LM146/LM346 Programmable Quad Operational Amplifiers

Check for Samples: LM146, LM346

FEATURES

- **(I_{SET}=10 µA)**
- **Programmable Electrical Characteristics**
- **Battery-Powered Operation**
- **Low Supply Current: 350 µA/Amplifier**
- **Ensured Gain Bandwidth Product: 0.8 MHz Min**
- **Large DC Voltage Gain: 120 dB**
- **Low Noise Voltage: 28 nV/√Hz**
- **Wide Power Supply Range: ±1.5V to ±22V**
- **Class AB Output Stage–No Crossover Distortion**
- **Ideal Pin Out for Biquad Active Filters**
- **Input Bias Currents are Temperature Compensated**

DESCRIPTION

The LM146 series of quad op amps consists of four independent, high gain, internally compensated, low power, programmable amplifiers. Two external resistors (R_{SET}) allow the user to program the gain bandwidth product, slew rate, supply current, input bias current, input offset current and input noise. For example, the user can trade-off supply current for bandwidth or optimize noise figure for a given source resistance. In a similar way, other amplifier characteristics can be tailored to the application. Except for the two programming pins at the end of the package, the LM146 pin-out is the same as the LM124 and LM148.

Connection Diagram

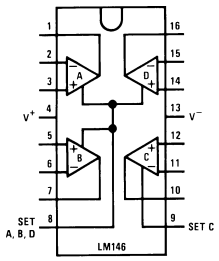


Figure 1. Dual-In-Line Package - Top View
See Package Number NFE0016A, D0016A or N16A

PROGRAMMING EQUATIONS

Total Supply Current = 1.4 mA (I_{SET}/10 µA)

Gain Bandwidth Product = 1 MHz (I_{SET}/10 µA)

Slew Rate = 0.4V/µs (I_{SET}/10 µA)

Input Bias Current ≈ 50 nA (I_{SET}/10 µA)

I_{SET} = Current into pin 8, pin 9 (see Schematic Diagram)

$$I_{SET} = \frac{V^+ - V^- - 0.6V}{R_{SET}} \quad (1)$$

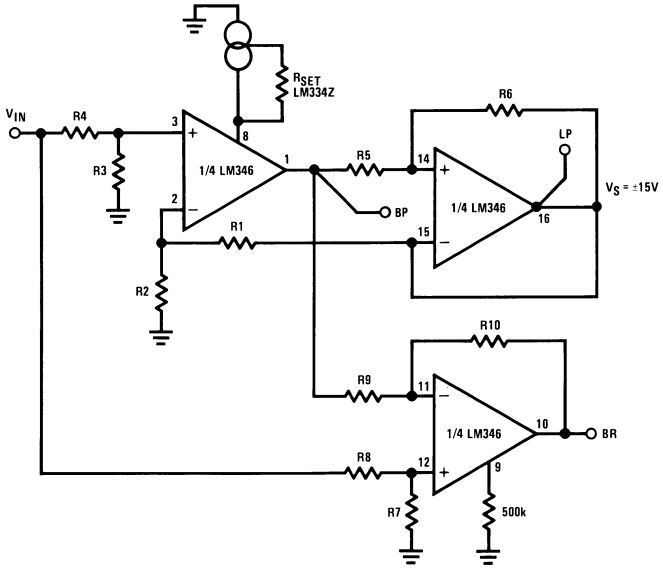
Please be aware that an important notice concerning availability, standard warranty, and use in critical applications of Texas Instruments semiconductor products and disclaimers thereto appears at the end of this data sheet.

All trademarks are the property of their respective owners.

UNLESS OTHERWISE NOTED this document contains PRODUCTION DATA information current as of publication date. Products conform to specifications per the terms of Texas Instruments standard warranty. Production processing does not necessarily include testing of all parameters.

Copyright © 2004, Texas Instruments Incorporated

Capacitorless Active Filters (Basic Circuit)



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(1)(2)(3)

			LM146	LM346
Supply Voltage			±22V	±18V
Differential Input Voltage(2)			±30V	±30V
CM Input Voltage(2)			±15V	±15V
Power Dissipation(4)			900 mW	500 mW
Output Short-Circuit Duration(5)			Continuous	Continuous
Operating Temperature Range			−55°C to +125°C	0°C to +70°C
Maximum Junction Temperature			150°C	100°C
Storage Temperature Range			−65°C to +150°C	−65°C to +150°C
Lead Temperature (Soldering, 10 seconds)			260°C	260°C
Thermal Resistance (θ_{jA})(4)	CDIP (NFE)	Pd	900 mW	900 mW
		θ_{jA}	100°C/W	100°C/W
	SOIC (D)	θ_{jA}		115°C/W
	PDIP (N)	Pd		500 mW
		θ_{jA}		90°C/W
Soldering Information	Dual-In-Line Package	Soldering (10 seconds)	+260°C	+260°C
	Small Outline Package	Vapor Phase (60 seconds)	+215°C	+215°C
		Infrared (15 seconds)	+220°C	+220°C
ESD rating is to be determined.				

(1) Refer to RETS146X for LM146J military specifications.
(2) For supply voltages less than ±15V, the absolute maximum input voltage is equal to the supply voltage.
(3) If Military/Aerospace specified devices are required, please contact the Texas Instruments Sales Office/ Distributors for availability and specifications.
(4) The maximum power dissipation for these devices must be derated at elevated temperatures and is dictated by T_{jMAX}, θ_{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.
(5) Any of the amplifier outputs can be shorted to ground indefinitely; however, more than one should not be simultaneously shorted as the maximum junction temperature will be exceeded.

Copyright © 2004, Texas Instruments Incorporated

DC ELECTRICAL CHARACTERISTICS

(V_S=±15V, I_{SET}=10 µA)[1]

Parameter	Conditions	LM146			LM346			Units
		Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage	V_{CM}=0V, R_S≤50Ω, T_A=25°C		0.5	5		0.5	6	mV
Input Offset Current	V_{CM}=0V, T_A=25°C		2	20		2	100	nA
Input Bias Current	V_{CM}=0V, T_A=25°C		50	100		50	250	nA
Supply Current (4 Op Amps)	T_A=25°C		1.4	2.0		1.4	2.5	mA
Large Signal Voltage Gain	R_L=10 kΩ, ΔV_{OUT}=±10V, T_A=25°C	100	1000		50	1000		V/mV
Input CM Range	T_A=25°C	±13.5	±14		±13.5	±14		V
CM Rejection Ratio	R_S≤10 kΩ, T_A=25°C	80	100		70	100		dB
Power Supply Rejection Ratio	R_S≤10 kΩ, T_A=25°C, V_S = ±5 to ±15V	80	100		74	100		dB
Output Voltage Swing	R_L≥10 kΩ, T_A=25°C	±12	±14		±12	±14		V
Short-Circuit	T_A=25°C	5	20	35	5	20	35	mA
Gain Bandwidth Product	T_A=25°C	0.8	1.2		0.5	1.2		MHz
Phase Margin	T_A=25°C		60			60		Deg
Slew Rate	T_A=25°C		0.4			0.4		V/µs
Input Noise Voltage	f=1 kHz, T_A=25°C		28			28		8 nV/$\sqrt{Hz}$
Channel Separation	R_L=10 kΩ, ΔV_{OUT}=0V to ±12V, T_A=25°C		120			120		dB
Input Resistance	T_A=25°C		1.0			1.0		MΩ
Input Capacitance	T_A=25°C		2.0			2.0		pF
Input Offset Voltage	V_{CM}=0V, R_S≤50Ω		0.5	6		0.5	7.5	mV
Input Offset Current	V_{CM}=0V		2	25		2	100	nA
Input Bias Current	V_{CM}=0V		50	100		50	250	nA
Supply Current (4 Op Amps)			1.7	2.2		1.7	2.5	mA
Large Signal Voltage Gain	R_L=10 kΩ, ΔV_{OUT}=±10V	50	1000		25	1000		V/mV
Input CM Range		±13.5	±14		±13.5	±14		V
CM Rejection Ratio	R_S≤50Ω	70	100		70	100		dB
Power Supply Rejection Ratio	R_S≤50Ω, V_S = ±5V to ±15V	76	100		74	100		dB
Output Voltage Swing	R_L≥10 kΩ	±12	±14		±12	±14		V

(1) These specifications apply over the absolute maximum operating temperature range unless otherwise noted.

DC ELECTRICAL CHARACTERISTIC

(V_S=±15V, I_{SET}=10 µA)

Parameter	Conditions	LM146			LM346			Units
		Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage	V_{CM}=0V, R_S≤50Ω, T_A=25°C		0.5	5		0.5	7	mV
Input Bias Current	V_{CM}=0V, T_A=25°C		7.5	20		7.5	100	nA
Supply Current (4 Op Amps)	T_A=25°C		140	250		140	300	µA
Gain Bandwidth Product	T_A=25°C	80	100		50	100		kHz

Copyright © 2004, Texas Instruments Incorporated

DC ELECTRICAL CHARACTERISTICS

(V_S=±1.5V, I_{SET}=10 µA)

Parameter	Conditions	LM146			LM346			Units
		Min	Typ	Max	Min	Typ	Max	
Input Offset Voltage	V_{CM}=0V, R_S≤50Ω, T_A=25°C		0.5	5		0.5	7	mV
Input CM Range	T_A=25°C	±0.7			±0.7			V
CM Rejection Ratio	R_S≤50Ω, T_A=25°C		80			80		dB
Output Voltage Swing	R_L≥10 kΩ, T_A=25°C	±0.6			±0.6			V

Copyright © 2004, Texas Instruments Incorporated

TYPICAL PERFORMANCE CHARACTERISTICS

Input Bias Current vs I_{SET}

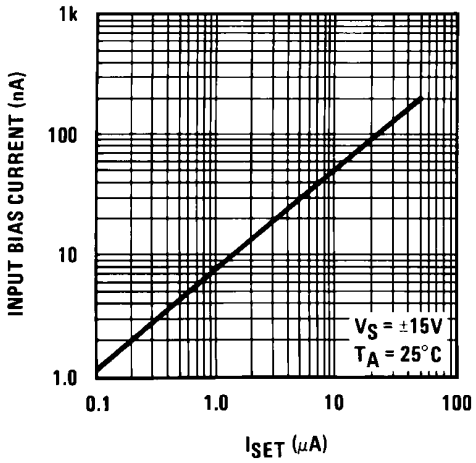


Figure 2.

Supply Current vs I_{SET}

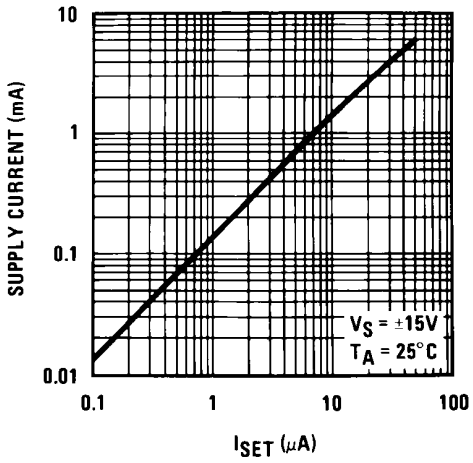


Figure 3.

Open Loop Voltage Gain vs I_{SET}

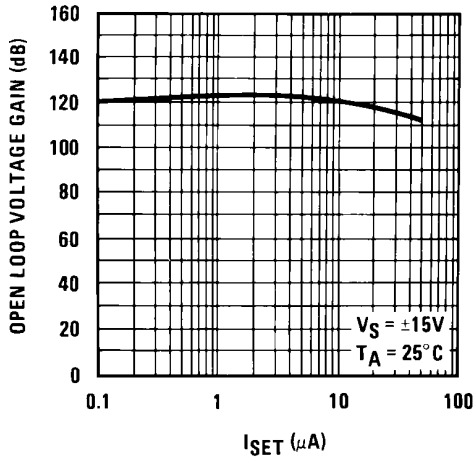


Figure 4.

Slew Rate vs I_{SET}

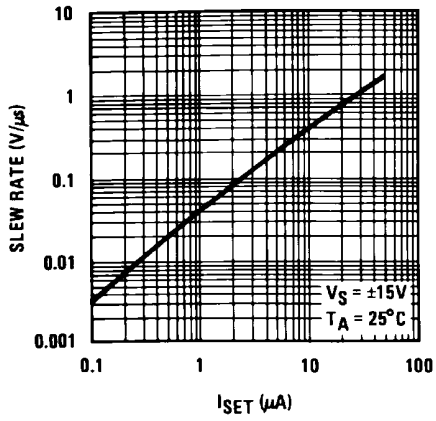


Figure 5.

Gain Bandwidth Product vs I_{SET}

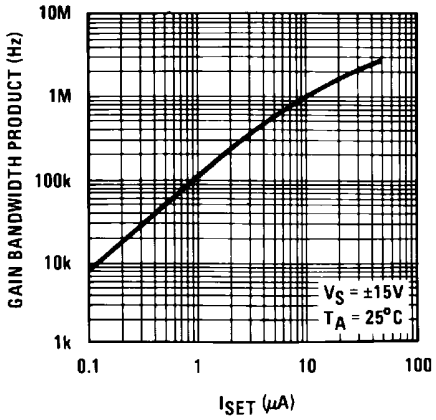


Figure 6.

Phase Margin vs I_{SET}

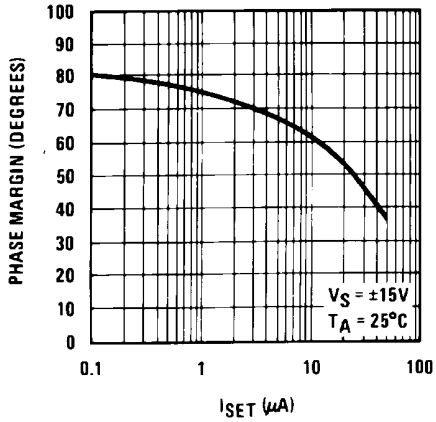


Figure 7.

Copyright © 2004, Texas Instruments Incorporated

TYPICAL PERFORMANCE CHARACTERISTICS (continued)

Input Offset Voltage vs I_{SET}

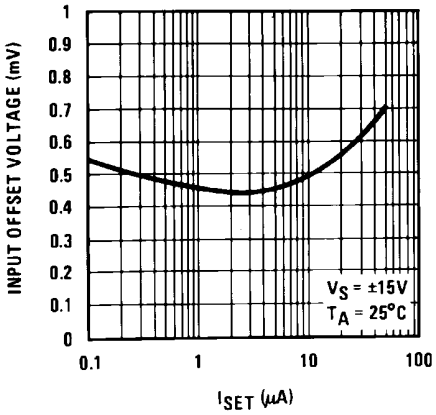


Figure 8.

Common-Mode Rejection Ratio vs I_{SET}

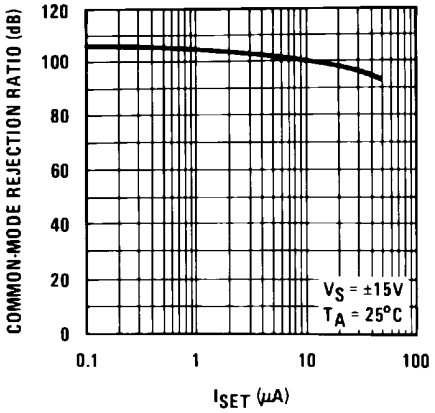


Figure 9.

Power Supply Rejection Ratio vs I_{SET}

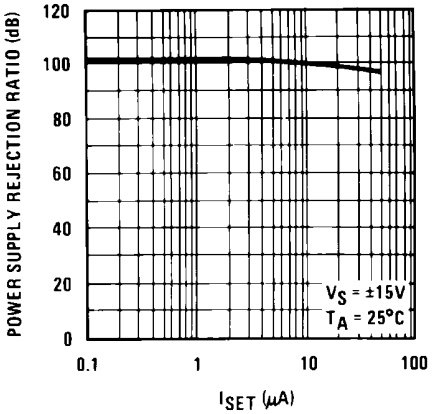


Figure 10.

Open Voltage Swing vs Supply Voltage

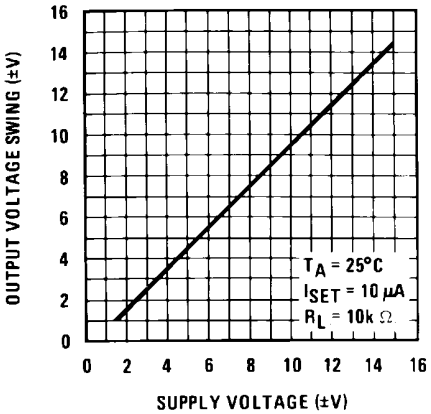


Figure 11.

Input Voltage Range vs Supply Voltage

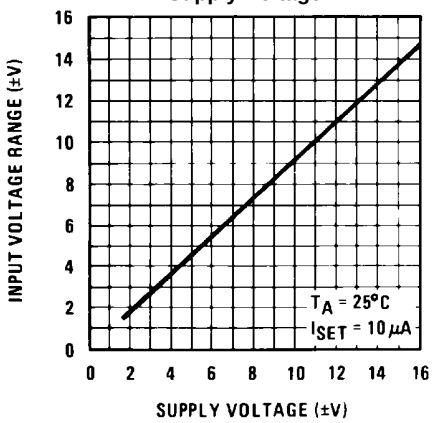


Figure 12.

Input Bias Current vs Input Common-Mode Voltage

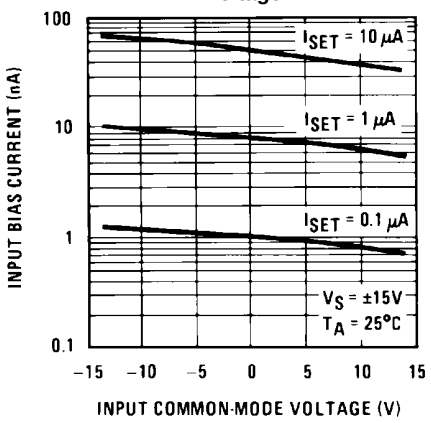


Figure 13.

Copyright © 2004, Texas Instruments Incorporated

TYPICAL PERFORMANCE CHARACTERISTICS (continued)

Input Bias Current vs Temperature

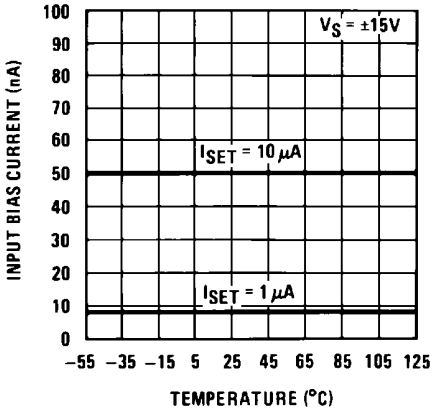


Figure 14.

Input Offset Current vs Temperature

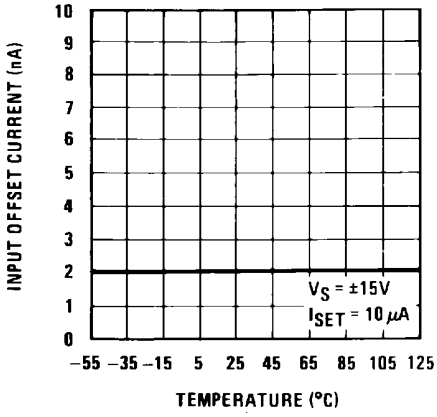


Figure 15.

Supply Current vs Temperature

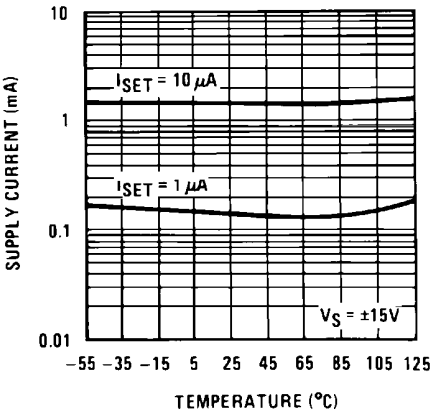


Figure 16.

Open Loop Voltage Gain vs Temperature

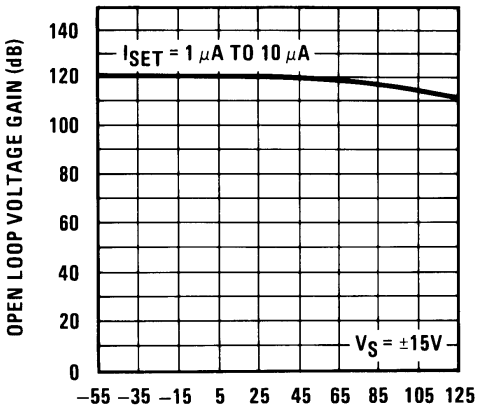


Figure 17.

Gain Bandwidth Product vs Temperature

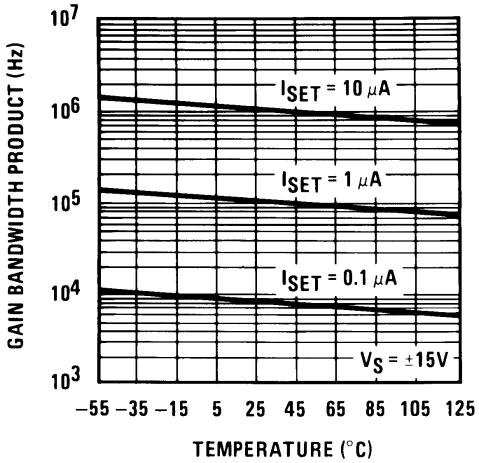


Figure 18.

Slew Rate vs Temperature

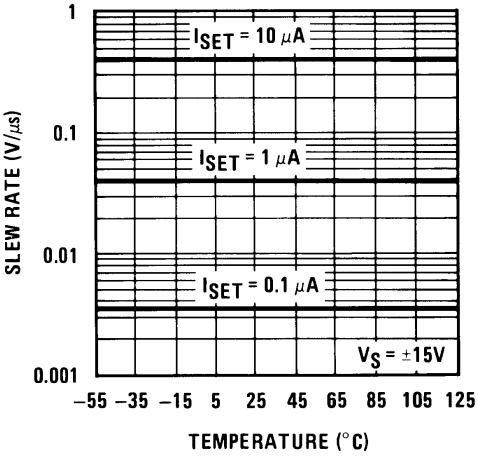


Figure 19.

Copyright © 2004, Texas Instruments Incorporated

TYPICAL PERFORMANCE CHARACTERISTICS (continued)

Input Noise Voltage vs Frequency

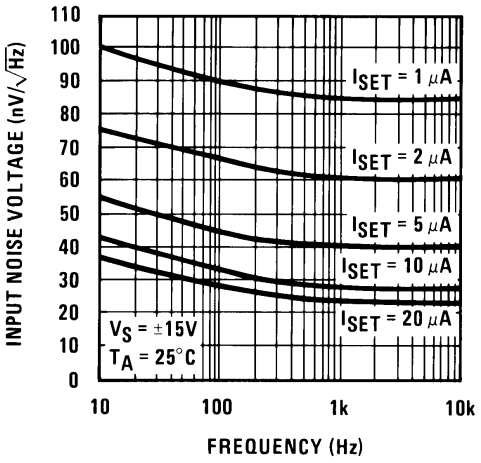


Figure 20.

Input Noise Current vs Frequency

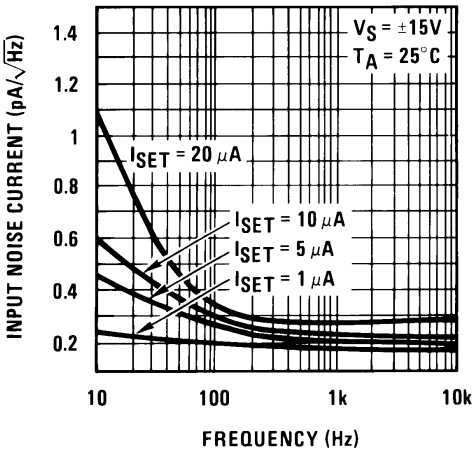


Figure 21.

Power Supply Rejection Ratio vs Frequency

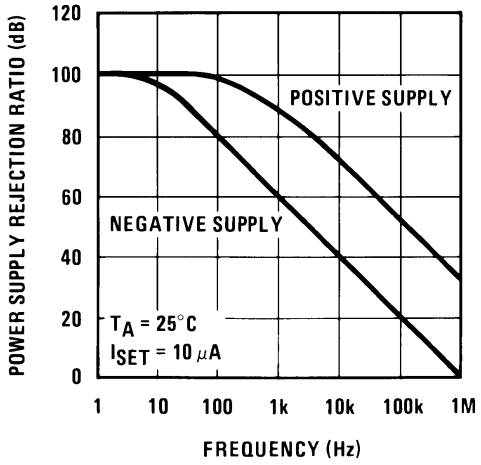


Figure 22.

Voltage Follower Pulse Response

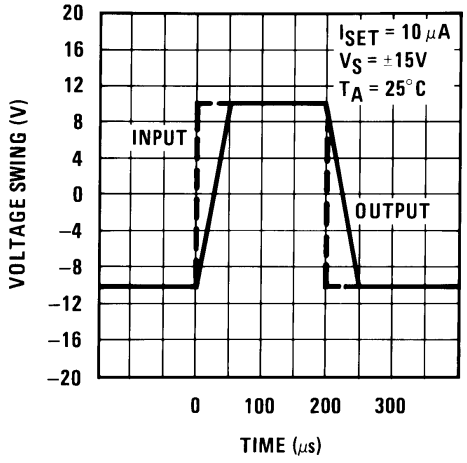


Figure 23.

Voltage Follower Transient Response

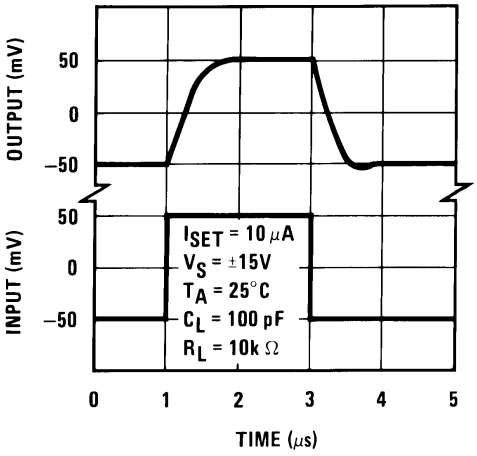


Figure 24.

Transient Response Test Circuit

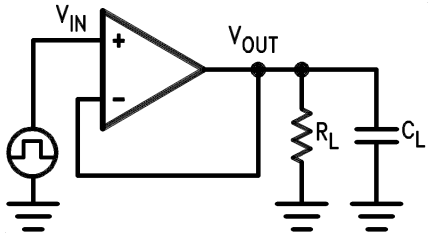


Figure 25.

Copyright © 2004, Texas Instruments Incorporated

APPLICATION HINTS

Avoid reversing the power supply polarity; the device will fail.

COMMON-MODE INPUT VOLTAGE

The negative common-mode voltage limit is one diode drop above the negative supply voltage. Exceeding this limit on either input will result in an output phase reversal. The positive common-mode limit is typically 1V below the positive supply voltage. No output phase reversal will occur if this limit is exceeded by either input.

OUTPUT VOLTAGE SWING VS I_{SET}

For a desired output voltage swing the value of the minimum load depends on the positive and negative output current capability of the op amp. The maximum available positive output current, (I_{CL+}), of the device increases with I_{SET} whereas the negative output current (I_{CL-}) is independent of I_{SET}. Figure 26 illustrates the above.

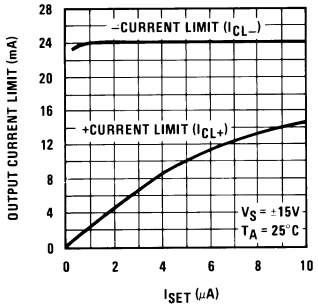


Figure 26. Output Current Limit vs I_{SET}

INPUT CAPACITANCE

The input capacitance, C_{IN}, of the LM146 is approximately 2 pF; any stray capacitance, C_S, (due to external circuit circuit layout) will add to C_{IN}. When resistive or active feedback is applied, an additional pole is added to the open loop frequency response of the device. For instance with resistive feedback (Figure 27), this pole occurs at ½π (R1||R2) (C_{IN} + C_S). Make sure that this pole occurs at least 2 octaves beyond the expected −3 dB frequency corner of the closed loop gain of the amplifier; if not, place a lead capacitor in the feedback such that the time constant of this capacitor and the resistance it parallels is equal to the $R_I(C_S + C_{IN})$, where R_I is the input resistance of the circuit.

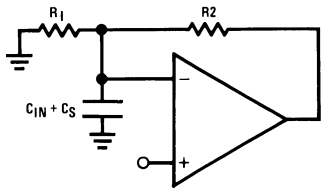


Figure 27. Resistive Feedback Circuit Example

TEMPERATURE EFFECT ON THE GBW

The GBW (gain bandwidth product), of the LM146 is directly proportional to I_{SET} and inversely proportional to the absolute temperature. When using resistors to set the bias current, I_{SET}, of the device, the GBW product will decrease with increasing temperature. Compensation can be provided by creating an I_{SET} current directly proportional to temperature (see Typical Applications).

ISOLATION BETWEEN AMPLIFIERS

The LM146 die is isothermally layed out such that crosstalk between *all 4* amplifiers is in excess of −105 dB (DC). Optimum isolation (better than −110 dB) occurs between amplifiers A and D, B and C; that is, if amplifier A dissipates power on its output stage, amplifier D is the one which will be affected the least, and vice versa. Same argument holds for amplifiers B and C.

Copyright © 2004, Texas Instruments Incorporated

LM146 TYPICAL PERFORMANCE SUMMARY

The LM146 typical behaviour is shown in Figure 28. The device is fully predictable. As the set current, I_{SET}, increases, the speed, the bias current, and the supply current increase while the noise power decreases proportionally and the V_{OS}remains constant. The usable GBW range of the op amp is 10 kHz to 3.5−4 MHz.

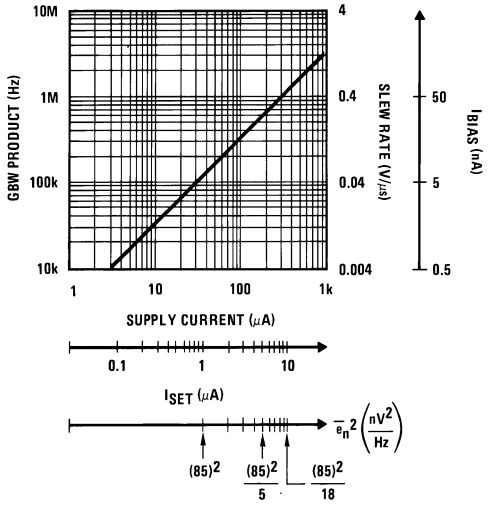


Figure 28. LM146 Typical Characteristics

Low Power Supply Operation: The quad op amp operates down to ±1.3V supply. Also, since the internal circuitry is biased through programmable current sources, no degradation of the device speed will occur.

SPEED VS POWER CONSUMPTION

LM146 vs LM4250 (single programmable). Through Figure 29, we observe that the LM146's power consumption has been optimized for GBW products above 200 kHz, whereas the LM4250 will reach a GBW of no more than 300 kHz. For GBW products below 200 kHz, the LM4250 will consume less power.

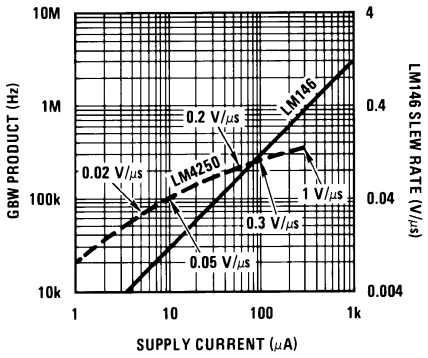
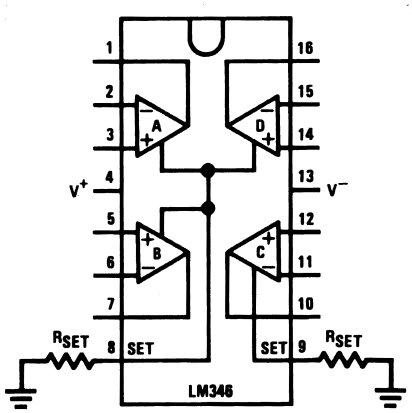


Figure 29. LM146 vs LM4250

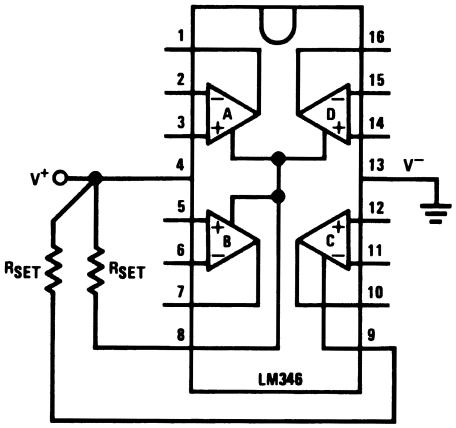
Copyright © 2004, Texas Instruments Incorporated

Typical Applications



$$I_{SET} \cong \frac{|V^-| - 0.6V}{R_{SET}}$$

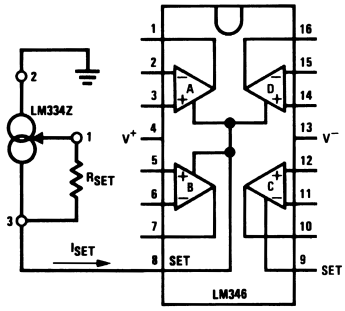
Figure 30. Dual Supply or Negative Supply Blasing



$$I_{SET} \cong \frac{V^+ - 0.6V}{R_{SET}}$$

Figure 31. Single (Positive) Supply Biasing

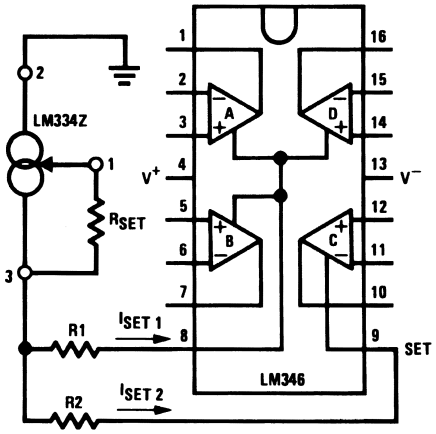
Copyright © 2004, Texas Instruments Incorporated



$$I_{SET} = \frac{67.7\ mV}{R_{SET}}$$

• The LM334 provides an I_{SET} directly proportional to absolute temperature. This cancels the slight GBW product Temperature coefficient of the LM346.

Figure 32. Current Source Biasing with Temperature Compensation



$$\frac{I_{SET1}}{I_{SET2}} = \frac{R2}{R1},\ I_{SET1} + I_{SET2} = \frac{67.7\ mV}{R_{SET}}$$

• For $I_{SET1} \cong I_{SET2}$ resistors R1 and R2 are not required if a slight error between the 2 set currents can be tolerated. If not, then use R1 = R2 to create a 100 mV drop across these resistors.

Figure 33. Biasing all 4 Amplifiers with Single Current Source

Copyright © 2004, Texas Instruments Incorporated

Active Filters Applications

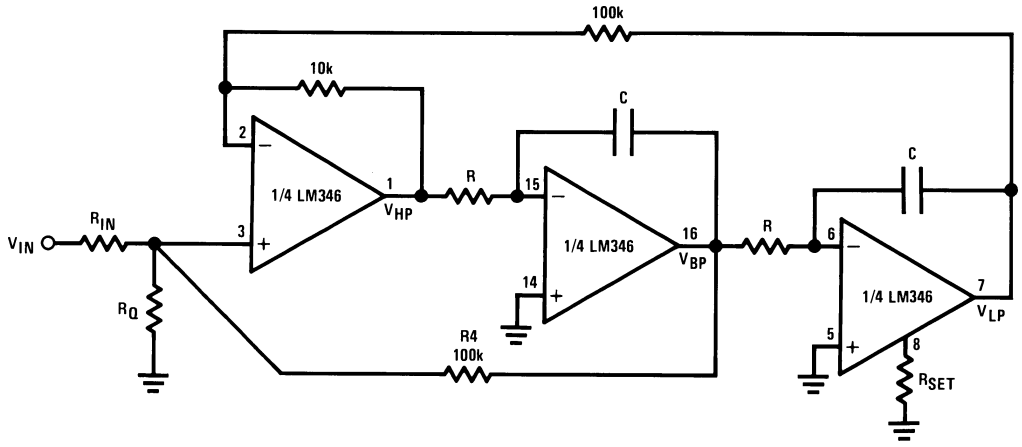


Figure 34. Basic (Non-Inverting "State Variable") Active Filter Building Block

- The LM146 quad programmable op amp is especially suited for active filters because of their adequate GBW product and low power consumption.

  Circuit synthesis equations (for circuit analysis equations, consult with the LM148 data sheet).

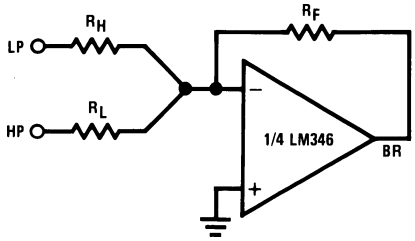
  Need to know desired: f_o = center frequency measured at the BP output

  Q_o = quality factor measured at the BP output

  H_o = gain at the output of interest (BP or HP or LP or all of them)

- Relation between different gains: $H_{o(BP)} = 0.316 \times Q_o \times H_{o(LP)}$; $H_{o(LP)} = 10 \times H_{o(HP)}$
- $R \times C = \dfrac{5.033 \times 10^{-2}}{f_o}$ (sec)
- For BP output: $R_Q = \left(\dfrac{3.478\ Q_o - H_{o(BP)}}{10^5} - \dfrac{H_{o(BP)}}{10^5 \times 3.748 \times Q_o}\right)^{-1}$; $R_{IN} = \dfrac{\left(\dfrac{3.478\ Q_o}{H_{o(BP)}} - 1\right)}{\dfrac{1}{RQ} + 10^{-5}}$
- For HP ouput: $R_Q = \dfrac{1.1 \times 10^5}{3.478\ Q_o\ (1.1 - H_{o(HP)}) - H_{o(HP)}}$; $R_{IN} = \dfrac{\dfrac{1.1}{H_{o(HP)}} - 1}{\dfrac{1}{RQ} + 10^{-5}}$
- For LP output: $R_Q = \dfrac{11 \times 10^5}{3.478\ Q_o\ (11 - H_{o(LP)}) - H_{o(LP)}}$; $R_{IN} = \dfrac{\dfrac{11}{H_{o(LP)}} - 1}{\dfrac{1}{RQ} + 10^{-5}}$
- For BR (notch) output: Use the 4th amplifier of the LM146 to sum the LP and HP outputs of the basic filter.

Note. All resistor values are given in ohms.



$$\sqrt{\frac{R_H}{R_L}} = 0.316\,\frac{f_{notch}}{f_o}$$

Determine R_F according to the desired gains: $H_{o(BR)}\Big|_{f<<f_{notch}} = \frac{R_F}{R_L} H_{o(LP)}$, $H_{o(BR)}\Big|_{f>>f_{notch}} = \frac{R_F}{R_H} H_{o(HP)}$

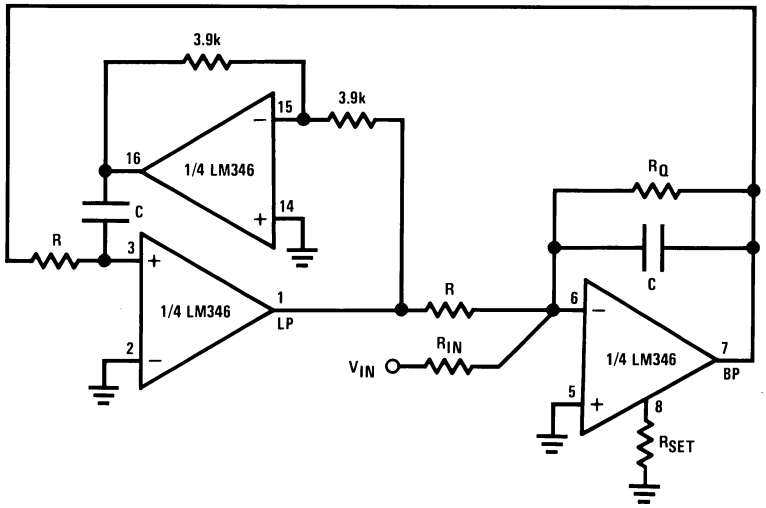
- **Where to use amplifier C:** Examine the above gain relations and determine the dynamics of the filter. Do not allow slew rate limiting in any output (V_{HP}, V_{BP}, V_{LP}), that is:

$$V_{IN(peak)} < 63.66 \times 10^3 \times \frac{I_{SET}}{10\ \mu A} \times \frac{1}{f_o \times H_o} \text{ (Volts)}$$

If necessary, use amplifier C, biased at higher I_{SET}, where you get the largest output swing.

Deviation from Theoretical Predictions: Due to the finite GBW products of the op amps the f_o, Q_o will be slightly different from the theoretical predictions.

$$f_{real} \cong \frac{f_o}{1 + \frac{2 f_o}{GBW}},\ Q_{real} \cong \frac{Q_o}{1 - \frac{3.2 f_o \times Q_o}{GBW}}$$



- If resistive biasing is used to set the LM346 performance, the Q_o of this filter building block is nearly insensitive to the op amp's GBW product temperature drift; it has also better noise performance than the state variable filter.

Figure 35. A Simple-to-Design BP, LP Filter Building Block

Circuit Synthesis Equations

$$H_{o(BP)} = Q_o H_{o(LP)};\ R \times C = \frac{0.159}{f_o};\ R_Q = Q_o \times R;\ R_{IN} = \frac{R_Q}{H_{o(BP)}} = \frac{R}{H_{o(LP)}}$$

•For the eventual use of amplifier C, see comments above. (2)

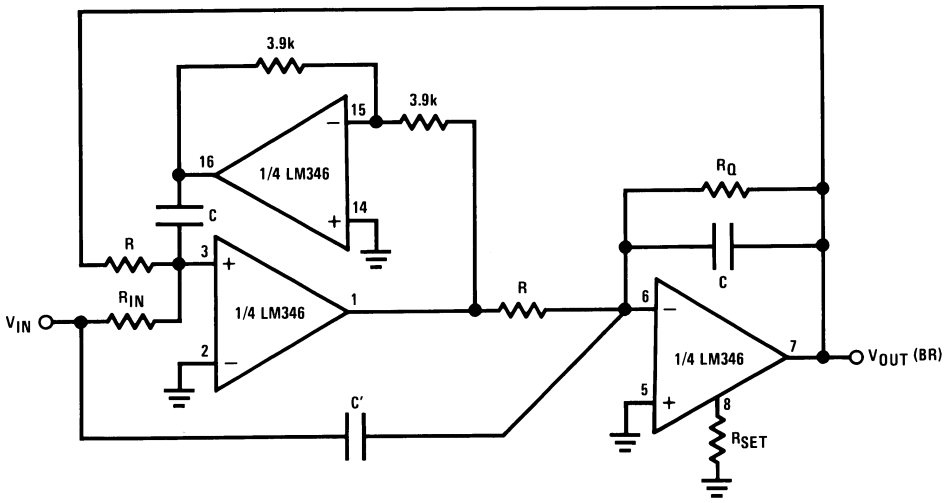


Figure 36. A 3-Amplifier Notch Filter (or Elliptic Filter Building Block)

Copyright © 2004, Texas Instruments Incorporated

Circuit Synthesis Equations

$$R \times C = \frac{0.159}{f_o}; R_o = Q_o \times R; R_{IN} = \frac{0.159 \times f_o}{C' \times f^2_{notch}}$$

$$H_{o(BR)}\Big|_{f << f_{notch}} = \frac{R}{R_{IN}} H_{o(BR)}\Big|_{f >> f_{notch}} = \frac{C'}{C}$$

•For nothing but a notch output: R_{IN}=R, C′=C. (3)

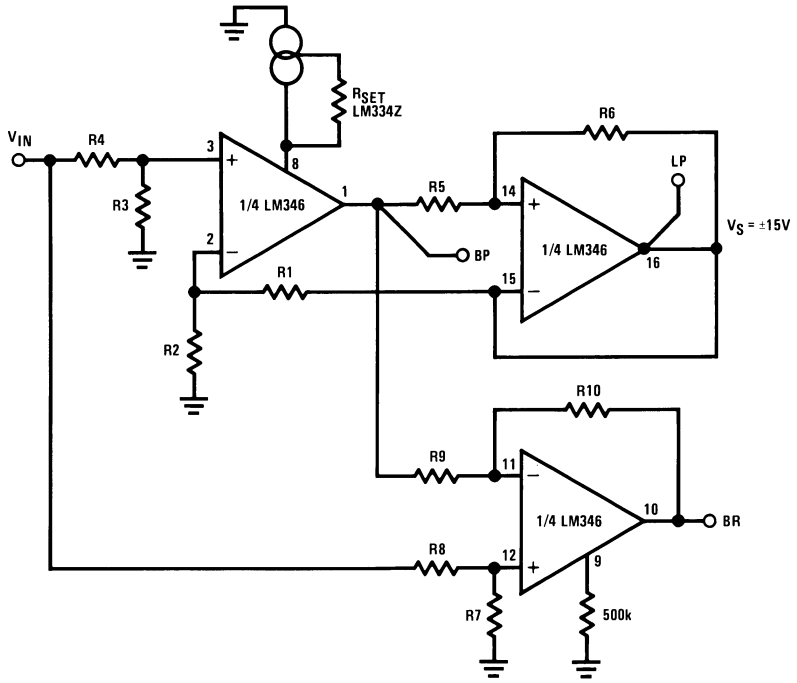


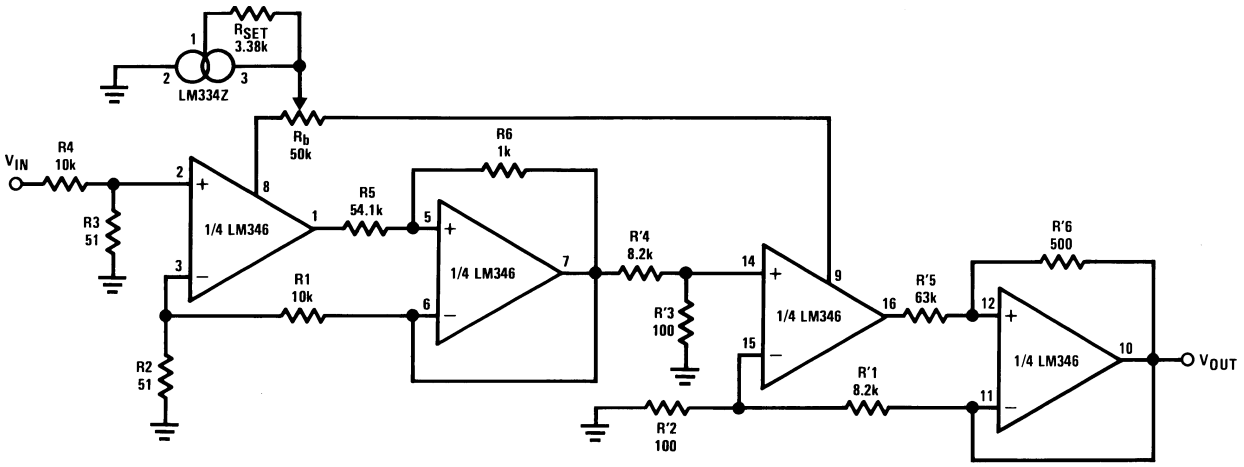
Figure 37. Capacitorless Active Filters (Basic Circuit)

- This is a BP, LP, BR filter. The filter characteristics are created by using the tunable frequency response of the LM346.
- **Limitations:** $Q_o < 10$, $f_o \times Q_o < 1.5$ MHz, output voltage should not exceed Vpeak(out) $\leq \frac{63.66 \times 10^3}{f_o} \times \frac{I_{SET}(\mu A)}{10\ \mu A}$ (V)
- Design equations: $a = \frac{R6 + R5}{R6}$, $b = \frac{R2}{R1 + R2}$, $c = \frac{R3}{R3 + R4}$, $d = \frac{R7}{R8 + R7}$, $e = \frac{R10}{R9 + R10}$, $f_{o(BP)} = f_u\sqrt{\frac{b}{a}}$, $H_{o(BP)} = a \times c$, $H_{o(LP)} = \frac{c}{b}$, $Q_o = \sqrt{a \times b}$

  $f_{o(BR)} = f_{o(BP)}$, $\left(1 - \frac{c}{b}\right) \cong f_{o(BP)}$ $(C << 1)$ provided that $d = H_{o(BP)} \times e$, $H_{o(BR)} = \frac{R10}{R9}$.
- Advantage: f_oQ_o, H_o can be independently adjusted; that is, the filter is extremely easy to tune.
- Tuning procedure (ex. BP tuning)

1. Pick up a convenient value for b; (b < 1)
2. Adjust Q_o through R5
3. Adjust $H_{o(BP)}$ through R4
4. Adjust f_o through R_{SET}. This adjusts the unity gain frequency (f_u) of the op amp.

Copyright © 2004, Texas Instruments Incorporated

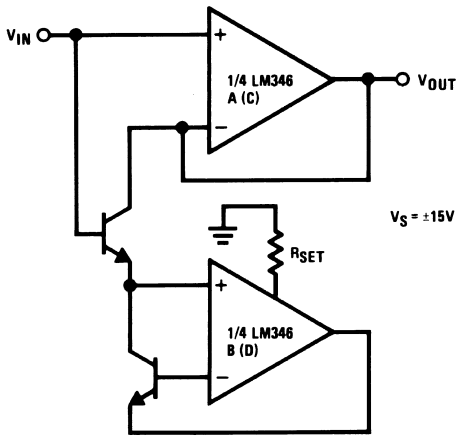


Ex: f_c = 20 kHz, H_o (gain of the filter) = 1, Q_{01} = 0.541, Q_{o2} = 1.306.

•Since for this filter the GBW product of all 4 amplifiers has been designed to be the same (~1 MHz) only one current source can be used to bias the circuit. Fine tuning can be further accomplished through R_b.

Figure 38. A 4th Order Butterworth Low Pass Capacitorless Filter

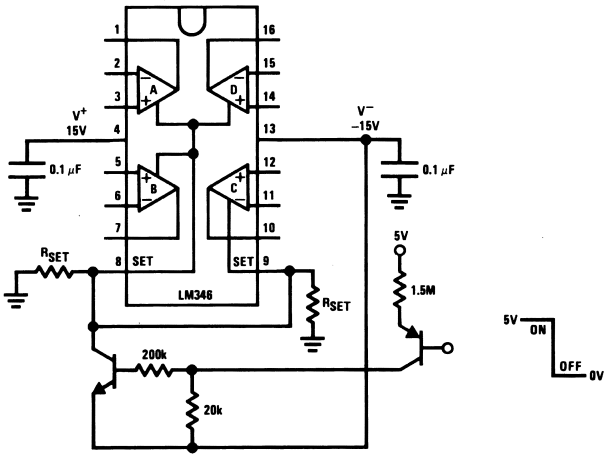
Miscellaneous Applications



• For better performance, use a matched NPN pair.

Figure 39. A Unity Gain Follower with Bias Current Reduction

Copyright © 2004, Texas Instruments Incorporated



• By pulling the SET pin(s) to V^- the op amp(s) shuts down and its output goes to a high impedance state. According to this property, the LM346 can be used as a very low speed analog switch.

Figure 40. Circuit Shutdown

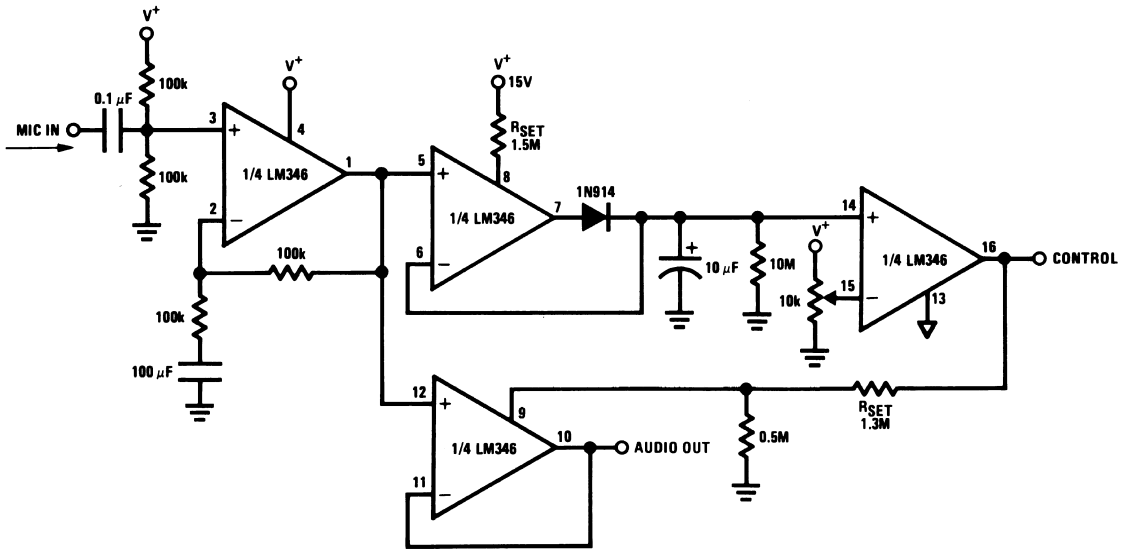
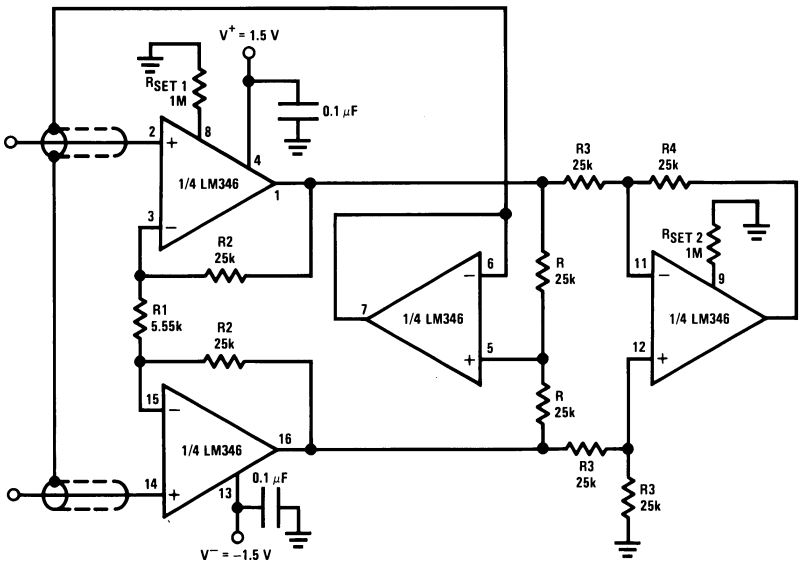


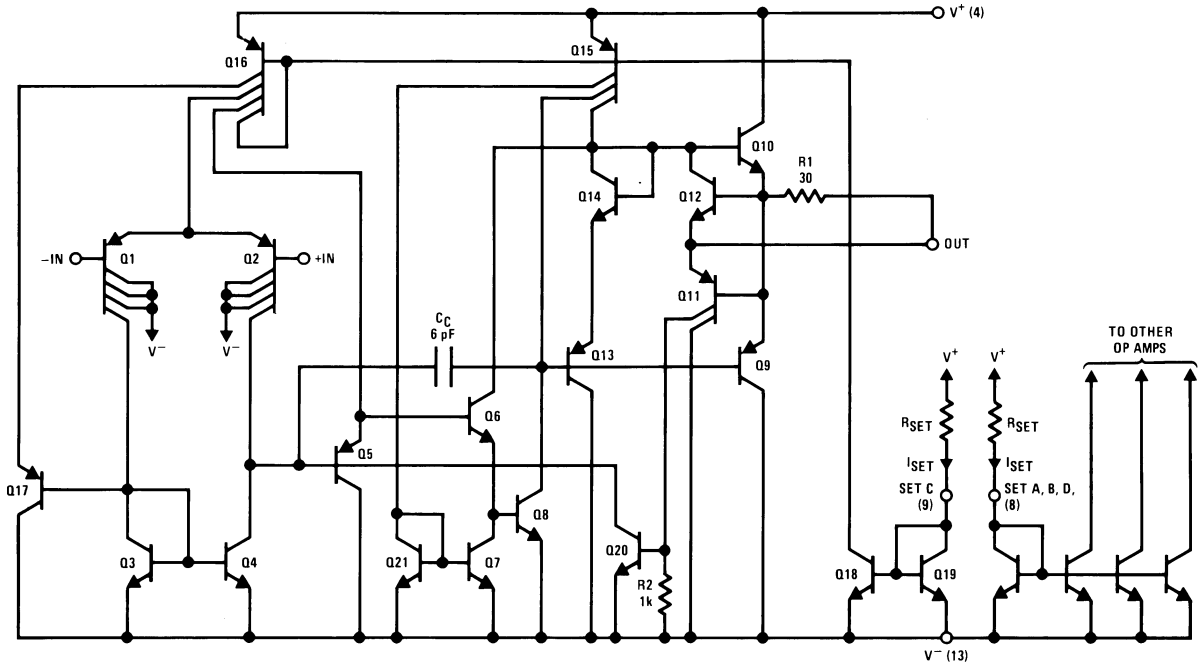
Figure 41. Voice Activated Switch and Amplifier



- CMRR: 100 dB (typ)
- Power dissipation: 0.4 mW

Figure 42. x10 Micropower Instrumentation Amplifier with Buffered Input Guarding

Schematic Diagram



Copyright © 2004, Texas Instruments Incorporated

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
LM346M/NOPB	ACTIVE	SOIC	D	16	48	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	0 to 70	LM346M	Samples
LM346MX/NOPB	ACTIVE	SOIC	D	16	2500	Green (RoHS & no Sb/Br)	CU SN	Level-1-260C-UNLIM	0 to 70	LM346M	Samples

(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.
OBSOLETE: 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)

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

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

(5) 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.

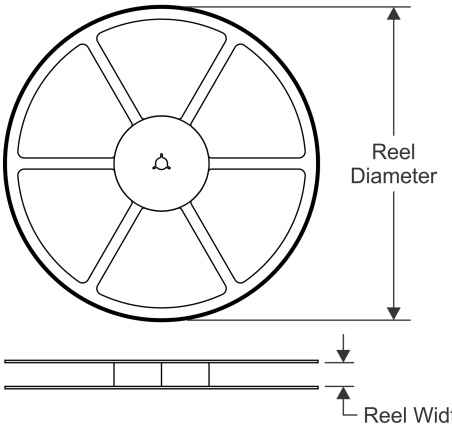
(6) Lead/Ball Finish - Orderable Devices may have multiple material finish options. Finish options are separated by a vertical ruled line. Lead/Ball Finish values may wrap to two lines if the finish value exceeds the maximum column width.

Important Information and Disclaimer: The information provided on this page represents TI's knowledge and belief as of the date that it is provided. TI bases its knowledge and belief on information provided by third parties, and makes no representation or warranty as to the accuracy of such information. Efforts are underway to better integrate information from third parties. TI has taken and continues to take reasonable steps to provide representative and accurate information but may not have conducted destructive testing or chemical analysis on incoming materials and chemicals. TI and TI suppliers consider certain information to be proprietary, and thus CAS numbers and other limited information may not be available for release.

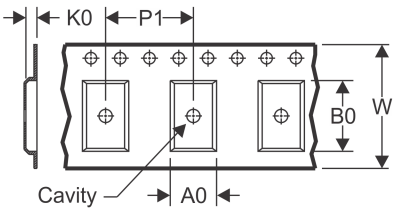
In no event shall TI's liability arising out of such information exceed the total purchase price of the TI part(s) at issue in this document sold by TI to Customer on an annual basis.

TAPE AND REEL INFORMATION

REEL DIMENSIONS

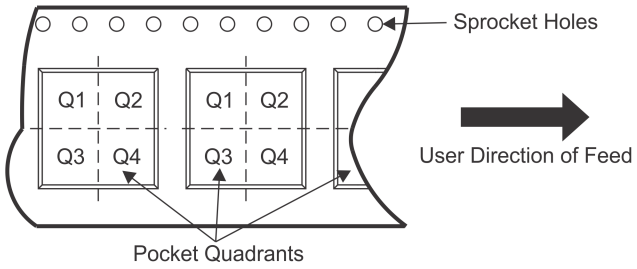


TAPE DIMENSIONS



A0	Dimension designed to accommodate the component width
B0	Dimension designed to accommodate the component length
K0	Dimension designed to accommodate the component thickness
W	Overall width of the carrier tape
P1	Pitch between successive cavity centers

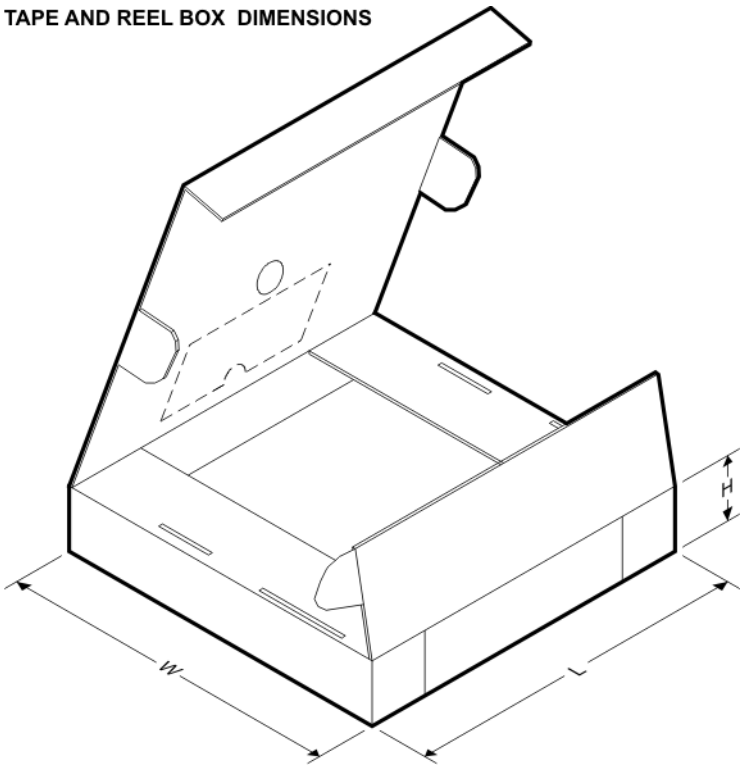
QUADRANT ASSIGNMENTS FOR PIN 1 ORIENTATION IN TAPE



*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
LM346MX/NOPB	SOIC	D	16	2500	330.0	16.4	6.5	10.3	2.3	8.0	16.0	Q1

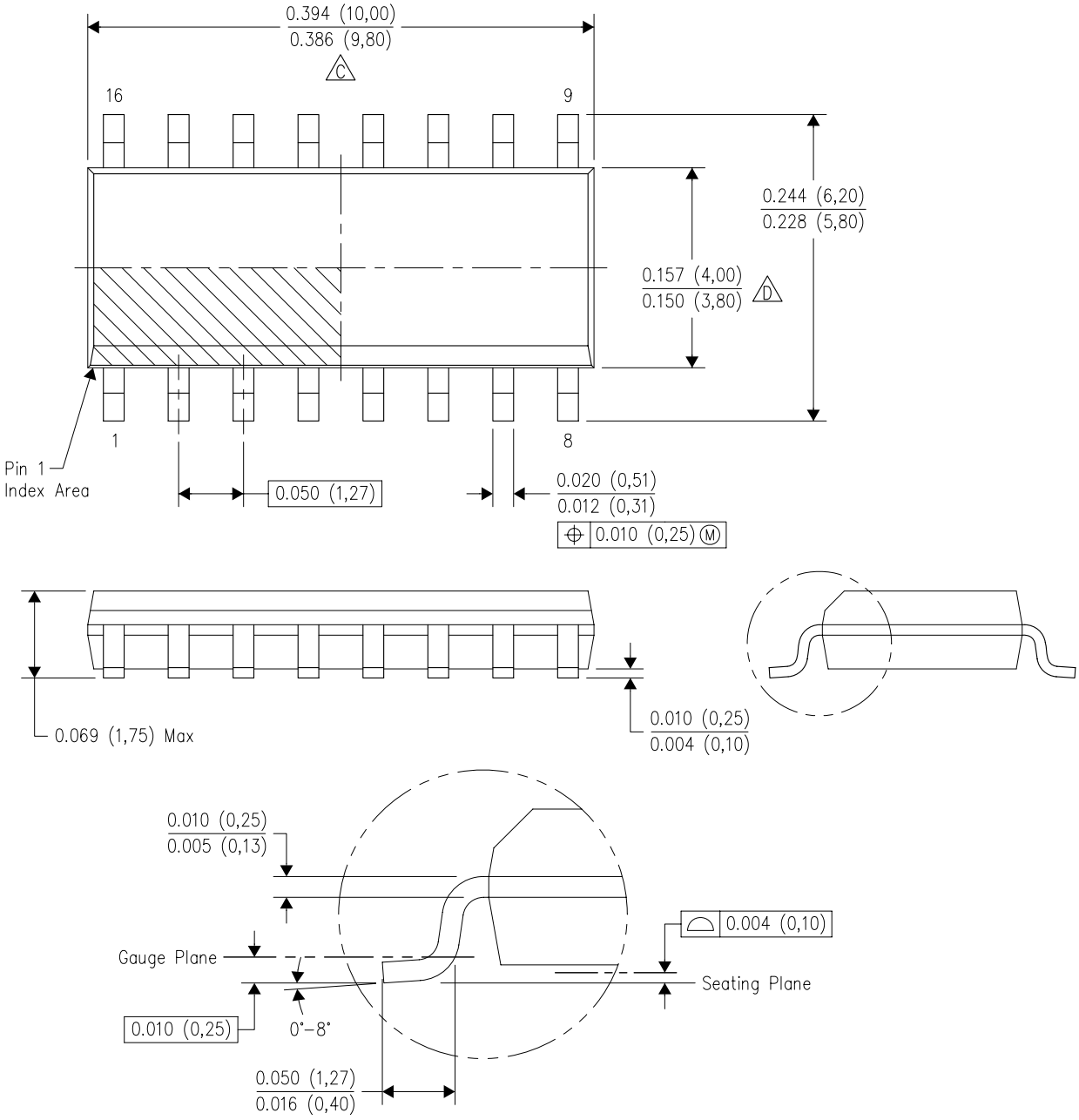
TAPE AND REEL BOX DIMENSIONS



*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
LM346MX/NOPB	SOIC	D	16	2500	367.0	367.0	35.0

D (R–PDSO–G16) PLASTIC SMALL OUTLINE



NOTES:
A. All linear dimensions are in inches (millimeters).
B. This drawing is subject to change without notice.
C. Body length does not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.006 (0,15) each side.
D. Body width does not include interlead flash. Interlead flash shall not exceed 0.017 (0,43) each side.
E. Reference JEDEC MS–012 variation AC.

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, enhancements, improvements and other changes to its semiconductor products and services per JESD46, latest issue, and to discontinue any product or service per JESD48, latest issue. Buyers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All semiconductor products (also referred to herein as “components”) are sold subject to TI’s terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its components to the specifications applicable at the time of sale, in accordance with the warranty in TI’s terms and conditions of sale of semiconductor products. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by applicable law, testing of all parameters of each component is not necessarily performed.

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

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

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

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

Buyer acknowledges and agrees that it is solely responsible for compliance with all legal, regulatory and safety-related requirements concerning its products, and any use of TI components in its applications, notwithstanding any applications-related information or support that may be provided by TI. Buyer represents and agrees that it has all the necessary expertise to create and implement safeguards which anticipate dangerous consequences of failures, monitor failures and their consequences, lessen the likelihood of failures that might cause harm and take appropriate remedial actions. Buyer will fully indemnify TI and its representatives against any damages arising out of the use of any TI components in safety-critical applications.

In some cases, TI components may be promoted specifically to facilitate safety-related applications. With such components, TI’s goal is to help enable customers to design and create their own end-product solutions that meet applicable functional safety standards and requirements. Nonetheless, such components are subject to these terms.

No TI components are authorized for use in FDA Class III (or similar life-critical medical equipment) unless authorized officers of the parties have executed a special agreement specifically governing such use.

Only those TI components which TI has specifically designated as military grade or “enhanced plastic” are designed and intended for use in military/aerospace applications or environments. Buyer acknowledges and agrees that any military or aerospace use of TI components which have ***not*** been so designated is solely at the Buyer's risk, and that Buyer is solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI has specifically designated certain components as meeting ISO/TS16949 requirements, mainly for automotive use. In any case of use of non-designated products, TI will not be responsible for any failure to meet ISO/TS16949.

Products		**Applications**	
Audio	www.ti.com/audio	Automotive and Transportation	www.ti.com/automotive
Amplifiers	amplifier.ti.com	Communications and Telecom	www.ti.com/communications
Data Converters	dataconverter.ti.com	Computers and Peripherals	www.ti.com/computers
DLP® Products	www.dlp.com	Consumer Electronics	www.ti.com/consumer-apps
DSP	dsp.ti.com	Energy and Lighting	www.ti.com/energy
Clocks and Timers	www.ti.com/clocks	Industrial	www.ti.com/industrial
Interface	interface.ti.com	Medical	www.ti.com/medical
Logic	logic.ti.com	Security	www.ti.com/security
Power Mgmt	power.ti.com	Space, Avionics and Defense	www.ti.com/space-avionics-defense
Microcontrollers	microcontroller.ti.com	Video and Imaging	www.ti.com/video
RFID	www.ti-rfid.com		
OMAP Applications Processors	www.ti.com/omap	**TI E2E Community**	e2e.ti.com
Wireless Connectivity	www.ti.com/wirelessconnectivity		

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265
Copyright © 2016, Texas Instruments Incorporated