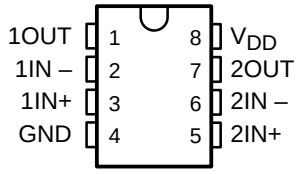
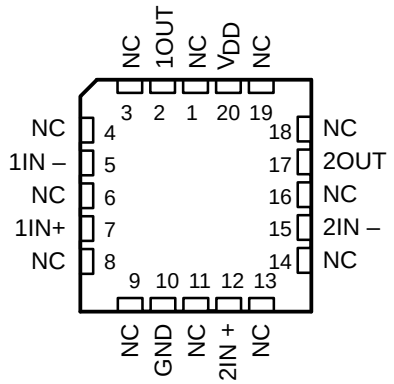
- **Power Dissipation as Low as 10 μW Typ Per Amplifier**
- **Operates on a Single Silver-Oxide Watch Battery, V_{DD} = 1.4 V Min**
- **V_{IO} . . . 450 μV Max in DIP and Small-Outline Package**
- **Input Offset Voltage Drift . . . 0.1 μV/Month Typ, Including the First 30 Days**
- **High-impedance LinCMOS™ Inputs**
  I_{IB} = 0.6 pA Typ
- **High Open-Loop Gain . . . 800 000 Typ**
- **Output Drive Capability > 20 mA**
- **Slew Rate . . . 47 V/ms Typ**
- **Common-Mode Input Voltage Range Extends Below the Negative Rail**
- **Output Voltage Range Includes Negative Rail**
- **On-Chip ESD-Protection Circuitry**
- **Small-Outline Package Option Also Available in Tape and Reel**

D, JG, OR P PACKAGE
(TOP VIEW)



FK PACKAGE
(TOP VIEW)



NC – No internal connection

description

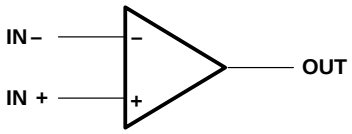
The TLC1078 operational amplifier offers ultra-low offset voltage, high gain, 110-kHz bandwidth, 47-V/ms slew rate, and just 150-μW power dissipation per amplifier.

With a supply voltage of 1.4 V, common-mode input to the negative rail, and output swing to the negative rail, the TLC1078C is an ideal solution for low-voltage battery-operated systems. The 20-mA output drive capability means that the TLC1078 can easily drive small resistive and large capacitive loads when needed, while maintaining ultra-low standby power dissipation.

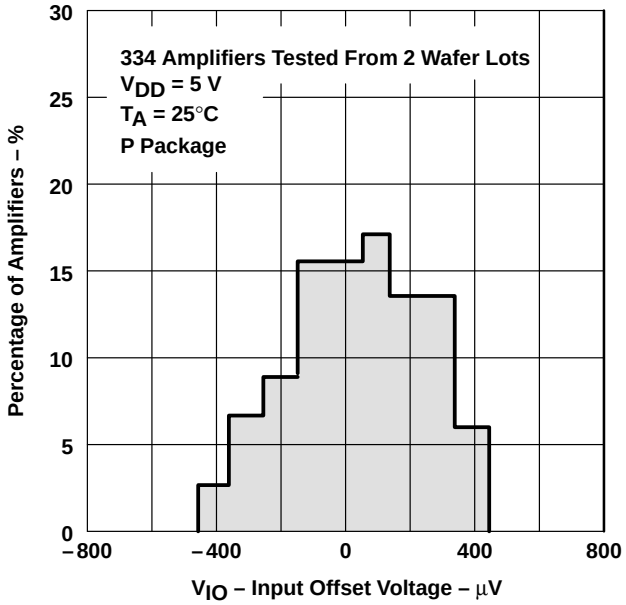
Since this device is functionally compatible as well as pin compatible with the TLC27L2 and TLC27L7, the TLC1078 easily upgrades existing designs that can benefit from its improved performance.

The TLC1078 incorporates internal ESD-protection circuits that will prevent functional failures at voltages up to 2000 V as tested under MIL-STD-883C, Method 3015.2; however, care should be exercised when handling these devices as exposure to ESD may result in degradation of the device parametric performance. The TLC1078 design also inhibits latch-up of the device inputs and outputs even with surge currents as large as 100 mA.

symbol (each amplifier)



DISTRIBUTION OF TLC1078
INPUT OFFSET VOLTAGE



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description (continued)

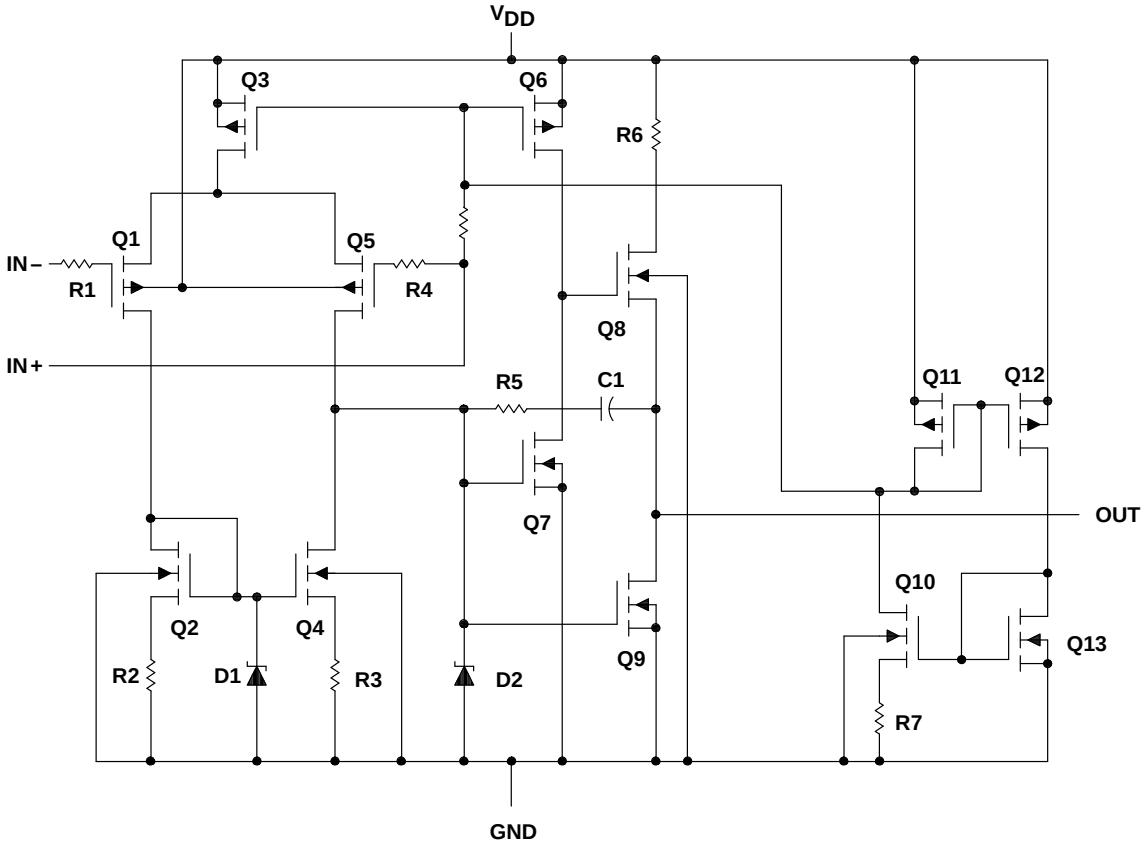
The C-suffix devices are characterized for operation from 0°C to 70°C. The I-suffix devices are characterized for operation from –40°C to 85°C. The M-suffix devices are characterized for operation over the full military temperature range of –55°C to 125°C. The wide range of packaging options includes small-outline and chip-carrier versions for high-density system applications.

AVAILABLE OPTIONS

T_A	PACKAGE			
	SMALL OUTLINE (D)	CHIP CARRIER (FK)	CERAMIC DIP (JG)	PLASTIC DIP (P)
0°C to 70°C	TLC1078CD	—	—	TLC1078CP
–40°C to 85°C	TLC1078ID	—	—	TLC1078IP
–55°C to 125°C	TLC1078MD	TLC1078MFK	TLC1078MJG	TLC1078MP

The D package is available taped and reeled. Add the suffix R to the device type (e.g., TLC1078CDR).

equivalent schematic (each amplifier)



COMPONENT COUNT	
Transistors	38
Diodes	12
Resistors	16
Capacitors	2

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

Supply voltage, V_{DD} (see Note 1) . . . . . 18 V
Differential input voltage, V_{ID} (see Note 2) . . . . . $\pm V_{DD}$
Input voltage range, V_I (any input) . . . . . –0.3 V to V_{DD}
Input current, I_I (each input) . . . . . ± 5 mA
Output current, I_O (each output) . . . . . ± 30 mA
Total current into V_{DD} (see Note 3) . . . . . 45 mA
Duration of short-circuit at (or below) T_A = 25°C (see Note 3) . . . . . unlimited
Continuous total dissipation . . . . . see Dissipation Rating Table
Operating free-air temperature range, T_A: C suffix . . . . . 0°C to 70°C
I suffix . . . . . –40°C to 85°C
M suffix . . . . . –55°C to 125°C
Storage temperature range . . . . . –65°C to 150°C
Case temperature for 60 seconds: FK package . . . . . 260°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package . . . . . 260°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG 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 network ground.
2. Differential voltages are at IN+ with respect to IN–.
3. The output may be shorted to either supply. Temperature and/or supply voltages must be limited to ensure that the maximum dissipation ratings are not exceeded.

DISSIPATION RATING TABLE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25°C$	$T_A = 70°C$ POWER RATING	$T_A = 85°C$ POWER RATING	$T_A = 125°C$ POWER RATING
D	725 mW	5.8 mW/°C	464 mW	377 mW	145 mW
FK	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
JG	1050 mW	8.4 mW/°C	672 mW	546 mW	210 mW
P	1000 mW	8.0 mW/°C	640 mW	520 mW	200 mW

recommended operating conditions

		C SUFFIX		I SUFFIX		M SUFFIX		UNIT
		MIN	MAX	MIN	MAX	MIN	MAX	
Supply voltage, V_{DD}		1.4	16	3	16	4	16	V
Common-mode input voltage, V_{IC}	V_{DD} = 5 V	–0.2	4	–0.2	4	0	4	V
	V_{DD} = 10 V	–0.2	9	–0.2	9	0	9	
Operating free-air temperature, T_A		0	70	–40	85	–55	125	°C

electrical characteristics at specified free-air temperature

PARAMETER		TEST CONDITIONS	T_A†	TLC1078C						UNIT
				V_{DD} = 5 V			V_{DD} = 10 V			
				MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage	V_O = 1.4 V, R_S = 50 Ω, V_{IC} = 0, R_I = 1 MΩ	25°C		160	450		180	600	μV
			Full range			800			950	
α_{VIO}	Temperature coefficient of input offset voltage		25°C to 70°C		1.1			1		μV/°C
I_{IO}	Input offset current (see Note 4)	V_O = V_{DD}/ 2, V_{IC} = V_{DD}/ 2	25°C		0.1			0.1		pA
			70°C		7	300		7	300	
I_{IB}	Input bias current (see Note 4)		25°C		0.6			0.7		pA
			70°C		40	600		50	600	
V_{ICR}	Common-mode input voltage range (see Note 5)		25°C	–0.2 to 4	–0.3 to 4.2		–0.2 to 9	–0.3 to 9.2		V
			Full range	–0.2 to 3.5			–0.2 to 8.5			V
V_{OH}	High-level output voltage	V_{ID} = 100 mV, R_L= 1 MΩ	25°C	3.2	4.1		8.2	8.9		V
			0°C	3.2	4.1		8.2	8.9		
			70°C	3.2	4.2		8.2	8.9		
V_{OL}	Low-level output voltage	V_{ID} = –100 mV, I_{OL} = 0	25°C		0	25		0	25	mV
			0°C		0	25		0	25	
			70°C		0	25		0	25	
A_{VD}	Large-signal differential voltage amplification	R_L= 1 MΩ, See Note 6	25°C	250	525		500	850		V/mV
			0°C	250	680		500	1010		
			70°C	200	380		350	660		
CMRR	Common-mode rejection ratio	V_{IC} = V_{ICR}min	25°C	70	95		75	97		dB
			0°C	70	95		75	97		
			70°C	70	95		75	97		
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{DD}/\Delta V_{IO}$)	V_O = 1.4 V	25°C	75	98		75	98		dB
			0°C	75	98		75	98		
			70°C	75	98		75	98		
I_{DD}	Supply current (two amplifiers)	V_O = V_{DD}/ 2, V_{IC} = V_{DD}/ 2, No load	25°C		20	34		29	46	μA
			0°C		24	42		36	66	
			70°C		16	28		22	40	

† Full range is 0°C to 70°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.
5. This range also applies to each input individually.
6. At V_{DD} = 5 V. V_O = 0.25 V to 2 V; at V_{DD} = 10 V, V_O = 1 V to 6 V.

electrical characteristics at specified free-air temperature

PARAMETER		TEST CONDITIONS	T_A†	TLC1078I						UNIT
				V_{DD} = 5 V			V_{DD} = 10 V			
				MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage	V_O = 1.4 V, R_S = 50 Ω, V_{IC} = 0, R_I = 1 MΩ	25°C		160	450		180	600	μV
			Full range			950			1100	
α_{VIO}	Temperature coefficient of input offset voltage		25°C to 85°C		1.1			1		μV/°C
I_{IO}	Input offset current (see Note 4)	V_O = V_{DD}/ 2, V_{IC} = V_{DD}/ 2	25°C		0.1			0.1		pA
			85°C		24	1000		26	1000	
I_{IB}	Input bias current (see Note 4)		25°C		0.6			0.7		pA
			85°C		200	2000		220	2000	
V_{ICR}	Common-mode input voltage range (see Note 5)		25°C	−0.2 to 4	−0.3 to 4.2		−0.2 to 9	−0.3 to 9.2		V
			Full range	−0.2 to 3.5			−0.2 to 8.5			V
V_{OH}	High-level output voltage	V_{ID} = 100 mV, R_L = 1 MΩ	25°C	3.2	4.1		8.2	8.9		V
			−40°C	3.2	4.1		8.2	8.9		
			85°C	3.2	4.2		8.2	8.9		
V_{OL}	Low-level output voltage	V_{ID} = −100 mV, I_{OL} = 0	25°C		0	25		0	25	mV
			−40°C		0	25		0	25	
			85°C		0	25		0	25	
A_{VD}	Large-signal differential voltage amplification	R_L = 1 MΩ, See Note 6	25°C	250	525		500	850		V/mV
			−40°C	250	900		500	1550		
			85°C	150	300		250	585		
CMRR	Common-mode rejection ratio	V_{IC} = V_{ICR}min	25°C	70	95		75	97		dB
			−40°C	70	95		75	97		
			85°C	70	95		75	97		
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{DD}/\Delta V_{IO}$)	V_O = 1.4 V	25°C	75	98		75	98		dB
			−40°C	75	98		75	98		
			85°C	75	98		75	98		
I_{DD}	Supply current (two amplifiers)	V_O = V_{DD}/ 2, V_{IC} = V_{DD}/ 2, No load	25°C		20	34		29	46	μA
			−40°C		31	54		50	86	
			85°C		15	26		20	36	

† Full range is −40°C to 80°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.
5. This range also applies to each input individually.
6. At V_{DD} = 5 V, V_O = 0.25 V to 2 V; at V_{DD} = 10 V, V_O = 1 V to 6 V.

electrical characteristics at specified operating free-air temperature

PARAMETER		TEST CONDITIONS	T_A†	TLC1078M						UNIT
				V_{DD} = 5 V			V_{DD} = 10 V			
				MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage	V_O = 1.4 V, V_{IC} = 0, R_S = 50 Ω, R_L = 1 MΩ	25°C		160	450		180	600	μV
			Full range			1250			1400	
α_{VIO}	Temperature coefficient of input offset voltage		25°C to 125°C		1.4			1.4		μV/°C
I_{IO}	Input offset current (see Note 4)	$V_O = V_{DD}/2$, $V_{IC} = V_{DD}/2$	25°C		0.1			0.1		pA
			125°C		1.4	15		1.8	15	nA
I_{IB}	Input bias current (see Note 4)		25°C		0.6			0.7		pA
			125°C		9	35		10	35	nA
V_{ICR}	Common-mode input voltage range (see Note 5)		25°C	0 to 4	−0.3 to 4.2		0 to 9	−0.3 to 9.2		V
			Full range	0 to 3.5			0 to 8.5			V
V_{OH}	High-level output voltage	V_{ID} = 100 mV, R_L = 1 MΩ	25°C	3.2	4.1		8.2	8.9		V
			−55°C	3.2	4.1		8.2	8.8		
			125°C	3.2	4.2		8.2	9		
V_{OL}	Low-level output voltage	V_{ID} = −100 mV, I_{OL} = 0	25°C		0	25		0	25	mV
			−55°C		0	25		0	25	
			125°C		0	25		0	25	
A_{VD}	Large-signal differential voltage amplification	R_L = 1 MΩ, See Note 6	25°C	250	525		500	850		V/mV
			−55°C	250	950		500	1750		
			125°C	35	200		75	380		
CMRR	Common-mode rejection ratio	$V_{IC} = V_{ICR}$min	25°C	70	95		75	97		dB
			−55°C	70	95		75	97		
			125°C	70	85		75	91		
k_{SVR}	Supply-voltage rejection ratio ($\Delta V_{DD}/\Delta V_{IO}$)	V_O = 1.4 V	25°C	75	98		75	98		dB
			−55°C	70	98		70	98		
			125°C	70	98		70	98		
I_{DD}	Supply current (two amplifiers)	$V_O = V_{DD}/2$, $V_{IC} = V_{DD}/2$, No load	25°C		20	34		29	46	μA
			−55°C		35	60		56	96	
			125°C		14	24		18	30	

† Full range is −55°C to 125°C.

NOTES: 4. The typical values of input bias current and input offset current below 5 pA were determined mathematically.
5. This range also applies to each input individually.
6. At V_{DD} = 5 V, V_O = 0.25 V to 2 V; at V_{DD} = 10 V, V_O = 1 V to 6 V.

operating characteristics at specified free-air temperature

PARAMETER		TEST CONDITIONS		T_A	TLC1078C						UNIT
					V_{DD} = 5 V			V_{DD} = 10 V			
					MIN	TYP	MAX	MIN	TYP	MAX	
SR	Slew rate at unity gain	R_L = 1 MΩ, V_{IPP} = 1 V,	C_L = 20 pF, See Figure 1	25°C		32			47		V/ms
				0°C		35			51		
				70°C		27			38		
V_n	Equivalent input noise voltage	f = 1 kHz,	R_S = 20 Ω	25°C		68			68		nV/√Hz
B_1	Unity-gain bandwidth	C_L = 20 pF,	See Figure 2	25°C		85			110		kHz
				0°C		100			125		
				70°C		65			90		
ϕ_m	Phase margin at unity gain	C_L = 20 pF,	See Figure 2	25°C		34°			38°		
				0°C		36°			40°		
				70°C		30°			34°		

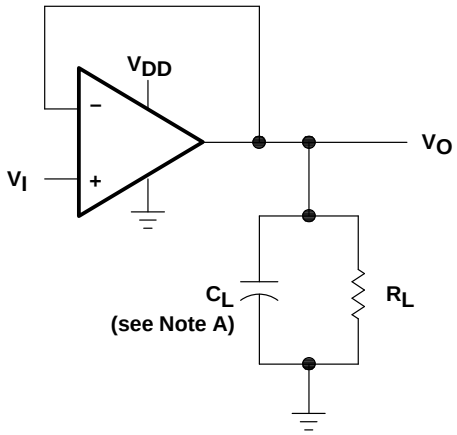
operating characteristics at specified free-air temperature

PARAMETER		TEST CONDITIONS		T_A	TLC1078I						UNIT
					V_{DD} = 5 V			V_{DD} = 10 V			
					MIN	TYP	MAX	MIN	TYP	MAX	
SR	Slew rate at unity gain	R_L = 1 MΩ, V_{IPP} = 1 V,	C_L = 20 pF, See Figure 1	25°C		32			47		V/ms
				–40°C		39			59		
				85°C		25			34		
V_n	Equivalent input noise voltage	f = 1 kHz,	R_S = 20 Ω	25°C		68			68		nV/√Hz
B_1	Unity-gain bandwidth	C_L = 20 pF,	See Figure 2	25°C		85			110		kHz
				–40 °C		130			155		
				85°C		55			80		
ϕ_m	Phase margin at unity gain	C_L = 20 pF,	See Figure 2	25°C		34°			38°		
				–40°C		38°			40°		
				85°C		28°			32°		

operating characteristics at specified free-air temperature

PARAMETER		TEST CONDITIONS		T_A	TLC1078M						UNIT
					V_{DD} = 5 V			V_{DD} = 10 V			
					MIN	TYP	MAX	MIN	TYP	MAX	
SR	Slew rate at unity gain	R_L = 1 MΩ, V_{IPP} = 1 V,	C_L = 20 pF, See Figure 1	25°C		32			47		V/ms
				–55°C		41			63		
				125°C		20			27		
V_n	Equivalent input noise voltage	f = 1 kHz,	R_S = 20 Ω	25°C		68			68		nV/√Hz
B_1	Unity-gain bandwidth	C_L = 20 pF,	See Figure 2	25°C		85			110		kHz
				–55°C		140			165		
				125°C		45			70		
ϕ_m	Phase margin at unity gain	C_L = 20 pF,	See Figure 2	25°C		34°			38°		
				–55°C		39°			43°		
				125°C		25°			29°		

PARAMETER MEASUREMENT INFORMATION



NOTE A: C_L includes fixture capacitance.

Figure 1. Slew-Rate Test Circuit

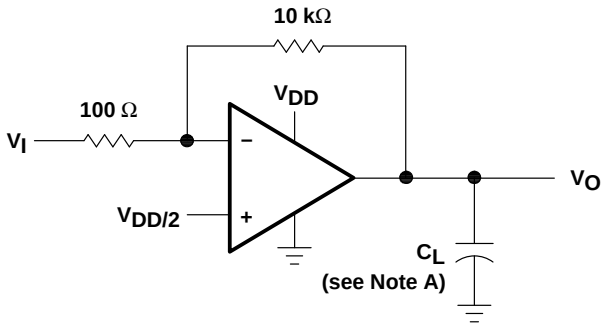


Figure 2. Unity-Gain Bandwidth and Phase-Margin Test Circuit

TYPICAL CHARACTERISTICS

Table of Graphs

			FIGURE
α_{VIO}	Temperature coefficient of input offset voltage	Distribution	3, 4
V_{OH}	High-level output voltage	vs High-level output current vs Supply voltage vs Temperature	5, 6 7 8
V_{OL}	Low-level output voltage	vs Common-mode input voltage vs Differential input voltage vs Free-air temperature vs Low-level output current	9, 10 11 12 13, 14
A_{VD}	Large-signal differential voltage amplification	vs Supply voltage vs Free-air temperature vs Frequency	15 16 27, 28
I_{IB}	Input bias current	vs Free-air temperature	17
I_{IO}	Input offset current	vs Free-air temperature	17
V_{IC}	Common-mode input voltage	vs Supply voltage	18
I_{DD}	Supply current	vs Supply voltage vs Free-air temperature	19 20
SR	Slew rate	vs Supply voltage vs Free-air temperature	21 22
	Normalized slew rate	vs Free-air temperature	23
V_{OM}	Maximum peak output voltage	vs Frequency	24
B_1	Unity-gain bandwidth	vs Free-air temperature vs Supply voltage	25 26
	Phase shift	vs Frequency	27, 28
ϕ_m	Phase margin	vs Supply voltage vs Free-air temperature vs Load capacitance	29 30 31
V_n	Equivalent input noise voltage	vs Frequency	32

TYPICAL CHARACTERISTICS

**DISTRIBUTION OF TLC1078
INPUT OFFSET VOLTAGE
TEMPERATURE COEFFICIENT**

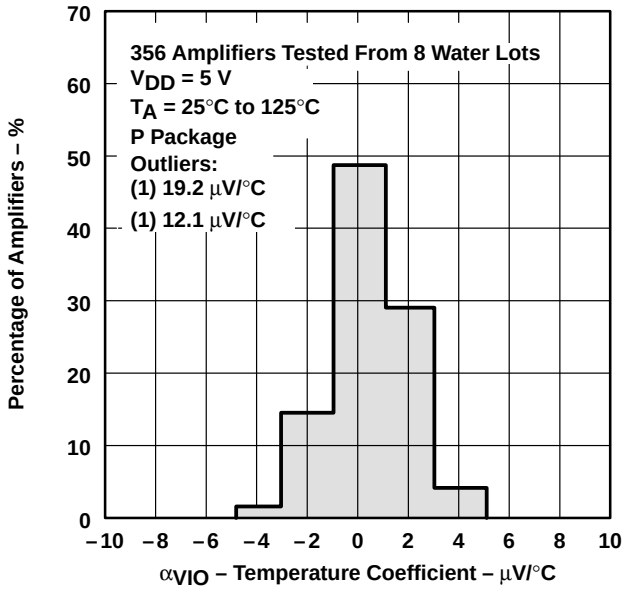


Figure 3

**DISTRIBUTION OF TLC1078
INPUT OFFSET VOLTAGE
TEMPERATURE COEFFICIENT**

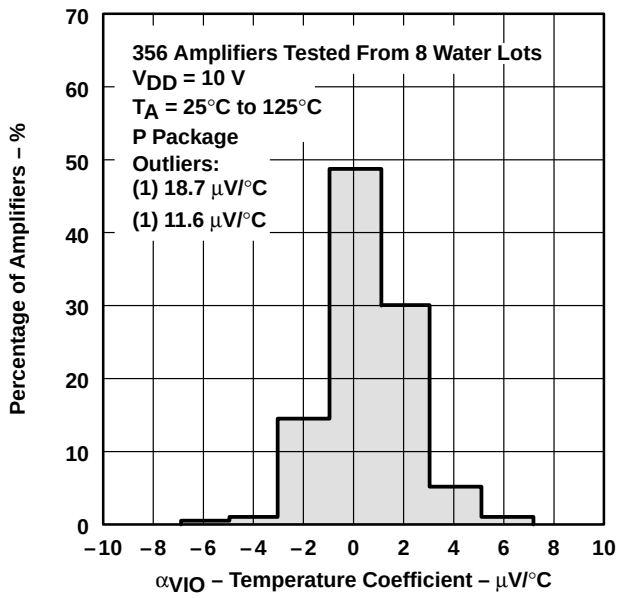
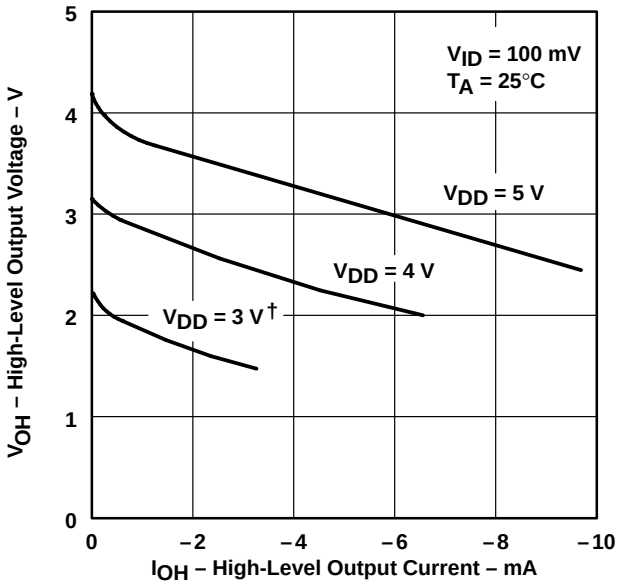


Figure 4

**HIGH-LEVEL OUTPUT VOLTAGE
vs
HIGH-LEVEL OUTPUT CURRENT**



† The V_{DD} = 3 V curve does not apply to the TLC1078M.

Figure 5

**HIGH-LEVEL OUTPUT VOLTAGE
vs
HIGH-LEVEL OUTPUT CURRENT**

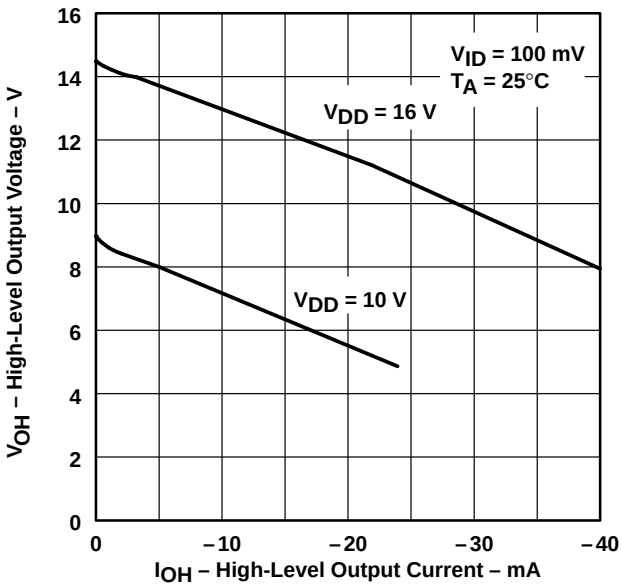


Figure 6

TYPICAL CHARACTERISTICS†

HIGH-LEVEL OUTPUT VOLTAGE vs SUPPLY VOLTAGE

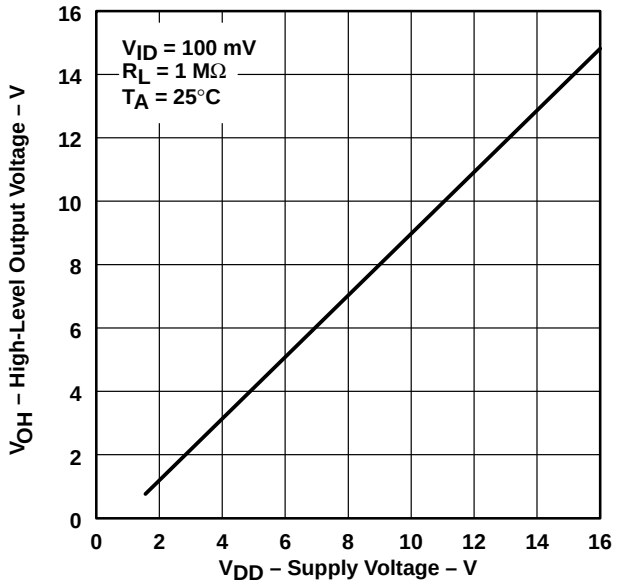


Figure 7

HIGH-LEVEL OUTPUT VOLTAGE vs FREE-AIR TEMPERATURE

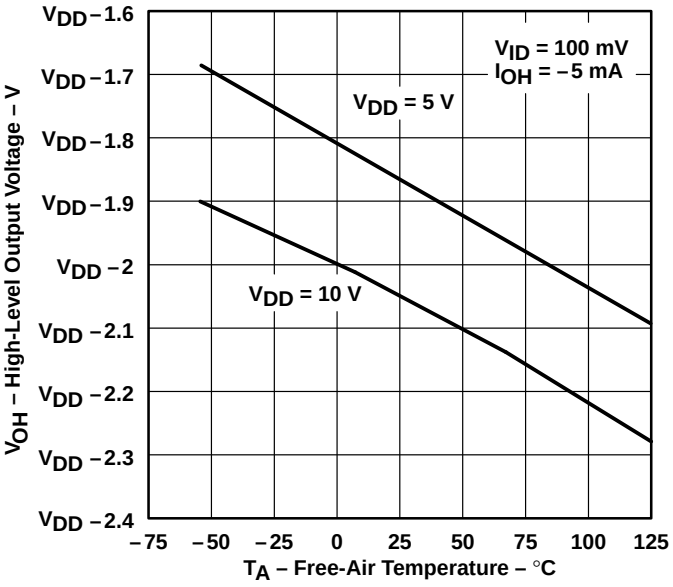


Figure 8

LOW-LEVEL OUTPUT VOLTAGE vs COMMON-MODE INPUT VOLTAGE

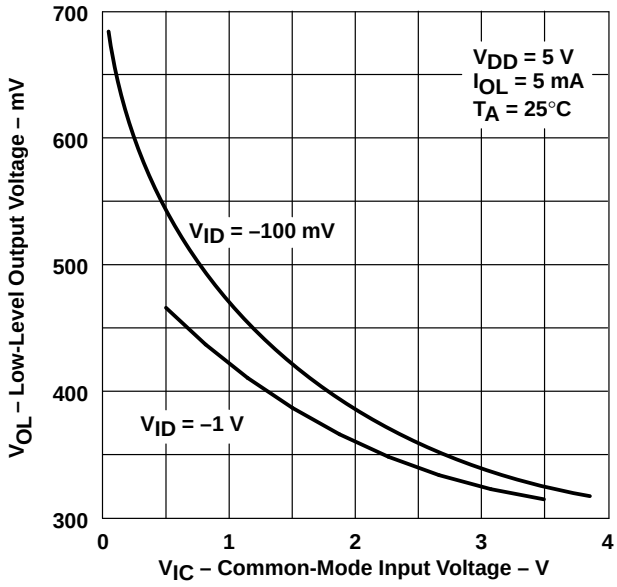


Figure 9

LOW-LEVEL OUTPUT VOLTAGE vs COMMON-MODE INPUT VOLTAGE

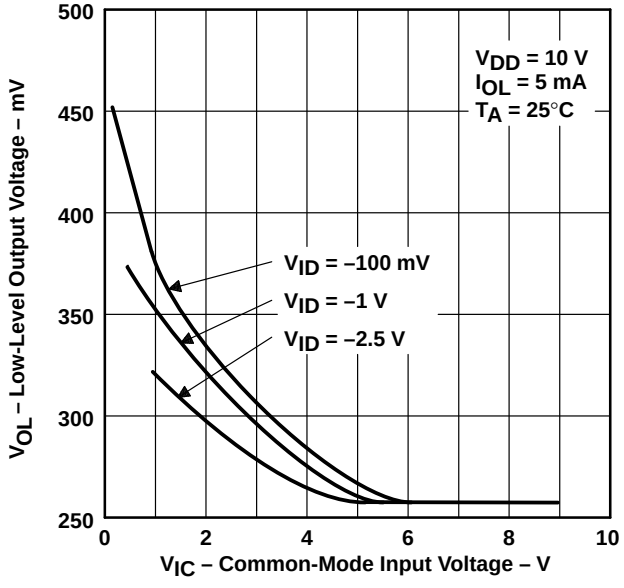


Figure 10

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

TYPICAL CHARACTERISTICS†

LOW-LEVEL OUTPUT VOLTAGE vs DIFFERENTIAL INPUT VOLTAGE

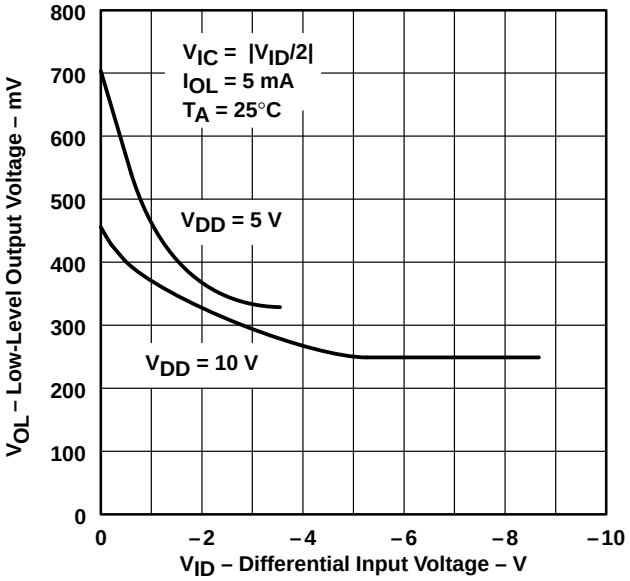


Figure 11

LOW-LEVEL OUTPUT VOLTAGE vs FREE-AIR TEMPERATURE

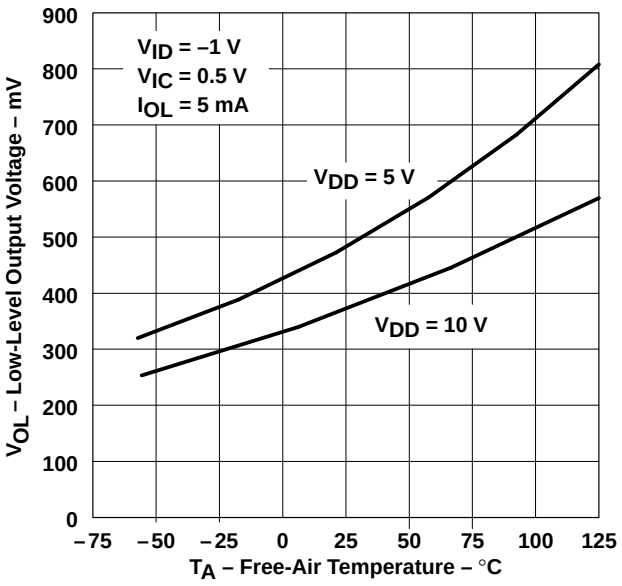


Figure 12

LOW-LEVEL OUTPUT VOLTAGE vs LOW-LEVEL OUTPUT CURRENT

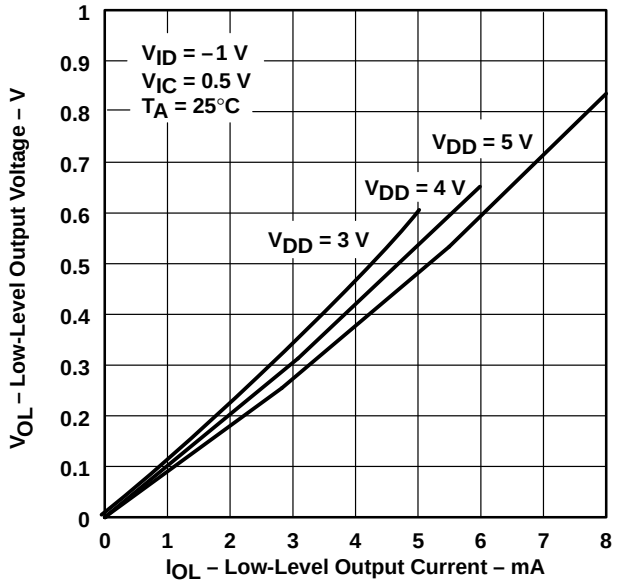


Figure 13

LOW-LEVEL OUTPUT VOLTAGE vs LOW-LEVEL OUTPUT CURRENT

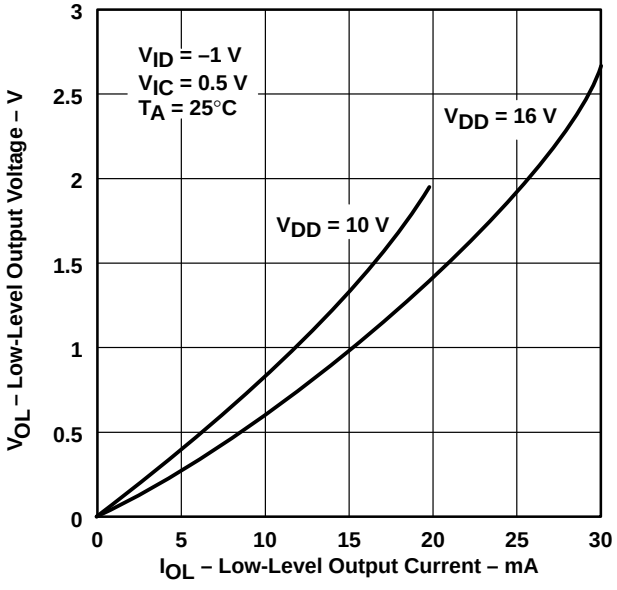


Figure 14

† 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 SUPPLY VOLTAGE

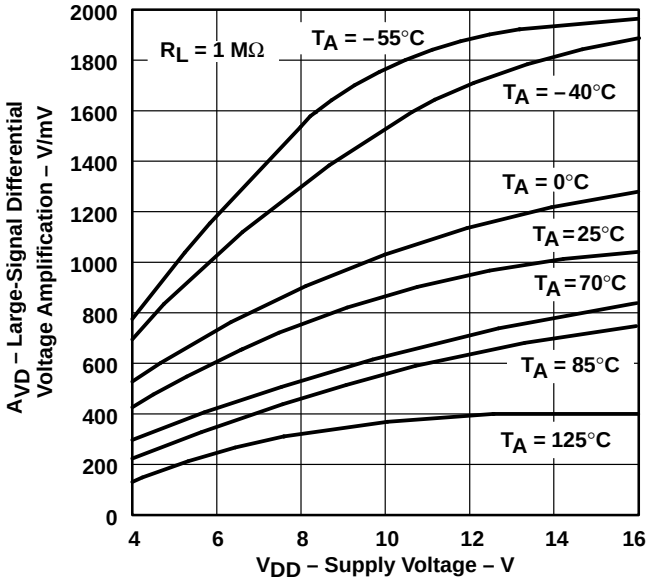


Figure 15

LARGE SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION vs FREE-AIR TEMPERATURE

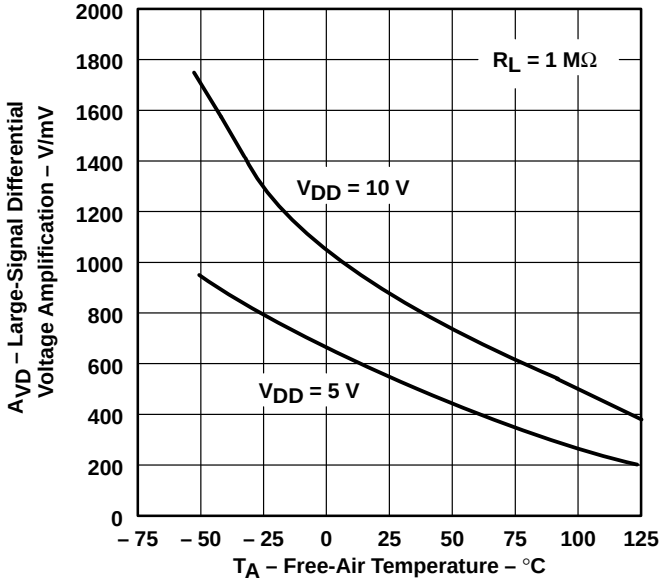
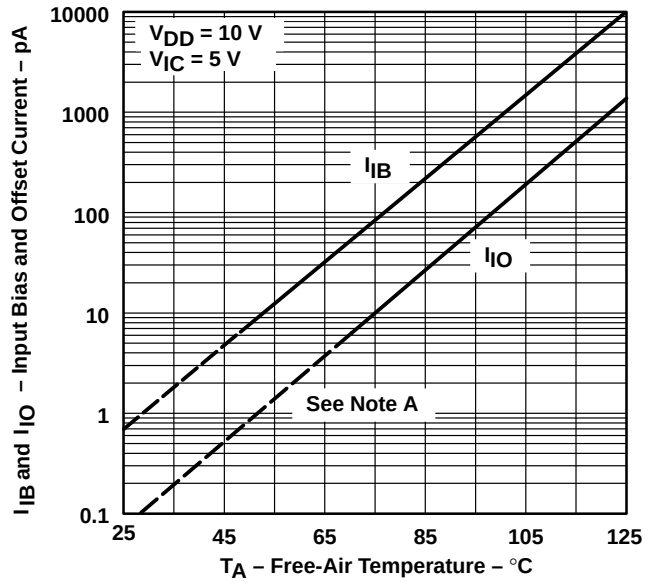


Figure 16

INPUT BIAS AND OFFSET CURRENT vs FREE-AIR TEMPERATURE



NOTE A: The typical values of input bias current and input offset current below 5 pA were determined mathematically.

Figure 17

COMMON-MODE INPUT VOLTAGE POSITIVE LIMIT vs SUPPLY VOLTAGE

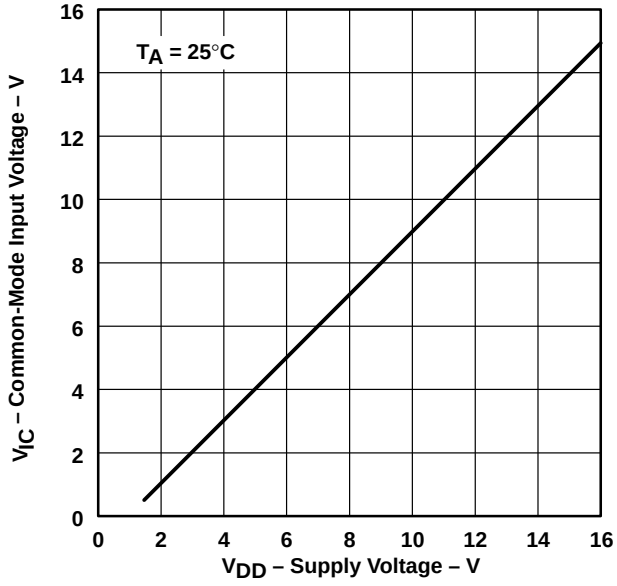


Figure 18

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

TYPICAL CHARACTERISTICS†

SUPPLY CURRENT vs SUPPLY VOLTAGE

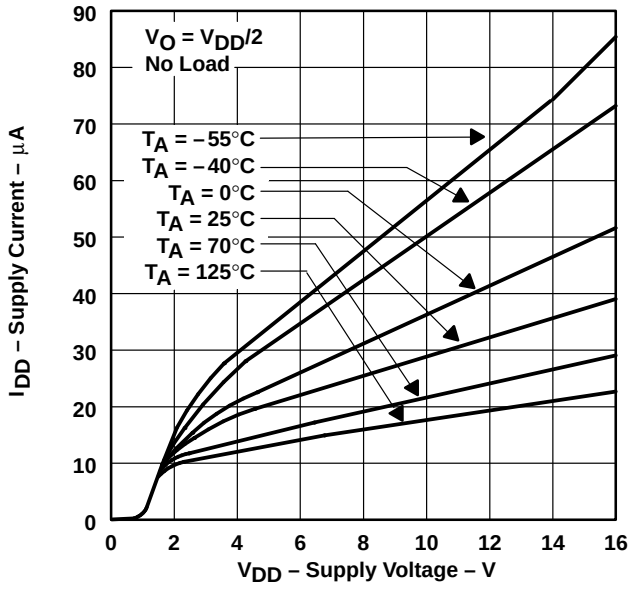


Figure 19

SUPPLY CURRENT vs FREE-AIR TEMPERATURE

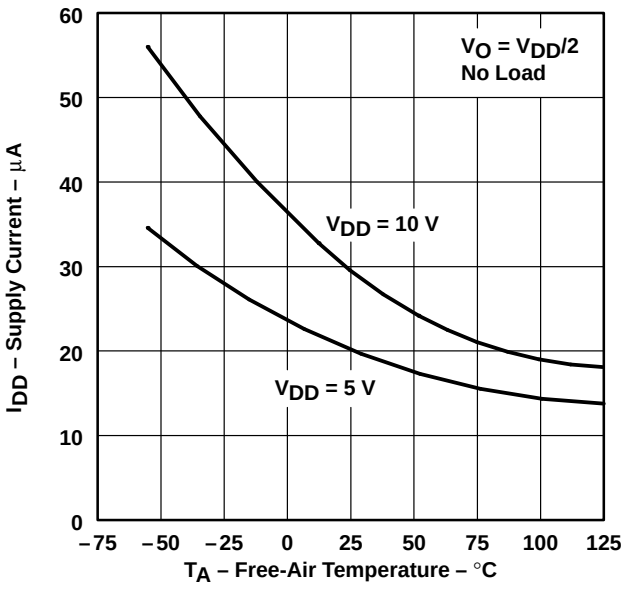


Figure 20

SLEW RATE vs SUPPLY VOLTAGE

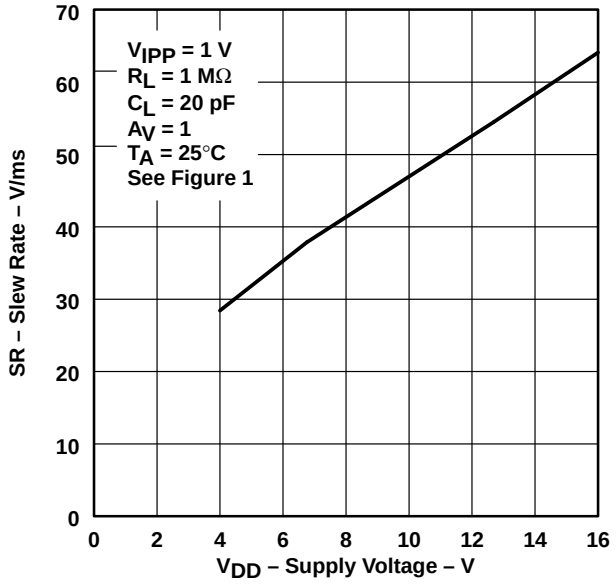


Figure 21

SLEW RATE vs FREE-AIR TEMPERATURE

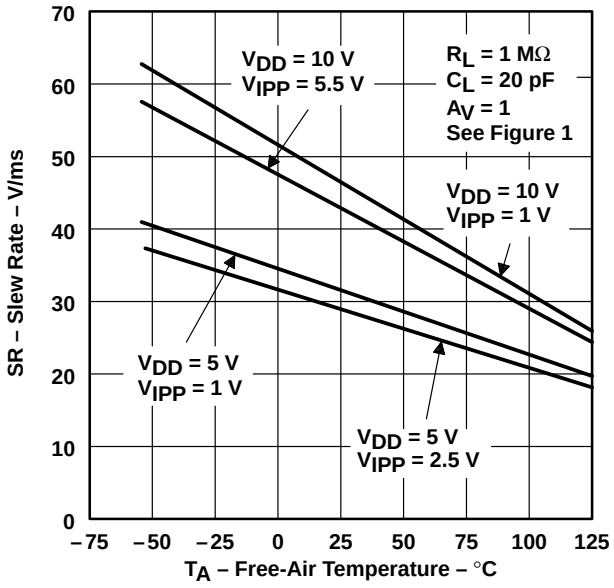


Figure 22

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

TYPICAL CHARACTERISTICS†

NORMALIZED SLEW RATE vs FREE-AIR TEMPERATURE

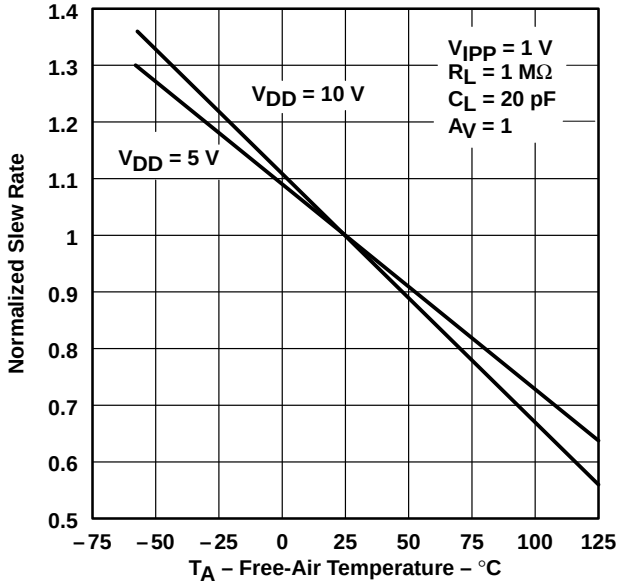


Figure 23

MAXIMUM PEAK OUTPUT VOLTAGE vs FREQUENCY

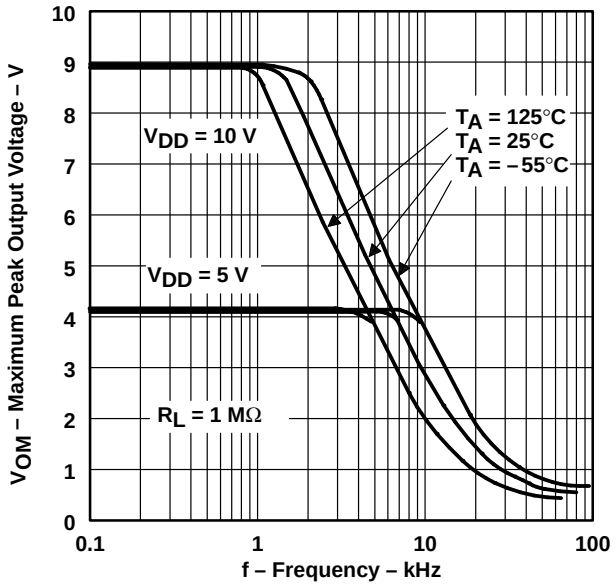


Figure 24

UNITY-GAIN BANDWIDTH vs FREE-AIR TEMPERATURE

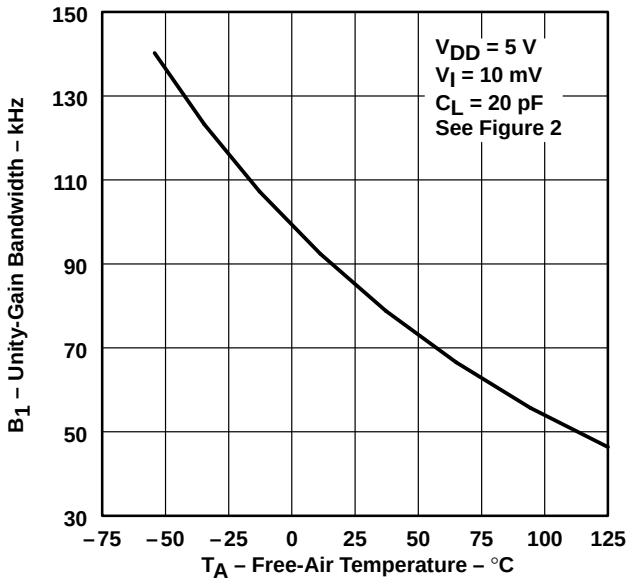


Figure 25

UNITY-GAIN BANDWIDTH vs SUPPLY VOLTAGE

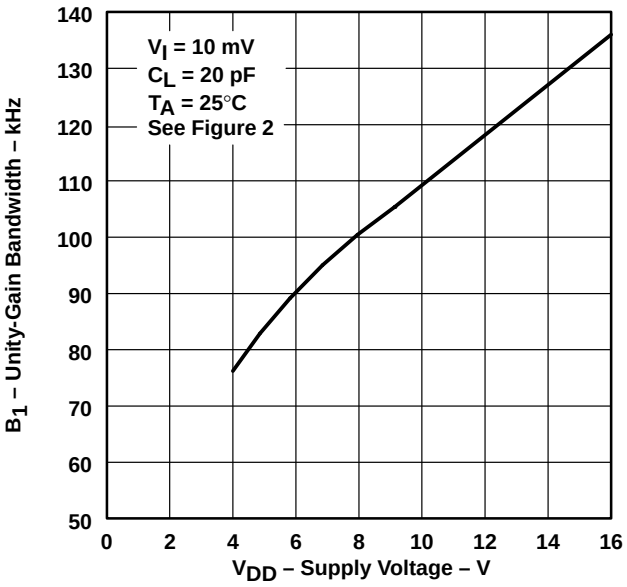


Figure 26

† 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

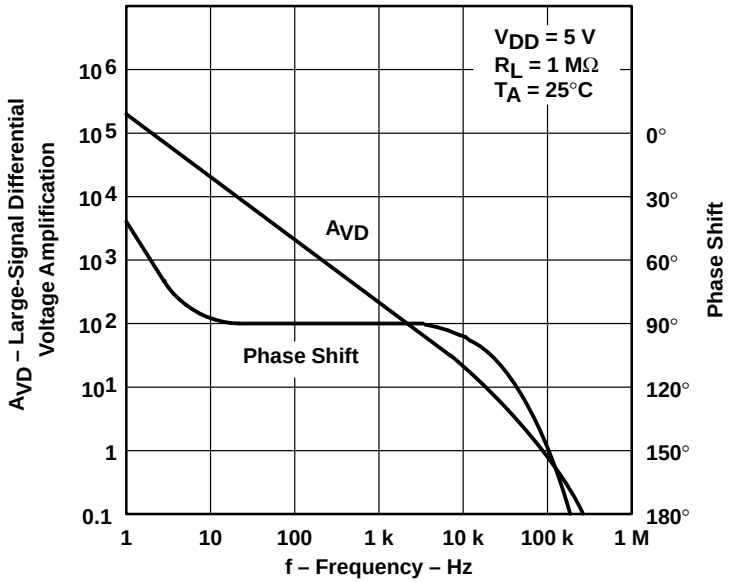


Figure 27

LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION AND PHASE SHIFT vs FREQUENCY

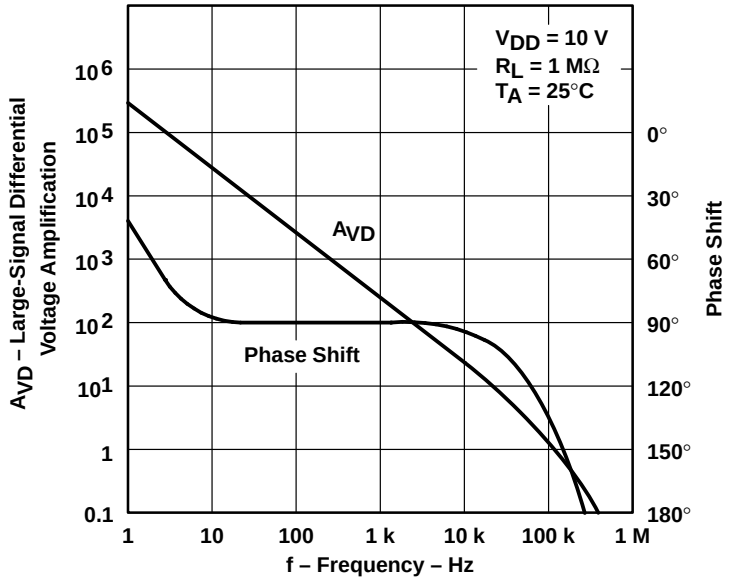


Figure 28

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

TYPICAL CHARACTERISTICS†

PHASE MARGIN vs SUPPLY VOLTAGE

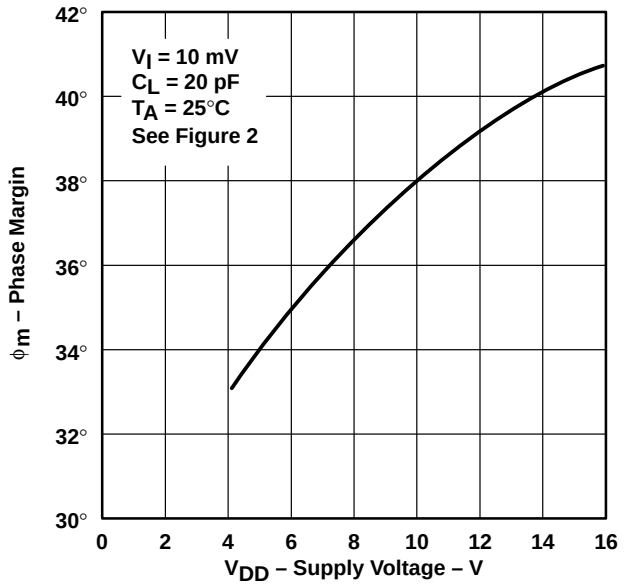


Figure 29

PHASE MARGIN vs FREE-AIR TEMPERATURE

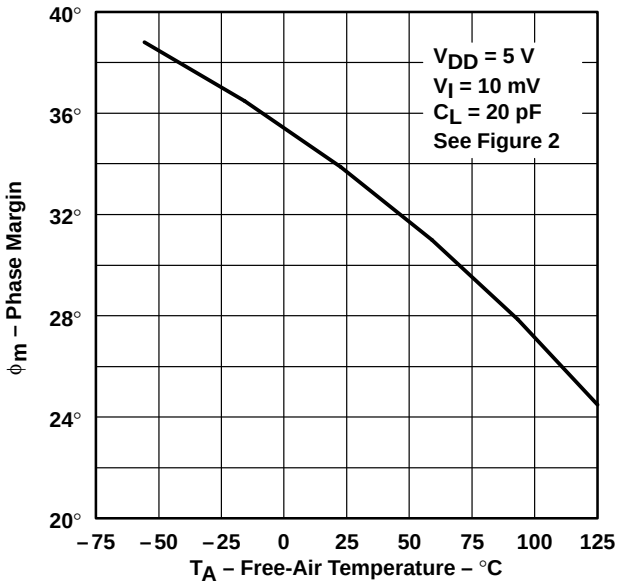


Figure 30

PHASE MARGIN vs CAPACITIVE LOAD

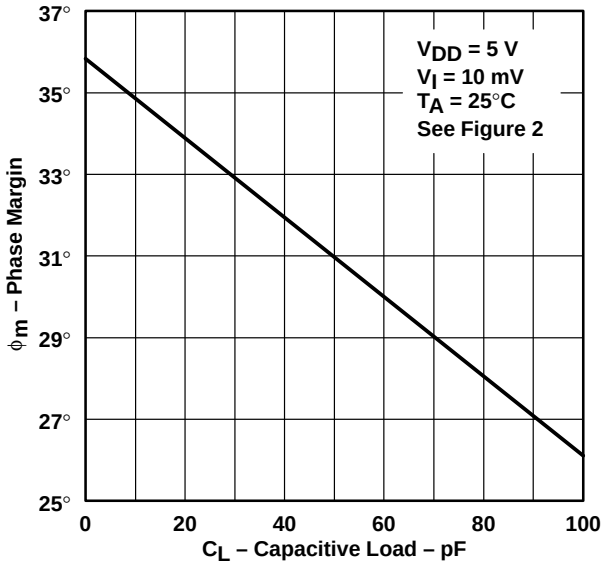


Figure 31

EQUIVALENT INPUT NOISE VOLTAGE vs FREQUENCY

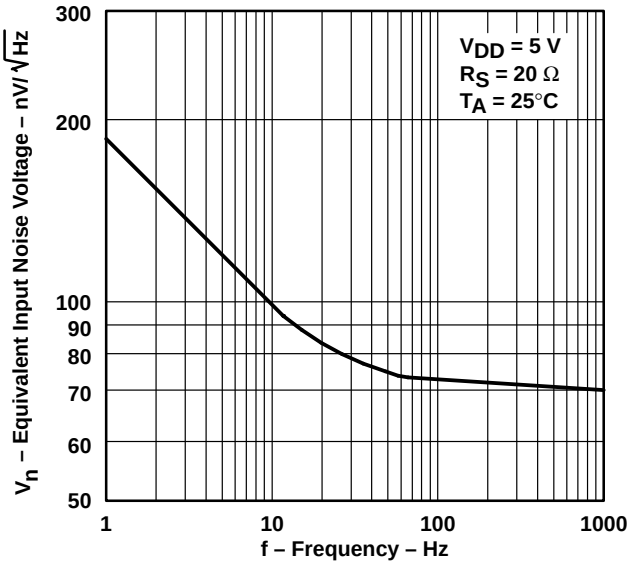


Figure 32

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

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