TEXAS INSTRUMENTS

LM442-MIL

SNOSD59 – JUNE 2017

LF442-MIL Dual Low Power JFET Input Operational Amplifier

1 Features

- 1/10 Supply Current of a LM1458: 400 μA (Max)
- Low Input Bias Current: 50 pA (Max)
- Low Input Offset Voltage: 1 mV (Max)
- Low Input Offset Voltage Drift: 7 μV/°C (Typ)
- High Gain Bandwidth: 1 MHz
- High Slew Rate: 1 V/μs
- Low Noise Voltage for Low Power: 35 nV/$\sqrt{Hz}$
- Low Input Noise Current: 0.01 pA/$\sqrt{Hz}$
- High Input Impedance: $10^{12}\Omega$
- High Gain V_O = ±10V, R_L = 10k: 50k (Min)

2 Applications

- High Speed Integrators
- Fast D/A Converters
- Sample and Hold Circuits

3 Description

The LF442-MIL dual low power operational amplifiers provide many of the same AC characteristics as the industry standard LM1458 while greatly improving the DC characteristics of the LM1458. The amplifiers have the same bandwidth, slew rate, and gain (10 kΩ load) as the LM1458 and only draw one tenth the supply current of the LM1458. In addition the well matched high voltage JFET input devices of the LF442-MIL reduce the input bias and offset currents by a factor of 10,000 over the LM1458. A combination of careful layout design and internal trimming ensures very low input offset voltage and voltage drift. The LF442-MIL also has a very low equivalent input noise voltage for a low power amplifier.

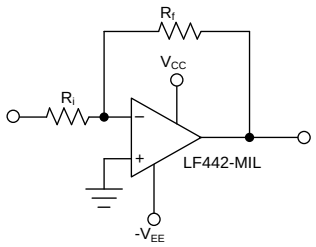
The LF442-MIL is pin compatible with the LM1458 allowing an immediate 10 times reduction in power drain in many applications. The LF442-MIL should be used where low power dissipation and good electrical characteristics are the major considerations.

Device Information(1)

PART NUMBER	PACKAGE	BODY SIZE (NOM)
LF442-MILACN	PDIP (8)	9.59 mm × 6.35 mm
LF442-MILAMH	TO-99 (8)	8.96 mm Diameter

(1) For all available packages, see the orderable addendum at the end of the data sheet.

Inverting Amplifier



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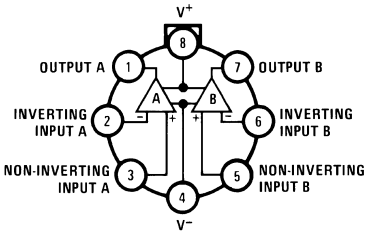
4 Revision History

NOTE: Page numbers for previous revisions may differ from page numbers in the current version.

DATE	REVISION	NOTES
June 2017	*	Initial release.

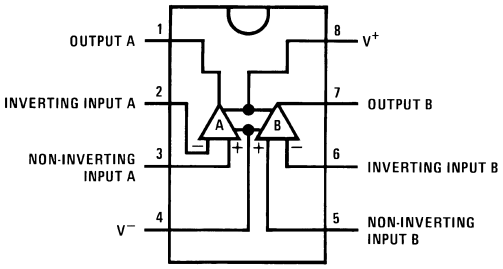
5 Pin Configuration and Functions

TO Package
8-Pin LMC
Top View



Pin 4 connected to case

P Package
8-Pin PDIP
Top View



Pin Functions

PIN		I/O	DESCRIPTION
NAME	NO.		
Inverting input A	2	Input	Amplifier A inverting input
Inverting input B	6	Input	Amplifier B inverting input
Noninverting input A	3	Input	Amplifier A noninverting input
Noninverting input B	5	Input	Amplifier B noninverting Input
Output A	1	Output	Amplifier A output
Output B	7	Output	Amplifier B output
V+	8	Power	Positive supply
V-	4	Power	Negative supply

6 Specifications

6.1 Absolute Maximum Ratings (1) (2)

Supply voltage	±18 V
Differential input voltage	±30 V
Input voltage range (3)	±15 V
Output short circuit duration (4)	Continuous
Storage temperature, T_{stg}	–65 to 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) Refer to RETS442X for LF442MH military specifications.
(3) Unless otherwise specified the absolute maximum negative input voltage is equal to the negative power supply voltage.
(4) 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.

6.2 Absolute Maximum Ratings (1) (2)

	LMC0008C Package	P0008E Package
T_J max	150°C	115°C
Operating temperature range	See (3) (4)	See (3) (4)
Lead Temperature (Soldering, 10 sec.)	260°C	260°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) Refer to RETS442X for LF442MH military specifications.
(3) These devices are available in both the commercial temperature range 0°C ≤ T_A ≤ 70°C and the military temperature range −55°C ≤ T_A ≤ 125°C. The temperature range is designated by the position just before the package type in the device number. A “C” indicates the commercial temperature range and an “M” indicates the military temperature range. The military temperature range is available in “H” package only.
(4) The value given is in static air.

6.3 Recommended Operating Conditions

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

	MIN	NOM	MAX	UNIT
Supply voltage			±15	V

6.4 Thermal Information

THERMAL METRIC (1)			LF442-MIL		UNIT
			LMC (TO)	P (PDIP)	
			8 PINS	8 PINS	
$R_{\theta JA}$ (Typical)	Junction-to-ambient thermal resistance	400 linear feet/min air flow	65	114	°C/W
		Static air	165	152	
$R_{\theta JC}$ (Typical)	Junction-to-case thermal resistance		21		°C/W

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

6.5 DC Electrical Characteristics(1)(2)

PARAMETER		TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_{OS}	Input offset voltage	R_S = 10 kΩ, T_A = 25°C			1	5	mV
		Over temperature				7.5	mV
$\Delta V_{OS}/\Delta T$	Average TC of input offset voltage	R_S = 10 kΩ			7		μV/°C
I_{OS}	Input offset voltage	V_S = ±15 V(1)(3)	T_J = 25°C		5	50	pA
			T_J = 70°C			1.5	nA
			T_J = 125°C				nA
I_B	Input bias current	V_S = ±15 V(1)(3)	T_J = 25°C		10	100	pA
			T_J = 70°C			3	nA
			T_J = 125°C				nA
R_{IN}	Input resistance	T_J = 25°C			10^{12}		Ω
A_{VOL}	Large signal voltage gain	V_S = ±15 V, V_O = ±10 V, R_L = 10 kΩ, T_A = 25°C		25	200		V/mV
		Over temperature		15	200		V/mV
V_O	Output voltage swing	V_S = ±15 V, R_L = 10 kΩ		±12	±13		V
V_{CM}	Input common-mode voltage range			±11	14		V
					−12		V
CMRR	Common-mode rejection ratio	R_S ≤ 10 kΩ		70	95		dB
PSRR	Supply voltage rejection ratio	See(4)		70	90		dB
I_S	Supply current				400	500	μA

(1) Unless otherwise specified, the specifications apply over the full temperature range of V_S = ±15 V for the LF442-MIL. V_{OS}, I_B, and I_{OS} are measured at V_{CM} = 0.
(2) Refer to RETS442X for LF442-MIL MH military specifications.
(3) The input bias currents are junction leakage currents which approximately double for every 10°C increase in the junction temperature, T_J. Due to limited production test time, the input bias currents measured are correlated to junction temperature. In normal operation the junction temperature rises above the ambient temperature as a result of internal power dissipation, P_D. $T_J = T_A + \theta_{JA}P_D$ where θ_{JA} is the thermal resistance from junction to ambient. Use of a heat sink is recommended if input bias current is to be kept to a minimum.
(4) Supply voltage rejection ratio is measured for both supply magnitudes increasing or decreasing simultaneously in accordance with common practice from ±15 V to ±5 V for the LF442-MIL.

6.6 AC Electrical Characteristics(1)(2)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
	Amplifier to amplifier coupling	T_A = 25°C, f = 1 Hz-20 kHz (Input referred)		−120		dB
SR	Slew rate	V_S = ±15 V, T_A = 25°C	0.6	1		V/μs
GBW	Gain-bandwidth product	V_S = ±15 V, T_A = 25°C	0.6	1		MHz
e_n	Equivalent input noise voltage	T_A = 25°C, R_S = 100 Ω, f = 1 kHz		35		nV/√Hz
i_n	Equivalent input noise current	T_A = 25°C, f = 1 kHz		0.01		pA/√Hz

(1) Unless otherwise specified, the specifications apply over the full temperature range and for V_S = ±15 V for the LF442-MIL. V_{OS}, I_B, and I_{OS} are measured at V_{CM} = 0.
(2) Refer to RETS442X for LF442-MIL MH military specifications.

6.7 Typical Characteristics

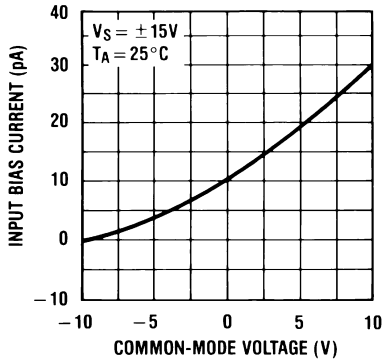


Figure 1. Input Bias Current

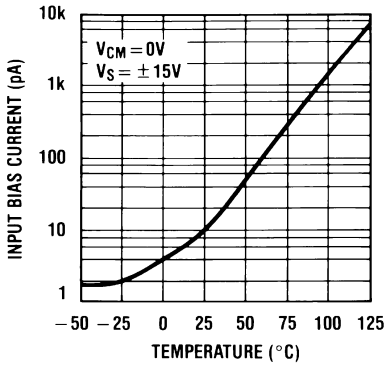


Figure 2. Input Bias Current

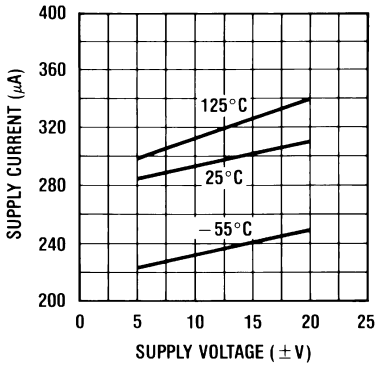


Figure 3. Supply Current

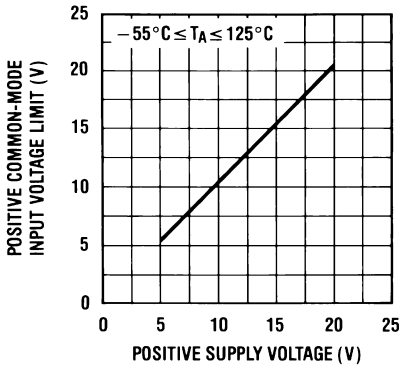


Figure 4. Positive Common-Mode Input Voltage Limit

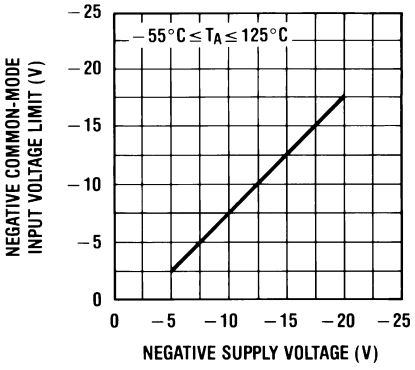


Figure 5. Negative Common-Mode Input Voltage Limit

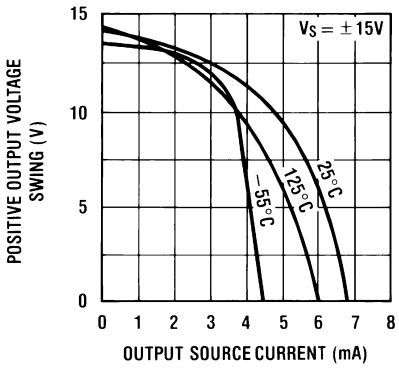


Figure 6. Positive Current Limit

Typical Characteristics (continued)

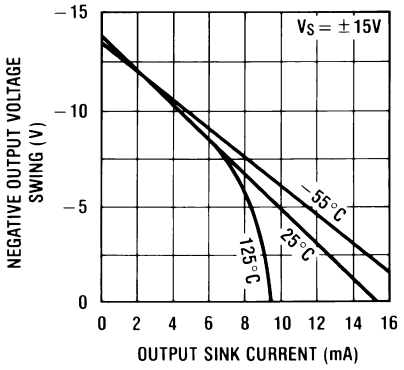


Figure 7. Negative Current Limit

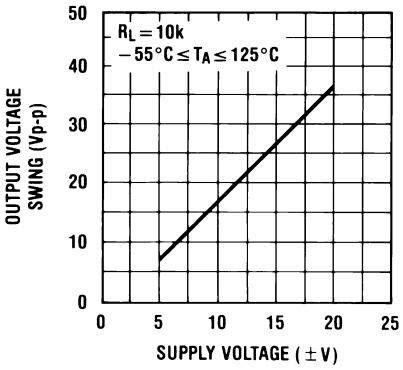


Figure 8. Output Voltage Swing

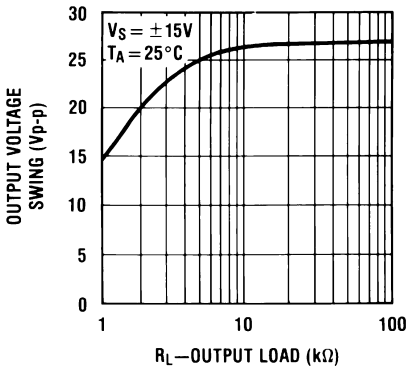


Figure 9. Output Voltage Swing

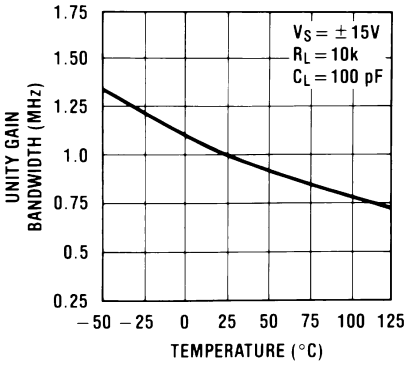


Figure 10. Gain Bandwidth

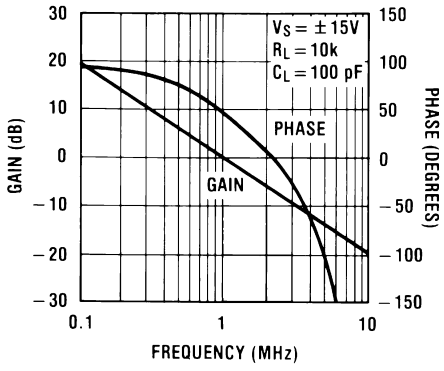


Figure 11. Bode Plot

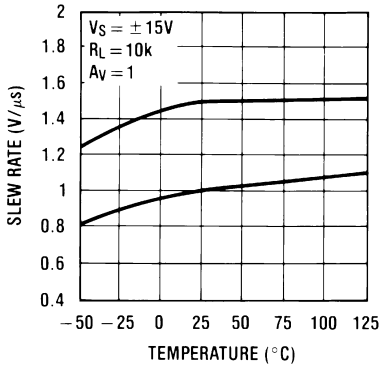


Figure 12. Slew Rate

Typical Characteristics (continued)

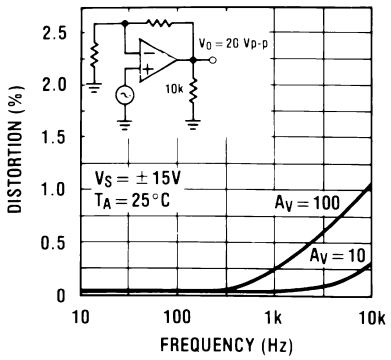


Figure 13. Distortion vs Frequency

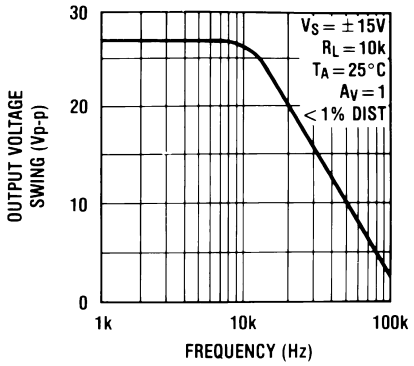


Figure 14. Undistorted Output Voltage Swing

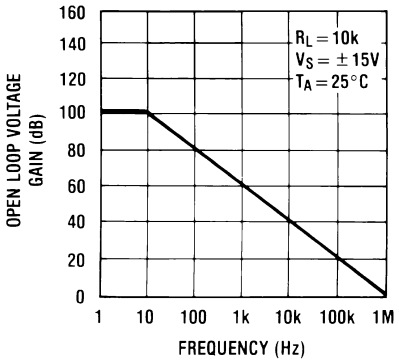


Figure 15. Open Loop Frequency Response

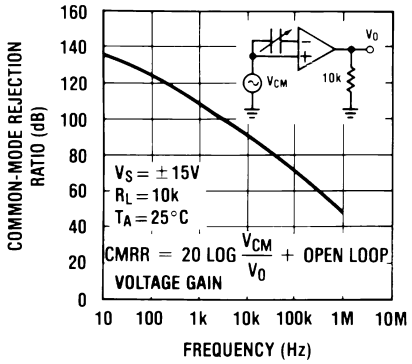


Figure 16. Common-Mode Rejection Ratio

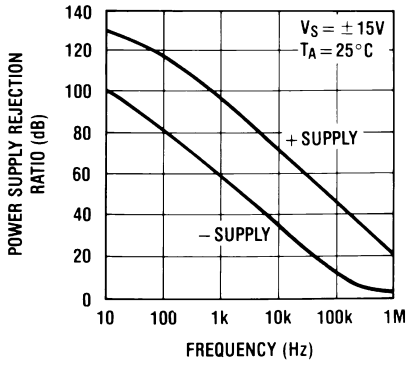


Figure 17. Power Supply Rejection Ratio

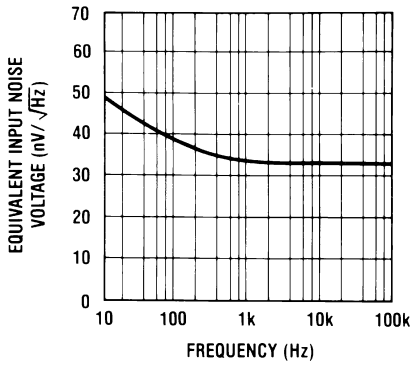


Figure 18. Equivalent Input Noise Voltage

Typical Characteristics (continued)

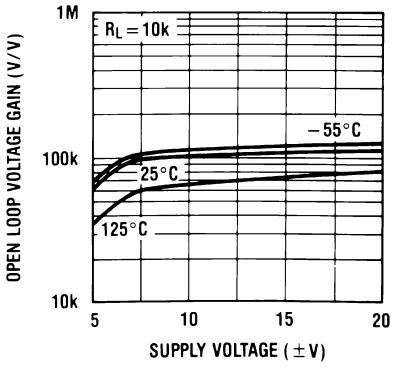


Figure 19. Open Loop Voltage Gain

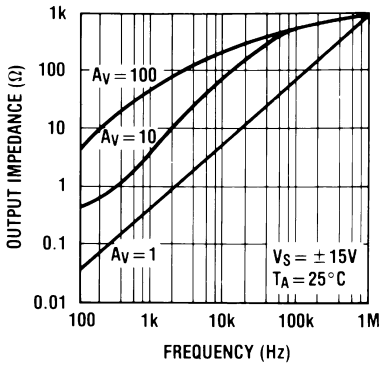


Figure 20. Output Impedance

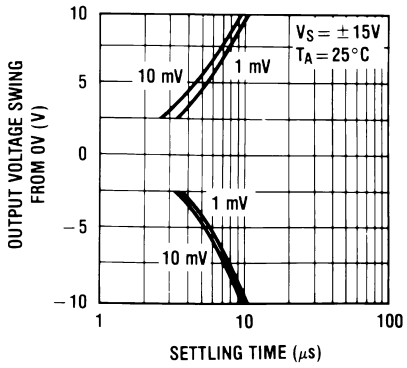


Figure 21. Inverter Settling Time

6.7.1 Pulse Response

R_L = 10 kΩ, C_L = 10 pF

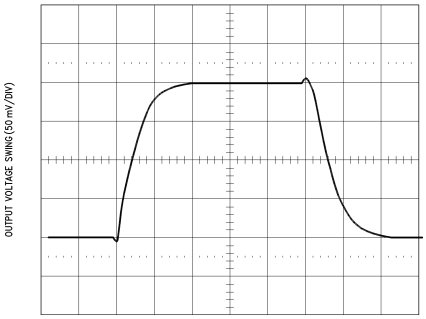


Figure 22. Small Signal Inverting

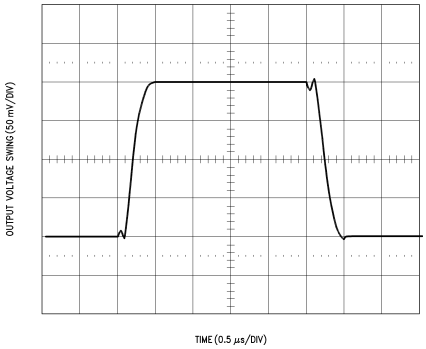


Figure 23. Small Signal Non-Inverting

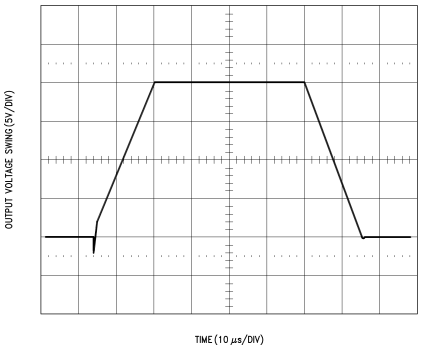


Figure 24. Large Signal Inverting

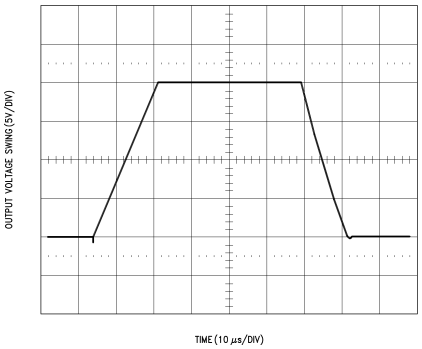


Figure 25. Large Signal Non-Inverting

7 Detailed Description

7.1 Overview

The LF442-MIL dual low power operational amplifiers provide many of the same AC characteristics as the industry standard LM1458 while greatly improving the DC characteristics of the LM1458. The amplifiers have the same bandwidth, slew rate, and gain (10 kΩ load) as the LM1458 and only draw one tenth the supply current of the LM1458. In addition the well matched high voltage JFET input devices of the LF442-MIL reduce the input bias and offset currents by a factor of 10,000 over the LM1458. A combination of careful layout design and internal trimming ensures very low input offset voltage and voltage drift. The LF442-MIL also has a very low equivalent input noise voltage for a low power amplifier.

The LF442-MIL is pin compatible with the LM1458 allowing an immediate 10 times reduction in power drain in many applications. The LF442-MIL should be used where low power dissipation and good electrical characteristics are the major considerations.

7.2 Functional Block Diagram

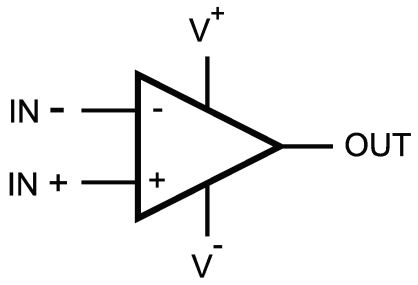


Figure 26. Each Amplifier

7.3 Feature Description

The amplifier's differential inputs consist of a non-inverting input (+IN) and an inverting input (-IN). The amplifier amplifies only the difference in voltage between the two inputs, which is called the differential input voltage. The output voltage of the op-amp V_{OUT} is given by the equation $V_{OUT} = A_{OL}(IN+ - IN-)$.

7.4 Device Functional Modes

7.4.1 Input and Output Stage

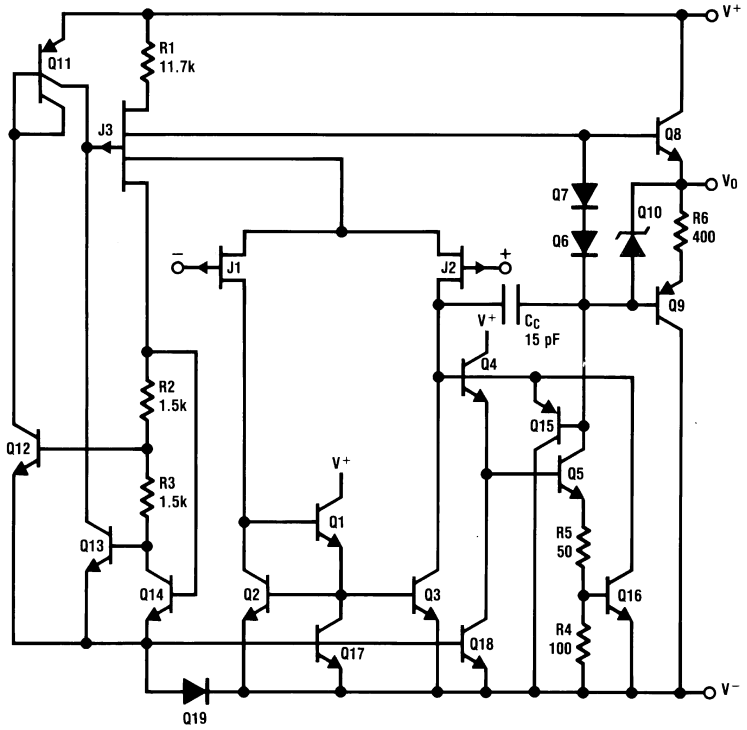


Figure 27. 1/2 Dual LF442-MIL

8 Application and Implementation

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.

8.1 Application Information

The LF442-MIL uses a combination of careful layout design and internal trimming to ensure very low input offset voltage and voltage drift. The LF442-MIL also has a very low equivalent input noise voltage for a low power amplifier. The LF442-MIL should be used where low power dissipation and good electrical characteristics are the major considerations.

8.2 Typical Applications

1. Battery Powered Strip Chart Preamplifier
2. "No FET" Low Power V to F Converter
3. High Efficiency Crystal Oven Controller
4. Conventional Log Amplifier
5. Unconvential Log Amplifier

8.2.1 Battery Powered Strip Chart Preamplifier

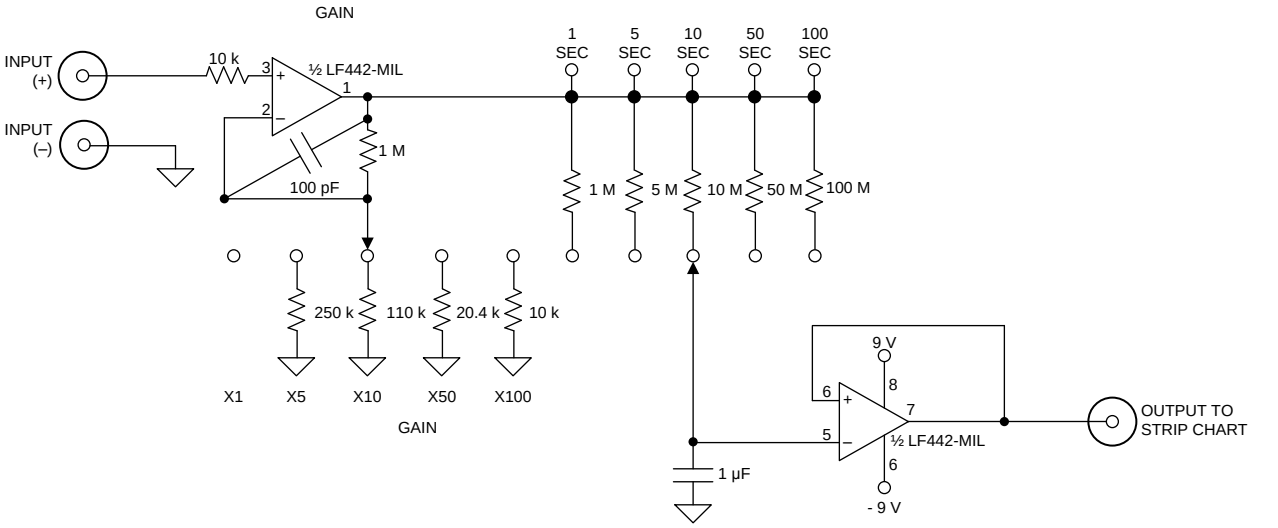


Figure 28. Battery Powered Strip Chart Preamplifier

8.2.1.1 Design Requirements

Runs from 9V batteries (±9V supplies).

Fully set gain and time constant.

Battery powered supply allows direct plug-in interface to strip chart recorder without common-mode problems.

Typical Applications (continued)

8.2.1.2 Detailed Design Procedure

This device is a dual low power op amp with internally trimmed input offset voltages and JFET input devices (BI-FET II). 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.

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

Each amplifier is individually biased to allow normal circuit operation with power supplies of ±3.0V. Supply voltages less than these may degrade the common-mode rejection and restrict the output voltage swing.

The amplifiers will drive a 10 kΩ load resistance to ± 10V over the full temperature range.

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.

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

8.2.1.3 Application Curves

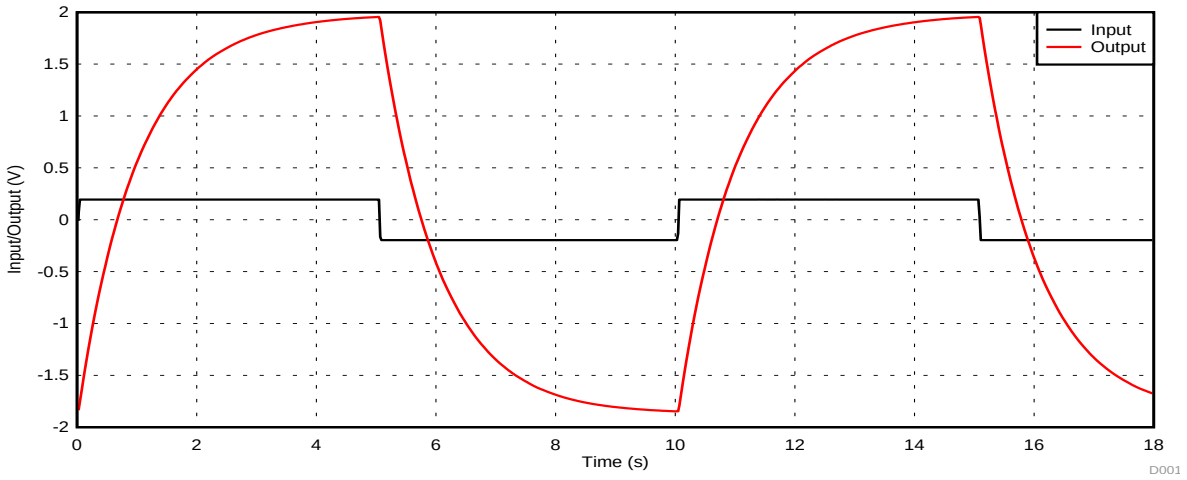


Figure 29. Input and Output Waveforms, Gain = 10, Time Constant = 1 Second

Typical Applications (continued)

8.2.2 "No FET" Low Power V to F Converter

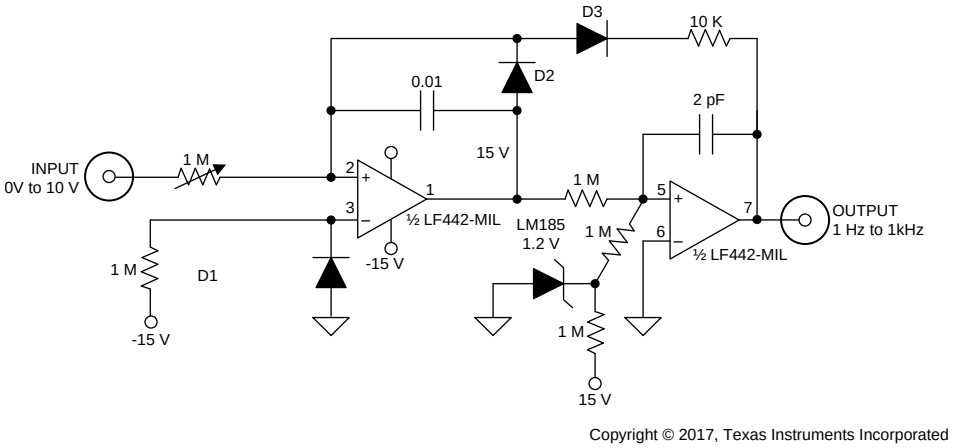


Figure 30. "No FET" Low Power V to F Converter

8.2.2.1 Design Requirements

1. Trim 1M pot for 1 kHz full-scale output.
2. 15 mW power drain.
3. No integrator reset FET required.
4. Mount D1 and D2 in close proximity.
5. 1% linearity to 1 kHz.

8.2.2.2 Detailed Design Procedure

See Section 8.2.1.2.

8.2.2.3 Application Curves

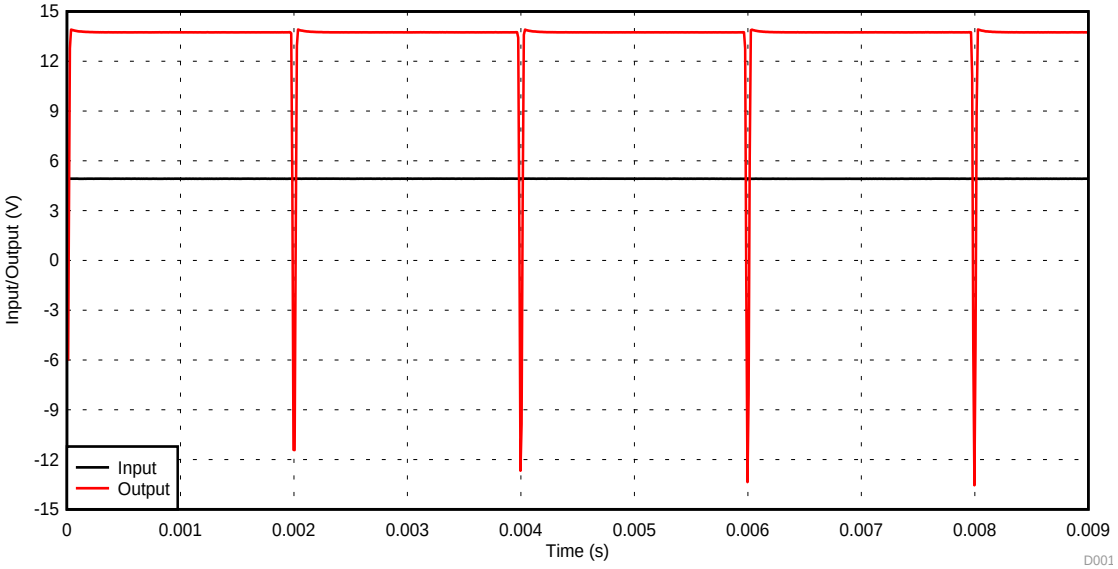


Figure 31. Input and Output Waveforms

Typical Applications (continued)

8.2.3 High Efficiency Crystal Oven Controller

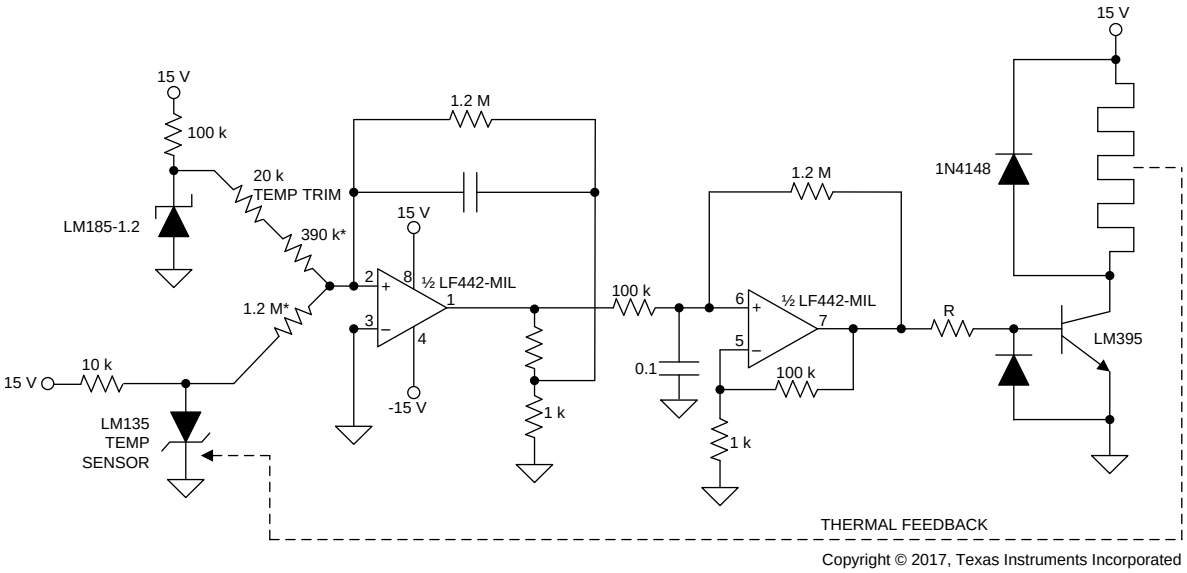


Figure 32. High Efficiency Crystal Oven Controller

8.2.3.1 Design Requirements

1. $T_{control}$= 75°C
2. A1's output represents the amplified difference between the LM335 temperature sensor and the crystal oven's temperature.
3. A2, a free running duty cycle modulator, drives the LM395 to complete a servo loop.
4. Switched mode operation yields high efficiency.
5. 1% metal film resistor.

8.2.3.2 Detailed Design Procedure

See Section 8.2.1.2.

8.2.4 Conventional Log Amplifier

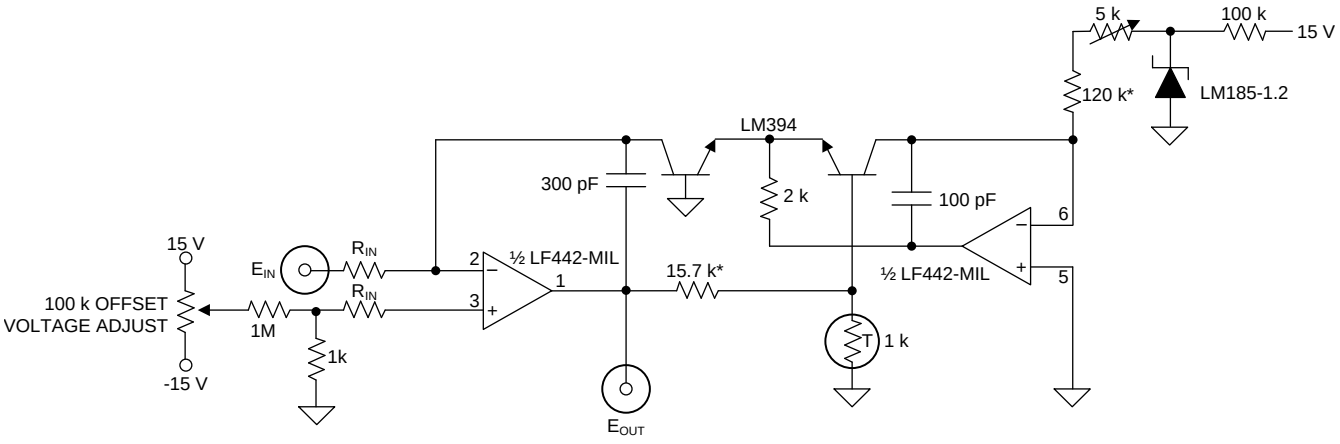


Figure 33. Conventional Log Amplifier

Typical Applications (continued)

$$E_{OUT} = -\left[\log 10\left(\frac{E_{IN}}{R_{IN}}\right) + 5\right]$$

8.2.4.1 Design Requirements

1. R_T = Tel Labs type Q81.
2. Trim 5k for 10 μA through the 5k–120k combination.
3. *1% film resistor

8.2.4.2 Detailed Design Procedure

See Section 8.2.1.2.

8.2.5 Unconventional Log Amplifier

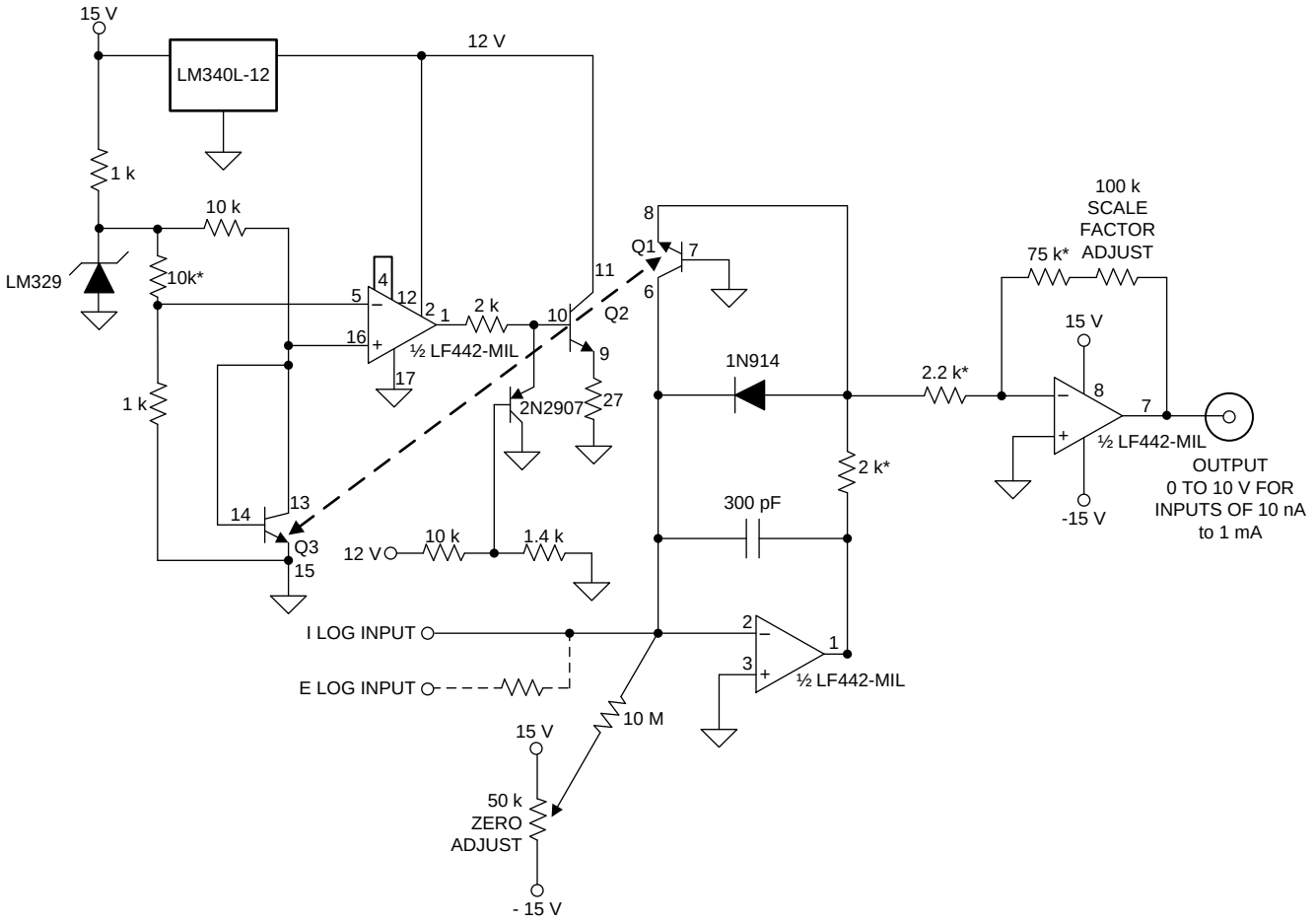


Figure 34. Unconventional Log Amplifier

8.2.5.1 Design Requirements

1. Q1, Q2, Q3 are included on LM389 amplifier chip which is temperature-stabilized by the LM389 and Q2-Q3, which act as a heater-sensor pair.
2. Q1, the logging transistor, is thus immune to ambient temperature variation and requires no temperature compensation at all.

Typical Applications (continued)

8.2.5.2 Detailed Design Procedure

See Section 8.2.1.2.

9 Power Supply Recommendations

For proper operation, the power supplies must be properly decoupled. For decoupling the supply lines it is suggested that 0.1µF capacitors be placed as close as possible to the op amp power supply pins. The minimum power supply voltage is ±5V.

10 Layout

10.1 Layout Guidelines

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.

10.2 Layout Example

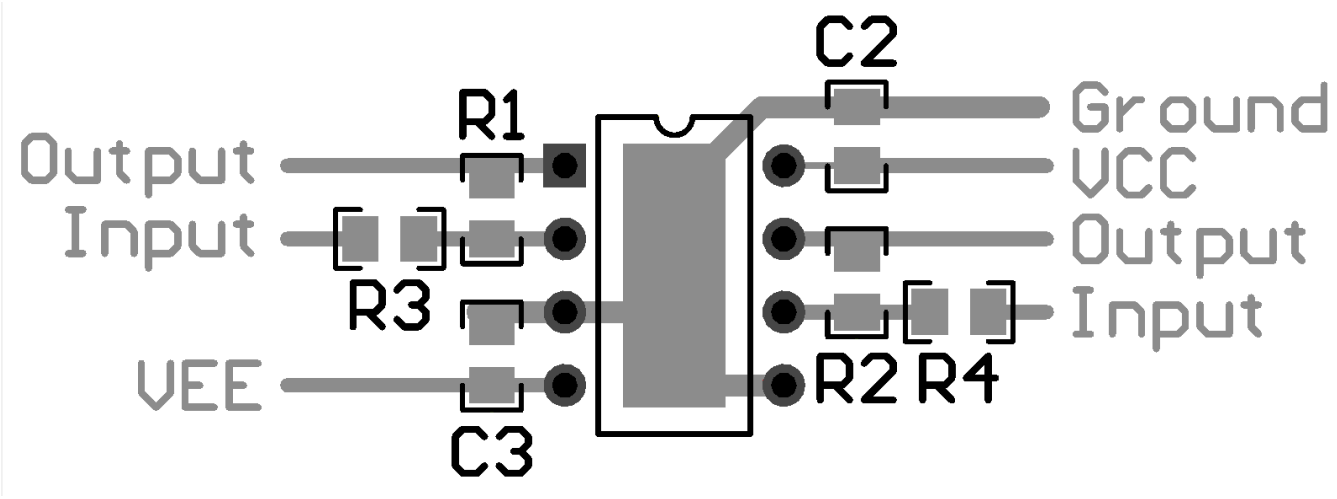


Figure 35. LF442-MIL Layout

11 Device and Documentation Support

11.1 Receiving Notification of Documentation Updates

To receive notification of documentation updates, navigate to the device product folder on ti.com. In the upper right corner, click on *Alert me* to register and receive a weekly digest of any product information that has changed. For change details, review the revision history included in any revised document.

11.2 Community Resources

The following links connect to TI community resources. Linked contents are provided "AS IS" by the respective contributors. They do not constitute TI specifications and do not necessarily reflect TI's views; see TI's Terms of Use.

TI E2E™ Online Community ***TI's Engineer-to-Engineer (E2E) Community.*** Created to foster collaboration among engineers. At e2e.ti.com, you can ask questions, share knowledge, explore ideas and help solve problems with fellow engineers.

Design Support ***TI's Design Support*** Quickly find helpful E2E forums along with design support tools and contact information for technical support.

11.3 Trademarks

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11.4 Electrostatic Discharge Caution

This integrated circuit can be damaged by ESD. Texas Instruments recommends that all integrated circuits be handled with appropriate precautions. Failure to observe proper handling and installation procedures can cause damage.

ESD damage can range from subtle performance degradation to complete device failure. Precision integrated circuits may be more susceptible to damage because very small parametric changes could cause the device not to meet its published specifications.

11.5 Glossary

SLYZ022 — *TI Glossary*.

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

12 Mechanical, Packaging, and Orderable Information

The following pages include mechanical, packaging, and orderable information. This information is the most current data available for the designated devices. This data is subject to change without notice and revision of this document. For browser-based versions of this data sheet, refer to the left-hand navigation.

PACKAGING INFORMATION

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)
LF442-MWA	Active	Production	WAFERSALE (YS) | 0	1 | NOT REQUIRED	-	Call TI	Level-1-NA-UNLIM	-40 to 85	
LF442AMH	Active	Production	TO-99 (LMC) | 8	500 | TRAY NON-STD	No	Call TI	Level-1-NA-UNLIM	-55 to 125	(LF442AMH, LF442AMH)
LF442AMH/NOPB	Active	Production	TO-99 (LMC) | 8	500 | OTHER	Yes	Call TI	Level-1-NA-UNLIM	-55 to 125	(LF442AMH, LF442AMH)

(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.

(3) **RoHS values:** Yes, No, RoHS Exempt. See the TI RoHS Statement for additional information and value definition.

(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.

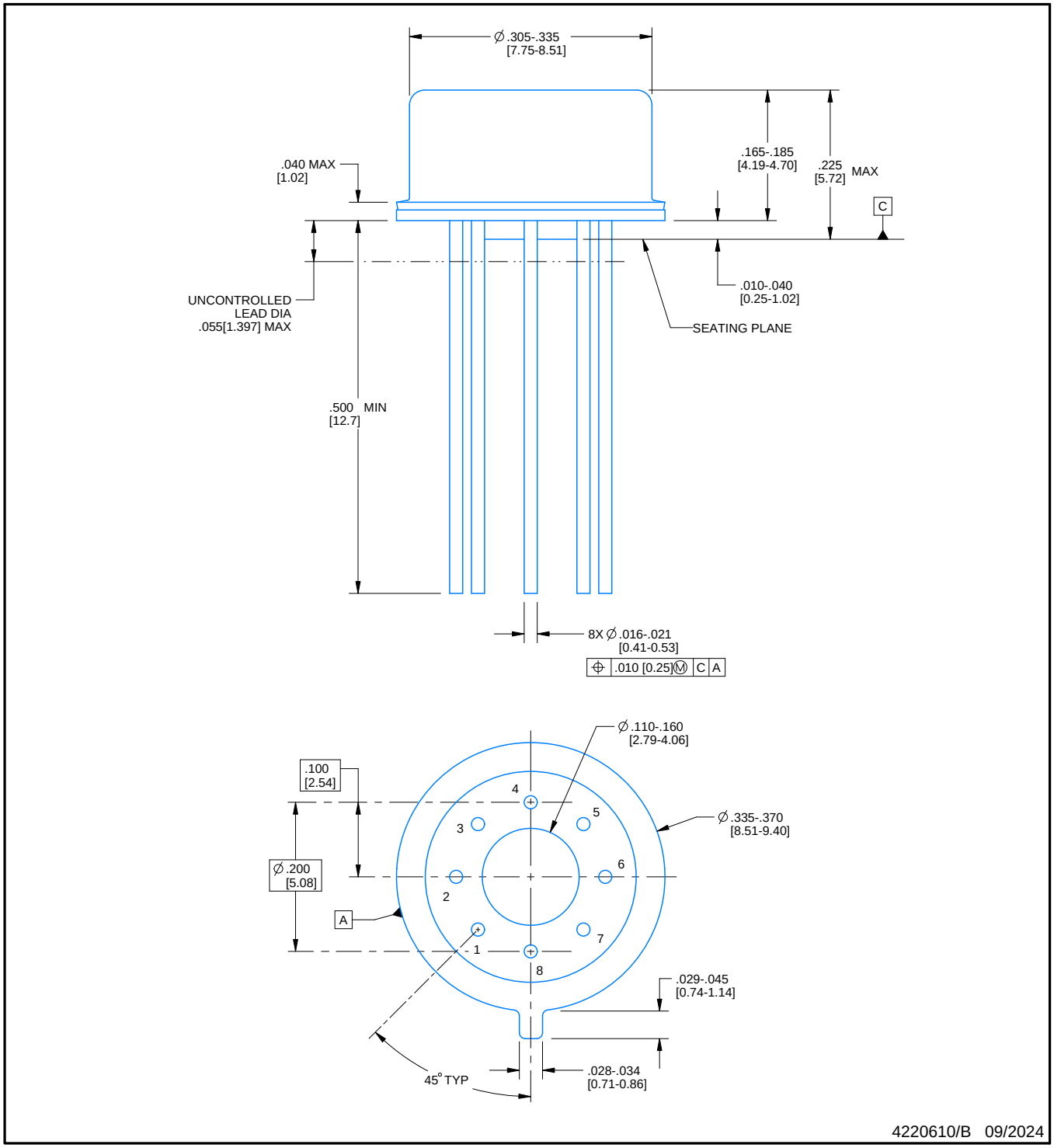
Multiple part markings will be inside parentheses. Only one part marking contained in parentheses and separated by a "~" will appear on a part. If a line is indented then it is a continuation of the previous line and the two combined represent the entire part marking for that device.

PACKAGE OUTLINE

LMC0008A

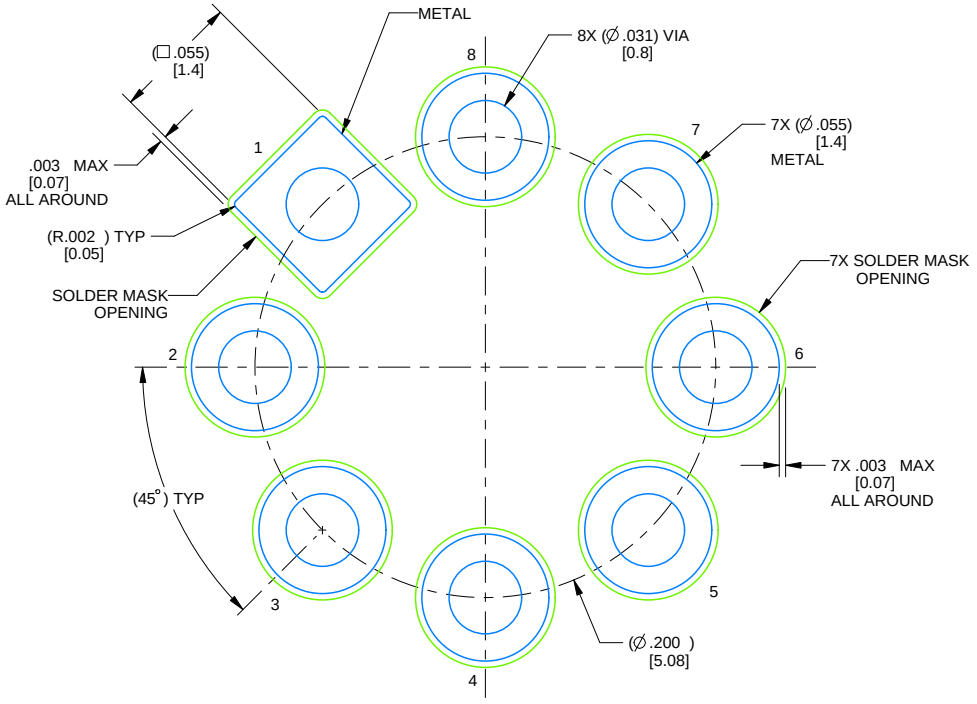
TO-CAN - 5.72 mm max height

TRANSISTOR OUTLINE



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.



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

4220610/B 09/2024

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