- **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)**
- **Available in TSSOP for Small Form-Factor Designs**

## description

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.

**AVAILABLE OPTIONS**

| $T_A$ | $V_{IO}$max AT 25°C | PACKAGED DEVICES | | | | | | CHIP FORM‡ (Y) |
|---|---|---|---|---|---|---|---|---|
| | | SMALL OUTLINE† (D) | CHIP CARRIER (FK) | CERAMIC DIP (J) | CERAMIC DIP (JG) | PLASTIC DIP (N) | PLASTIC DIP (P) | |
| 0°C to 70°C | 800 μV | TL051ACD<br>TL052ACD | — | — | — | — | TL051ACP<br>TL052ACP | TL051Y<br>TL052Y<br>TL054Y |
| | 1.5 mV | TL051CD<br>TL052CD<br>TL054ACD | — | — | — | TL054ACN | TL051CP<br>TL052CP | |
| | 4 mV | TL054CD | — | — | — | TL054CN | — | |
| –40°C to 85°C | 800 μV | TL051AID<br>TL052AID | — | — | — | — | TL051AIP<br>TL052AIP | — |
| | 1.5 mV | TL051ID<br>TL052ID<br>TL054AID | — | — | — | TL054AIN | TL051IP<br>TL052IP | |
| | 4 mV | TL054ID | — | | — | TL054IN | — | |
| –55°C to 125°C | 800 μV | TL051AMD<br>TL052AMD | TL051AMFK<br>TL052AMFK | — | TL051AMJG<br>TL052AMJG | — | TL051AMP<br>TL052AMP | — |
| | 1.5 mV | TL051MD<br>TL052MD<br>TL054AMD | TL051MFK<br>TL052MFK<br>TL054AMFK | TL054AMJ | TL051MJG<br>TL052MJG | TL054AMN | TL051MP<br>TL052MP | |
| | 4 mV | TL054MD | TL054MFK | TL054MJ | — | TL054MN | — | |

† The D packages are available taped and reeled. Add R suffix to device type (e.g., TL054CDR).
‡ Chip forms are tested at 25°C.

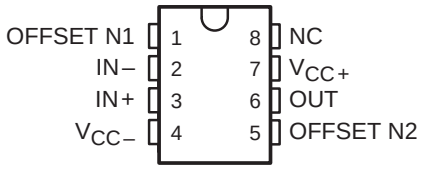
Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

## description (continued)

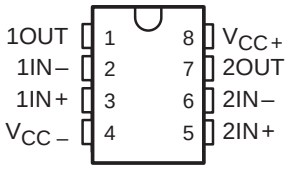
Because BiFET operational amplifiers are designed for use with dual power supplies, care must be taken to observe common-mode input voltage limits and output swing when operating from a single supply. DC biasing of the input signal is required and loads should be terminated to a virtual-ground node at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

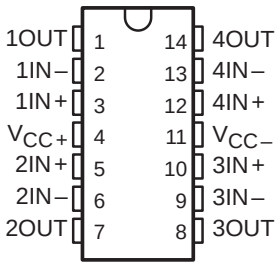
**TL051**
**D, JG, OR P PACKAGE**
**(TOP VIEW)**



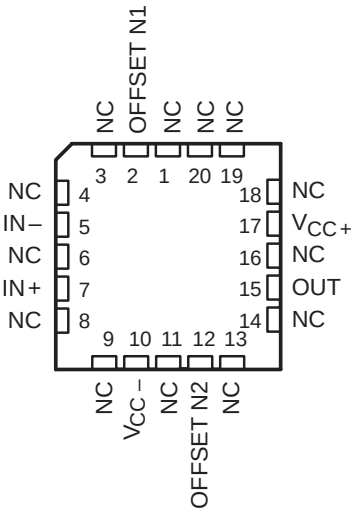

**TL052**
**D, JG, OR P PACKAGE**
**(TOP VIEW)**



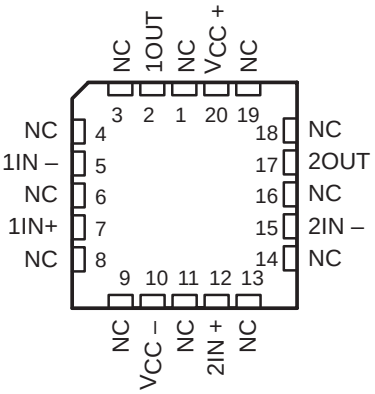

**TL054**
**D, J, OR N PACKAGE**
**(TOP VIEW)**



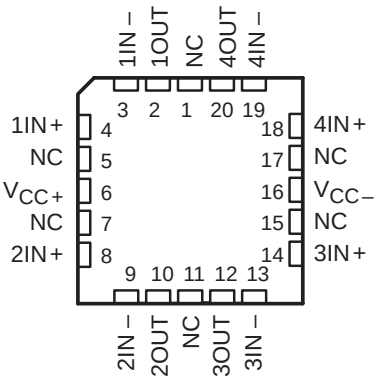

**TL051**
**FK PACKAGE**
**(TOP VIEW)**




**TL052**
**FK PACKAGE**
**(TOP VIEW)**

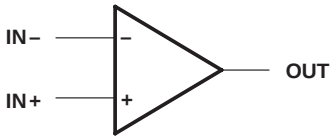



**TL054**
**FK PACKAGE**
**(TOP VIEW)**

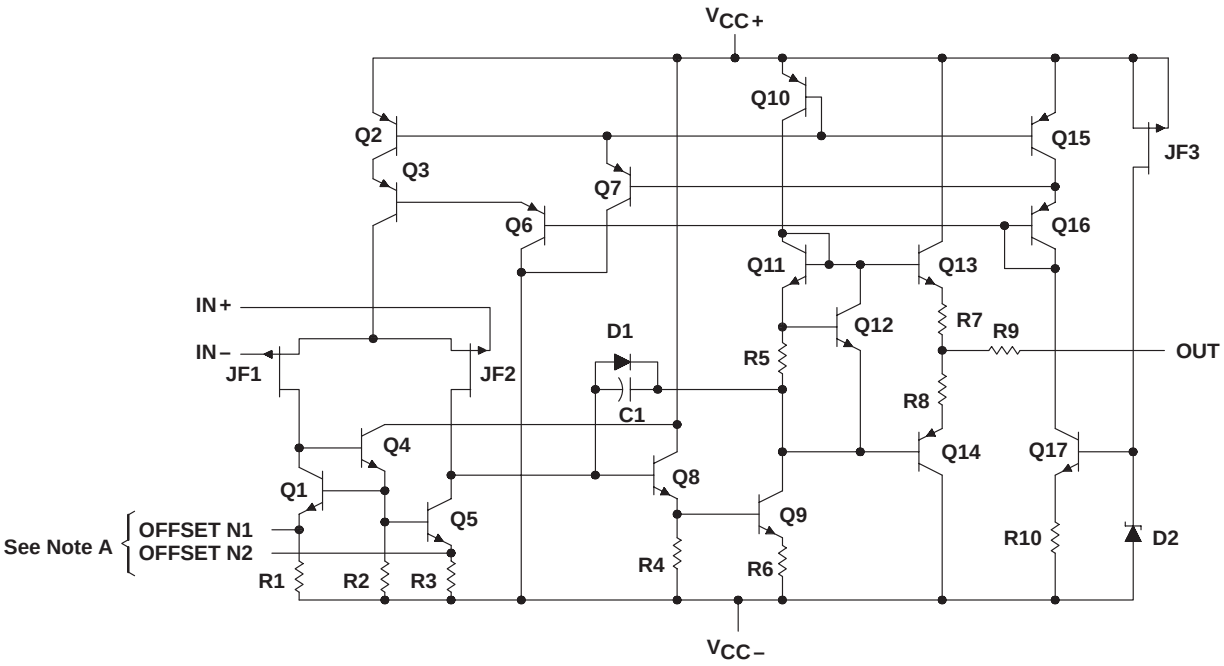



NC – No internal connection

## symbol (each amplifier)




## equivalent schematic (each amplifier)




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

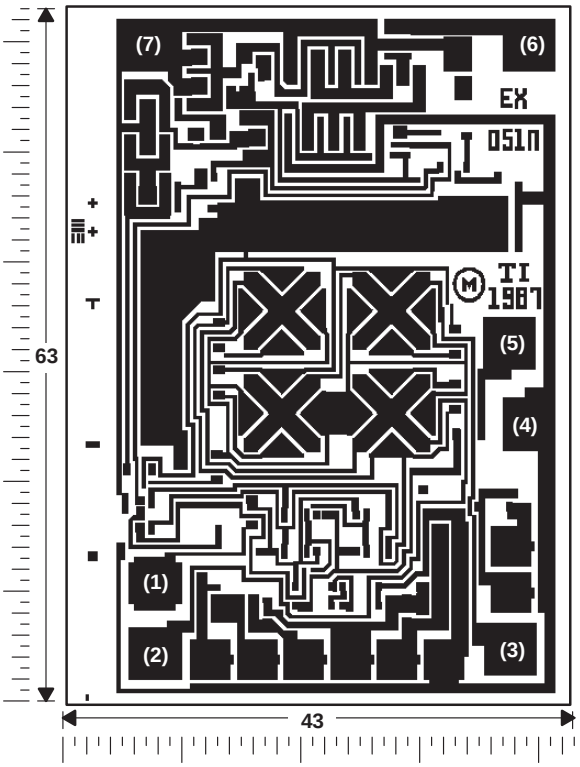
| ACTUAL DEVICE COMPONENT COUNT† | | | |
|---|---|---|---|
| **COMPONENT** | **TL051** | **TL052** | **TL054** |
| Transistors | 20 | 34 | 62 |
| Resistors | 10 | 19 | 37 |
| Diodes | 2 | 3 | 5 |
| Capacitors | 1 | 2 | 4 |

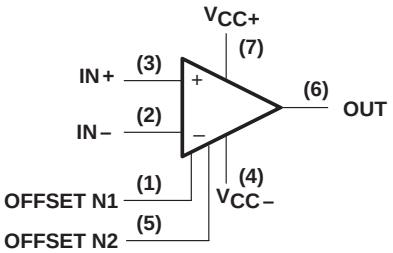
† These figures include all four amplifiers and all ESD, bias, and trim circuitry.

## TL051Y chip information

This chip, when properly assembled, displays characteristics similar to the TL051. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.

**BONDING PAD ASSIGNMENTS**




**CHIP THICKNESS: 15 MILS TYPICAL**

**BONDING PADS: 4 × 4 MILS MINIMUM**

**$T_J$max = 150°C**

**TOLERANCES ARE ±10%.**

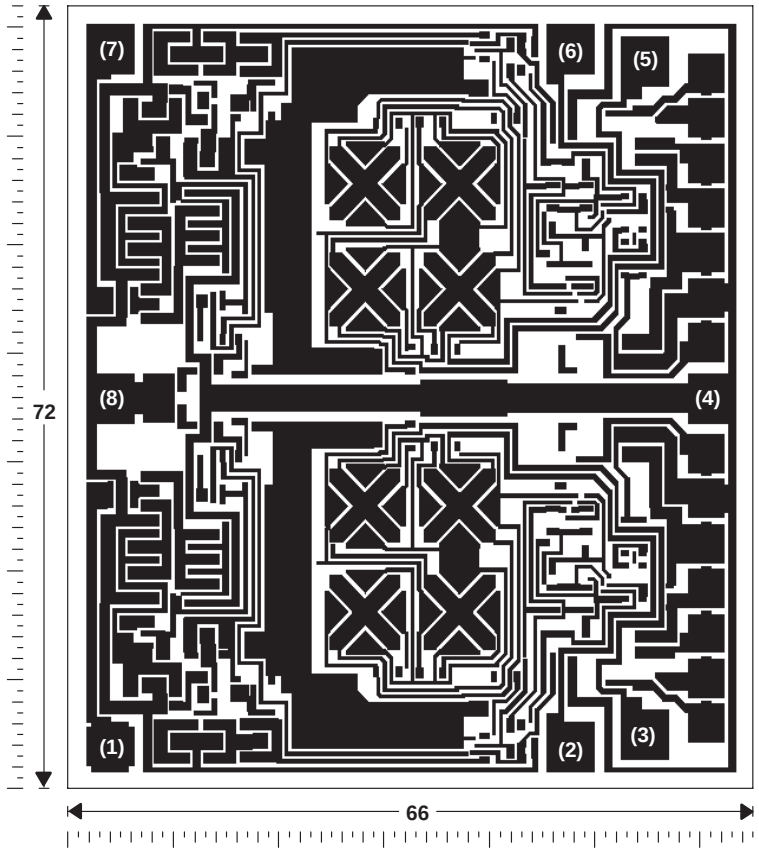
**ALL DIMENSIONS ARE IN MILS.**

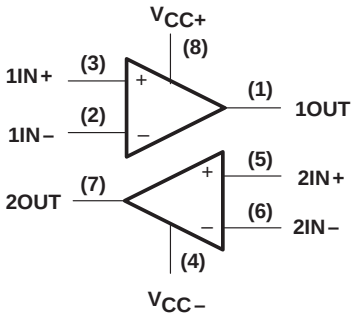
**PIN (4) IS INTERNALLY CONNECTED TO BACKSIDE OF CHIP.**

## TL052Y chip information

This chip, when properly assembled, displays characteristics similar to the TL052. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. Chips may be mounted with conductive epoxy or a gold-silicon preform.

**BONDING PAD ASSIGNMENTS**




**CHIP THICKNESS: 15 MILS TYPICAL**

**BONDING PADS: 4 × 4 MILS MINIMUM**

**$T_J$max = 150°C**

**TOLERANCES ARE ±10%.**

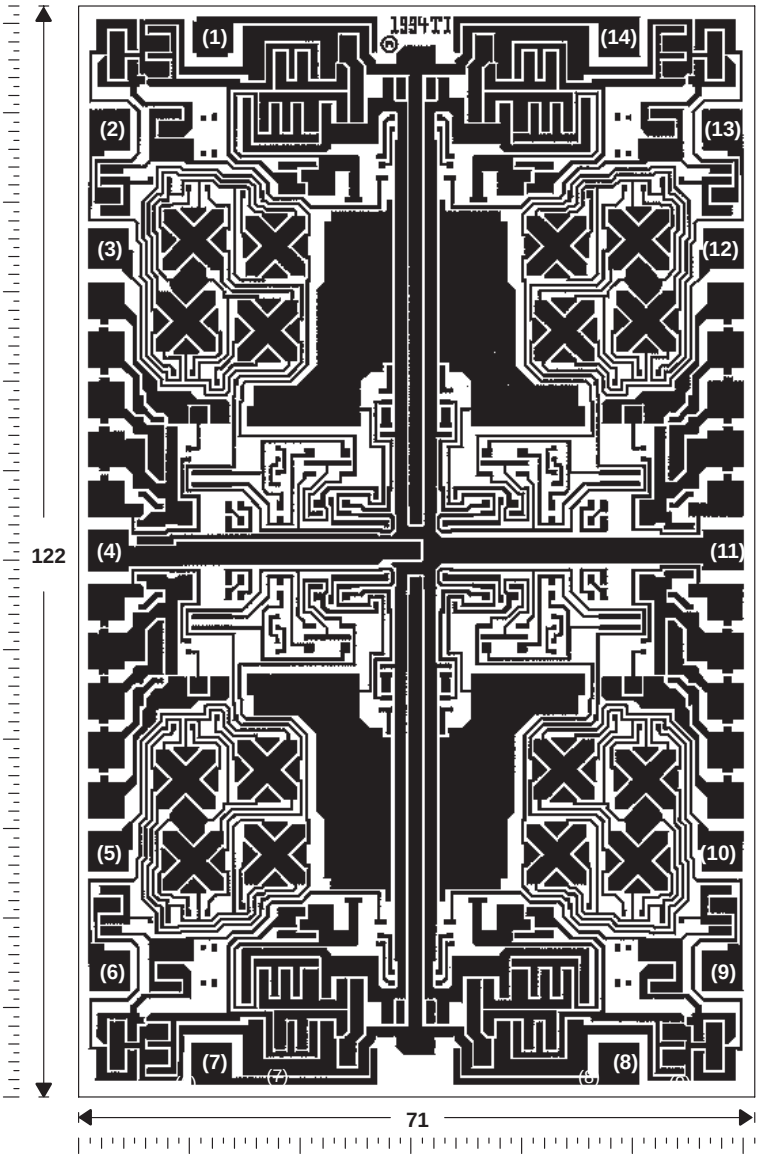
**ALL DIMENSIONS ARE IN MILS.**

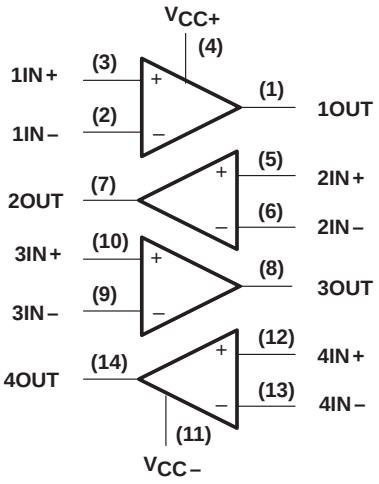
**PIN (4) IS INTERNALLY CONNECTED TO BACKSIDE OF CHIP.**

## TL054 chip information

This chip, when properly assembled, displays characteristics similar to the TL054C. Thermal compression or ultrasonic bonding may be used on the doped-aluminum bonding pads. These chips may be mounted with conductive epoxy or a gold-silicon preform.

**BONDING PAD ASSIGNMENTS**




**CHIP THICKNESS: 15 MILS TYPICAL**

**BONDING PADS: 4 × 4 MILS MINIMUM**

**$T_J$max = 150°C**

**TOLERANCES ARE ±10%.**

**ALL DIMENSIONS ARE IN MILS.**

**PIN (11) IS INTERNALLY CONNECTED TO BACKSIDE OF THE CHIP.**

## 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 (see Note 4) . . . . . unlimited
Continuous total power 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 (1/16inch) from case for 10 seconds: D, N, or P package . . . . . 260°C
Lead temperature 1,6 mm (1/16inch) from case for 60 seconds: J or 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 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. 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.

**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–8 | 725 mW | 5.8 mW/°C | 464 mW | 377 mW | 145 mW |
| D–14 | 950 mW | 7.6 mW/°C | 608 mW | 494 mW | 190 mW |
| FK | 1375 mW | 11.0 mW/°C | 880 mW | 715 mW | 275 mW |
| J | 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 |
| N | 1575 mW | 12.6 mW/°C | 1008 mW | 819 mW | 315 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, $V_{CC\pm}$ | | ±5 | ±15 | ±5 | ±15 | ±5 | ±15 | V |
| Common-mode input voltage, $V_{IC}$ | $V_{CC\pm}$ = ±5 V | –1 | 4 | –1 | 4 | –1 | 4 | V |
| | $V_{CC\pm}$ = ±15 V | –11 | 11 | –11 | 11 | –11 | 11 | |
| Operating free-air temperature, $T_A$ | | 0 | 70 | –40 | 85 | –55 | 125 | °C |

## TL051C and TL051AC electrical characteristics at specified free-air temperature

| PARAMETER | | TEST CONDITIONS | | $T_A$† | TL051C, TL051AC | | | | | | 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 | 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 | |
| $\alpha_{VIO}$ | 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 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 |
| | | | | 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 Ω | | 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 Ω | | 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 $V_{CC\pm}$ = ±5 V, $V_O$ = ±2.3 V, or for $V_{CC\pm}$ = ±15 V, $V_O$ = ±10 V.

## TL051C and TL051AC operating characteristics at specified free-air temperature

| PARAMETER | | TEST CONDITIONS | | $T_A$† | TL051C, TL051AC | | | | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | $V_{CC\pm}$ = ±5 V | | | $V_{CC\pm}$ = ±15 V | | | |
| | | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR+ | Positive slew rate at unity gain‡ | $R_L$ = 2 kΩ, See Figure 1 | $C_L$ = 100 pF, | 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 | $V_{I(PP)}$ = ±10 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, f = 1 kHz | $R_L$ = 2 kΩ, | 25°C | | 0.003% | | | 0.003% | | |
| $B_1$ | Unity-gain bandwidth | $V_I$ = 10 mV, $C_L$ = 25 pF, | $R_L$ = 2 kΩ, See Figure 4 | 25°C | | 3 | | | 3.1 | | MHz |
| | | | | 0°C | | 3.2 | | | 3.3 | | |
| | | | | 70°C | | 2.7 | | | 2.8 | | |
| $\phi_m$ | Phase margin at unity gain | $V_I$ = 10 mV, $C_L$ = 25 pF, | $R_L$ = 2 kΩ, See Figure 4 | 25°C | | 59° | | | 62° | | |
| | | | | 0°C | | 58° | | | 62° | | |
| | | | | 70°C | | 59° | | | 62° | | |

† Full range is 0°C to 70°C.
‡ For $V_{CC\pm}$ = ±5 V, $V_{I(PP)}$ = ±1 V; for $V_{CC\pm}$ = ±15 V, $V_{I(PP)}$ = ±5 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 $V_{CC\pm}$ = ±5 V, $V_O$rms = 1 V; for $V_{CC\pm}$ = ±15 V, $V_O$rms = 6 V.

## TL051I and TL051AI electrical characteristics at specified free-air temperature

| PARAMETER | | TEST CONDITIONS | | $T_A$† | TL051I, TL051AI | | | | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | $V_{CC\pm}$ = ±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 | 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 | |
| $\alpha_{VIO}$ | 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 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 | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm}/\Delta V_{IO}$) | $V_O$ = 0, $R_S$ = 50 Ω | | 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 $V_{CC\pm}$ = ±5 V, $V_O$ = ±2.3 V, or for $V_{CC\pm}$ = ±15 V, $V_O$ = ±10 V.

## TL051I and TL051AI operating characteristics at specified free-air temperature

| PARAMETER | | TEST CONDITIONS | | $T_A$† | TL051I, TL051AI | | | | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | $V_{CC\pm}$ = ±5 V | | | $V_{CC\pm}$ = ±15 V | | | |
| | | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR+ | Positive slew rate at unity gain‡ | $R_L$ = 2 kΩ, See Figure 1 | $C_L$ = 100 pF, | 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 | $V_{I(PP)}$ = ±10 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, f = 1 kHz | $R_L$ = 2 kΩ, | 25°C | | 0.003% | | | 0.003% | | |
| $B_1$ | Unity-gain bandwidth | $V_I$ = 10 mV, $C_L$ = 25 pF, | $R_L$ = 2 kΩ, See Figure 4 | 25°C | | 3 | | | 3.1 | | MHz |
| | | | | –40°C | | 3.5 | | | 3.6 | | |
| | | | | 85°C | | 2.6 | | | 2.7 | | |
| $\phi_m$ | Phase margin at unity gain | $V_I$ = 10 mV, $C_L$ = 25 pF, | $R_L$ = 2 kΩ, See Figure 4 | 25°C | | 59° | | | 62° | | |
| | | | | –40°C | | 58° | | | 61° | | |
| | | | | 85°C | | 59° | | | 62° | | |

† Full range is –40°C to 85°C.
‡ For $V_{CC\pm}$ = ±5 V, $V_{I(PP)}$ = ±1 V; for $V_{CC\pm}$ = ±15 V, $V_{I(PP)}$ = ±5 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 $V_{CC\pm}$ = ±5 V, $V_O$rms = 1 V; for $V_{CC\pm}$ = ±15 V, $V_O$rms = 6 V.

## TL051M and TL051AM electrical characteristics at specified free-air temperature

| PARAMETER | | TEST CONDITIONS | | $T_A$† | TL051M, TL051AM | | | | | | 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 | TL051M | 25°C | | 0.75 | 3.5 | | 0.59 | 1.5 | mV |
| | | | | Full range | | | 6.5 | | | 4.5 | |
| | | | TL051AM | 25°C | | 0.55 | 2.8 | | 0.35 | 0.8 | |
| | | | | Full range | | | 5.8 | | | 3.8 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | TL051M | 25°C to 125°C | | 8 | | | 8 | | µV/°C |
| | | | TL051AM | 25°C to 125°C | | 8 | | | 8 | | |
| | 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 |
| | | | | 125°C | | 1 | 20 | | 2 | 20 | nA |
| $I_{IB}$ | Input bias current | $V_O$ = 0, $V_{IC}$ = 0, See Figure 5 | | 25°C | | 20 | 200 | | 30 | 200 | pA |
| | | | | 125°C | | 10 | 50 | | 20 | 50 | 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 |
| | | | | −55°C | 30 | 76 | | 60 | 149 | | |
| | | | | 125°C | 10 | 32 | | 15 | 49 | | |
| $r_i$ | 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 |
| | | | | −55°C | 65 | 83 | | 75 | 92 | | |
| | | | | 125°C | 65 | 84 | | 75 | 94 | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm}/\Delta V_{IO}$) | $V_O$ = 0, $R_S$ = 50 Ω | | 25°C | 75 | 99 | | 75 | 99 | | dB |
| | | | | −55°C | 75 | 98 | | 75 | 98 | | |
| | | | | 125°C | 75 | 100 | | 75 | 100 | | |
| $I_{CC}$ | Supply current | $V_O$ = 0, No load | | 25°C | | 2.6 | 3.2 | | 2.7 | 3.2 | mA |
| | | | | −55°C | | 2.3 | 3.2 | | 2.4 | 3.2 | |
| | | | | 125°C | | 2.4 | 3.2 | | 2.5 | 3.2 | |

† Full range is −55°C to 125°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, or for $V_{CC\pm}$ = ±15 V, $V_O$ = ±10 V.

## TL051M and TL051AM operating characteristics at specified free-air temperature

| PARAMETER | | TEST CONDITIONS | | $T_A$ | TL051M, TL051AM | | | | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | $V_{CC\pm}$ = ±5 V | | | $V_{CC\pm}$ = ±15 V | | | |
| | | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR+ | Positive slew rate at unity gain† | $R_L$ = 2 kΩ, See Figure 1 | $C_L$ = 100 pF, | 25°C | | 16 | | | 13 | 20 | V/μs |
| SR– | Negative slew rate at unity gain† | | | 25°C | | 15 | | | 13 | | |
| $t_r$ | Rise time | $V_{I(PP)}$ = ±10 mV, $R_L$ = 2 kΩ, $C_L$ = 100 pF, See Figures 1 and 2 | | 25°C | | 55 | | | 56 | | ns |
| | | | | –55°C | | 51 | | | 52 | | |
| | | | | 125°C | | 68 | | | 68 | | |
| $t_f$ | Fall time | | | 25°C | | 55 | | | 57 | | |
| | | | | –55°C | | 51 | | | 52 | | |
| | | | | 125°C | | 68 | | | 69 | | |
| | Overshoot factor | | | 25°C | | 24% | | | 19% | | |
| | | | | –55°C | | 25% | | | 19% | | |
| | | | | 125°C | | 25% | | | 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 | | | 19 | | |
| $V_{N(PP)}$ | 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, f = 1 kHz | $R_L$ = 2kΩ, | 25°C | | 0.003% | | | 0.003% | | |
| $B_1$ | Unity-gain bandwidth | $V_I$ = 10 mV, $C_L$ = 25 pF, | $R_L$ = 2 kΩ, See Figure 4 | 25°C | | 3 | | | 3.1 | | MHz |
| | | | | –55°C | | 3.6 | | | 3.7 | | |
| | | | | 125°C | | 2.3 | | | 2.4 | | |
| $\phi_m$ | Phase margin at unity gain | $V_I$ = 10 mV, $C_L$ = 25 pF, | $R_L$ = 2 kΩ, See Figure 4 | 25°C | | 59° | | | 62° | | |
| | | | | –55°C | | 57° | | | 61° | | |
| | | | | 125°C | | 59° | | | 62° | | |

† For $V_{CC\pm}$ = ±5 V, $V_{I(PP)}$ = ±1 V; for $V_{CC\pm}$ = ±15 V, $V_{I(PP)}$ = ±5 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 $V_{CC\pm}$ = ±5 V, $V_O$rms = 1 V; for $V_{CC\pm}$ = ±15 V, $V_O$rms = 6 V.

## TL051Y electrical characteristics, $T_A$ = 25°C

| PARAMETER | | TEST CONDITIONS | TL051Y | | | | | | 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 | | 0.75 | | | 0.59 | | mV |
| $I_{IO}$ | Input offset current | $V_O$ = 0, $V_{IC}$ = 0, See Figure 5 | | 4 | | | 5 | | pA |
| $I_{IB}$ | Input bias current | $V_O$ = 0, $V_{IC}$ = 0, See Figure 5 | | 20 | | | 30 | | pA |
| $V_{ICR}$ | Common-mode input voltage range | | | −2.3 to 5.6 | | | −12.3 to 15.6 | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | $R_L$ = 10 kΩ | | 4.2 | | | 13.9 | | V |
| | | $R_L$ = 2 kΩ | | 3.8 | | | 12.7 | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | $R_L$ = 10 kΩ | | −3.5 | | | −13.2 | | V |
| | | $R_L$ = 2 kΩ | | −3.2 | | | −12 | | |
| $A_{VD}$ | Large-signal differential voltage amplification† | $R_L$ = 2 kΩ | | 59 | | | 105 | | V/mV |
| $r_i$ | Input resistance | | | $10^{12}$ | | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | | 10 | | | 12 | | pF |
| CMRR | Common-mode rejection ratio | $V_{IC}$ = $V_{ICR}$min, $V_O$ = 0, $R_S$ = 50 Ω | | 85 | | | 93 | | dB |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm}/\Delta V_{IO}$) | $V_O$ = 0, $R_S$ = 50 Ω | | 99 | | | 99 | | dB |
| $I_{CC}$ | Supply current | $V_O$ = 0, No load | | 2.6 | | | 2.7 | | mA |

† For $V_{CC\pm}$ = ±5 V, $V_O$ = ±2.3 V, or for $V_{CC\pm}$ = ±15 V, $V_O$ = ±10 V.

## TL051Y operating characteristics, $T_A$ = 25°C

| PARAMETER | | TEST CONDITIONS | | TL051Y | | | | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | $V_{CC\pm}$ = ±5 V | | | $V_{CC\pm}$ = ±15 V | | | |
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR+ | Positive slew rate at unity gain† | $R_L$ = 2 kΩ, $C_L$ = 100 pF, See Figure 1 | | | 16 | | | 20 | | V/μs |
| SR– | Negative slew rate at unity gain† | | | | 15 | | | 18 | | |
| $t_r$ | Rise time | $V_{I(PP)}$ = ±10 mV, $R_L$ = 2 kΩ, $C_L$ = 100 pF, See Figures 1 and 2 | | | 55 | | | 56 | | ns |
| $t_f$ | Fall time | | | | 55 | | | 57 | | |
| | Overshoot factor | | | | 24% | | | 19% | | |
| $V_n$ | Equivalent input noise voltage‡ | $R_S$ = 20 Ω, See Figure 3 | f = 10 Hz | | 75 | | | 75 | | nV/√Hz |
| | | | f = 1 kHz | | 18 | | | 18 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | | f = 10 Hz to 10 kHz | | 4 | | | 4 | | μV |
| $I_n$ | Equivalent input noise current | f = 1 kHz | | | 0.01 | | | 0.01 | | pA/√Hz |
| THD | Total harmonic distortion§ | $R_S$ = 1 kΩ, f = 1 kHz | $R_L$ = 2 kΩ, | | 0.003% | | | 0.003% | | |
| $B_1$ | Unity-gain bandwidth | $V_I$ = 10 mV, $C_L$ = 25 pF, | $R_L$ = 2 kΩ, See Figure 4 | | 3 | | | 3.1 | | MHz |
| $\phi_m$ | Phase margin at unity gain | $V_I$ = 10 mV, $C_L$ = 25 pF, | $R_L$ = 2 kΩ, See Figure 4 | | 59° | | | 62° | | |

† For $V_{CC\pm}$ = ±5 V, $V_{I(PP)}$ = ±1 V; for $V_{CC\pm}$ = ±15 V, $V_{I(PP)}$ = ±5 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 $V_{CC\pm}$ = ±5 V, $V_O$rms = 1 V; for $V_{CC\pm}$ = ±15 V, $V_O$rms = 6 V.

## TL052C and TL052AC electrical characteristics at specified free-air temperature

| PARAMETER | | TEST CONDITIONS | | $T_A$† | TL052C, TL052AC | | | | | | 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 | 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 | |
| $\alpha_{VIO}$ | 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 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 |
| | | | | 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 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 |
| | | | | 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 Ω | 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 $V_{CC\pm}$ = ±5 V, $V_O$ = ±2.3 V; at $V_{CC\pm}$ = ±15 V, $V_O$ = ±10 V.

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

| PARAMETER | | TEST CONDITIONS | $T_A$ | TL052C, TL052AC | | | | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | $V_{CC\pm}$ = ±5 V | | | $V_{CC\pm}$ = ±15 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 Ω | 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 | | | | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | $V_{CC\pm}$ = ±5 V | | | $V_{CC\pm}$ = ±15 V | | | |
| | | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR + | Slew rate at unity gain | $R_L$ = 2 kΩ, $C_L$ = 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 | $V_{I(PP)}$ = ±10 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 | | 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 t 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, $C_L$ = 25 pF, $R_L$ = 2 kΩ, See Figure 4 | | 25°C | | 3 | | | 3 | | MHz |
| | | | | 0°C | | 3.2 | | | 3.2 | | |
| | | | | 70°C | | 2.6 | | | 2.7 | | |
| $\phi_m$ | Phase margin at unity gain | $V_I$ = 10 mV, $C_L$ = 25 pF, $R_L$ = 2 kΩ, See Figure 4 | | 25°C | | 60° | | | 63° | | |
| | | | | 0°C | | 59° | | | 63° | | |
| | | | | 70°C | | 60° | | | 63° | | |

† Full range is 0°C to 70°C.
‡ For $V_{CC\pm}$ = ±5 V, $V_{I(PP)}$ = ±1 V; for $V_{CC\pm}$ = ±15 V, $V_{I(PP)}$ = ±5 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 $V_{CC\pm}$ = ±5 V, $V_{O(RMS)}$ = 1 V; for $V_{CC\pm}$ = ±15 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 | |
| $\alpha_{VIO}$ | 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 |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | $V_{CC\pm}$ = ±5 V | | | $V_{CC\pm}$ = ±15 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 Ω | 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | $V_{CC\pm}$ = ± 5 V | | | $V_{CC\pm}$ = ± 15 V | | | |
| | | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR + | Slew rate at unity gain‡ | $R_L$ = 2 kΩ, $C_L$ = 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 | $V_{I(PP)}$ = ±10 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 | | 71 | | | 71 | | |
| | | | 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 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 | | MHz |
| | | | | –40°C | | 3.5 | | | 3.6 | | |
| | | | | 85°C | | 2.5 | | | 2.6 | | |
| $\phi_m$ | Phase margin at unity gain | $V_I$ = 10 mV, $R_L$ = 2 kΩ, $C_L$ = 25 pF, See Figure 4 | | 25°C | | 60° | | | 63° | | |
| | | | | –40°C | | 58° | | | 61° | | |
| | | | | 85°C | | 60° | | | 63° | | |

† Full range is –40°C to 85°C.
‡ For $V_{CC\pm}$ = ±5 V, $V_{I(PP)}$ = ±1 V; for $V_{CC\pm}$ = ±15 V, $V_{I(PP)}$ = ±5 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 $V_{CC\pm}$ = ±5 V, $V_{O(RMS)}$ = 1 V; for $V_{CC\pm}$ = ±15 V, $V_{O(RMS)}$ = 6 V.

## TL052M and TL052AM electrical characteristics at specified free-air temperature

| PARAMETER | | TEST CONDITIONS | | $T_A$† | TL052M, TL052AM | | | | | | 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 | TL052M | 25°C | | 0.73 | 3.5 | | 0.65 | 1.5 | mV |
| | | | | Full range | | | 6.5 | | | 4.5 | |
| | | | TL052AM | 25°C | | 0.51 | 2.8 | | 0.4 | 0.8 | |
| | | | | Full range | | | 5.8 | | | 3.8 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | TL052M | 25°C to 125°C | | 10 | | | 9 | | µV/°C |
| | | | TL052AM | 25°C to 125°C | | 9 | | | 8 | | |
| | 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 |
| | | | | 125°C | | 1 | 20 | | 2 | 20 | nA |
| $I_{IB}$ | Input bias current | $V_O$ = 0, See Figure 5 | $V_{IC}$ = 0, | 25°C | | 20 | 200 | | 30 | 200 | pA |
| | | | | 125°C | | 10 | 50 | | 20 | 50 | 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 |
| | | | | −55°C | 30 | 76 | | 60 | 149 | | |
| | | | | 125°C | 10 | 32 | | 15 | 49 | | |
| $r_i$ | 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 |
| | | | | −55°C | 65 | 83 | | 75 | 92 | | |
| | | | | 125°C | 65 | 84 | | 75 | 94 | | |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm}/\Delta V_{IO}$) | $V_O$ = 0, | $R_S$ = 50 Ω | 25°C | 75 | 99 | | 75 | 99 | | dB |
| | | | | −55°C | 75 | 98 | | 75 | 98 | | |
| | | | | 125°C | 75 | 100 | | 75 | 100 | | |
| $I_{CC}$ | Supply current (two amplifiers) | $V_O$ = 0, | No load | 25°C | | 4.6 | 5.6 | | 4.8 | 5.6 | mA |
| | | | | −55°C | | 4.4 | 6.4 | | 4.5 | 6.4 | |
| | | | | 125°C | | 4.2 | 6.4 | | 4.4 | 6.4 | |
| $V_{O1}/V_{O2}$ | Crosstalk attenuation | $A_{VD}$ = 100 | | 25°C | | 120 | | | 120 | | dB |

† Full range is – 55°C to 125°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.

## TL052M and TL052AM operating characteristics at specified free-air temperature

| PARAMETER | | TEST CONDITIONS | | $T_A$† | TL052M, TL052AM | | | | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | $V_{CC\pm}$ = ± 5 V | | | $V_{CC\pm}$ = ± 15 V | | | |
| | | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR + | Positive slew rate at unity gain‡ | $R_L$ = 2 kΩ, $C_L$ = 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 | $V_{I(PP)}$ = ± 10 mV, $R_L$ = 2 kΩ, $C_L$ = 100 pF, See Figures 1 and 2 | | 25°C | | 55 | | | 56 | | ns |
| | | | | –55°C | | 51 | | | 52 | | |
| | | | | 125°C | | 68 | | | 68 | | |
| $t_f$ | Fall time | | | 25°C | | 55 | | | 57 | | |
| | | | | –55°C | | 51 | | | 52 | | |
| | | | | 125°C | | 68 | | | 69 | | |
| | Overshoot factor | | | 25°C | | 24% | | | 19% | | |
| | | | | –55°C | | 25% | | | 19% | | |
| | | | | 125°C | | 25% | | | 19% | | |
| $V_n$ | Equivalent input noise voltage§ | $R_S$ = 20 Ω, See Figure 3 | f = 10 Hz | 25°C | | 71 | | | 71 | | nV/√Hz |
| | | | f = 1 kHz | 25°C | | 19 | | | 19 | | |
| $V_{N(PP)}$ | 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 kΩ, f = 1 kHz | $R_L$ = 2 kΩ, | 25°C | | 0.003% | | | 0.003% | | |
| $B_1$ | Unity-gain bandwidth | $V_I$ = 10 mV, $C_L$ = 25 pF, | $R_L$ = 2 kΩ, See Figure 4 | 25°C | | 3 | | | 3 | | MHz |
| | | | | –55°C | | 3.6 | | | 3.7 | | |
| | | | | 125°C | | 2.3 | | | 2.4 | | |
| $\phi_m$ | Phase margin at unity gain | $V_I$ = 10 mV, $C_L$ = 25 pF, | $R_L$ = 2 kΩ, See Figure 4 | 25°C | | 60° | | | 63° | | |
| | | | | –55°C | | 57° | | | 61° | | |
| | | | | 125°C | | 60° | | | 63° | | |

† Full range is – 55°C to 125°C.
‡ For $V_{CC\pm}$ = ±5 V, $V_{I(PP)}$ = ±1 V; for $V_{CC\pm}$ = ±15 V, $V_{I(PP)}$ = ±5 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 $V_{CC\pm}$ = ±5 V, $V_{O(RMS)}$ = 1 V; for $V_{CC\pm}$ = ±15 V, $V_{O(RMS)}$ = 6 V.

## TL052Y electrical characteristics, $T_A$ = 25°C

| PARAMETER | | TEST CONDITIONS | | TL052Y | | | | | | 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, $R_S$ = 50 Ω | $V_{IC}$ = 0, | | 0.73 | | | 0.65 | | mV |
| | Input offset voltage long-term drift | | | | 0.04 | | | 0.04 | | μV/mo |
| $I_{IO}$ | Input offset current | $V_O$ = 0, See Figure 5 | $V_{IC}$ = 0, | | 4 | | | 5 | | pA |
| $I_{IB}$ | Input bias current | $V_O$ = 0, See Figure 5 | $V_{IC}$ = 0, | | 20 | | | 30 | | pA |
| $V_{ICR}$ | Common-mode input voltage range | | | | –2.3 to 5.6 | | | –12.3 to 15.6 | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | $R_L$ = 10 kΩ | | | 4.2 | | | 13.9 | | V |
| | | $R_L$ = 2 kΩ | | | 3.8 | | | 12.7 | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | $R_L$ = 10 kΩ | | | –3.5 | | | –13.2 | | |
| | | $R_L$ = 2 kΩ | | | –3.2 | | | –12 | | |
| $A_{VD}$ | Large-signal differential voltage amplification† | $R_L$ = 2 kΩ | | | 59 | | | 105 | | V/mV |
| $r_i$ | Input resistance | | | | $10^{12}$ | | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | | | 10 | | | 12 | | pF |
| CMRR | Common-mode rejection ratio | $V_{IC}$ = $V_{ICR}$min, $V_O$ = 0, | $R_S$ = 50 Ω | | 85 | | | 93 | | dB |
| $k_{SVR}$ | Supply-voltage rejection ratio ($\Delta V_{CC\pm}/\Delta V_{IO}$) | $V_O$ = 0, | $R_S$ = 50 Ω | | 99 | | | 99 | | dB |
| $I_{CC}$ | Supply current (two amplifiers) | $V_O$ = 0, | No load | | 4.6 | | | 4.8 | | mA |
| $V_{O1}/V_{O2}$ | Crosstalk attenuation | $A_{VD}$ = 100 | | | 120 | | | 120 | | dB |

† For $V_{CC\pm}$ = ±5 V, $V_O$ = ±2.3 V; at $V_{CC\pm}$ = ±15 V, $V_O$ = ±10 V.

## TL052Y operating characteristics, $T_A$ = 25°C

| PARAMETER | | TEST CONDITIONS | | TL052Y | | | | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | $V_{CC\pm}$ = ±5 V | | | $V_{CC\pm}$ = ±15 V | | | |
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR + | Positive slew rate at unity gain† | $R_L$ = 2 kΩ, See Figure 1 | $C_L$ = 100 pF, | | 17.8 | | | 20.7 | | V/µs |
| SR – | Negative slew rate at unity gain† | | | | 15.4 | | | 17.8 | | |
| $t_r$ | Rise time | $V_{I(PP)}$ = ±10 mV, $R_L$ = 2 kΩ, See Figures 1 and 2 | $C_L$ = 100 pF, | | 55 | | | 56 | | ns |
| $t_f$ | Fall time | | | | 55 | | | 57 | | |
| | Overshoot factor | | | | 24% | | | 19% | | |
| $V_n$ | Equivalent input noise voltage‡ | $R_S$ = 20 Ω, See Figure 3 | f = 10 Hz | | 71 | | | 71 | | nV/√Hz |
| | | | f = 1 kHz | | 19 | | | 19 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise current | | f = 10 Hz to 10 kHz | | 4 | | | 4 | | µV |
| $I_n$ | Equivalent input noise current | f = 1 kHz | | | 0.01 | | | 0.01 | | pA/√Hz |
| THD | Total harmonic distortion§ | $R_S$ = 1 kΩ, f = 1 kHz | $R_L$ = 2 kΩ, | | 0.003% | | | 0.003% | | |
| $B_1$ | Unity-gain bandwidth | $V_I$ = 10 mV, $C_L$ = 25 pF, | $R_L$ = 2 kΩ, See Figure 4 | | 3 | | | 3 | | MHz |
| $\phi_m$ | Phase margin at unity gain | $V_I$ = 10 mV, $C_L$ = 25 pF, | $R_L$ = 2 kΩ, See Figure 4 | | 60° | | | 63° | | |

† 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 $V_{CC\pm}$ = ±5 V, $V_{I(PP)}$ = ±1 V; for $V_{CC\pm}$ = ±15 V, $V_{I(PP)}$ = ±5 V.
§ For $V_{CC\pm}$ = ±5 V, $V_{O(RMS)}$ = 1 V; for $V_{CC\pm}$ = ±15 V, $V_{O(RMS)}$ = 6 V.

## TL054C and TL054AC electrical characteristics at specified free-air temperature

| PARAMETER | | TEST CONDITIONS | | $T_A$† | TL054C, TL054AC | | | | | | 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 | 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 | |
| $\alpha_{VIO}$ | 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 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 |
| | | | | 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 Ω | | 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 ($\Delta V_{CC\pm}/\Delta V_{IO}$) | $V_{CC\pm}$ = ±5 V to ±15 V, $V_O$ = 0, $R_S$ = 50 Ω | | 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 $V_{CC\pm}$ = ±5 V, $V_O$ = ±2.3 V, at $V_{CC\pm}$ = ±15 V, $V_O$ = ±10 V.B

## TL054C and TL054AC operating characteristics at specified free-air temperature

| PARAMETER | | TEST CONDITIONS | | $T_A$† | TL054C, TL054C | | | | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | $V_{CC\pm}$ = ±5 V | | | $V_{CC\pm}$ = ±15 V | | | |
| | | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| 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 | | |
| SR– | Negative slew rate at unity gain‡ | | | 70°C | | 14.4 | | 8 | 17.5 | | |
| | | | | 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 | $V_{I(PP)}$ = ±10 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, $C_L$ = 25 pF, $R_L$ = 2 kΩ, See Figure 4 | | 25°C | | 2.7 | | | 2.7 | | MHz |
| | | | | 0°C | | 3 | | | 3 | | |
| | | | | 70°C | | 2.4 | | | 2.4 | | |
| $\phi_m$ | Phase margin at unity gain | $V_I$ = 10 mV, $C_L$ = 25 pF, $R_L$ = 2 kΩ, See Figure 4 | | 25°C | | 61° | | | 64° | | |
| | | | | 0°C | | 60° | | | 64° | | |
| | | | | 70°C | | 61° | | | 63° | | |

† Full range is 0°C to 70°C.
‡ For $V_{CC\pm}$ = ±5 V, $V_{I(PP)}$ = ±1 V; for $V_{CC\pm}$ = ±15 V, $V_{I(PP)}$ = ±5 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 $V_{CC\pm}$ = ±5 V, $V_{O(rms)}$ = 1 V; for $V_{CC\pm}$ = ±15 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 | |
| $\alpha_{VIO}$ | 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 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | $V_{CC\pm}$ = ±5 V | | | $V_{CC\pm}$ = ±15 V | | | |
| | | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR+ | Positive slew rate at unity gain | $R_L$ = 2 kΩ, See Figure 1 | $C_L$ = 100 pF, | 25°C | | 15.4 | | 10 | 17.8 | | V/μs |
| | | | | –40°C | | 16.4 | | 8 | 18 | | |
| SR– | Negative slew rate at unity gain‡ | | | 85°C | | 14 | | 8 | 17.3 | | |
| | | | | 25°C | | 13.9 | | 10 | 15.9 | | |
| | | | | –40°C | | 14.7 | | 8 | 16.1 | | |
| | | | | 85°C | | 13 | | 8 | 15.3 | | |
| $t_r$ | Rise time | $V_{I(PP)}$ = ±10 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 | | 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, f = 1 kHz | $R_L$ = 2 kΩ, | 25°C | | 0.003% | | | 0.003% | | |
| $B_1$ | Unity-gain bandwidth | $V_I$ = 10 mV, $C_L$ = 25 pF, | $R_L$ = 2 kΩ, See Figure 4 | 25°C | | 2.7 | | | 2.7 | | MHz |
| | | | | –40°C | | 3.3 | | | 3.3 | | |
| | | | | 85°C | | 2.3 | | | 2.4 | | |
| $\phi_m$ | Phase margin at unity gain | $V_I$ = 10 mV, $C_L$ = 25 pF, | $R_L$ = 2 kΩ, See Figure 4 | 25°C | | 61° | | | 64° | | |
| | | | | –40°C | | 59° | | | 62° | | |
| | | | | 85°C | | 61° | | | 64° | | |

† Full range is –40°C to 85°C.
‡ For $V_{CC\pm}$ = ±5 V, $V_{I(PP)}$ = ±1 V; for $V_{CC\pm}$ = ±15 V, $V_{I(PP)}$ = ±5 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 $V_{CC\pm}$ = ±5 V, $V_{o(rms)}$ = 1 V; for $V_{CC\pm}$ = ±15 V, $V_{o(rms)}$ = 6 V.

## TL054M and TL054AM electrical characteristics at specified free-air temperature

| PARAMETER | | TEST CONDITIONS | | $T_A$† | TL054M, TL054AM | | | | | | 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 | TL054M | 25°C | | 0.64 | 5.5 | | 0.56 | 4 | mV |
| | | | | Full range | | | 10.5 | | | 9 | |
| | | | TL054AM | 25°C | | 0.57 | 3.5 | | 0.5 | 1.5 | |
| | | | | Full range | | | 8.5 | | | 6.5 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | | TL054M | 25°C to 85°C | | 21 | | | 20 | | µV/°C |
| | | | TL054AM | 25°C to 85°C | | 21 | | | 20 | | |
| | 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 |
| | | | | 125°C | | 1 | 20 | | 2 | 20 | nA |
| $I_{IB}$ | Input bias current | $V_O$ = 0, $V_{IC}$ = 0, See Figure 5 | | 25°C | | 20 | 200 | | 30 | 200 | pA |
| | | | | 125°C | | 10 | 50 | | 20 | 50 | 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 |
| | | | | −55°C | 30 | 99 | | 60 | 209 | | |
| | | | | 125°C | 10 | 35 | | 15 | 35 | | |
| $r_i$ | 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 |
| | | | | −55°C | 65 | 83 | | 75 | 92 | | |
| | | | | 125°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 | 98 | | |
| | | | | 85°C | 75 | 100 | | 75 | 100 | | |
| $I_{CC}$ | Supply current (four amplifiers) | $V_O$ = 0, No load | | 25°C | | 8.1 | 11.2 | | 8.4 | 11.2 | mA |
| | | | | −55°C | | 7.8 | 12.8 | | 8.1 | 12.8 | |
| | | | | 125°C | | 7.1 | 11.2 | | 7.5 | 11.2 | |
| $V_{O1}/V_{O2}$ | Crosstalk attenuation | $A_{VD}$ = 100 | | 25°C | | 120 | | | 120 | | dB |

† Full range is −55°C to 125°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.

## TL054M and TL054AM operating characteristics at specified free-air temperature

| PARAMETER | | TEST CONDITIONS | | $T_A$† | TL054M, TL054AM | | | | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | $V_{CC\pm}$ = ±5 V | | | $V_{CC\pm}$ = ±15 V | | | |
| | | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR+ | Positive slew rate at unity gain | $R_L$ = 2 kΩ, See Figure 1 | $C_L$ = 100 pF, | 25°C | | 15.4 | | 10 | 17.8 | | V/μs |
| | | | | –55°C | | 16.7 | | | 18.3 | | |
| SR– | Negative slew rate at unity gain‡ | | | 125°C | | 12.9 | | | 16.7 | | |
| | | | | 25°C | | 13.9 | | 10 | 15.9 | | |
| | | | | –55°C | | 14.7 | | | 16.3 | | |
| | | | | 125°C | | 12.2 | | | 14.5 | | |
| $t_r$ | Rise time | $V_{I(PP)}$ = ±10 mV, $R_L$ = 2 kΩ, $C_L$ = 100 pF, See Figures 1 and 2 | | 25°C | | 55 | | | 56 | | ns |
| | | | | –55°C | | 51 | | | 52 | | |
| | | | | 125°C | | 68 | | | 68 | | |
| $t_f$ | Fall time | | | 25°C | | 55 | | | 57 | | |
| | | | | –55°C | | 51 | | | 52 | | |
| | | | | 125°C | | 68 | | | 69 | | |
| | Overshoot factor | | | 25°C | | 24% | | | 19% | | |
| | | | | –55°C | | 25% | | | 19% | | |
| | | | | 125°C | | 25% | | | 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, f = 1 kHz | $R_L$ = 2 kΩ, | 25°C | | 0.003% | | | 0.003% | | |
| $B_1$ | Unity-gain bandwidth | $V_I$ = 10 mV, $C_L$ = 25 pF, | $R_L$ = 2 kΩ, See Figure 4 | 25°C | | 2.7 | | | 2.7 | | MHz |
| | | | | –55°C | | 3.4 | | | 3.4 | | |
| | | | | 125°C | | 2.1 | | | 2.1 | | |
| $\phi_m$ | Phase margin at unity gain | $V_I$ = 10 mV, $C_L$ = 25 pF, | $R_L$ = 2 kΩ, See Figure 4 | 25°C | | 61° | | | 64° | | |
| | | | | –55°C | | 58° | | | 62° | | |
| | | | | 125°C | | 60° | | | 64° | | |

† Full range is –55°C to 125°C.
‡ For $V_{CC\pm}$ = ±5 V, $V_{I(PP)}$ = ±1 V; for $V_{CC\pm}$ = ±15 V, $V_{I(PP)}$ = ±5 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 $V_{CC\pm}$ = ±5 V, $V_o$rms = 1 V; for $V_{CC\pm}$ = ±15 V, $V_o$rms = 6 V.

## TL054Y electrical characteristics, $T_A$ = 25°C

| PARAMETER | | TEST CONDITIONS | TL054Y | | | | | | 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 | | 0.64 | | | 0.56 | | mV |
| $I_{IO}$ | Input offset current | $V_O$ = 0, $V_{IC}$ = 0, See Figure 5 | | 4 | | | 5 | | pA |
| $I_{IB}$ | Input bias current | $V_O$ = 0, $V_{IC}$ = 0, See Figure 5 | | 20 | | | 30 | | pA |
| $V_{ICR}$ | Common-mode input voltage range | | | –2.3 to 5.6 | | | –12.3 to 15.6 | | V |
| $V_{OM+}$ | Maximum positive peak output voltage swing | $R_L$ = 10 kΩ | | 4.2 | | | 13.9 | | V |
| | | $R_L$ = 2 kΩ | | 3.8 | | | 12.7 | | |
| $V_{OM-}$ | Maximum negative peak output voltage swing | $R_L$ = 10 kΩ | | –3.5 | | | –13.2 | | V |
| | | $R_L$ = 2 kΩ | | –3.2 | | | –12 | | |
| $A_{VD}$ | Large-signal differential voltage amplification† | $R_L$ = 2 kΩ, | | 72 | | | 133 | | V/mV |
| $r_i$ | Input resistance | | | $10^{12}$ | | | $10^{12}$ | | Ω |
| $c_i$ | Input capacitance | | | 10 | | | 12 | | pF |
| CMRR | Common-mode rejection ratio | $V_{IC}$ = $V_{ICR}$min, $V_O$ = 0, $R_S$ = 50 Ω | | 84 | | | 92 | | dB |
| $k_{SVR}$ | 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 | | 99 | | | 99 | | dB |
| $I_{CC}$ | Supply current (four amplifiers) | $V_O$ = 0, No load | | 8.1 | | | 8.4 | | mA |
| $V_{O1}/V_{O2}$ | Crosstalk attenuation | $A_{VD}$ = 100 | | 120 | | | 120 | | dB |

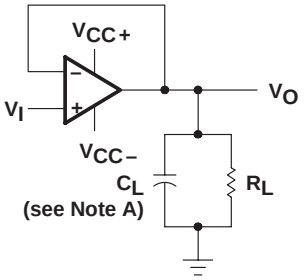
† For $V_{CC\pm}$ = ±5 V, $V_O$ = ±2.3 V, at $V_{CC\pm}$ = ±15 V, $V_O$ = ±10 V.

## TL054Y operating characteristics, $T_A$ = 25°C

| PARAMETER | | TEST CONDITIONS | | TL054Y | | | | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | $V_{CC\pm}$ = ±5 V | | | $V_{CC\pm}$ = ±15 V | | | |
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| SR+ | Positive slew rate at unity gain† | $R_L$ = 2 kΩ, $C_L$ = 100 pF, See Figure 1 | | | 15.4 | | | 17.8 | | V/μs |
| SR– | Negative slew rate at unity gain | | | | 13.9 | | | 15.9 | | |
| $t_r$ | Rise time | $V_{I(PP)}$ = ±10 mV, $R_L$ = 2 kΩ, $C_L$ = 100 pF, See Figures 1 and 2 | | | 55 | | | 56 | | ns |
| $t_f$ | Fall time | | | | 55 | | | 57 | | |
| | Overshoot factor | | | | 24% | | | 19% | | |
| $V_n$ | Equivalent input noise voltage‡ | $R_S$ = 20 Ω, See Figure 3 | f = 10 Hz | | 75 | | | 75 | | nV/√Hz |
| | | | f = 1 kHz | | 21 | | | 21 | | |
| $V_{N(PP)}$ | Peak-to-peak equivalent input noise voltage | | f = 10 Hz to 10 kHz | | 4 | | | 4 | | μV |
| $I_n$ | Equivalent input noise current | f = 1 kHz | | | 0.01 | | | 0.01 | | pA/√Hz |
| THD | Total harmonic distortion§ | $R_S$ = 1 kΩ, $R_L$ = 2 kΩ, f = 1 kHz | | | 0.003% | | | 0.003% | | |
| $B_1$ | Unity-gain bandwidth | $V_I$ = 10 mV, $C_L$ = 25 pF, $R_L$ = 2 kΩ, See Figure 4 | | | 2.7 | | | 2.7 | | MHz |
| $\phi_m$ | Phase margin at unity gain | $V_I$ = 10 mV, $C_L$ = 25 pF, $R_L$ = 2 kΩ, See Figure 4 | | | 61° | | | 64° | | |

† For $V_{CC\pm}$ = ±5 V, $V_{I(PP)}$ = ±1 V; for $V_{CC\pm}$ = ±15 V, $V_{I(PP)}$ = ±5 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 $V_{CC\pm}$ = ±5 V, $V_{o(rms)}$ = 1 V; for $V_{CC\pm}$ = ±15 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**

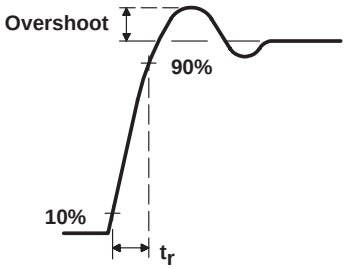



**Figure 2 . Rise Time and Overshoot Waveform**

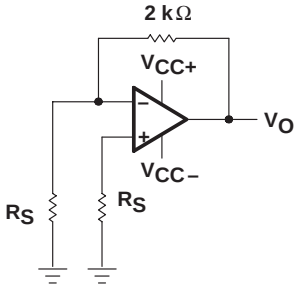
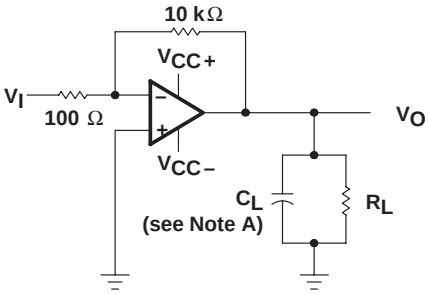



**Figure 3 . Noise-Voltage Test Circuit**




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.

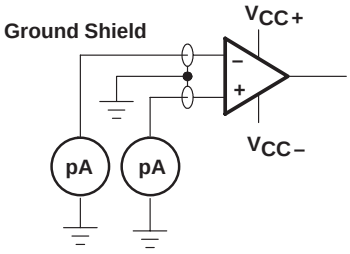



**Figure 5. Input-Bias and Offset-Current Test Circuit**

### 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 can easily exceed the actualdevice 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 is then 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 are then 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 |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | Distribution | 12, 13, 14 |
| $I_{IB}$ | Input bias current | vs Common-mode input voltage<br>vs Free-air temperature | 15<br>16 |
| $I_{IO}$ | Input offset current | vs Free-air temperature | 16 |
| $V_{IC}$ | Common-mode input voltage range limits | vs Supply voltage<br>vs Free-air temperature | 17<br>18 |
| $V_O$ | Output voltage | vs Differential input voltage | 19, 20 |
| $V_{OM}$ | Maximum peak output voltage | vs Supply voltage<br>vs Output current<br>vs Free-air temperature | 21<br>25, 26<br>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<br>vs Frequency<br>vs Free-air temperature | 29<br>30<br>31, 32, 33 |
| CMRR | Common-mode rejection ratio | vs Frequency<br>vs Free-air temperature | 34, 35<br>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<br>vs Time<br>vs Free-air temperature | 39<br>40<br>41 |
| $I_{CC}$ | Supply current | vs Supply voltage<br>vs Free-air temperature | 42, 43, 44<br>45, 46, 47 |
| SR | Slew rate | vs Load resistance<br>vs Free-air temperature | 48 – 53<br>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<br>vs Free-air temperature | 64, 65, 66<br>67, 68, 69 |
| $\phi_m$ | Phase margin | vs Supply voltage<br>vs Load capacitance<br>vs Free-air temperature | 70, 71, 72<br>73, 74, 75<br>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

DISTRIBUTION OF TL051
INPUT OFFSET VOLTAGE

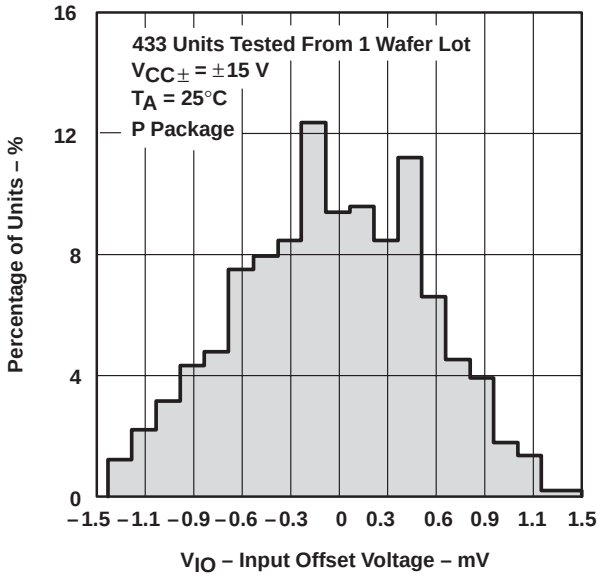



Figure 6

DISTRIBUTION OF TL051A
INPUT OFFSET VOLTAGE

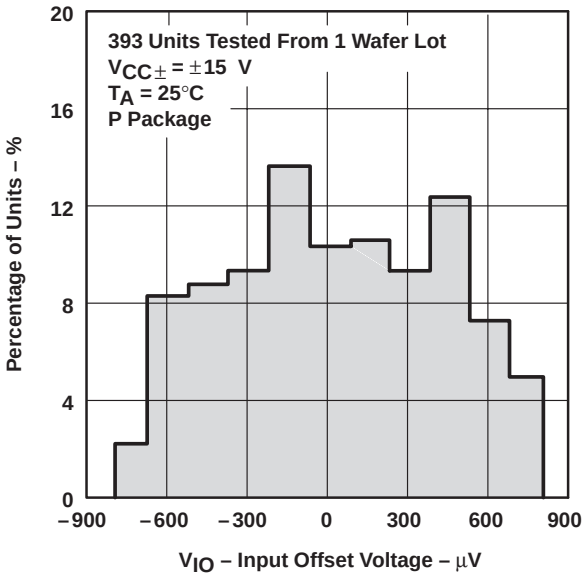



Figure 7

DISTRIBUTION OF TL052
INPUT OFFSET VOLTAGE

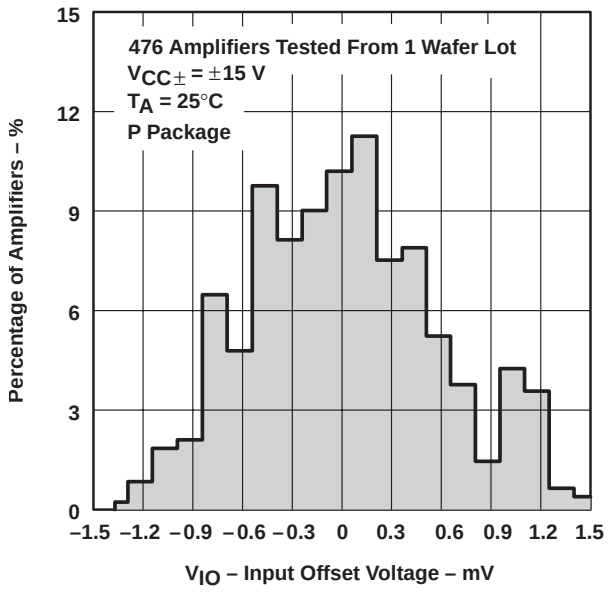



Figure 8

DISTRIBUTION OF TL052A
INPUT OFFSET VOLTAGE

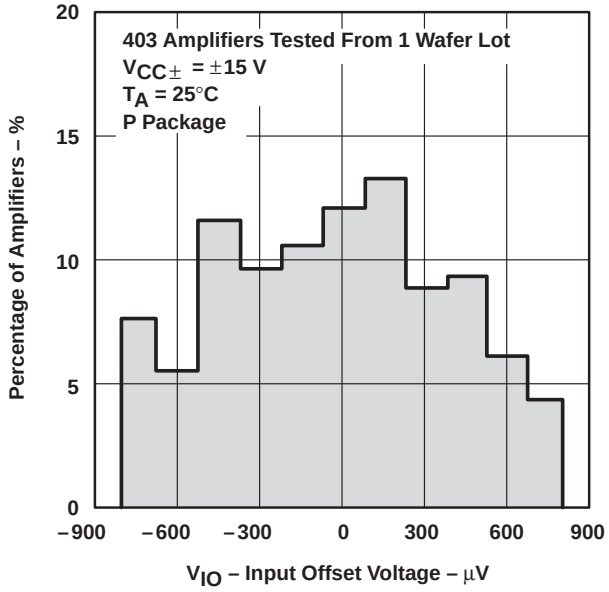



Figure 9

## TYPICAL CHARACTERISTICS

**DISTRIBUTION OF TL054
INPUT OFFSET VOLTAGE**

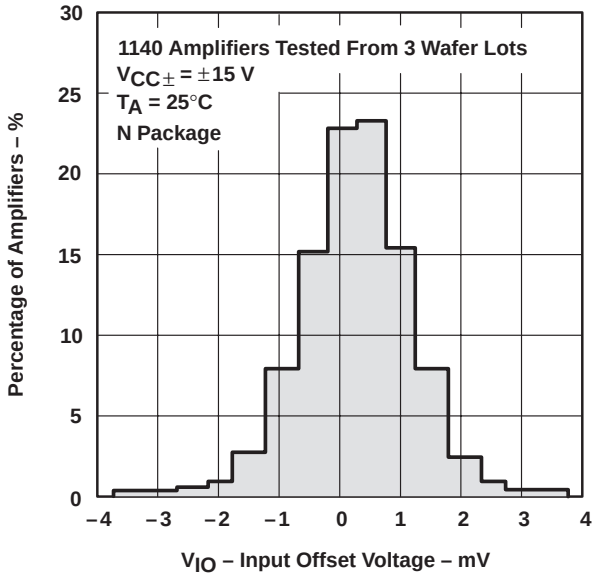



Figure 10

**DISTRIBUTION OF TL054A
INPUT OFFSET VOLTAGE**

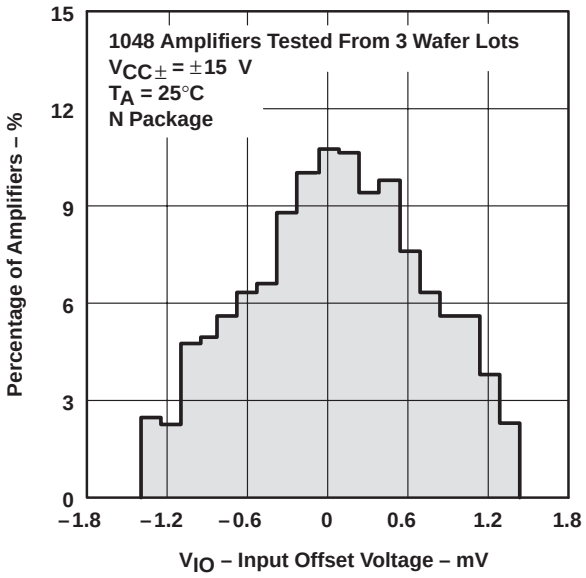



Figure 11

**DISTRIBUTION OF TL051
INPUT OFFSET VOLTAGE
TEMPERATURE COEFFICIENT**

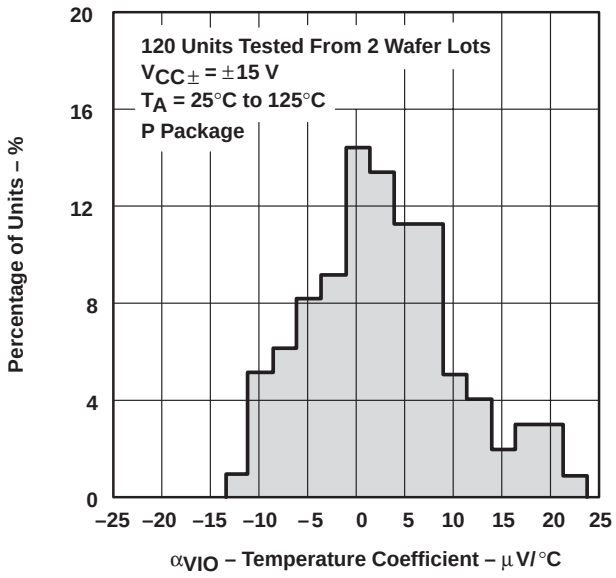



Figure 12

**DISTRIBUTION OF TL052
INPUT OFFSET VOLTAGE
TEMPERATURE COEFFICIENT**

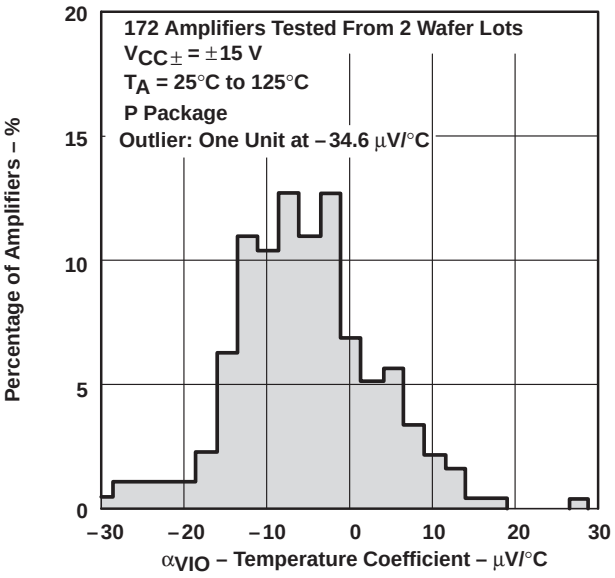



Figure 13

## TYPICAL CHARACTERISTICS

**DISTRIBUTION OF TL054 INPUT OFFSET VOLTAGE TEMPERATURE COEFFICIENT**

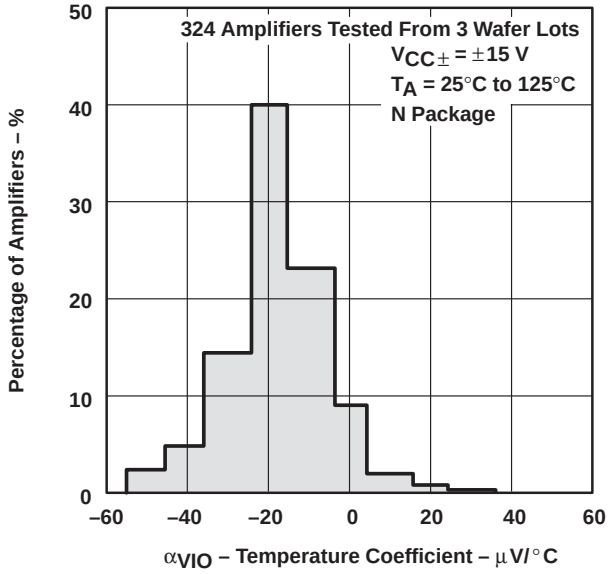



Figure 14

**INPUT BIAS CURRENT vs COMMON-MODE INPUT VOLTAGE**

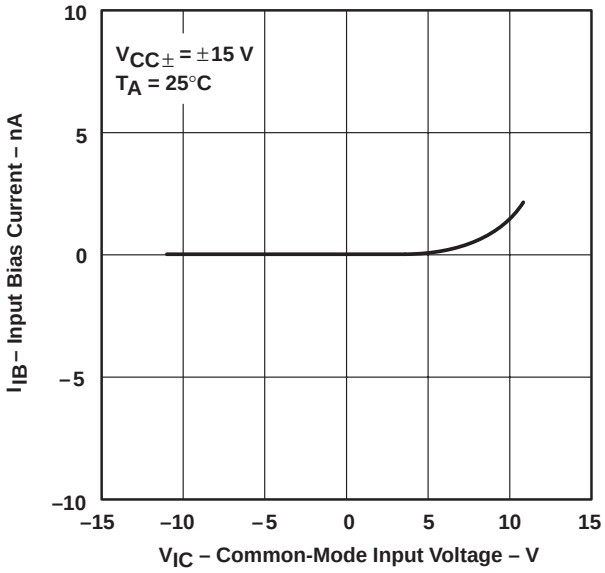



Figure 15

**INPUT BIAS CURRENT AND INPUT OFFSET CURRENT† vs FREE-AIR TEMPERATURE**

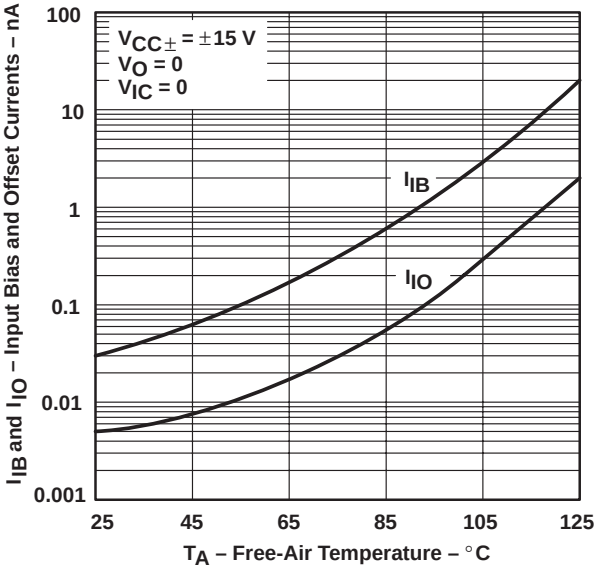



Figure 16

**COMMON-MODE INPUT VOLTAGE RANGE LIMITS vs SUPPLY VOLTAGE**

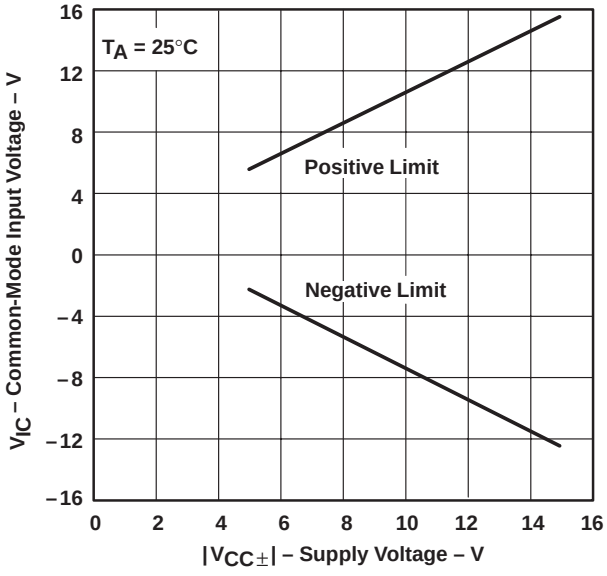



Figure 17

† 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

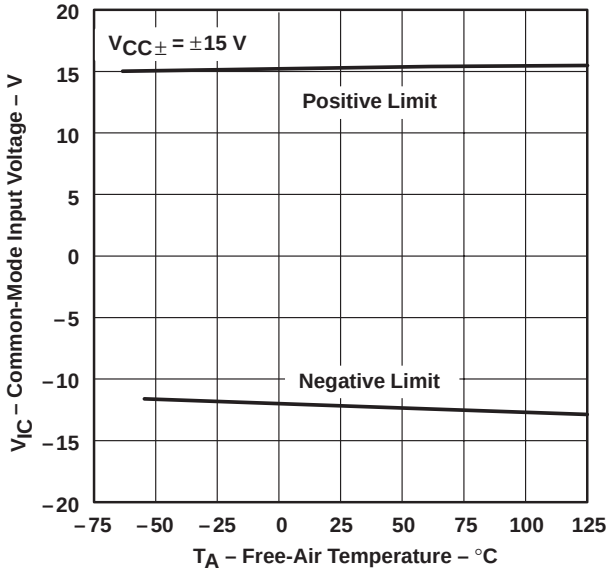



Figure 18

OUTPUT VOLTAGE
vs
DIFFERENTIAL INPUT VOLTAGE

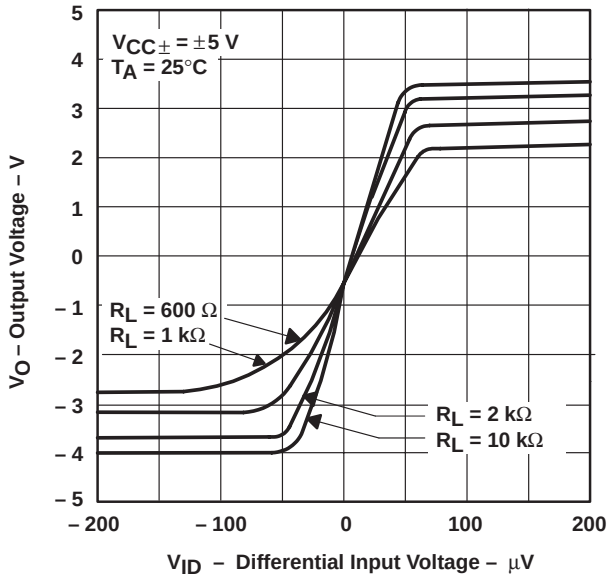



Figure 19

OUTPUT VOLTAGE
vs
DIFFERENTIAL INPUT VOLTAGE

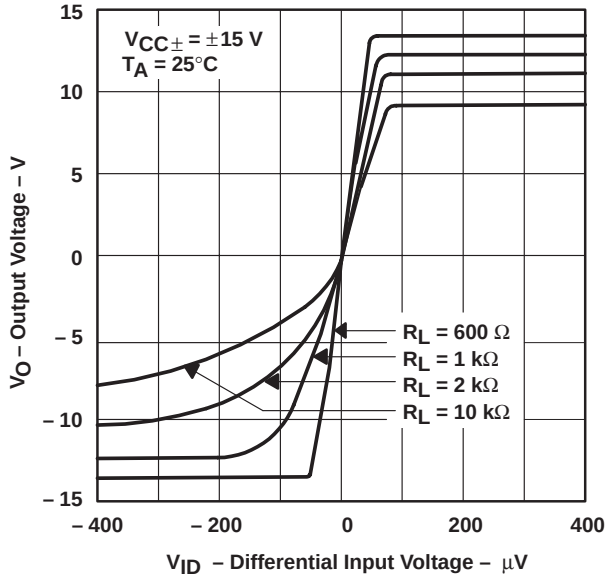



Figure 20

MAXIMUM PEAK OUTPUT VOLTAGE
vs
SUPPLY VOLTAGE

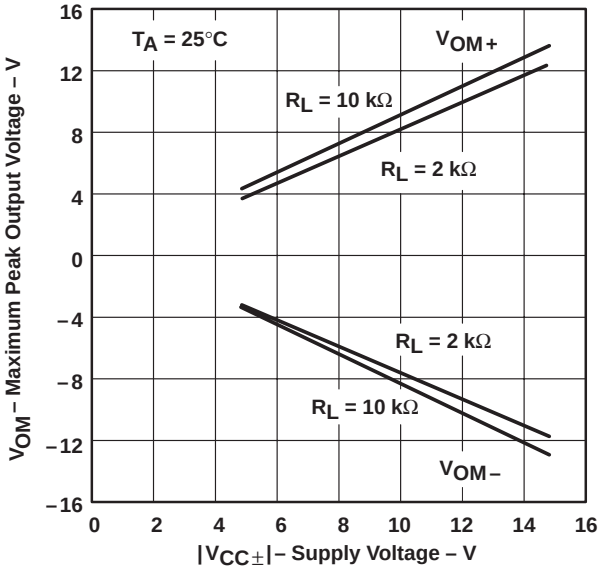



Figure 21

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

## TYPICAL CHARACTERISTICS

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE† vs FREQUENCY

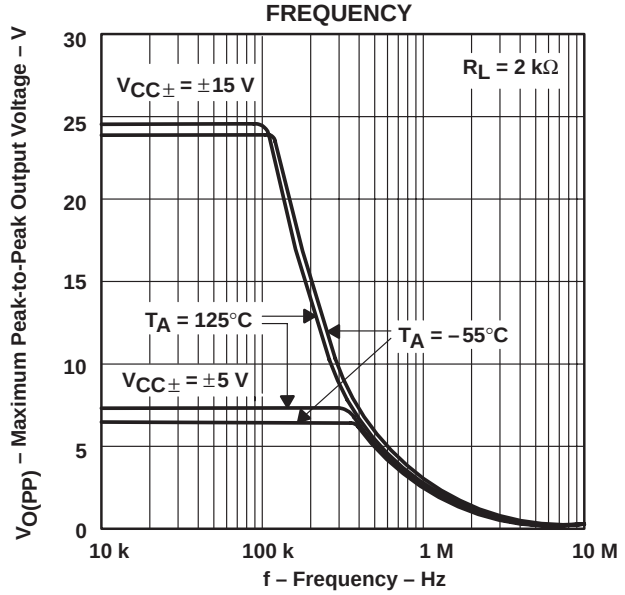



Figure 22

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE vs FREQUENCY

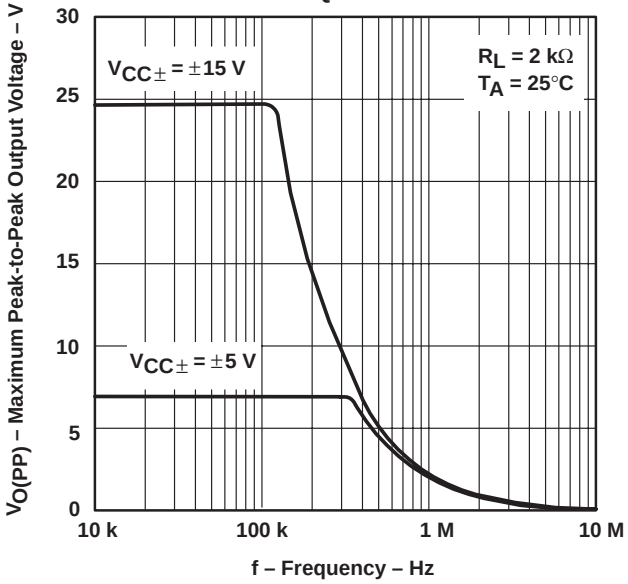



Figure 23

MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE vs FREQUENCY

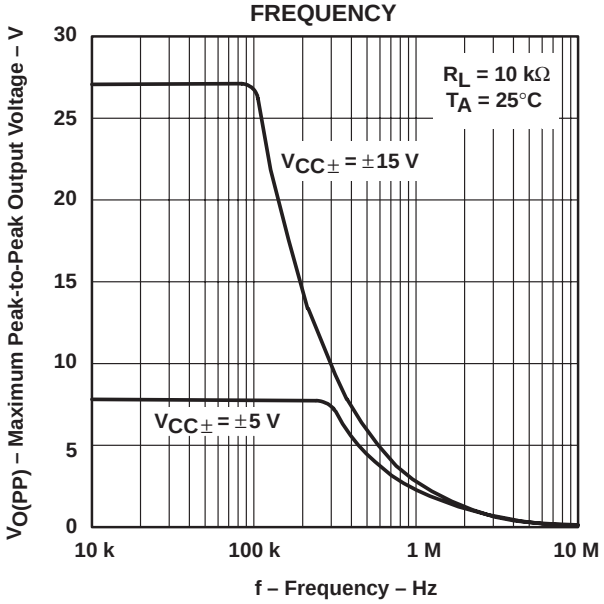



Figure 24

MAXIMUM PEAK OUTPUT VOLTAGE vs OUTPUT CURRENT

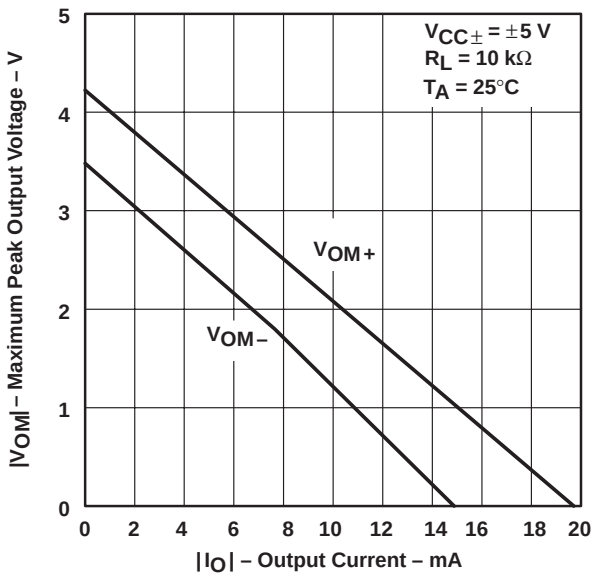



Figure 25

† 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**

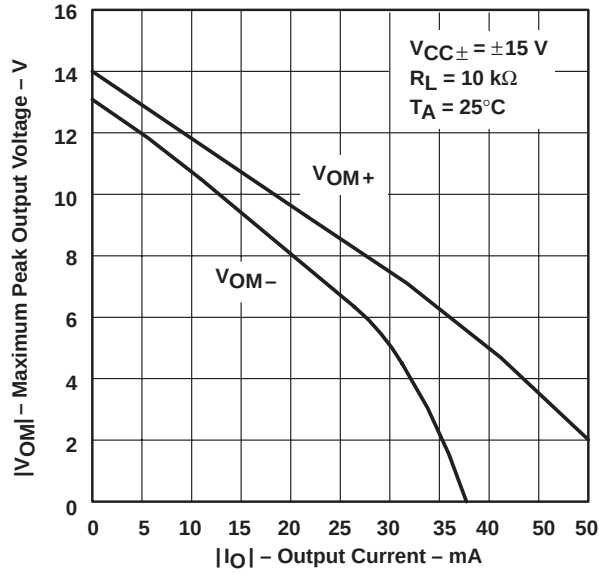



Figure 26

**MAXIMUM PEAK OUTPUT VOLTAGE† vs FREE-AIR TEMPERATURE**

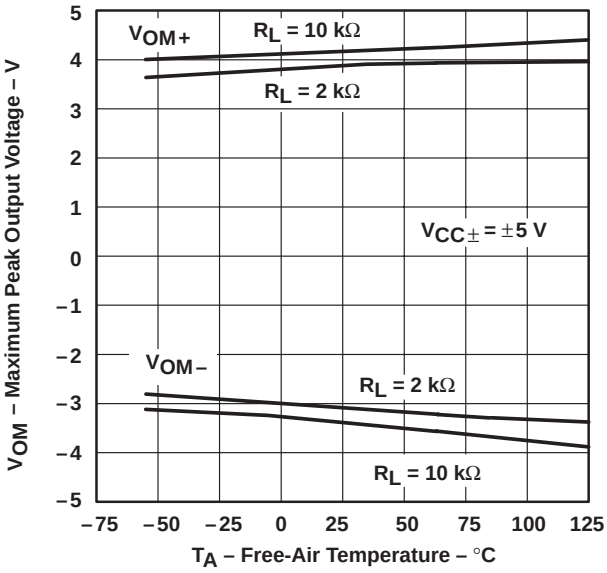



Figure 27

**MAXIMUM PEAK OUTPUT VOLTAGE† vs FREE-AIR TEMPERATURE**

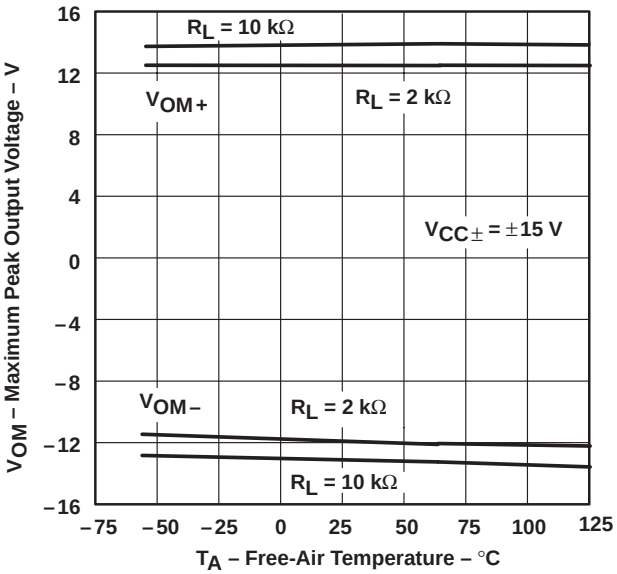



Figure 28

**LARGE-SIGNAL DIFFERENTIAL VOLTAGE AMPLIFICATION vs LOAD RESISTANCE**

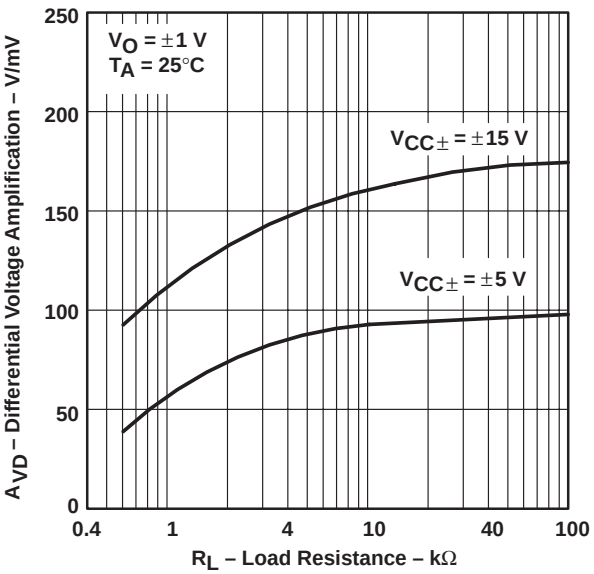



Figure 29

† 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**

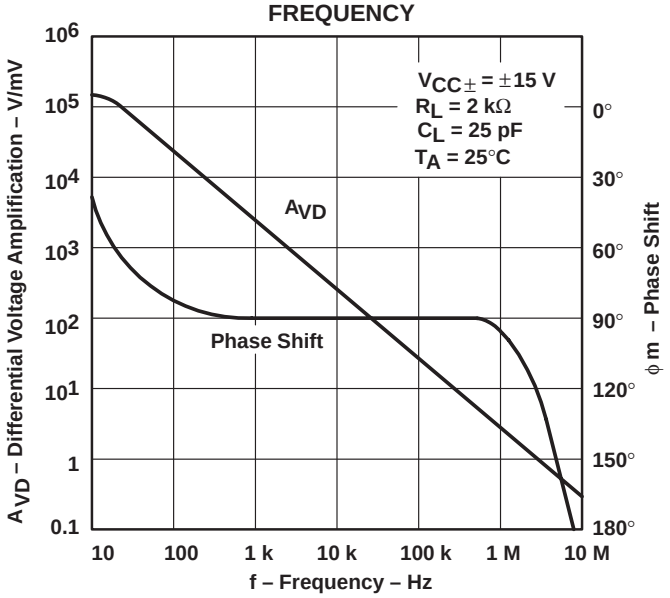



**Figure 30**

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

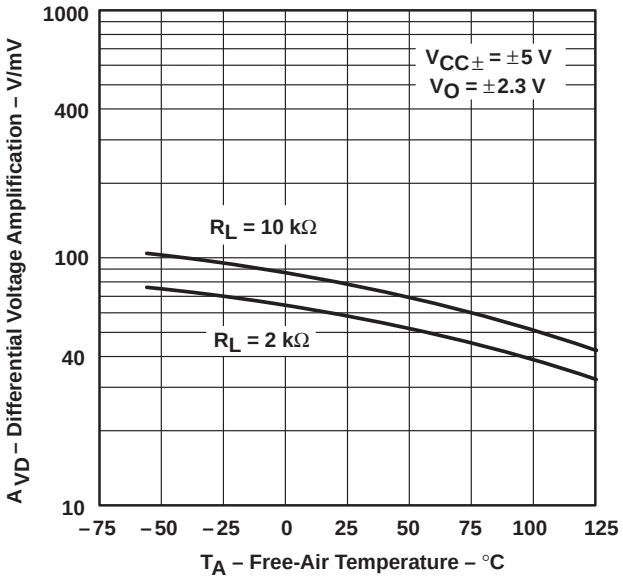



**Figure 31**

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

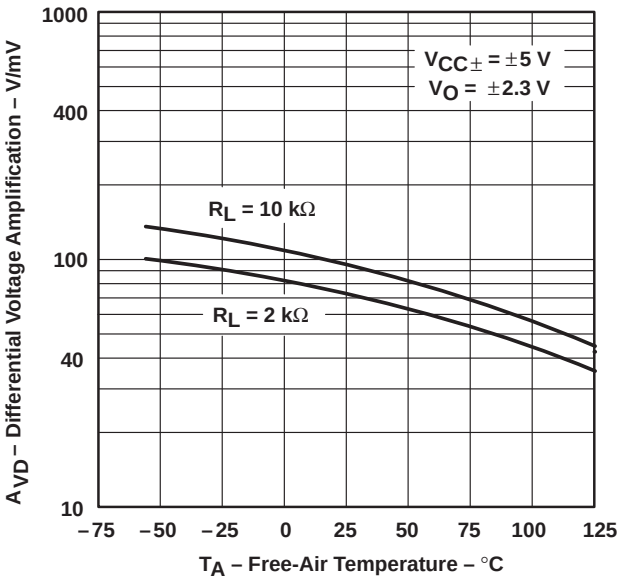



**Figure 32**

† 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**

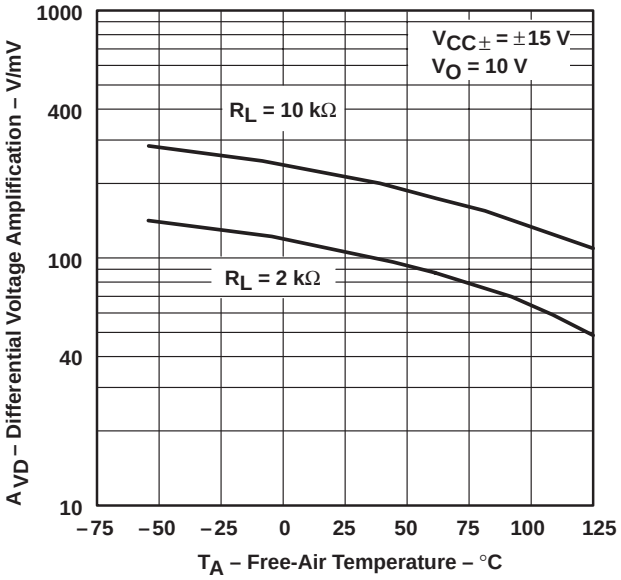



Figure 33

**COMMON-MODE REJECTION RATIO vs FREQUENCY**

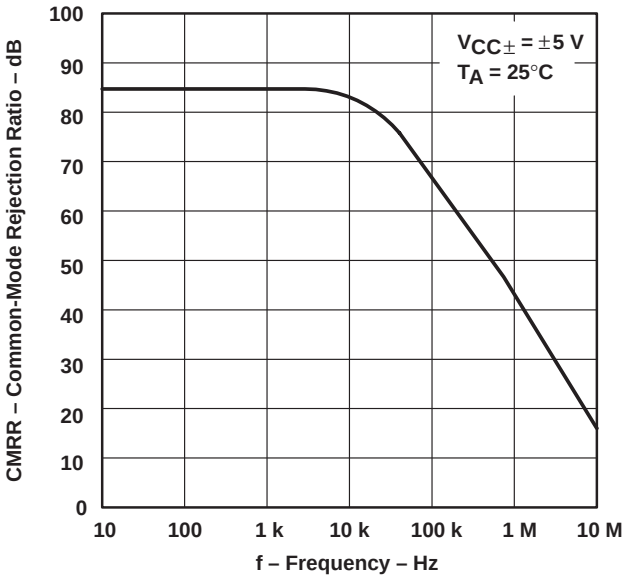



Figure 34

**COMMON-MODE REJECTION RATIO vs FREQUENCY**

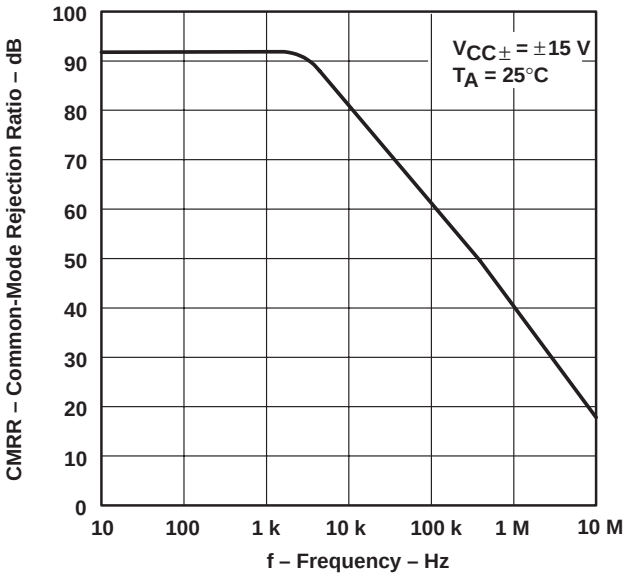



Figure 35

**COMMON-MODE REJECTION RATIO† vs FREE-AIR TEMPERATURE**

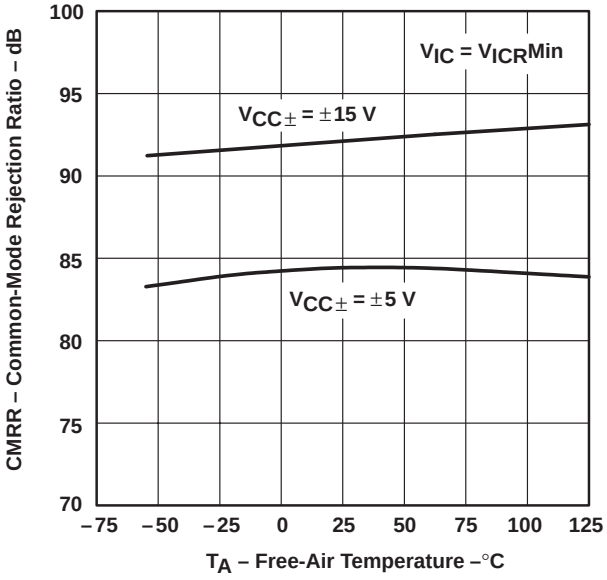



Figure 36

† 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**

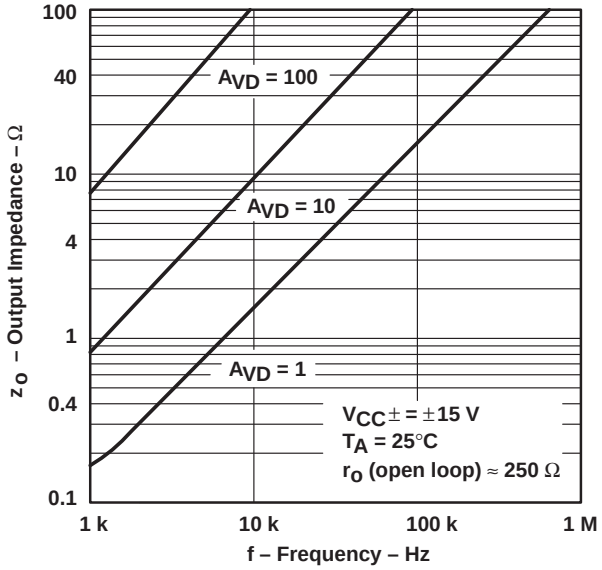



Figure 37

**SUPPLY-VOLTAGE REJECTION RATIO† vs FREE-AIR TEMPERATURE**

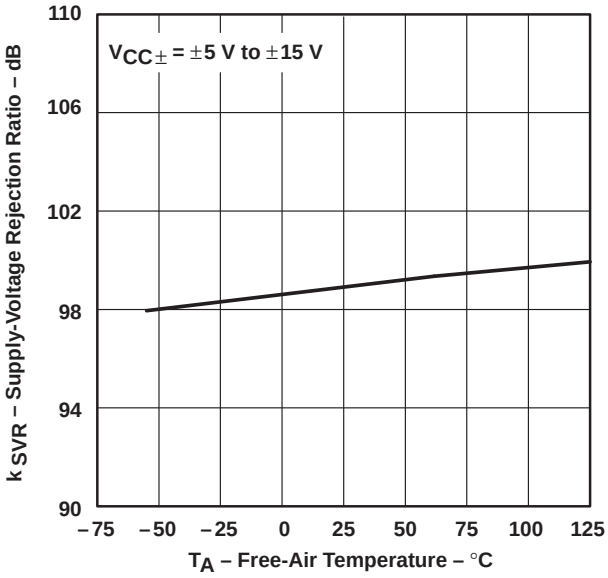



Figure 38

**SHORT-CIRCUIT OUTPUT CURRENT vs SUPPLY VOLTAGE**

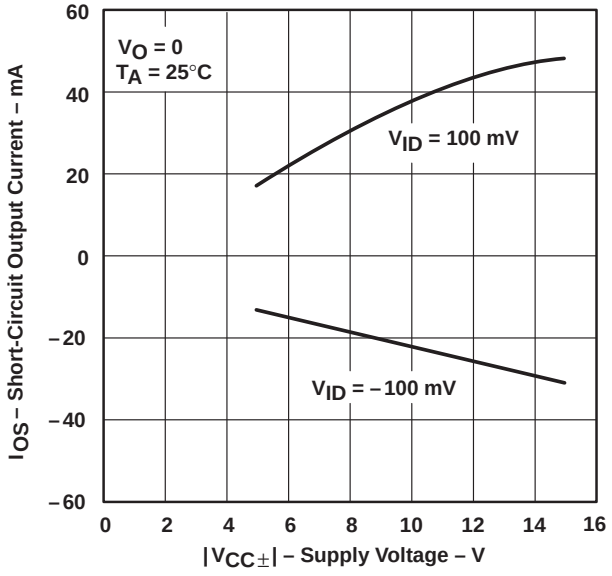



Figure 39

**SHORT-CIRCUIT OUTPUT CURRENT vs TIME**

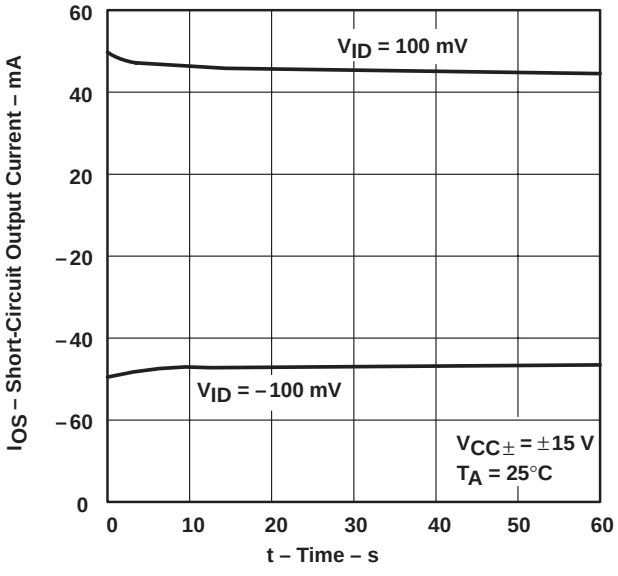



Figure 40

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

## TYPICAL CHARACTERISTICS

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

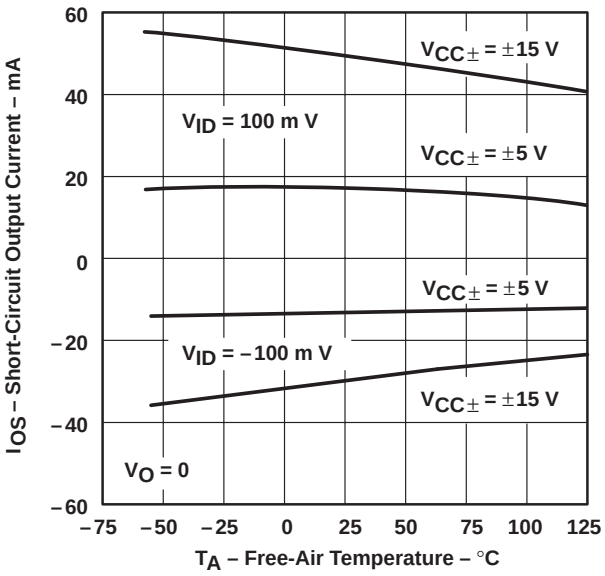



Figure 41

**TL051 SUPPLY CURRENT† vs SUPPLY VOLTAGE**

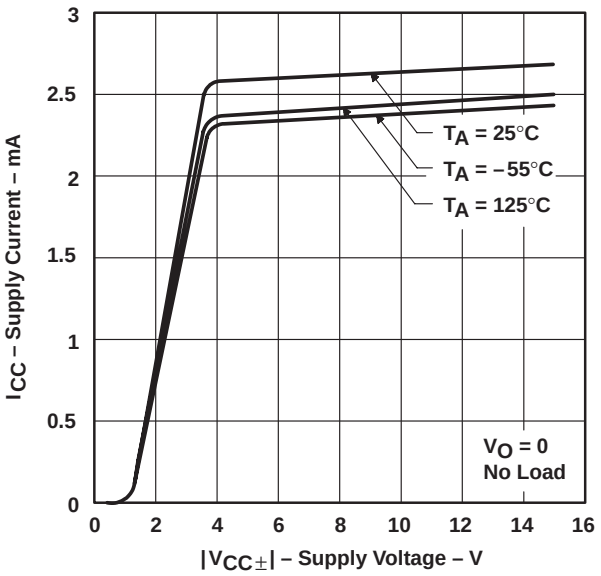



Figure 42

**TL052 SUPPLY CURRENT† vs SUPPLY VOLTAGE**

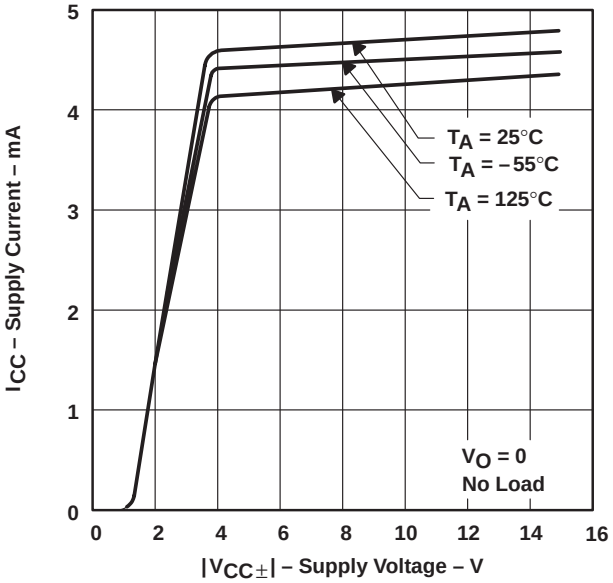



Figure 43

**TL054 SUPPLY CURRENT† vs SUPPLY VOLTAGE**

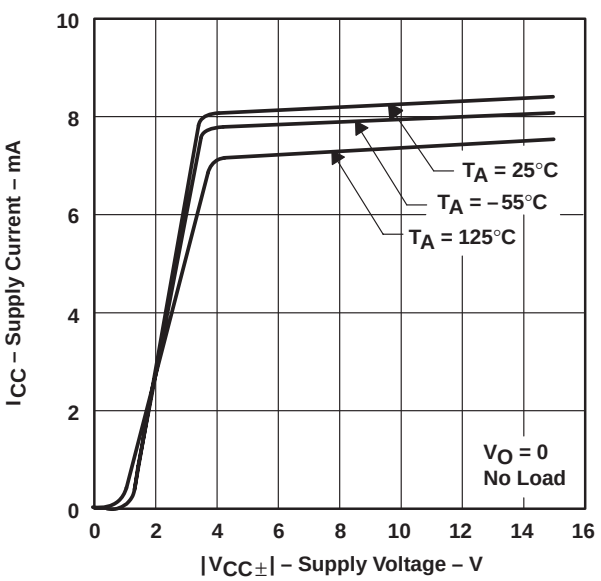



Figure 44

† 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**

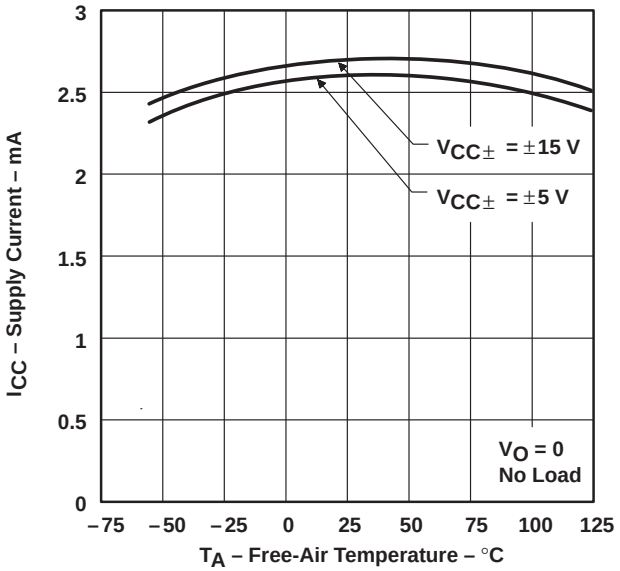



**Figure 45**

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

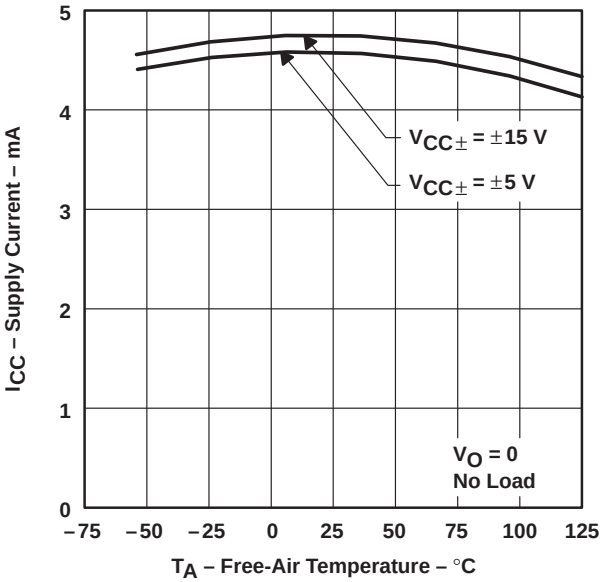



**Figure 46**

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

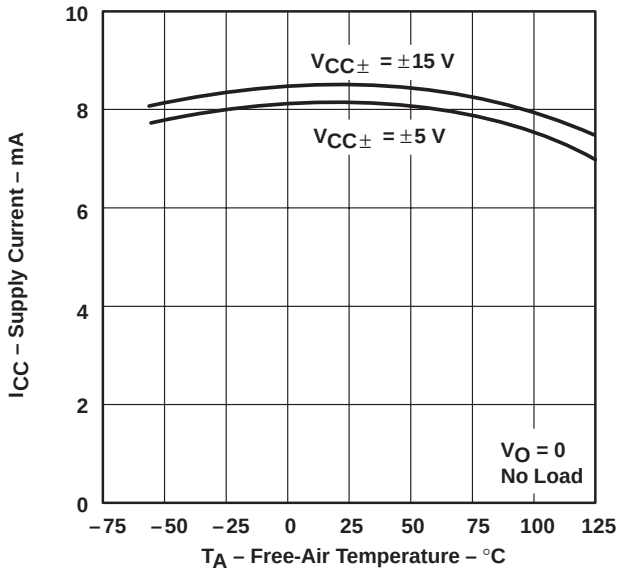



**Figure 47**

**TL051
SLEW RATE vs LOAD RESISTANCE**

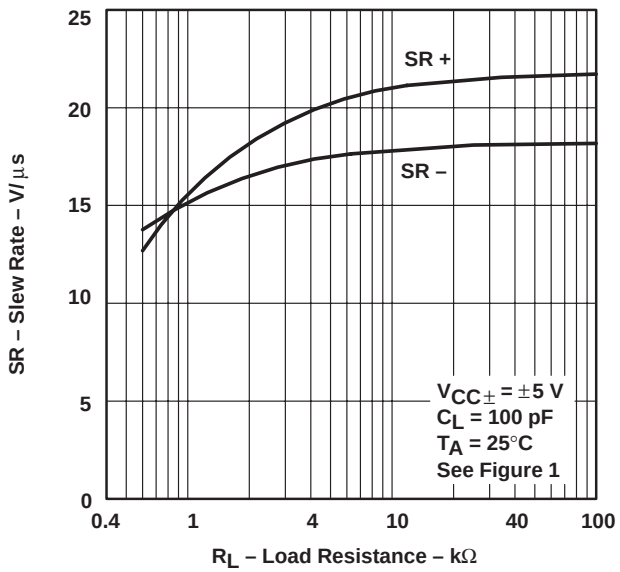



**Figure 48**

† 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

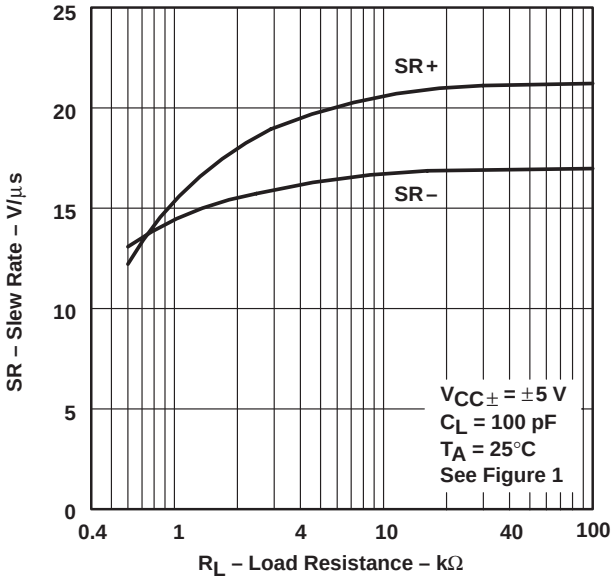



Figure 49

TL054
SLEW RATE
vs
LOAD RESISTANCE

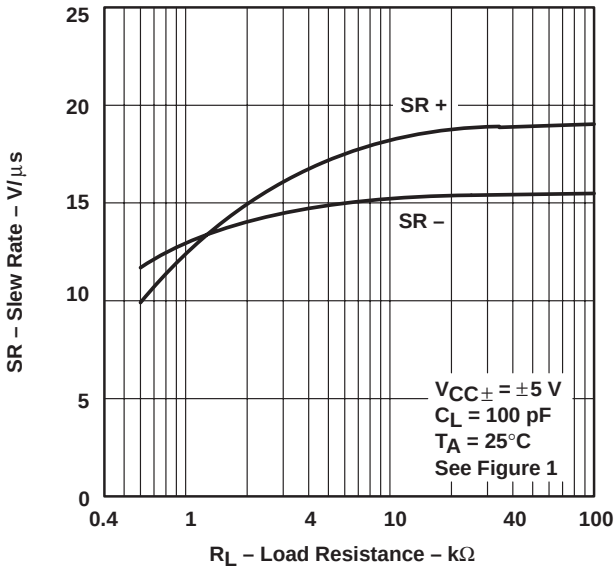



Figure 50

TL051
SLEW RATE
vs
LOAD RESISTANCE

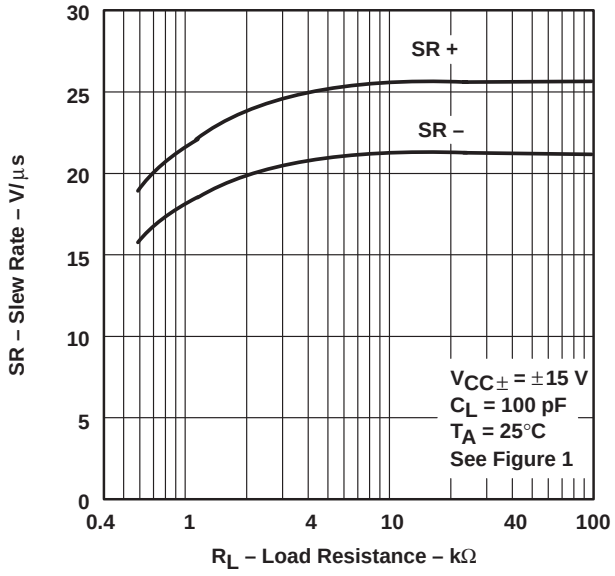



Figure 51

TL052
SLEW RATE
vs
LOAD RESISTANCE

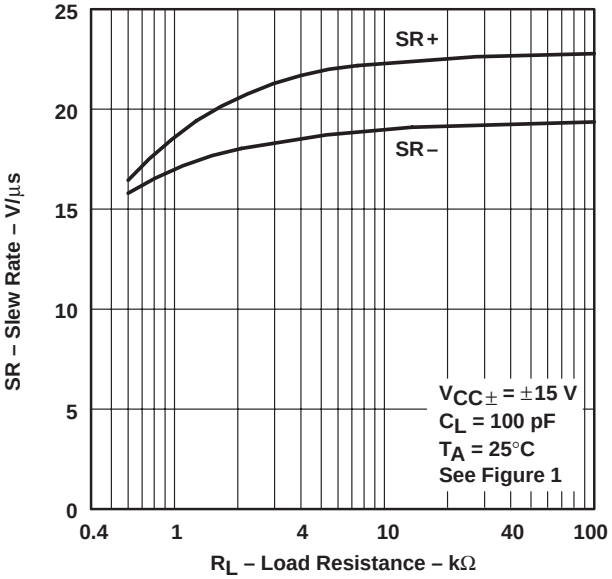



Figure 52

## TYPICAL CHARACTERISTICS

**TL054**
**SLEW RATE**
**vs**
**LOAD RESISTANCE**

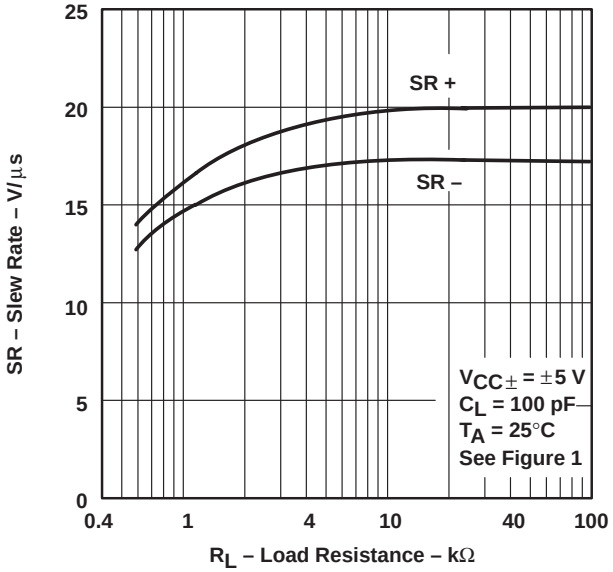



**Figure 53**

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

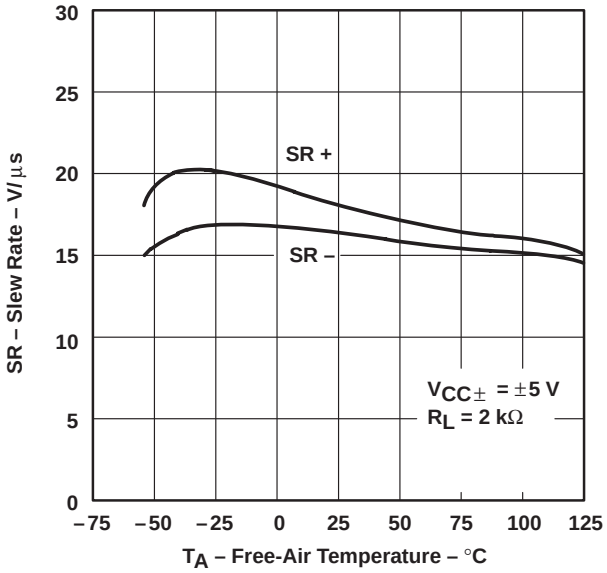



**Figure 54**

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

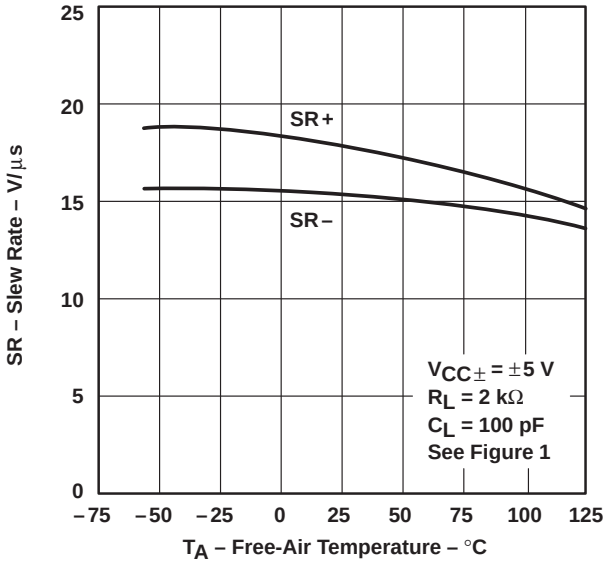



**Figure 55**

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

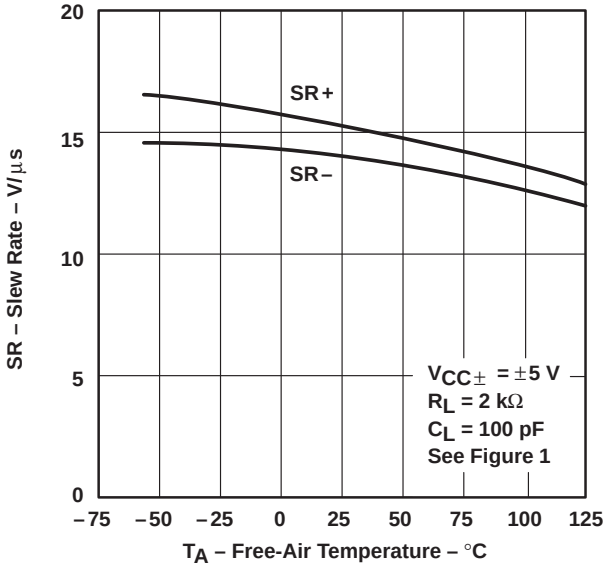



**Figure 56**

† 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**

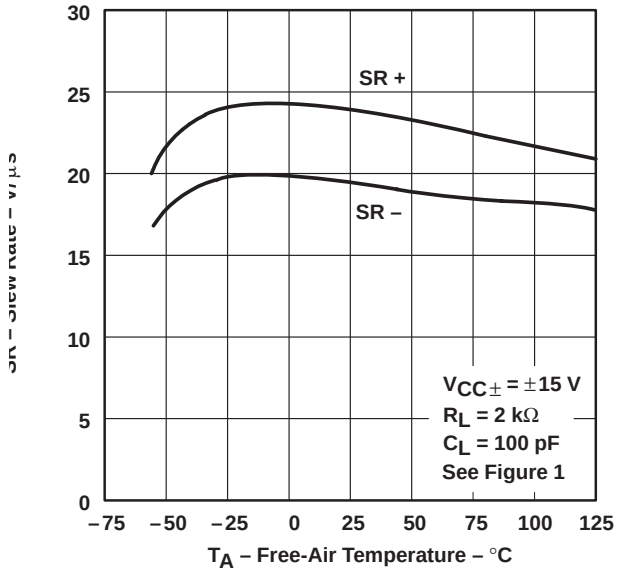



**Figure 57**

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

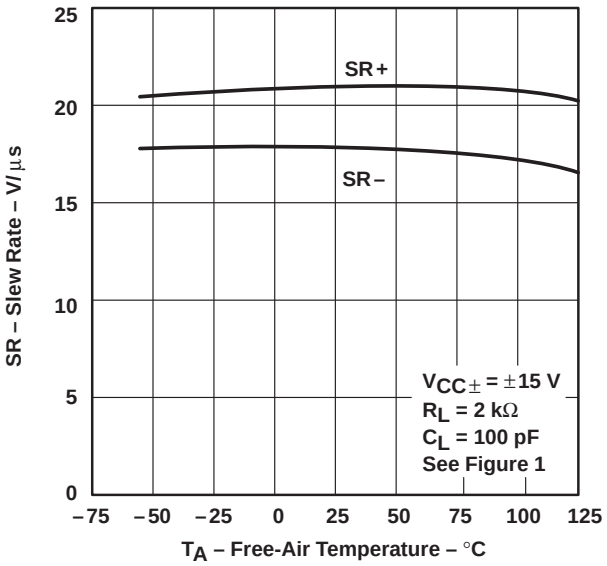



**Figure 58**

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

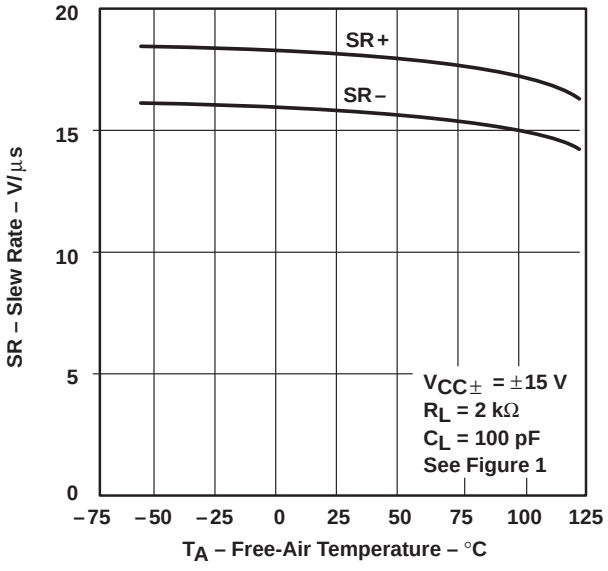



**Figure 59**

**OVERSHOOT FACTOR vs LOAD CAPACITANCE**

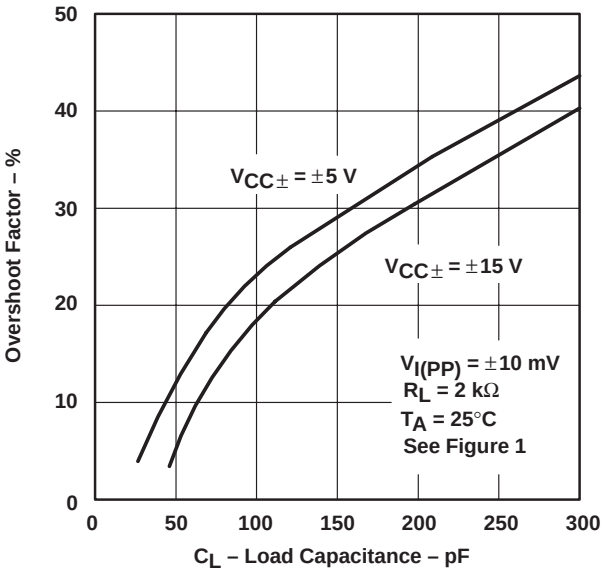



**Figure 60**

† 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**

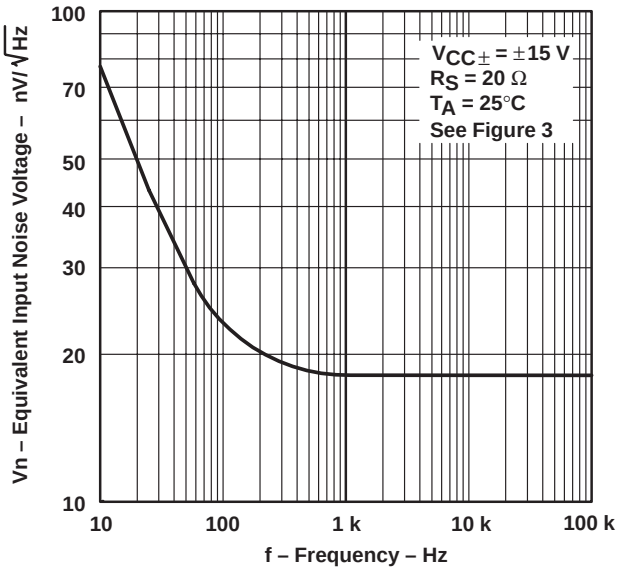



**Figure 61**

**TL052 AND TL054
EQUIVALENT INPUT NOISE VOLTAGE
vs
FREQUENCY**

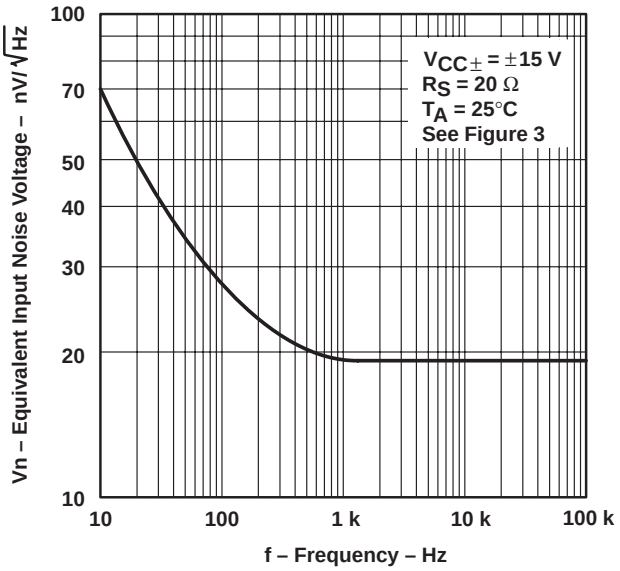



**Figure 62**

**TOTAL HARMONIC DISTORTION
vs
FREQUENCY**

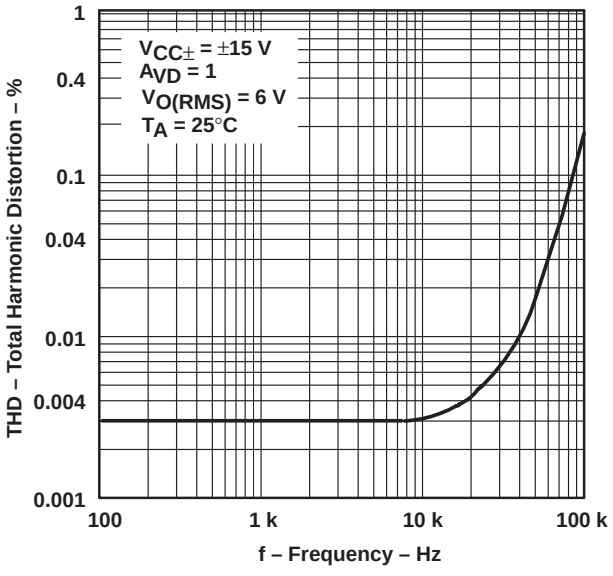



**Figure 63**

**TL051
UNITY-GAIN BANDWIDTH
vs
SUPPLY VOLTAGE**

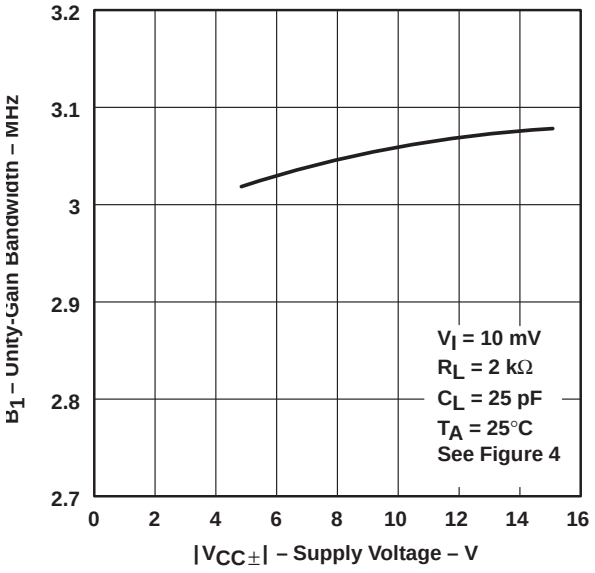



**Figure 64**

## TYPICAL CHARACTERISTICS

**TL052**
**UNITY-GAIN BANDWIDTH**
**vs**
**SUPPLY VOLTAGE**

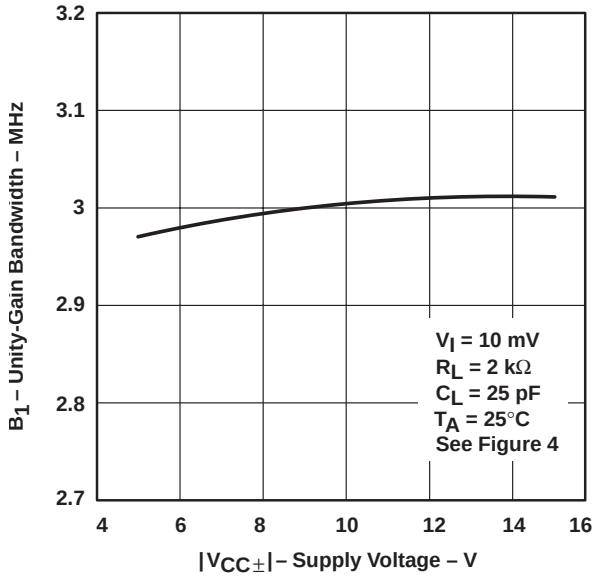



**Figure 65**

**TL054**
**UNITY-GAIN BANDWIDTH**
**vs**
**SUPPLY VOLTAGE**

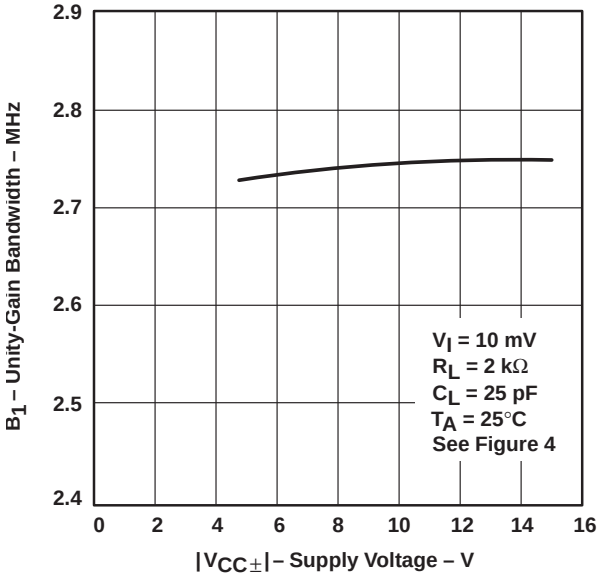



**Figure 66**

**TL051**
**UNITY-GAIN BANDWIDTH†**
**vs**
**FREE-AIR TEMPERATURE**

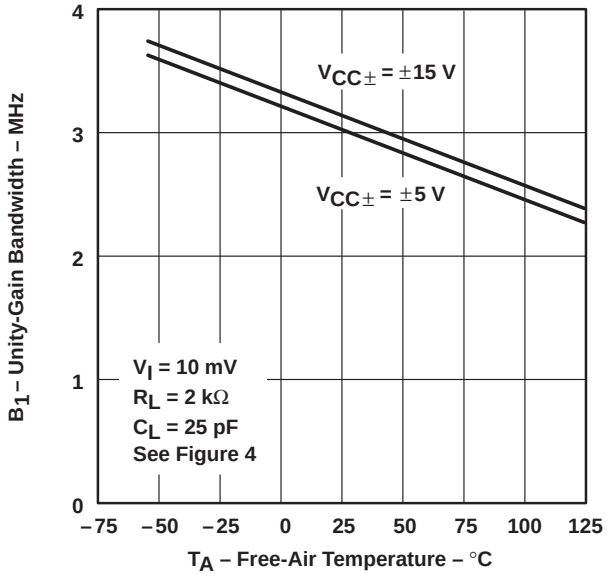



**Figure 67**

**TL052**
**UNITY-GAIN BANDWIDTH†**
**vs**
**FREE-AIR TEMPERATURE**

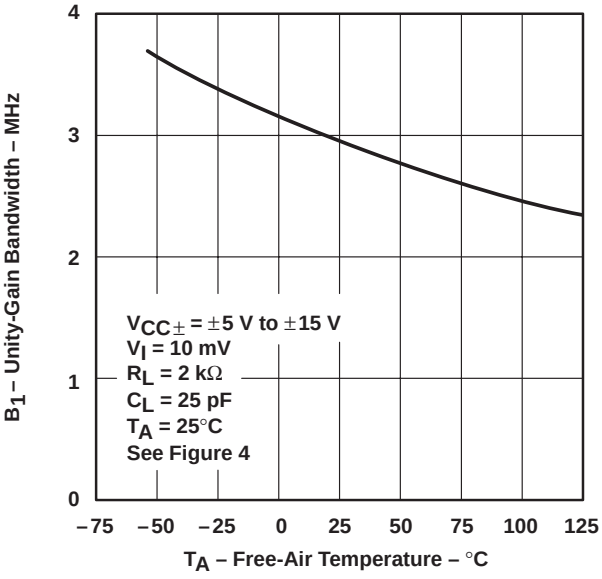



**Figure 68**

† 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**

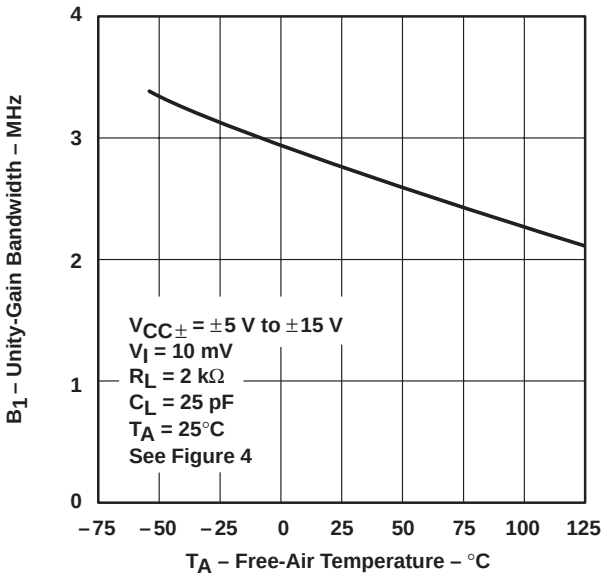



**Figure 69**

**TL051**
**PHASE MARGIN**
**vs**
**SUPPLY VOLTAGE**

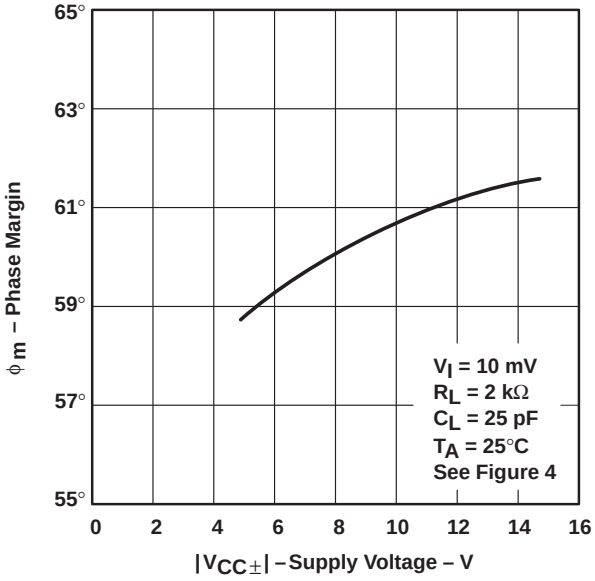



**Figure 70**

**TL052**
**PHASE MARGIN**
**vs**
**SUPPLY VOLTAGE**

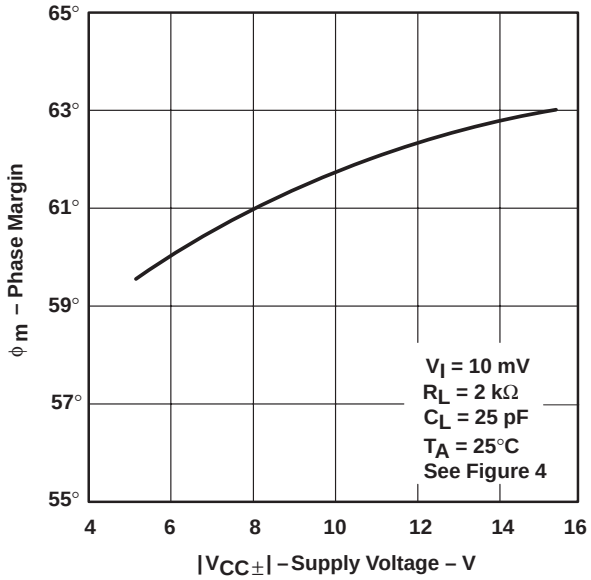



**Figure 71**

**TL054**
**PHASE MARGIN**
**vs**
**SUPPLY VOLTAGE**

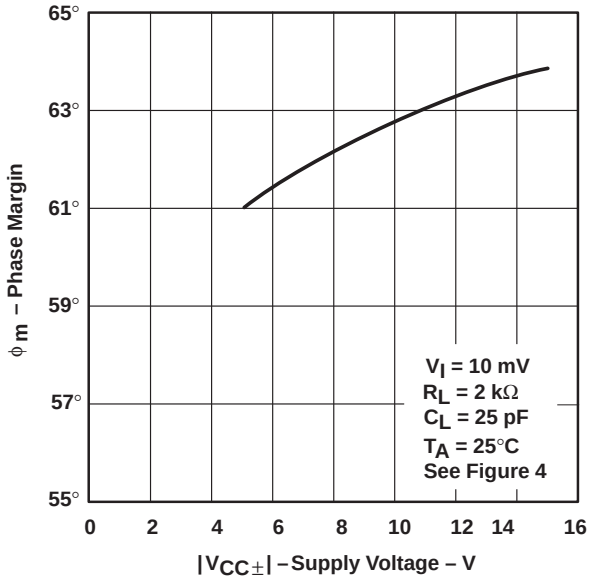



**Figure 72**

† 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**

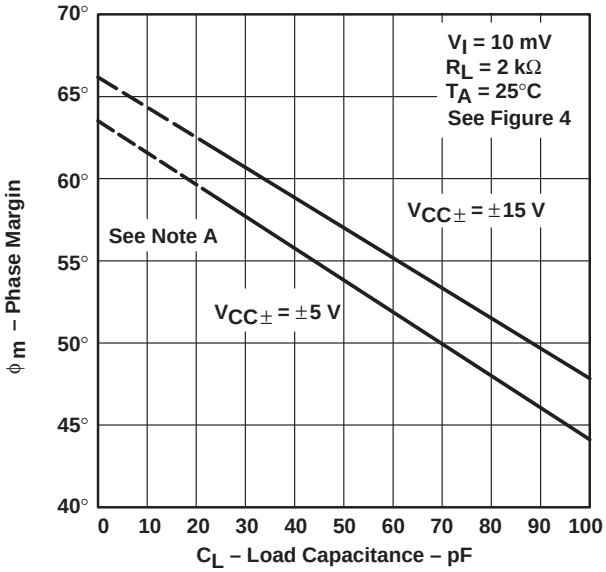



Figure 73

**TL052
PHASE MARGIN† vs LOAD CAPACITANCE**

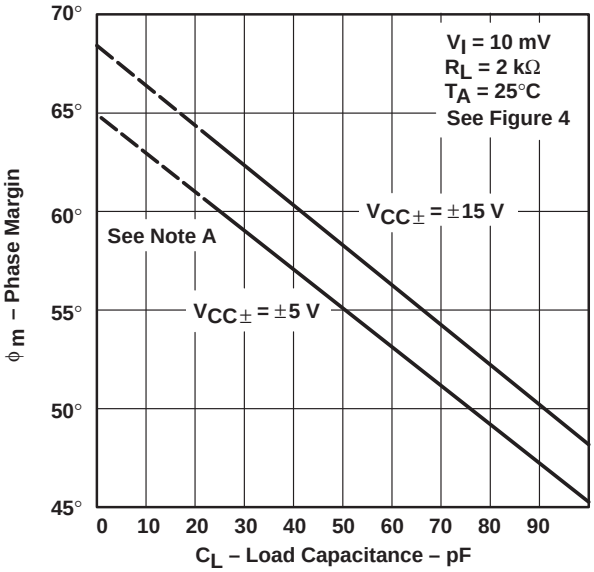



Figure 74

**TL054
PHASE MARGIN† vs LOAD CAPACITANCE**

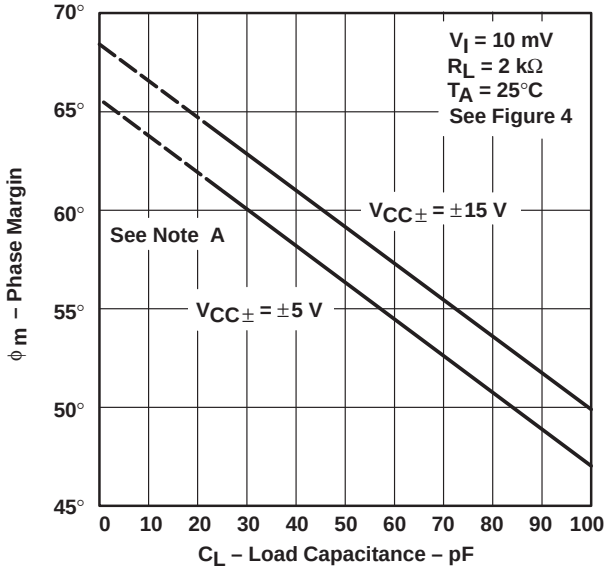



Figure 75

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

## TYPICAL CHARACTERISTICS

**TL051**
**PHASE MARGIN†**
**vs**
**FREE-AIR TEMPERATURE**

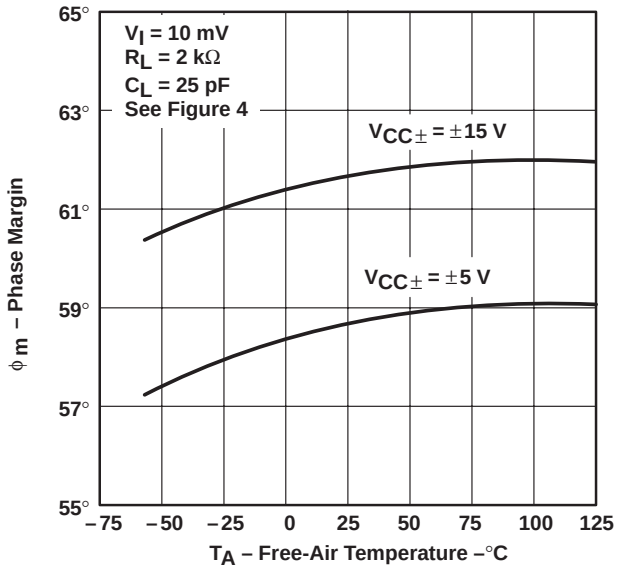



**Figure 76**

**TL052**
**PHASE MARGIN†**
**vs**
**FREE-AIR TEMPERATURE**

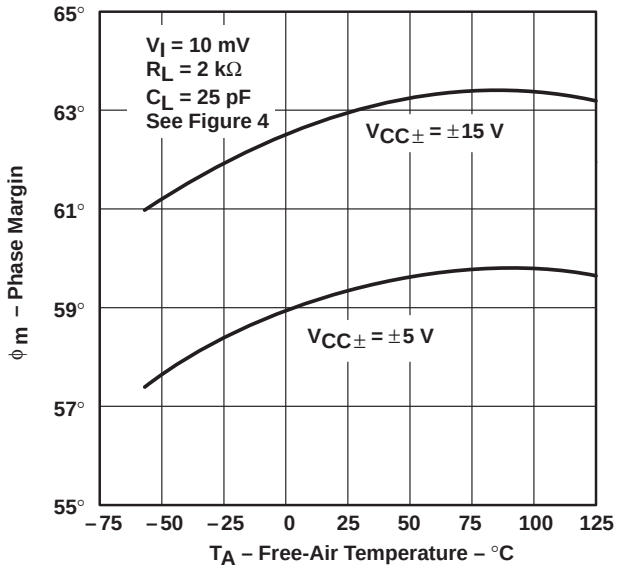



**Figure 77**

**TL054**
**PHASE MARGIN†**
**vs**
**FREE-AIR TEMPERATURE**

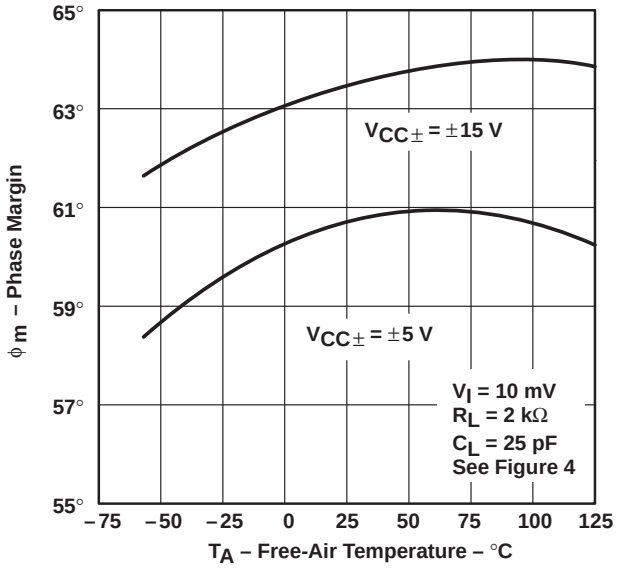



**Figure 78**

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

## TYPICAL CHARACTERISTICS

**VOLTAGE-FOLLOWER
SMALL-SIGNAL
PULSE RESPONSE**

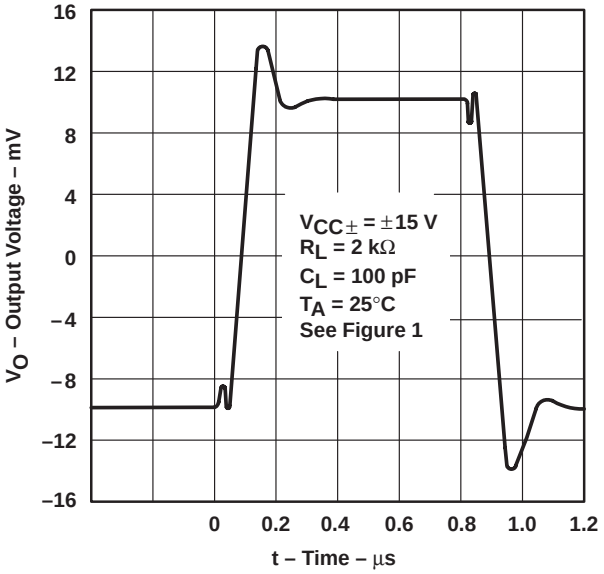



**Figure 79**

**VOLTAGE-FOLLOWER
LARGE-SIGNAL
PULSE RESPONSE**

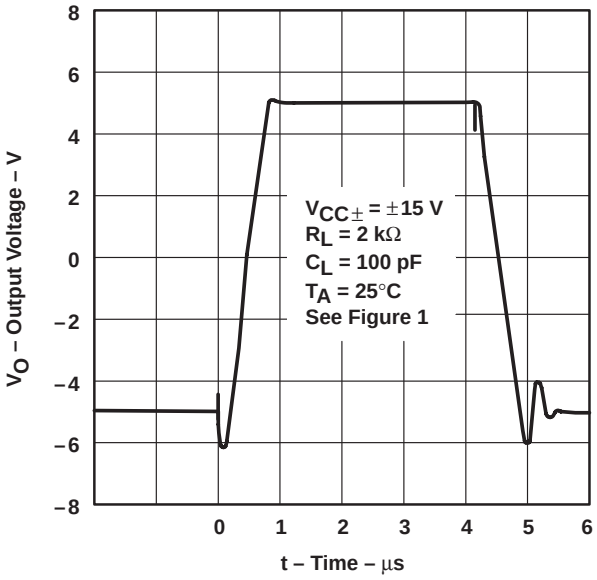
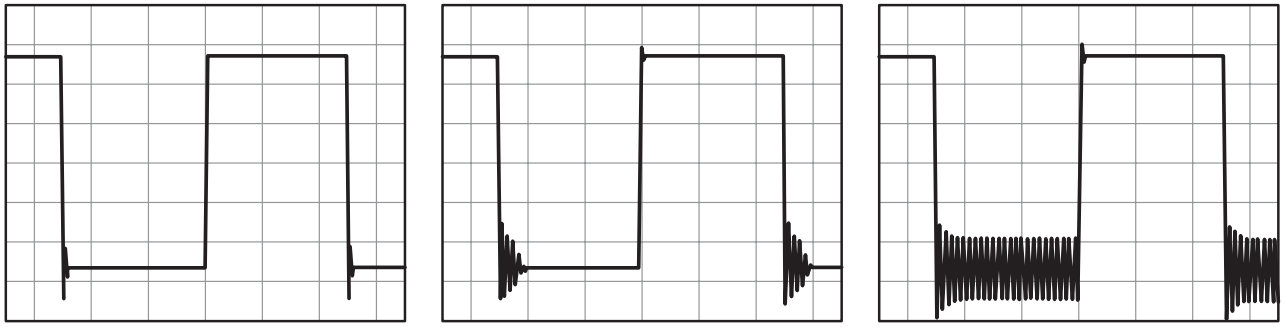



**Figure 80**

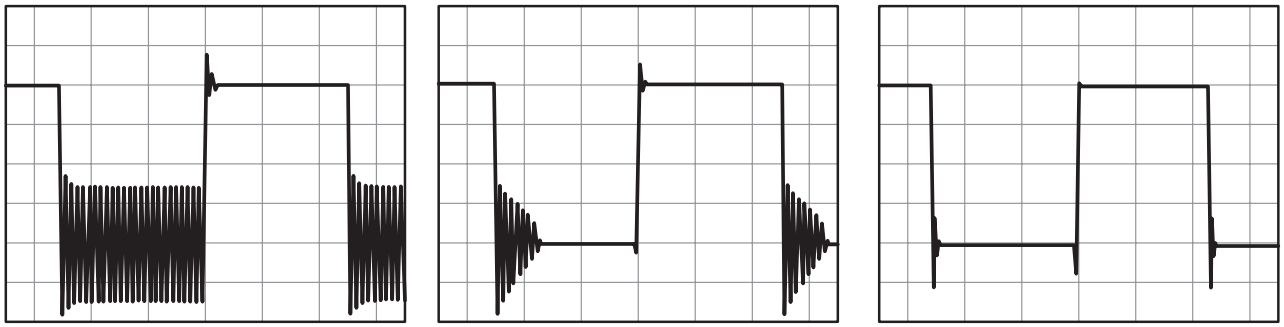
## APPLICATION INFORMATION

### 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, thereby 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).

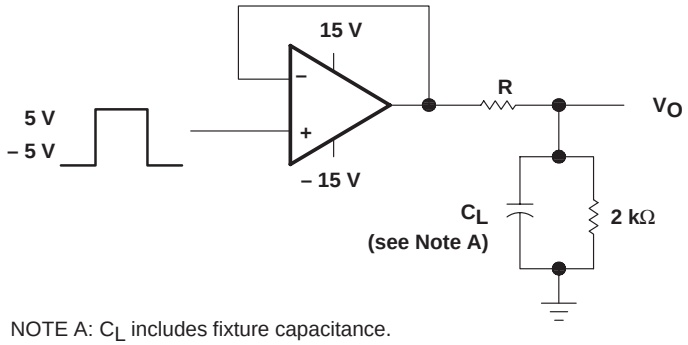


(a) $C_L$ = 100 pF, R = 0 (b) $C_L$ = 300 pF, R = 0 (c) $C_L$ = 350 pF, R = 0



(d) $C_L$ = 1000 pF, R = 0 (e) $C_L$ 1000 pF, R = 50 Ω (f) $C_L$ = 1000 pF, R = 2 kΩ

**Figure 81. Effect of Capacitive Loads**




NOTE A: $C_L$ includes fixture capacitance.

**Figure 82. Test Circuit for Output Characteristics**

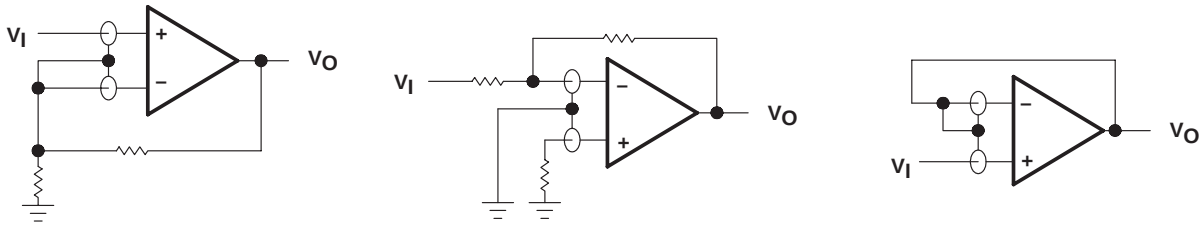
## APPLICATION INFORMATION

### 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 can easily 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.




**(a) NONINVERTING AMPLIFIER** **(b) INVERTING AMPLIFIER** **(c) UNITY-GAIN AMPLIFIER**

**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

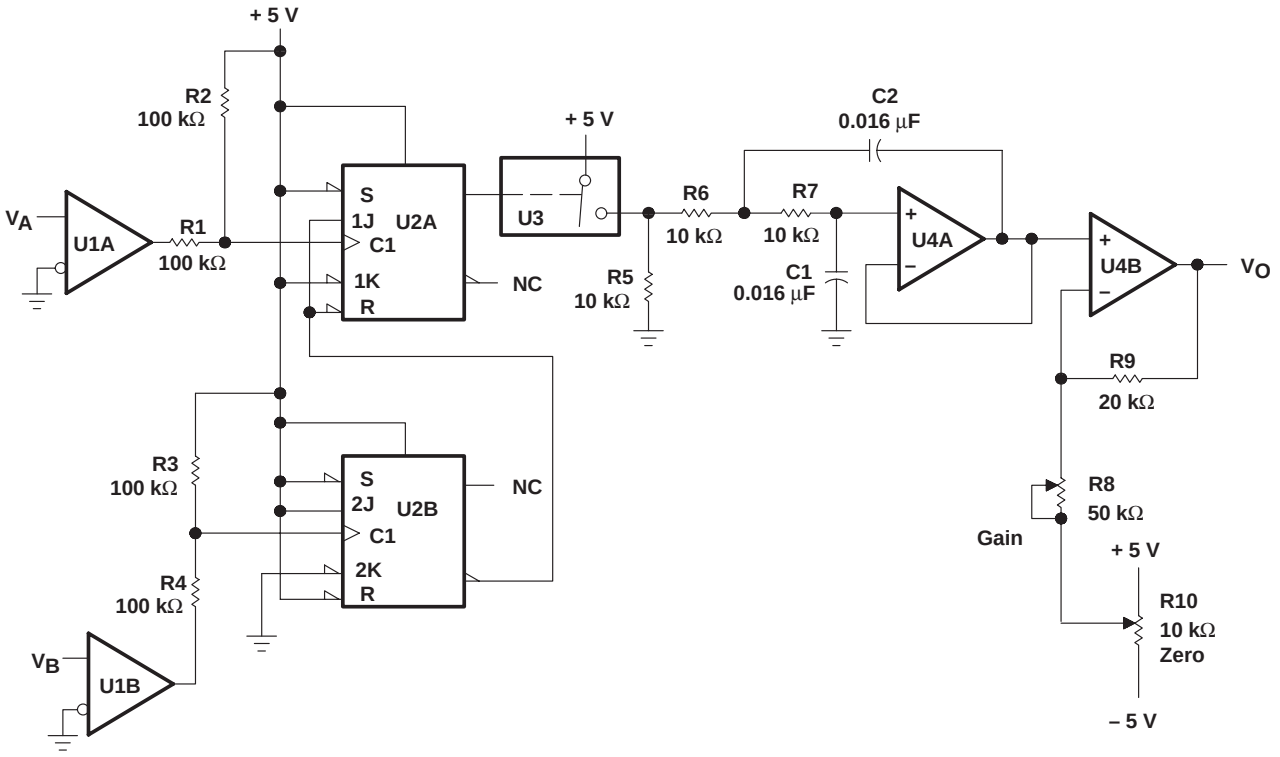
### phase meter

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 half the frequency of $V_B$. Flip-flop U2A also produces a square wave at half the input frequency. The pulse duration of U2A varies from zero to half the period, where zero corresponds to zero phase delay between $V_A$ and $V_B$ and 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

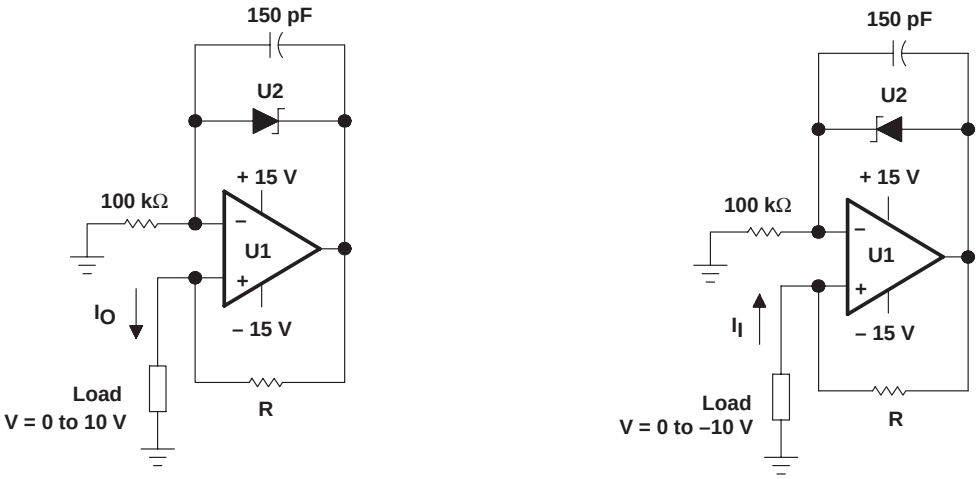
**Figure 84. Phase Meter**

## 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 is simply 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 B: 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

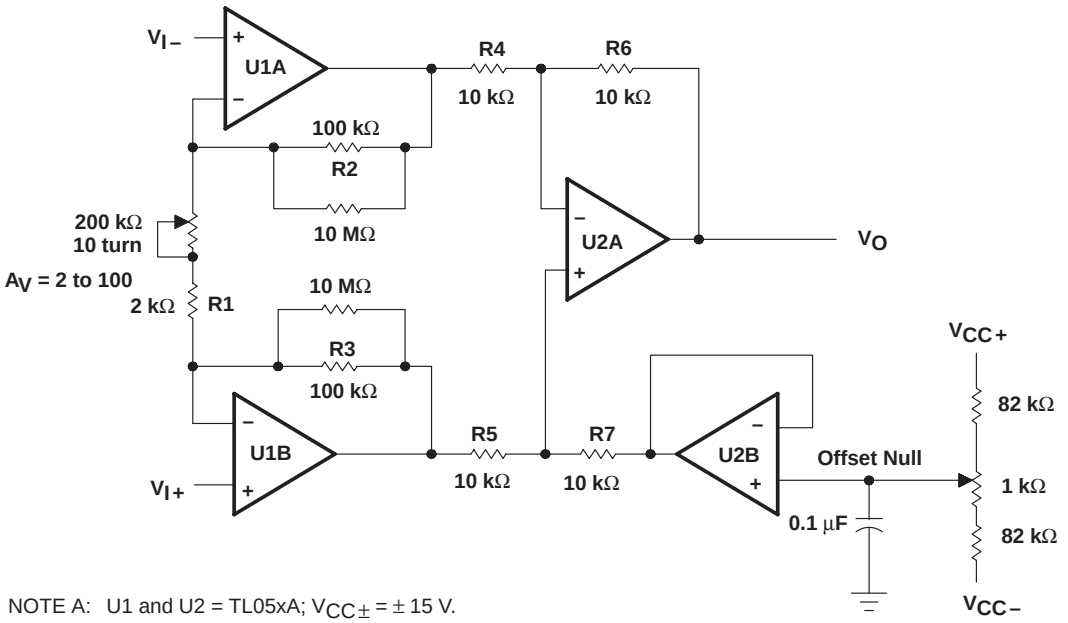
The instrumentation amplifier in Figure 86 benefits greatly from the high input impedance and stable input offset voltage of the TL05xA. Amplifiers U1A, U1B, and U2A form the actual instrumentation amplifier, while U2B provides offset null. Potentiometer R1 provides gain adjust. With R1 = 2 kΩ, the circuit 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 whenever 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**

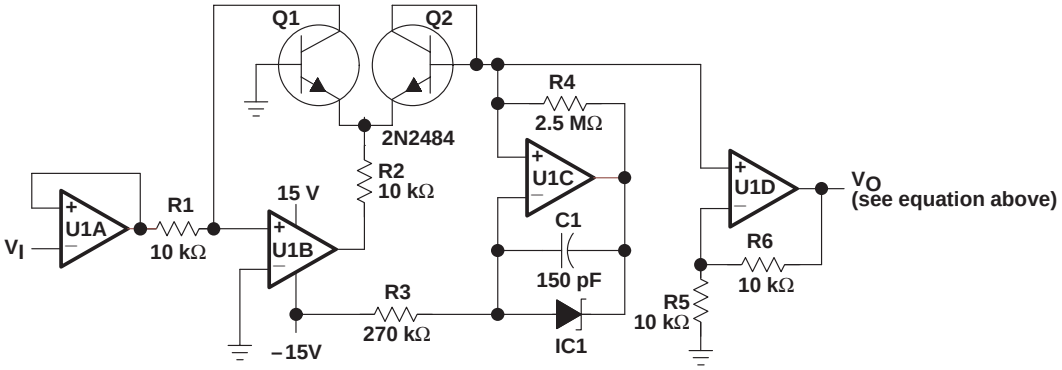
## APPLICATION INFORMATION

### 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:

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




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

**Figure 87. Log Amplifier**

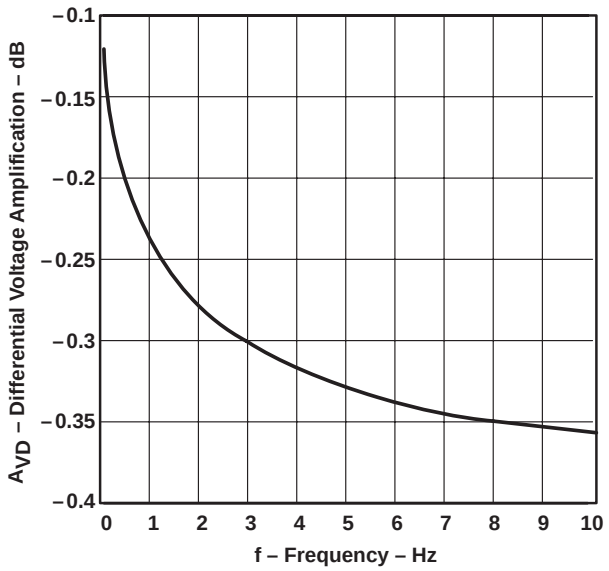



**Figure 88. Output Voltage vs Input Voltage for Log Amplifier**

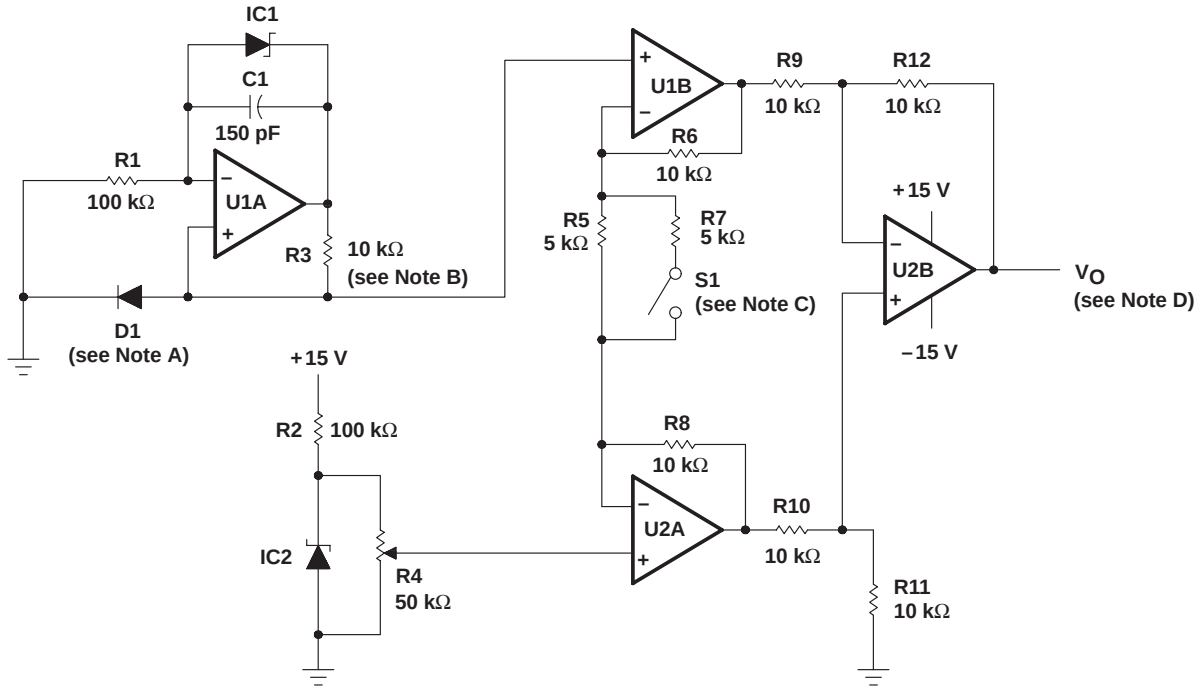
## APPLICATION INFORMATION

### 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 that 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 and 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.

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

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

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

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

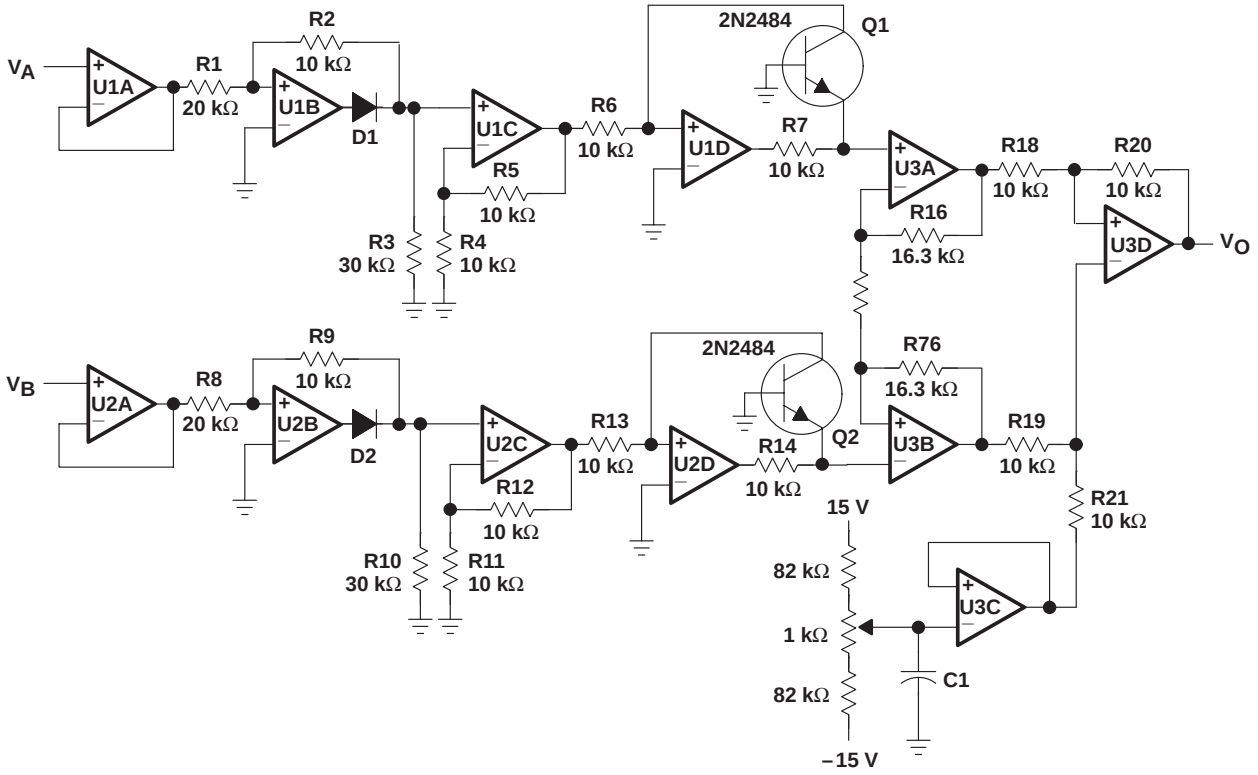
$$X\ dB = \frac{8.686}{kT/q}\left[V_{BE(Q1)} - V_{BE(Q2)}\right] = 336\left[V_{BE(Q1)} - V_{BE(Q2)}\right]\ \text{at}\ 25°C$$

where

$k = 1.38 \times 10^{-23}$, $q = 1.602 \times 10^{-19}$, and T is in kelvins.

This would give 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**

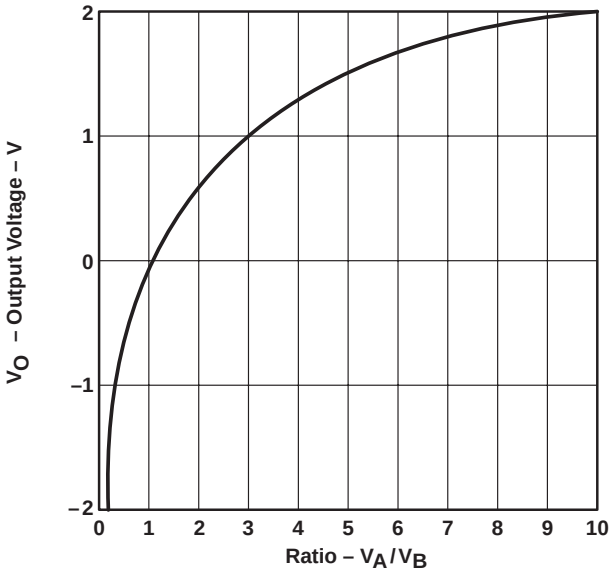



**Figure 91. Output Voltage vs the Ratio of the Input Voltages for Voltage-to-dB Converter**

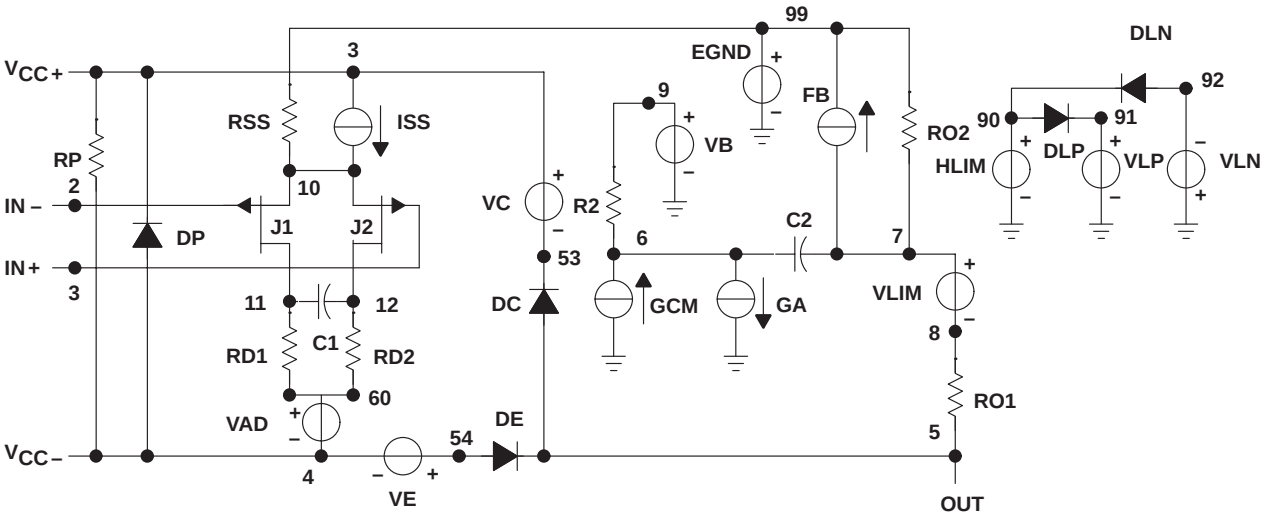
## APPLICATION INFORMATION

### macromodel information

Macromodel information provided was derived using Microsim *Parts*™, the model generation software used with Microsim *PSpice*™. The Boyle macromodel (see Note 5) 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 5: G. R. Boyle, B. M. Cohn, D. O. Pederson, and J. E. Solomon, “Macromodeling of Intergrated 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**

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