

# LF411

*LF411 Low Offset, Low Drift JFET Input Operational Amplifier*



Literature Number: SNOSBH6C

# LF411

## Low Offset, Low Drift JFET Input Operational Amplifier

### General Description

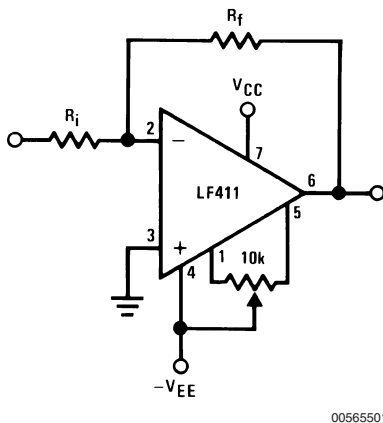
These devices are low cost, high speed, JFET input operational amplifiers with very low input offset voltage and guaranteed input offset voltage drift. They require low supply current yet maintain a large gain bandwidth product and fast slew rate. In addition, well matched high voltage JFET input devices provide very low input bias and offset currents. The LF411 is pin compatible with the standard LM741 allowing designers to immediately upgrade the overall performance of existing designs.

These amplifiers may be used in applications such as high speed integrators, fast D/A converters, sample and hold circuits and many other circuits requiring low input offset voltage and drift, low input bias current, high input impedance, high slew rate and wide bandwidth.

### Features

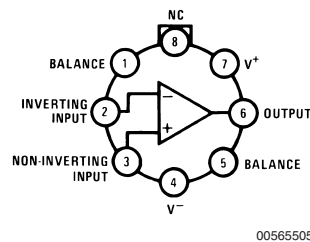
- Internally trimmed offset voltage: 0.5 mV(max)
- Input offset voltage drift: 10  $\mu\text{V}/^\circ\text{C}$ (max)
- Low input bias current: 50 pA
- Low input noise current: 0.01 pA/ $\sqrt{\text{Hz}}$
- Wide gain bandwidth: 3 MHz(min)
- High slew rate: 10V/ $\mu\text{s}$ (min)
- Low supply current: 1.8 mA
- High input impedance:  $10^{12}\Omega$
- Low total harmonic distortion:  $\leq 0.02\%$
- Low 1/f noise corner: 50 Hz
- Fast settling time to 0.01%: 2  $\mu\text{s}$

### Typical Connection



### Connection Diagrams

#### Metal Can Package

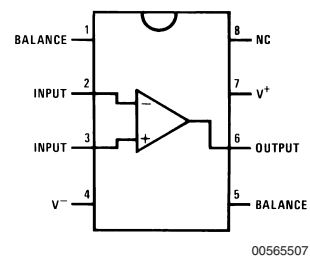


Note: Pin 4 connected to case.

#### Top View

Order Number LF411ACH  
or LF411MH/883 (Note 11)  
See NS Package Number H08A

#### Dual-In-Line Package



#### Top View

Order Number LF411ACN, LF411CN  
See NS Package Number N08E

### Ordering Information

#### LF411XYZ

- X indicates electrical grade
- Y indicates temperature range
  - “M” for military
  - “C” for commercial
- Z indicates package type
  - “H” or “N”

BI-FET II™ is a trademark of National Semiconductor Corporation.

### Absolute Maximum Ratings (Note 1)

If Military/Aerospace specified devices are required, please contact the National Semiconductor Sales Office/Distributors for availability and specifications.

	LF411A	LF411		H Package	N Package
Supply Voltage	±22V	±18V	$T_{jmax}$	150°C	115°C
Differential Input Voltage	±38V	±30V	$\theta_{jA}$	162°C/W (Still Air)	120°C/W
Input Voltage Range (Note 2)	±19V	±15V		65°C/W (400 LF/min Air Flow)	
Output Short Circuit Duration	Continuous	Continuous	$\theta_{jC}$	20°C/W	
			Operating Temp. Range	(Note 4)	(Note 4)
			Storage Temp. Range	-65°C ≤ T <sub>A</sub> ≤ 150°C	-65°C ≤ T <sub>A</sub> ≤ 150°C
			Lead Temp. (Soldering, 10 sec.)	260°C	260°C
Power Dissipation (Notes 3, 10)	670 mW	670 mW	ESD Tolerance		Rating to be determined.

### DC Electrical Characteristics (Note 5)

Symbol	Parameter	Conditions	LF411A			LF411			Units
			Min	Typ	Max	Min	Typ	Max	
V <sub>OS</sub>	Input Offset Voltage	R <sub>S</sub> =10 kΩ, T <sub>A</sub> =25°C		0.3	0.5		0.8	2.0	mV
ΔV <sub>OS</sub> /ΔT	Average TC of Input Offset Voltage	R <sub>S</sub> =10 kΩ (Note 6)		7	10		7	20 (Note 6)	μV/°C
I <sub>OS</sub>	Input Offset Current	V <sub>S</sub> =±15V (Notes 5, 7)	T <sub>J</sub> =25°C	25	100		25	100	pA
			T <sub>J</sub> =70°C					2	nA
			T <sub>J</sub> =125°C					25	nA
I <sub>B</sub>	Input Bias Current	V <sub>S</sub> =±15V (Notes 5, 7)	T <sub>J</sub> =25°C	50	200		50	200	pA
			T <sub>J</sub> =70°C					4	nA
			T <sub>J</sub> =125°C					50	nA
R <sub>IN</sub>	Input Resistance	T <sub>J</sub> =25°C		10 <sup>12</sup>			10 <sup>12</sup>	Ω	
A <sub>VOL</sub>	Large Signal Voltage Gain	V <sub>S</sub> =±15V, V <sub>O</sub> =±10V, R <sub>L</sub> =2k, T <sub>A</sub> =25°C	50	200		25	200		V/mV
		Over Temperature	25	200		15	200		V/mV
V <sub>O</sub>	Output Voltage Swing	V <sub>S</sub> =±15V, R <sub>L</sub> =10k	±12	±13.5		±12	±13.5		V
V <sub>CM</sub>	Input Common-Mode Voltage Range		±16	+19.5		±11	+14.5		V
				-16.5			-11.5		V
CMRR	Common-Mode Rejection Ratio	R <sub>S</sub> ≤10k	80	100		70	100		dB
PSRR	Supply Voltage Rejection Ratio	(Note 8)	80	100		70	100		dB
I <sub>S</sub>	Supply Current			1.8	2.8		1.8	3.4	mA

### AC Electrical Characteristic (Note 5)

Symbol	Parameter	Conditions	LF411A			LF411			Units
			Min	Typ	Max	Min	Typ	Max	
SR	Slew Rate	V <sub>S</sub> =±15V, T <sub>A</sub> =25°C	10	15		8	15		V/μs
GBW	Gain-Bandwidth Product	V <sub>S</sub> =±15V, T <sub>A</sub> =25°C	3	4		2.7	4		MHz
e <sub>n</sub>	Equivalent Input Noise Voltage	T <sub>A</sub> =25°C, R <sub>S</sub> =100Ω, f=1 kHz		25			25		nV/√Hz
i <sub>n</sub>	Equivalent Input Noise Current	T <sub>A</sub> =25°C, f=1 kHz		0.01			0.01		pA/√Hz

## AC Electrical Characteristic (Note 5) (Continued)

Symbol	Parameter	Conditions	LF411A			LF411			Units
			Min	Typ	Max	Min	Typ	Max	
THD	Total Harmonic Distortion	$A_V=+10$ , $R_L=10k$ , $V_O=20$ Vp-p, $BW=20$ Hz–20 kHz		<0.02			<0.02		%

**Note 1:** "Absolute Maximum Ratings" indicate limits beyond which damage to the device may occur. Operating Ratings indicate conditions for which the device is functional, but do not guarantee specific performance limits.

**Note 2:** Unless otherwise specified the absolute maximum negative input voltage is equal to the negative power supply voltage.

**Note 3:** For operating at elevated temperature, these devices must be derated based on a thermal resistance of  $\theta_{JA}$ .

**Note 4:** These devices are available in both the commercial temperature range  $0^\circ\text{C} \leq T_A \leq 70^\circ\text{C}$  and the military temperature range  $-55^\circ\text{C} \leq T_A \leq 125^\circ\text{C}$ . The temperature range is designated by the position just before the package type in the device number. A "C" indicates the commercial temperature range and an "M" indicates the military temperature range. The military temperature range is available in "H" package only.

**Note 5:** Unless otherwise specified, the specifications apply over the full temperature range and for  $V_S = \pm 20\text{V}$  for the LF411A and for  $V_S = \pm 15\text{V}$  for the LF411.  $V_{OS}$ ,  $I_B$ , and  $I_{OS}$  are measured at  $V_{CM} = 0$ .

**Note 6:** The LF411A is 100% tested to this specification. The LF411 is sample tested to insure at least 90% of the units meet this specification.

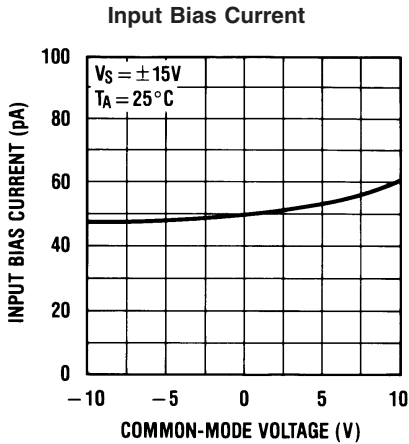
**Note 7:** The input bias currents are junction leakage currents which approximately double for every  $10^\circ\text{C}$  increase in the junction temperature,  $T_j$ . Due to limited production test time, the input bias currents measured are correlated to junction temperature. In normal operation the junction temperature rises above the ambient temperature as a result of internal power dissipation,  $P_D$ .  $T_j = T_A + \theta_{JA} P_D$  where  $\theta_{JA}$  is the thermal resistance from junction to ambient. Use of a heat sink is recommended if input bias current is to be kept to a minimum.

**Note 8:** Supply voltage rejection ratio is measured for both supply magnitudes increasing or decreasing simultaneously in accordance with common practice, from  $\pm 15\text{V}$  to  $\pm 5\text{V}$  for the LF411 and from  $\pm 20\text{V}$  to  $\pm 5\text{V}$  for the LF411A.

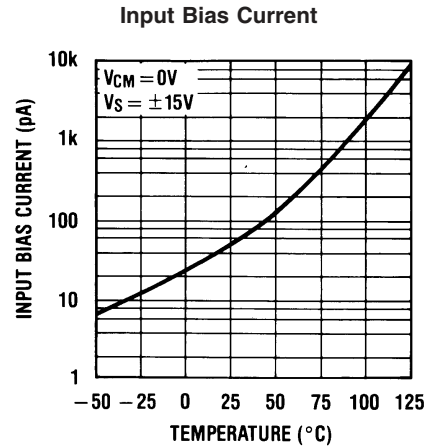
**Note 9:** RETS 411X for LF411MH and LF411MJ military specifications.

**Note 10:** Max. Power Dissipation is defined by the package characteristics. Operating the part near the Max. Power Dissipation may cause the part to operate outside guaranteed limits.

## Typical Performance Characteristics

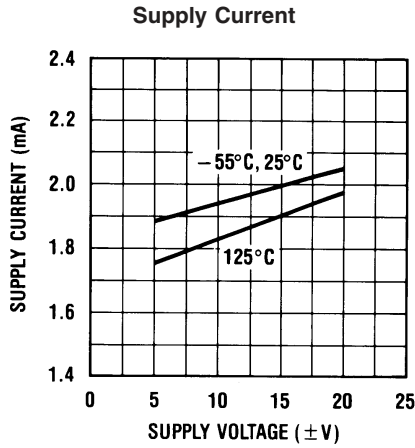


00565511

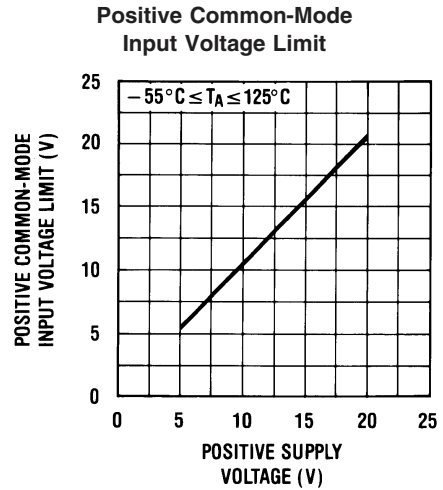


00565512

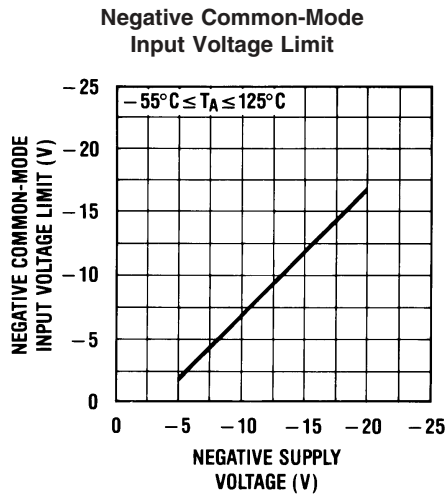
Typical Performance Characteristics (Continued)



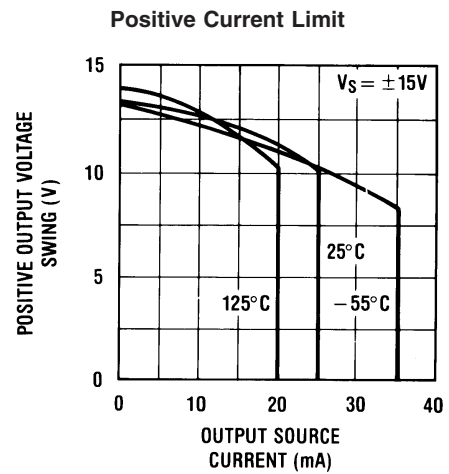
00565513



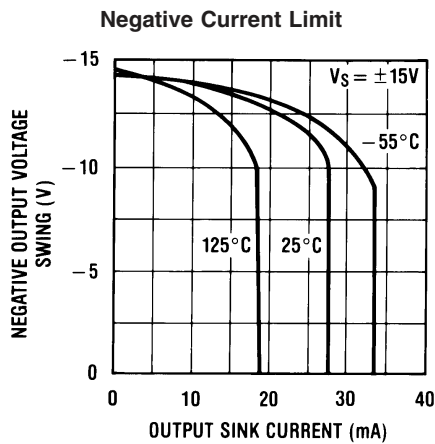
00565514



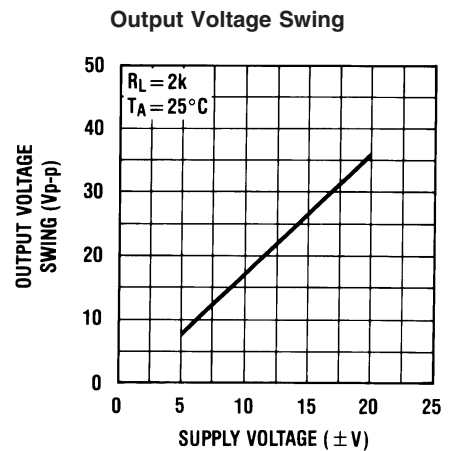
00565515



00565516

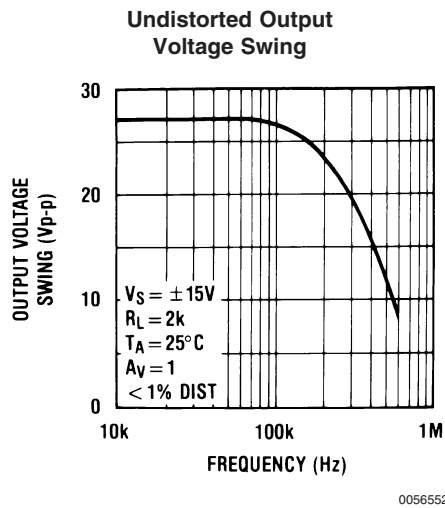
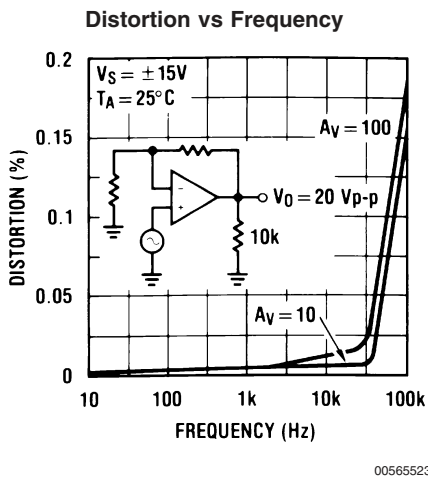
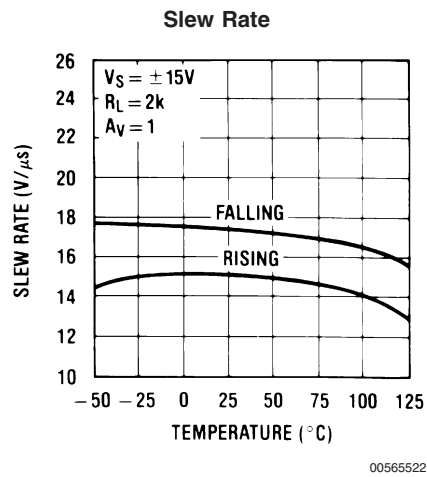
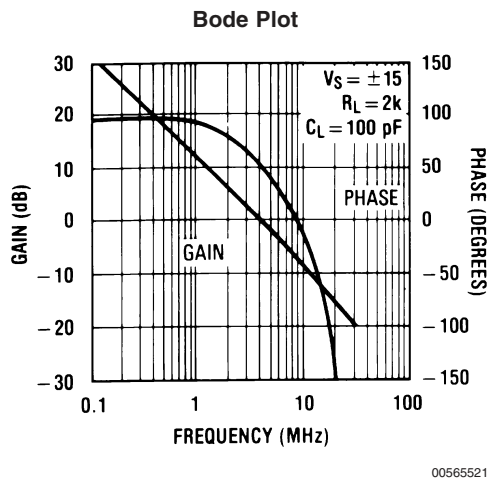
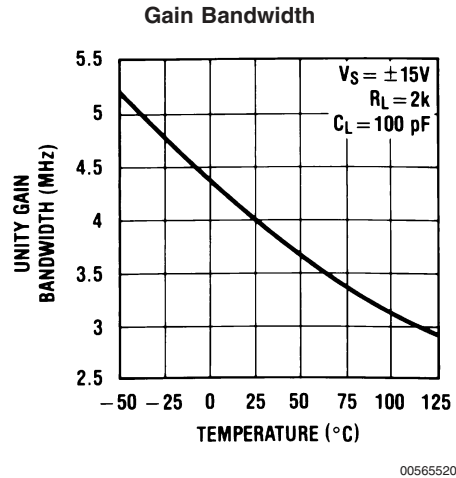
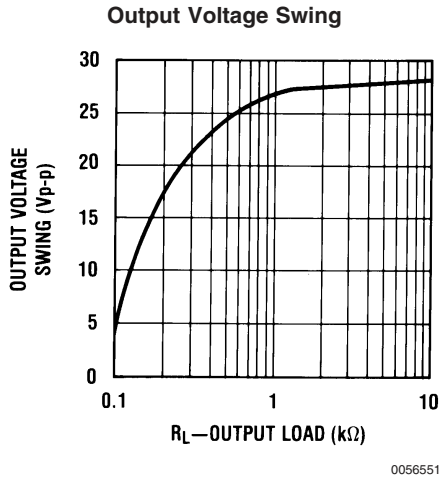


00565517



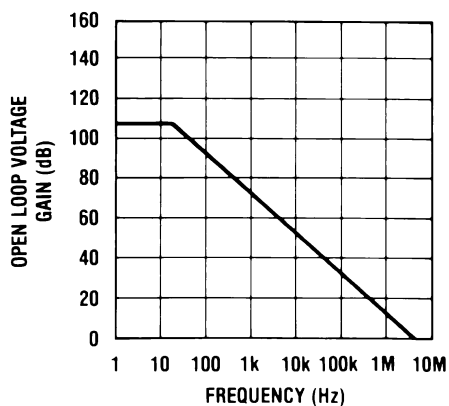
00565518

Typical Performance Characteristics (Continued)



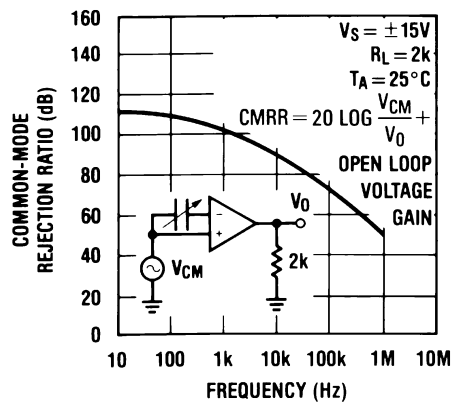
# Typical Performance Characteristics (Continued)

Open Loop Frequency Response



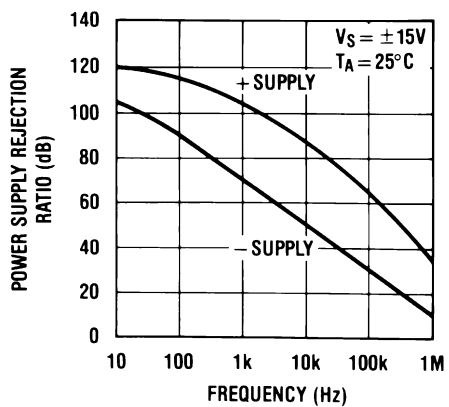
00565525

Common-Mode Rejection Ratio



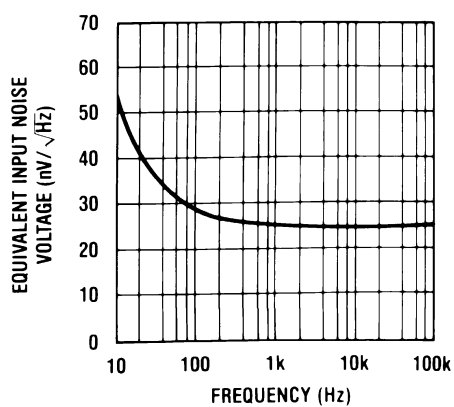
00565526

Power Supply Rejection Ratio



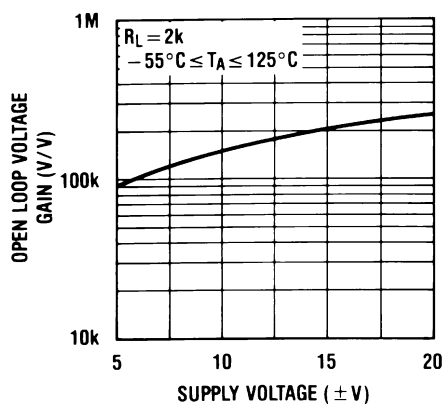
00565527

Equivalent Input Noise Voltage



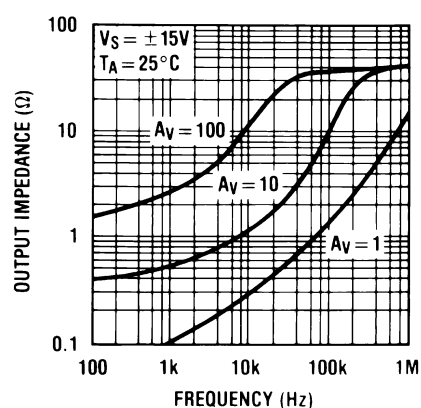
00565528

Open Loop Voltage Gain



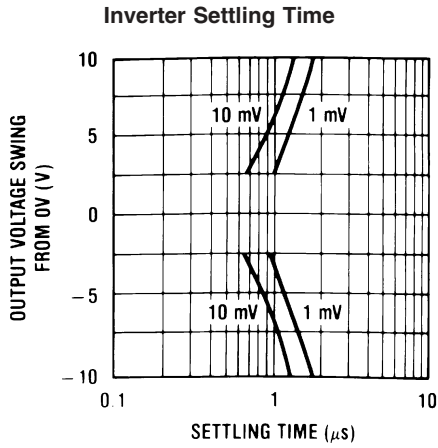
00565529

Output Impedance



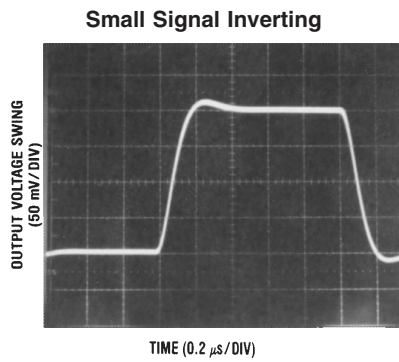
00565530

# Typical Performance Characteristics (Continued)

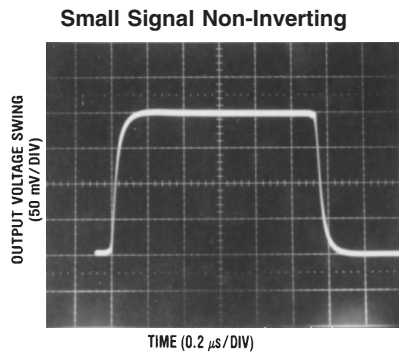


00565531

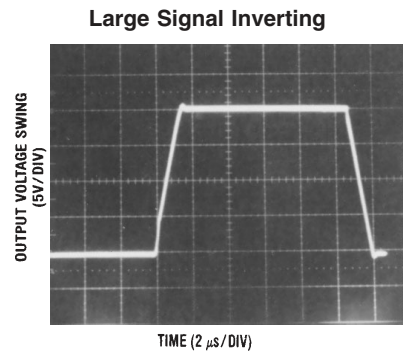
## Pulse Response $R_L=2\text{ k}\Omega, C_L=10\text{ pF}$



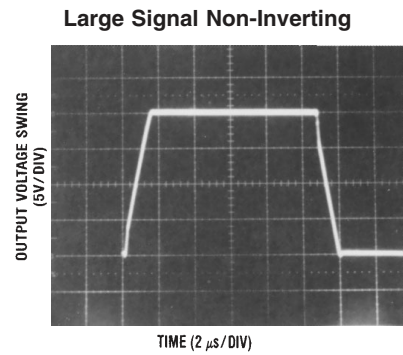
00565539



00565540



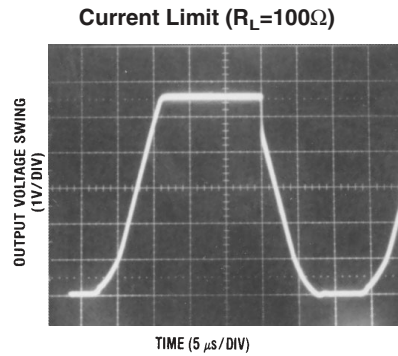
00565541



00565542



## Pulse Response $R_L=2\text{ k}\Omega$ , $C_L=10\text{ pF}$ (Continued)



### Application Hints

The LF411 series of internally trimmed JFET input op amps (BI-FET II™) provide very low input offset voltage and guaranteed input offset voltage drift. These JFETs have large reverse breakdown voltages from gate to source and drain eliminating the need for clamps across the inputs. Therefore, large differential input voltages can easily be accommodated without a large increase in input current. The maximum differential input voltage is independent of the supply voltages. However, neither of the input voltages should be allowed to exceed the negative supply as this will cause large currents to flow which can result in a destroyed unit.

Exceeding the negative common-mode limit on either input will force the output to a high state, potentially causing a reversal of phase to the output. Exceeding the negative common-mode limit on both inputs will force the amplifier output to a high state. In neither case does a latch occur since raising the input back within the common-mode range again puts the input stage and thus the amplifier in a normal operating mode.

Exceeding the positive common-mode limit on a single input will not change the phase of the output; however, if both inputs exceed the limit, the output of the amplifier may be forced to a high state.

The amplifier will operate with a common-mode input voltage equal to the positive supply; however, the gain bandwidth and slew rate may be decreased in this condition. When the negative common-mode voltage swings to within 3V of the negative supply, an increase in input offset voltage may occur.

The LF411 is biased by a zener reference which allows normal circuit operation on  $\pm 4.5\text{V}$  power supplies. Supply voltages less than these may result in lower gain bandwidth and slew rate.

The LF411 will drive a  $2\text{ k}\Omega$  load resistance to  $\pm 10\text{V}$  over the full temperature range. If the amplifier is forced to drive heavier load currents, however, an increase in input offset voltage may occur on the negative voltage swing and finally reach an active current limit on both positive and negative swings.

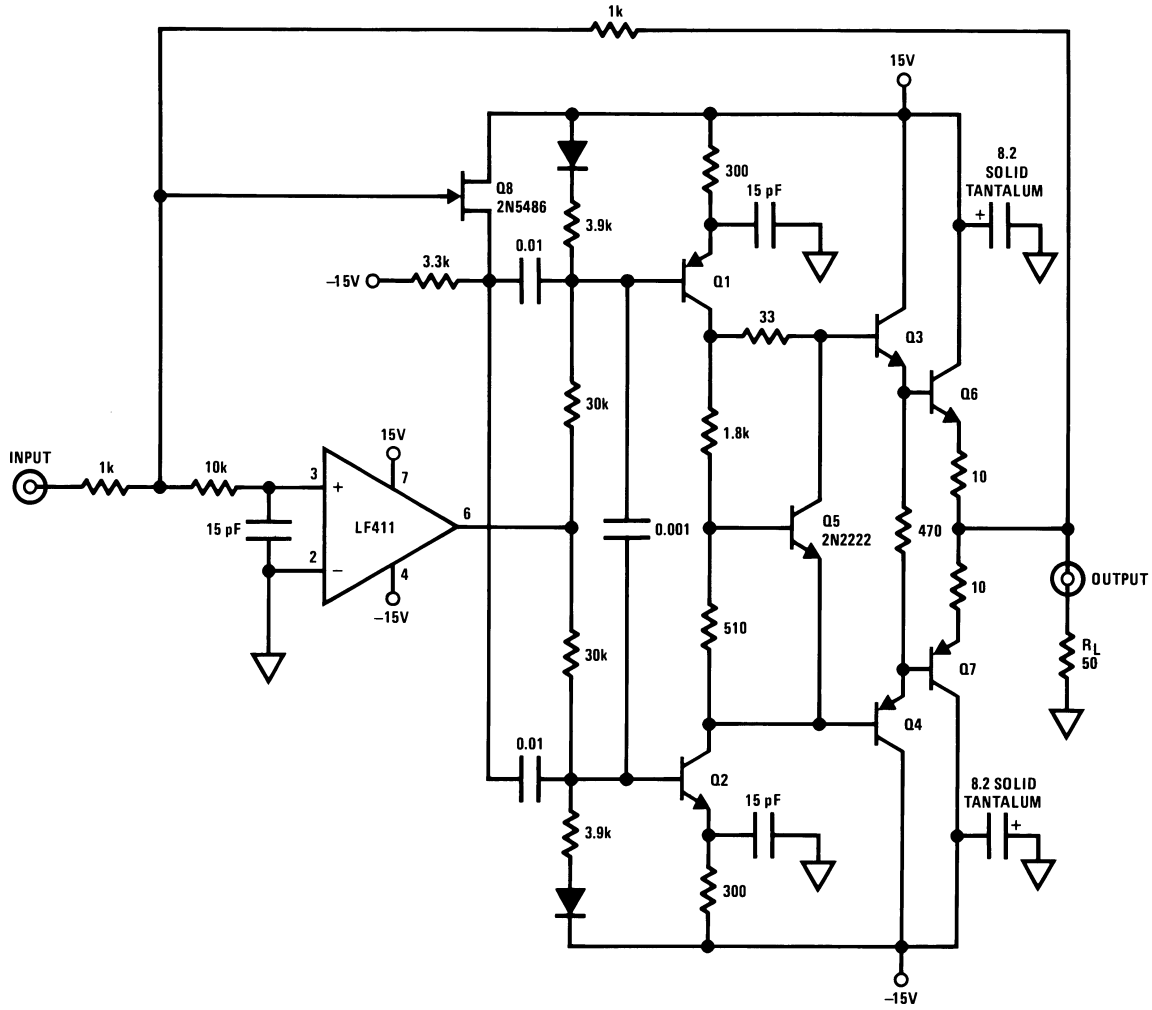
Precautions should be taken to ensure that the power supply for the integrated circuit never becomes reversed in polarity or that the unit is not inadvertently installed backwards in a socket as an unlimited current surge through the resulting forward diode within the IC could cause fusing of the internal conductors and result in a destroyed unit.

As with most amplifiers, care should be taken with lead dress, component placement and supply decoupling in order to ensure stability. For example, resistors from the output to an input should be placed with the body close to the input to minimize "pick-up" and maximize the frequency of the feedback pole by minimizing the capacitance from the input to ground.

A feedback pole is created when the feedback around any amplifier is resistive. The parallel resistance and capacitance from the input of the device (usually the inverting input) to AC ground set the frequency of the pole. In many instances the frequency of this pole is much greater than the expected 3 dB frequency of the closed loop gain and consequently there is negligible effect on stability margin. However, if the feedback pole is less than approximately 6 times the expected 3 dB frequency, a lead capacitor should be placed from the output to the input of the op amp. The value of the added capacitor should be such that the RC time constant of this capacitor and the resistance it parallels is greater than or equal to the original feedback pole time constant.

# Typical Applications

## High Speed Current Booster

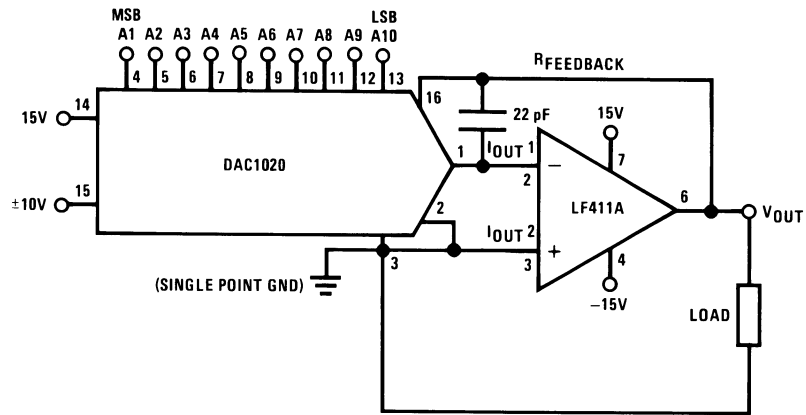


PNP=2N2905  
 NPN=2N2219 unless noted  
 TO-5 heat sinks for Q6-Q7

00565509

Typical Applications (Continued)

10-Bit Linear DAC with No  $V_{OS}$  Adjust



00565532

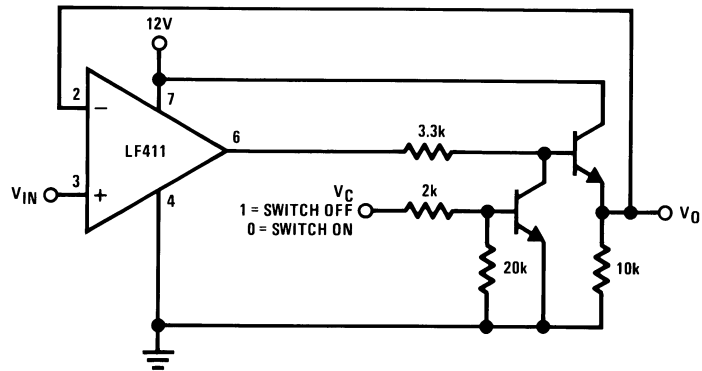
$$V_{OUT} = -V_{REF} \left( \frac{A_1}{2} + \frac{A_2}{4} + \frac{A_3}{8} + \dots + \frac{A_{10}}{1024} \right)$$

$$-10V \leq V_{REF} \leq 10V$$

$$0 \leq V_{OUT} \leq -\frac{1023}{1024} V_{REF}$$

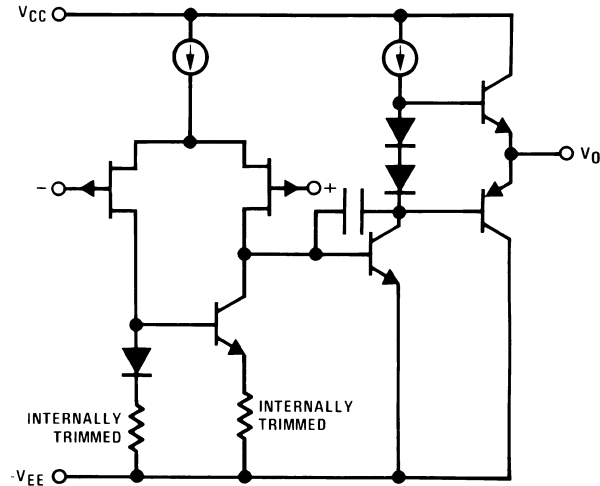
where  $A_N=1$  if the  $A_N$  digital input is high  
 $A_N=0$  if the  $A_N$  digital input is low

Single Supply Analog Switch with Buffered Output



00565533

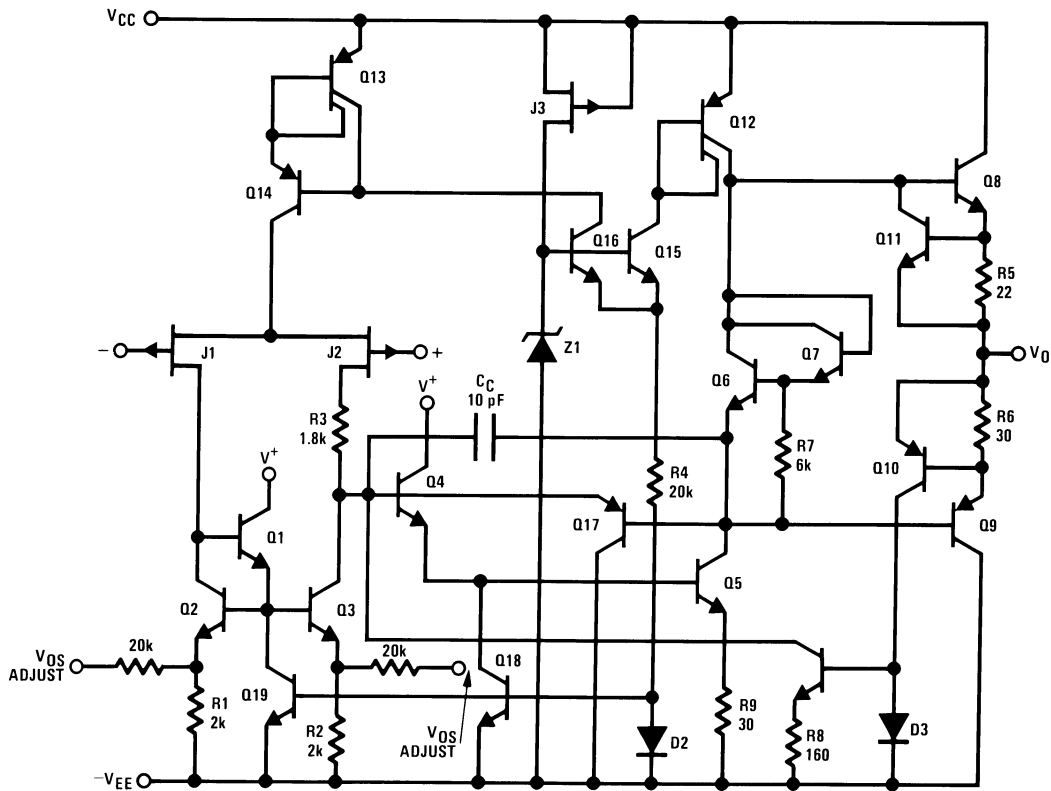
### Simplified Schematic



00565506

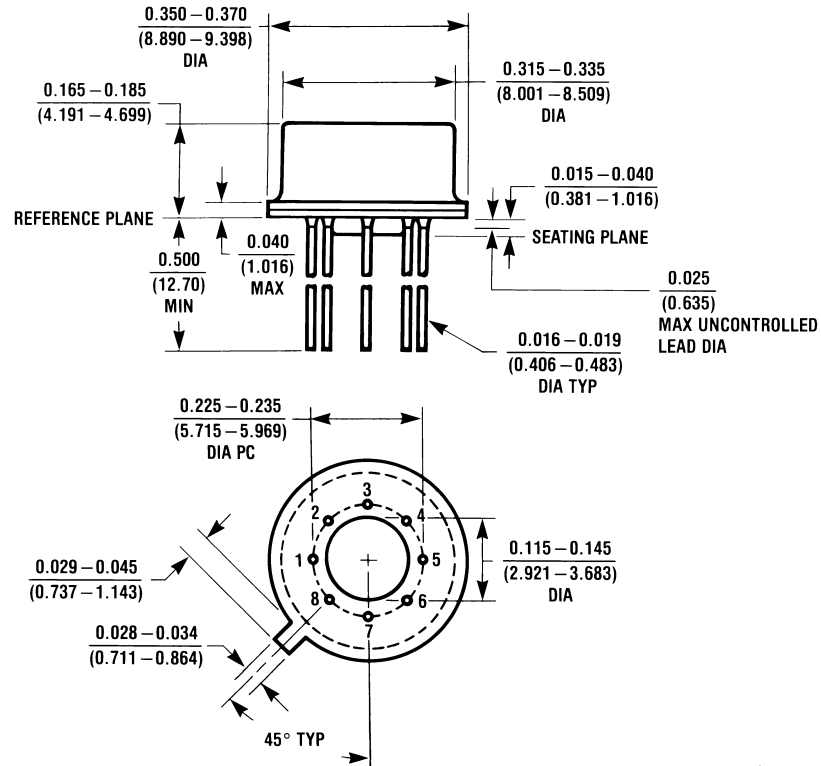
Note 11: Available per JM38510/11904

### Detailed Schematic

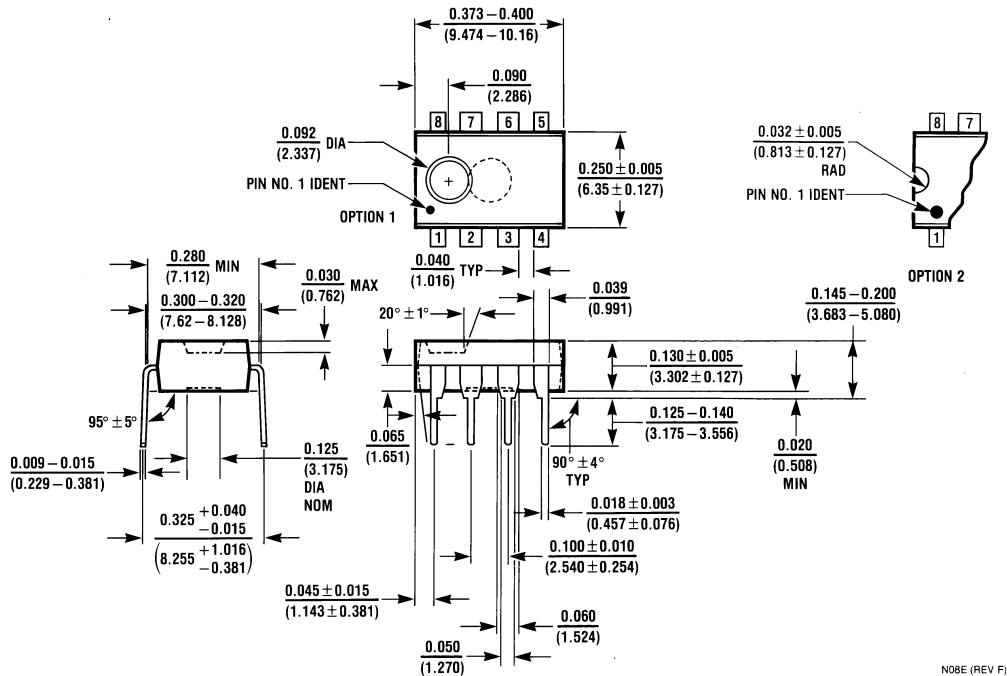


00565534

**Physical Dimensions** inches (millimeters) unless otherwise noted



**Metal Can Package (H)**  
Order Number LF411MH/883 or LF411ACH  
NS Package Number H08A



**Molded Dual-In-Line Package (N)**  
Order Number LF411ACN or LF411CN  
NS Package Number N08E

## Notes

### LIFE SUPPORT POLICY

NATIONAL'S PRODUCTS ARE NOT AUTHORIZED FOR USE AS CRITICAL COMPONENTS IN LIFE SUPPORT DEVICES OR SYSTEMS WITHOUT THE EXPRESS WRITTEN APPROVAL OF THE PRESIDENT AND GENERAL COUNSEL OF NATIONAL SEMICONDUCTOR CORPORATION. As used herein:

- |  |   |
|--|---|
| <p>1. Life support devices or systems are devices or systems which, (a) are intended for surgical implant into the body, or (b) support or sustain life, and whose failure to perform when properly used in accordance with instructions for use provided in the labeling, can be reasonably expected to result in a significant injury to the user.</p> | <p>2. A critical component is any component of a life support device or system whose failure to perform can be reasonably expected to cause the failure of the life support device or system, or to affect its safety or effectiveness.</p> |
|--|---|

### BANNED SUBSTANCE COMPLIANCE

National Semiconductor certifies that the products and packing materials meet the provisions of the Customer Products Stewardship Specification (CSP-9-111C2) and the Banned Substances and Materials of Interest Specification (CSP-9-111S2) and contain no "Banned Substances" as defined in CSP-9-111S2.



**National Semiconductor**  
**Americas Customer**  
**Support Center**  
 Email: [new.feedback@nsc.com](mailto:new.feedback@nsc.com)  
 Tel: 1-800-272-9959

**National Semiconductor**  
**Europe Customer Support Center**  
 Fax: +49 (0) 180-530 85 86  
 Email: [europa.support@nsc.com](mailto:europa.support@nsc.com)  
 Deutsch Tel: +49 (0) 69 9508 6208  
 English Tel: +44 (0) 870 24 0 2171  
 Français Tel: +33 (0) 1 41 91 8790

**National Semiconductor**  
**Asia Pacific Customer**  
**Support Center**  
 Email: [ap.support@nsc.com](mailto:ap.support@nsc.com)

**National Semiconductor**  
**Japan Customer Support Center**  
 Fax: 81-3-5639-7507  
 Email: [jpn.feedback@nsc.com](mailto:jpn.feedback@nsc.com)  
 Tel: 81-3-5639-7560

[www.national.com](http://www.national.com)

## IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

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

TI assumes no liability for applications assistance or customer product design. Customers are responsible for their products and applications using TI components. To minimize the risks associated with customer products and applications, customers should provide adequate design and operating safeguards.

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI to use such products or services or a warranty or endorsement thereof. Use of such information may require a license from a third party under the patents or other intellectual property of the third party, or a license from TI under the patents or other intellectual property of TI.

Reproduction of TI information in TI data books or data sheets is permissible only if reproduction is without alteration and is accompanied by all associated warranties, conditions, limitations, and notices. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

Resale of TI products or services with statements different from or beyond the parameters stated by TI for that product or service voids all express and any implied warranties for the associated TI product or service and is an unfair and deceptive business practice. TI is not responsible or liable for any such statements.

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

### Products

Audio	<a href="http://www.ti.com/audio">www.ti.com/audio</a>
Amplifiers	<a href="http://amplifier.ti.com">amplifier.ti.com</a>
Data Converters	<a href="http://dataconverter.ti.com">dataconverter.ti.com</a>
DLP® Products	<a href="http://www.dlp.com">www.dlp.com</a>
DSP	<a href="http://dsp.ti.com">dsp.ti.com</a>
Clocks and Timers	<a href="http://www.ti.com/clocks">www.ti.com/clocks</a>
Interface	<a href="http://interface.ti.com">interface.ti.com</a>
Logic	<a href="http://logic.ti.com">logic.ti.com</a>
Power Mgmt	<a href="http://power.ti.com">power.ti.com</a>
Microcontrollers	<a href="http://microcontroller.ti.com">microcontroller.ti.com</a>
RFID	<a href="http://www.ti-rfid.com">www.ti-rfid.com</a>
OMAP Mobile Processors	<a href="http://www.ti.com/omap">www.ti.com/omap</a>
Wireless Connectivity	<a href="http://www.ti.com/wirelessconnectivity">www.ti.com/wirelessconnectivity</a>

### Applications

Communications and Telecom	<a href="http://www.ti.com/communications">www.ti.com/communications</a>
Computers and Peripherals	<a href="http://www.ti.com/computers">www.ti.com/computers</a>
Consumer Electronics	<a href="http://www.ti.com/consumer-apps">www.ti.com/consumer-apps</a>
Energy and Lighting	<a href="http://www.ti.com/energy">www.ti.com/energy</a>
Industrial	<a href="http://www.ti.com/industrial">www.ti.com/industrial</a>
Medical	<a href="http://www.ti.com/medical">www.ti.com/medical</a>
Security	<a href="http://www.ti.com/security">www.ti.com/security</a>
Space, Avionics and Defense	<a href="http://www.ti.com/space-avionics-defense">www.ti.com/space-avionics-defense</a>
Transportation and Automotive	<a href="http://www.ti.com/automotive">www.ti.com/automotive</a>
Video and Imaging	<a href="http://www.ti.com/video">www.ti.com/video</a>

TI E2E Community Home Page

[e2e.ti.com](http://e2e.ti.com)

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265  
Copyright © 2011, Texas Instruments Incorporated