High-Speed Amplifiers

290-MHz, high-speed, low-distortion amplifier

Check out EVMs, samples available for high-speed amplifiers

Smallest ADSL central office line driver package—MicroStar Junior™ BGA

Read Sine On online at www.ti.com/sc/sineon
New Technology

BiCom-II process technology improves performance in high-speed applications

The gap between digital and analog technologies is closing rapidly with the introduction of BiCom-II process technology.

The process technology provides fast, low-noise 15-volt analog transistors, benefitting virtually all high-speed application areas, especially broadband communications. BiCom-II provides board space savings, lowers silicon costs and consumes less power, all while increasing the functionality of analog and mixed-signal products.

This high-performance complementary bipolar analog process gives TI the ability to combine much higher densities of digital logic on chip with leading-edge analog transistors—meaning smaller devices with more functionality and better performance for broadband applications.

The technology includes a high-performance, 5-volt, submicron digital CMOS process that enables the on-chip implementation of logic functions. These on-chip, CMOS logic functions require less silicon area, cost less to implement and consume less power than bipolar logic. Devices manufactured using the BiCom-II process technology will support on-chip CMOS logic functions with 20 times the gate density of previous bipolar processes. This process technology also integrates a full library of standard digital functions with analog blocks, as well as the ability to use standard digital design tools.

Additional important features of the BiCom-II process technology include thin film resistors, dielectric isolation of transistors for improved noise immunity between analog and digital circuits, and laser-trimmable metal links. All of these features significantly enhance the characteristics of the process for building high-performance analog and mixed-signal functions.

Current Feedback

420-MHz, low-distortion amplifier

THS3001

Get samples, EVMs, datasheets and application reports at: www.ti.com/sc/docs/products/analog/ths3001.html

- High speed
  - Bandwidth: 420 MHz (G=1, -3 dB)
  - Slew rate: 6500 V/µs
- Harmonic distortion: –96 dBc total at 1 MHz
- Video performance
  - Differential gain: 0.01%
  - Differential phase: 0.02°
- Output drive: 100 mA
- Supply voltage range: ±5 V to ±15 V
- Applications include
  - High-end communications
  - Wireless communication base stations
  - Ultra-fast analog-to-digital converter or digital-to-analog converter buffers
  - High-end imaging
  - High-quality video
- Packaging: 8-pin DWP (SOIC) or 8-pin DGN (MSOP PowerPAD™)
- Pricing starts at $3.39 each in quantities of 1,000

THS3001 evaluation module

For technical support and ordering literature, see page 15.
±15-V voltage feedback amplifier offers benchmark performance

THS4001

Get samples, EVMs, datasheets and application reports at: www.ti.com/sc/docs/products/analog/ths4001.html

➤ High speed
  • Bandwidth: 270 MHz (G=1, -3 dB)
  • Slew rate: 400 V/µs
  • Harmonic distortion: -72 dBc total at 1 MHz

➤ Video performance
  • Differential gain: 0.04%
  • Differential phase: 0.15°

➤ Output drive: 100 mA
➤ Supply voltage range: ±2.5 V to ±15 V
➤ Applications include
  • High-end communications
  • Wireless communication base stations
  • Ultra-fast analog-to-digital converter or digital-to-analog converter buffers
  • High-end imaging
  • High-quality video
➤ Pricing starts at $2.01 each in quantities of 1,000

THS4011/2

Get samples, EVMs, datasheets and application reports at: www.ti.com/sc/docs/products/analog/ths4011.html
www.ti.com/sc/docs/products/analog/ths4012.html

➤ Harmonic distortion: low -80 dBc total at 1 MHz
➤ High speed
  • Bandwidth: 290 MHz
  • Slew rate: 310 V/µs
➤ Output drive: 110 mA
➤ Voltage noise: 7.5 nV/√Hz
➤ Video performance
  • Differential gain: 0.006%
  • Differential phase: 0.01°
➤ Supply voltage: ±5 V to ±15 V
➤ Packaging: standard SOIC or new MSOP PowerPAD™
➤ Pricing (in quantities of 1,000)
  THS4011 is $2.29 each
  THS4012 is $3.81 each

Distortion vs. frequency

THS4001 performance

COMPETITOR A
• 70 MHz
  • 45 ns

COMPETITOR B
• 130 MHz
  • 80 ns

COMPETITOR C
• 200 MHz
  • 36 ns

THS4001
• 270 MHz
  • 40 ns

VCC = ±15 V
R1 = 150 Ω
G = 2

Second harmonic
Third harmonic

100 K 1 M 10 M
f – Frequency (Hz)
Low voltage/noise amplifiers for communications applications

Get samples, EVMs, datasheets and application reports at:
www.ti.com/sc/docs/products/analog/ths4021.html
www.ti.com/sc/docs/products/analog/ths4022.html

100-MHz amplifiers offer ultra-low 1.6-nV/√Hz voltage noise

Get samples, EVMs and datasheets at:
www.ti.com/sc/docs/products/analog/ths4031.html
www.ti.com/sc/docs/products/analog/ths4032.html

High speed
- Bandwidth: 350 MHz (G=10, -3 dB)
- Slew rate: 470 V/µs
- Stable at a gain of 10(-9) or greater
- Voltage noise: ultra-low 1.5 nV/√Hz
- Wide range of power supplies:
  - VCC = ±5 V to ±15 V
- Applications include
  - High-end communications
  - Wireless communication base station
  - Ultra-fast analog-to-digital converter or digital-to-analog converter buffers
  - High-end imaging
  - High-quality video
- Packaging: standard SOIC or MSOP PowerPAD™
- Pricing (in quantities of 1,000)
  - THS4021 is $2.19 each
  - THS4022 is $3.65 each

Voltage and current noise vs. frequency

Voltage noise vs. frequency

For technical support and ordering literature, see page 15.
180-MHz amplifier drives any capacitive load

**THS4041/2**

Get samples, EVMs and datasheets at:
www.ti.com/sc/docs/products/analog/ths4041.html
www.ti.com/sc/docs/products/analog/ths4042.html

- **High speed**
  - Bandwidth: 180 MHz (G=1, -3 dB)
  - Slew rate: 400 V/µs
  - Harmonic distortion: -72 dBc total at 1 MHz
- **Drives any capacitive load**
- **Video performance**
  - Differential gain: 0.02%
  - Differential phase: 0.02°
- **Output drive**: 115 mA
- **Supply voltage range**: ±5 V to ±15 V
- **Applications include**
  - High-end communications
  - Wireless communication base station
  - Ultra-fast analog-to-digital converter or digital-to-analog converter buffers
  - High-end imaging
  - High-quality video
- **Packaging**: standard SOIC or MSOP PowerPAD™
- **Pricing (in quantities of 1,000)**
  - THS4041 is $1.64 each
  - THS4042 is $3.25 each

**Output amplitude vs. frequency**

**Bandwidth vs. capacitive load**

<table>
<thead>
<tr>
<th>Bandwidth G=1, -3 dB</th>
<th>Capacitive Load</th>
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<tbody>
<tr>
<td>180 MHz</td>
<td>0 pF</td>
</tr>
<tr>
<td>70 MHz</td>
<td>100 pF</td>
</tr>
<tr>
<td>30 MHz</td>
<td>500 pF</td>
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</table>

70-MHz, low-cost amplifier

**THS4051/2**

Get samples, EVMs and datasheets at:
www.ti.com/sc/docs/products/analog/ths4051.html
www.ti.com/sc/docs/products/analog/ths4052.html

- **High speed**
  - Bandwidth: 70 MHz (G=1, -3 dB)
  - Slew rate: 240 V/µs
  - Harmonic distortion: -62 dBc total at 1 MHz
- **Video performance**
  - Differential gain: 0.03%
  - Differential phase: 0.03°
- **Output drive**: 115 mA
- **Supply voltage range**: ±5 V to ±15 V
- **Applications include**
  - High-end communications
  - Wireless communication base station
  - Ultra-fast analog-to-digital converter or digital-to-analog converter buffers
  - High-end imaging
  - High-quality video
- **Packaging**: standard SOIC or MSOP PowerPAD™
- **Pricing (in quantities of 1,000)**
  - THS4051 is $1.09 each
  - THS4052 is $1.42 each

**THS4051 block diagram**

**THS4052 block diagram**

**Packages**

**Read Sine On online at** www.ti.com/sc/sineon
180-MHz, general-purpose amplifier

**THS4061/2**

- **Get samples, EVMs and datasheets at:**
  - www.ti.com/sc/docs/products/analog/ths4061.html
  - www.ti.com/sc/docs/products/analog/ths4062.html

- **High speed**
  - Bandwidth: 180 MHz (G=1, -3 dB)
  - Slew rate: 400 V/µs
  - Harmonic distortion: -72 dBc total at 1 MHz

- **Video performance**
  - Differential gain: 0.02%
  - Differential phase: 0.02°

- **Output drive:** 115 mA
- **Supply voltage range:** ±5 V to ±15 V

- **Applications include**
  - High-end communications
  - Wireless communication base station
  - Ultra-fast analog-to-digital converter or digital-to-analog converter buffers
  - High-end imaging
  - High-quality video

- **Packaging:** standard SOIC or MSOP PowerPAD™

- **Pricing** (in quantities of 1,000)
  - THS4061 is $1.39 each
  - THS4062 is $1.75 each

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175-MHz, low-power amps offer excellent video performance

**THS4081/2**

- **Get samples and datasheets at:**
  - www.ti.com/sc/docs/products/analog/ths4081.html
  - www.ti.com/sc/docs/products/analog/ths4082.html

- **High speed**
  - Bandwidth: 175 MHz (G=1, -3 dB)
  - Slew rate: 230 V/µs
  - Settling time: 43 ns (0.1%) on

- **High output-drive:** IO = 85 mA (typ)

- **Ultra low 3.4-mA-per-channel quiescent current**

- **Excellent video performance**
  - Bandwidth: 35 MHz (G=1, 0.1 dB)
  - Differential gain: 0.01%
  - Differential phase: 0.05°

- **Very low distortion**
  - THD = -64 dBc (f=1 MHz, R_L=150 Ω)
  - THD = -79 dBc (f=1 MHz, R_L=1 kΩ)

- **Supply voltage range:** ±5 V to ±15 V

- **Applications include**
  - High-end communications
  - High-end imaging/video processing
  - Any application requiring low power

- **Packaging:** standard SOIC or MSOP PowerPAD™, 8-pin DWP(SOIC), or 8-pin DGN(MSOP) PowerPAD™

- **Pricing** (in quantities of 1,000)
  - THS4081 is $1.78 each
  - THS4082 is $2.97 each

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**Supply current vs. supply voltage**

For technical support and ordering literature, see page 15.
500-mA, high output-current line driver and receiver

**THS6002**

Get samples, EVMs, datasheets and application reports at: www.ti.com/sc/docs/products/analog/ths6002.html

- **Driver features**
  - Bandwidth: 140 MHz (-3 dB) into 25-Ω load
  - Bandwidth: 315 MHz (-3 dB) into 100-Ω load
  - Slew rate: 1000 V/µs
- **Output drive**: 500 mA into 25-Ω load
- **Harmonic distortion**: -62 dBc total at 1 MHz

- **Receiver features**
  - Bandwidth: 330 MHz (-3 dB) into 150-Ω load
  - Slew rate: 900 V/µs
- **Thermal shutdown and short circuit protection**

- **Applications include**
  - Full-rate central office ADSL line cards
  - ADSL modem
  - High-end communications

- **Packaging**: 20-pin SOIC PowerPAD™
- **Pricing starts at**: $5.23 each in quantities of 1,000

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500-mA, dual-differential line driver

**THS6012**

Get samples, EVMs and datasheets at: www.ti.com/sc/docs/products/analog/ths6012.html

- **High speed**
  - Bandwidth: 140 MHz (-3 dB) into 25-Ω load
  - Bandwidth: 315 MHz (-3 dB) into 100-Ω load
  - Slew rate: 1300 V/µs
- **Output drive**: 500 mA into 25-Ω load
- **Harmonic distortion**: -62 dBc total at 1 MHz
- **Thermal shutdown and short circuit protection**
- **Applications include**
  - Full-rate central office ADSL line cards
  - High-end communications
  - ADSL modem
- **Packaging**: 20-pin SOIC PowerPAD™ and MicroStar Junior™ BGA (see page 10)
- **Pricing starts at**: $4.40 each in quantities of 1,000

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**THS6002 block diagram**

![THS6002 block diagram](image-url)
250-mA, high output-current line driver

**THS6022**

Get samples, EVMs and datasheets at:
www.ti.com/sc/docs/products/analog/ths6022.html

- High speed
  - Bandwidth: 210 MHz (-3 dB) into 50-Ω load
  - Bandwidth: 300 MHz (-3 dB) into 100-Ω load
  - Slew rate: 1900 V/µs
- Output drive: 250 mA into 50-Ω load
- Harmonic distortion: -66 dBc total at 1 MHz
- Thermal shutdown and short-circuit protection
- Applications include
  - Short-loop full-rate central office ADSL line cards
  - ADSL modem
  - High-end communications
- Packaging: 14-pin TSSOP PowerPAD™ or MicroStar Junior™ BGA package (see page 10)
- Pricing starts at $2.64 each in quantities of 1,000

Typical client-side ADSL application

Low-noise xDSL dual-differential receiver

**THS6062**

Get samples, EVMs and datasheets at:
www.ti.com/sc/docs/products/analog/ths6062.html

- xDSL receiver
- High speed
  - Bandwidth: 100 MHz
  - Slew rate: 100 V/µs
- Voltage noise: low 1.6 nV/√Hz
- Very low distortion
  - Harmonic distortion: -72 dBc total at 1 MHz (R_L=150 Ω)
  - Harmonic distortion: -90 dBc total at 1 MHz (R_L=1k Ω)
- Supply voltage range: 5-V single supply, ±5 V to ±15 V
- Applications include
  - Full-rate central office ADSL line cards
  - ADSL modem
  - High-end communications
- Packaging: 8-pin standard SOIC or 8-pin MSOP PowerPAD™
- Pricing starts at $2.15 each in quantities of 1,000

THS6062 block diagram

For technical support and ordering literature, see page 15.
Low-power ADSL central office line driver

**THS6032**

➤ 1.35-W total power dissipation for full-rate ADSL into a 25-Ω load
➤ Low-impedance shutdown mode allows reception of incoming signal during standby
➤ Low distortion
  • THD = -60 dBc at f=1 MHz
  • \( V_{OPP} \) = 20-V, 25-Ω load
➤ 400 mA minimum output current into a 25-Ω load
➤ High speed
  • Bandwidth: 100-MHz (-3 dB), 25-Ω load
  • Slew rate: 1200 V/µs
➤ Thermal shutdown and short circuit protection
➤ Applications include
  • Full-rate central office ADSL line cards
  • High-end communications
➤ Packaging: 20-pin SOIC PowerPAD™ or MicroStar Junior™ BGA package (see page 10)
➤ Pricing starts at $4.07 each in quantities of 1,000

**THS6032**

(MicroStar Junior™ BGA package pictured)

Get samples, EVMs and datasheets at:
www.ti.com/sc/docs/products/analog/ths6032.html

Low-power ADSL differential receiver

**THS6072**

➤ Low 3.4-mA-per-channel quiescent current
➤ Voltage noise: 10 nV/√Hz
➤ High speed
  • Bandwidth: 175 MHz (G=1, -3 dB)
  • Slew rate: 230 V/µs
➤ Very low distortion
  • THD = -79 dBc (f=1 MHz, \( R_L \)=1 kΩ)
➤ High output drive: \( I_O \) = 85 mA (typ)
➤ Wide range of power supplies
  • \( V_{CC} \) = ±5 V to ±15 V
➤ Applications include
  • Full-rate central office ADSL line cards
  • ADSL modem
  • High-end communications
➤ Packaging: standard 8-pin SOIC or 8-pin MSOP PowerPAD™
➤ Pricing starts at $2.15 each in quantities of 1,000

**THS6072** block diagram

Get samples and datasheets at:
www.ti.com/sc/docs/products/analog/ths6072.html

➤ 1.35-W total power dissipation for full-rate ADSL into a 25-Ω load
➤ Low-impedance shutdown mode allows reception of incoming signal during standby
➤ Low distortion
  • THD = -60 dBc at f=1 MHz
  • \( V_{OPP} \) = 20-V, 25-Ω load
➤ 400 mA minimum output current into a 25-Ω load
➤ High speed
  • Bandwidth: 100-MHz (-3 dB), 25-Ω load
  • Slew rate: 1200 V/µs
➤ Thermal shutdown and short circuit protection
➤ Applications include
  • Full-rate central office ADSL line cards
  • High-end communications
➤ Packaging: 20-pin SOIC PowerPAD™ or MicroStar Junior™ BGA package (see page 10)
➤ Pricing starts at $4.07 each in quantities of 1,000

**THS6072** block diagram

Read *Sine On* online at www.ti.com/sc/sineon
Dual programmable gain
ADSL receiver

THS7001/2

Get samples, EVMs and datasheets at:
www.ti.com/sc/docs/products/analog/ths7001.html
www.ti.com/sc/docs/products/analog/ths7002.html

- High speed
  - Bandwidth: 70 MHz (-3 dB)
  - Slew rate: 200 V/µs
- Separate pre-amp and PGA stage
- Pre-amp features
  - Low 1.7 nV/√Hz voltage noise
  - Accessible output pin for external filtering
- PGA features
  - Digital programmable gain
  - Constant -3 dB bandwidth
  - Gain/attenuation range: -22 dB to 20 dB
  - Step resolution of 6 dB
  - Output clamp protection
- Shutdown control
- Supply voltage range: ±5 V to ±15 V
- Applications include
  - Full-rate central office ADSL line cards
  - ADSL modem
  - High-end communications
- Packaging: TSSOP PowerPAD™
- Pricing: (in quantities of 1,000)
  THS7001 is $3.39 each
  THS7002 is $5.41 each

THS7001/2 block diagram

MicroStar Junior™ BGA package
reduces ADSL line driver size

Get application reports* at:
www-s.ti.com/sc/techlit/ssa009

- MicroStar Junior™ BGA package ADSL line drivers
  - One-fifth the size of current SOIC PowerPAD™ line drivers
  - Excellent thermal dissipation through series of solder alloy balls
  - 0.5-mm solder ball pitch ranges

MicroStar Junior™ structure, smallest ADSL central office line driver package at 5 mm

Example: 24 pin, 5x4 mm (5040), 0.5 mm pitch

High-speed amps available in MicroStar Junior™ BGA package

<table>
<thead>
<tr>
<th>Device</th>
<th>Package Designator</th>
<th>Package Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>THS6012</td>
<td>20-pin BGA</td>
<td>GQE</td>
</tr>
<tr>
<td>THS6022</td>
<td>14-pin BGA</td>
<td>GQE</td>
</tr>
<tr>
<td>THS6032</td>
<td>20-pin BGA</td>
<td>GQE</td>
</tr>
</tbody>
</table>

*Adobe Acrobat is required to view
High-Speed Amplifier Evaluation Modules

The following evaluation modules (EVMs) are available for high-speed amplifier devices. To order any of the EVM kits listed, please call our toll-free order desk number at 1-800-477-8924 in North America. To order in Asia, Europe, and other regions, contact the TI Product Information Center for your region (see page 15) or contact your local TI distributor; see www.ti.com/sc/docs/distmenu.htm for distributor listings.

Each EVM kit contains an evaluation board, data sheet and a user’s guide for the evaluation board. Some kits also include application notes and other necessary hardware. For a full list of analog EVMs, visit www.ti.com/sc/docs/tools/analog/index.html

<table>
<thead>
<tr>
<th>Evaluation Module</th>
<th>Description</th>
<th>Price</th>
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<tbody>
<tr>
<td>THS3001EVM</td>
<td>420 MHz, 6500 V/µs</td>
<td>$50</td>
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<tr>
<td>THS4001EVM</td>
<td>300 MHz, 400 V/µs</td>
<td>$50</td>
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<tr>
<td>THS4011EVM</td>
<td>290 MHz, 310 V/µs</td>
<td>$50</td>
</tr>
<tr>
<td>THS4012EVM</td>
<td>290 MHz, 310 V/µs, dual</td>
<td>$50</td>
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<tr>
<td>THS4021EVM</td>
<td>350 MHz, 470 V/µs, low noise</td>
<td>$50</td>
</tr>
<tr>
<td>THS4022EVM</td>
<td>350 MHz, 470 V/µs, low noise, dual</td>
<td>$50</td>
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<tr>
<td>THS4031EVM</td>
<td>100 MHz, 100 V/µs, low noise</td>
<td>$50</td>
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<td>THS4032EVM</td>
<td>100 MHz, 100 V/µs, low noise, dual</td>
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<td>THS4041EVM</td>
<td>165 MHz, 400 V/µs</td>
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<td>THS6002EVM</td>
<td>ADSL line driver/receiver, quad</td>
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<td>500-mA, dual-differential line driver</td>
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<td>250-mA, dual-differential line driver</td>
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<td>70-MHz, programmable-gain amplifier</td>
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<tr>
<td>THS7002EVM</td>
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High-Speed Amplifier Product Tree

*Not yet released
## Selection Guide for High-Speed Amplifiers

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<tr>
<th>Part Number</th>
<th>Architecture</th>
<th>Supply Voltage</th>
<th>A CL</th>
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<td>CFB</td>
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For technical support and ordering literature, see page 15.
# Selection Guide for High-Speed Amplifiers

<table>
<thead>
<tr>
<th>Settling Time to 0.1%/0.01%</th>
<th>THD 1MHz</th>
<th>Differential Gain/Error Phase</th>
<th>$V_n$</th>
<th>$V_{OS}$</th>
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<td>%</td>
<td>deg</td>
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Check with your local TI sales office for current pricing.
High-Speed Amplifiers Application Reports

To access any of the following application reports, type the URL
www-s.ti.com/sc/techlit/litnumber
and replace litnumber with the number in parentheses beside the title. For a full list of analog application reports, visit www.ti.com/sc/docs/apps/analog/index.html

- 10-MHZ Butterworth Filter Using the Operational Amplifier THS4001 (sloa032)
- Analog Applications Journal November 1999 (slyt010)
- Analog Applications Journal February 2000 (slyt012)
- Analysis of the Sallen Key Architecture (sloa024)
- Building a Simple Spice Model for the THS3001 (sloa018)
- Current Feedback Amplifier Analysis and Compensation (sloa021)
- Driving Capacitance with the THS3001 (sloa014)
- Driving Capacitance with the THS4001 (sloa015)
- DSP Solutions for Voiceband and ADSI Modem (spaa005)
- Effect of Parasitic Capacitance in Op Amp Circuits (sloa013)
- Electrostatic Discharge Application Note (ssya008)
- Feedback Amplifier Analysis Tools (sloa017)
- Gain Block Analysis for the THS3001 (sloa019)
- Measuring Differential Gain and Phase (sloa040)
- MicroStar Junior™ Made Easy (ssya009)
- MicroStar BGA™ Packaging Reference Guide (ssyz015)
- Noise Analysis in Operational Amplifier Circuits (slva043)
- PCI ADSL Adapter Using the Texas Instruments TNETD2000P ChipSet (spaa006)
- PowerPAD™ Made Easy (slma004)
- PowerPAD™ Thermally Enhanced Package Application Report (slma002)
- Signal Conditioning Piezoelectric Sensors (sloa033)
- Signal Conditioning Wheatstone Resistive Bridge Sensors (sloa034)
- Thermal Characteristics of Linear and Logic Packages Using JEDEC PCB Designs (szza017)
- THS3001 Spice Model Performance (sloa038)
- THS4001 Spice Model Performance (sloa029)
- Understanding Basic Analog Active Devices (sloa026)
- Understanding Basic Analog Circuit Equations (sloa025)
- Understanding Basic Analog Passive Devices (sloa027)
- Using References to Generate Offsets for the TLV55XX Family Data Converters (slla063)
- Voltage Feedback vs. Current Feedback Op Amps (slva051)

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