	26 27, 28, 29
I_{OS}	Short-circuit output current	vs Supply voltage vs Free-air temperature	30 – 33 34 – 37
I_{CC}	Supply current	vs Supply voltage vs Free-air temperature	38, 39, 40 41, 42, 43
CMRR	Common-mode rejection ratio	vs Frequency	44, 45, 46
SR	Slew rate	vs Free-air temperature	47, 48, 49
	Voltage-follower small-signal pulse response		50, 51
	Voltage-follower large-signal pulse response		52 – 57
$V_{N(PP)}$	Peak-to-peak equivalent input noise voltage	0.1 to 1 Hz 0.1 to 10 Hz	58 59
V_n	Equivalent input noise voltage	vs Frequency	60
B_1	Unity-gain bandwidth	vs Supply voltage vs Free-air temperature	61, 62 63, 64
ϕ_m	Phase margin	vs Supply voltage vs Load capacitance vs Free-air temperature	65, 66 67, 68 69, 70
	Phase shift	vs Frequency	26

TYPICAL CHARACTERISTICS

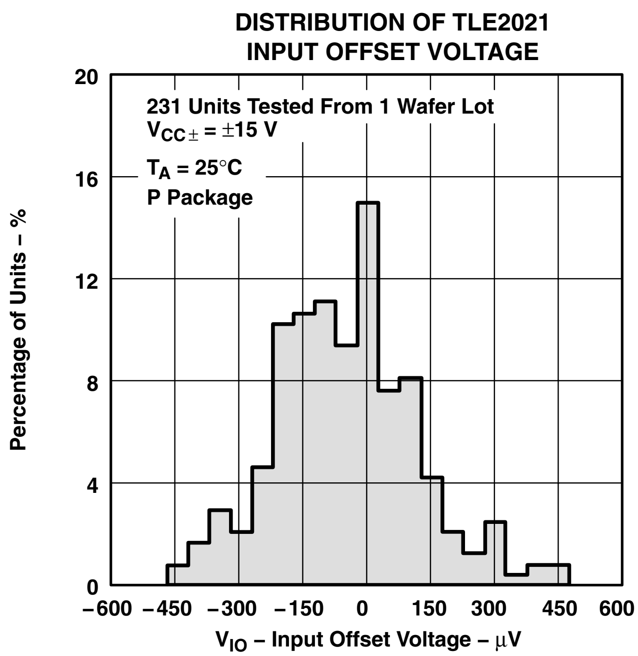


Figure 5

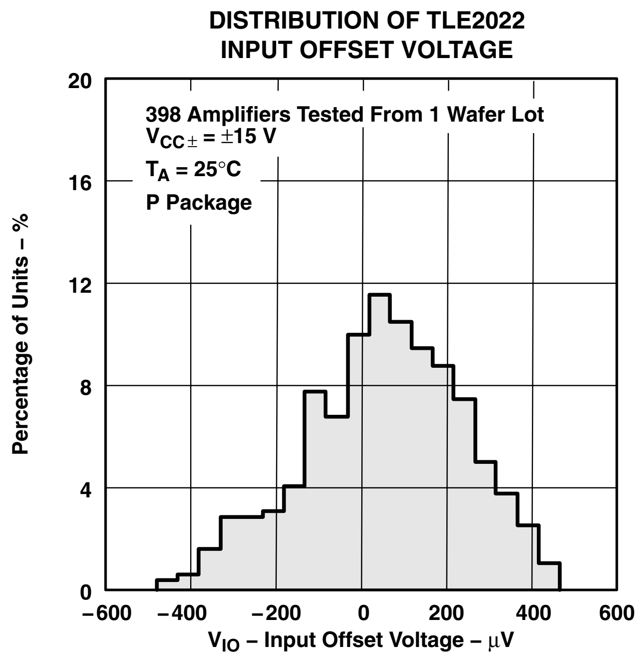


Figure 6

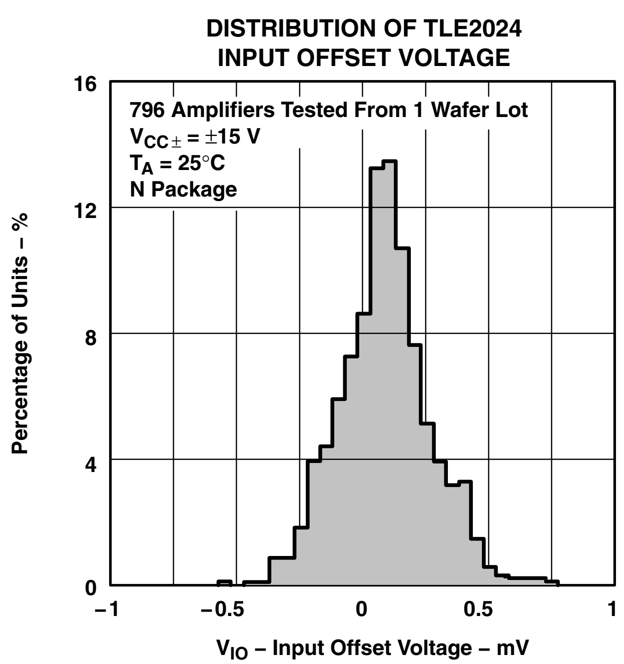


Figure 7

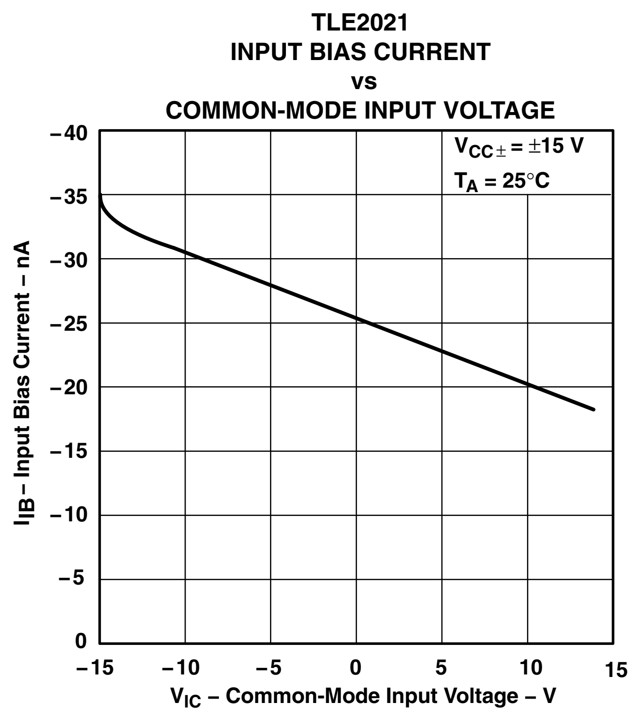


Figure 8

TYPICAL CHARACTERISTICS

TLE2022
INPUT BIAS CURRENT
vs
COMMON-MODE INPUT VOLTAGE

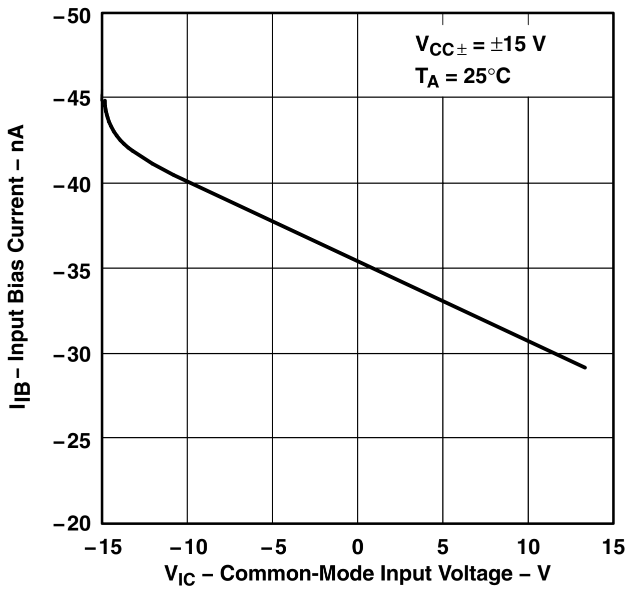


Figure 9

TLE2024
INPUT BIAS CURRENT
vs
COMMON-MODE INPUT VOLTAGE

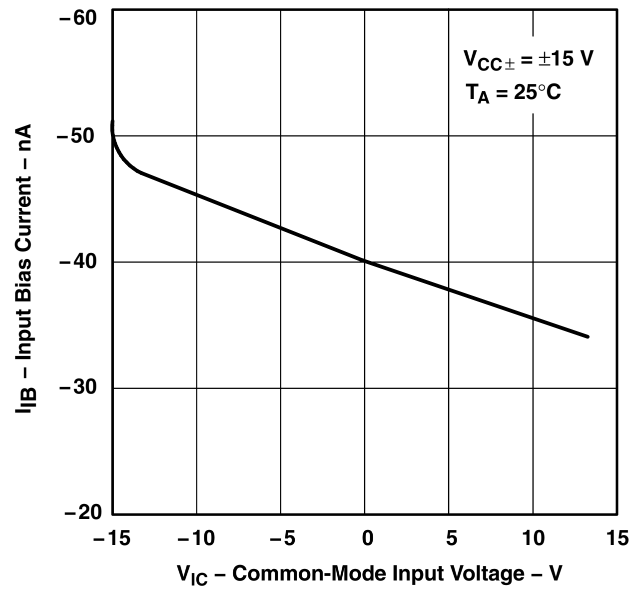


Figure 10

TLE2021
INPUT BIAS CURRENT†
vs
FREE-AIR TEMPERATURE

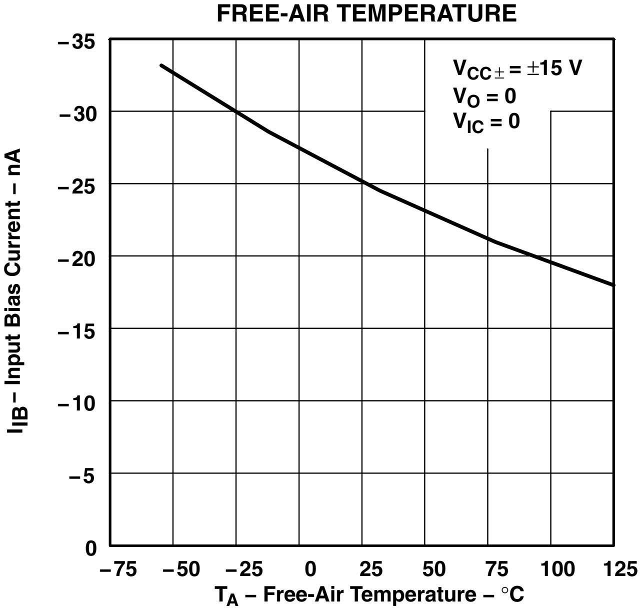


Figure 11

TLE2022
INPUT BIAS CURRENT†
vs
FREE-AIR TEMPERATURE

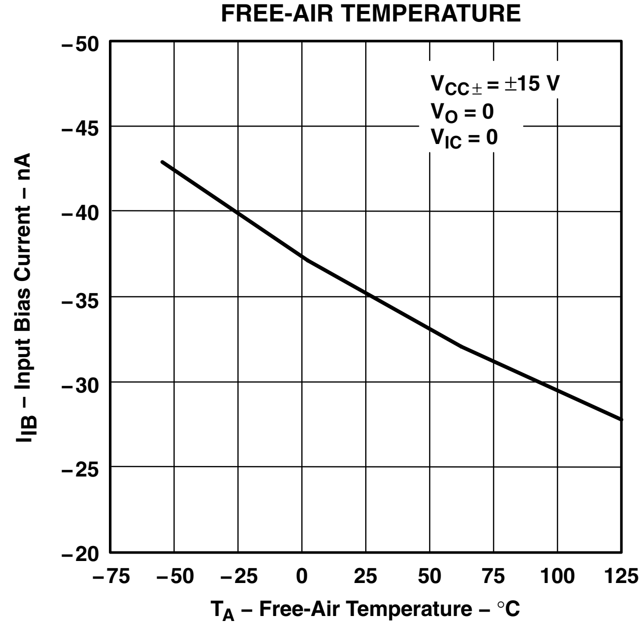


Figure 12

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

TYPICAL CHARACTERISTICS

TLE2024
INPUT BIAS CURRENT†
vs
FREE-AIR TEMPERATURE

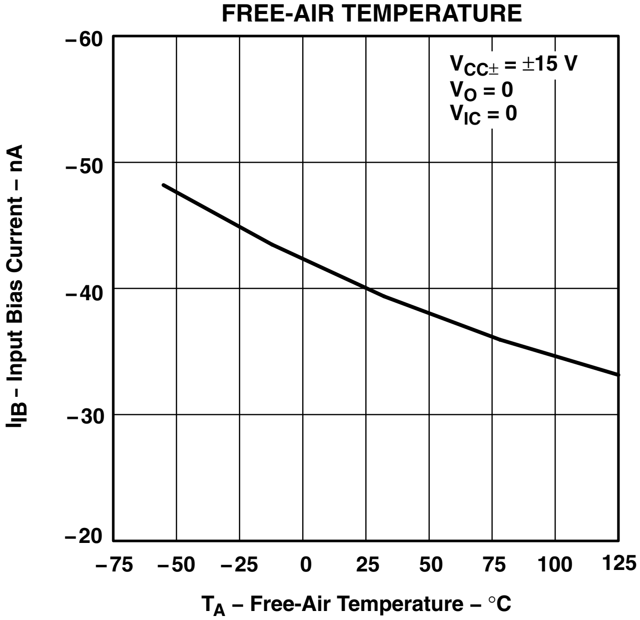


Figure 13

INPUT CURRENT
vs
DIFFERENTIAL INPUT VOLTAGE

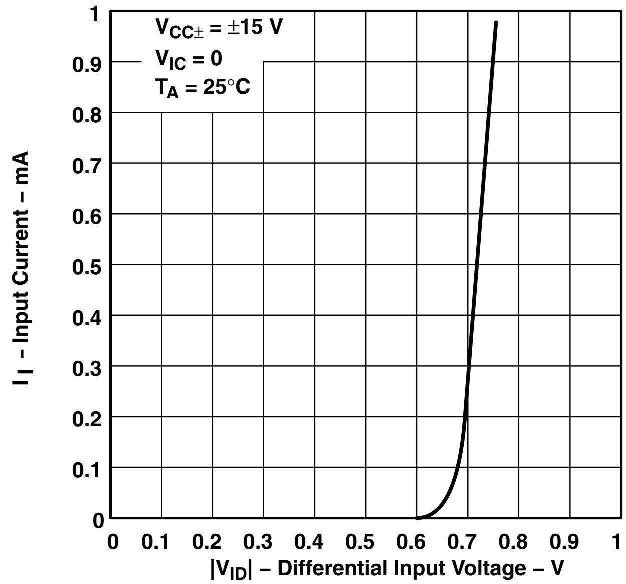


Figure 14

TLE2021
MAXIMUM PEAK OUTPUT VOLTAGE
vs
OUTPUT CURRENT

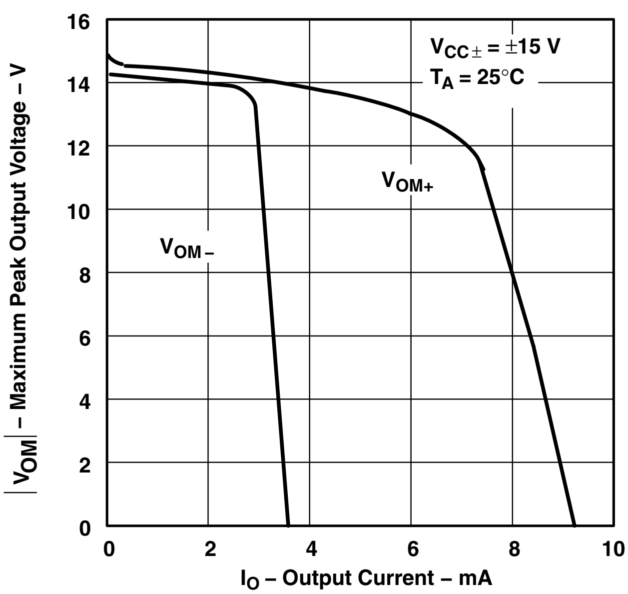


Figure 15

TLE2022
MAXIMUM PEAK OUTPUT VOLTAGE
vs
OUTPUT CURRENT

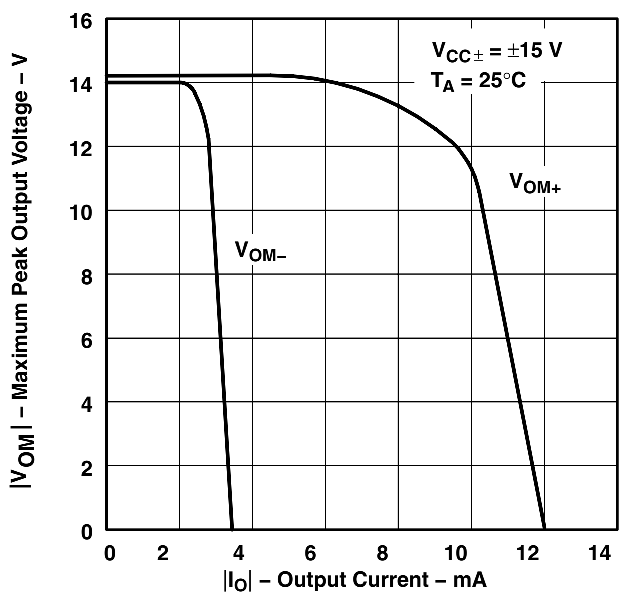


Figure 16

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

TYPICAL CHARACTERISTICS

TLE2024
MAXIMUM PEAK OUTPUT VOLTAGE
vs
OUTPUT CURRENT

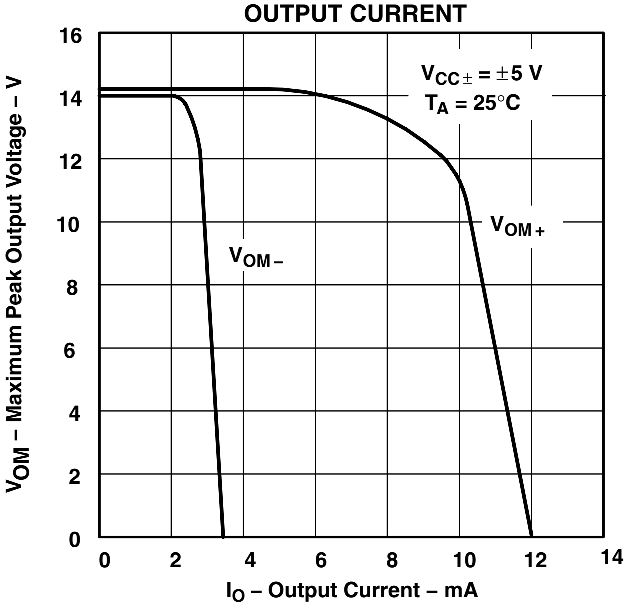


Figure 17

MAXIMUM PEAK OUTPUT VOLTAGE†
vs
FREE-AIR TEMPERATURE

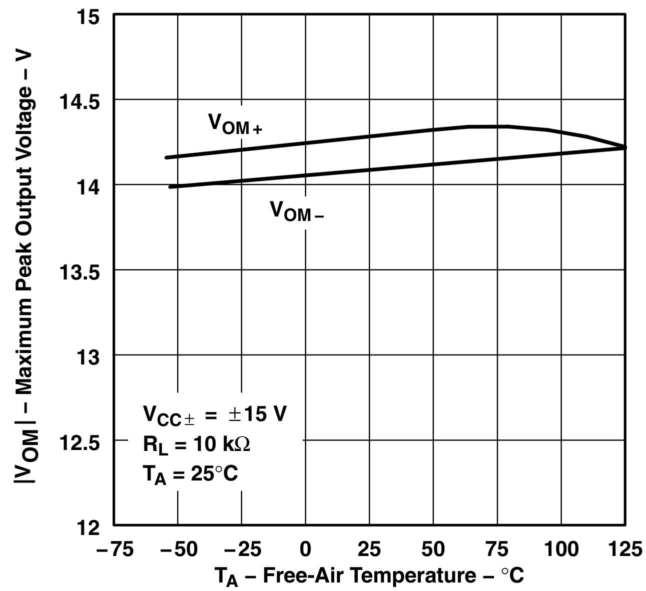


Figure 18

TLE2021
HIGH-LEVEL OUTPUT VOLTAGE
vs
HIGH-LEVEL OUTPUT CURRENT

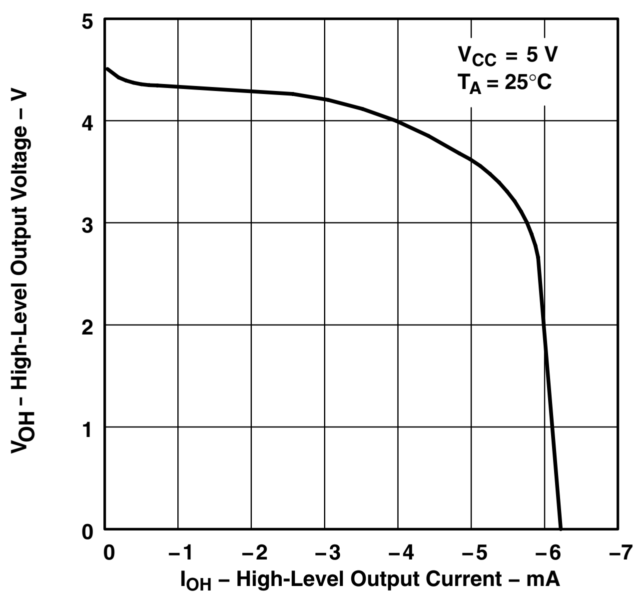


Figure 19

TLE2022 AND TLE2024
HIGH-LEVEL OUTPUT VOLTAGE
vs
HIGH-LEVEL OUTPUT CURRENT

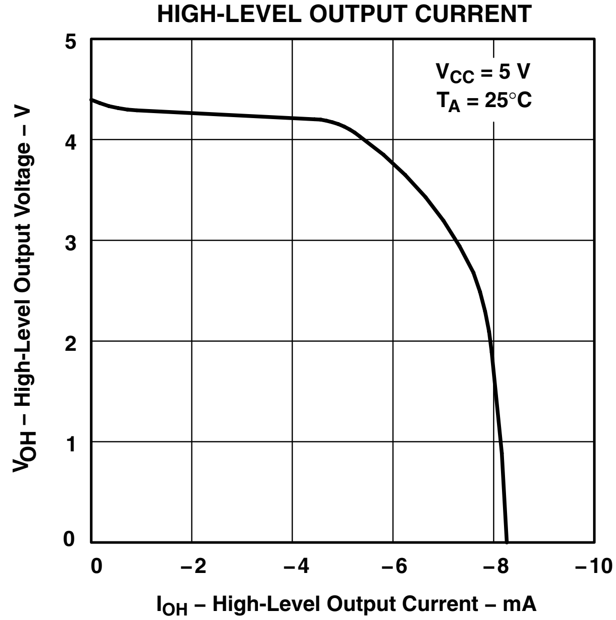


Figure 20

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

TYPICAL CHARACTERISTICS

HIGH-LEVEL OUTPUT VOLTAGE† vs FREE-AIR TEMPERATURE

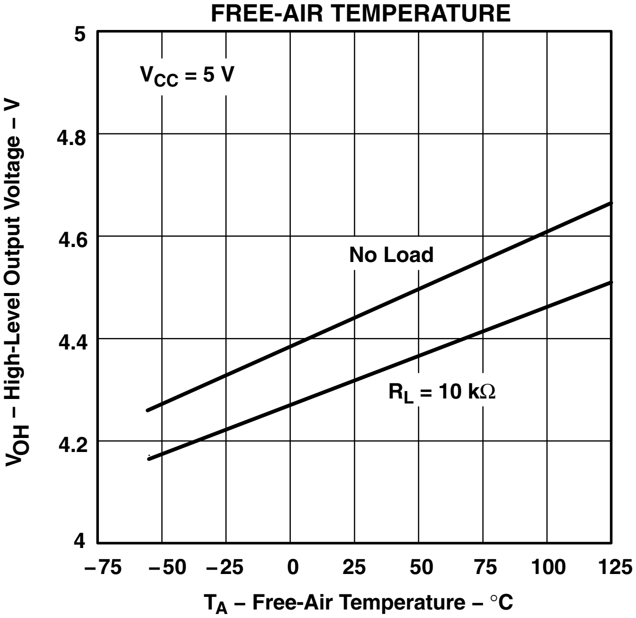


Figure 21

LOW-LEVEL OUTPUT VOLTAGE vs LOW-LEVEL OUTPUT CURRENT

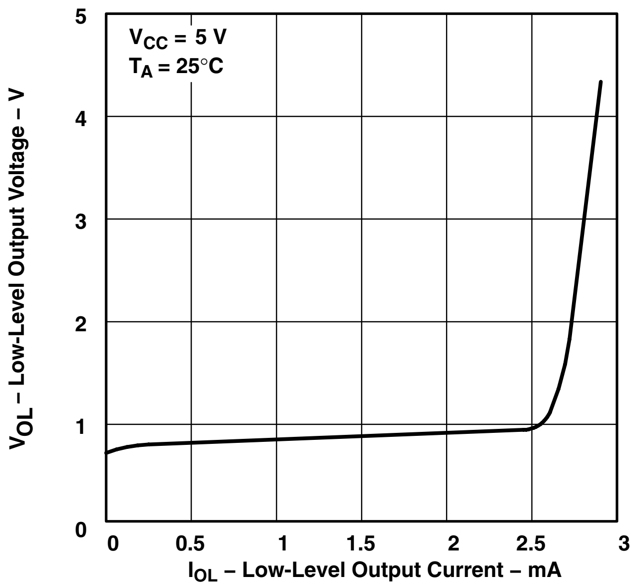


Figure 22

LOW-LEVEL OUTPUT VOLTAGE† vs FREE-AIR TEMPERATURE

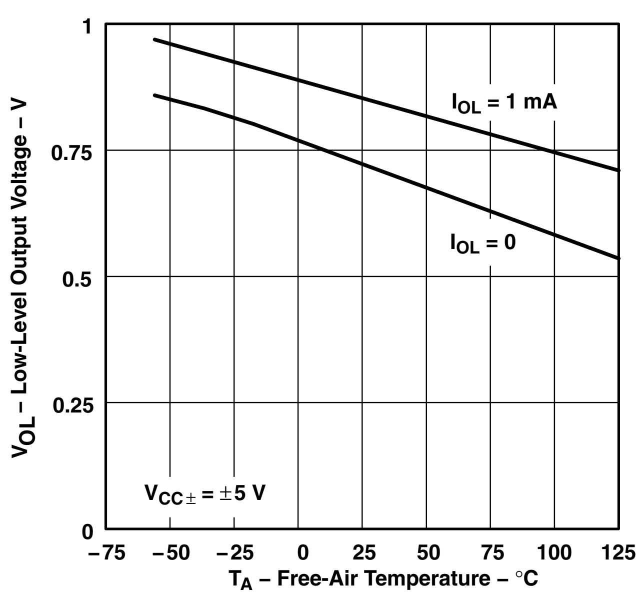


Figure 23

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE vs FREQUENCY

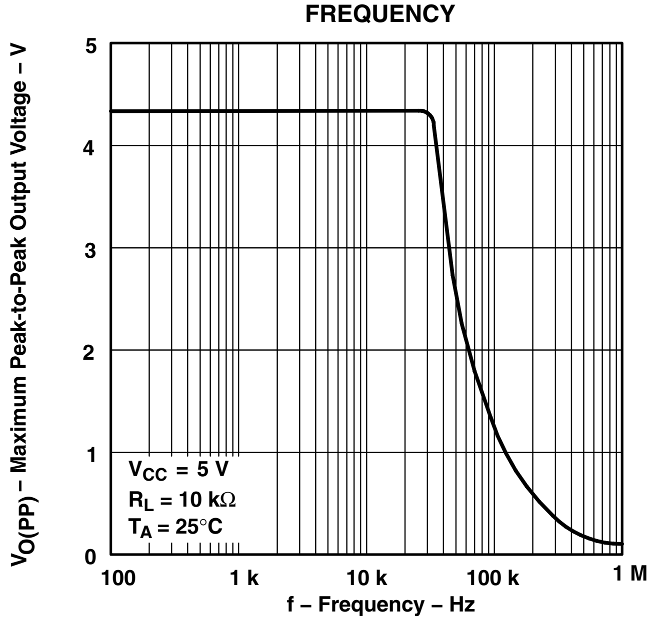


Figure 24

† 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-TO-PEAK OUTPUT VOLTAGE vs FREQUENCY

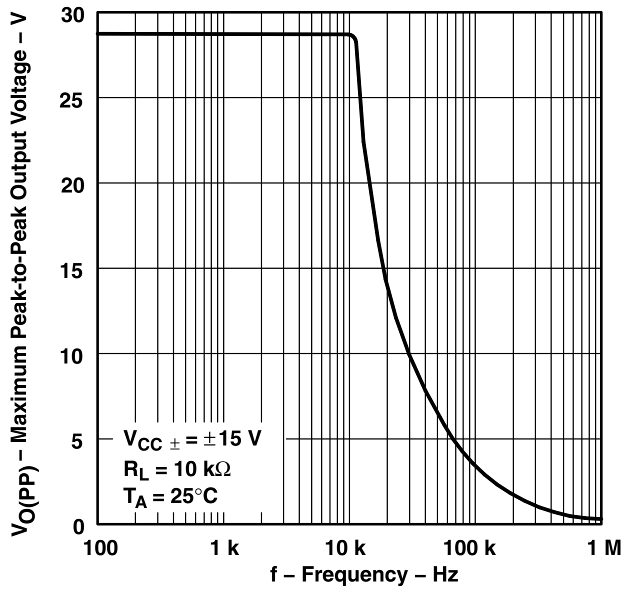


Figure 25

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT vs FREQUENCY

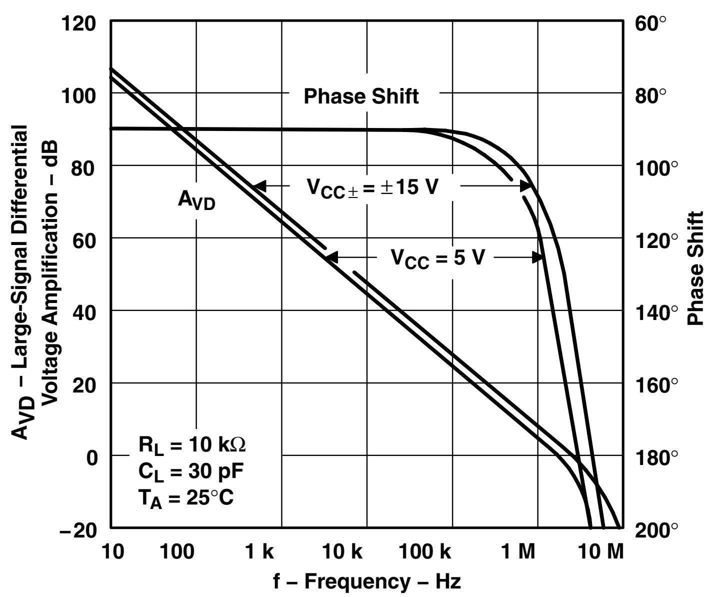


Figure 26

TYPICAL CHARACTERISTICS

TLE2021
LARGE-SCALE DIFFERENTIAL VOLTAGE AMPLIFICATION†
vs
FREE-AIR TEMPERATURE

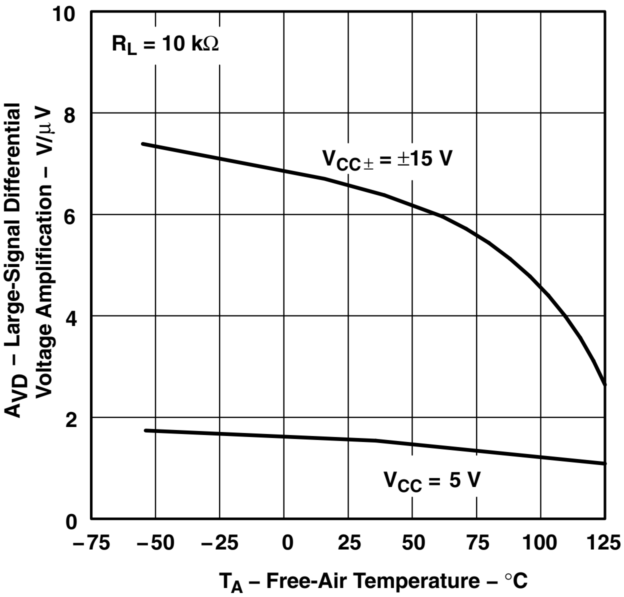


Figure 27

TLE2022
LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION†
vs
FREE-AIR TEMPERATURE

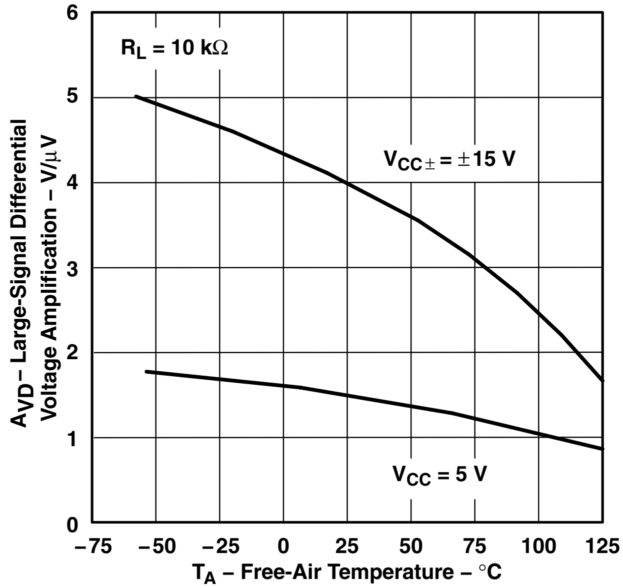


Figure 28

TLE2024
LARGE-SCALE DIFFERENTIAL VOLTAGE AMPLIFICATION†
vs
FREE-AIR TEMPERATURE

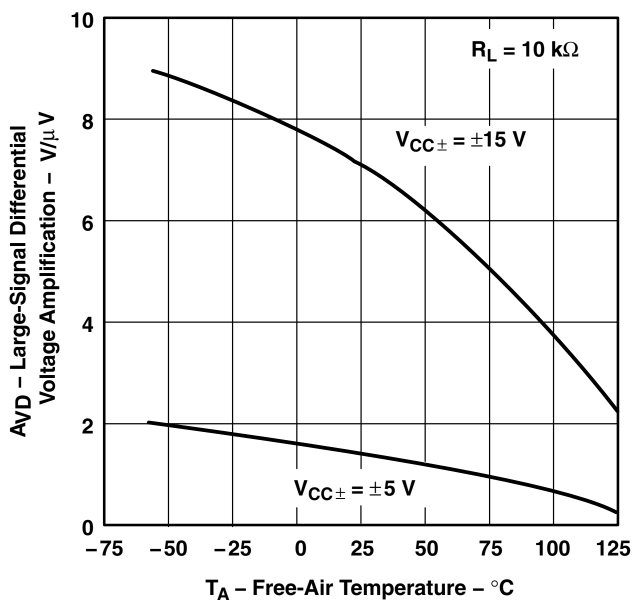


Figure 29

TLE2021
SHORT-CIRCUIT OUTPUT CURRENT
vs
SUPPLY VOLTAGE

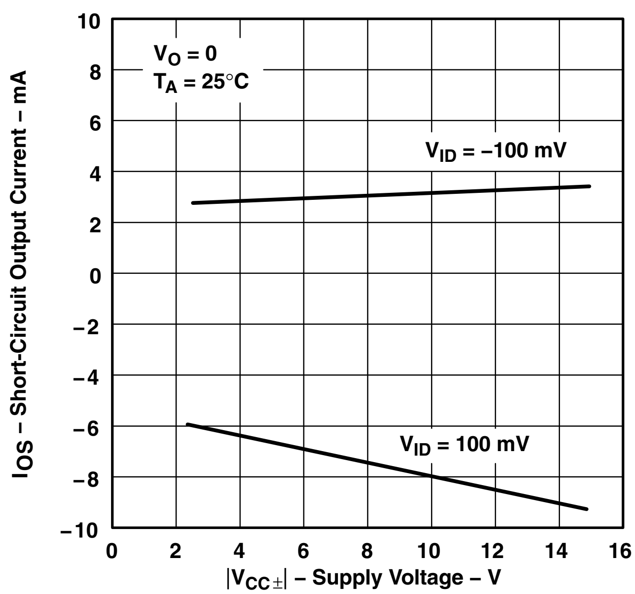


Figure 30

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

TYPICAL CHARACTERISTICS

TLE2022 AND TLE2024
SHORT-CIRCUIT OUTPUT CURRENT
vs
SUPPLY VOLTAGE

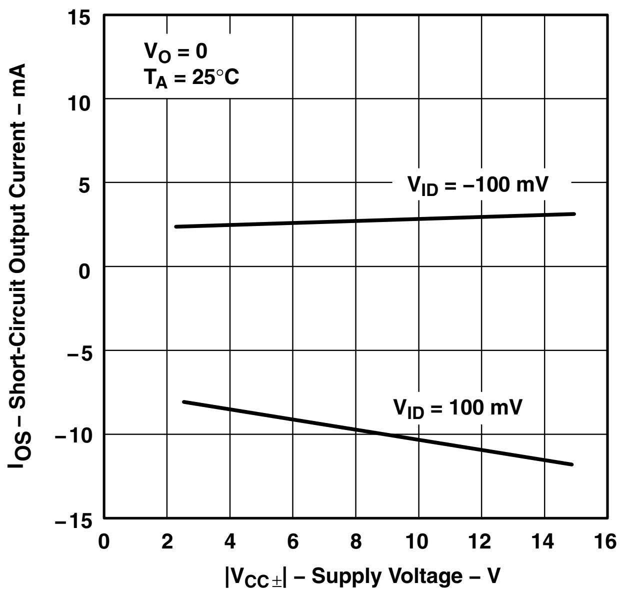


Figure 31

TLE2021
SHORT-CIRCUIT OUTPUT CURRENT
vs
SUPPLY VOLTAGE

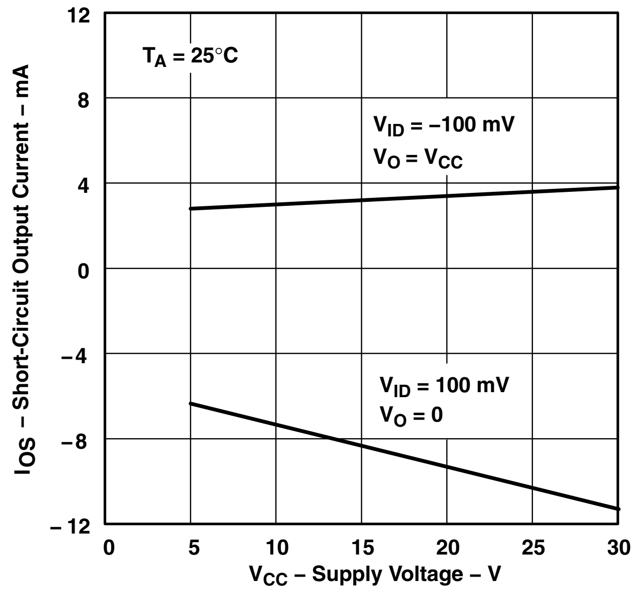


Figure 32

TLE2022 AND TLE2024
SHORT-CIRCUIT OUTPUT CURRENT
vs
SUPPLY VOLTAGE

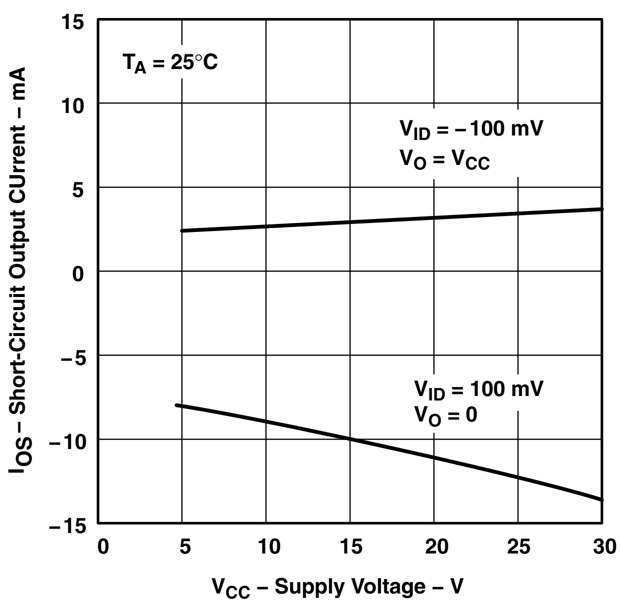


Figure 33

TLE2021
SHORT-CIRCUIT OUTPUT CURRENT†
vs
FREE-AIR TEMPERATURE

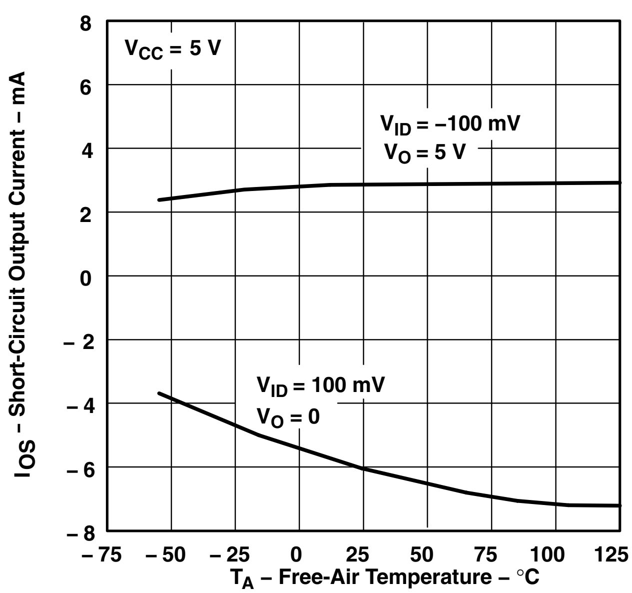


Figure 34

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

TYPICAL CHARACTERISTICS

TLE2022 AND TLE2024
SHORT-CIRCUIT OUTPUT CURRENT†
vs
FREE-AIR TEMPERATURE

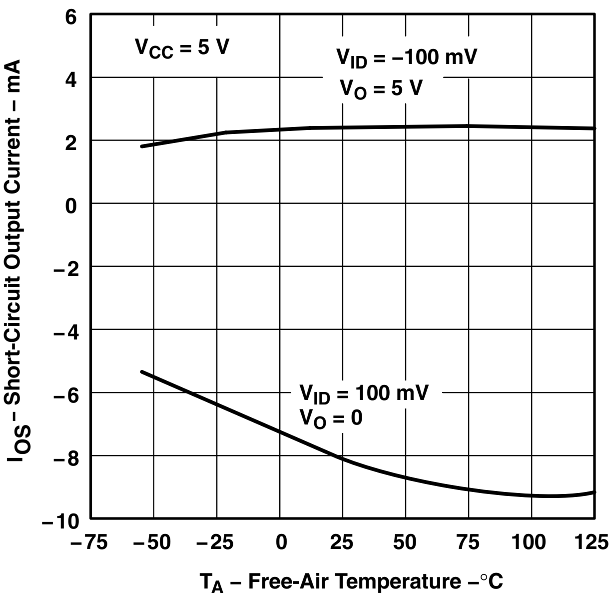


Figure 35

TLE2021
SHORT-CIRCUIT OUTPUT CURRENT†
vs
FREE-AIR TEMPERATURE

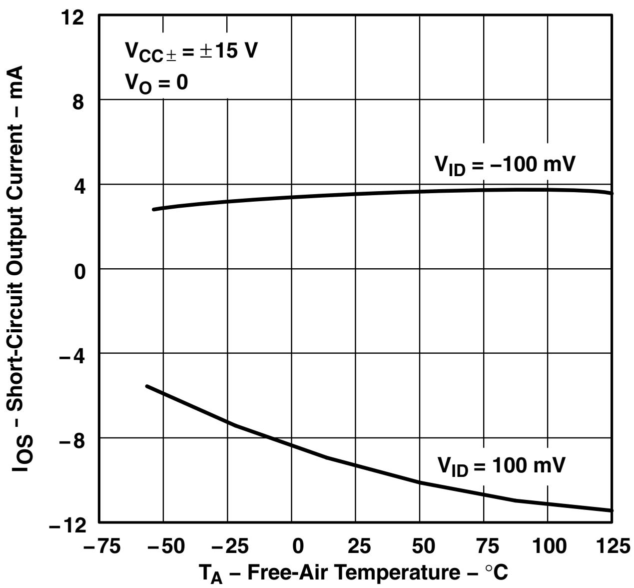


Figure 36

TLE2022 AND TLE2024
SHORT-CIRCUIT OUTPUT CURRENT†
vs
FREE-AIR TEMPERATURE

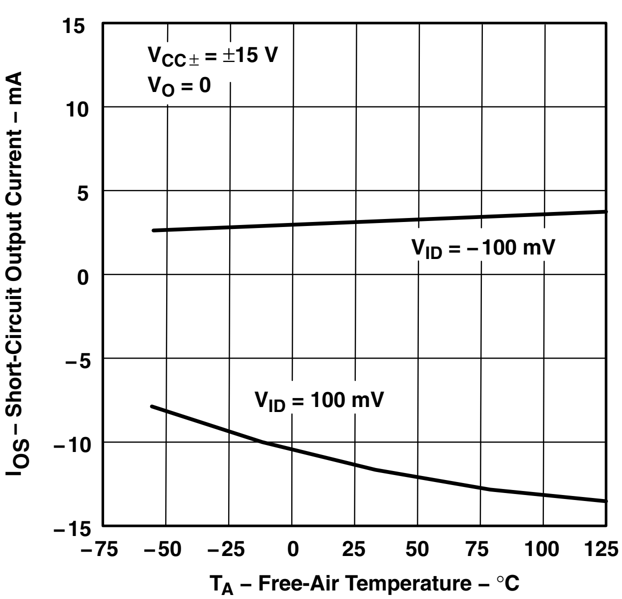


Figure 37

TLE2021
SUPPLY CURRENT
vs
SUPPLY VOLTAGE

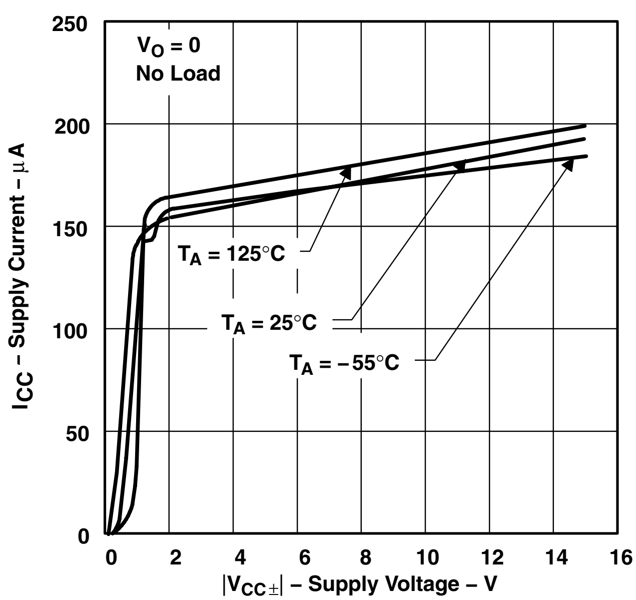


Figure 38

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

TYPICAL CHARACTERISTICS

TLE2022
SUPPLY CURRENT
vs
SUPPLY VOLTAGE

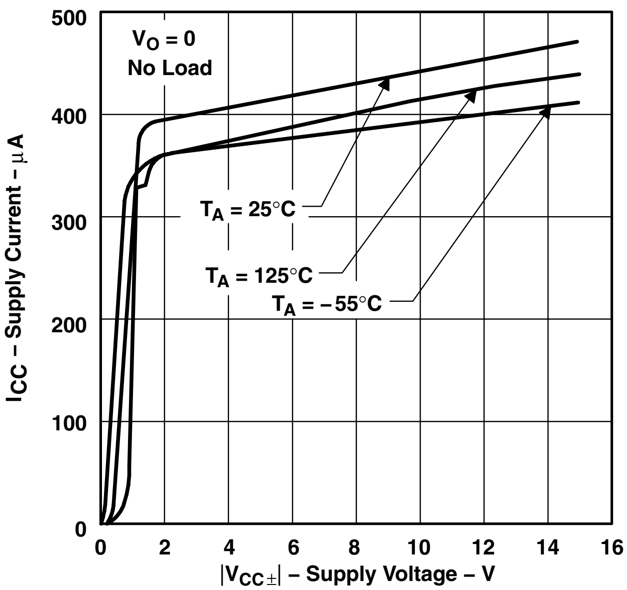


Figure 39

TLE2024
SUPPLY CURRENT
vs
SUPPLY VOLTAGE

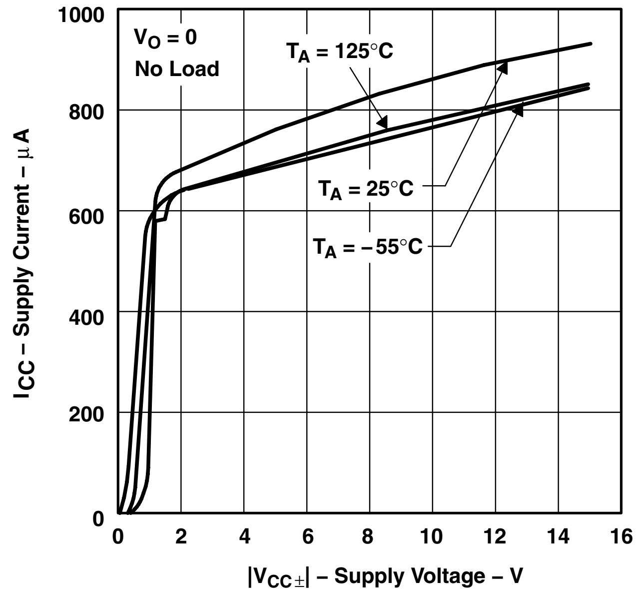


Figure 40

TLE2021
SUPPLY CURRENT†
vs
FREE-AIR TEMPERATURE

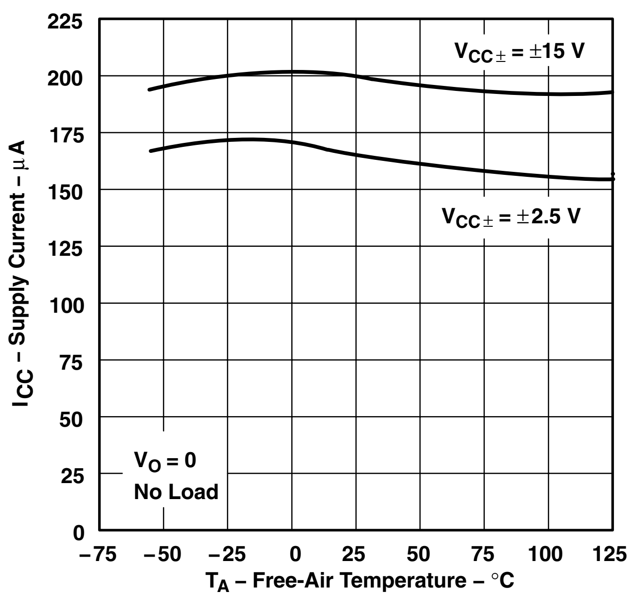


Figure 41

TLE2022
SUPPLY CURRENT†
vs
FREE-AIR TEMPERATURE

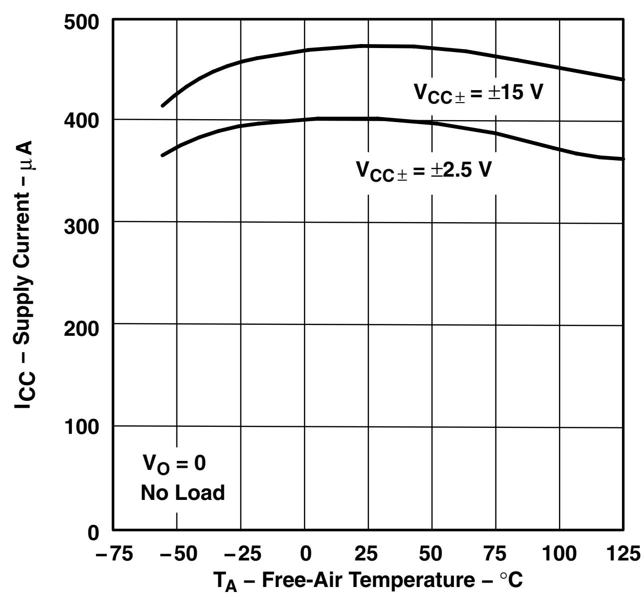


Figure 42

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

TYPICAL CHARACTERISTICS

TLE2024
SUPPLY CURRENT†
vs
FREE-AIR TEMPERATURE

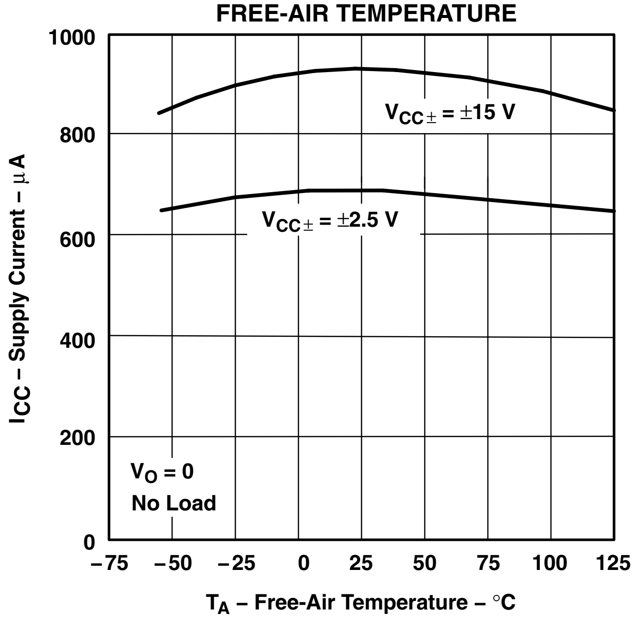


Figure 43

TLE2021
COMMON-MODE REJECTION RATIO
vs
FREQUENCY

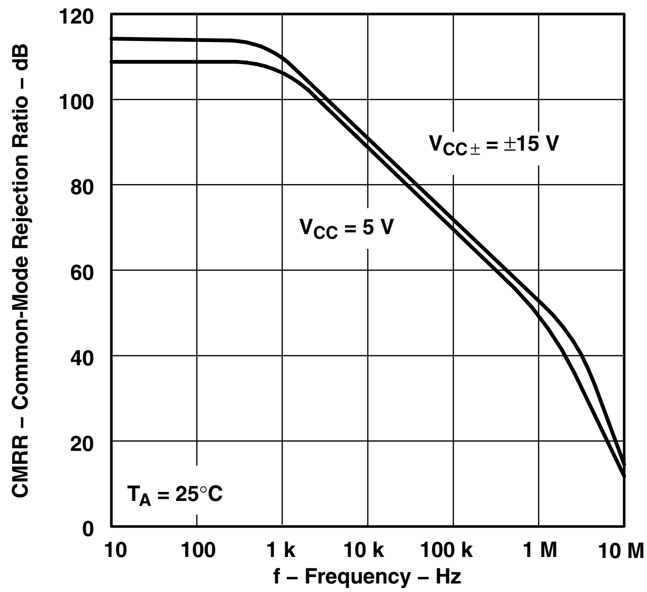


Figure 44

TLE2022
COMMON-MODE REJECTION RATIO
vs
FREQUENCY

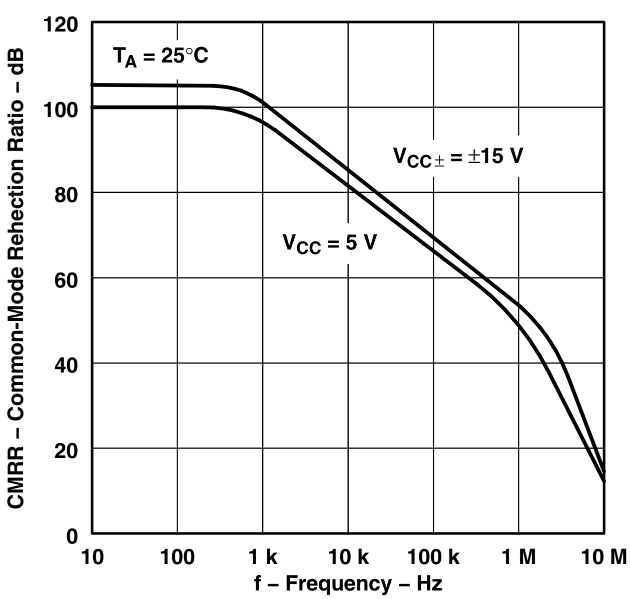


Figure 45

TLE2024
COMMON-MODE REJECTION RATIO
vs
FREQUENCY

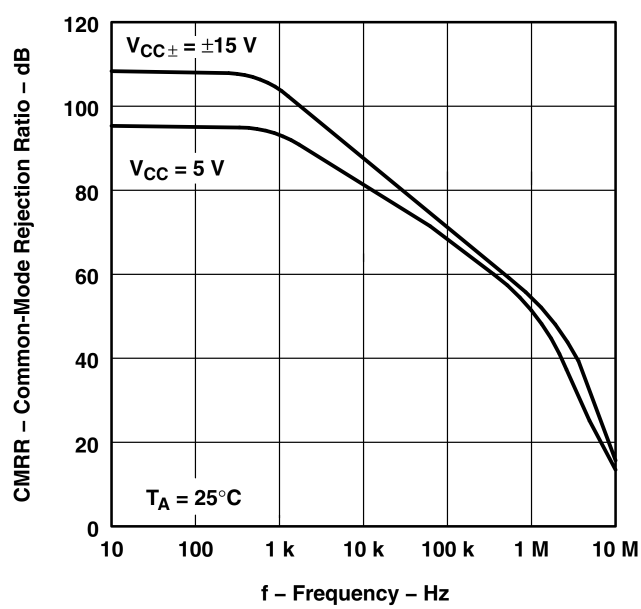


Figure 46

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

TYPICAL CHARACTERISTICS

TLE2021
SLEW RATE†
vs
FREE-AIR TEMPERATURE

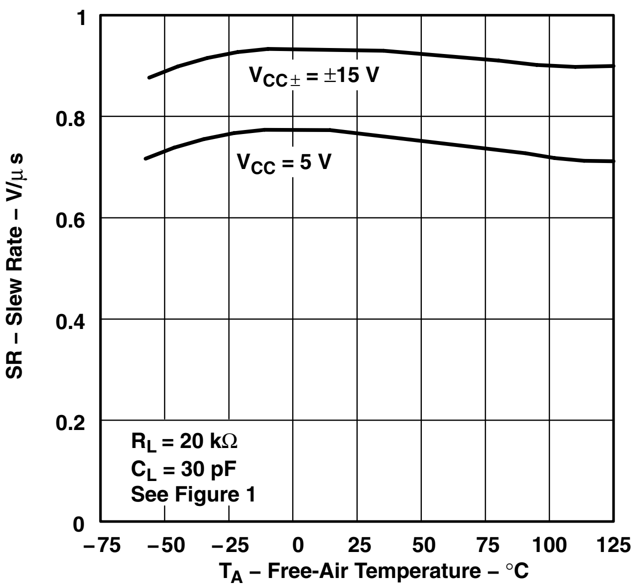


Figure 47

TLE2022
SLEW RATE†
vs
FREE-AIR TEMPERATURE

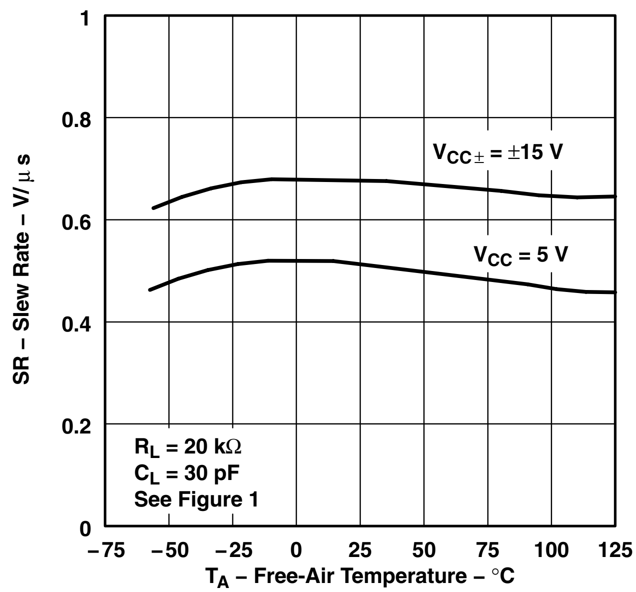


Figure 48

TLE2024
SLEW RATE†
vs
FREE-AIR TEMPERATURE

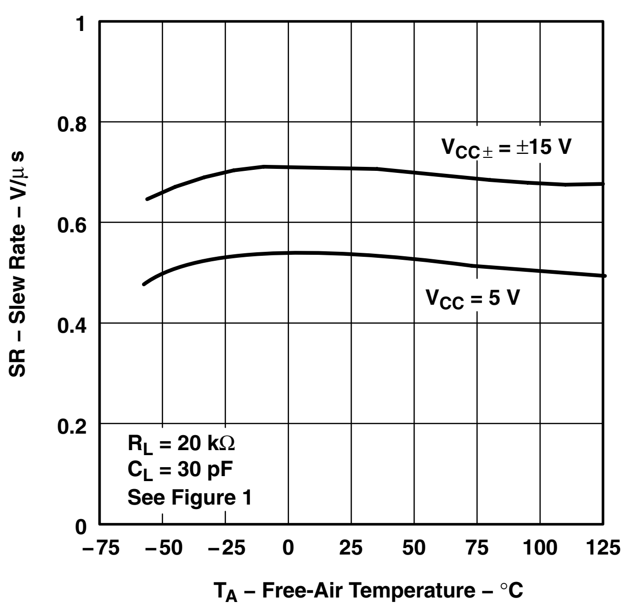


Figure 49

VOLTAGE-FOLLOWER
SMALL-SIGNAL
PULSE RESPONSE

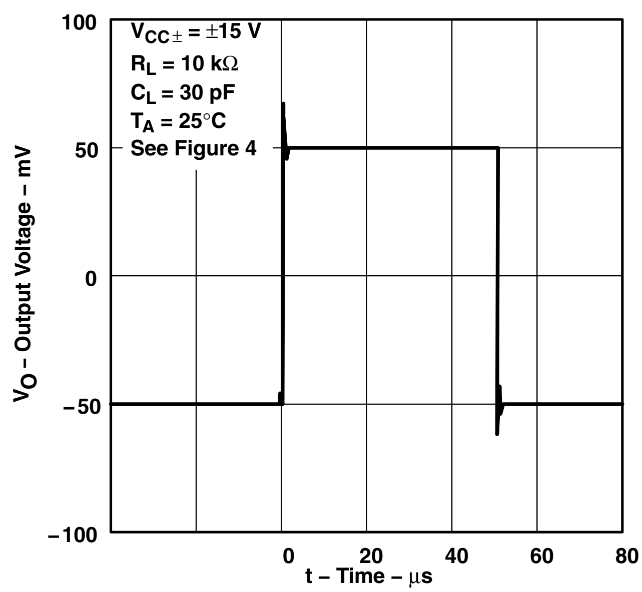


Figure 50

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

TYPICAL CHARACTERISTICS

VOLTAGE-FOLLOWER
SMALL-SIGNAL
PULSE RESPONSE

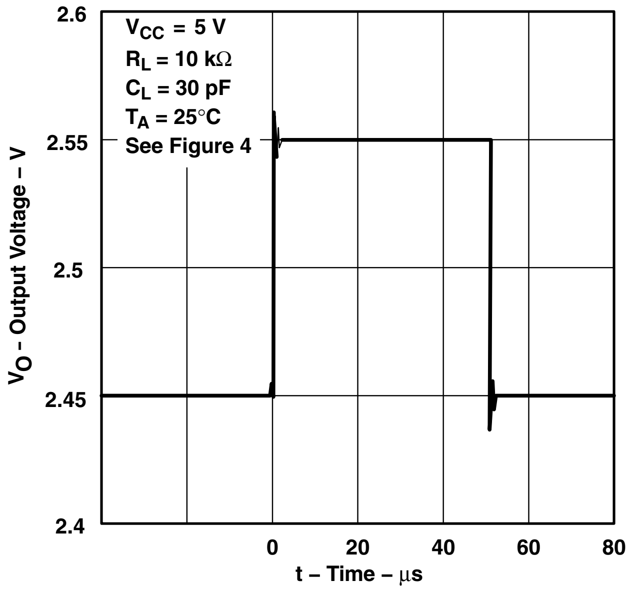


Figure 51

TLE2021
VOLTAGE-FOLLOWER LARGE-SIGNAL
PULSE RESPONSE

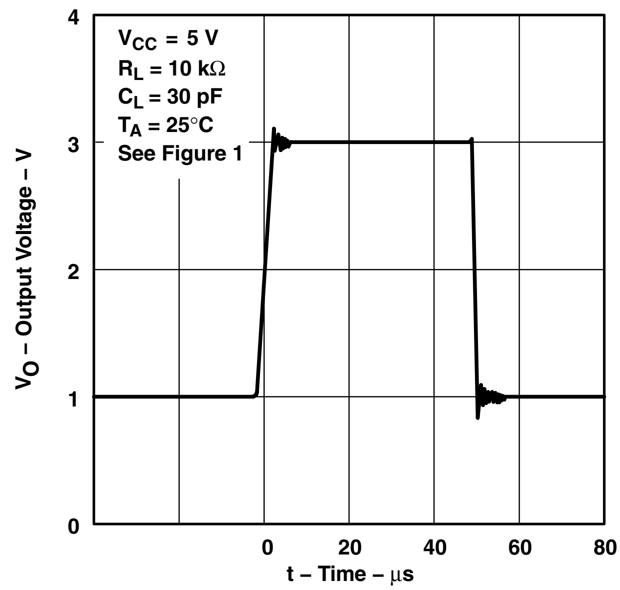


Figure 52

TLE2022
VOLTAGE-FOLLOWER LARGE-SIGNAL
PULSE RESPONSE

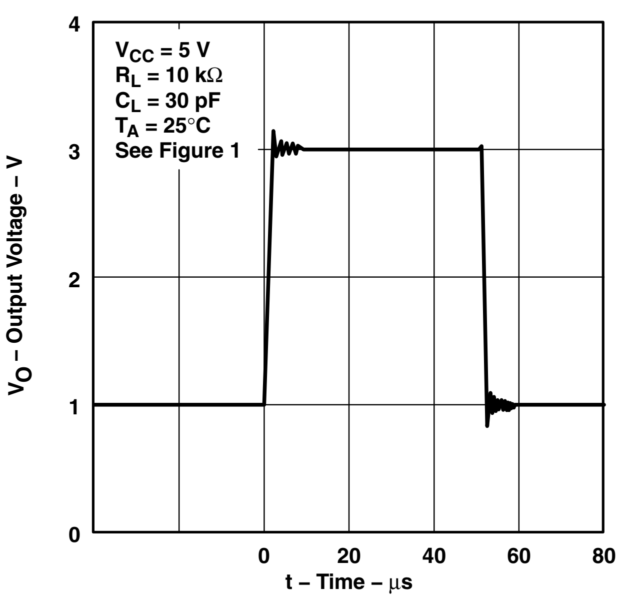


Figure 53

TLE2024
VOLTAGE-FOLLOWER LARGE-SCALE
PULSE RESPONSE

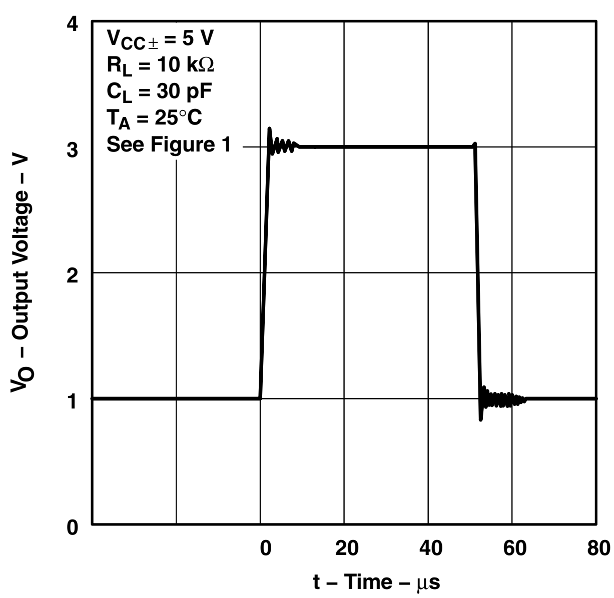


Figure 54

TYPICAL CHARACTERISTICS

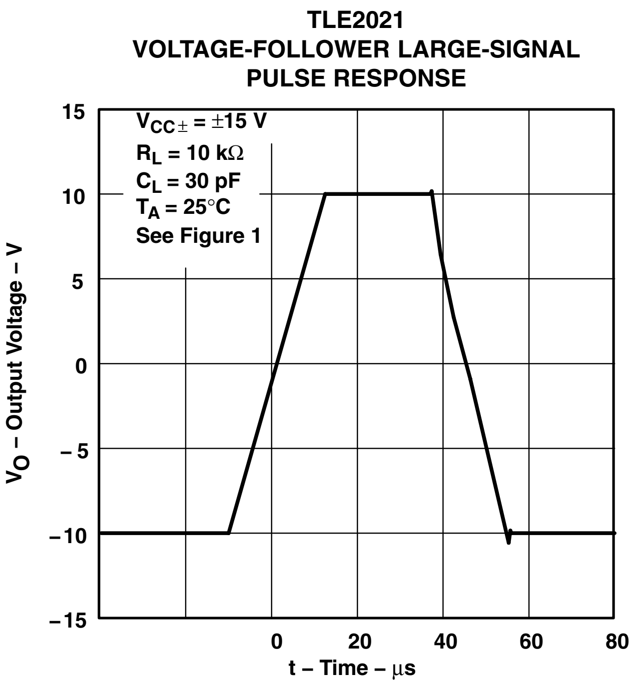


Figure 55

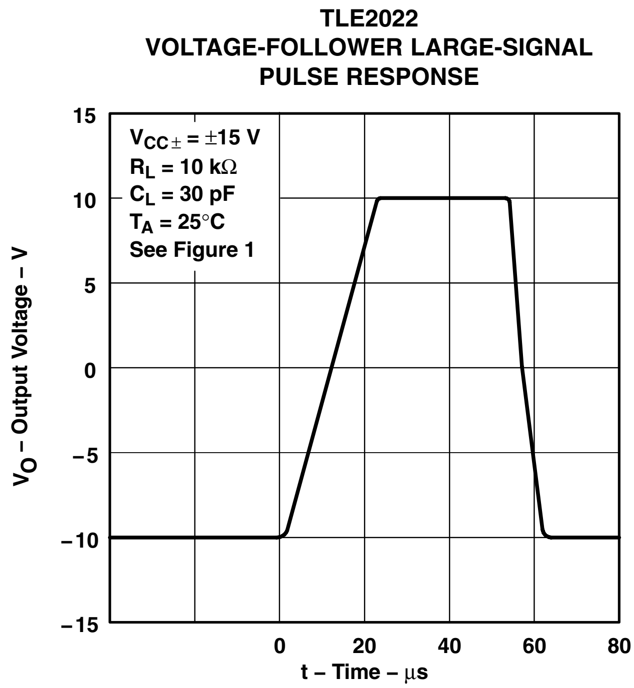


Figure 56

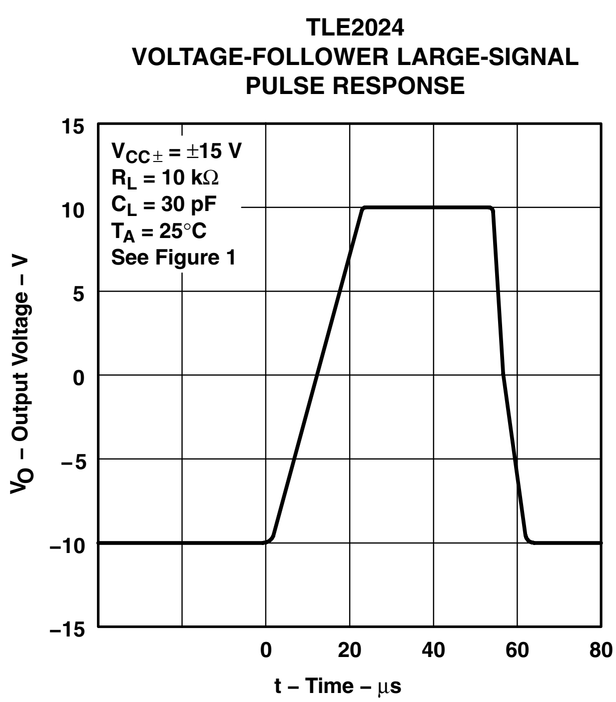


Figure 57

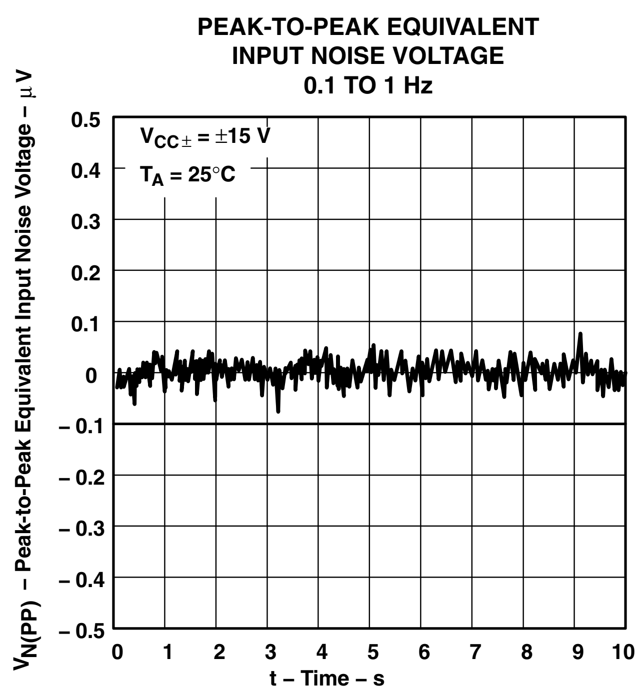


Figure 58

TYPICAL CHARACTERISTICS

PEAK-TO-PEAK EQUIVALENT INPUT NOISE VOLTAGE 0.1 TO 10 Hz

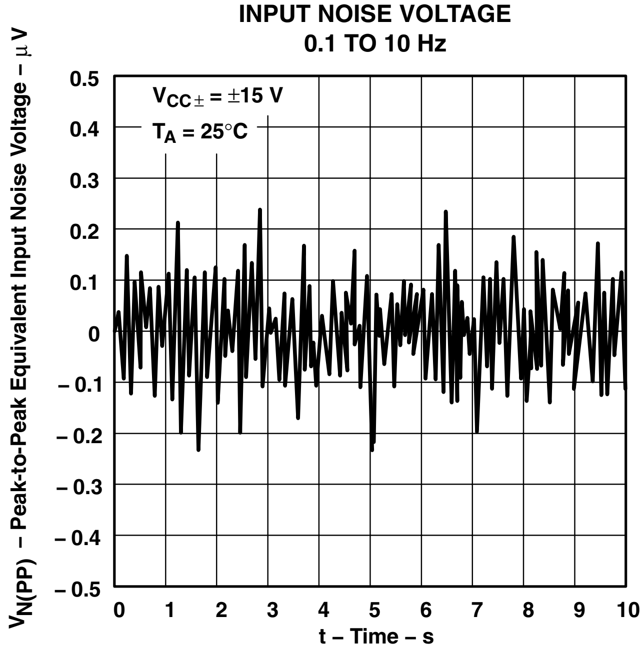


Figure 59

EQUIVALENT INPUT NOISE VOLTAGE vs FREQUENCY

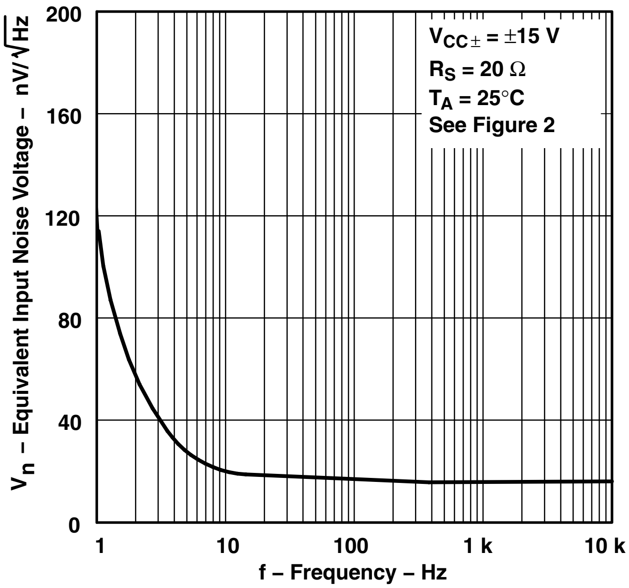


Figure 60

TLE2021 UNITY-GAIN BANDWIDTH vs SUPPLY VOLTAGE

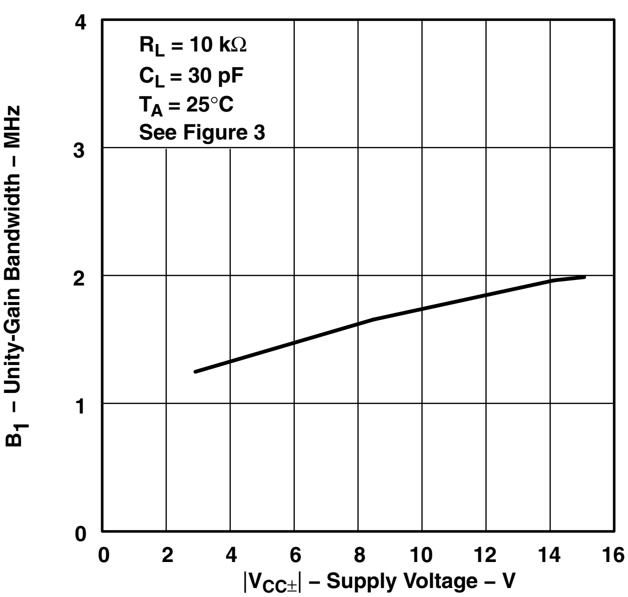


Figure 61

TLE2022 AND TLE2024 UNITY-GAIN BANDWIDTH vs SUPPLY VOLTAGE

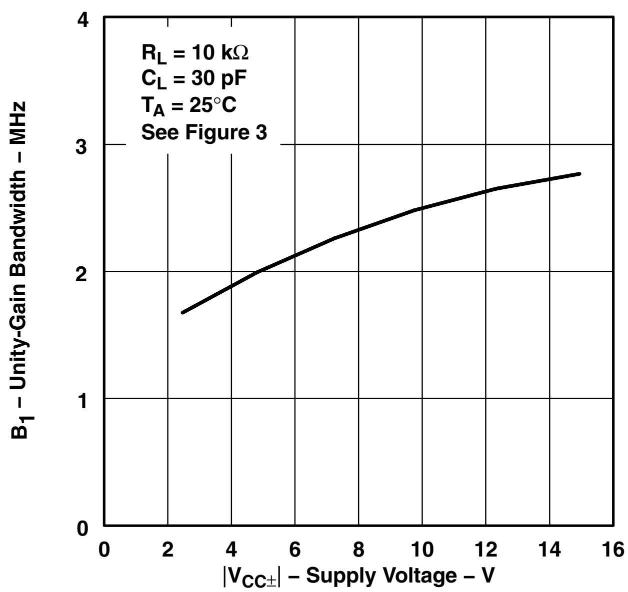


Figure 62

TYPICAL CHARACTERISTICS

**TLE2021
UNITY-GAIN BANDWIDTH†
vs
FREE-AIR TEMPERATURE**

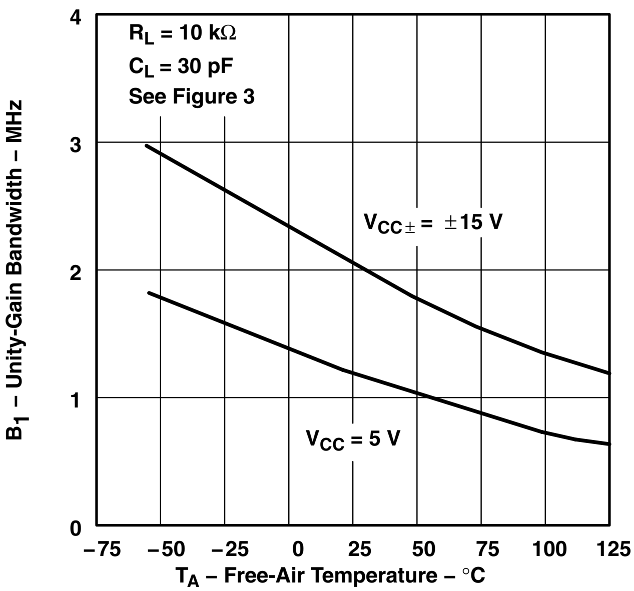


Figure 63

**TLE2022 AND TLE2024
UNITY-GAIN BANDWIDTH†
vs
FREE-AIR TEMPERATURE**

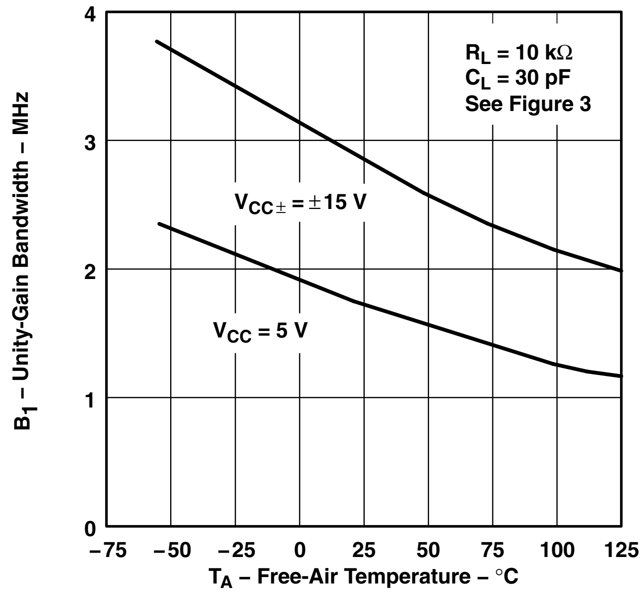


Figure 64

**TLE2021
PHASE MARGIN
vs
SUPPLY VOLTAGE**

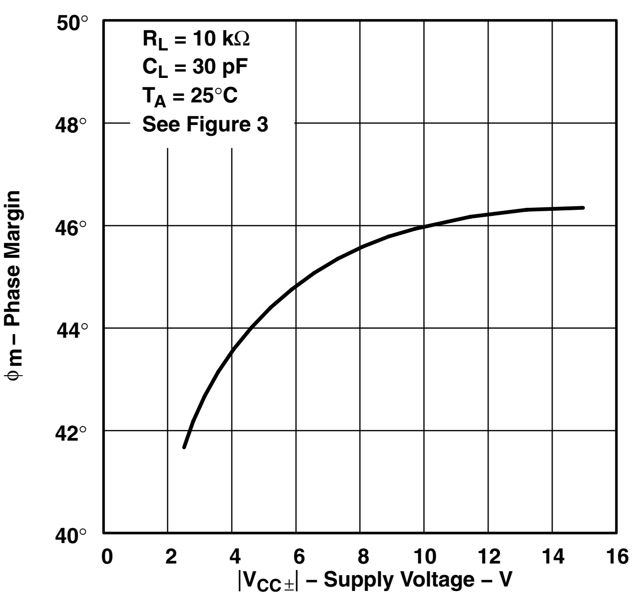


Figure 65

**TLE2022 AND TLE2024
PHASE MARGIN
vs
SUPPLY VOLTAGE**

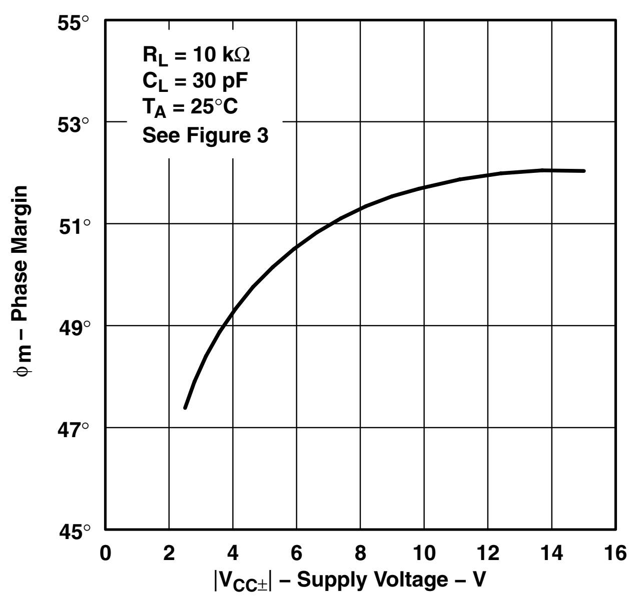


Figure 66

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

TYPICAL CHARACTERISTICS

TLE2021
PHASE MARGIN
vs
LOAD CAPACITANCE

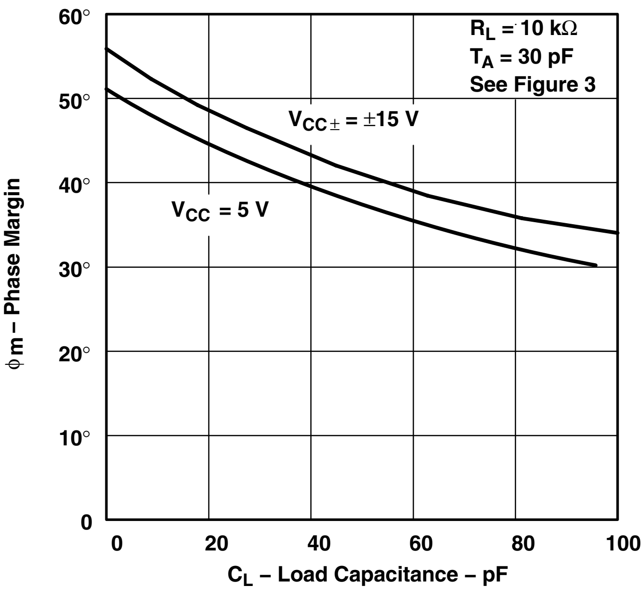


Figure 67

TLE2022 AND TLE2024
PHASE MARGIN
vs
LOAD CAPACITANCE

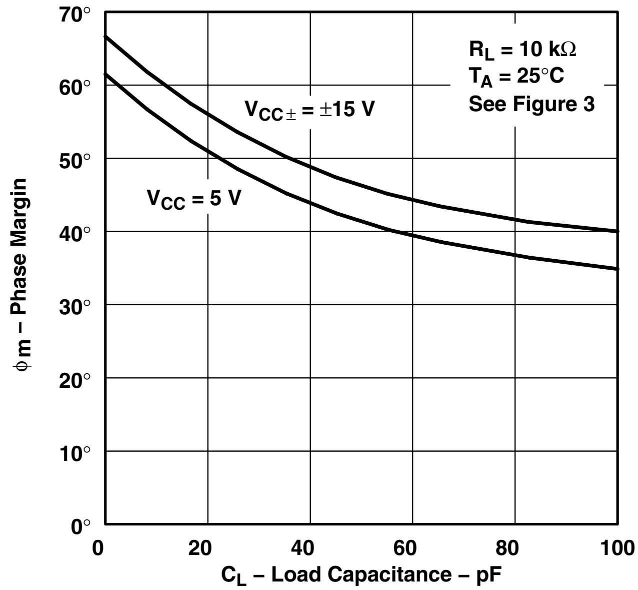


Figure 68

TLE2021
PHASE MARGIN†
vs
FREE-AIR TEMPERATURE

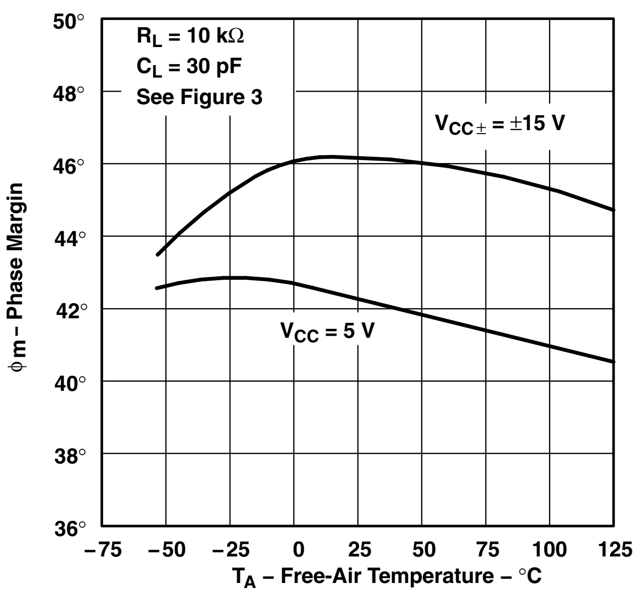


Figure 69

TLE2022 AND TLE2024
PHASE MARGIN†
vs
FREE-AIR TEMPERATURE

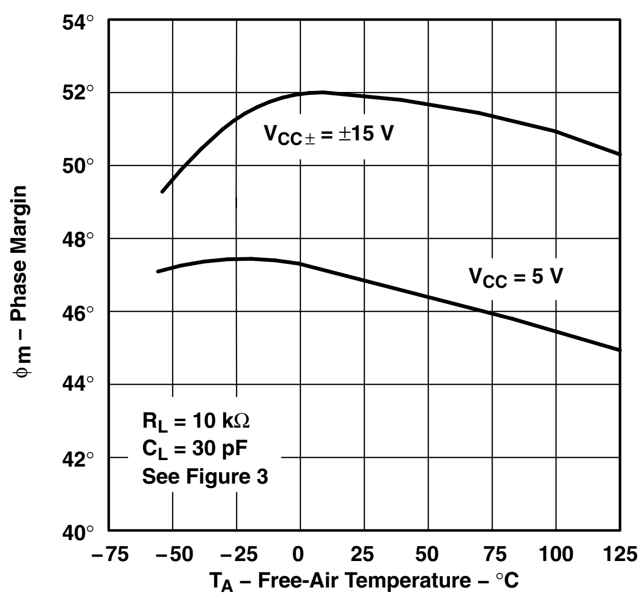


Figure 70

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

APPLICATION INFORMATION

voltage-follower applications

The TLE202x circuitry includes input-protection diodes to limit the voltage across the input transistors; however, no provision is made in the circuit to limit the current if these diodes are forward biased. This condition can occur when the device is operated in the voltage-follower configuration and driven with a fast, large-signal pulse. It is recommended that a feedback resistor be used to limit the current to a maximum of 1 mA to prevent degradation of the device. This feedback resistor forms a pole with the input capacitance of the device. For feedback resistor values greater than 10 kΩ, this pole degrades the amplifier phase margin. This problem can be alleviated by adding a capacitor (20 pF to 50 pF) in parallel with the feedback resistor (see Figure 71).

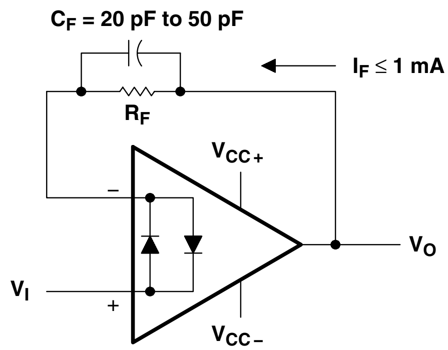


Figure 71. Voltage Follower

Input offset voltage nulling

The TLE202x series offers external null pins that further reduce the input offset voltage. The circuit in Figure 72 can be connected as shown if this feature is desired. When external nulling is not needed, the null pins may be left disconnected.

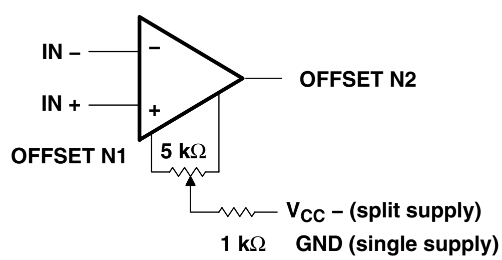


Figure 72. Input Offset Voltage Null Circuit

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 5) and subcircuit in Figure 73, Figure 74, and Figure 75 were generated using the TLE202x typical electrical and operating characteristics at 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 5: 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).

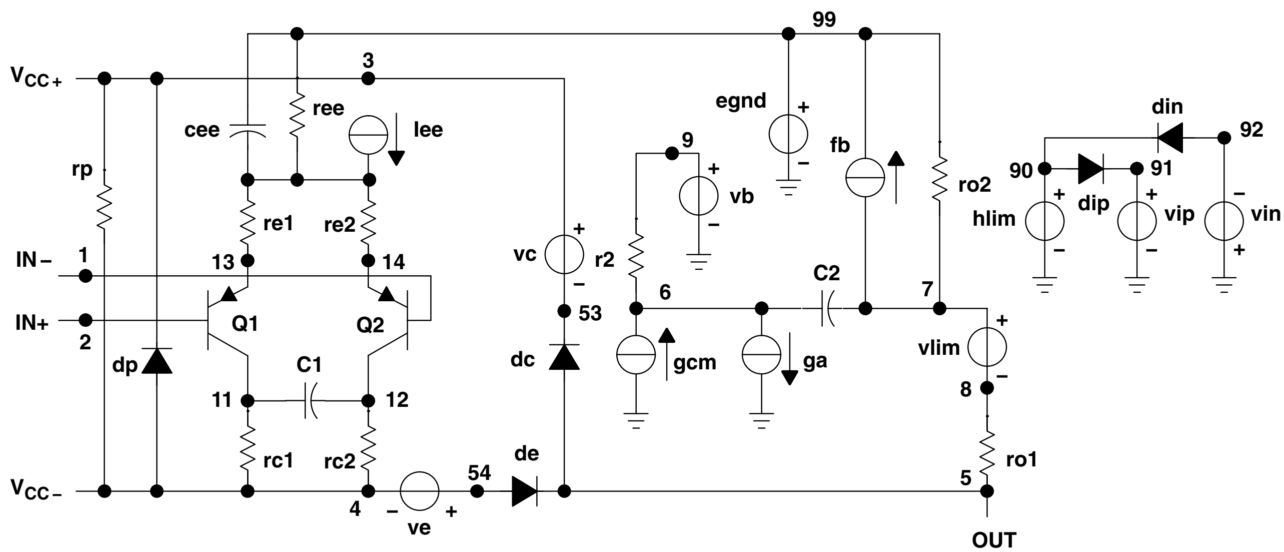


Figure 73. Boyle Subcircuit

PSpice and *Parts* are trademarks of MicroSim Corporation.

```
.SUBCKT TLE2021  1 2 3 4 5
*
  c1     11   12 6.244E−12
  c2     6    7  13.4E−12
  c3     87   0  10.64E−9
  cpsr   85   86 15.9E−9
  dcm+   81   82 dx
  dcm−   83   81 dx
  dc     5    53 dx
  de     54   5  dx
  dlp    90   91 dx
  dln    92   90 dx
  dp     4    3  dx
  ecmr   84   99 (2 99) 1
  egnd   99   0  poly(2) (3,0) (4,0) 0 .5 .5
  epsr   85   0  poly(1) (3,4) −60E−6  2.0E−6
  ense   89   2  poly(1) (88,0) 120E−6  1
  fb     7    99 poly(6) vb vc ve vlp vln vpsr 0 547.3E6
  + −50E7 50E7 50E7 −50E7 547E6
  ga     6    0  11 12 188.5E−6
  gcm    0    6  10 99 335.2E−12
  gpsr   85   86 (85,86) 100E−6
  grc1   4    11 (4,11) 1.885E−4
  grc2   4    12 (4,12) 1.885E−4
  gre1   13   10 (13,10) 6.82E−4
  gre2   14   10 (14,10) 6.82E−4
  hlim   90   0  vlim 1k
  hcmr   80   1  poly(2) vcm+ vcm− 0 1E2 1E2
  irp    3    4  185E−6
  iee    3    10 dc 15.67E−6
  iio    2    0  2E−9
  i1     88   0  1E−21
  q1     11   89 13 qx
  q2     12   80 14 qx
  R2     6    9  100.0E3
  rcm    84   81 1K
  ree    10   99 14.76E6
  rn1    87   0  2.55E8
  rn2    87   88 11.67E3
  ro1    8    5  62
  ro2    7    99 63
  vcm+   82   99 13.3
  vcm−   83   99 −14.6
  vb     9    0  dc 0
  vc     3    53 dc 1.300
  ve     54   4  dc 1.500
  vlim   7    8  dc 0
  vlp    91   0  dc 3.600
  vln    0    92 dc 3.600
  vpsr   0    86 dc 0
.model dx d(is=800.0E−18)
.model qx pnp(is=800.0E−18 bf=270)
.ends
```

Figure 74. Boyle Macromodel for the TLE2021

```
.SUBCKT TLE2022  1 2 3 4 5
*
  c1    11  12 6.814E-12
  c2    6   7  20.00E-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
+ 45.47E6 -50E6 50E6 50E6 -50E6
  ga 6  0   11 12 377.9E-6
  gcm 0 6   10 99 7.84E-10
  iee   3   10 DC 18.07E-6
  hlim 90   0 vlim 1k
  q1    11  2 13 qx
  q2    12  1 14 qx
  r2    6   9 100.0E3
  rc1  4   11 2.842E3
  rc2  4   12 2.842E3
  ge1  13  10 (10,13) 31.299E-3
  ge2  14  10 (10,14) 31.299E-3
  ree  10  99 11.07E6
  ro1  8   5 250
  ro2  7   99 250
  rp   3   4 137.2E3
  vb   9   0 dc 0
  vc   3   53 dc 1.300
  ve   54  4 dc 1.500
  vlim 7   8 dc 0
  vlp  91  0 dc 3
  vln  0   92 dc 3
.model dx  d(is=800.0E-18)
.model qx  pnp(is=800.0E-18 bf=257.1)
.ends
```

Figure 75. Boyle Macromodel for the TLE2022

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
TLE2021AQDRG4Q1	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 125	2021AQ	Samples
TLE2021AQDRQ1	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 125	2021AQ	Samples
TLE2021QDRG4Q1	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 125	2021Q1	Samples
TLE2021QDRQ1	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 125	2021Q1	Samples
TLE2022AQDRG4Q1	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 125	2022AQ	Samples
TLE2022QDRG4Q1	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 125	2022Q1	Samples
TLE2022QDRQ1	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 125	2022Q1	Samples
TLE2024AQDWRG4Q1	ACTIVE	SOIC	DW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 125	2024AQ1	Samples
TLE2024QDWRG4Q1	ACTIVE	SOIC	DW	16	2000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM	-40 to 125	2024Q1	Samples

(1) The marketing status values are defined as follows:
ACTIVE: Product device recommended for new designs.
LIFEBUY: TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.
NRND: Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.
PREVIEW: Device has been announced but is not in production. Samples may or may not be available.
OBSOLETE: TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been defined.
Pb-Free (RoHS): TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.
Pb-Free (RoHS Exempt): This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.
Green (RoHS & no Sb/Br): TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

(3) MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

(4) There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

(5) Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

OTHER QUALIFIED VERSIONS OF TLE2021-Q1, TLE2021A-Q1, TLE2022-Q1, TLE2022A-Q1, TLE2024-Q1, TLE2024A-Q1 :

- Catalog: TLE2021, TLE2021A, TLE2022, TLE2022A, TLE2024, TLE2024A
- Enhanced Product: TLE2021-EP, TLE2021A-EP, TLE2022-EP, TLE2022A-EP, TLE2024-EP, TLE2024A-EP
- Military: TLE2021M, TLE2021AM, TLE2022M, TLE2022AM, TLE2024M, TLE2024AM

NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product
- Enhanced Product - Supports Defense, Aerospace and Medical Applications
- Military - QML certified for Military and Defense Applications

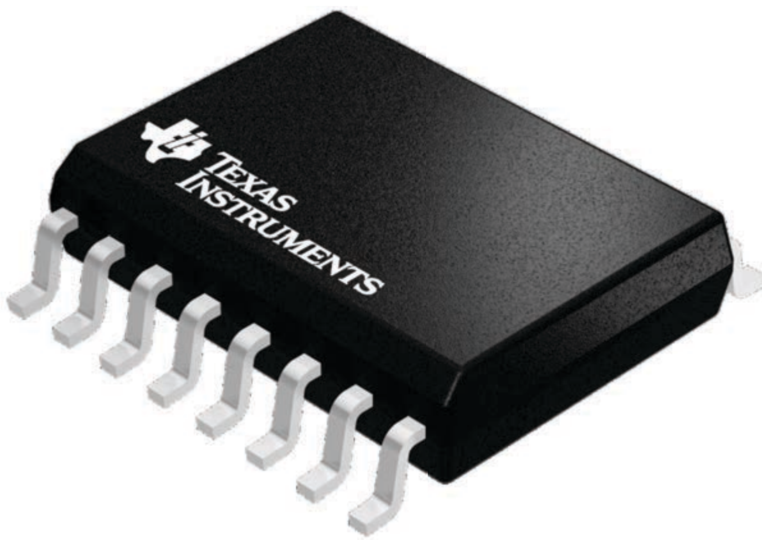
DW 16

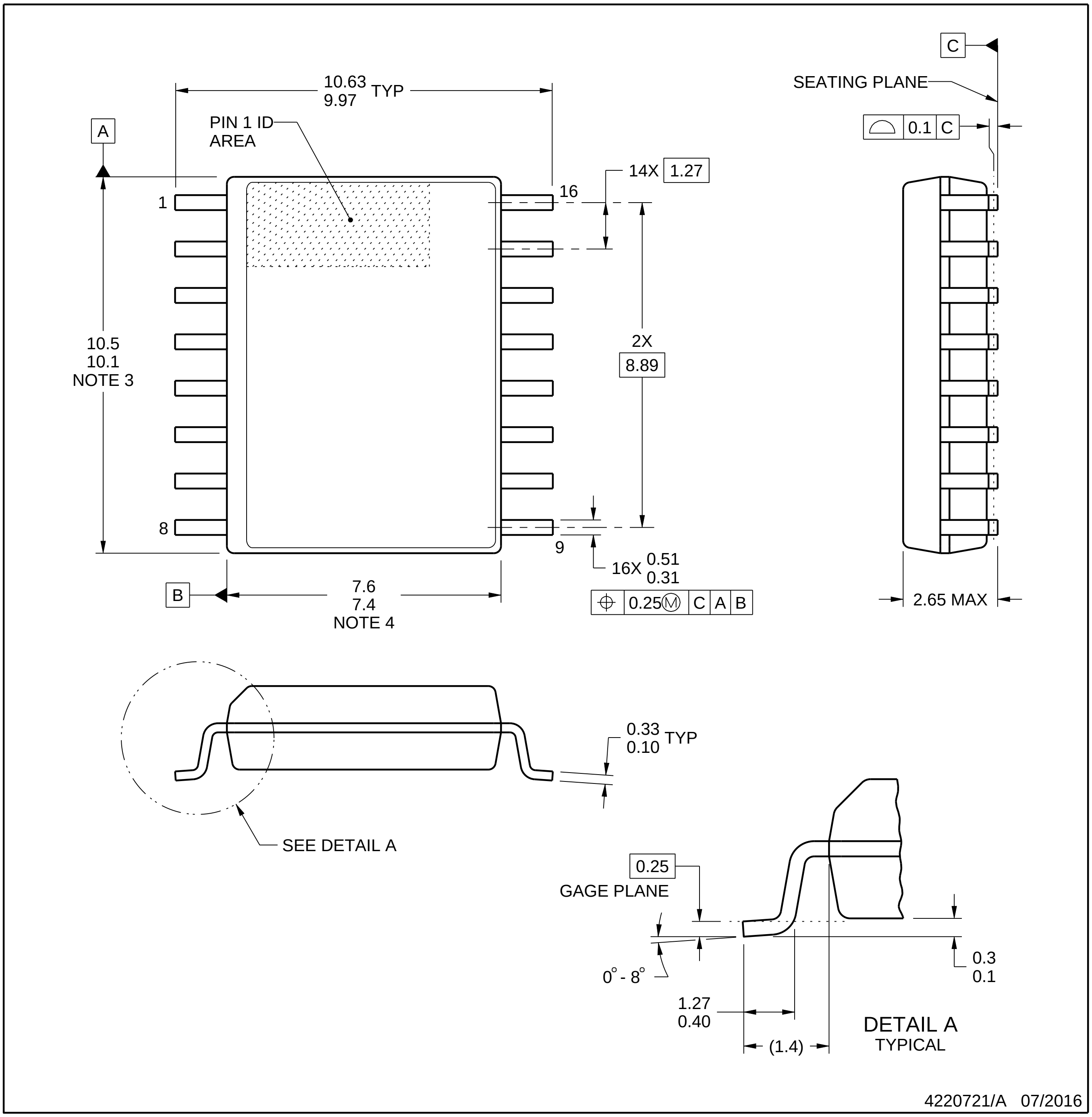
SOIC - 2.65 mm max height

7.5 x 10.3, 1.27 mm pitch

SMALL OUTLINE INTEGRATED CIRCUIT

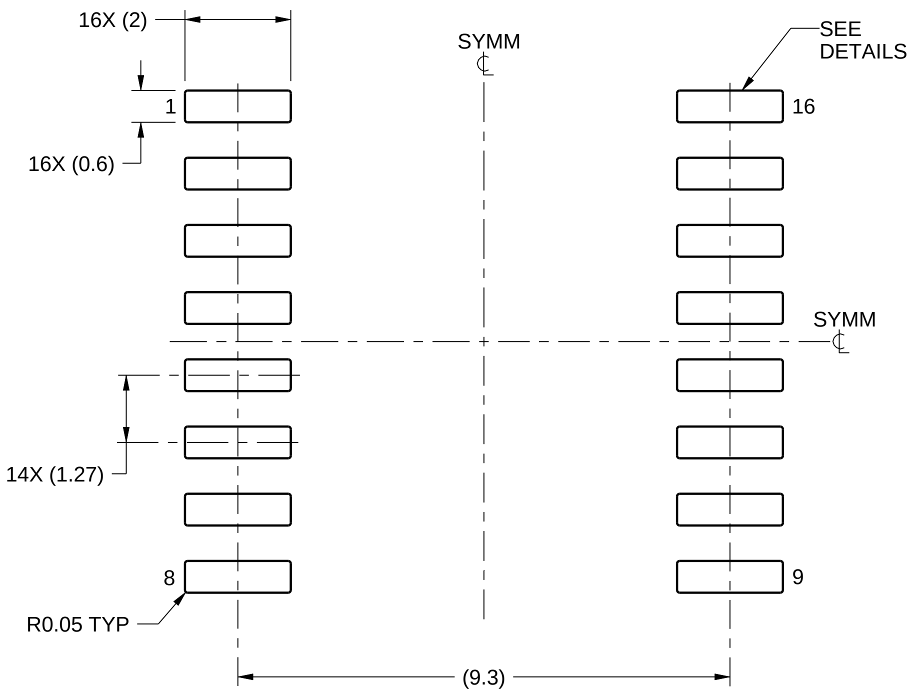
This image is a representation of the package family, actual package may vary.
Refer to the product data sheet for package details.



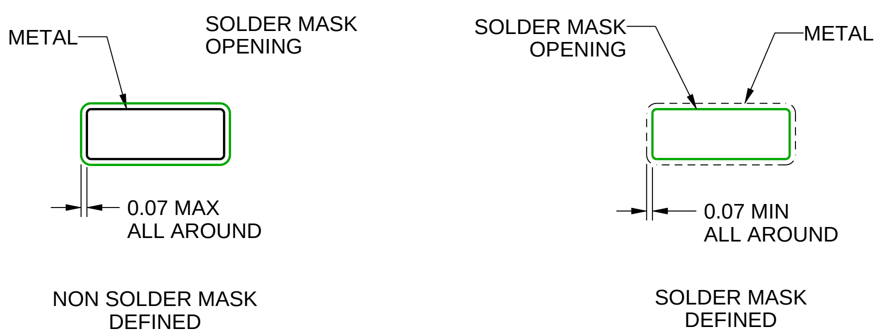


NOTES:

1. All linear dimensions are in millimeters. Dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.15 mm, per side.
4. This dimension does not include interlead flash. Interlead flash shall not exceed 0.25 mm, per side.
5. Reference JEDEC registration MS-013.



LAND PATTERN EXAMPLE
SCALE:7X

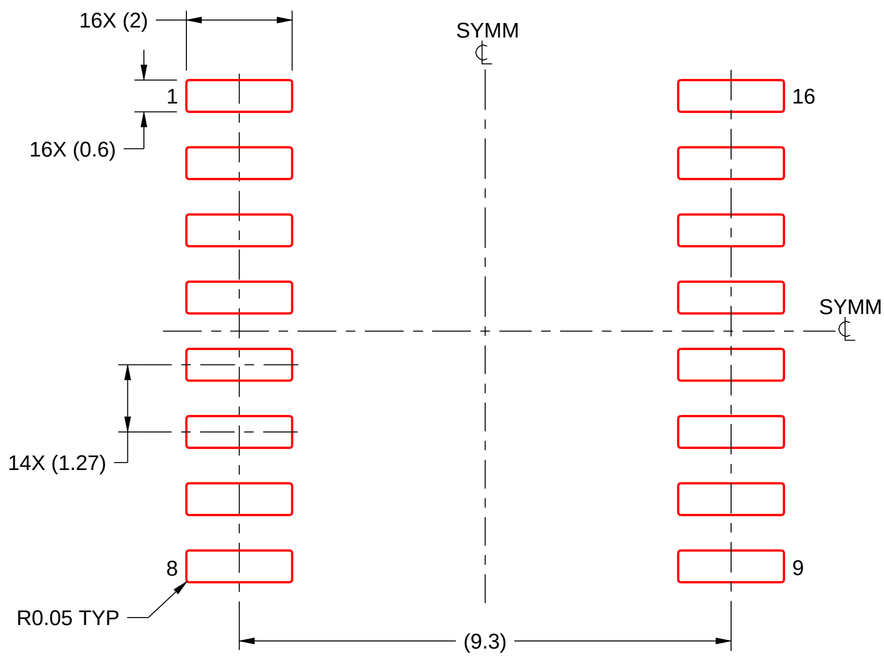


SOLDER MASK DETAILS

4220721/A 07/2016

NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

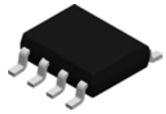


SOLDER PASTE EXAMPLE
BASED ON 0.125 mm THICK STENCIL
SCALE:7X

4220721/A 07/2016

NOTES: (continued)

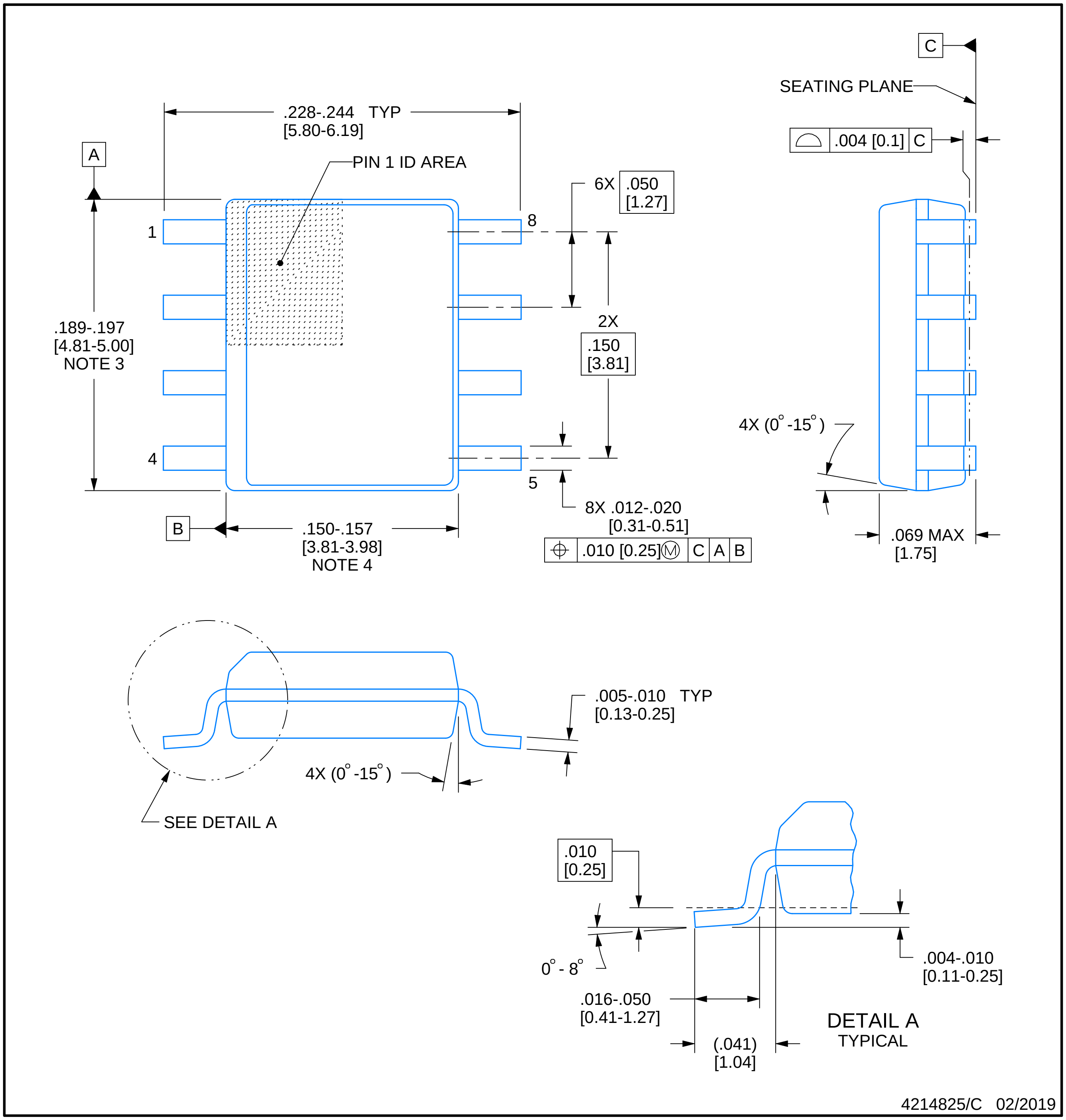
8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.



PACKAGE OUTLINE

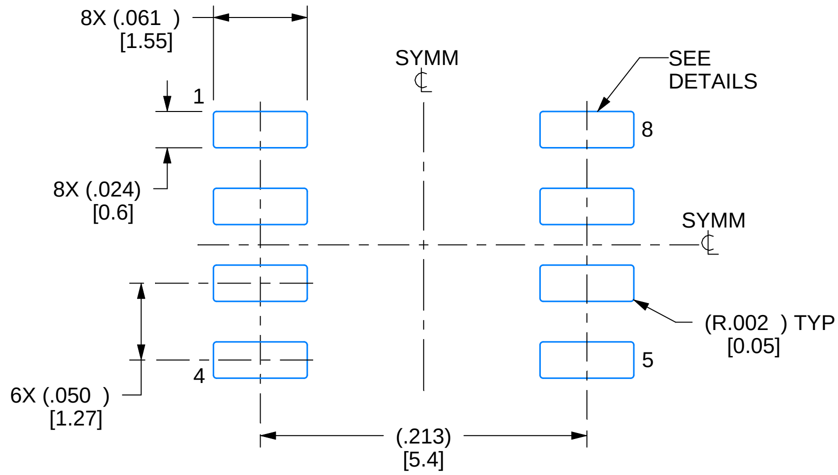
SOIC - 1.75 mm max height

SMALL OUTLINE INTEGRATED CIRCUIT

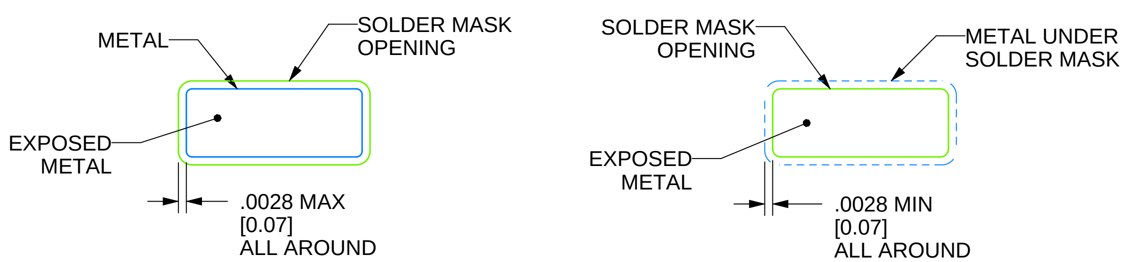


NOTES:

1. Linear dimensions are in inches [millimeters]. Dimensions in parenthesis are for reference only. Controlling dimensions are in inches. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. This dimension does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed .006 [0.15] per side.
4. This dimension does not include interlead flash.
5. Reference JEDEC registration MS-012, variation AA.



LAND PATTERN EXAMPLE
EXPOSED METAL SHOWN
SCALE:8X



NON SOLDER MASK DEFINED

SOLDER MASK DEFINED

SOLDER MASK DETAILS

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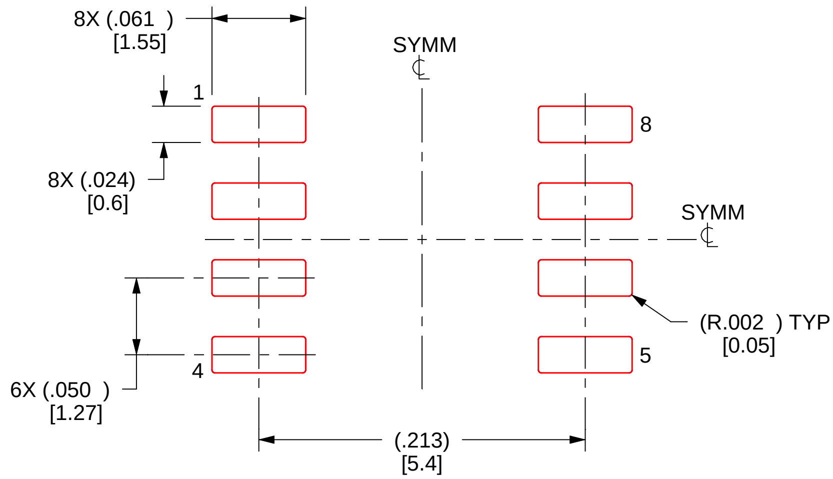
NOTES: (continued)

6. Publication IPC-7351 may have alternate designs.
7. Solder mask tolerances between and around signal pads can vary based on board fabrication site.



SOLDER PASTE EXAMPLE
BASED ON .005 INCH [0.125 MM] THICK STENCIL
SCALE:8X

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NOTES: (continued)

8. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
9. Board assembly site may have different recommendations for stencil design.