



April 1998

## LF411

### Low Offset, Low Drift JFET Input Operational Amplifier

#### General Description

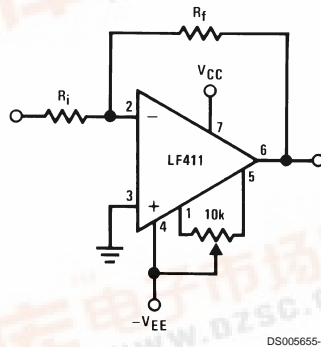
These devices are low cost, high speed, JFET input operational amplifiers with very low input offset voltage and guaranteed input offset voltage drift. They require low supply current yet maintain a large gain bandwidth product and fast slew rate. In addition, well matched high voltage JFET input devices 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  $\text{pA}/\sqrt{\text{Hz}}$
- 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  $A_V=10$ ,  
 $R_L=10\text{k}$ ,  $V_O=20\text{ Vp-p}$ , BW=20 Hz–20 kHz: <0.02%
- Low 1/f noise corner: 50 Hz
- Fast settling time to 0.01%: 2  $\mu\text{s}$

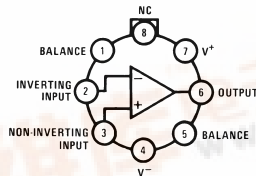
#### Typical Connection



DS005655-1

#### Connection Diagrams

##### Metal Can Package



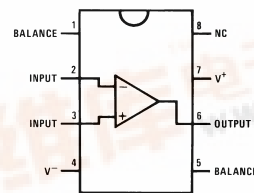
DS005655-5

Note: Pin 4 connected to case.

##### Top View

Order Number LF411ACH  
or LF411MH/883 (Note 1)  
See NS Package Number H08A

##### Dual-In-Line Package



DS005655-7

##### Top View

Order Number LF411ACN,  
LF411CN or LF411MJ/883 (Note 1)  
See NS Package Number N08E or J08A

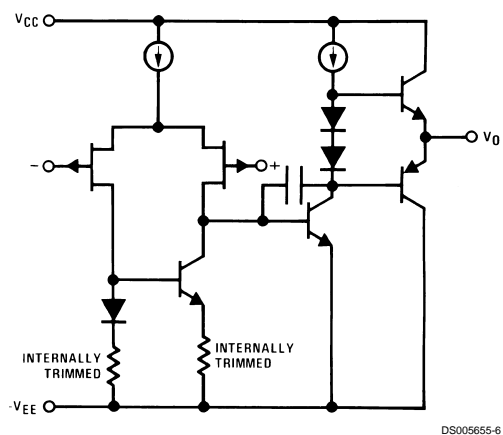
#### Ordering Information

##### LF411XYZ

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



## Simplified Schematic



**Note 1:** Available per JM38510/11904

## Absolute Maximum Ratings (Note 2)

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	$T_{j,max}$	150°C	115°C
Differential Input Voltage	±38V	±30V	$\theta_{JA}$	162°C/W (Still Air)	120°C/W
Input Voltage Range (Note 3)	±19V	±15V	$\theta_{JC}$	65°C/W (400 LF/min Air Flow)	
Output Short Circuit Duration	Continuous	Continuous	Operating Temp. Range	20°C/W	
			Storage Temp. Range	(Note 5)	(Note 5)
			Lead Temp. (Soldering, 10 sec.)	–65°C ≤ $T_A$ ≤ 150°C	–65°C ≤ $T_A$ ≤ 150°C
Power Dissipation (Notes 4, 11)	670 mW	670 mW	ESD Tolerance	260°C	260°C
					Rating to be determined.

## DC Electrical Characteristics (Note 6)

Symbol	Parameter	Conditions	LF411A			LF411			Units
			Min	Typ	Max	Min	Typ	Max	
$V_{OS}$	Input Offset Voltage	$R_S=10\text{ k}\Omega$ , $T_A=25^\circ\text{C}$		0.3	0.5		0.8	2.0	mV
$\Delta V_{OS}/\Delta T$	Average TC of Input Offset Voltage	$R_S=10\text{ k}\Omega$ (Note 7)		7	10		7	20 (Note 7)	$\mu\text{V}/^\circ\text{C}$
$I_{OS}$	Input Offset Current	$V_S=\pm 15\text{V}$ (Notes 6, 8)	$T_J=25^\circ\text{C}$	25	100		25	100	pA
					2			2	nA
					25			25	nA
$I_B$	Input Bias Current	$V_S=\pm 15\text{V}$ (Notes 6, 8)	$T_J=25^\circ\text{C}$	50	200		50	200	pA
			$T_J=70^\circ\text{C}$		4			4	nA
			$T_J=125^\circ\text{C}$		50			50	nA
$R_{IN}$	Input Resistance	$T_J=25^\circ\text{C}$		$10^{12}$			$10^{12}$		$\Omega$
$A_{VOL}$	Large Signal Voltage Gain	$V_S=\pm 15\text{V}$ , $V_O=\pm 10\text{V}$ , $R_L=2\text{k}$ , $T_A=25^\circ\text{C}$	50	200		25	200		V/mV
		Over Temperature	25	200		15	200		V/mV
$V_O$	Output Voltage Swing	$V_S=\pm 15\text{V}$ , $R_L=10\text{k}$	±12	±13.5		±12	±13.5		V
$V_{CM}$	Input Common-Mode Voltage Range		±16	+19.5		±11	+14.5		V
				–16.5			–11.5		V
CMRR	Common-Mode Rejection Ratio	$R_S\leq 10\text{k}$	80	100		70	100		dB
PSRR	Supply Voltage Rejection Ratio	(Note 9)	80	100		70	100		dB
$I_S$	Supply Current			1.8	2.8		1.8	3.4	mA

## AC Electrical Characteristic (Note 6)

Symbol	Parameter	Conditions	LF411A			LF411			Units
			Min	Typ	Max	Min	Typ	Max	
SR	Slew Rate	$V_S=\pm 15\text{V}$ , $T_A=25^\circ\text{C}$	10	15		8	15		V/ $\mu\text{s}$
GBW	Gain-Bandwidth Product	$V_S=\pm 15\text{V}$ , $T_A=25^\circ\text{C}$	3	4		2.7	4		MHz
$e_n$	Equivalent Input Noise Voltage	$T_A=25^\circ\text{C}$ , $R_S=100\Omega$ , $f=1\text{ kHz}$		25			25		$\text{nV}/\sqrt{\text{Hz}}$
$i_n$	Equivalent Input Noise Current	$T_A=25^\circ\text{C}$ , $f=1\text{ kHz}$		0.01			0.01		$\text{pA}/\sqrt{\text{Hz}}$

**Note 2:** "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 3:** Unless otherwise specified the absolute maximum negative input voltage is equal to the negative power supply voltage.

## AC Electrical Characteristic (Note 6) (Continued)

**Note 4:** For operating at elevated temperature, these devices must be derated based on a thermal resistance of  $\theta_{JA}$ .

**Note 5:** 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 6:** 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 7:** 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 8:** 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.

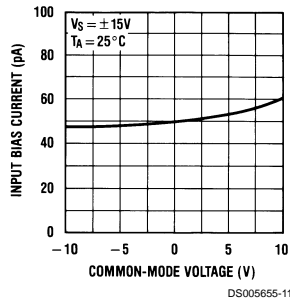
**Note 9:** Supply voltage rejection ratio is measured for both supply magnitudes increasing or decreasing simultaneously in accordance with common practice, from  $\pm 15\text{V}$  to  $\pm 5\text{V}$  for the LF411 and from  $\pm 20\text{V}$  to  $\pm 5\text{V}$  for the LF411A.

**Note 10:** RETS 411X for LF411MH and LF411MJ military specifications.

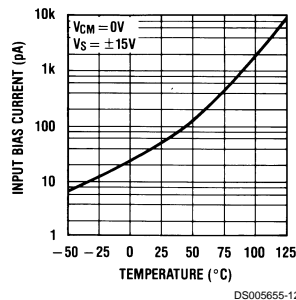
**Note 11:** Max. Power Dissipation is defined by the package characteristics. Operating the part near the Max. Power Dissipation may cause the part to operate outside guaranteed limits.

## Typical Performance Characteristics

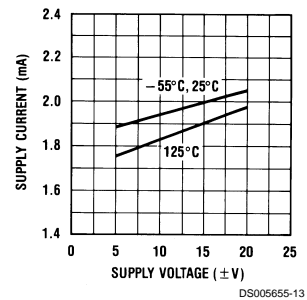
Input Bias Current



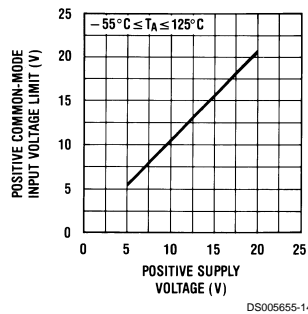
Input Bias Current



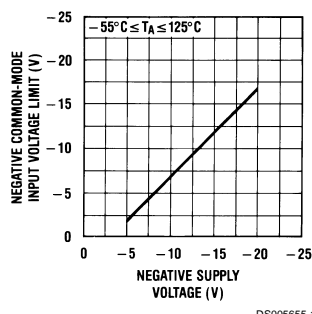
Supply Current



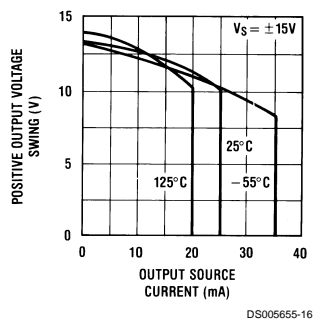
Positive Common-Mode Input Voltage Limit



Negative Common-Mode Input Voltage Limit

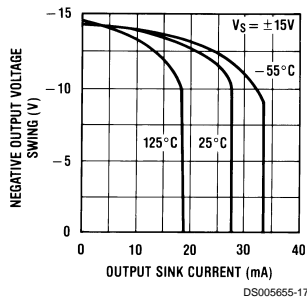


Positive Current Limit

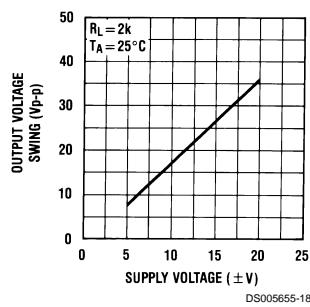


## Typical Performance Characteristics (Continued)

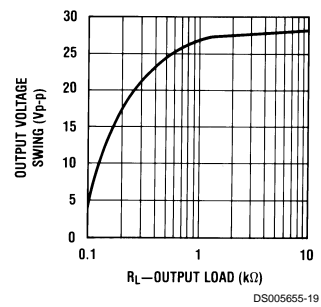
**Negative Current Limit**



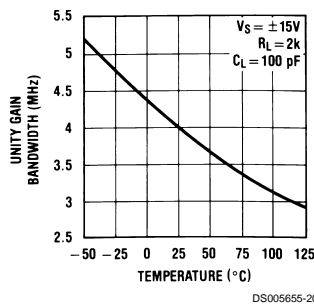
**Output Voltage Swing**



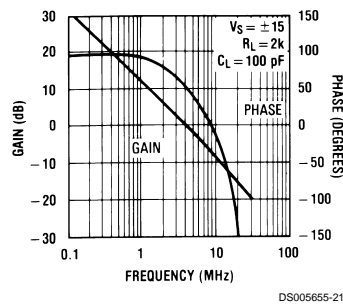
**Output Voltage Swing**



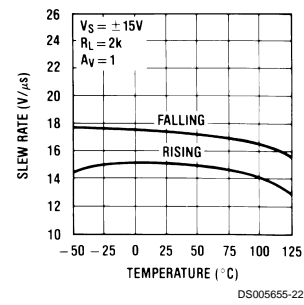
**Gain Bandwidth**



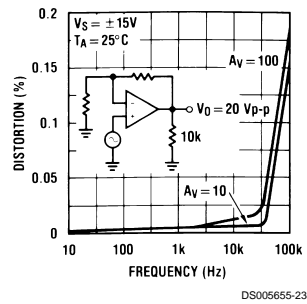
**Bode Plot**



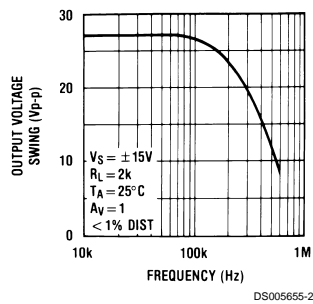
**Slew Rate**



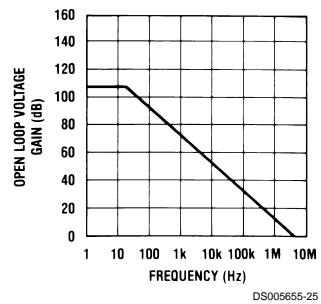
**Distortion vs Frequency**



**Undistorted Output Voltage Swing**

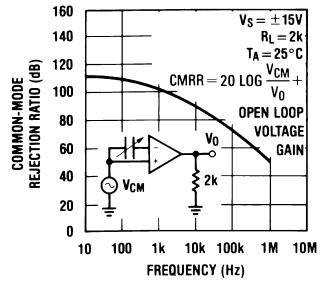


**Open Loop Frequency Response**



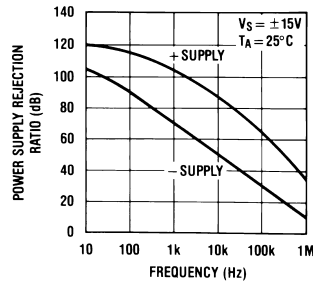
## Typical Performance Characteristics (Continued)

**Common-Mode Rejection Ratio**



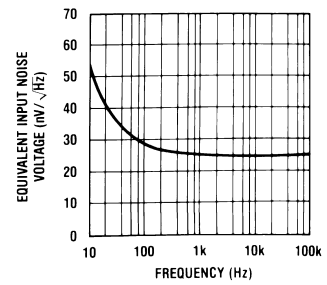
DS005655-26

**Power Supply Rejection Ratio**



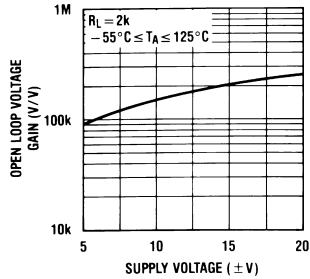
DS005655-27

**Equivalent Input Noise Voltage**



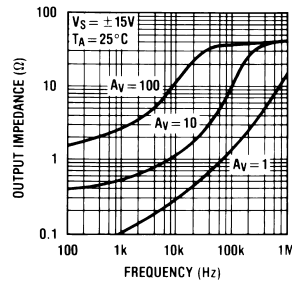
DS005655-28

**Open Loop Voltage Gain**



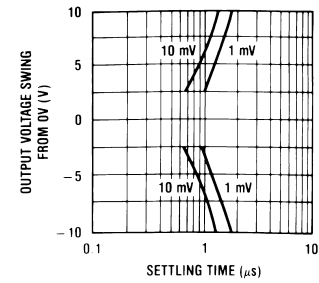
DS005655-29

**Output Impedance**



DS005655-30

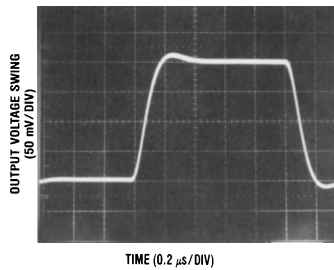
**Inverter Settling Time**



DS005655-31

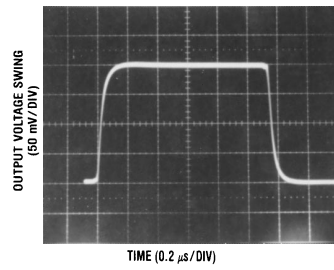
## Pulse Response $R_L = 2k\Omega$ , $C_L = 10pF$

**Small Signal Inverting**



DS005655-39

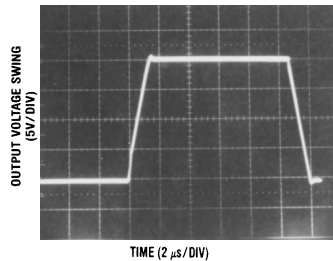
**Small Signal Non-Inverting**



DS005655-40

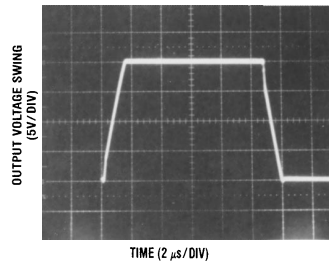
## Pulse Response $R_L=2\text{ k}\Omega$ , $C_L=10\text{ pF}$ (Continued)

Large Signal Inverting



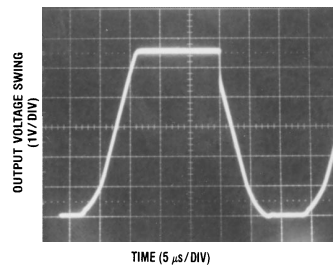
DS005655-41

Large Signal Non-Inverting



DS005655-42

Current Limit ( $R_L=100\Omega$ )



DS005655-43

## 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.

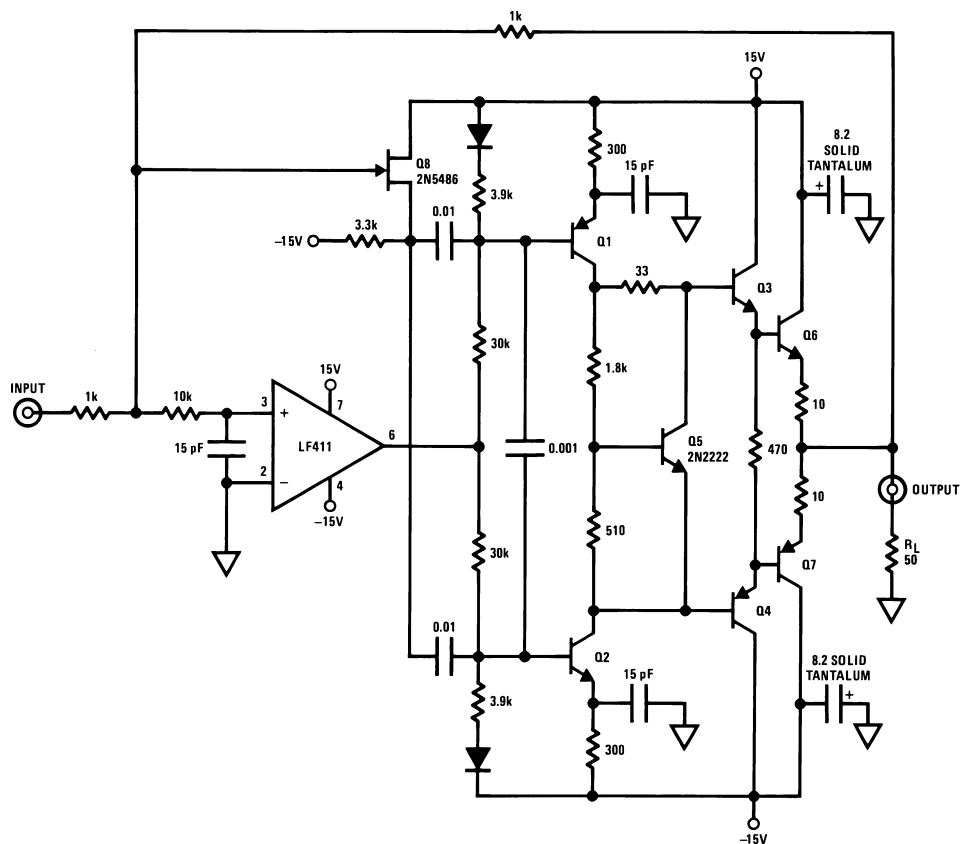
Precautions should be taken to ensure that the power supply for the integrated circuit never becomes reversed in polarity or that the unit is not inadvertently installed backwards in a socket as an unlimited current surge through the resulting forward diode within the IC could cause fusing of the internal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

### High Speed Current Booster

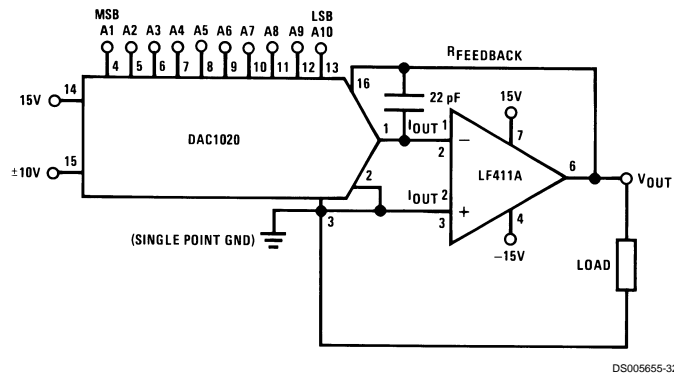


PNP=2N2905  
NPN=2N2219 unless noted  
TO-5 heat sinks for Q6-Q7

DS005655-9

## Typical Applications (Continued)

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



DS005655-32

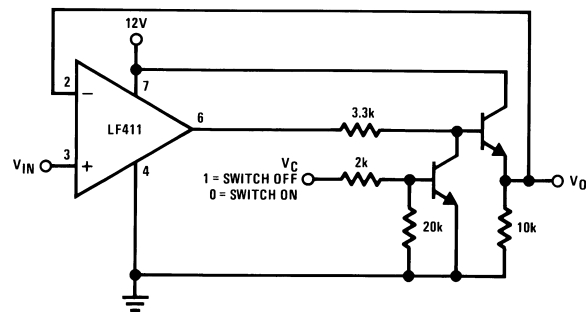
$$V_{OUT} = -V_{REF} \left( \frac{A_1}{2} + \frac{A_2}{4} + \frac{A_3}{8} + \dots + \frac{A_{10}}{1024} \right)$$

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

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

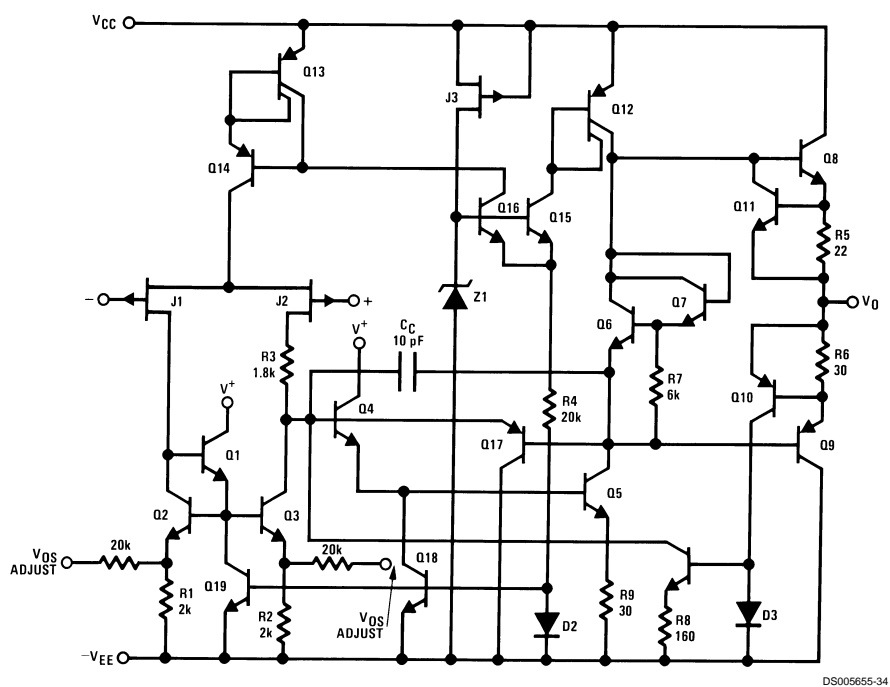
where  $A_N=1$  if the  $A_N$  digital input is high  
 $A_N=0$  if the  $A_N$  digital input is low

Single Supply Analog Switch with Buffered Output

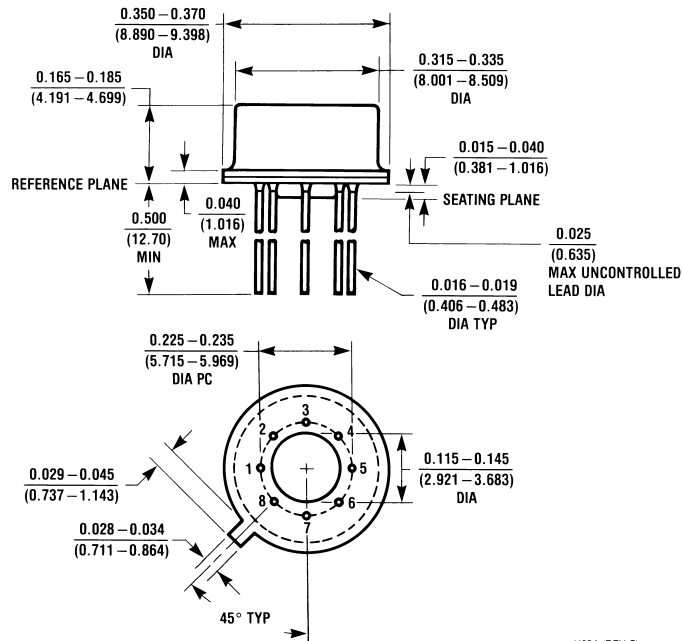


DS005655-33

## Detailed Schematic

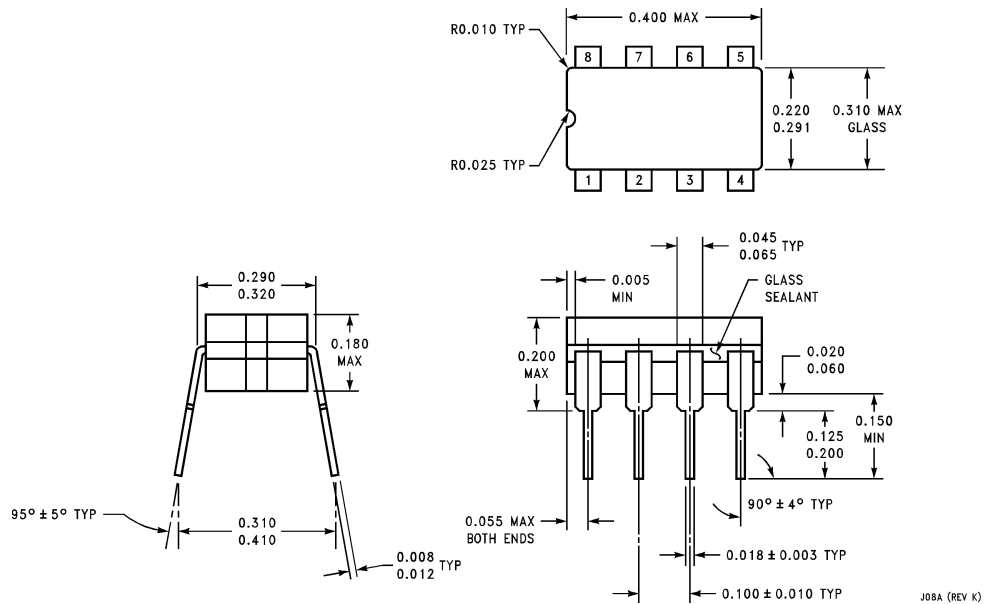


**Physical Dimensions** inches (millimeters) unless otherwise noted



H08A (REV C)

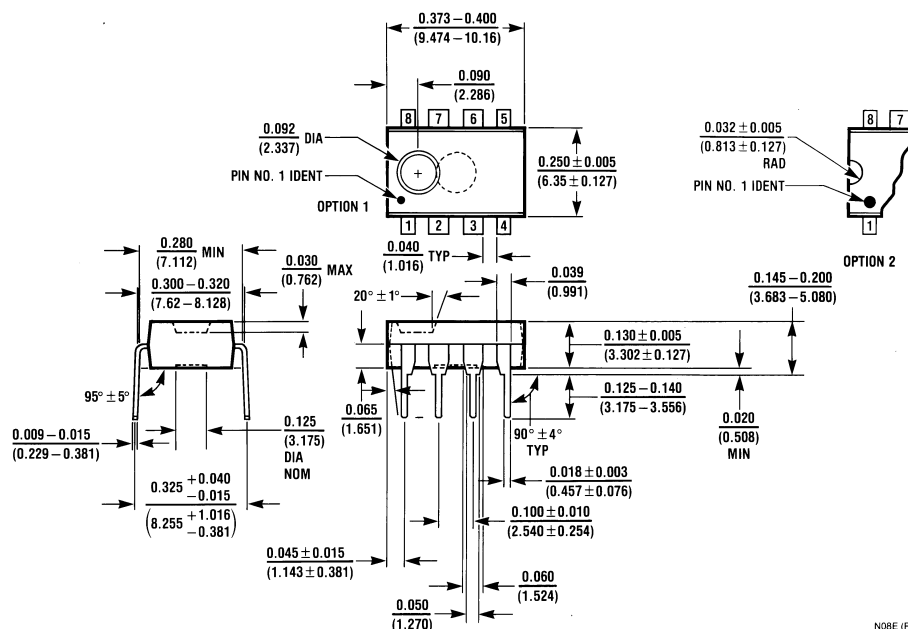
**Metal Can Package (H)**  
Order Number LF411MH/883 or LF411ACH  
NS Package Number H08A



J08A (REV K)

**Ceramic Dual-In-Line Package (J)**  
Order Number LF411MJ/883  
NS Package Number J08A

# Physical Dimensions inches (millimeters) unless otherwise noted (Continued)



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

N08E (REV F)

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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.



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