

## LF155/LF156/LF256/LF257/LF355/LF356/LF357 JFET Input Operational Amplifiers

Check for Samples: [LF155](#), [LF156](#), [LF355](#), [LF356](#), [LF357](#)

### FEATURES

#### Advantages

- **Replace Expensive Hybrid and Module FET Op Amps**
- **Rugged JFETs Allow Blow-Out Free Handling Compared with MOSFET Input Devices**
- **Excellent for Low Noise Applications Using Either High or Low Source Impedance—Very Low 1/f Corner**
- **Offset Adjust Does Not Degrade Drift or Common-Mode Rejection as in Most Monolithic Amplifiers**
- **New Output Stage Allows Use of Large Capacitive Loads (5,000 pF) without Stability Problems**
- **Internal Compensation and Large Differential Input Voltage Capability**

### APPLICATIONS

- **Precision High Speed Integrators**
- **Fast D/A and A/D Converters**
- **High Impedance Buffers**
- **Wideband, Low Noise, Low Drift Amplifiers**
- **Logarithmic Amplifiers**
- **Photocell Amplifiers**
- **Sample and Hold Circuits**

### DESCRIPTION

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/low offset voltage and offset voltage drift, coupled with offset adjust which does not degrade drift or common-mode rejection. The devices are also designed for high slew rate, wide bandwidth, extremely fast settling time, low voltage and current noise and a low 1/f noise corner.

#### Common Features

- Low Input Bias Current: 30pA
- Low Input Offset Current: 3pA
- High Input Impedance:  $10^{12}\Omega$
- Low Input Noise Current:  $0.01 \text{ pA}/\sqrt{\text{Hz}}$
- High Common-Mode Rejection Ratio: 100 dB
- Large DC Voltage Gain: 106 dB

**Table 1. Uncommon Features**

	LF155/ LF355	LF156/ LF256/ LF356	LF257/ LF357 ( $A_V=5$ )	Units
Extremely fast settling time to 0.01%	4	1.5	1.5	$\mu\text{s}$
Fast slew rate	5	12	50	V/ $\mu\text{s}$
Wide gain bandwidth	2.5	5	20	MHz
Low input noise voltage	20	12	12	nV / $\sqrt{\text{Hz}}$

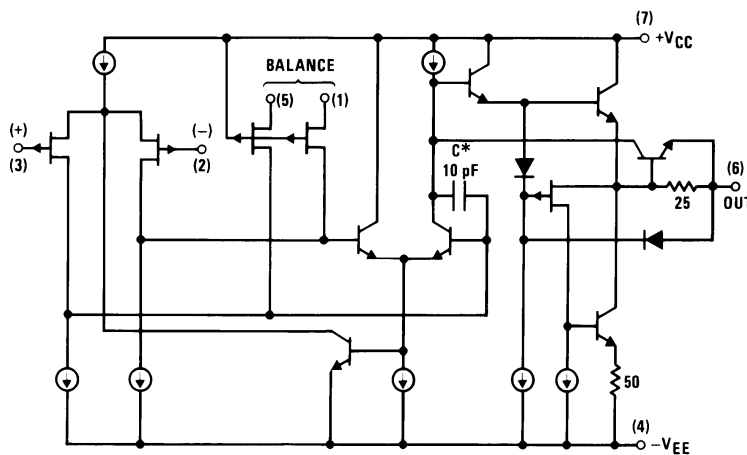


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### Simplified Schematic



\*3pF in LF357 series.



These devices have limited built-in ESD protection. The leads should be shorted together or the device placed in conductive foam during storage or handling to prevent electrostatic damage to the MOS gates.

**Absolute Maximum Ratings<sup>(1)(2)</sup>**

	<b>LF155/6</b>	<b>LF256/7/LF356B</b>	<b>LF355/6/7</b>
Supply Voltage	±22V	±22V	±18V
Differential Input Voltage	±40V	±40V	±30V
Input Voltage Range <sup>(3)</sup>	±20V	±20V	±16V
Output Short Circuit Duration	Continuous	Continuous	Continuous
$T_{JMAX}$			
LMC Package	150°C	115°C	115°C
P Package		100°C	100°C
D Package		100°C	100°C
Power Dissipation at $T_A = 25^\circ\text{C}$ <sup>(1) (4)</sup>			
LMC Package (Still Air)	560 mW	400 mW	400 mW
LMC Package (400 LF/Min Air Flow)	1200 mW	1000 mW	1000 mW
P Package		670 mW	670 mW
D Package		380 mW	380 mW
Thermal Resistance (Typical) $\theta_{JA}$			
LMC Package (Still Air)	160°C/W	160°C/W	160°C/W
LMC Package (400 LF/Min Air Flow)	65°C/W	65°C/W	65°C/W
P Package		130°C/W	130°C/W
D Package		195°C/W	195°C/W
(Typical) $\theta_{JC}$			
LMC Package	23°C/W	23°C/W	23°C/W
Storage Temperature Range	-65°C to +150°C	-65°C to +150°C	-65°C to +150°C
Soldering Information (Lead Temp.)			
TO-99 Package			
Soldering (10 sec.)	300°C	300°C	300°C
PDIP Package			
Soldering (10 sec.)	260°C	260°C	260°C
SOIC Package			
Vapor Phase (60 sec.)		215°C	215°C
Infrared (15 sec.)		220°C	220°C
ESD tolerance			
(100 pF discharged through 1.5k $\Omega$ )	1000V	1000V	1000V

- (1) The maximum power dissipation for these devices must be derated at elevated temperatures and is dictated by  $T_{JMAX}$ ,  $\theta_{JA}$ , and the ambient temperature,  $T_A$ . The maximum available power dissipation at any temperature is  $P_D = (T_{JMAX} - T_A) / \theta_{JA}$  or the 25°C  $P_{dMAX}$ , whichever is less.
- (2) If Military/Aerospace specified devices are required, contact the TI Sales Office/Distributors for availability and specifications.
- (3) Unless otherwise specified the absolute maximum negative input voltage is equal to the negative power supply voltage.
- (4) Max. Power Dissipation is defined by the package characteristics. Operating the part near the Max. Power Dissipation may cause the part to operate outside specified limits.

**DC Electrical Characteristics**

Symbol	Parameter	Conditions	LF155/6			LF256/7 LF356B			LF355/6/7			Units
			Min	Typ	Max	Min	Typ	Max	Min	Typ	Max	
V <sub>OS</sub>	Input Offset Voltage	R <sub>S</sub> =50Ω, T <sub>A</sub> =25°C		3	5		3	5		3	10	mV
		Over Temperature			7			6.5			13	mV
ΔV <sub>OS</sub> /ΔT	Average TC of Input Offset Voltage	R <sub>S</sub> =50Ω		5			5			5		μV/°C
ΔTC/ΔV <sub>OS</sub>	Change in Average TC with V <sub>OS</sub> Adjust	R <sub>S</sub> =50Ω, <sup>(2)</sup>		0.5			0.5			0.5		μV/°C per mV
I <sub>OS</sub>	Input Offset Current	T <sub>J</sub> =25°C, <sup>(1) (3)</sup>		3	20		3	20		3	50	pA
		T <sub>J</sub> ≤T <sub>HIGH</sub>			20			1			2	nA
I <sub>B</sub>	Input Bias Current	T <sub>J</sub> =25°C, <sup>(1) (3)</sup>		30	100		30	100		30	200	pA
		T <sub>J</sub> ≤T <sub>HIGH</sub>			50			5			8	nA
R <sub>IN</sub>	Input Resistance	T <sub>J</sub> =25°C		10 <sup>12</sup>			10 <sup>12</sup>			10 <sup>12</sup>		Ω
A <sub>VOL</sub>	Large Signal Voltage Gain	V <sub>S</sub> =±15V, T <sub>A</sub> =25°C	50	200		50	200		25	200		V/mV
		V <sub>O</sub> =±10V, R <sub>L</sub> =2k										
		Over Temperature	25			25			15			V/mV
V <sub>O</sub>	Output Voltage Swing	V <sub>S</sub> =±15V, R <sub>L</sub> =10k	±12	±13		±12	±13		±12	±13		V
		V <sub>S</sub> =±15V, R <sub>L</sub> =2k	±10	±12		±10	±12		±10	±12		V
V <sub>CM</sub>	Input Common-Mode Voltage Range	V <sub>S</sub> =±15V	±11	+15.1		±11	±15.1		+10	+15.1		V
				-12			-12			-12		V
CMRR	Common-Mode Rejection Ratio		85	100		85	100		80	100		dB
PSRR	Supply Voltage Rejection Ratio	<sup>(4)</sup>	85	100		85	100		80	100		dB

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

	LF155/156	LF256/257	LF356B	LF355/6/7
Supply Voltage, V <sub>S</sub>	±15V ≤ V <sub>S</sub> ≤ ±20V	±15V ≤ V <sub>S</sub> ≤ ±20V	±15V ≤ V <sub>S</sub> ±20V	V <sub>S</sub> = ±15V
T <sub>A</sub>	-55°C ≤ T <sub>A</sub> ≤ +125°C	-25°C ≤ T <sub>A</sub> ≤ +85°C	0°C ≤ T <sub>A</sub> ≤ +70°C	0°C ≤ T <sub>A</sub> ≤ +70°C
T <sub>HIGH</sub>	+125°C	+85°C	+70°C	+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 (0.5μV/°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.
- (4) Supply Voltage Rejection is measured for both supply magnitudes increasing or decreasing simultaneously, in accordance with common practice.

**DC Electrical Characteristics**

T<sub>A</sub> = T<sub>J</sub> = 25°C, V<sub>S</sub> = ±15V

Parameter	LF155		LF355		LF156/256/257/356B		LF356		LF357		Units
	Typ	Max	Typ	Max	Typ	Max	Typ	Max	Typ	Max	
Supply Current	2	4	2	4	5	7	5	10	5	10	mA

## AC Electrical Characteristics

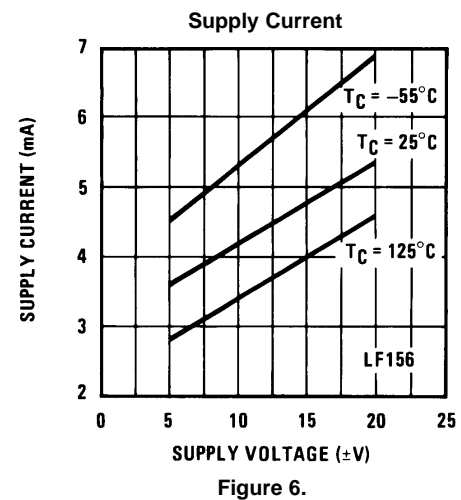
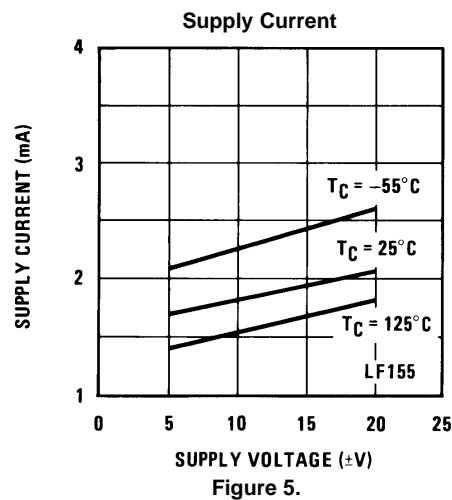
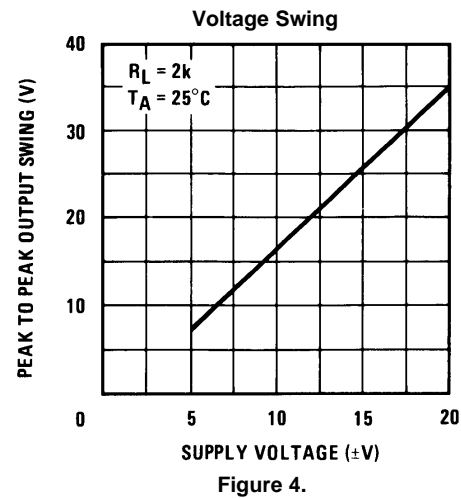
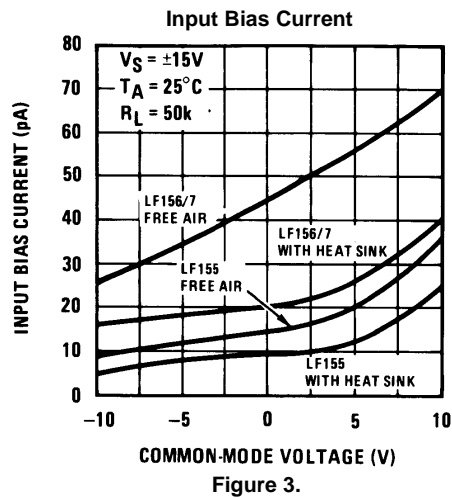
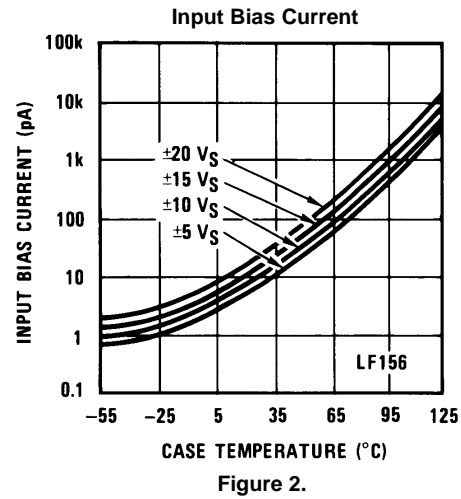
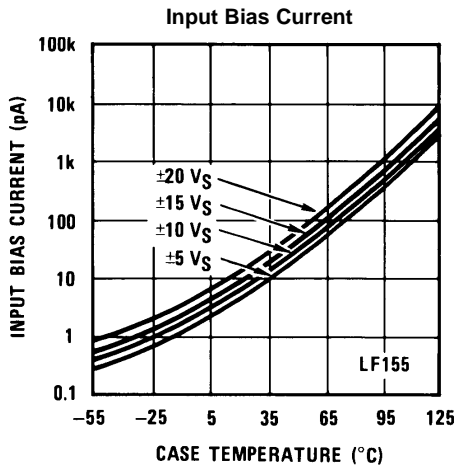
 $T_A = T_J = 25^\circ\text{C}$ ,  $V_S = \pm 15\text{V}$ 

Symbol	Parameter	Conditions	LF155/355	LF156/256/ 356B	LF156/256/356/ LF356B	LF257/357	Units
			Typ	Min	Typ	Typ	
SR	Slew Rate	LF155/6: $A_V=1$ ,	5	7.5	12		V/ $\mu\text{s}$
		LF357: $A_V=5$				50	V/ $\mu\text{s}$
GBW	Gain Bandwidth Product		2.5		5	20	MHz
$t_s$	Settling Time to 0.01%	(1)	4		1.5	1.5	$\mu\text{s}$
$e_n$	Equivalent Input Noise Voltage	$R_S=100\Omega$					
		$f=100\text{ Hz}$	25		15	15	nV/ $\sqrt{\text{Hz}}$
		$f=1000\text{ Hz}$	20		12	12	nV/ $\sqrt{\text{Hz}}$
$i_n$	Equivalent Input Current Noise	$f=100\text{ Hz}$	0.01		0.01	0.01	pA/ $\sqrt{\text{Hz}}$
		$f=1000\text{ Hz}$	0.01		0.01	0.01	pA/ $\sqrt{\text{Hz}}$
$C_{IN}$	Input Capacitance		3		3	3	pF

- (1) Settling time is defined here, for a unity gain inverter connection using 2 k $\Omega$  resistors for the LF155/6. 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 10V step input is applied to the inverter. For the LF357,  $A_V = -5$ , the feedback resistor from output to input is 2k $\Omega$  and the output step is 10V (See [Settling Time Test Circuit](#)).

### Typical DC Performance Characteristics

Curves are for LF155 and LF156 unless otherwise specified.



Typical DC Performance Characteristics (continued)

Curves are for LF155 and LF156 unless otherwise specified.

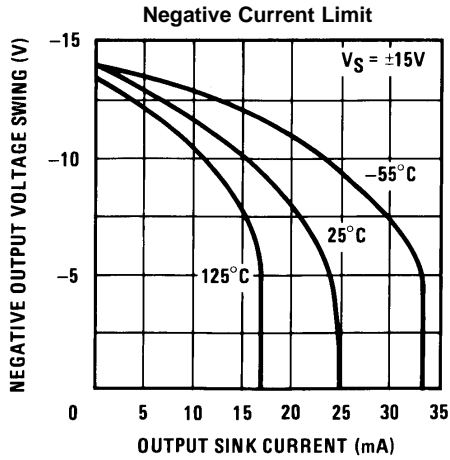


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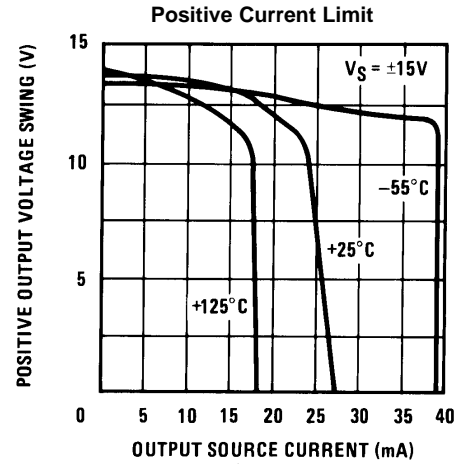


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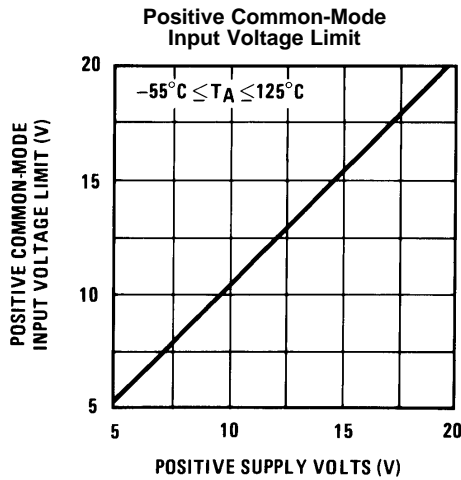


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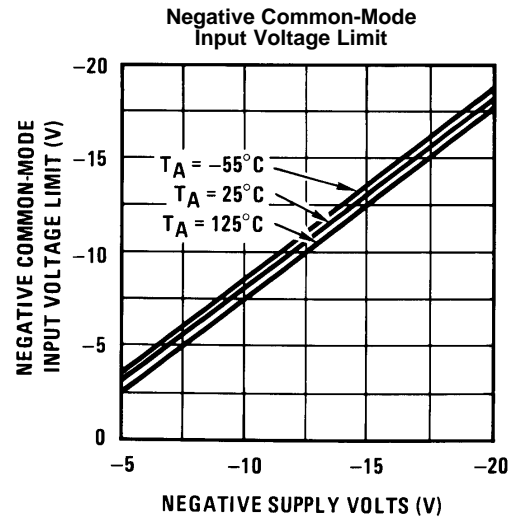


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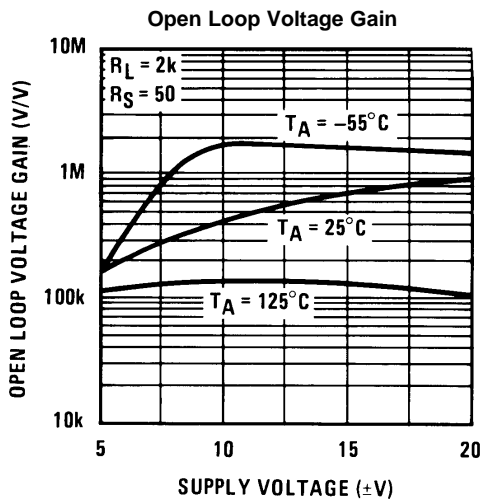


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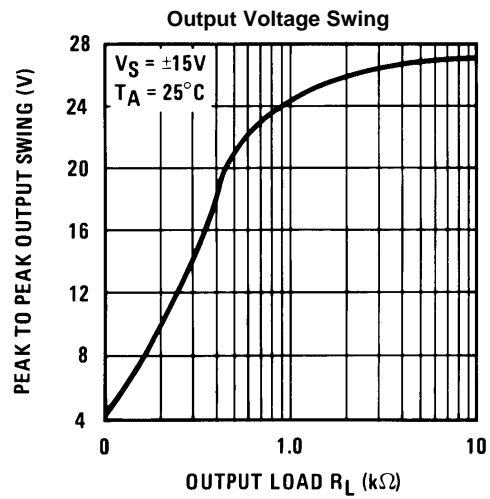


Figure 12.

**Typical AC Performance Characteristics**

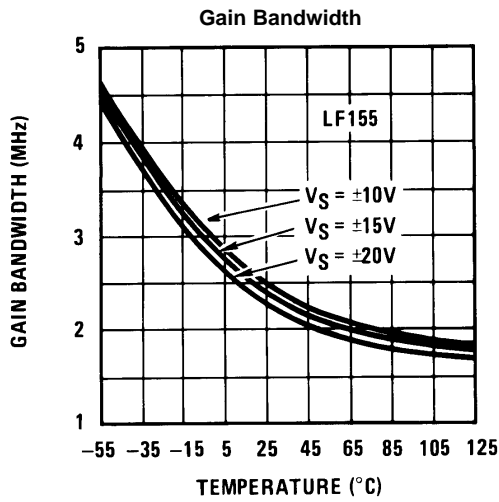


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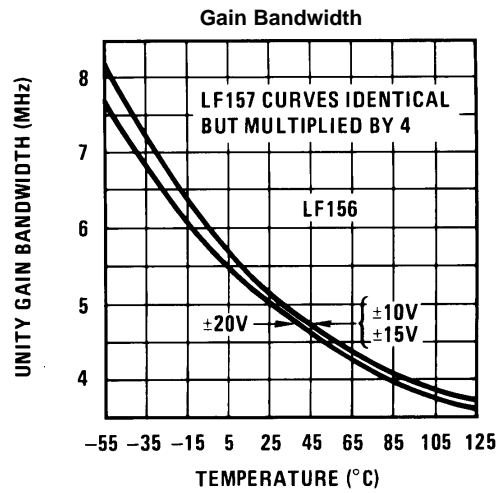


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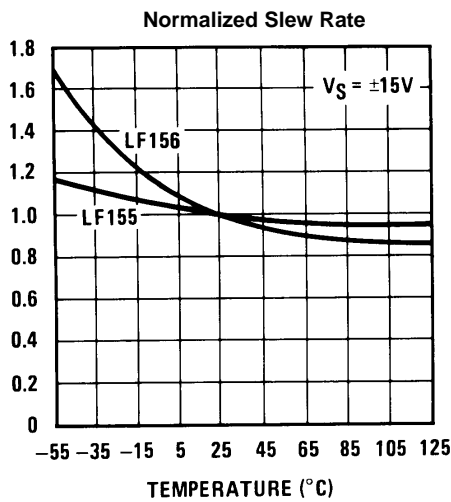


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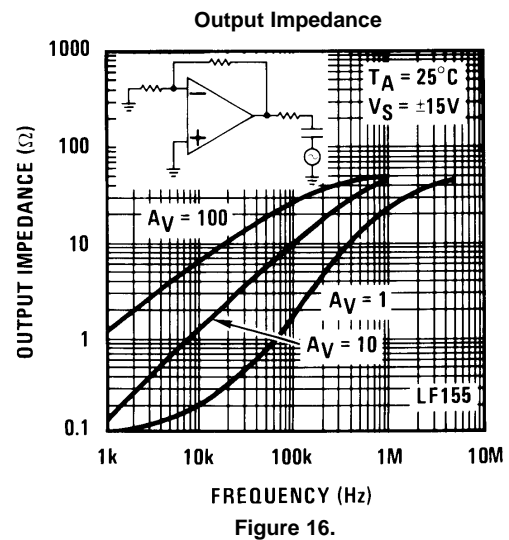


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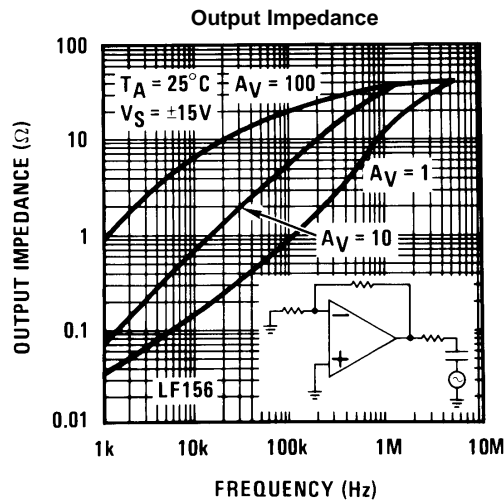


Figure 17.

Typical AC Performance Characteristics (continued)

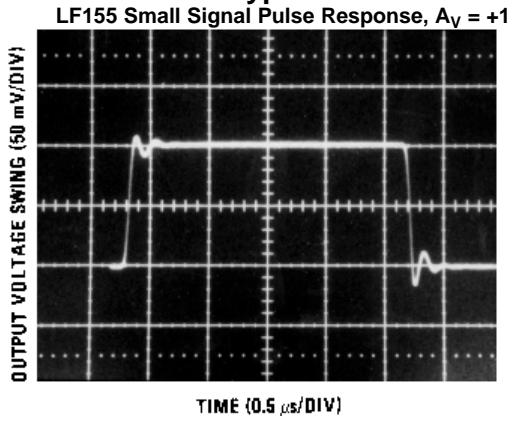


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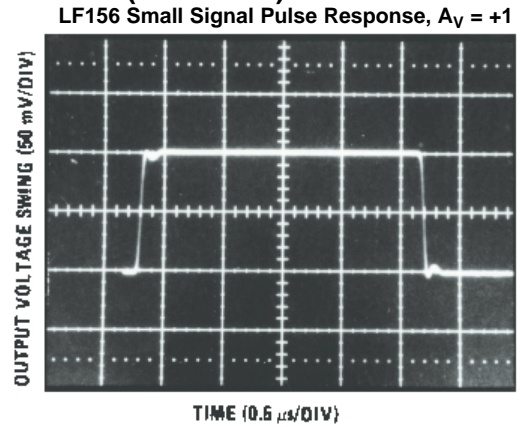


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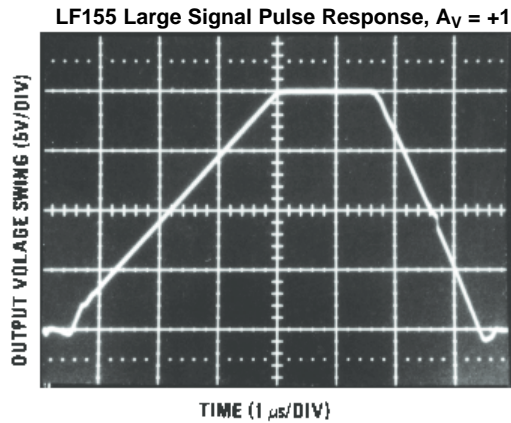


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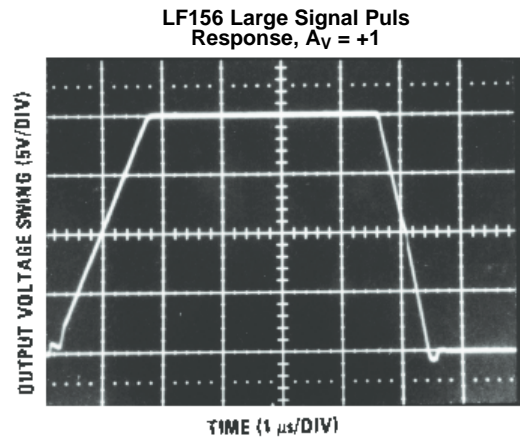


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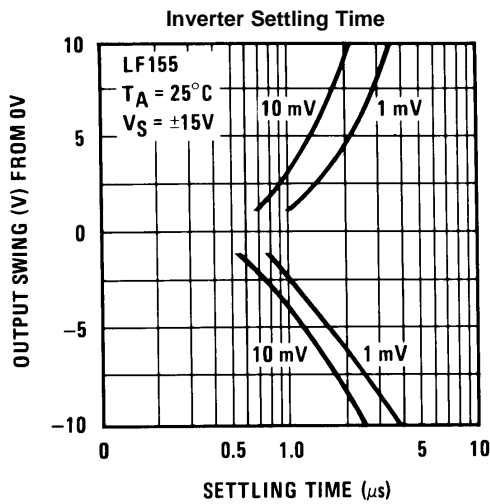


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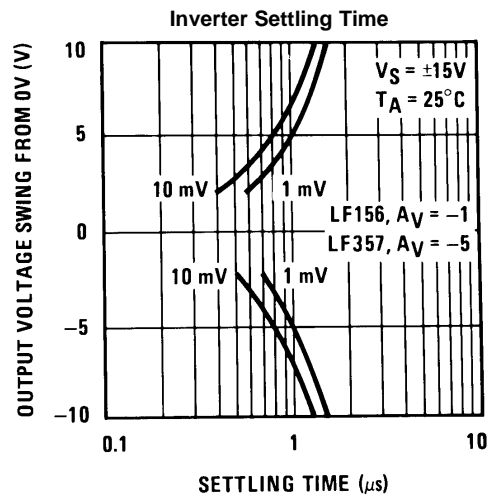


Figure 23.

Typical AC Performance Characteristics (continued)

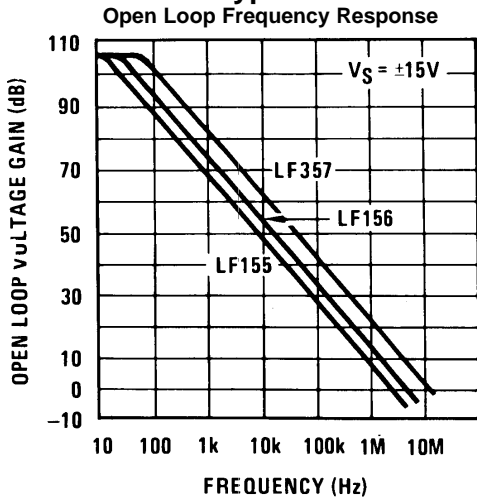


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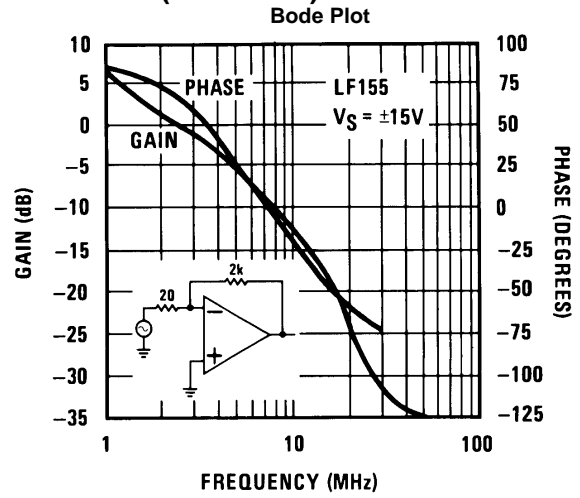


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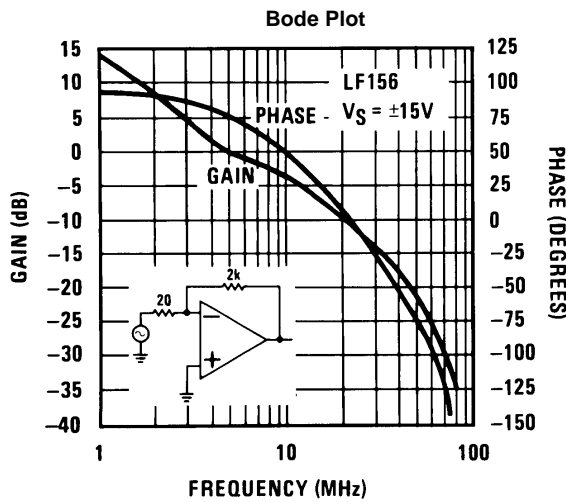


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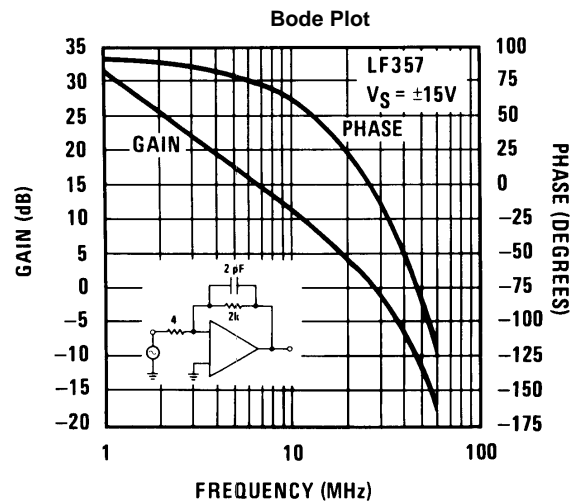


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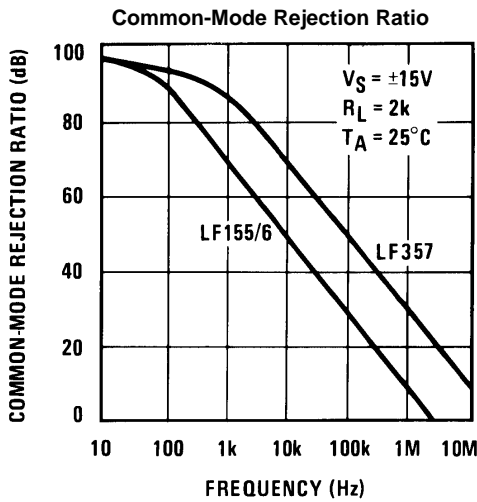


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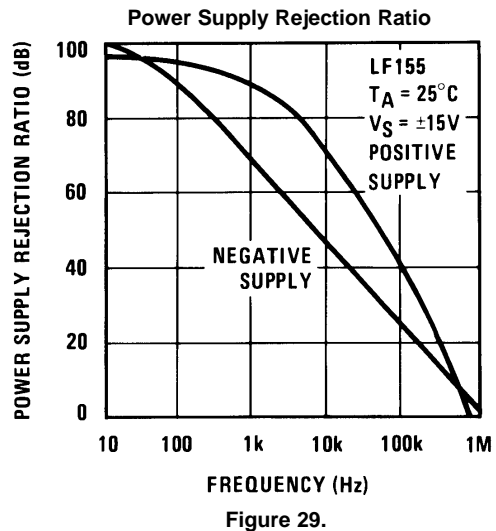


Figure 29.

Typical AC Performance Characteristics (continued)

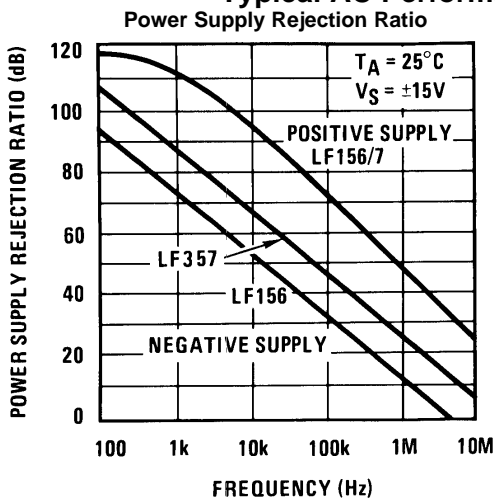


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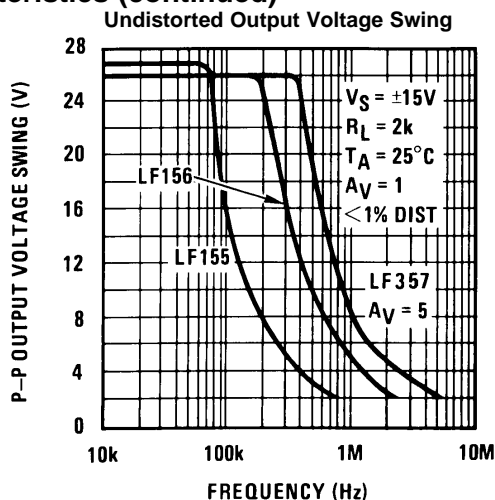


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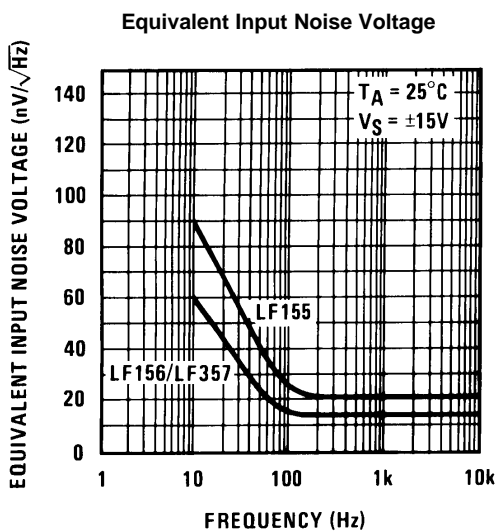


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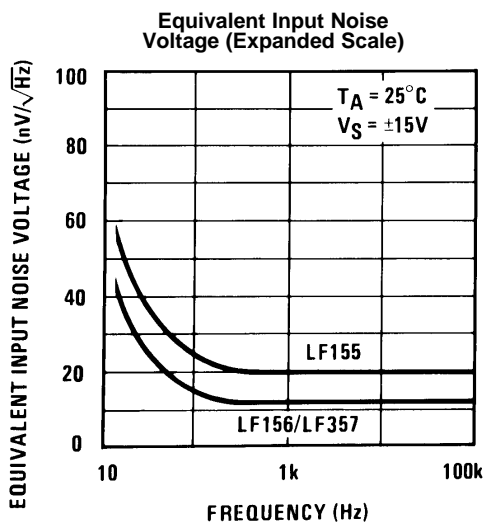
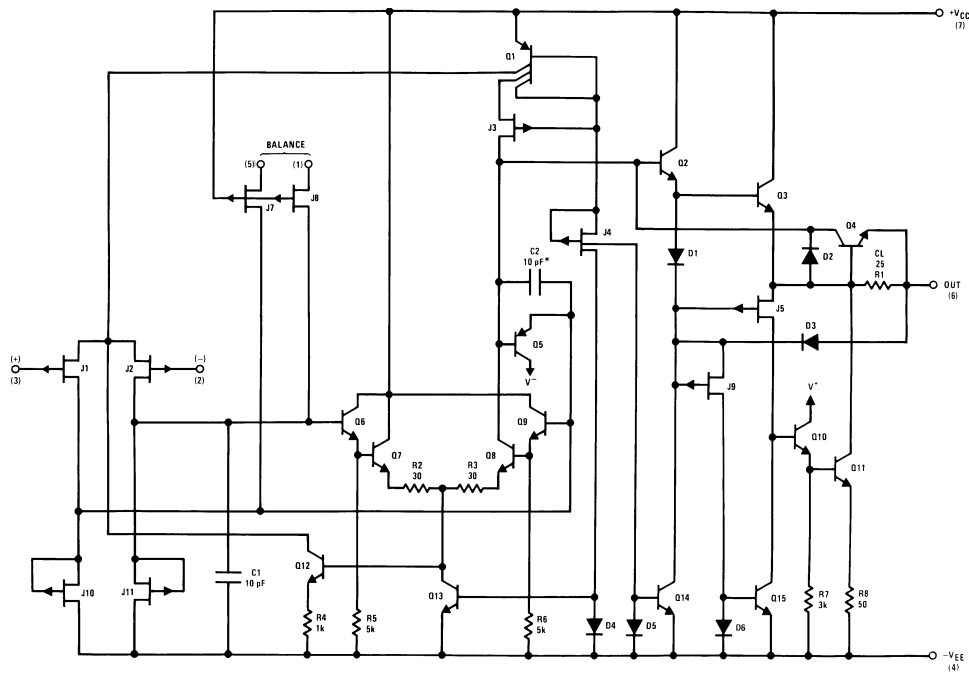


Figure 33.

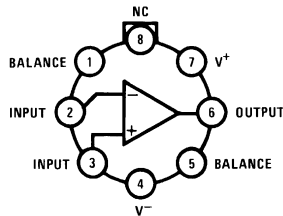
DETAILED SCHEMATIC



\*C = 3pF in LF357 series.

Connection Diagrams

(Top Views)



\*Available per JM38510/11401 or JM38510/11402

Figure 34. TO-99 Package (LMC)  
See Package Number LMC (O-MBCY-W8)

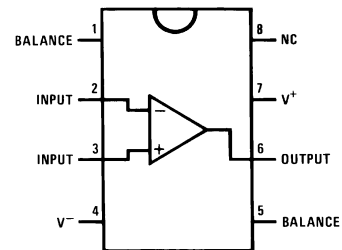


Figure 35. SOIC and PDIP Package (D and P)  
See Package Number D (R-PDSO-G8) or P (R-PDIP-T8)

## APPLICATION HINTS

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.

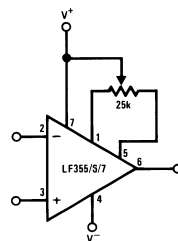
Precautions should be taken to ensure that the power supply for the integrated circuit never becomes reversed in polarity or that the unit is not inadvertently installed backwards in a socket as an unlimited current surge through the resulting forward diode within the IC could cause fusing of the internal 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 “pickup” and maximize the frequency of the feedback pole by minimizing the capacitance from the input to ground.

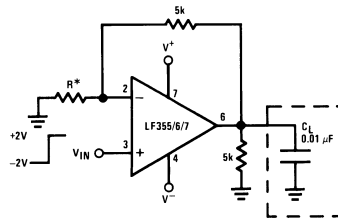
A feedback pole is created when the feedback around any amplifier is resistive. The parallel resistance and capacitance from the input of the device (usually the inverting input) to AC ground set the frequency of the pole. In many instances the frequency of this pole is much greater than the expected 3dB 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.

### Typical Circuit Connections



**Figure 36.  $V_{OS}$  Adjustment**

- $V_{OS}$  is adjusted with a 25k 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.)

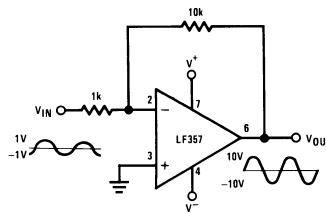


\*LF155/6 R = 5k, LF357 R = 1.25k

**Figure 37. Driving Capacitive Loads**

Due to a unique output stage design, these amplifiers have the ability to drive large capacitive loads and still maintain stability.  $C_{L(MAX)} \approx 0.01\mu F$ .

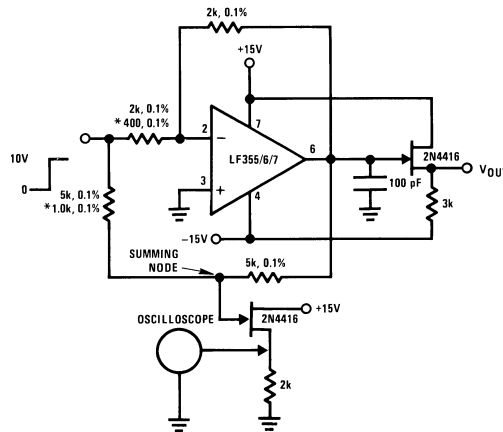
Overshoot  $\leq 20\%$ , Settling time ( $t_s$ )  $\approx 5\mu s$



For distortion  $\leq 1\%$  and a 20 Vp-p  $V_{OUT}$  swing, power bandwidth is: 500kHz.

**Figure 38. LF357 - A Large Power BW Amplifier**

**Typical Applications**



**Figure 39. Settling Time Test Circuit**

- Settling time is tested with the LF155/6 connected as unity gain inverter and LF357 connected for  $A_V = -5$
- FET used to isolate the probe capacitance
- Output = 10V step
- $A_V = -5$  for LF357

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

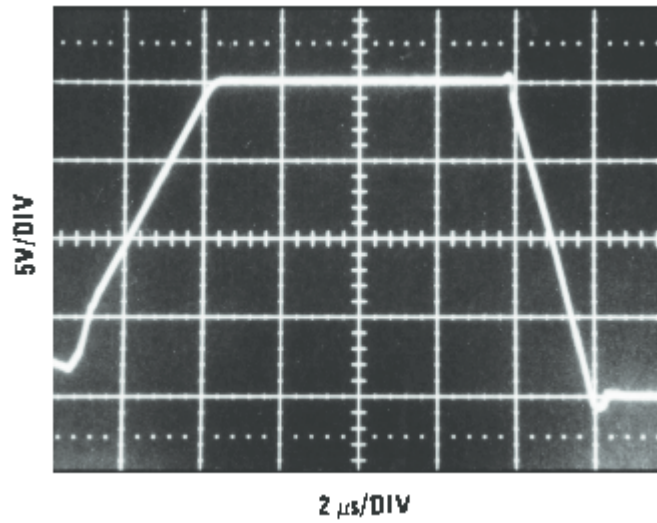


Figure 40. LF355

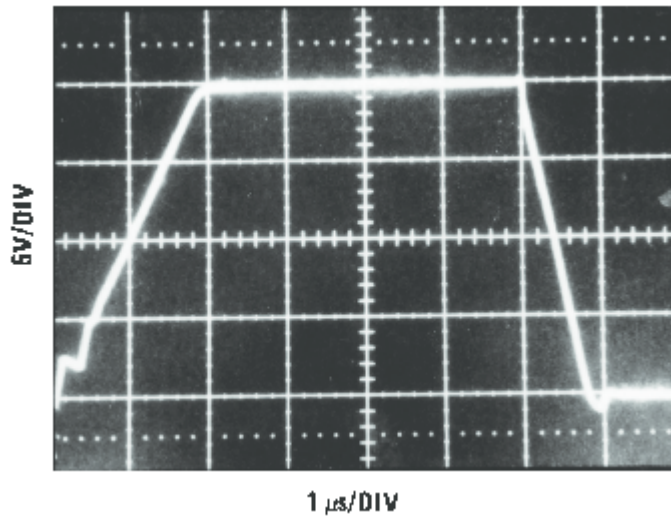


Figure 41. LF356

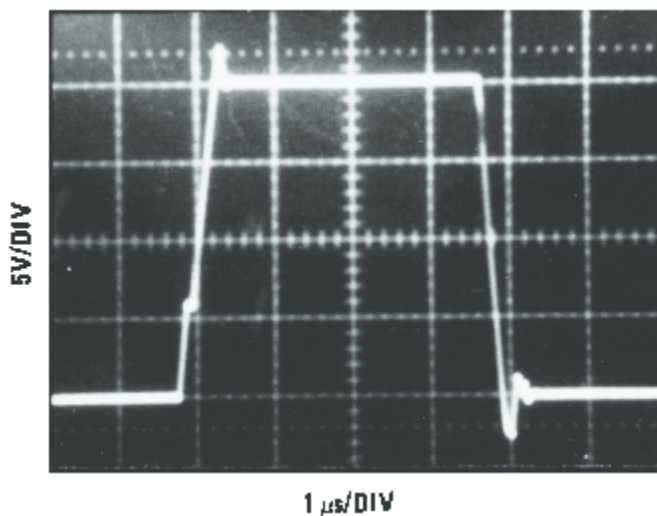


Figure 42. LF357

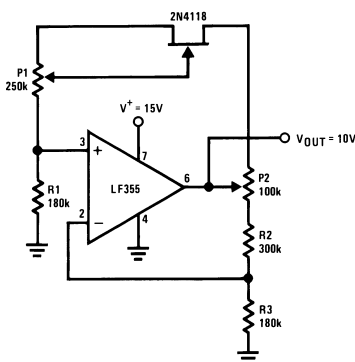


Figure 43. Low Drift Adjustable Voltage Reference

- $\Delta V_{OUT}/\Delta T = \pm 0.002\%/^{\circ}\text{C}$
- All resistors and potentiometers should be wire-wound
- P1: drift adjust
- P2:  $V_{OUT}$  adjust
- Use LF155 for
  - Low  $I_B$
  - Low drift
  - Low supply current

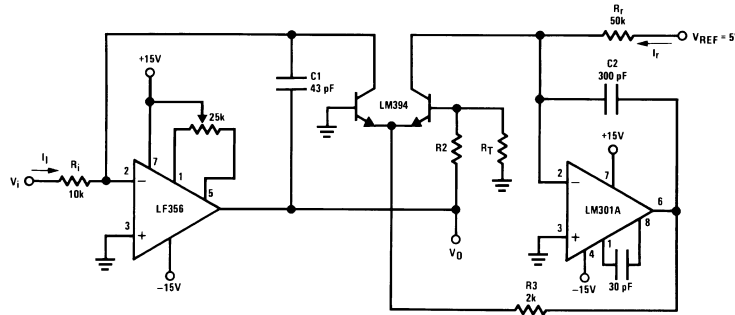


Figure 44. Fast Logarithmic Converter

- 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  $\Delta I_i = 1$  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

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

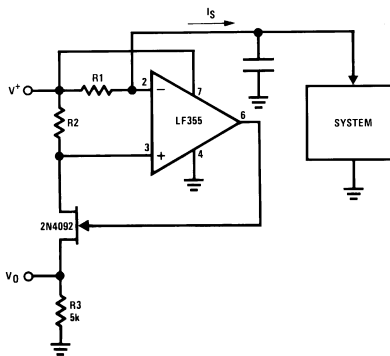


Figure 45. Precision Current Monitor

- $V_O = 5 R_1/R_2$  (V/mA of  $I_S$ )
- R1, R2, R3: 0.1% resistors
- Use LF155 for
  - Common-mode range to supply range
  - Low  $I_B$
  - Low  $V_{OS}$
  - Low Supply Current

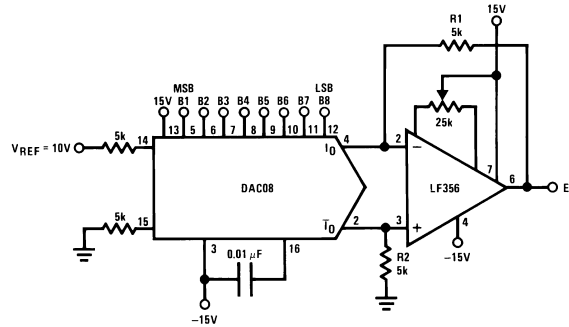
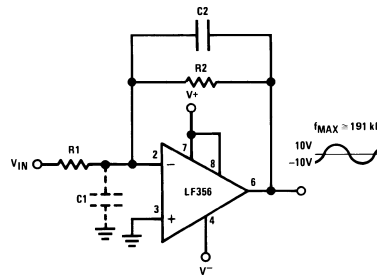


Figure 46. 8-Bit D/A Converter with Symmetrical Offset Binary Operation

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

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



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

Figure 47. Wide BW Low Noise, Low Drift Amplifier

- Parasitic input capacitance C1 ≈ (3pF for LF155, LF156 and LF357 plus any additional layout capacitance) interacts with feedback elements and creates undesirable high frequency pole. To compensate add C2 such that: R2 C2 ≈ R1 C1.

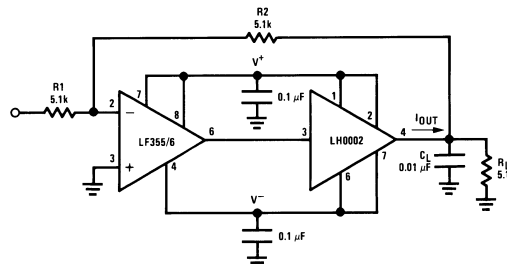
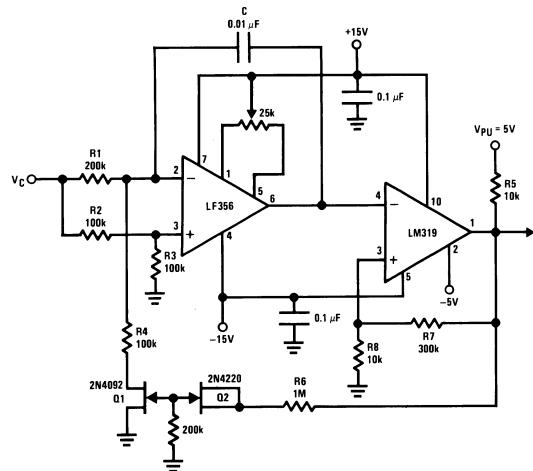


Figure 48. Boosting the LF156 with a Current Amplifier

- I<sub>OUT(MAX)</sub> ≈ 150mA (will drive R<sub>L</sub> ≥ 100Ω)
- $\frac{\Delta V_{OUT}}{\Delta T} = \frac{0.15}{10^{-2}} \text{ V}/\mu\text{s}$  (with C<sub>L</sub> shown)
- No additional phase shift added by the current amplifier



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

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

Figure 49. Decades VCO

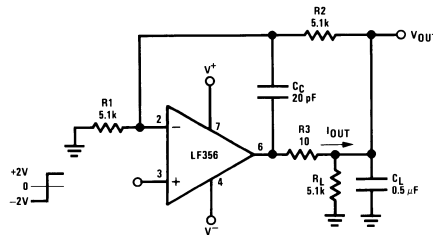


Figure 50. Isolating Large Capacitive Loads

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

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

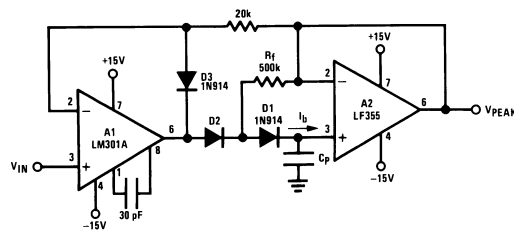
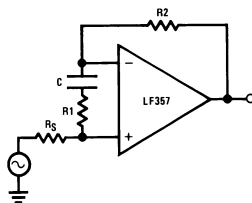


Figure 51. Low Drift Peak Detector

- By adding D1 and  $R_f$ ,  $V_{D1}=0$  during hold mode. Leakage of D2 provided by feedback path through  $R_f$ .
- Leakage of circuit is essentially  $I_b$  (LF155, LF156) plus capacitor leakage of  $C_p$ .
- Diode D3 clamps  $V_{OUT}$  (A1) to  $V_{IN}-V_{D3}$  to improve speed and to limit reverse bias of D2.
- Maximum input frequency should be  $\ll \frac{1}{2\pi R_f C_{D2}}$  where  $C_{D2}$  is the shunt capacitance of D2.



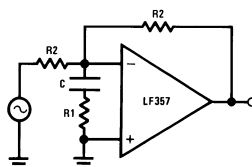
$$R_1 C \geq \frac{1}{(2\pi) (5 \text{ MHz})}$$

$$R_1 = \frac{R_2 + R_S}{4}$$

$$A_{V(DC)} = 1$$

$$f_{-3 \text{ dB}} \approx 5 \text{ MHz}$$

**Figure 52. Non-Inverting Unity Gain Operation for LF157**



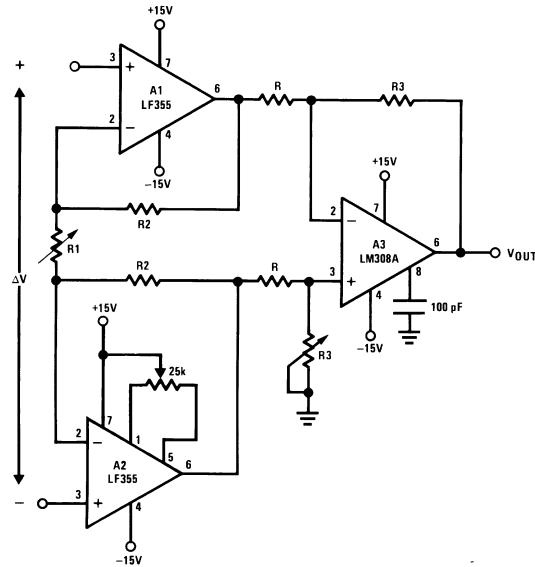
$$R_1 C \geq \frac{1}{(2\pi) (5 \text{ MHz})}$$

$$R_1 = \frac{R_2}{4}$$

$$A_{V(DC)} = -1$$

$$f_{-3 \text{ dB}} \approx 5 \text{ MHz}$$

**Figure 53. Inverting Unity Gain for LF157**



$$\bullet V_{OUT} = \frac{R3}{R} \left[ \frac{2R2}{R1} + 1 \right] \Delta V, V^- + 2V \leq V_{IN} \text{ common-mode} \leq V^+$$

**Figure 54. High Impedance, Low Drift Instrumentation Amplifier**

- System  $V_{OS}$  adjusted via A2  $V_{OS}$  adjust
- Trim R3 to boost up CMRR to 120 dB. Instrumentation amplifier resistor array recommended for best accuracy and lowest drift

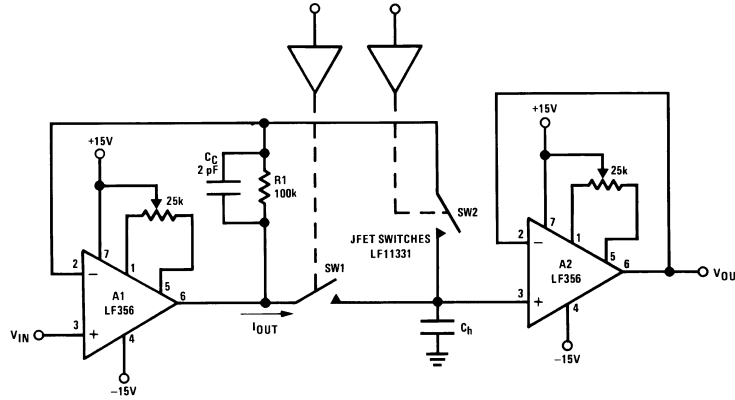


Figure 55. Fast Sample and Hold

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

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

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

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

- LF156 develops full  $S_r$  output capability for  $V_{IN} \geq 1V$
- 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

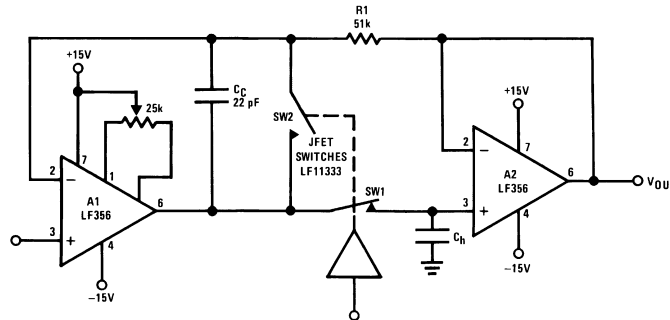


Figure 56. High Accuracy Sample and Hold

- 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  $V_{OS}$

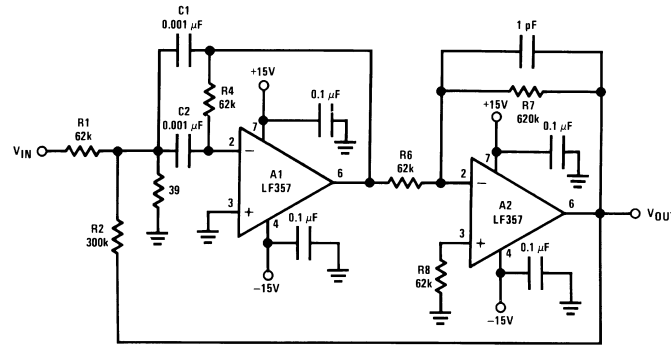


Figure 57. High Q Band Pass Filter

- By adding positive feedback (R2)
- Q increases to 40
- $f_{BP} = 100 \text{ kHz}$
- $\frac{V_{OUT}}{V_{IN}} = 10\sqrt{Q}$
- Clean layout recommended
- Response to a 1Vp-p tone burst: 300µs

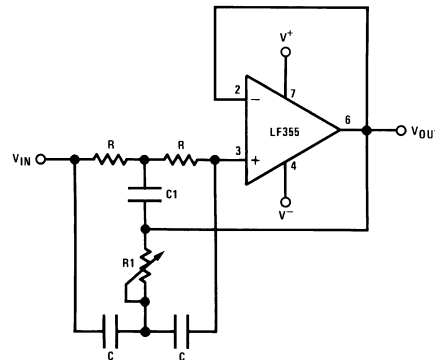


Figure 58. High Q Notch Filter

- $2R1 = R = 10M\Omega$
- $2C = C1 = 300pF$
- Capacitors should be matched to obtain high Q
- $f_{NOTCH} = 120 \text{ Hz}$ , notch = -55 dB,  $Q > 100$
- Use LF155 for
  - Low  $I_B$
  - Low supply current

## REVISION HISTORY

Changes from Revision B (March 2013) to Revision C	Page
• Changed layout of National Data Sheet to TI format .....	<a href="#">23</a>

**PACKAGING INFORMATION**

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish (6)	MSL Peak Temp (3)	Op Temp (°C)	Device Marking (4/5)	Samples
LF156H	ACTIVE	TO-99	LMC	8	500	TBD	Call TI	Call TI	-55 to 125	LF156H	<a href="#">Samples</a>
LF156H/NOPB	ACTIVE	TO-99	LMC	8	500	Green (RoHS & no Sb/Br)	POST-PLATE	Level-1-NA-UNLIM	-55 to 125	LF156H	<a href="#">Samples</a>
LF256H	ACTIVE	TO-99	LMC	8	500	TBD	Call TI	Call TI	-25 to 85	LF256H	<a href="#">Samples</a>
LF256H/NOPB	ACTIVE	TO-99	LMC	8	500	Green (RoHS & no Sb/Br)	POST-PLATE	Level-1-NA-UNLIM	-25 to 85	LF256H	<a href="#">Samples</a>
LF356H	ACTIVE	TO-99	LMC	8	500	TBD	Call TI	Call TI	0 to 70	LF356H	<a href="#">Samples</a>
LF356H/NOPB	ACTIVE	TO-99	LMC	8	500	Green (RoHS & no Sb/Br)	POST-PLATE	Level-1-NA-UNLIM	0 to 70	LF356H	<a href="#">Samples</a>
LF356M	NRND	SOIC	D	8	95	TBD	Call TI	Call TI	0 to 70	LF356 M	
LF356M/NOPB	ACTIVE	SOIC	D	8	95	Green (RoHS & no Sb/Br)	SN   CU SN	Level-1-260C-UNLIM	0 to 70	LF356 M	<a href="#">Samples</a>
LF356MX	NRND	SOIC	D	8	2500	TBD	Call TI	Call TI	0 to 70	LF356 M	
LF356MX/NOPB	ACTIVE	SOIC	D	8	2500	Green (RoHS & no Sb/Br)	SN   CU SN	Level-1-260C-UNLIM	0 to 70	LF356 M	<a href="#">Samples</a>
LF356N	NRND	PDIP	P	8	40	TBD	Call TI	Call TI	0 to 70	LF 356N	
LF356N/NOPB	ACTIVE	PDIP	P	8	40	Green (RoHS & no Sb/Br)	CU SN	Level-1-NA-UNLIM	0 to 70	LF 356N	<a href="#">Samples</a>

(1) The marketing status values are defined as follows:

**ACTIVE:** Product device recommended for new designs.

**LIFEBUY:** TI has announced that the device will be discontinued, and a lifetime-buy period is in effect.

**NRND:** Not recommended for new designs. Device is in production to support existing customers, but TI does not recommend using this part in a new design.

**PREVIEW:** Device has been announced but is not in production. Samples may or may not be available.

**OBSELETE:** TI has discontinued the production of the device.

(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check <http://www.ti.com/productcontent> for the latest availability information and additional product content details.

**TBD:** The Pb-Free/Green conversion plan has not been defined.

**Pb-Free (RoHS):** TI's terms "Lead-Free" or "Pb-Free" mean semiconductor products that are compatible with the current RoHS requirements for all 6 substances, including the requirement that lead not exceed 0.1% by weight in homogeneous materials. Where designed to be soldered at high temperatures, TI Pb-Free products are suitable for use in specified lead-free processes.

---

**Pb-Free (RoHS Exempt):** This component has a RoHS exemption for either 1) lead-based flip-chip solder bumps used between the die and package, or 2) lead-based die adhesive used between the die and leadframe. The component is otherwise considered Pb-Free (RoHS compatible) as defined above.

**Green (RoHS & no Sb/Br):** TI defines "Green" to mean Pb-Free (RoHS compatible), and free of Bromine (Br) and Antimony (Sb) based flame retardants (Br or Sb do not exceed 0.1% by weight in homogeneous material)

<sup>(3)</sup> MSL, Peak Temp. - The Moisture Sensitivity Level rating according to the JEDEC industry standard classifications, and peak solder temperature.

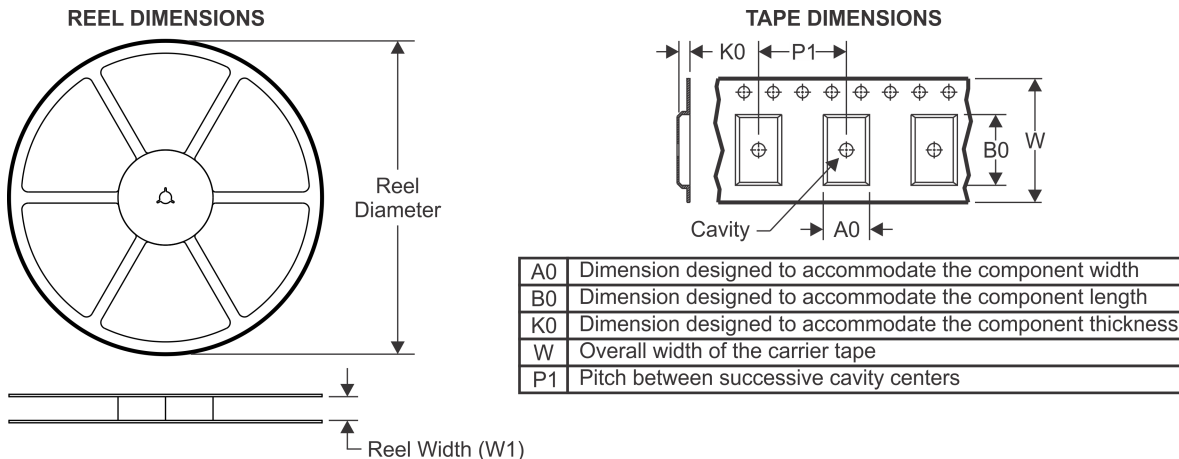
<sup>(4)</sup> There may be additional marking, which relates to the logo, the lot trace code information, or the environmental category on the device.

<sup>(5)</sup> Multiple Device Markings will be inside parentheses. Only one Device Marking contained in parentheses and separated by a "~" will appear on a device. If a line is indented then it is a continuation of the previous line and the two combined represent the entire Device Marking for that device.

<sup>(6)</sup> Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

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**TAPE AND REEL INFORMATION**

**QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE**


\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Reel Diameter (mm)	Reel Width W1 (mm)	A0 (mm)	B0 (mm)	K0 (mm)	P1 (mm)	W (mm)	Pin1 Quadrant
LF356MX	SOIC	D	8	2500	330.0	12.4	6.5	5.4	2.0	8.0	12.0	Q1
LF356MX/NOPB	SOIC	D	8	2500	330.0	12.4	6.5	5.4	2.0	8.0	12.0	Q1

**TAPE AND REEL BOX DIMENSIONS**

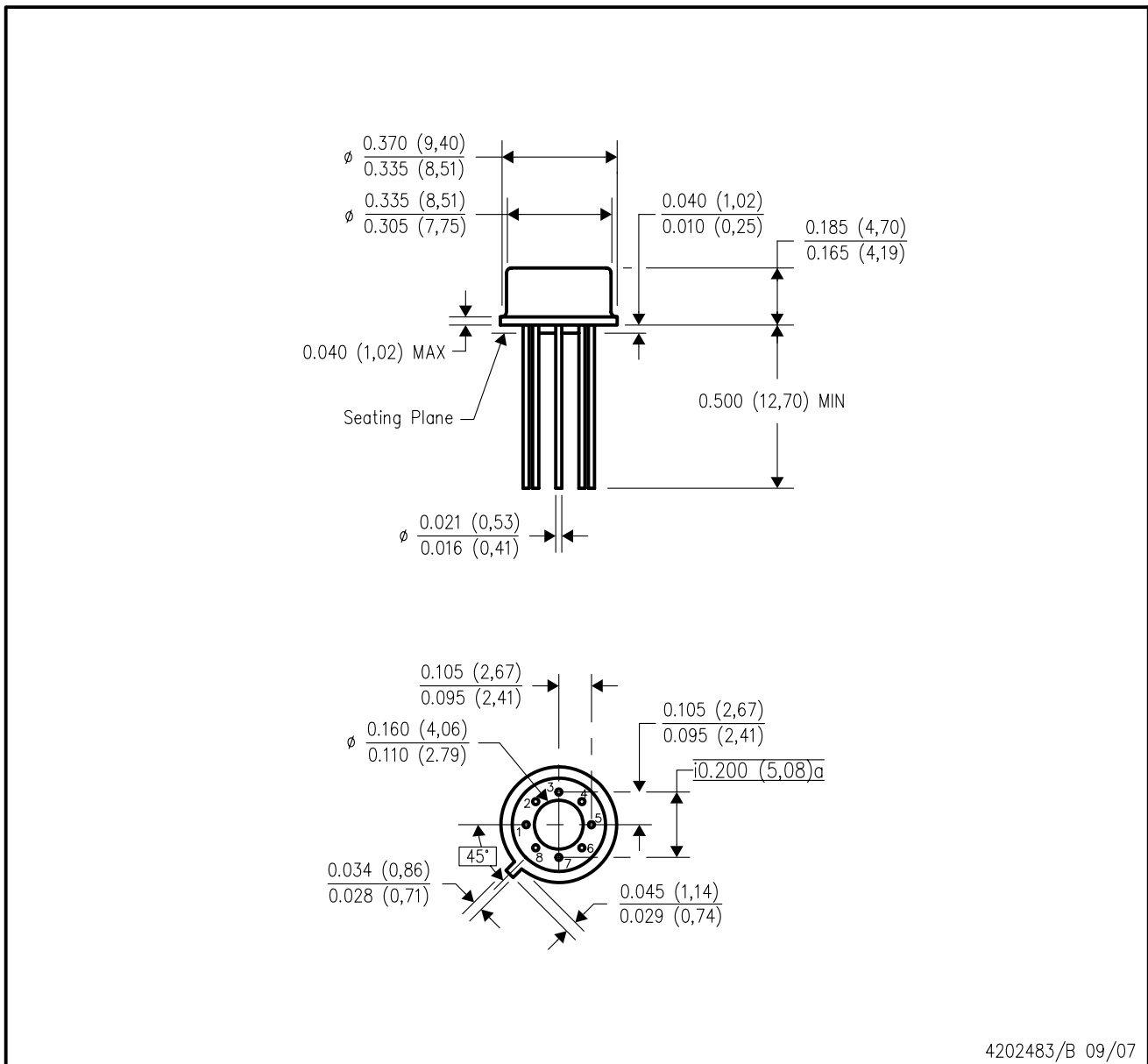


\*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LF356MX	SOIC	D	8	2500	367.0	367.0	35.0
LF356MX/NOPB	SOIC	D	8	2500	367.0	367.0	35.0

LMC (O-MBCY-W8)

METAL CYLINDRICAL PACKAGE



- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - B. This drawing is subject to change without notice.
  - C. Leads in true position within 0.010 (0,25) R @ MMC at seating plane.
  - D. Pin numbers shown for reference only. Numbers may not be marked on package.
  - E. Falls within JEDEC MO-002/TO-99.

P (R-PDIP-T8)

PLASTIC DUAL-IN-LINE PACKAGE



- NOTES:
- A. All linear dimensions are in inches (millimeters).
  - B. This drawing is subject to change without notice.
  - C. Falls within JEDEC MS-001 variation BA.



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### Applications

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