# LINEAR TECHNOLOGY

LT1355/LT1356

Dual and Quad
12MHz, 400V/μs Op Amps

# FEATURES

- **12MHz Gain-Bandwidth**
- **400V/μs Slew Rate**
- **1.25mA Maximum Supply Current per Amplifier**
- Unity Gain Stable
- C-Load™ Op Amp Drives All Capacitive Loads
- 10nV/√Hz Input Noise Voltage
- 800μV Maximum Input Offset Voltage
- 300nA Maximum Input Bias Current
- 70nA Maximum Input Offset Current
- 12V/mV Minimum DC Gain, $R_L=1k$
- 230ns Settling Time to 0.1%, 10V Step
- 280ns Settling Time to 0.01%, 10V Step
- ±12.5V Minimum Output Swing into 500Ω
- ±3V Minimum Output Swing into 150Ω
- Specified at ±2.5V, ±5V, and ±15V

# APPLICATIONS

- Wideband Amplifiers
- Buffers
- Active Filters
- Data Acquisition Systems
- Photodiode Amplifiers

# DESCRIPTION

The LT1355/LT1356 are dual and quad low power high speed operational amplifiers with outstanding AC and DC performance. The amplifiers feature much lower supply current and higher slew rate than devices with comparable bandwidth. The circuit topology is a voltage feedback amplifier with matched high impedance inputs and the slewing performance of a current feedback amplifier. The high slew rate and single stage design provide excellent settling characteristics which make the circuit an ideal choice for data acquisition systems. Each output drives a 500Ω load to ±12.5V with ±15V supplies and a 150Ω load to ±3V on ±5V supplies. The amplifiers are stable with any capacitive load making them useful in buffer applications.

The LT1355/LT1356 are members of a family of fast, high performance amplifiers using this unique topology and employing Linear Technology Corporation's advanced bipolar complementary processing. For a single amplifier version of the LT1355/LT1356 see the LT1354 data sheet. For higher bandwidth devices with higher supply currents see the LT1357 through LT1365 data sheets. Bandwidths of 25MHz, 50MHz, and 70MHz are available with 2mA, 4mA, and 6mA of supply current per amplifier. Singles, duals, and quads of each amplifier are available.
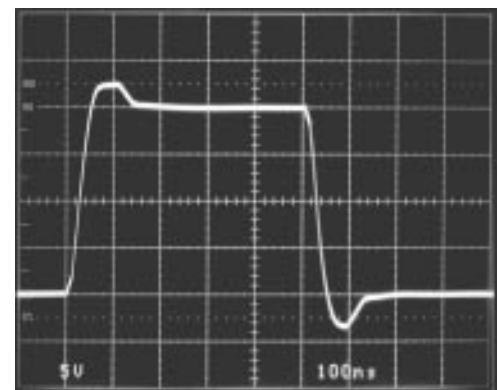
# TYPICAL APPLICATION

**100kHz, 4th Order Butterworth Filter**
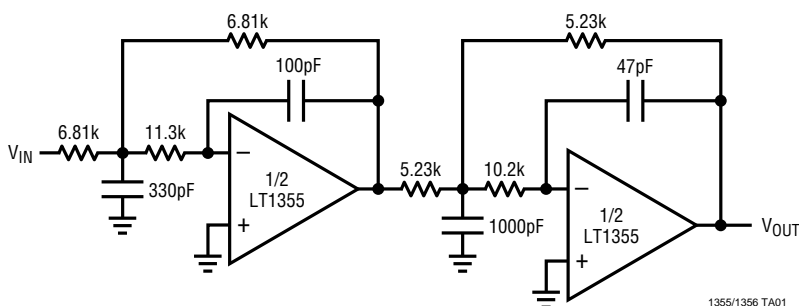


1355/1356 TA01

**A$_V$ = –1 Large-Signal Response**



1355/1356 TA02

# ABSOLUTE MAXIMUM RATINGS

Total Supply Voltage (V$^+$ to V$^-$) ............................... 36V
Differential Input Voltage ...................................... ±10V
Input Voltage ......................................................±V$_S$
Output Short-Circuit Duration (Note 1) ........... Indefinite
Operating Temperature Range ............... −40°C to 85°C

Specified Temperature Range ................. −40°C to 85°C
Maximum Junction Temperature (See Below)
   Plastic Package .............................................150°C
Storage Temperature Range ................ −65°C to 150°C
Lead Temperature (Soldering, 10 sec).................300°C

# PACKAGE/ORDER INFORMATION

| | |
|---|---|
| **TOP VIEW**<br>OUT A [1]    [8] V$^+$<br>−IN A [2] A   [7] OUT B<br>+IN A [3]   B [6] −IN B<br>V$^-$ [4]    [5] +IN B<br><br>N8 PACKAGE<br>8-LEAD PLASTIC DIP<br>T$_{JMAX}$ = 150°C, θ$_{JA}$ = 130°C/W | **ORDER PART NUMBER**<br><br>LT1355CN8 |
| **TOP VIEW**<br>OUT A [1]    [8] V$^+$<br>−IN A [2] A   [7] OUT B<br>+IN A [3]   B [6] −IN B<br>V$^-$ [4]    [5] +IN B<br><br>S8 PACKAGE<br>8-LEAD PLASTIC SOIC<br>T$_{JMAX}$ = 150°C, θ$_{JA}$ = 190°C/W | **ORDER PART NUMBER**<br><br>LT1355CS8<br><br>**S8 PART MARKING**<br><br>1355 |
| **TOP VIEW**<br>OUT A [1]    [14] OUT D<br>−IN A [2] A   D [13] −IN D<br>+IN A [3]    [12] +IN D<br>V$^+$ [4]    [11] V$^-$<br>+IN B [5]    [10] +IN C<br>−IN B [6] B   C [9] −IN C<br>OUT B [7]    [8] OUT C<br><br>N PACKAGE<br>14-LEAD PLASTIC DIP<br><br>T$_{JMAX}$ = 150°C, θ$_{JA}$ = 110°C/W | **ORDER PART NUMBER**<br><br>LT1356CN |
| **TOP VIEW**<br>OUT A [1]    [16] OUT D<br>−IN A [2] A   D [15] −IN D<br>+IN A [3]    [14] +IN D<br>V$^+$ [4]    [13] V$^-$<br>+IN B [5]    [12] +IN C<br>−IN B [6] B   C [11] −IN C<br>OUT B [7]    [10] OUT C<br>NC [8]    [9] NC<br><br>S PACKAGE<br>16-LEAD PLASTIC SOIC<br>T$_{JMAX}$ = 150°C, θ$_{JA}$ = 150°C/W | **ORDER PART NUMBER**<br><br>LT1356CS |

Consult factory for Industrial and Military grade parts.

# ELECTRICAL CHARACTERISTICS  T$_A$ = 25°C, V$_{CM}$ = 0V unless otherwise noted.

| SYMBOL | PARAMETER | CONDITIONS | V$_{SUPPLY}$ | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| V$_{OS}$ | Input Offset Voltage | | ±15V | | 0.3 | 0.8 | mV |
| | | | ±5V | | 0.3 | 0.8 | mV |
| | | | ±2.5V | | 0.4 | 1.0 | mV |
| I$_{OS}$ | Input Offset Current | | ±2.5V to ±15V | | 20 | 70 | nA |
| I$_B$ | Input Bias Current | | ±2.5V to ±15V | | 80 | 300 | nA |
| e$_n$ | Input Noise Voltage | f = 10kHz | ±2.5V to ±15V | | 10 | | nV/√Hz |
| i$_n$ | Input Noise Current | f = 10kHz | ±2.5V to ±15V | | 0.6 | | pA/√Hz |
| R$_{IN}$ | Input Resistance | V$_{CM}$ = ±12V | ±15V | 70 | 160 | | MΩ |
| | Input Resistance | Differential | ±15V | | 11 | | MΩ |
| C$_{IN}$ | Input Capacitance | | ±15V | | 3 | | pF |

# ELECTRICAL CHARACTERISTICS $T_A = 25°C$, $V_{CM} = 0V$ unless otherwise noted.

| SYMBOL | PARAMETER | CONDITIONS | $V_{SUPPLY}$ | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|
| | Input Voltage Range $^+$ | | ±15V | 12.0 | 13.4 | | V |
| | | | ±5V | 2.5 | 3.5 | | V |
| | | | ±2.5V | 0.5 | 1.1 | | V |
| | Input Voltage Range $^-$ | | ±15V | | −13.2 | −12.0 | V |
| | | | ±5V | | −3.4 | −2.5 | V |
| | | | ±2.5V | | −0.9 | −0.5 | V |
| CMRR | Common-Mode Rejection Ratio | $V_{CM} = ±12V$ | ±15V | 83 | 97 | | dB |
| | | $V_{CM} = ±2.5V$ | ±5V | 78 | 84 | | dB |
| | | $V_{CM} = ±0.5V$ | ±2.5V | 68 | 75 | | dB |
| PSRR | Power Supply Rejection Ratio | $V_S = ±2.5V$ to ±15V | | 92 | 106 | | dB |
| $A_{VOL}$ | Large-Signal Voltage Gain | $V_{OUT} = ±12V$, $R_L = 1k$ | ±15V | 12 | 36 | | V/mV |
| | | $V_{OUT} = ±10V$, $R_L = 500Ω$ | ±15V | 5 | 15 | | V/mV |
| | | $V_{OUT} = ±2.5V$, $R_L = 1k$ | ±5V | 12 | 36 | | V/mV |
| | | $V_{OUT} = ±2.5V$, $R_L = 500Ω$ | ±5V | 5 | 15 | | V/mV |
| | | $V_{OUT} = ±2.5V$, $R_L = 150Ω$ | ±5V | 1 | 4 | | V/mV |
| | | $V_{OUT} = ±1V$, $R_L = 500Ω$ | ±2.5V | 5 | 20 | | V/mV |
| $V_{OUT}$ | Output Swing | $R_L = 1k$, $V_{IN} = ±40mV$ | ±15V | 13.3 | 13.8 | | ±V |
| | | $R_L = 500Ω$, $V_{IN} = ±40mV$ | ±15V | 12.5 | 13.0 | | ±V |
| | | $R_L = 500Ω$, $V_{IN} = ±40mV$ | ±5V | 3.5 | 4.0 | | ±V |
| | | $R_L = 150Ω$, $V_{IN} = ±40mV$ | ±5V | 3.0 | 3.3 | | ±V |
| | | $R_L = 500Ω$, $V_{IN} = ±40mV$ | ±2.5V | 1.3 | 1.7 | | ±V |
| $I_{OUT}$ | Output Current | $V_{OUT} = ±12.5V$ | ±15V | 25 | 30 | | mA |
| | | $V_{OUT} = ±3V$ | ±5V | 20 | 25 | | mA |
| $I_{SC}$ | Short-Circuit Current | $V_{OUT} = 0V$, $V_{IN} = ±3V$ | ±15V | 30 | 42 | | mA |
| SR | Slew Rate | $A_V = -2$, (Note 2) | ±15V | 200 | 400 | | V/μs |
| | | | ±5V | 70 | 120 | | V/μs |
| | Full Power Bandwidth | 10V Peak, (Note 3) | ±15V | | 6.4 | | MHz |
| | | 3V Peak, (Note 3) | ±5V | | 6.4 | | MHz |
| GBW | Gain-Bandwidth | $f = 200kHz$, $R_L = 2k$ | ±15V | 9.0 | 12.0 | | MHz |
| | | | ±5V | 7.5 | 10.5 | | MHz |
| | | | ±2.5V | | 9.0 | | MHz |
| $t_r$, $t_f$ | Rise Time, Fall Time | $A_V = 1$, 10%-90%, 0.1V | ±15V | | 14 | | ns |
| | | | ±5V | | 17 | | ns |
| | Overshoot | $A_V = 1$, 0.1V | ±15V | | 20 | | % |
| | | | ±5V | | 18 | | % |
| | Propagation Delay | 50% $V_{IN}$ to 50% $V_{OUT}$, 0.1V | ±15V | | 16 | | ns |
| | | | ±5V | | 19 | | ns |
| $t_s$ | Settling Time | 10V Step, 0.1%, $A_V = -1$ | ±15V | | 230 | | ns |
| | | 10V Step, 0.01%, $A_V = -1$ | ±15V | | 280 | | ns |
| | | 5V Step, 0.1%, $A_V = -1$ | ±5V | | 240 | | ns |
| | | 5V Step, 0.01%, $A_V = -1$ | ±5V | | 380 | | ns |
| | Differential Gain | $f = 3.58MHz$, $A_V = 2$, $R_L = 1k$ | ±15V | | 2.2 | | % |
| | | | ±5V | | 2.1 | | % |
| | Differential Phase | $f = 3.58MHz$, $A_V = 2$, $R_L = 1k$ | ±15V | | 3.1 | | Deg |
| | | | ±5V | | 3.1 | | Deg |
| $R_O$ | Output Resistance | $A_V = 1$, $f = 100kHz$ | ±15V | | 0.7 | | Ω |
| | Channel Separation | $V_{OUT} = ±10V$, $R_L = 500Ω$ | ±15V | 100 | 113 | | dB |
| $I_S$ | Supply Current | Each Amplifier | ±15V | | 1.0 | 1.25 | mA |
| | | Each Amplifier | ±5V | | 0.9 | 1.20 | mA |

# ELECTRICAL CHARACTERISTICS  $0°C \leq T_A \leq 70°C$, $V_{CM} = 0V$ unless otherwise noted.

| SYMBOL | PARAMETER | CONDITIONS | $V_{SUPPLY}$ | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|---|
| $V_{OS}$ | Input Offset Voltage | | ±15V | ● | | | 1.0 | mV |
| | | | ±5V | ● | | | 1.0 | mV |
| | | | ±2.5V | ● | | | 1.2 | mV |
| | Input $V_{OS}$ Drift | (Note 4) | ±2.5V to ±15V | ● | | 5 | 8 | µV/°C |
| $I_{OS}$ | Input Offset Current | | ±2.5V to ±15V | ● | | | 100 | nA |
| $I_B$ | Input Bias Current | | ±2.5V to ±15V | ● | | | 450 | nA |
| CMRR | Common-Mode Rejection Ratio | $V_{CM} = ±12V$ | ±15V | ● | 81 | | | dB |
| | | $V_{CM} = ±2.5V$ | ±5V | ● | 77 | | | dB |
| | | $V_{CM} = ±0.5V$ | ±2.5V | ● | 67 | | | dB |
| PSRR | Power Supply Rejection Ratio | $V_S = ±2.5V$ to ±15V | | ● | 90 | | | dB |
| $A_{VOL}$ | Large-Signal Voltage Gain | $V_{OUT} = ±12V$, $R_L = 1k$ | ±15V | ● | 10.0 | | | V/mV |
| | | $V_{OUT} = ±10V$, $R_L = 500Ω$ | ±15V | ● | 3.3 | | | V/mV |
| | | $V_{OUT} = ±2.5V$, $R_L = 1k$ | ±5V | ● | 10.0 | | | V/mV |
| | | $V_{OUT} = ±2.5V$, $R_L = 500Ω$ | ±5V | ● | 3.3 | | | V/mV |
| | | $V_{OUT} = ±2.5V$, $R_L = 150Ω$ | ±5V | ● | 0.6 | | | V/mV |
| | | $V_{OUT} = ±1V$, $R_L = 500Ω$ | ±2.5V | ● | 3.3 | | | V/mV |
| $V_{OUT}$ | Output Swing | $R_L = 1k$, $V_{IN} = ±40mV$ | ±15V | ● | 13.2 | | | ±V |
| | | $R_L = 500Ω$, $V_{IN} = ±40mV$ | ±15V | ● | 12.0 | | | ±V |
| | | $R_L = 500Ω$, $V_{IN} = ±40mV$ | ±5V | ● | 3.4 | | | ±V |
| | | $R_L = 150Ω$, $V_{IN} = ±40mV$ | ±5V | ● | 2.8 | | | ±V |
| | | $R_L = 500Ω$, $V_{IN} = ±40mV$ | ±2.5V | ● | 1.2 | | | ±V |
| $I_{OUT}$ | Output Current | $V_{OUT} = ±12V$ | ±15V | ● | 24.0 | | | mA |
| | | $V_{OUT} = ±2.8V$ | ±5V | ● | 18.7 | | | mA |
| $I_{SC}$ | Short-Circuit Current | $V_{OUT} = 0V$, $V_{IN} = ±3V$ | ±15V | ● | 24 | | | mA |
| SR | Slew Rate | $A_V = -2$, (Note 2) | ±15V | ● | 150 | | | V/µs |
| | | | ±5V | ● | 60 | | | V/µs |
| GBW | Gain-Bandwidth | $f = 200kHz$, $R_L = 2k$ | ±15V | ● | 7.5 | | | MHz |
| | | | ±5V | ● | 6.0 | | | MHz |
| | Channel Separation | $V_{OUT} = ±10V$, $R_L = 500Ω$ | ±15V | ● | 98 | | | dB |
| $I_S$ | Supply Current | Each Amplifier | ±15V | ● | | | 1.45 | mA |
| | | Each Amplifier | ±5V | ● | | | 1.40 | mA |

# ELECTRICAL CHARACTERISTICS  $-40°C \leq T_A \leq 85°C$, $V_{CM} = 0V$ unless otherwise noted. (Note 5)

| SYMBOL | PARAMETER | CONDITIONS | $V_{SUPPLY}$ | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|---|
| $V_{OS}$ | Input Offset Voltage | | ±15V | ● | | | 1.5 | mV |
| | | | ±5V | ● | | | 1.5 | mV |
| | | | ±2.5V | ● | | | 1.7 | mV |
| | Input $V_{OS}$ Drift | (Note 4) | ±2.5V to ±15V | ● | | 5 | 8 | µV/°C |
| $I_{OS}$ | Input Offset Current | | ±2.5V to ±15V | ● | | | 200 | nA |
| $I_B$ | Input Bias Current | | ±2.5V to ±15V | ● | | | 550 | nA |
| CMRR | Common-Mode Rejection Ratio | $V_{CM} = ±12V$ | ±15V | ● | 80 | | | dB |
| | | $V_{CM} = ±2.5V$ | ±5V | ● | 76 | | | dB |
| | | $V_{CM} = ±0.5V$ | ±2.5V | ● | 66 | | | dB |
| PSRR | Power Supply Rejection Ratio | $V_S = ±2.5V$ to ±15V | | ● | 90 | | | dB |

# ELECTRICAL CHARACTERISTICS $-40°C \leq T_A \leq 85°C$, $V_{CM} = 0V$ unless otherwise noted. (Note 5)

| SYMBOL | PARAMETER | CONDITIONS | V$_{SUPPLY}$ | | MIN | TYP | MAX | UNITS |
|---|---|---|---|---|---|---|---|---|
| A$_{VOL}$ | Large-Signal Voltage Gain | V$_{OUT}$ = ±12V, R$_L$ = 1k | ±15V | ● | 7.0 | | | V/mV |
| | | V$_{OUT}$ = ±10V, R$_L$ = 500Ω | ±15V | ● | 1.7 | | | V/mV |
| | | V$_{OUT}$ = ±2.5V, R$_L$ = 1k | ±5V | ● | 7.0 | | | V/mV |
| | | V$_{OUT}$ = ±2.5V, R$_L$ = 500Ω | ±5V | ● | 1.7 | | | V/mV |
| | | V$_{OUT}$ = ±2.5V, R$_L$ = 150Ω | ±5V | ● | 0.4 | | | V/mV |
| | | V$_{OUT}$ = ±1V, R$_L$ = 500Ω | ±2.5V | ● | 1.7 | | | V/mV |
| V$_{OUT}$ | Output Swing | R$_L$ = 1k, V$_{IN}$ = ±40mV | ±15V | ● | 13.0 | | | ±V |
| | | R$_L$ = 500Ω, V$_{IN}$ = ±40mV | ±15V | ● | 11.5 | | | ±V |
| | | R$_L$ = 500Ω, V$_{IN}$ = ±40mV | ±5V | ● | 3.4 | | | ±V |
| | | R$_L$ = 150Ω, V$_{IN}$ = ±40mV | ±5V | ● | 2.6 | | | ±V |
| | | R$_L$ = 500Ω, V$_{IN}$ = ±40mV | ±2.5V | ● | 1.2 | | | ±V |
| I$_{OUT}$ | Output Current | V$_{OUT}$ = ±11.5V | ±15V | ● | 23.0 | | | mA |
| | | V$_{OUT}$ = ±2.6V | ±5V | ● | 17.3 | | | mA |
| I$_{SC}$ | Short-Circuit Current | V$_{OUT}$ = 0V, V$_{IN}$ = ±3V | ±15V | ● | 23 | | | mA |
| SR | Slew Rate | A$_V$ = −2, (Note 2) | ±15V | ● | 120 | | | V/μs |
| | | | ±5V | ● | 50 | | | V/μs |
| GBW | Gain-Bandwidth | f = 200kHz, R$_L$ = 2k | ±15V | ● | 7.0 | | | MHz |
| | | | ±5V | ● | 5.5 | | | MHz |
| | Channel Separation | V$_{OUT}$ = ±10V, R$_L$ = 500Ω | ±15V | ● | 98 | | | dB |
| I$_S$ | Supply Current | Each Amplifier | ±15V | ● | | | 1.50 | mA |
| | | Each Amplifier | ±5V | ● | | | 1.45 | mA |

The ● denotes specifications that apply over the full operating temperature range.

**Note 1**: A heat sink may be required to keep the junction temperature below absolute maximum when the output is shorted indefinitely.

**Note 2**: Slew rate is measured between ±10V on the output with ±6V input for ±15V supplies and ±1V on the output with ±1.75V input for ±5V supplies.

**Note 3**: Full power bandwidth is calculated from the slew rate measurement: FPBW = (SR)/2πV$_P$.

**Note 4**: This parameter is not 100% tested.

**Note 5**: The LT1355/LT1356 are not tested and are not quality-assurance sampled at −40°C and at 85°C. These specifications are guaranteed by design, correlation, and/or inference from 0°C, 25°C, and/or 70°C tests.
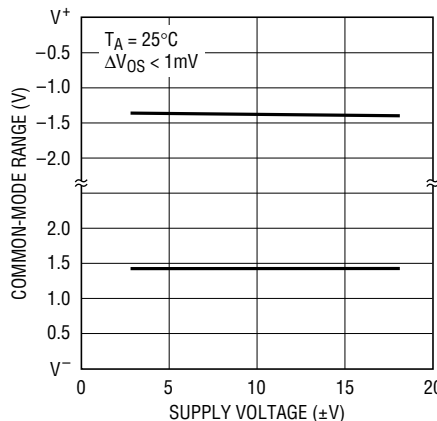
# TYPICAL PERFORMANCE CHARACTERISTICS
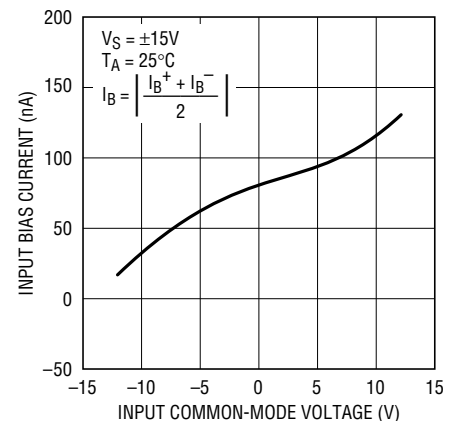
**Supply Current vs Supply Voltage and Temperature**
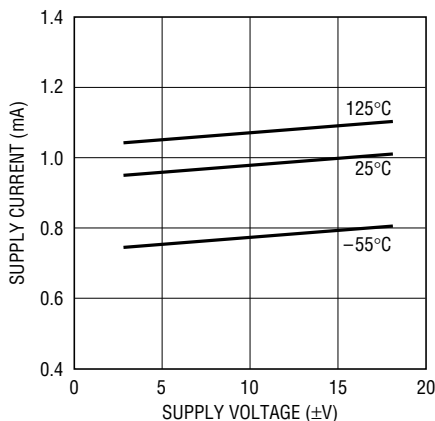


1355/1356 G01

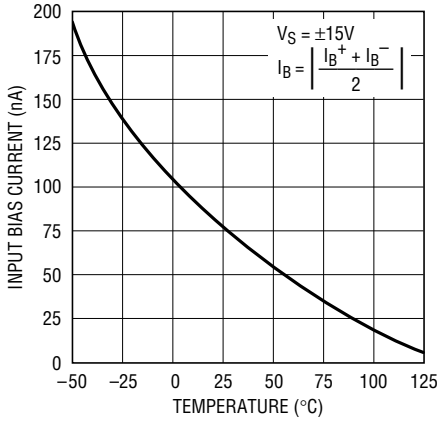**Input Common-Mode Range vs Supply Voltage**



1355/1356 G02

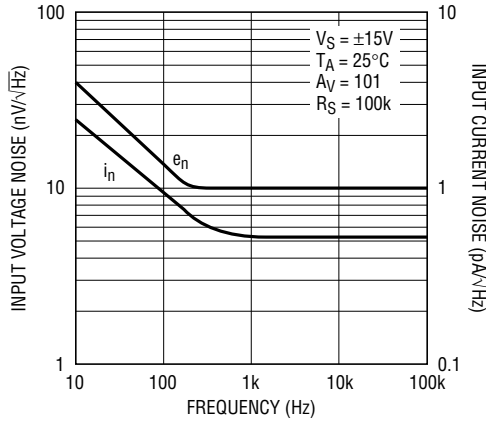**Input Bias Current vs Input Common-Mode Voltage**



1355/1356 G03

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# TYPICAL PERFORMANCE CHARACTERISTICS
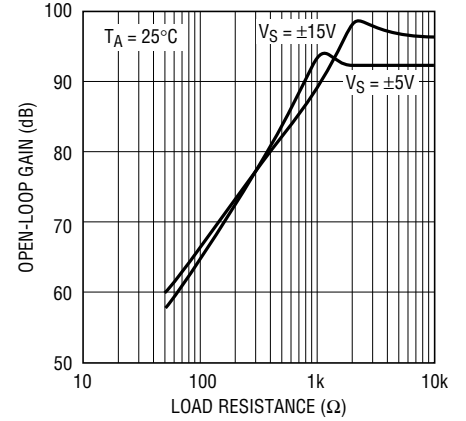
**Input Bias Current vs Temperature**

$$V_S = \pm 15V$$
$$I_B = \left| \frac{I_B^+ + I_B^-}{2} \right|$$

*X-axis:* TEMPERATURE (°C) — −50 to 125
*Y-axis:* INPUT BIAS CURRENT (nA) — 0 to 200

1355/1356 G04

**Input Noise Spectral Density**

$$V_S = \pm 15V$$
$$T_A = 25°C$$
$$A_V = 101$$
$$R_S = 100k$$

$i_n$   $e_n$

*X-axis:* FREQUENCY (Hz) — 10 to 100k
*Y-axis (left):* INPUT VOLTAGE NOISE (nV/√Hz) — 1 to 100
*Y-axis (right):* INPUT CURRENT NOISE (pA/√Hz) — 0.1 to 10

1355/1356 G05

**Open-Loop Gain vs Resistive Load**

$T_A = 25°C$   $V_S = \pm 15V$   $V_S = \pm 5V$

*X-axis:* LOAD RESISTANCE (Ω) — 10 to 10k
*Y-axis:* OPEN-LOOP GAIN (dB) — 50 to 100

1355/1356 G06

**Open-Loop Gain vs Temperature**

$$V_S = \pm 15V$$
$$R_L = 1k$$
$$V_O = \pm 12V$$

*X-axis:* TEMPERATURE (°C) — −50 to 125
*Y-axis:* OPEN-LOOP GAIN (dB) — 88 to 97
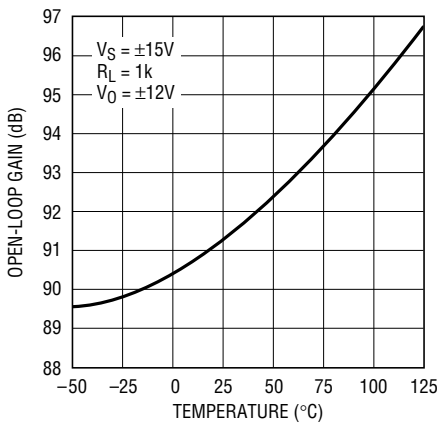
1355/1356 G07

**Output Voltage Swing vs Supply Voltage**

$T_A = 25°C$   $R_L = 1k$   $R_L = 500\Omega$

$R_L = 500\Omega$   $R_L = 1k$

*X-axis:* SUPPLY VOLTAGE (±V) — 0 to 20
*Y-axis:* OUTPUT VOLTAGE SWING (V)
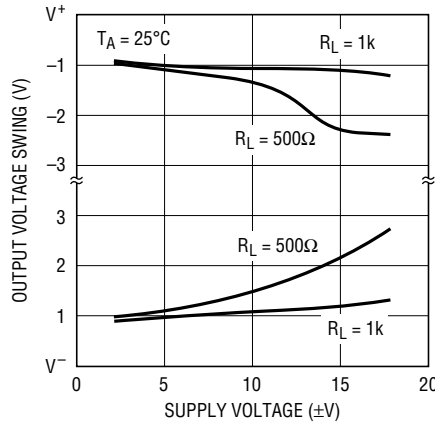
1355/1356 G08

**Output Voltage Swing vs Load Current**

$$V_S = \pm 5V$$
$$V_{IN} = 100mV$$

85°C   −40°C   25°C

85°C   25°C   −40°C

*X-axis:* OUTPUT CURRENT (mA) — −50 to 50
*Y-axis:* OUTPUT VOLTAGE SWING (V)
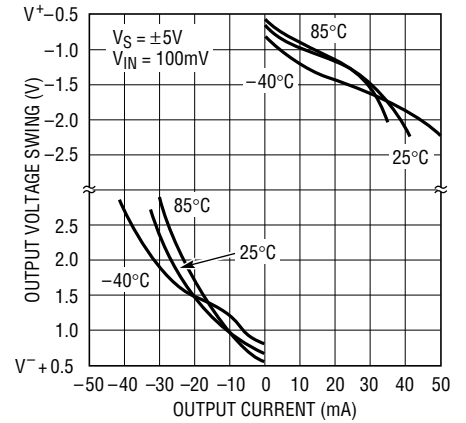
1355/1356 G09

**Output Short-Circuit Current vs Temperature**

$$V_S = \pm 5V$$

SINK   SOURCE

*X-axis:* TEMPERATURE (°C) — −50 to 125
*Y-axis:* OUTPUT SHORT-CIRCUIT CURRENT (mA) — 20 to 65
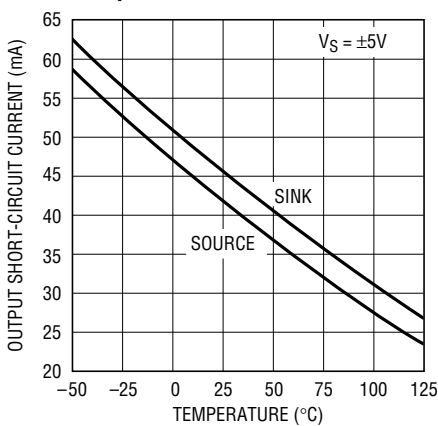
1355/1356 G10

**Settling Time vs Output Step (Noninverting)**

$$V_S = \pm 15V$$
$$A_V = 1$$

10mV   1mV

10mV   1mV

*X-axis:* SETTLING TIME (ns) — 50 to 350
*Y-axis:* OUTPUT SWING (V) — −10 to 10
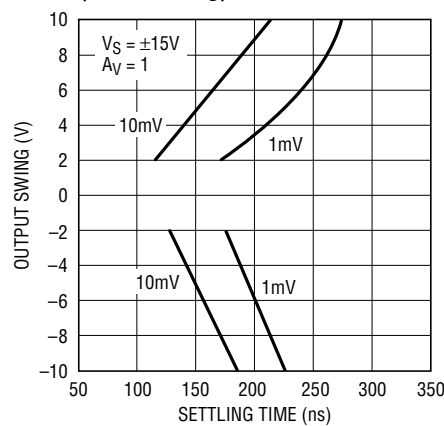
1355/1356 G11

**Settling Time vs Output Step (Inverting)**

$$V_S = \pm 15V$$
$$A_V = -1$$

10mV   1mV

1mV   10mV

*X-axis:* SETTLING TIME (ns) — 50 to 350
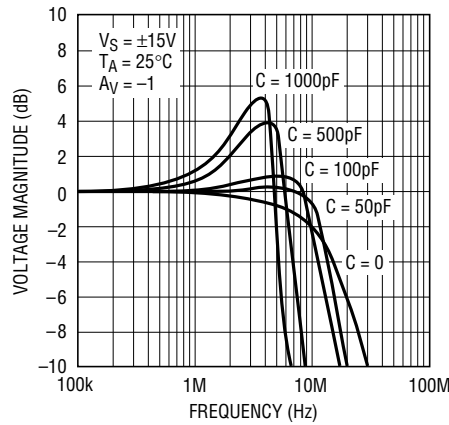*Y-axis:* OUTPUT SWING (V) — −10 to 10

1355/1356 G12

6
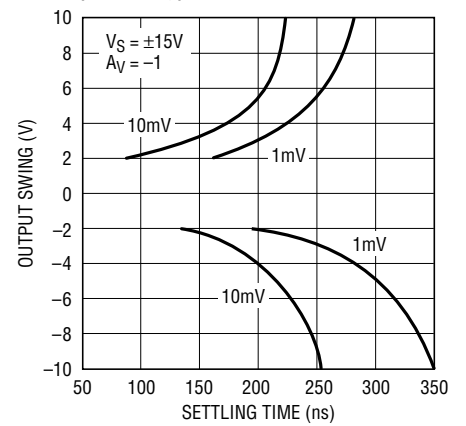
# TYPICAL PERFORMANCE CHARACTERISTICS

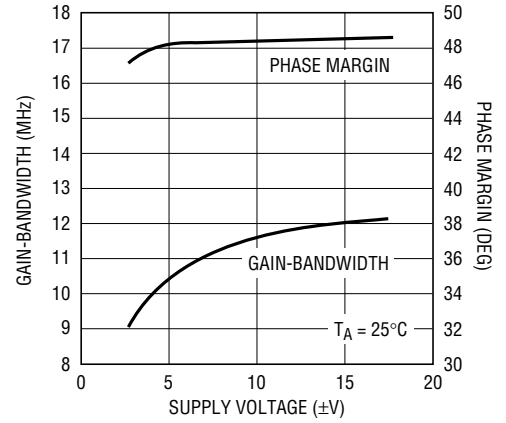**Output Impedance vs Frequency**
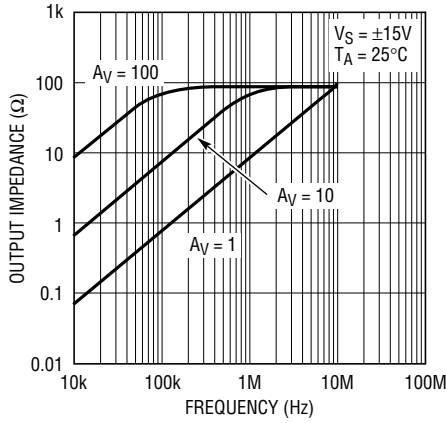


1355/1356 G13

**Frequency Response vs Capacitive Load**
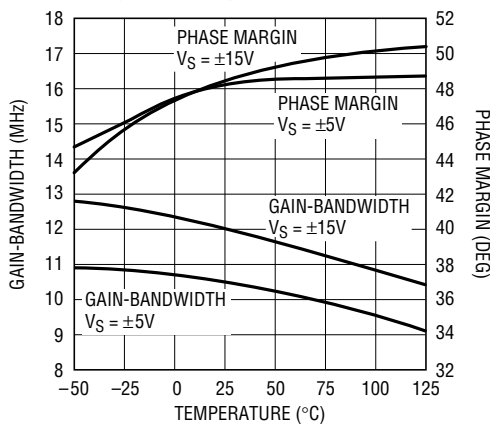


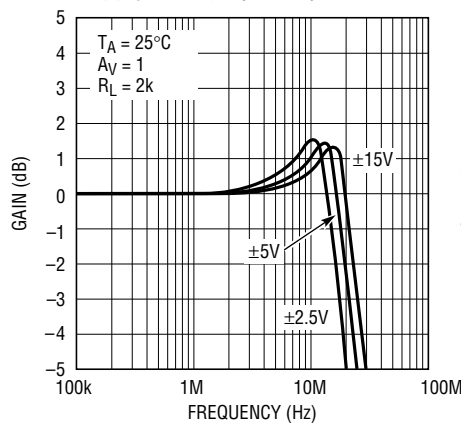1355/1356 G19

**Gain-Bandwidth and Phase Margin vs Supply Voltage**



1355/1356 G15

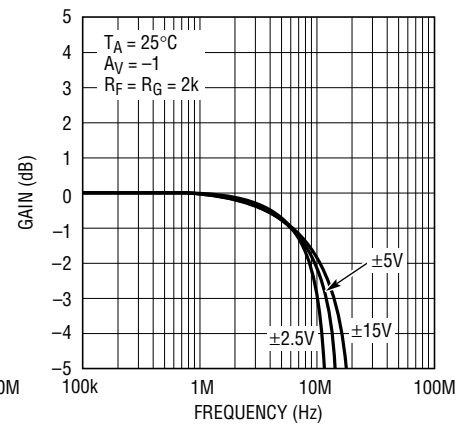**Gain-Bandwidth and Phase Margin vs Temperature**



1355/1356 G16
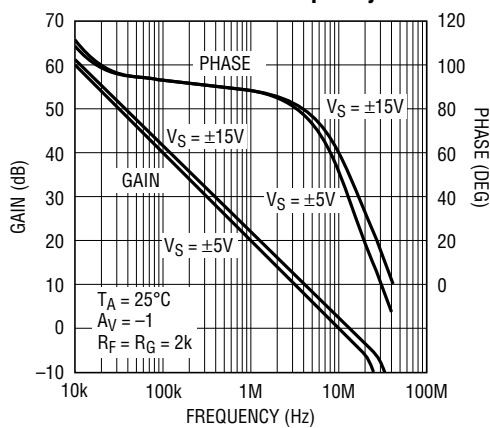
**Frequency Response vs Supply Voltage (A$_V$ = 1)**



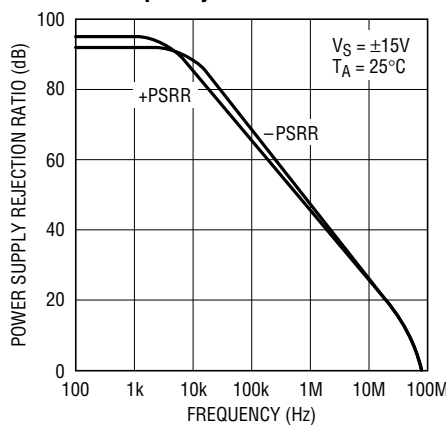1355/1356 G17

**Frequency Response vs Supply Voltage (A$_V$ = −1)**



1355/1356 G18

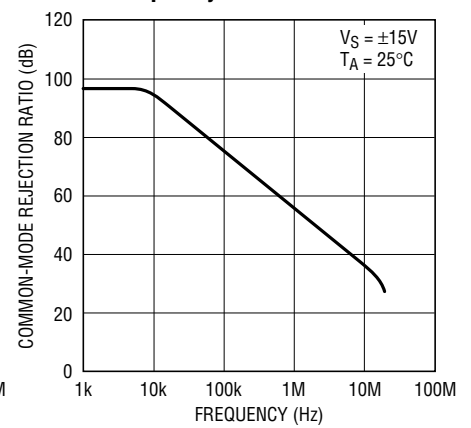**Gain and Phase vs Frequency**



1355/1356 G14

**Power Supply Rejection Ratio vs Frequency**
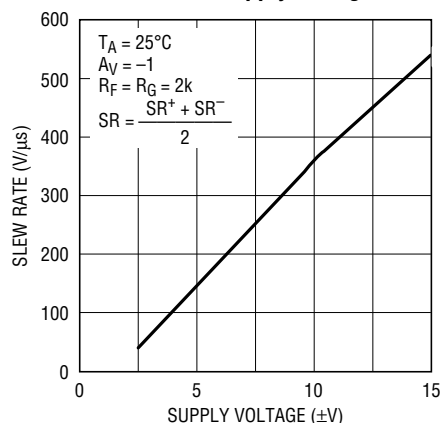


1355/1356 G20

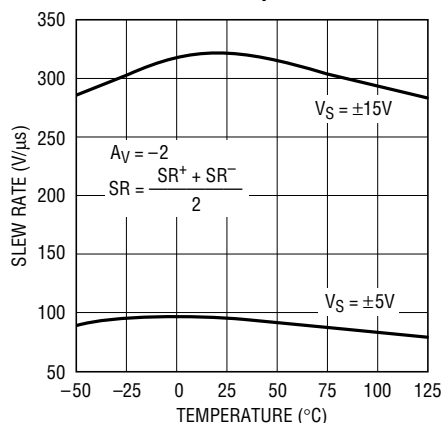**Common-Mode Rejection Ratio vs Frequency**



1355/1356 G21

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# TYPICAL PERFORMANCE CHARACTERISTICS
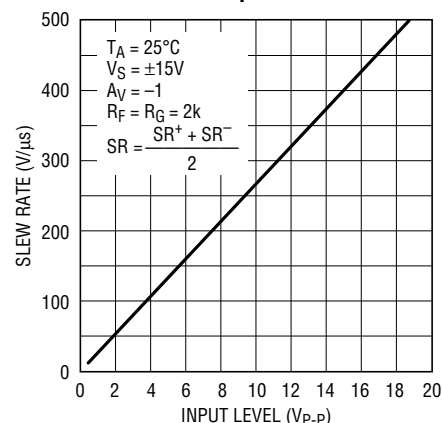
### Slew Rate vs Supply Voltage

$T_A = 25°C$
$A_V = -1$
$R_F = R_G = 2k$
$$SR = \frac{SR^+ + SR^-}{2}$$

1355/1356 G22

### Slew Rate vs Temperature

$A_V = -2$
$$SR = \frac{SR^+ + SR^-}{2}$$

$V_S = \pm15V$

$V_S = \pm5V$

1355/1356 G23

### Slew Rate vs Input Level

$T_A = 25°C$
$V_S = \pm15V$
$A_V = -1$
$R_F = R_G = 2k$
$$SR = \frac{SR^+ + SR^-}{2}$$

1355/1356 G24

### Total Harmonic Distortion vs Frequency

$T_A = 25°C$
$V_O = 3V_{RMS}$
$R_L = 2k$

$A_V = -1$

$A_V = 1$
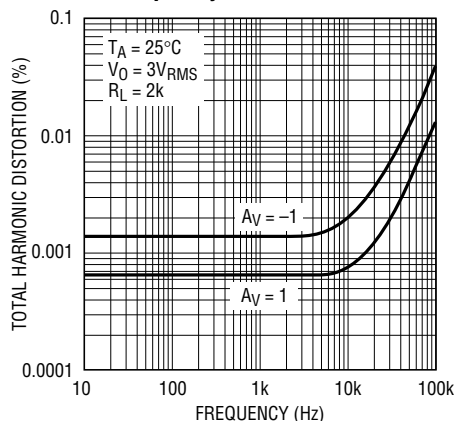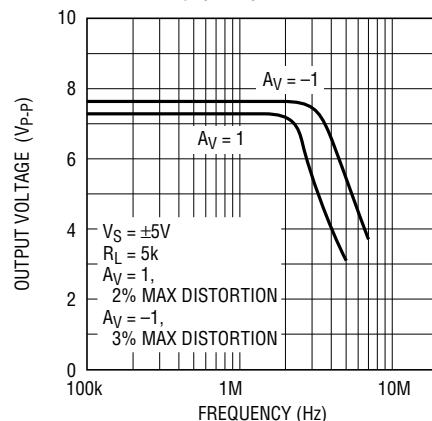
1355/1356 G25

### Undistorted Output Swing vs Frequency ($\pm15V$)

$A_V = -1$

$A_V = 1$

$V_S = \pm15V$
$R_L = 5k$
$A_V = 1$,
  1% MAX DISTORTION
$A_V = -1$,
  4% MAX DISTORTION
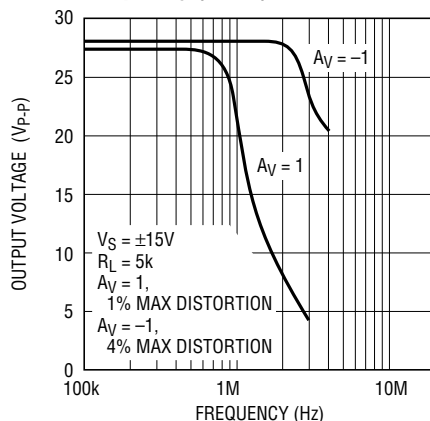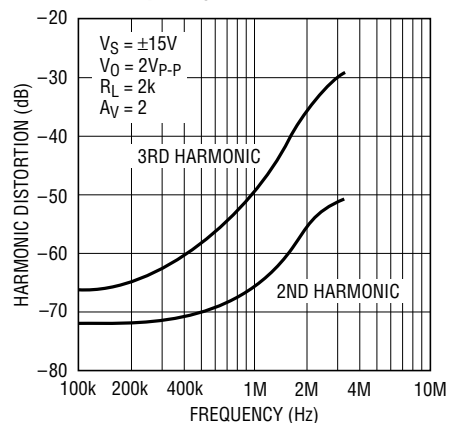
1355/1356 G26

### Undistorted Output Swing vs Frequency ($\pm5V$)

$A_V = -1$

$A_V = 1$

$V_S = \pm5V$
$R_L = 5k$
$A_V = 1$,
  2% MAX DISTORTION
$A_V = -1$,
  3% MAX DISTORTION
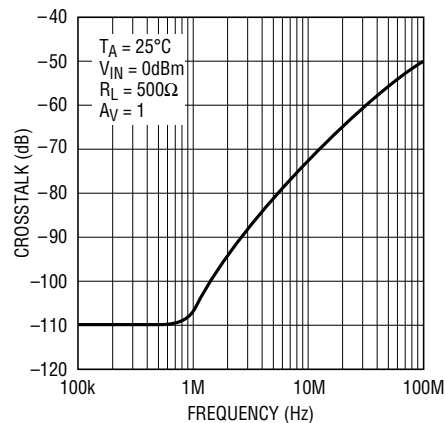
1355/1356 G27

### 2nd and 3rd Harmonic Distortion vs Frequency

$V_S = \pm15V$
$V_O = 2V_{P-P}$
$R_L = 2k$
$A_V = 2$

3RD HARMONIC

2ND HARMONIC
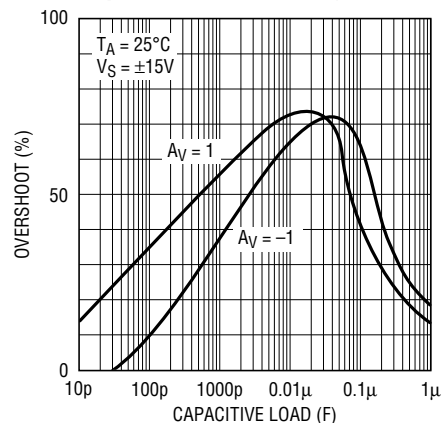
1355/1356 G28

### Crosstalk vs Frequency

$T_A = 25°C$
$V_{IN} = 0dBm$
$R_L = 500\Omega$
$A_V = 1$

1355/1356 G29

### Capacitive Load Handling

$T_A = 25°C$
$V_S = \pm15V$

$A_V = 1$

$A_V = -1$

1355/1356 G30

# TYPICAL PERFORMANCE CHARACTERISTICS

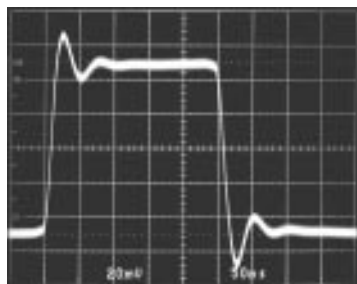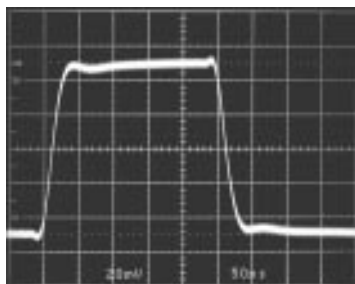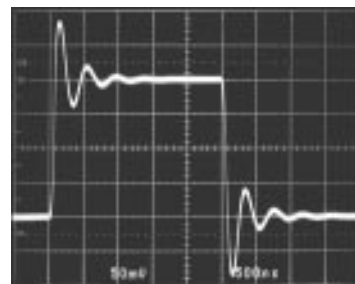**Small-Signal Transient**
**($A_V = 1$)**
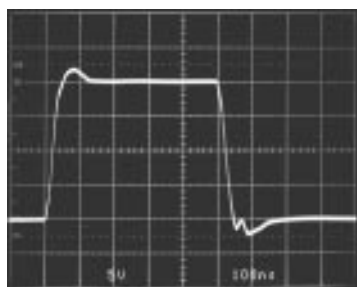


1355/1356 G31

**Small-Signal Transient**
**($A_V = -1$)**



1355/1356 G32

**Small- Signal Transient**
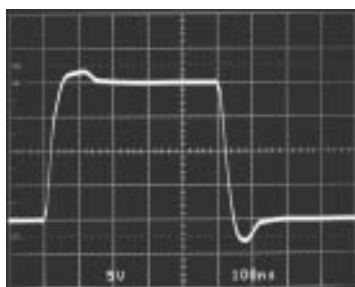**($A_V = -1$, $C_L = 1000pF$)**



1355/1356 G33

**Large-Signal Transient**
**($A_V = 1$)**
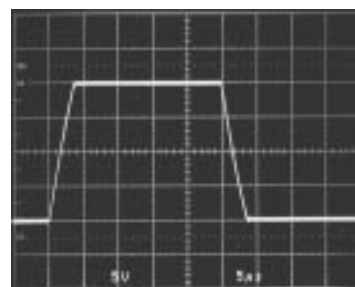


1355/1356 G34

**Large-Signal Transient**
**($A_V = -1$)**



1355/1356 G35

**Large-Signal Transient**
**($A_V = 1$, $C_L = 10,000pF$)**



1355/1356 G36

# APPLICATIONS INFORMATION

**Layout and Passive Components**

The LT1355/LT1356 amplifiers are easy to use and tolerant of less than ideal layouts. For maximum performance (for example, fast 0.01% settling) use a ground plane, short lead lengths, and RF-quality bypass capacitors ($0.01\mu F$ to $0.1\mu F$). For high drive current applications use low ESR bypass capacitors ($1\mu F$ to $10\mu F$ tantalum).

The parallel combination of the feedback resistor and gain setting resistor on the inverting input combine with the input capacitance to form a pole which can cause peaking or oscillations. If feedback resistors greater than $5k\Omega$ are used, a parallel capacitor of value

$$C_F > R_G \times C_{IN}/R_F$$

should be used to cancel the input pole and optimize dynamic performance. For unity-gain applications where a large feedback resistor is used, $C_F$ should be greater than or equal to $C_{IN}$.

**Capacitive Loading**

The LT1355/LT1356 are stable with any capacitive load. As the capacitive load increases, both the bandwidth and phase margin decrease so there will be peaking in the frequency domain and in the transient response. Coaxial cable can be driven directly, but for best pulse fidelity a resistor of value equal to the characteristic impedance of the cable (i.e., $75\Omega$) should be placed in series with the output. The other end of the cable should be terminated with the same value resistor to ground.

# APPLICATIONS INFORMATION

## Input Considerations

Each of the LT1355/LT1356 amplifier inputs is the base of an NPN and PNP transistor whose base currents are of opposite polarity and provide first-order bias current cancellation. Because of variation in the matching of NPN and PNP beta, the polarity of the input current can be positive or negative. The offset current does not depend on beta matching and is well controlled. The use of balanced source resistance at each input is recommended for applications where DC accuracy must be maximized. The inputs can withstand differential input voltages of up to 10V without damage and need no clamping or source resistance for protection.

## Circuit Operation

The LT1355/LT1356 circuit topology is a true voltage feedback amplifier that has the slewing behavior of a current feedback amplifier. The operation of the circuit can be understood by referring to the simplified schematic. The inputs are buffered by complementary NPN and PNP emitter followers which drive an 800$\Omega$ resistor. The input voltage appears across the resistor generating currents which are mirrored into the high impedance node. Complementary followers form an output stage which buffers the gain node from the load. The bandwidth is set by the input resistor and the capacitance on the high impedance node. The slew rate is determined by the current available to charge the gain node capacitance. This current is the differential input voltage divided by R1, so the slew rate is proportional to the input. Highest slew rates are therefore seen in the lowest gain configurations. For example, a 10V output step in a gain of 10 has only a 1V input step, whereas the same output step in unity gain has a 10 times greater input step. The curve of Slew Rate vs Input Level illustrates this relationship. The LT1355/LT1356 are tested for slew rate in a gain of –2 so higher slew rates can be expected in gains of 1 and –1, and lower slew rates in higher gain configurations.

The RC network across the output stage is bootstrapped when the amplifier is driving a light or moderate load and has no effect under normal operation. When driving a capacitive load (or a low value resistive load) the network is incompletely bootstrapped and adds to the compensation at the high impedance node. The added capacitance slows down the amplifier which improves the phase margin by moving the unity-gain frequency away from the pole formed by the output impedance and the capacitive load. The zero created by the RC combination adds phase to ensure that even for very large load capacitances, the total phase lag can never exceed 180 degrees (zero phase margin) and the amplifier remains stable.

## Power Dissipation

The LT1355/LT1356 combine high speed and large output drive in small packages. Because of the wide supply voltage range, it is possible to exceed the maximum junction temperature under certain conditions. Maximum junction temperature ($T_J$) is calculated from the ambient temperature ($T_A$) and power dissipation ($P_D$) as follows:

LT1355CN8:  $T_J = T_A + (P_D \times 130°C/W)$
LT1355CS8:  $T_J = T_A + (P_D \times 190°C/W)$
LT1356CN:   $T_J = T_A + (P_D \times 110°C/W)$
LT1356CS:   $T_J = T_A + (P_D \times 150°C/W)$

Worst case power dissipation occurs at the maximum supply current and when the output voltage is at 1/2 of either supply voltage (or the maximum swing if less than 1/2 supply voltage). For each amplifier $P_{DMAX}$ is:

$$P_{DMAX} = (V^+ - V^-)(I_{SMAX}) + (V^+/2)^2/R_L$$

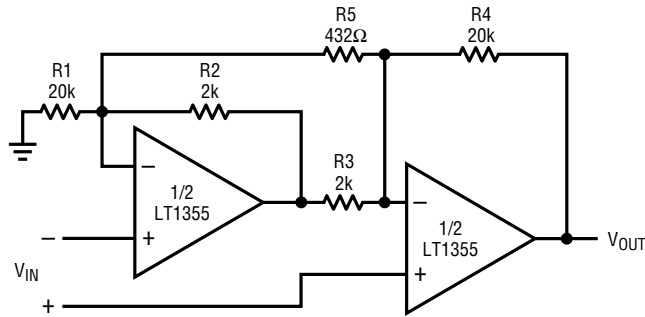Example: LT1356 in S16 at 70°C, $V_S = \pm15V$, $R_L = 1k$

$$P_{DMAX} = (30V)(1.45mA) + (7.5V)^2/1kW = 99.8mW$$

$$T_{JMAX} = 70°C + (4 \times 99.8mW)(150°C/W) = 130°C$$

# TYPICAL APPLICATIONS

**Instrumentation Amplifier**
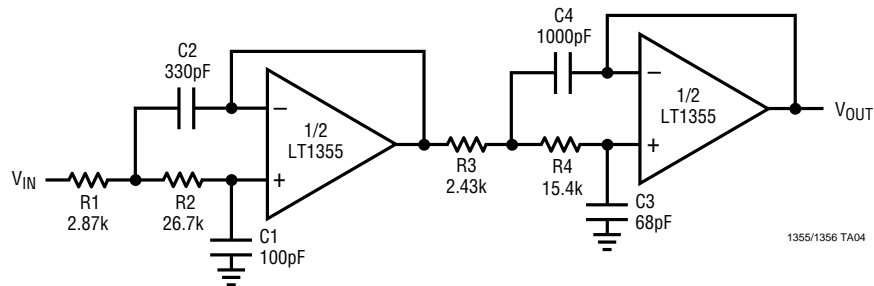


$$A_V = \frac{R4}{R3}\left[1 + \frac{1}{2}\left(\frac{R2}{R1} + \frac{R3}{R4}\right) + \frac{R2 + R3}{R5}\right] = 104$$

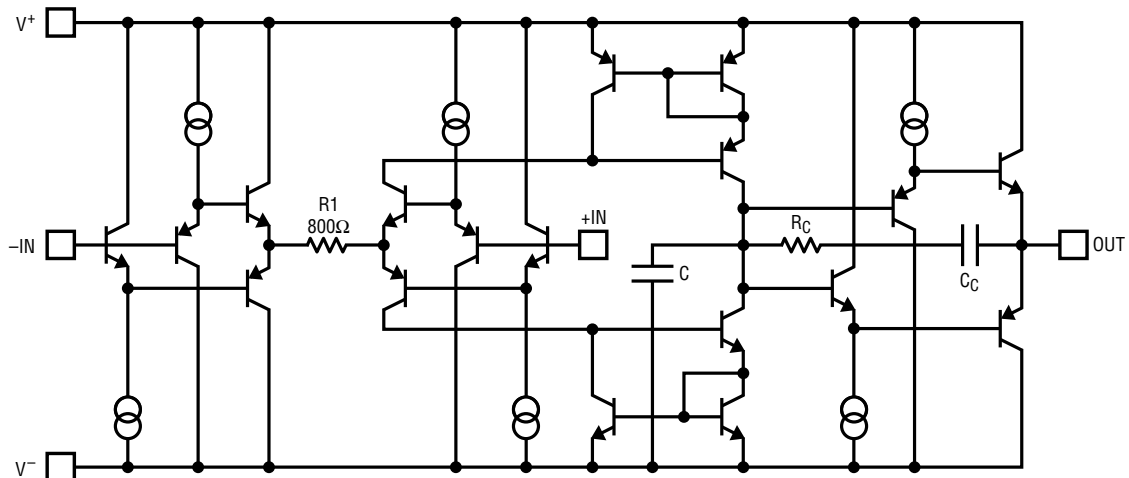TRIM R5 FOR GAIN
TRIM R1 FOR COMMON-MODE REJECTION
BW = 120kHz

1355/1356 TA03

**100kHz, 4th Order Butterworth Filter
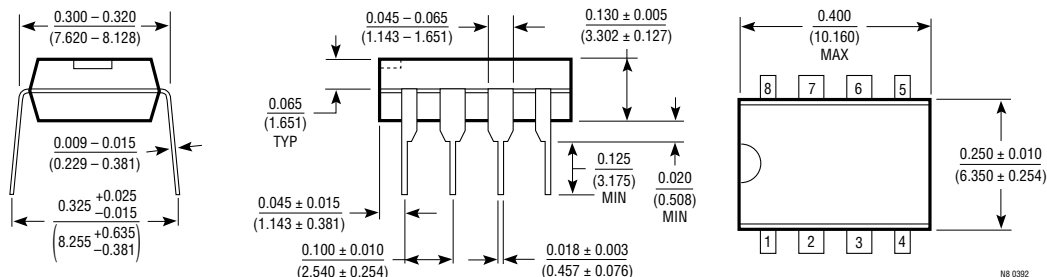(Sallen-Key)**



1355/1356 TA04

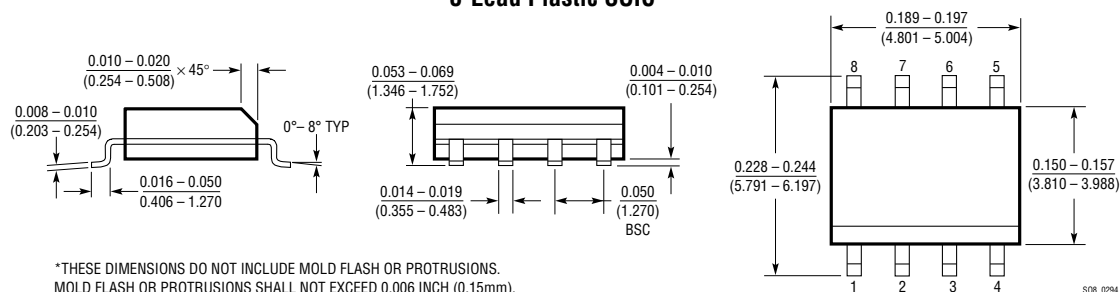# SIMPLIFIED SCHEMATIC



1355/1356 SS01

## PACKAGE DESCRIPTION

Dimension in inches (millimeters) unless otherwise noted.
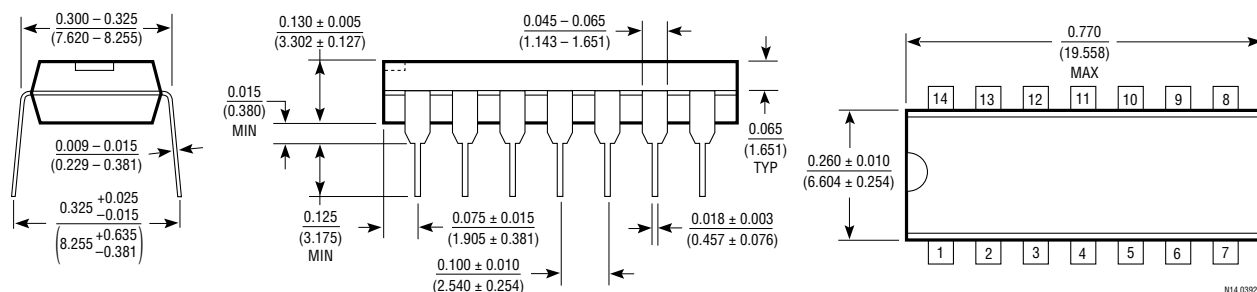
### N8 Package
### 8-Lead Plastic DIP

0.300 – 0.320
(7.620 – 8.128)

0.045 – 0.065
(1.143 – 1.651)

0.130 ± 0.005
(3.302 ± 0.127)

0.065
(1.651)
TYP

0.009 – 0.015
(0.229 – 0.381)

0.125
(3.175)
MIN

0.020
(0.508)
MIN

0.045 ± 0.015
(1.143 ± 0.381)

0.325 +0.025 −0.015
(8.255 +0.635 −0.381)

0.100 ± 0.010
(2.540 ± 0.254)

0.018 ± 0.003
(0.457 ± 0.076)

0.400
(10.160)
MAX

0.250 ± 0.010
(6.350 ± 0.254)

N8 0392

### S8 Package
### 8-Lead Plastic SOIC

0.010 – 0.020
(0.254 – 0.508) × 45°

0.008 – 0.010
(0.203 – 0.254)

0° – 8° TYP

0.016 – 0.050
0.406 – 1.270

0.053 – 0.069
(1.346 – 1.752)

0.004 – 0.010
(0.101 – 0.254)

0.014 – 0.019
(0.355 – 0.483)

0.050
(1.270)
BSC

0.189 – 0.197
(4.801 – 5.004)

0.228 – 0.244
(5.791 – 6.197)

0.150 – 0.157
(3.810 – 3.988)

*THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.
MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.006 INCH (0.15mm).

SO8 0294

### N Package
### 14-Lead Plastic DIP

0.300 – 0.325
(7.620 – 8.255)

0.130 ± 0.005
(3.302 ± 0.127)

0.045 – 0.065
(1.143 – 1.651)

0.015
(0.380)
MIN

0.009 – 0.015
(0.229 – 0.381)

0.065
(1.651)
TYP

0.325 +0.025 −0.015
(8.255 +0.635 −0.381)

0.125
(3.175)
MIN

0.075 ± 0.015
(1.905 ± 0.381)

0.018 ± 0.003
(0.457 ± 0.076)

0.100 ± 0.010
(2.540 ± 0.254)

0.770
(19.558)
MAX

0.260 ± 0.010
(6.604 ± 0.254)

N14 0392

### S Package
### 16-Lead Plastic SOIC

0.010 – 0.020
(0.254 – 0.508) × 45°

0.008 – 0.010
(0.203 – 0.254)

0° – 8° TYP

0.016 – 0.050
0.406 – 1.270

0.053 – 0.069
(1.346 – 1.752)

0.004 – 0.010
(0.101 – 0.254)

0.014 – 0.019
(0.355 – 0.483)

0.050
(1.270)
TYP

0.386 – 0.394*
(9.804 – 10.008)

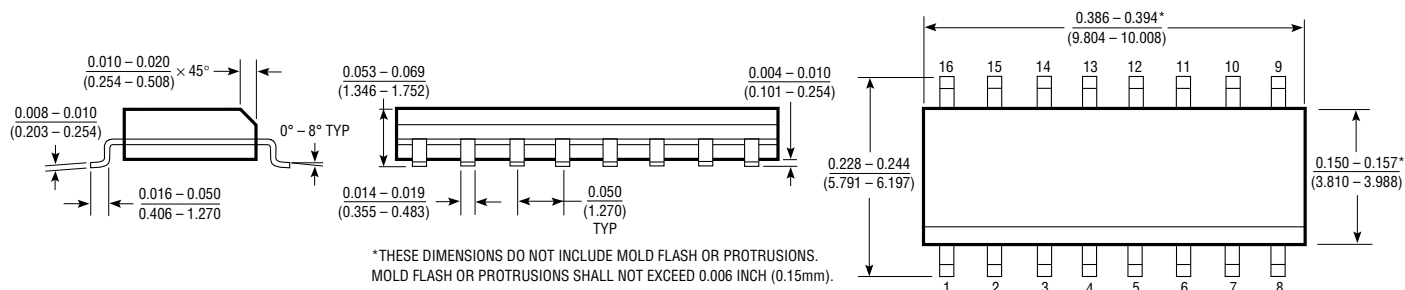0.228 – 0.244
(5.791 – 6.197)

0.150 – 0.157*
(3.810 – 3.988)

*THESE DIMENSIONS DO NOT INCLUDE MOLD FLASH OR PROTRUSIONS.
MOLD FLASH OR PROTRUSIONS SHALL NOT EXCEED 0.006 INCH (0.15mm).