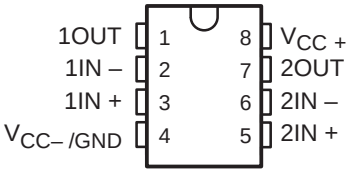
- **Wide Range of Supply Voltages**
  **Single Supply . . . 5 V to 30 V**
  **Dual Supplies . . . ± 2.5 V to ± 15 V**
- **Class AB Output Stage**
- **True Differential Input Stage**
- **Low Input Bias Current**
- **Internal Frequency Compensation**
- **Short-Circuit Protection**

**D OR P PACKAGE**
**(TOP VIEW)**

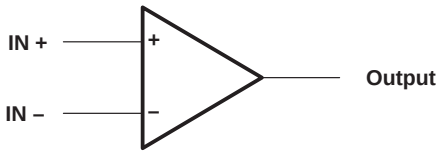



## description

The TL322C and the TL322I are dual operational amplifiers similar in performance to the uA741 but with several distinct advantages. They are designed to operate from a single supply over a range of voltages from 5 V to 30 V. Operation from split supplies is also possible provided the difference between the two supplies is 5 V to 30 V. The common-mode input range includes the negative supply. Output range is from the negative supply to $V_{CC}$ –1.5 V. Quiescent supply currents per amplifier are typically less than one-half those of the uA741.

The TL322C is characterized for operation from 0°C to 70°C. The TL322I is characterized for operation from –40°C to 85°C.

**symbol (each amplifier)**

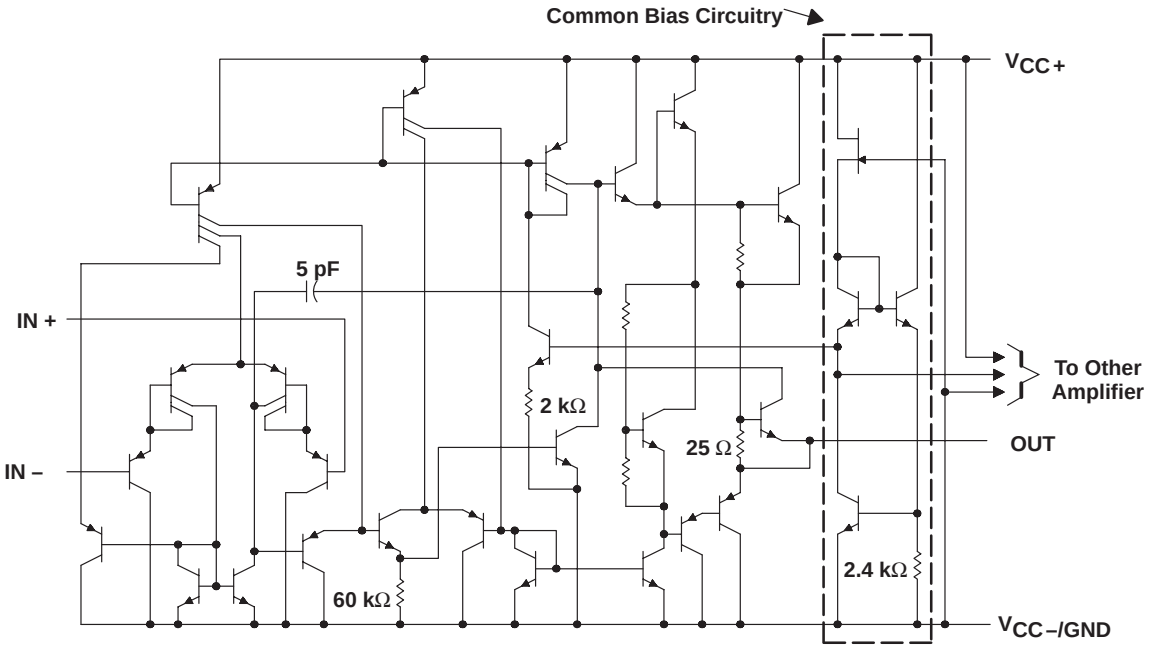



**AVAILABLE OPTIONS**

| $T_A$ | $V_{IO}$ MAX AT 25°C | PACKAGE | |
|---|---|---|---|
| | | SMALL OUTLINE (D) | PLASTIC DIP (P) |
| 0°C to 70°c | 10 mV | TL322CD | TL322CP |
| 0°C to 70°c | 8 mV | TL322ID | TL322IP |

D packages are available taped and reeled. Add R suffix to device type, (e.g., TL322CDR).

## schematic (each amplifier)




All component values shown are nominal.

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

| | TL322C | TL322I | UNIT |
|---|---|---|---|
| Supply voltage $V_{CC+}$ (see Note 1) | 18 | 18 | V |
| Supply voltage $V_{CC-}$ (see Note 1) | –18 | –18 | V |
| Supply voltage $V_{CC+}$ (with respect to $V_{CC-}$) | 36 | 36 | V |
| Differential input voltage (see Note 2) | ±36 | ±36 | V |
| Input voltage (see Notes 1 and 3) | ±18 | ±18 | V |
| Continuous total power disspation | See Dissipation Rating Table | | |
| Operating free-air temperature range | 0 to 70 | –40 to 85 | °C |
| Storage temperature range | –65 to 150 | –65 to 150 | °C |
| Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds | 260 | 260 | °C |

NOTES: 1. These voltage values are with respect to the midpoint between $V_{CC+}$ and $V_{CC-}$.
2. Differential voltages are at the noninverting input terminal with respect to the inverting input terminal.
3. Neither input must ever be more positive than $V_{CC+}$ or more negative than $V_{CC-}$.

**DISSIPATION RATING TABLE**

| PACKAGE | $T_A \le 25°C$ POWER RATING | DERATING FACTOR | DERATE ABOVE $T_A$ | $T_A = 70°C$ POWER RATING | $T_A = 85°C$ POWER RATING |
|---|---|---|---|---|---|
| D | 680 mW | 5.8 mW/°C | 33°C | 464 mW | 377 mW |
| P | 680 mW | 8.0 mW/°C | 65°C | 640 mW | 520 mW |

## recommended operating conditions

| | MIN | NOM | MAX | UNIT |
|---|---|---|---|---|
| Single supply voltage, $V_{CC}$ | 5 | | 30 | V |
| Dual supply voltage, $V_{CC+}$ | 2.5 | | 15 | V |
| Dual supply voltage, $V_{CC-}$ | – 2.5 | | – 15 | V |

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

| PARAMETER | | TEST CONDITIONS† | | TL322C | | | TL322I | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_O$ = 0, $R_S$ = 50 Ω | 25°C | | 2 | 10 | | 2 | 8 | mV |
| | | | Full range | | | 12 | | | 10 | |
| $\alpha_{VIO}$ | Temperature coefficient of input offset voltage | $V_O$ = 0, $R_S$ = 50 Ω | 25°C | | 10 | | | 10 | | μV/°C |
| $I_{IO}$ | Input offset current | $V_O$ = 0 | 25°C | | 30 | 50 | | 30 | 75 | nA |
| | | | Full range | | | 200 | | | 250 | |
| $\alpha_{IIO}$ | Temperature coefficient of input offset current | $V_O$ = 0 | 25°C | | 50 | | | 50 | | pA/°C |
| $I_{IB}$ | Input bias current | $V_O$ = 0 | 25°C | | −0.2 | −0.5 | | −0.2 | −0.5 | μA |
| | | | Full range | | | −0.8 | | | −1 | |
| $V_{ICR}$ | Common-mode input voltage range‡ | | 25°C | $V_{CC-}$ to 13 | $V_{CC-}$ to 13.5 | | $V_{CC-}$ to 13 | $V_{CC-}$ to 13.5 | | V |
| $V_{OM}$ | Peak output voltage swing | $R_L$ = 10 kΩ | 25°C | ±12 | ±13.5 | | ±12 | ±12.5 | | V |
| | | $R_L$ = 2 kΩ | 25°C | ±10 | ±13 | | ±10 | ±12 | | |
| | | | Full range | ±10 | | | ±10 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O$ = ±10 V, $R_L$ = 2 kΩ | 25°C | 20 | 200 | | 20 | 200 | | V/mV |
| | | | Full range | 15 | | | 15 | | | |
| $B_{OM}$ | Maximum-output-swing bandwidth | $V_{O(PP)}$ = 20 V, $A_{VD}$ = 1, THD ≤ 5%, $R_L$ = 2 kΩ | 25°C | | 9 | | | 9 | | kHz |
| $B_1$ | Unity-gain bandwidth | $V_O$ = 50 mV, $R_L$ = 10 kΩ | 25°C | | 1 | | | 1 | | MHz |
| $\phi_m$ | Phase margin | $R_L$ = 2 kΩ, $C_L$ = 200 pF | 25°C | | 60° | | | 60° | | |
| $r_i$ | Input resistance | f = 20 Hz | 25°C | 0.3 | 1 | | 0.3 | 1 | | MΩ |
| $r_o$ | Output resistance | f = 20 Hz | 25°C | | 75 | | | 75 | | Ω |
| CMRR | Common-mode rejection ratio | $V_{IC}$ = $V_{ICR}$ min, $R_S$ = 50 Ω | 25°C | 70 | 90 | | 70 | 90 | | dB |
| $k_{SVS}$ | Supply voltage sensitivity ($\Delta V_{IO}/\Delta V_{CC}$) | $V_{CC}$ = ±2.5 V to ±15 V, $R_S$ = 50 Ω | 25°C | | 30 | 150 | | 30 | 150 | μV/V |
| $I_{OS}$ | Short-circuit output current§ | $V_O$ = 0 | 25°C | ±10 | ±30 | ±45 | ±10 | ±30 | ±45 | mA |
| $I_{CC}$ | Total supply current | $V_O$ = 0, No load | 25°C | | 1.4 | 4 | | 1.4 | 4 | mA |

† All characteristics are under open-loop conditions unless otherwise noted. Full range for $T_A$ is 0°C to 70°C for TL322C and −40°C to 85°C for TL322I.
‡ The $V_{ICR}$ limits are directly linked volt-for-volt to supply voltage; the positive limit is 2 V less than $V_{CC+}$.
§ Temperature and/or supply voltages must be limited to ensure that the dissipation rating is not exceeded.

## electrical characteristics, $V_{CC+}$ = 5 V, $V_{CC-}$ = 0 V, $T_A$ = 25°C (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS† | TL322C | | | TL322I | | | UNIT |
|---|---|---|---|---|---|---|---|---|---|
| | | | MIN | TYP | MAX | MIN | TYP | MAX | |
| $V_{IO}$ | Input offset voltage | $V_O$ = 2.5 V, $R_S$ = 50 Ω | | 2 | 10 | | | 8 | mV |
| $I_{IO}$ | Input offset current | $V_O$ = 2.5 V | | 30 | 50 | | | 75 | nA |
| $I_{IB}$ | Input bias current | | | −0.2 | −0.5 | | | −0.5 | pA |
| $V_{OM}$ | Peak output voltage swing‡ | $R_L$ = 10 kΩ | 3.3 | 3.5 | | 3.3 | 3.5 | | V |
| | | $R_L$ = 10 kΩ, $V_{CC+}$ = 5 V to 30 V | $V_{CC+}$ −1.7 | | | $V_{CC+}$ −1.7 | | | |
| $A_{VD}$ | Large-signal differential voltage amplification | $V_O$ = 1.7 V to 3.3 V, $R_L$ = 2 kΩ | 20 | 200 | | 20 | 200 | | V/mV |
| $k_{SVS}$ | Supply voltage sensitivity ($\Delta V_{IO}/\Delta V_{CC+}$) | $V_{CC}$ = ±2.5 V to ±15 V | | | 150 | | | 150 | μV/V |
| $I_{CC}$ | Supply current | $V_O$ = 2.5 V, No load | | 1.2 | 4 | | 1.2 | 4 | mA |
| $V_{o1}/V_{o2}$ | Crosstalk attenuation | $A_{VD}$ = 100, f = 1 kHz to 20 kHz | | 120 | | | 120 | | dB |

† All characteristics are specified under open-loop conditions.
‡ Output will swing essentially to ground.

## switching characteristics, $V_{CC+}$ = 15 V, $V_{CC-}$ = – 15 V $A_{VD}$ = 1, $T_A$ = 25°C (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|
| SR | Slew rate at unity gain | $V_I$ = ±10 V, $C_L$ = 100 pF, See Figure 1 | | 0.6 | | V/μs |
| $t_r$ | Rise time | $\Delta V_O$ = 50 mV, $C_L$ = 100 pF, $R_L$ = 10 kΩ, See Figure 1 | | 0.35 | | μs |
| $t_f$ | Fall time | | | 0.35 | | μs |
| | Overshoot factor | | | 20% | | |
| | Crossover distortion | $V_{I(PP)}$ = 30 mV, $V_{O(PP)}$= 2 V, f = 10 kHz | | 1% | | |

## PARAMETER MEASUREMENT INFORMATION

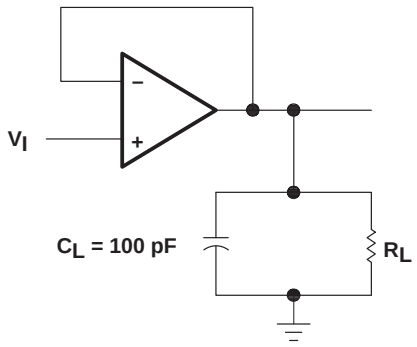



**Figure 1. Unity-Gain Amplifier**

## TYPICAL CHARACTERISTICS†

**INPUT BIAS CURRENT vs FREE-AIR TEMPERATURE**

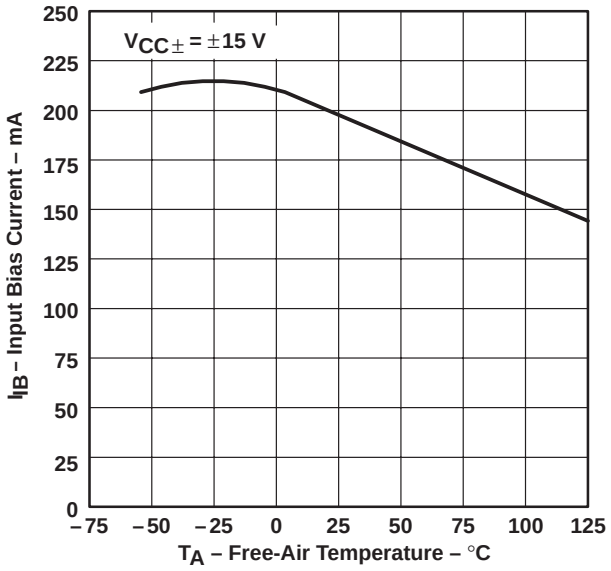



Figure 2

**INPUT BIAS CURRENT vs SUPPLY VOLTAGE**

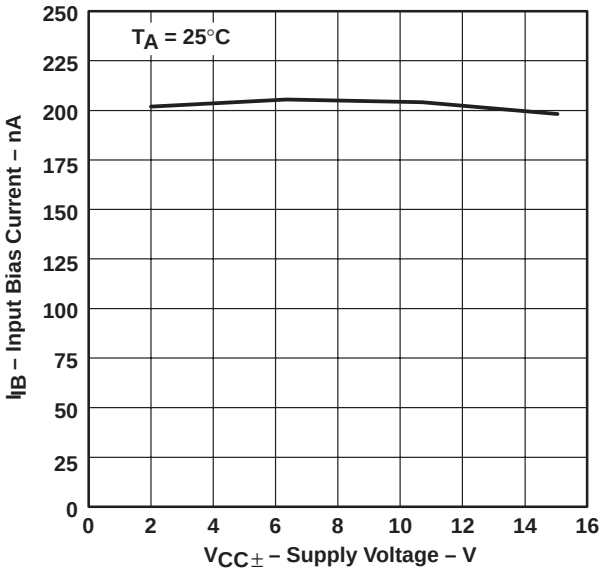



Figure 3

**MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE vs SUPPLY VOLTAGE**

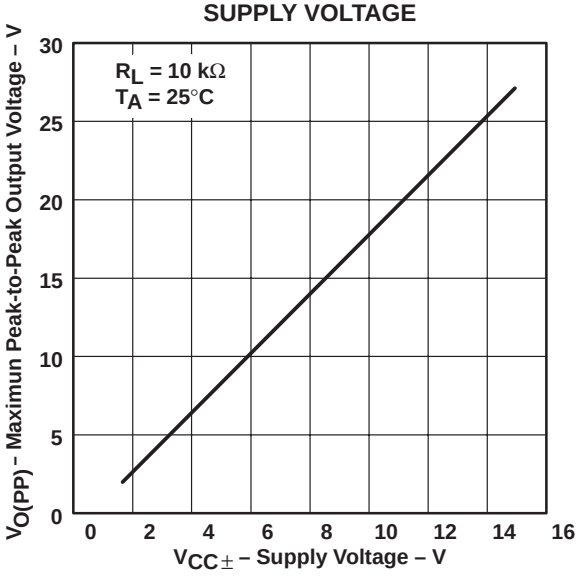



Figure 4

**MAXIMUM PEAK-TO-PEAK OUTPUT VOLTAGE vs FREQUENCY**

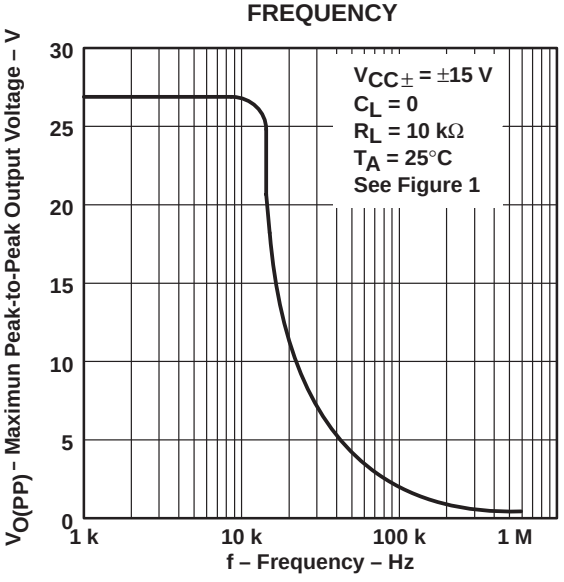



Figure 5

† 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 FREQUENCY**

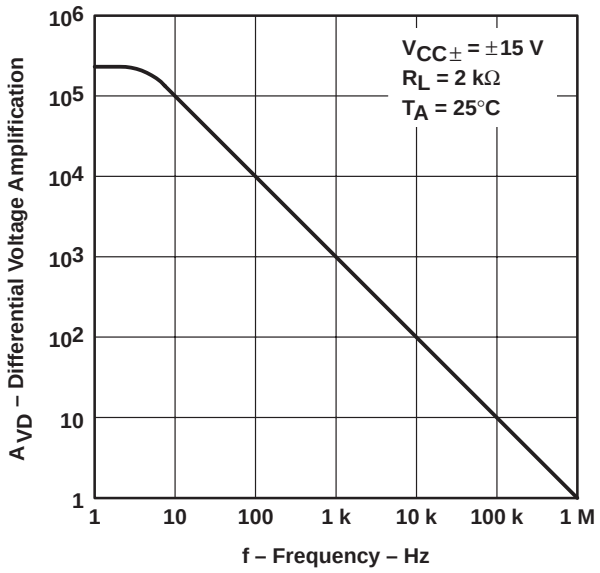



**Figure 6**

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

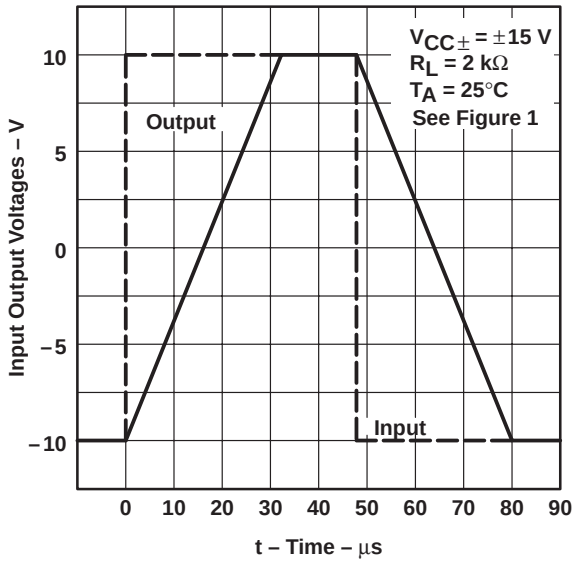



**Figure 7**

## IMPORTANT NOTICE

Texas Instruments and its subsidiaries (TI) reserve the right to make changes to their products or to discontinue any product or service without notice, and advise customers to obtain the latest version of relevant information to verify, before placing orders, that information being relied on is current and complete. All products are sold subject to the terms and conditions of sale supplied at the time of order acknowledgement, including those pertaining to warranty, patent infringement, and limitation of liability.

TI warrants performance of its semiconductor products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are utilized to the extent TI deems necessary to support this warranty. Specific testing of all parameters of each device is not necessarily performed, except those mandated by government requirements.

CERTAIN APPLICATIONS USING SEMICONDUCTOR PRODUCTS MAY INVOLVE POTENTIAL RISKS OF DEATH, PERSONAL INJURY, OR SEVERE PROPERTY OR ENVIRONMENTAL DAMAGE ("CRITICAL APPLICATIONS"). TI SEMICONDUCTOR PRODUCTS ARE NOT DESIGNED, AUTHORIZED, OR WARRANTED TO BE SUITABLE FOR USE IN LIFE-SUPPORT DEVICES OR SYSTEMS OR OTHER CRITICAL APPLICATIONS. INCLUSION OF TI PRODUCTS IN SUCH APPLICATIONS IS UNDERSTOOD TO BE FULLY AT THE CUSTOMER'S RISK.

In order to minimize risks associated with the customer's applications, adequate design and operating safeguards must be provided by the customer to minimize inherent or procedural hazards.

TI assumes no liability for applications assistance or customer product design. TI does not warrant or represent that any license, either express or implied, is granted under any patent right, copyright, mask work right, or other intellectual property right of TI covering or relating to any combination, machine, or process in which such semiconductor products or services might be or are used. TI's publication of information regarding any third party's products or services does not constitute TI's approval, warranty or endorsement thereof.