

## LF356-MIL JFET入力オペアンプ

### 1 特長

#### • 利点

- 高価なハイブリッドおよびモジュールFETオペアンプの代替
- 堅牢なJFETにより、MOSFET入力デバイスと比較してブローアウトなしの動作
- ソースのインピーダンスが高くても低くても、低ノイズ・アプリケーション用に最適 - 非常に低い1/fコーナー
- ほとんどのモノリシック・アンプと異なり、オフセット調整によりドリフトや同相除去の劣化なし
- 新しい出力段により、安定性の問題なしに大きな容量性負荷(5,000pF)を使用可能
- 内部補償および大きな差動入力電圧能力

#### • 共通機能

- 低い入力バイアス電流: 30pA
- 低い入力オフセット電流: 3pA
- 高い入力インピーダンス:  $10^{12}\Omega$
- 低い入力ノイズ電流:  $0.01\text{pA}/\sqrt{\text{Hz}}$
- 高い同相除去率: 100dB
- 大きなDC電圧ゲイン: 106dB

#### • 非共通機能

- 非常に短いセトリング時間: 0.01%まで $1.5\mu\text{s}$
- 高いスルー・レート:  $12\text{V}/\mu\text{s}$
- 広いゲイン帯域幅: 5MHz
- 低い入力ノイズ電圧:  $12\text{nV}/\sqrt{\text{Hz}}$

### 2 アプリケーション

- 高精度の高速インテグレータ
- 高速D/AおよびA/Dコンバータ
- 高インピーダンスのバッファ
- 広帯域、低ノイズ、低ドリフト係数のアンプ
- 対数アンプ
- フォトセル・アンプ
- サンプル・アンド・ホールド回路

### 3 概要

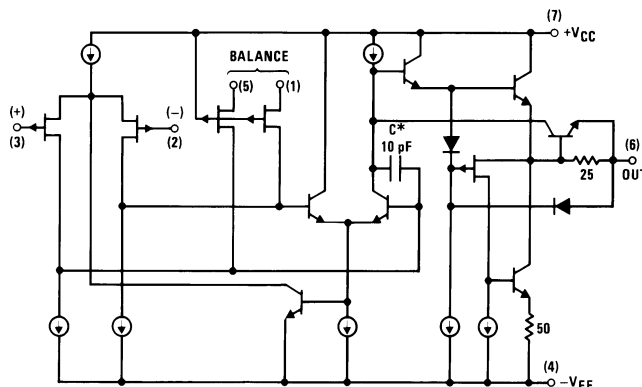
LF356-MILデバイスは、適切に一致した高電圧JFETを、標準バイポーラ・トランジスタと同じチップに組み入れた(BI-FET™テクノロジー)、最初のモノリシックJFET入力オペアンプです。これらのアンプは低い入力バイアス電流とオフセット電流、低いオフセット電圧とオフセット電圧ドリフト係数を特長とし、オフセット調整によってドリフト係数や同相除去が劣化しません。また、これらのデバイスは高いスルー・レート、広い帯域幅、非常に短いセトリング時間、低い電圧および電流ノイズ、低い1/fノイズ・コーナーも実現するよう設計されています。

#### 製品情報<sup>(1)</sup>

型番	パッケージ	本体サイズ(公称)
LF356-MIL	SOIC (8)	4.90mm×3.91mm
	TO-CAN (8)	9.08mm×9.08mm
	PDIP (8)	9.81mm×6.35mm

(1) 提供されているすべてのパッケージについては、巻末の注文情報を参照してください。

#### 概略回路図



LF357シリーズで3pF

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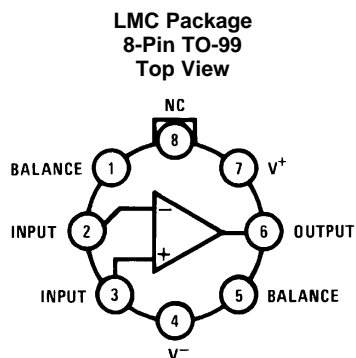
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## 4 改訂履歴

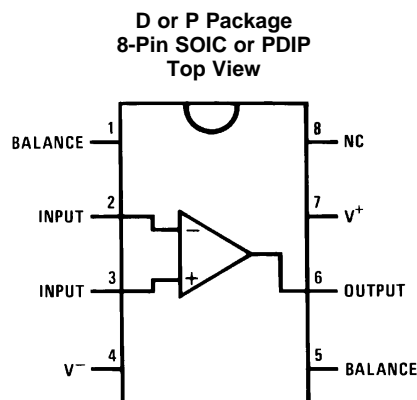
資料番号末尾の英字は改訂を表しています。その改訂履歴は英語版に準じています。

日付	改訂内容	注
2017年6月	*	初版

## 5 Pin Configuration and Functions



Available per JM38510/11401 or  
JM38510/11402



### Pin Functions

PIN		I/O	DESCRIPTION
NAME	NO.		
BALANCE	1, 5	I	Balance for input offset voltage
+INPUT	3	I	Noninverting input
-INPUT	2	I	Inverting input
NC	8	—	No connection
OUTPUT	6	O	Output
V+	7	—	Positive power supply
V-	4	—	Negative power supply

## 6 Specifications

### 6.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted) <sup>(1)(2)(3)</sup>

			MIN	MAX	UNIT
Supply voltage				±18	V
Differential input voltage				±30	V
Input voltage <sup>(4)</sup>				±16	V
Output short circuit duration			Continuous		—
T <sub>JMAX</sub>	LMC package		115		°C
	P package		100		
	D package		100		
Soldering information (lead temp.)	TO-99 package	Soldering (10 sec.)	300		°C
	PDIP package	Soldering (10 sec.)	260		
	SOIC package	Vapor phase (60 sec.)	215		
		Infrared (15 sec.)	220		
Storage temperature, T <sub>stg</sub>			-65	150	°C

- (1) Stresses beyond those listed under *Absolute Maximum Ratings* may cause permanent damage to the device. These are stress ratings only, which do not imply functional operation of the device at these or any other conditions beyond those indicated under *Recommended Operating Conditions*. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
- (2) The maximum power dissipation for these devices must be derated at elevated temperatures and is dictated by T<sub>JMAX</sub>, θ<sub>JA</sub>, and the ambient temperature, T<sub>A</sub>. The maximum available power dissipation at any temperature is P<sub>D</sub> = (T<sub>JMAX</sub> - T<sub>A</sub>) / θ<sub>JA</sub> or the 25°C P<sub>DMAX</sub>, whichever is less.
- (3) If Military/Aerospace specified devices are required, contact the TI Sales Office/Distributors for availability and specifications.
- (4) Unless otherwise specified the absolute maximum negative input voltage is equal to the negative power supply voltage.

## 6.2 ESD Ratings

		VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human body model (HBM), per ANSI/ESDA/JEDEC JS-001 <sup>(1)(2)</sup>	±1000 V

- (1) JEDEC document JEP155 states that 500-V HBM allows safe manufacturing with a standard ESD control process.  
 (2) 100 pF discharged through 1.5-k $\Omega$  resistor

## 6.3 Recommended Operating Conditions

over operating free-air temperature range (unless otherwise noted)

	MIN	NOM	MAX	UNIT
Supply voltage, $V_S$			±15	V
$T_A$	0	$T_A$	70	°C

## 6.4 Thermal Information

THERMAL METRIC <sup>(1)</sup>	LF356-MIL		UNIT
	D (SOIC)	P (PDIP)	
	8 PINS	8 PINS	
$R_{\theta JA}$	Junction-to-ambient thermal resistance		°C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance		°C/W
$R_{\theta JB}$	Junction-to-board thermal resistance		°C/W
$\psi_{JT}$	Junction-to-top characterization parameter		°C/W
$\psi_{JB}$	Junction-to-board characterization parameter		°C/W

- (1) For more information about traditional and new thermal metrics, see the [Semiconductor and IC Package Thermal Metrics](#) application report.

## 6.5 AC Electrical Characteristics, $T_A = T_J = 25^\circ\text{C}$ , $V_S = \pm 15\text{ V}$

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
SR	Slew Rate	$A_V = 1$		12		V/ $\mu\text{s}$
GBW	Gain Bandwidth Product			5		MHz
$t_s$	Settling Time to 0.01% <sup>(1)</sup>			1.5		$\mu\text{s}$
$e_n$	Equivalent Input Noise Voltage	$R_S = 100\ \Omega$	$f = 100\ \text{Hz}$	15		nV/ $\sqrt{\text{Hz}}$
			$f = 1000\ \text{Hz}$	12		nV/ $\sqrt{\text{Hz}}$
$i_n$	Equivalent Input Current Noise	$f = 100\ \text{Hz}$		0.01		pA/ $\sqrt{\text{Hz}}$
			$f = 1000\ \text{Hz}$		0.01	
$C_{IN}$	Input Capacitance			3		pF

- (1) Settling time is defined here, for a unity gain inverter connection using 2-k $\Omega$  resistors for the LF15x. It is the time required for the error voltage (the voltage at the inverting input pin on the amplifier) to settle to within 0.01% of its final value from the time a 10-V step input is applied to the inverter. For the LF357,  $A_V = -5$ , the feedback resistor from output to input is 2 k $\Omega$  and the output step is 10 V (See [Settling Time Test Circuit](#)).

## 6.6 DC Electrical Characteristics, $T_A = T_J = 25^\circ\text{C}$ , $V_S = \pm 15\text{ V}$

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Supply current			5	10	mA

## 6.7 DC Electrical Characteristics

See <sup>(1)</sup>

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
V <sub>OS</sub>	Input offset voltage	R <sub>S</sub> = 50 Ω	T <sub>A</sub> = 25°C		3	10	mV
			Over temperature			13	
ΔV <sub>OS</sub> /ΔT	Average TC of input offset voltage	R <sub>S</sub> = 50 Ω			5		μV/°C
ΔTC/ΔV <sub>OS</sub>	Change in average TC with V <sub>OS</sub> adjust	R <sub>S</sub> = 50 Ω <sup>(2)</sup>			0.5		μV/°C per mV
I <sub>OS</sub>	Input offset current	T <sub>J</sub> = 25°C <sup>(1) (3)</sup>			3	50	pA
		T <sub>J</sub> ≤ T <sub>HIGH</sub>				2	nA
I <sub>B</sub>	Input bias current	T <sub>J</sub> = 25°C <sup>(1) (3)</sup>			30	200	pA
		T <sub>J</sub> ≤ T <sub>HIGH</sub>				8	nA
R <sub>IN</sub>	Input resistance	T <sub>J</sub> = 25°C			10 <sup>12</sup>		Ω
A <sub>VOL</sub>	Large signal voltage gain	V <sub>S</sub> = ±15 V, V <sub>O</sub> = ±10 V, R <sub>L</sub> = 2 kΩ	T <sub>A</sub> = 25°C		25	200	V/mV
			Over temperature			15	
V <sub>O</sub>	Output voltage swing	V <sub>S</sub> = ±15 V, R <sub>L</sub> = 10 kΩ			±12	±13	V
		V <sub>S</sub> = ±15 V, R <sub>L</sub> = 2 kΩ			±10	±12	
V <sub>CM</sub>	Input common-mode voltage range	V <sub>S</sub> = ±15 V	V <sub>CM, High</sub>		10	15.1	V
			V <sub>CM, Low</sub>			-12	
CMRR	Common-mode rejection ratio				80	100	dB
PSRR	Supply voltage rejection ratio <sup>(1)</sup>				80	100	dB

(1) Unless otherwise stated, these test conditions apply:

Supply Voltage, V <sub>S</sub>	V <sub>S</sub> = ±15 V
T <sub>A</sub>	0°C ≤ T <sub>A</sub> ≤ +70°C
T <sub>HIGH</sub>	+70°C

and V<sub>OS</sub>, I<sub>B</sub> and I<sub>OS</sub> are measured at V<sub>CM</sub> = 0.

- (2) The Temperature Coefficient of the adjusted input offset voltage changes only a small amount (0.5 μV/°C typically) for each mV of adjustment from its original unadjusted value. Common-mode rejection and open-loop voltage gain are also unaffected by offset adjustment.
- (3) The input bias currents are junction leakage currents which approximately double for every 10°C increase in the junction temperature, T<sub>J</sub>. 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<sub>d</sub>. T<sub>J</sub> = T<sub>A</sub> + θ<sub>JA</sub> P<sub>d</sub> where θ<sub>JA</sub> 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.
- (1) Supply Voltage Rejection is measured for both supply magnitudes increasing or decreasing simultaneously, in accordance with common practice.

## 6.8 Power Dissipation Ratings

		MIN	MAX	UNIT
Power Dissipation at T <sub>A</sub> = 25°C <sup>(1) (2)</sup>	LMC Package (Still Air)		400	mW
	LMC Package (400 LF/Min Air Flow)		1000	
	P Package		670	
	D Package		380	

- (1) The maximum power dissipation for these devices must be derated at elevated temperatures and is dictated by T<sub>JMAX</sub>, θ<sub>JA</sub>, and the ambient temperature, T<sub>A</sub>. The maximum available power dissipation at any temperature is P<sub>D</sub> = (T<sub>JMAX</sub> - T<sub>A</sub>) / θ<sub>JA</sub> or the 25°C P<sub>dMAX</sub>, whichever is less.
- (2) Maximum power dissipation is defined by the package characteristics. Operating the part near the maximum power dissipation may cause the part to operate outside specified limits.

## 6.9 Typical Characteristics

### 6.9.1 Typical AC Performance Characteristics

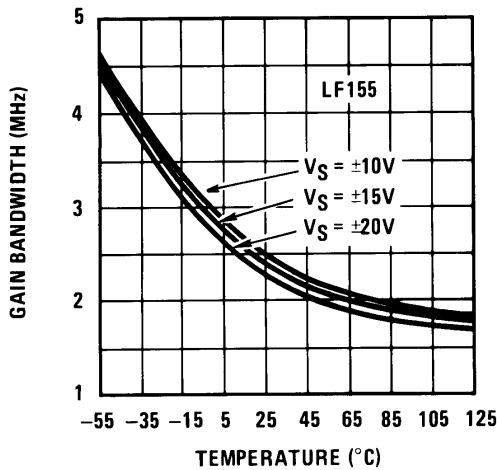


Figure 1. Gain Bandwidth

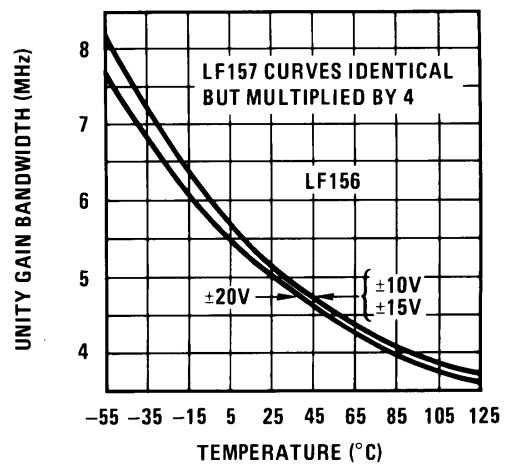


Figure 2. Gain Bandwidth

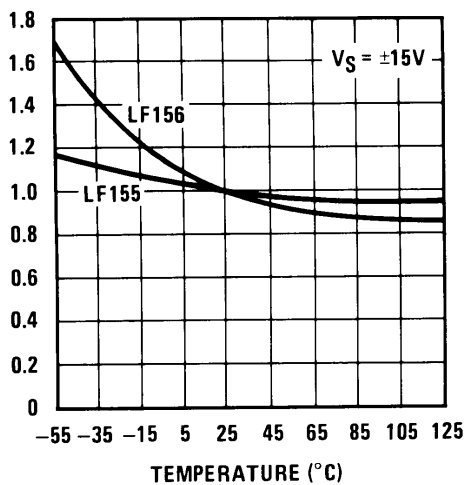


Figure 3. Normalized Slew Rate

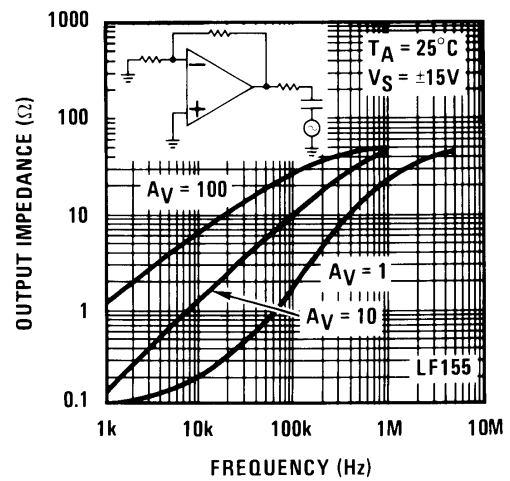


Figure 4. Output Impedance

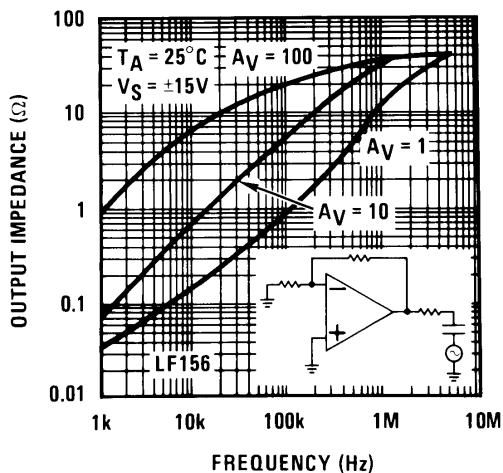


Figure 5. Output Impedance

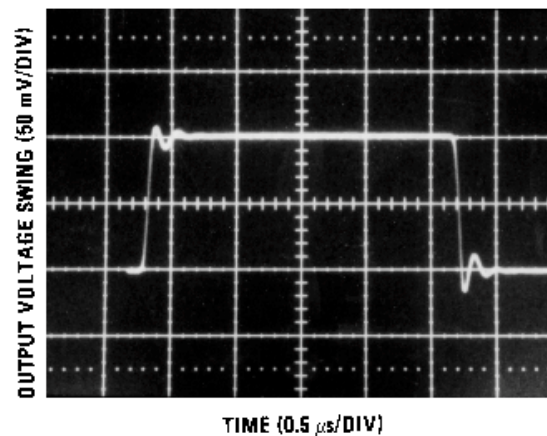


Figure 6. LF155 Small Signal Pulse Response,  $A_V = +1$

Typical AC Performance Characteristics (continued)

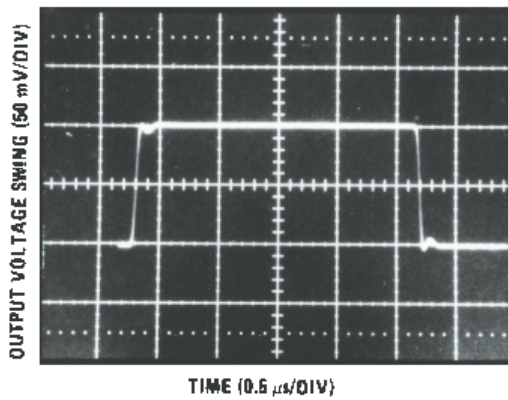


Figure 7. LF156 Small Signal Pulse Response,  $A_V = +1$

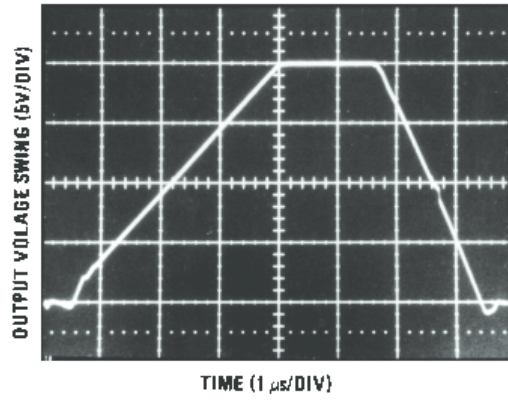


Figure 8. LF155 Large Signal Pulse Response,  $A_V = +1$

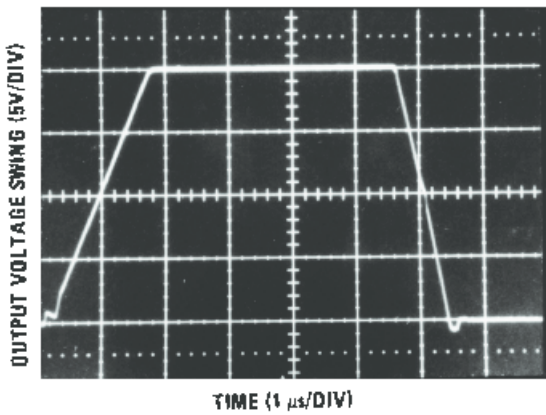


Figure 9. LF156 Large Signal Puls Response,  $A_V = +1$

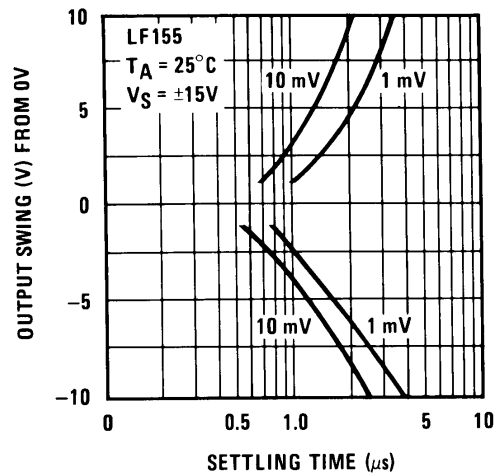


Figure 10. Inverter Settling Time

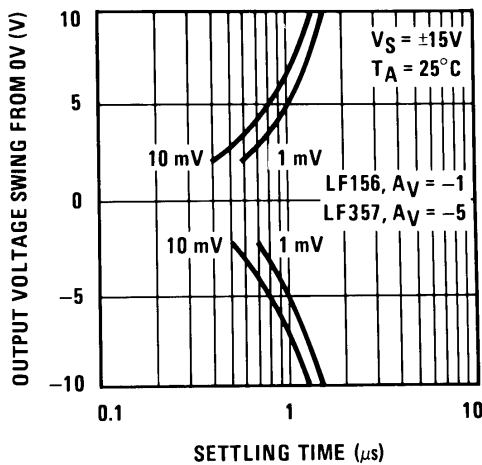


Figure 11. Inverter Settling Time

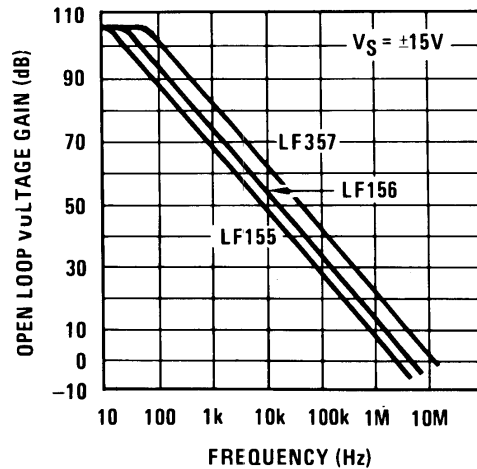


Figure 12. Open-Loop Frequency Response

Typical AC Performance Characteristics (continued)

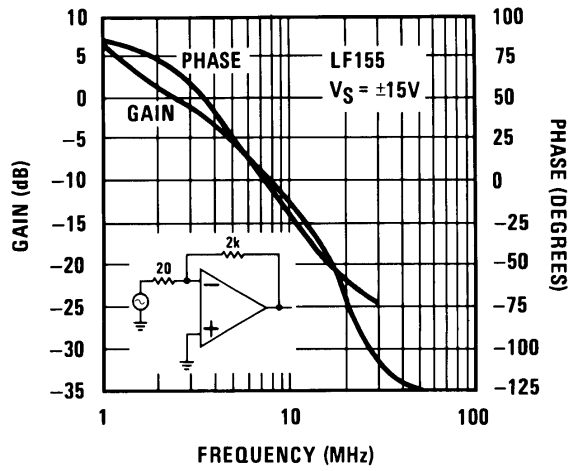


Figure 13. Bode Plot

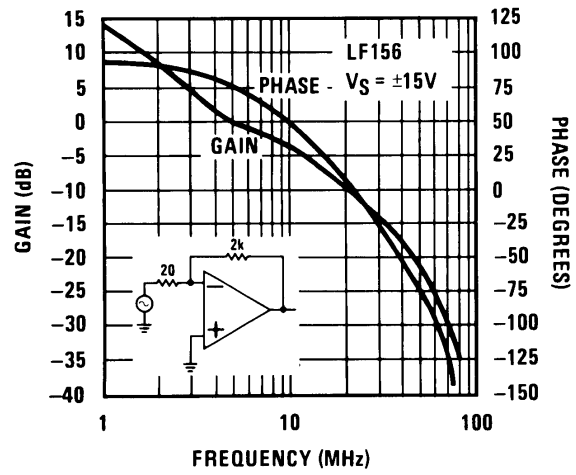


Figure 14. Bode Plot

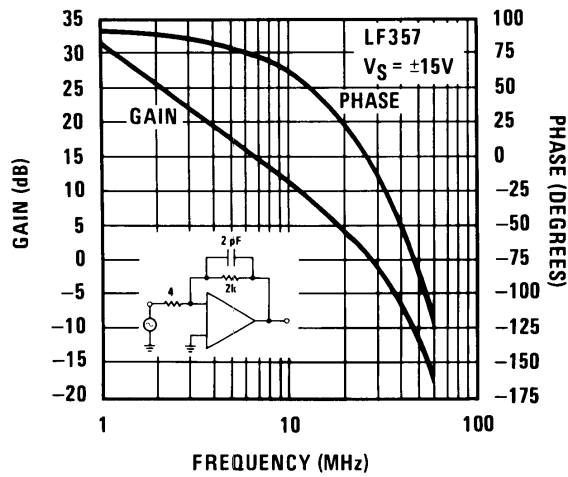


Figure 15. Bode Plot

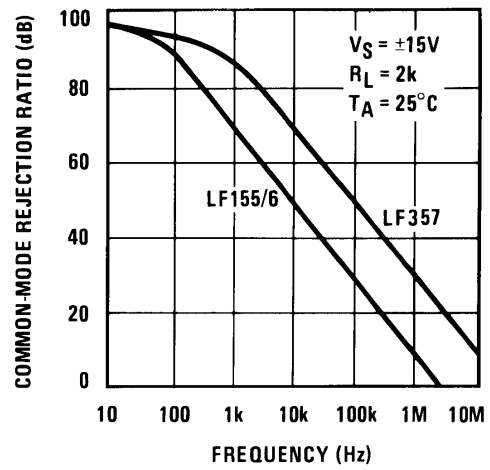


Figure 16. Common-Mode Rejection Ratio

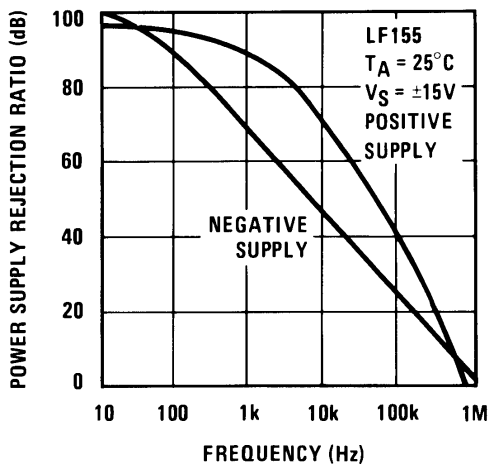


Figure 17. Power Supply Rejection Ratio

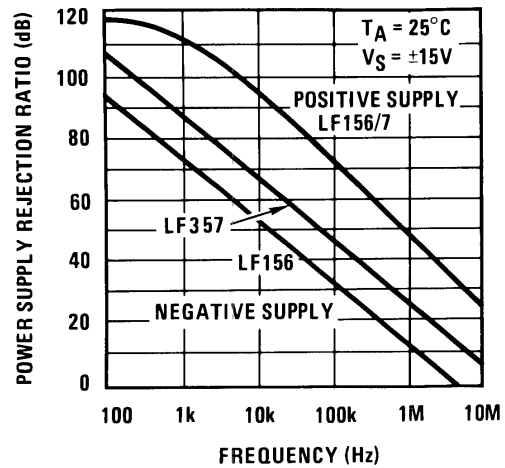


Figure 18. Power Supply Rejection Ratio

Typical AC Performance Characteristics (continued)

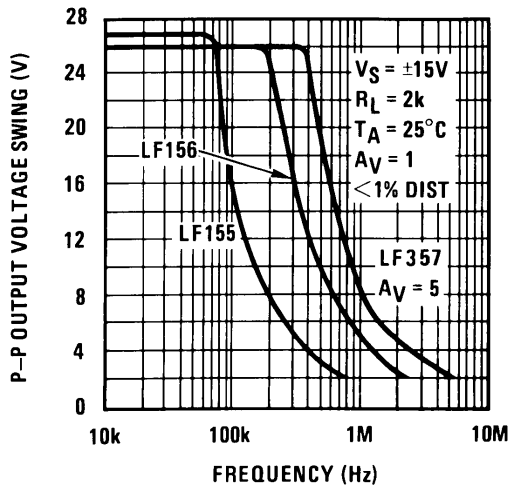


Figure 19. Undistorted Output Voltage Swing

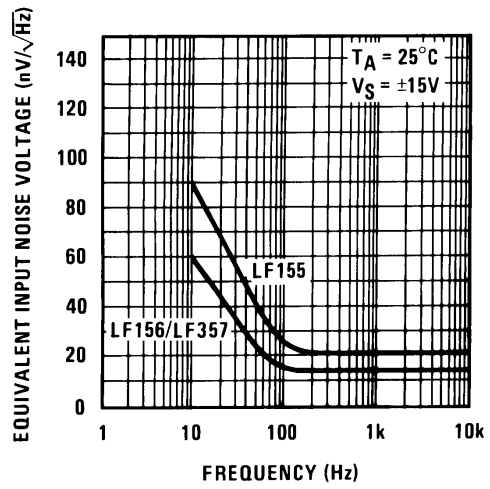


Figure 20. Equivalent Input Noise Voltage

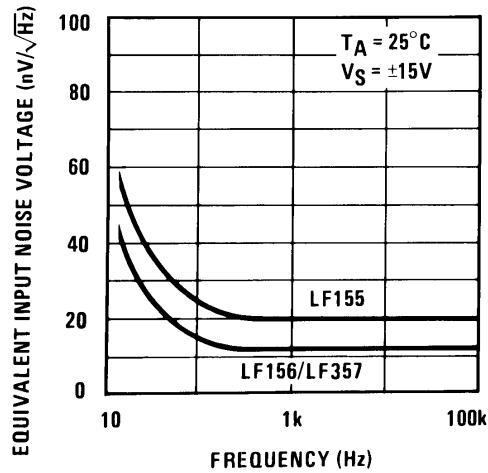


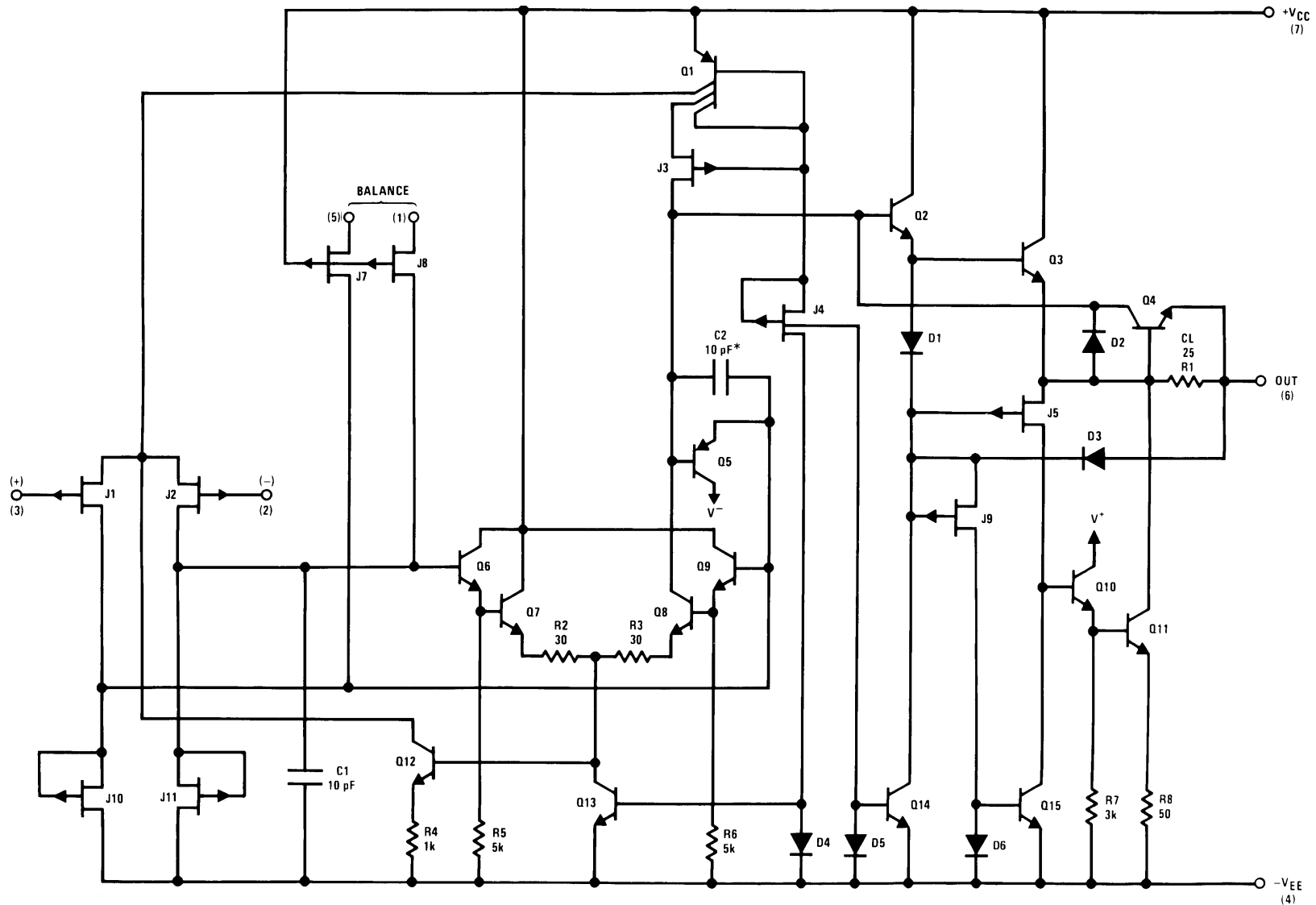
Figure 21. Equivalent Input Noise Voltage (Expanded Scale)

## 7 Detailed Description

### 7.1 Overview

These are the first monolithic JFET input operational amplifiers to incorporate well matched, high voltage JFETs on the same chip with standard bipolar transistors (BI-FET Technology). These amplifiers feature low input bias and offset currents, as well as low offset voltage and offset voltage drift, coupled with offset adjust which does not degrade drift or common-mode rejection. These devices can replace expensive hybrid and module FET operational amplifiers. Designed for low voltage and current noise and a low 1/f noise corner, these devices are excellent for low noise applications using either high or low source impedance.

7.2 Functional Block Diagram



\*C = 3 pF in LF357 series.

Figure 22. Detailed Schematic

## 7.3 Feature Description

### 7.3.1 Large Differential Input Voltage

These are operational amplifiers with JFET input devices. 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.

### 7.3.2 Large Common-Mode Input Voltage

These amplifiers will operate with the common-mode input voltage equal to the positive supply. In fact, the common-mode voltage can exceed the positive supply by approximately 100 mV independent of supply voltage and over the full operating temperature range. The positive supply can therefore be used as a reference on an input as, for example, in a supply current monitor and/or limiter.

## 7.4 Device Functional Modes

The LF356-MIL has a single functional mode and operates according to the conditions listed in the [Recommended Operating Conditions](#).

## 8 Application and Implementation

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### NOTE

Information in the following applications sections is not part of the TI component specification, and TI does not warrant its accuracy or completeness. TI's customers are responsible for determining suitability of components for their purposes. Customers should validate and test their design implementation to confirm system functionality.

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### 8.1 Application Information

These are op amps with JFET input devices. 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 will be forced to a high state.

These amplifiers will operate with the common-mode input voltage equal to the positive supply. In fact, the common-mode voltage can exceed the positive supply by approximately 100 mV independent of supply voltage and over the full operating temperature range. The positive supply can therefore be used as a reference on an input as, for example, in a supply current monitor and/or limiter.

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.

All of the bias currents in these amplifiers are set by FET current sources. The drain currents for the amplifiers are therefore essentially independent of supply voltage.

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 six 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.

## 8.2 Typical Application

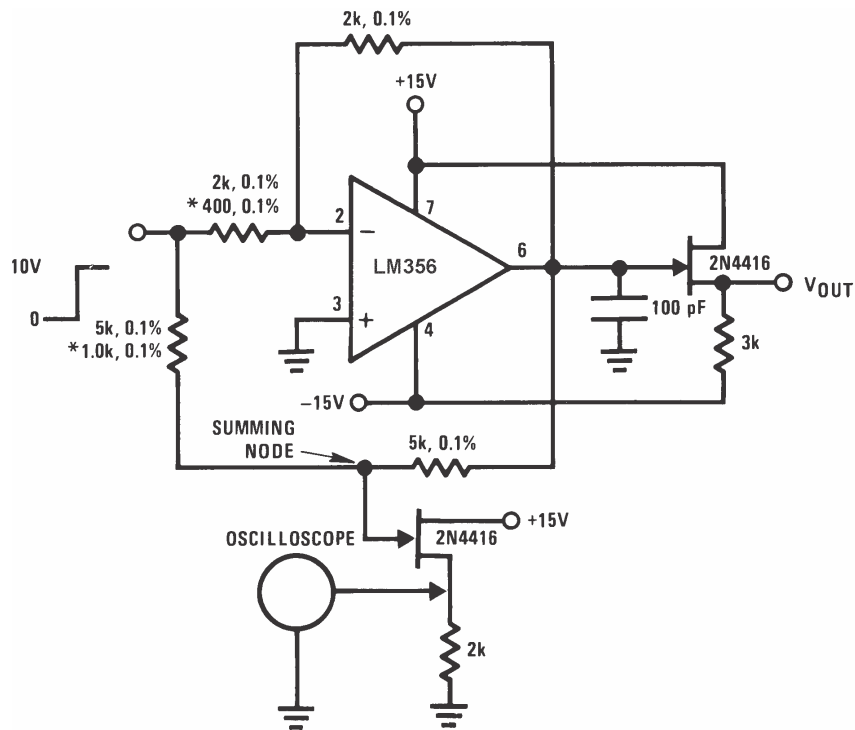


Figure 23. Settling Time Test Circuit

### 8.2.1 Design Requirements

Settling time is tested with the LF35x connected as unity gain inverter and LF357 connected for  $A_V = -5$

### 8.2.2 Detailed Design Procedure

Connect the circuit components as shown in Figure 23. In particular, use FET to isolate the probe capacitance.

Apply a 10-V step function to the input.

Use an oscilloscope to probe the circuit as shown in Figure 23.

### 8.2.3 Application Curve

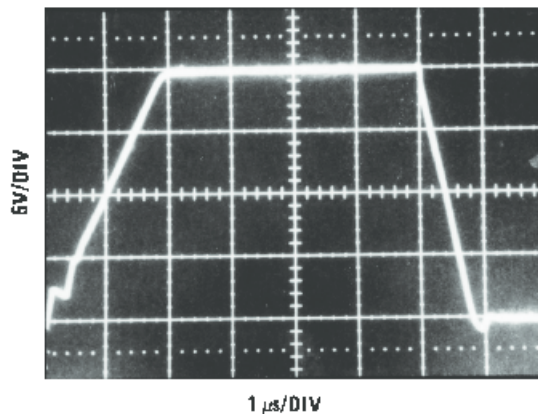


Figure 24. Large Signal Inverter Output,  $V_{OUT}$  (from Settling Time Circuit)

### 8.3 System Examples

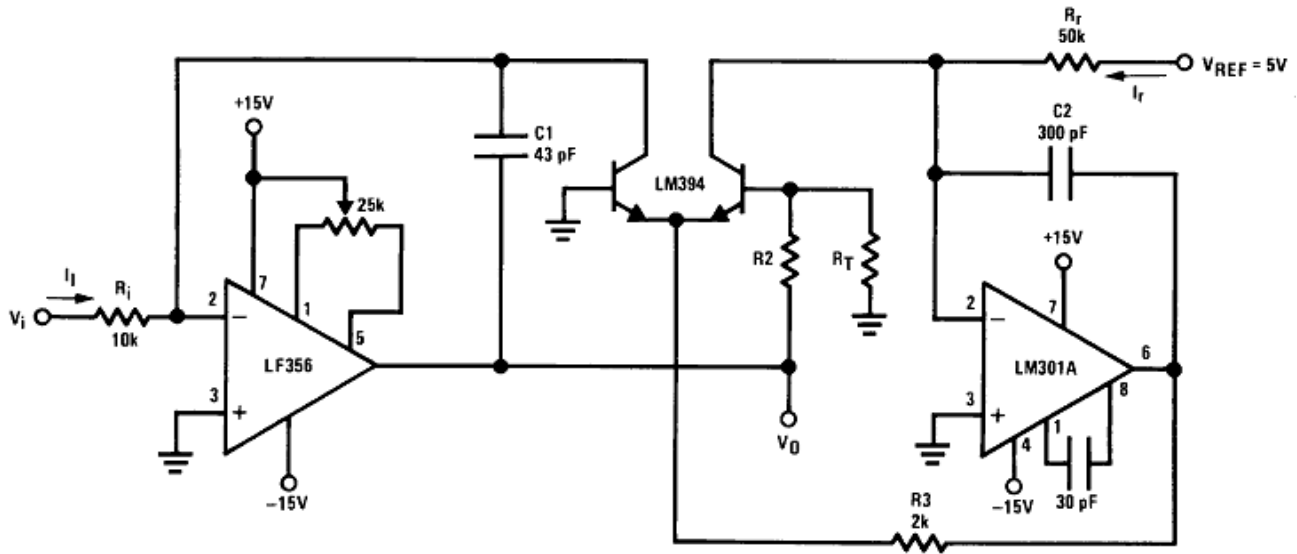


Figure 25. Fast Logarithmic Converter

- Dynamic range:  $100 \mu\text{A} \leq I_i \leq 1 \text{ mA}$  (5 decades),  $|V_O| = 1 \text{ V/decade}$
- Transient response:  $3 \mu\text{s}$  for  $\Delta I_i = 1 \text{ decade}$
- C1, C2, R2, R3: added dynamic compensation
- $V_{OS}$  adjust the LF156 to minimize quiescent error
- $R_T$ : Tel Labs type Q81 + 0.3%/°C

$$|V_{OUT}| = \left[ 1 + \frac{R_2}{R_T} \right] \frac{kT}{q} \ln V_i \left[ \frac{R_f}{V_{REF} R_i} \right] = \log V_i \frac{1}{R_i I_r} \quad R_2 = 15.7\text{k}, R_T = 1\text{k}, 0.3\%/^{\circ}\text{C} \text{ (for temperature compensation)}$$

(1)

System Examples (continued)

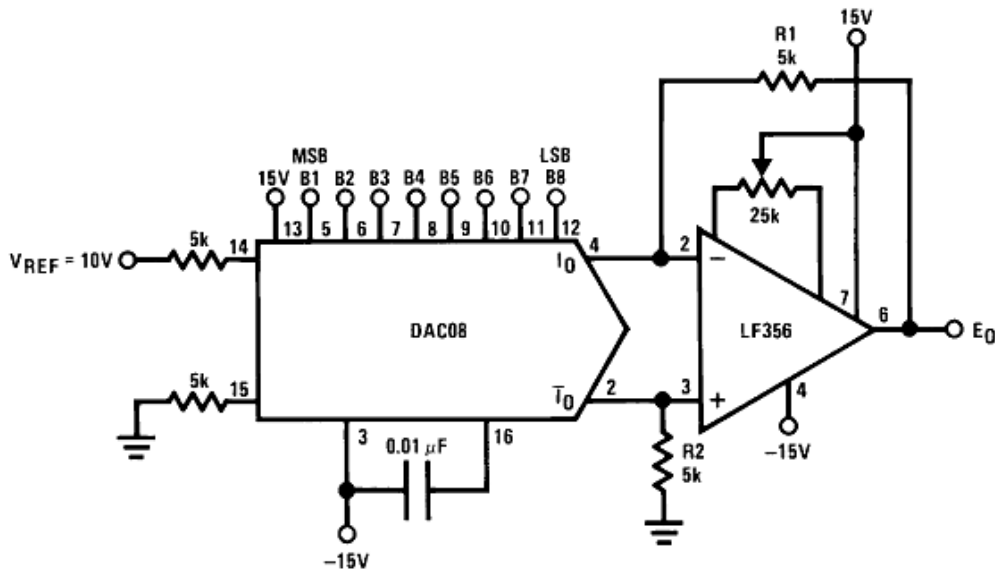


Figure 26. 8-Bit D/A Converter With Symmetrical Offset Binary Operation

- R1, R2 should be matched within ±0.05%
- Full-scale response time: 3 μs

Table 1. Bit Illustration of the 8-Bit D/A Converter

E <sub>O</sub>	B1	B2	B3	B4	B5	B6	B7	B8	COMMENTS
+9.920	1	1	1	1	1	1	1	1	Positive Full-Scale
+0.040	1	0	0	0	0	0	0	0	(+) Zero-Scale
-0.040	0	1	1	1	1	1	1	1	(-) Zero-Scale
-9.920	0	0	0	0	0	0	0	0	Negative Full-Scale

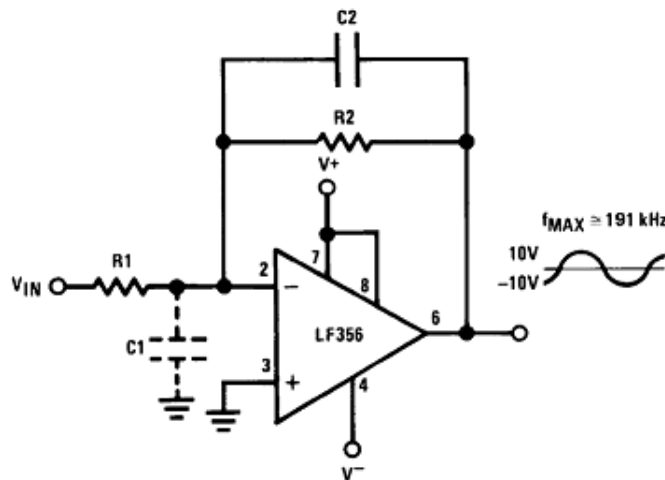


Figure 27. Wide BW Low Noise, Low Drift Amplifier

• Power BW:  $f_{MAX} = \frac{S_r}{2\pi V_p} \cong 191 \text{ kHz}$

(2)

Parasitic input capacitance  $C_1 \approx (3 \text{ pF for LF155, LF156 and LF357 plus any additional layout capacitance})$  interacts with feedback elements and creates undesirable high frequency pole. To compensate add  $C_2$  such that:  $R_2 C_2 \approx R_1 C_1$ .

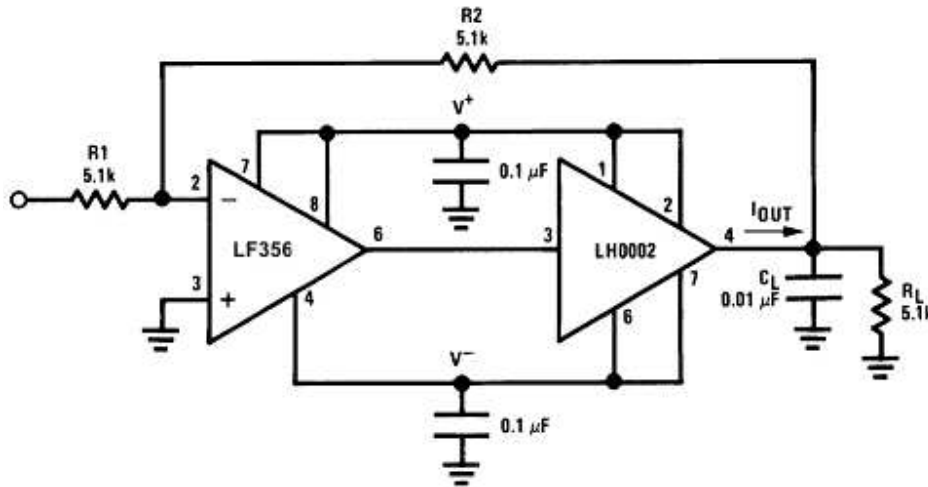


Figure 28. Boosting the LF156 With a Current Amplifier

- $I_{OUT(MAX)} \approx 150 \text{ mA}$  (will drive  $R_L \geq 100 \Omega$ )
    - $\frac{\Delta V_{OUT}}{\Delta T} = \frac{0.15}{10^{-2}} \text{ V}/\mu\text{s}$  (with  $C_L$  shown)
  - No additional phase shift added by the current amplifier
- (3)

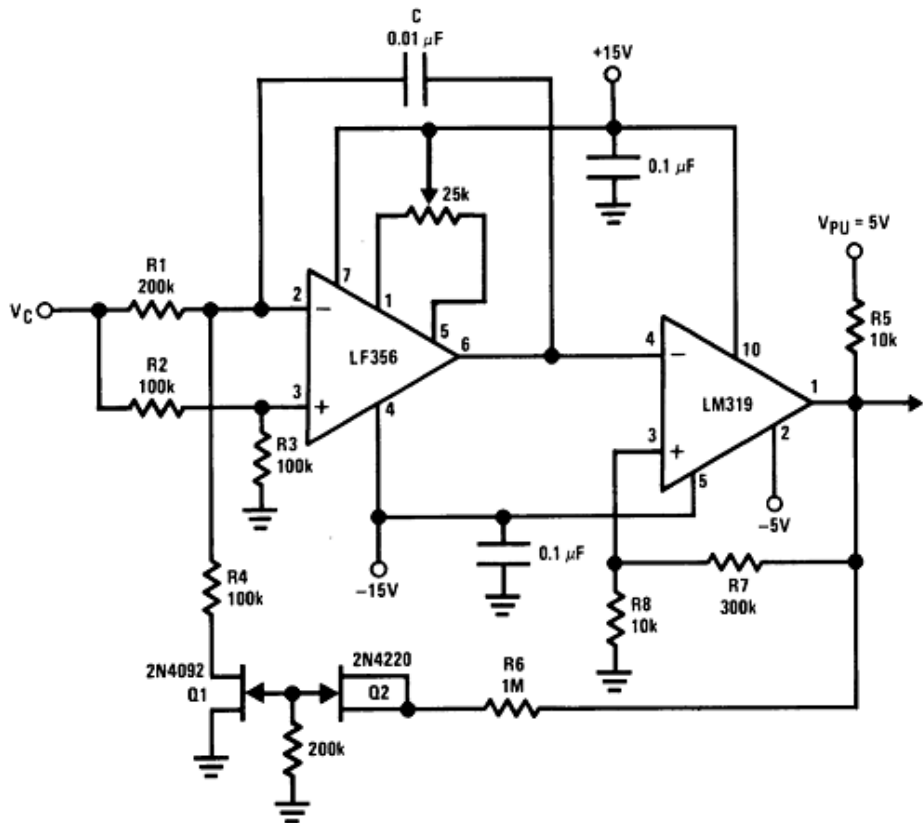
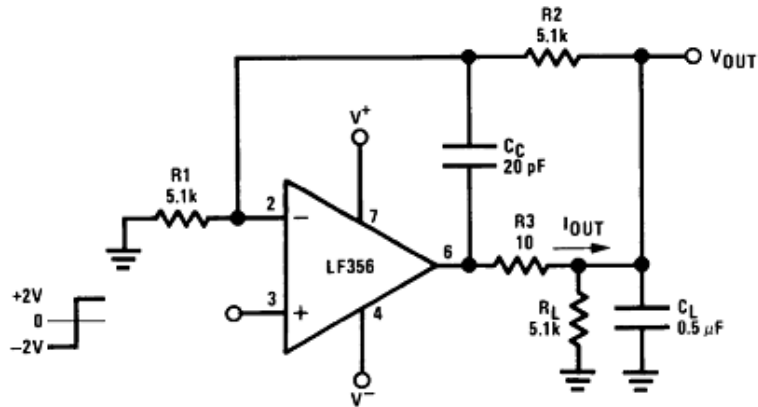


Figure 29. Decades VCO

R1, R4 matched. Linearity 0.1% over 2 decades.

$$f = \frac{V_C (R8 + R7)}{(8 V_{PU} R8 R1) C'} \quad 0 \leq V_C \leq 30V, 10 \text{ Hz} \leq f \leq 10 \text{ kHz} \quad (4)$$



**Figure 30. Isolating Large Capacitive Loads**

- Overshoot 6%
- $t_s$  10  $\mu$ s
- When driving large  $C_L$ , the  $V_{OUT}$  slew rate determined by  $C_L$  and  $I_{OUT(MAX)}$ :

$$\frac{\Delta V_{OUT}}{\Delta T} = \frac{I_{OUT}}{C_L} \cong \frac{0.02}{0.5} \text{ V}/\mu\text{s} = 0.04 \text{ V}/\mu\text{s} \text{ (with } C_L \text{ shown)} \quad (5)$$

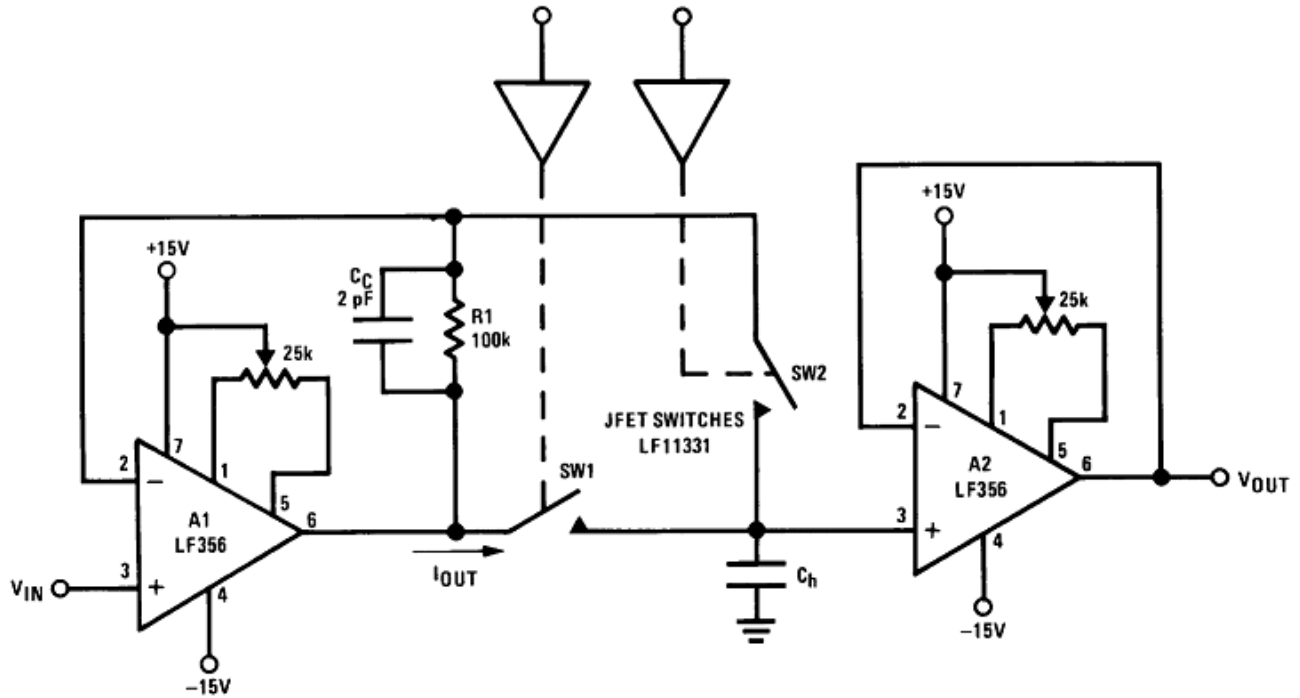


Figure 31. Fast Sample and Hold

- Both amplifiers (A1, A2) have feedback loops individually closed with stable responses (overshoot negligible)
- Acquisition time  $T_A$ , estimated by:

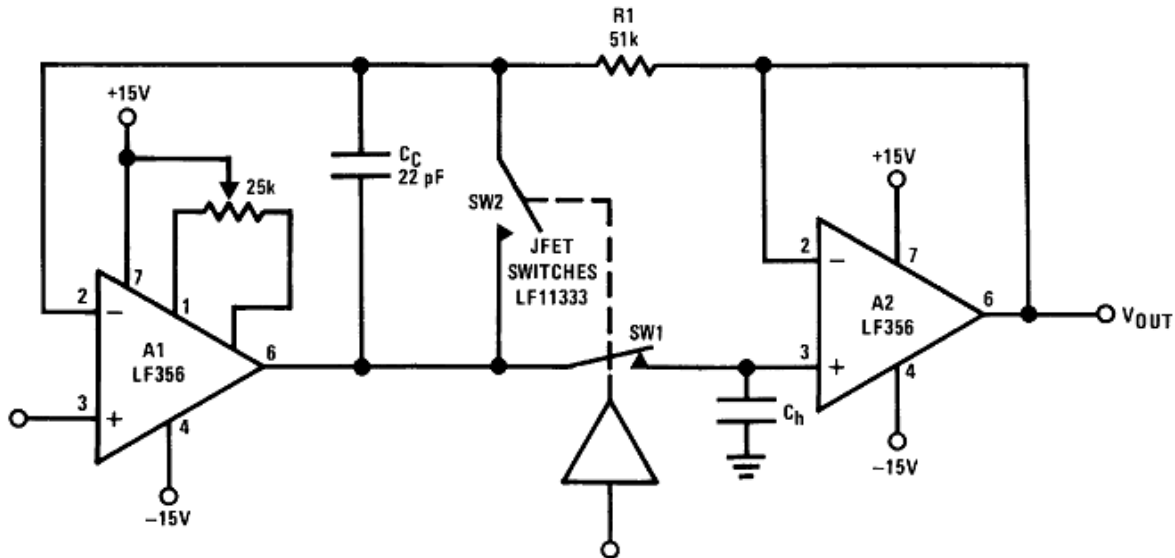
$$T_A \cong \left[ \frac{2R_{ON} \cdot V_{IN} \cdot C_h}{S_r} \right]^{1/2} \text{ provided that:}$$

$$V_{IN} < 2\pi S_r R_{ON} C_h \text{ and } T_A > \frac{V_{IN} C_h}{I_{OUT(MAX)}}, R_{ON} \text{ is of SW1}$$

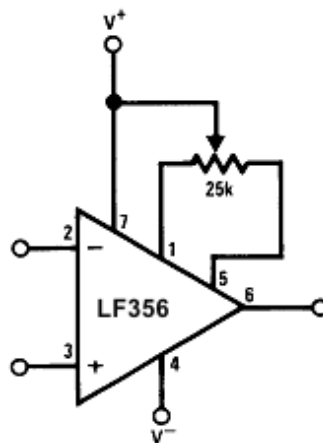
$$\text{If inequality not satisfied: } T_A \cong \frac{V_{IN} C_h}{20 \text{ mA}}$$

(6)

- LF156 develops full  $S_r$  output capability for  $V_{IN} \geq 1 \text{ V}$
- Addition of SW2 improves accuracy by putting the voltage drop across SW1 inside the feedback loop
- Overall accuracy of system determined by the accuracy of both amplifiers, A1 and A2


**Figure 32. High Accuracy Sample and Hold**

- By closing the loop through A2, the  $V_{OUT}$  accuracy will be determined uniquely by A1.
  - No  $V_{OS}$  adjust required for A2.
- $T_A$  can be estimated by same considerations as previously but, because of the added
  - propagation delay in the feedback loop (A2) the overshoot is not negligible.
- Overall system slower than fast sample and hold
- R1,  $C_C$ : additional compensation
- Use LF156 for
  - Fast settling time
  - Low  $V_{OS}$


**Figure 33.  $V_{OS}$  Adjustment**

- $V_{OS}$  is adjusted with a 25-k potentiometer
- The potentiometer wiper is connected to  $V^+$
- For potentiometers with temperature coefficient of 100 ppm/°C or less the additional drift with adjust is  $\approx 0.5 \mu\text{V}/^\circ\text{C}/\text{mV}$  of adjustment
- Typical overall drift:  $5 \mu\text{V}/^\circ\text{C} \pm (0.5 \mu\text{V}/^\circ\text{C}/\text{mV of adj.})$

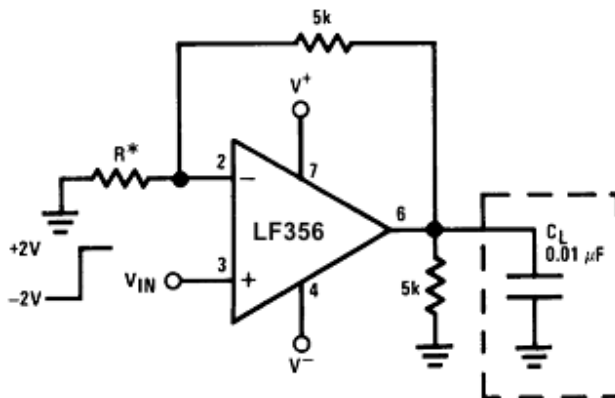


Figure 34. Driving Capacitive Loads

- \*LF15x R = 5k, LF357 R = 1.25 k
- Due to a unique output stage design, these amplifiers have the ability to drive large capacitive loads and still maintain stability.  $C_{L(MAX)} \approx 0.01 \mu\text{F}$ .
- Overshoot  $\leq 20\%$ , Settling time ( $t_s$ )  $\approx 5 \mu\text{s}$

## 9 Power Supply Recommendations

See the [Recommended Operating Conditions](#) for the minimum and maximum values for the supply input voltage and operating junction temperature.

## 10 Layout

### 10.1 Layout Guidelines

#### 10.1.1 Printed-Circuit-Board Layout For High-Impedance Work

It is generally recognized that any circuit which must operate with less than 1000 pA of leakage current requires special layout of the PCB. When one wishes to take advantage of the low input bias current of the LF356-MIL, typically less than 30 pA, it is essential to have an excellent layout. Fortunately, the techniques of obtaining low leakages are quite simple. First, the user must not ignore the surface leakage of the PCB, even though it may sometimes appear acceptably low, because under conditions of high humidity or dust or contamination, the surface leakage will be appreciable.

To minimize the effect of any surface leakage, lay out a ring of foil completely surrounding the inputs of the LF356-MIL and the terminals of capacitors, diodes, conductors, resistors, relay terminals, and so forth, connected to the inputs of the op amp, as in [Figure 39](#). To have a significant effect, guard rings must be placed on both the top and bottom of the PCB. This PC foil must then be connected to a voltage that is at the same voltage as the amplifier inputs, because no leakage current can flow between two points at the same potential. For example, a PCB trace-to-pad resistance of 10 TΩ, which is normally considered a very large resistance, could leak 5 pA if the trace were a 5-V bus adjacent to the pad of the input. If a guard ring is used and held close to the potential of the amplifier inputs, it will significantly reduce this leakage current.

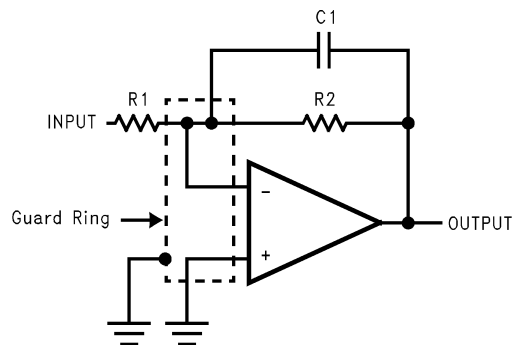


Figure 35. Inverting Amplifier

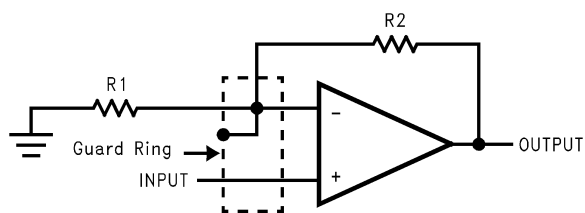
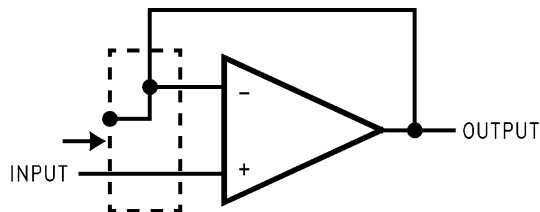


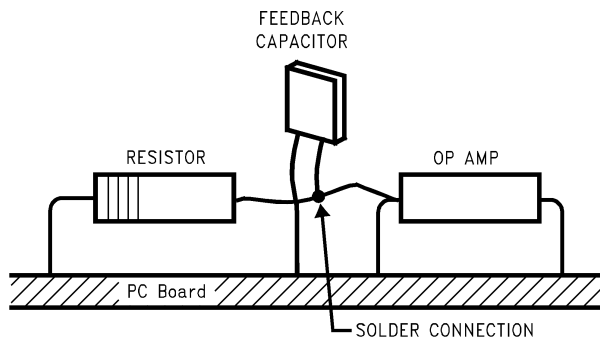
Figure 36. Noninverting Amplifier

## Layout Guidelines (continued)



**Figure 37. Typical Connections Of Guard Rings**

The designer should be aware that when it is inappropriate to lay out a PCB for the sake of just a few circuits, there is another technique which is even better than a guard ring on a PCB: Do not insert the input pin of the amplifier into the board at all, but bend it up in the air and use only air as an insulator. Air is an excellent insulator. In this case you may have to forego some of the advantages of PCB construction, but the advantages are sometimes well worth the effort of using point-to-point up-in-the-air wiring. See [Figure 38](#).

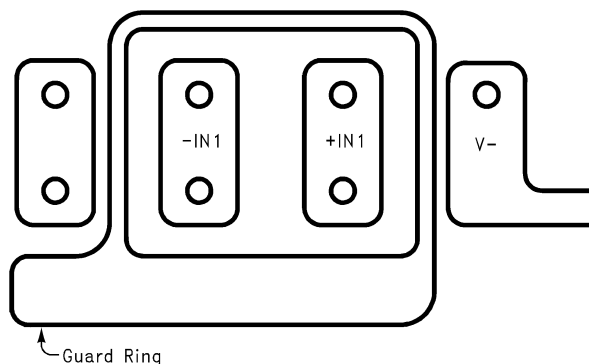


(Input pins are lifted out of PCB and soldered directly to components. All other pins connected to PCB).

**Figure 38. Air Wiring**

Another potential source of leakage that might be overlooked is the device package. When the LF356-MIL is manufactured, the device is always handled with conductive finger cots. This is to assure that salts and skin oils do not cause leakage paths on the surface of the package. We recommend that these same precautions be adhered to, during all phases of inspection, test and assembly.

## 10.2 Layout Example



**Figure 39. Examples Of Guard Ring In PCB Layout**

## 11 デバイスおよびドキュメントのサポート

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### 11.5 Glossary

[SLYZ022](#) — *TI Glossary*.

This glossary lists and explains terms, acronyms, and definitions.

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Orderable part number	Status (1)	Material type (2)	Package   Pins	Package qty   Carrier	RoHS (3)	Lead finish/ Ball material (4)	MSL rating/ Peak reflow (5)	Op temp (°C)	Part marking (6)
LF356 MWC	Active	Production	WAFERSALE (YS)   0	1   NOT REQUIRED	-	Call TI	Level-1-NA-UNLIM	-40 to 85	
<a href="#">LF356H</a>	Active	Production	TO-99 (LMC)   8	500   OTHER	No	Call TI	Level-1-NA-UNLIM	0 to 70	( LF356H, LF356H)
<a href="#">LF356H/NOPB</a>	Active	Production	TO-99 (LMC)   8	500   OTHER	Yes	Call TI	Level-1-NA-UNLIM	0 to 70	( LF356H, LF356H)

(1) **Status:** For more details on status, see our [product life cycle](#).

(2) **Material type:** When designated, preproduction parts are prototypes/experimental devices, and are not yet approved or released for full production. Testing and final process, including without limitation quality assurance, reliability performance testing, and/or process qualification, may not yet be complete, and this item is subject to further changes or possible discontinuation. If available for ordering, purchases will be subject to an additional waiver at checkout, and are intended for early internal evaluation purposes only. These items are sold without warranties of any kind.

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(4) **Lead finish/Ball material:** Parts may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead finish/Ball material values may wrap to two lines if the finish value exceeds the maximum column width.

(5) **MSL rating/Peak reflow:** The moisture sensitivity level ratings and peak solder (reflow) temperatures. In the event that a part has multiple moisture sensitivity ratings, only the lowest level per JEDEC standards is shown. Refer to the shipping label for the actual reflow temperature that will be used to mount the part to the printed circuit board.

(6) **Part marking:** There may be an additional marking, which relates to the logo, the lot trace code information, or the environmental category of the part.

Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "-" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

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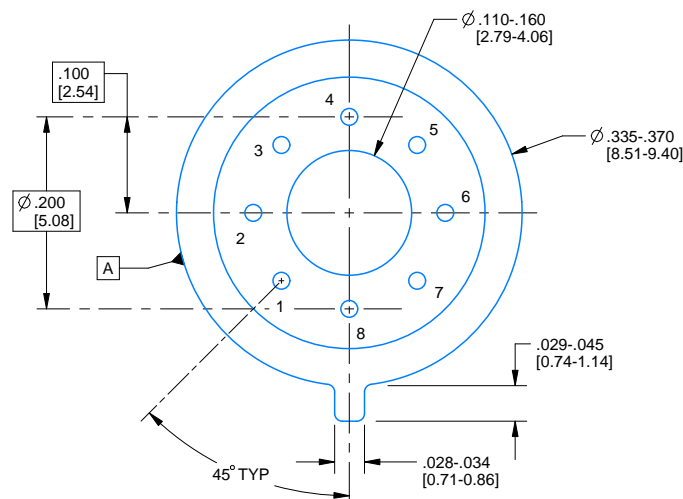
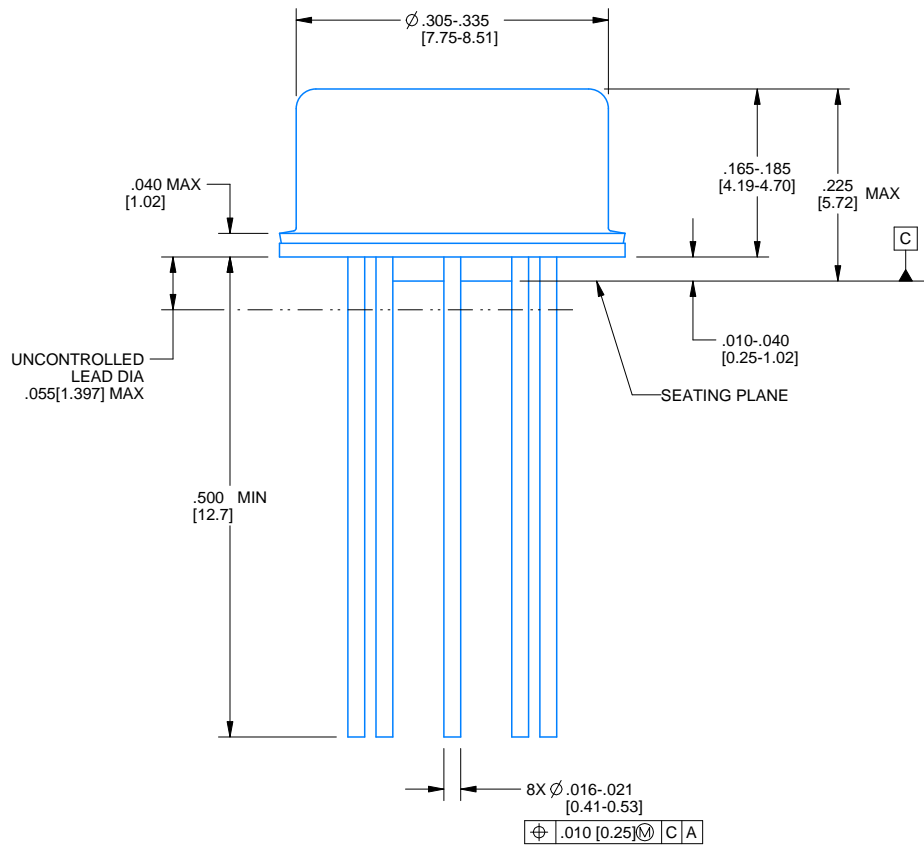
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# PACKAGE OUTLINE

## LMC0008A

### TO-CAN - 5.72 mm max height

TRANSISTOR OUTLINE



4220610/B 09/2024

#### NOTES:

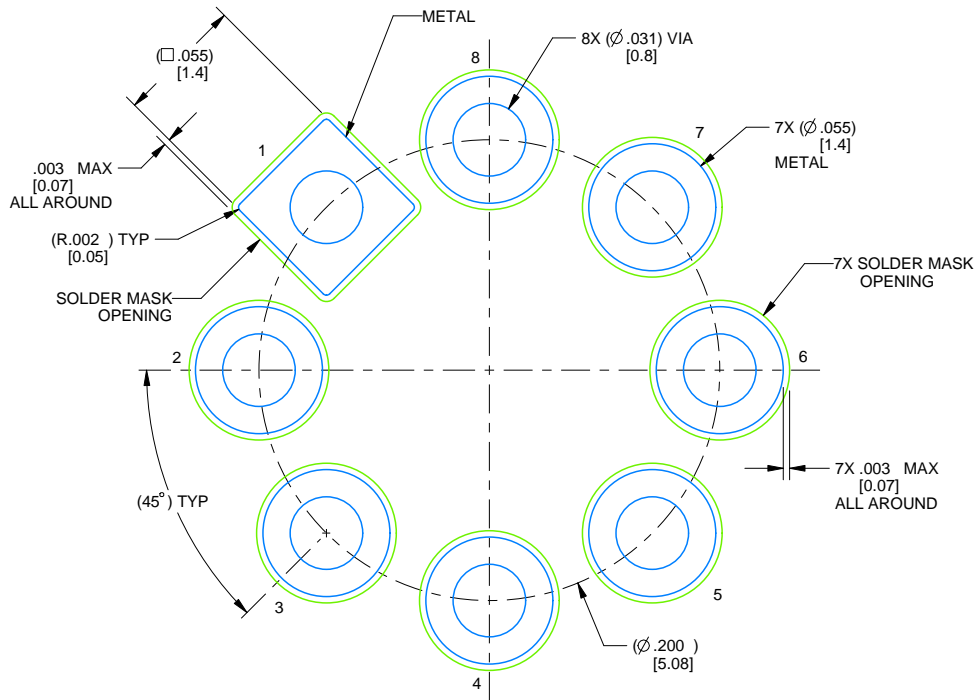
1. All linear dimensions are in inches [millimeters]. Any dimensions in parenthesis are for reference only. Dimensioning and tolerancing per ASME Y14.5M.
2. This drawing is subject to change without notice.
3. Pin numbers shown for reference only. Numbers may not be marked on package.
4. Reference JEDEC registration MO-002/TO-99.

# EXAMPLE BOARD LAYOUT

## LMC0008A

### TO-CAN - 5.72 mm max height

TRANSISTOR OUTLINE



LAND PATTERN EXAMPLE  
NON-SOLDER MASK DEFINED  
SCALE: 12X

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