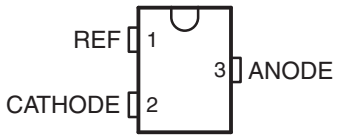
ADJUSTABLE PRECISION SHUNT REGULATORS

FEATURES

- **Qualified for Automotive Applications**
- **Operation From –40°C to 125°C**
- **Reference Voltage Tolerance at 25°C**
  - **0.5%...B Grade**
  - **1%...A Grade**
- **Typical Temperature Drift...14 mV**
- **Low Output Noise**
- **Typical Output Impedance...0.2 Ω**
- **Sink Current Capability...1 mA to 100 mA**
- **Adjustable Output Voltage...V_{ref} to 36 V**

DBZ (SOT-23-3) PACKAGE
(TOP VIEW)



DESCRIPTION/ORDERING INFORMATION

The TL432 devices are three-terminal adjustable shunt regulators with specified thermal stability over the automotive temperature range. The output voltage can be set to any value between V_{ref} (approximately 2.5 V) and 36 V with two external resistors (see Figure 17). These devices have a typical output impedance of 0.2 Ω. Active output circuitry provides a very sharp turn-on characteristic, making these devices excellent replacements for Zener diodes in many applications such as onboard regulation, adjustable power supplies, and switching power supplies.

The TL432 devices are offered in two grades with initial tolerances (at 25°C) of 0.5% and 1%, for the B and A grade, respectively. In addition, low output drift vs temperature ensures good stability over the entire temperature range.

The devices are characterized for operation from –40°C to 125°C.

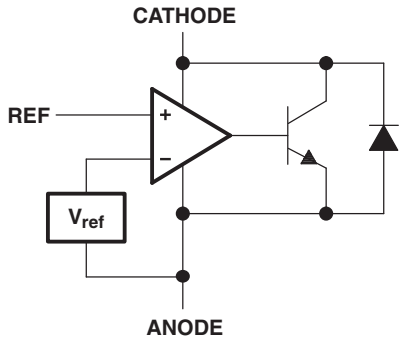
ORDERING INFORMATION(1)

T_A	V_{ref} TOLERANCE (T_A = 25°C)	PACKAGE(2)		ORDERABLE PART NUMBER	TOP-SIDE MARKING
–40°C to 125°C	A Grade: 1%	SOT23 – DBZ	Reel of 3000	TL432AQDBZRQ1	TOIQ
	B Grade: 0.5 %			TL432BQDBZRQ1	TOHQ

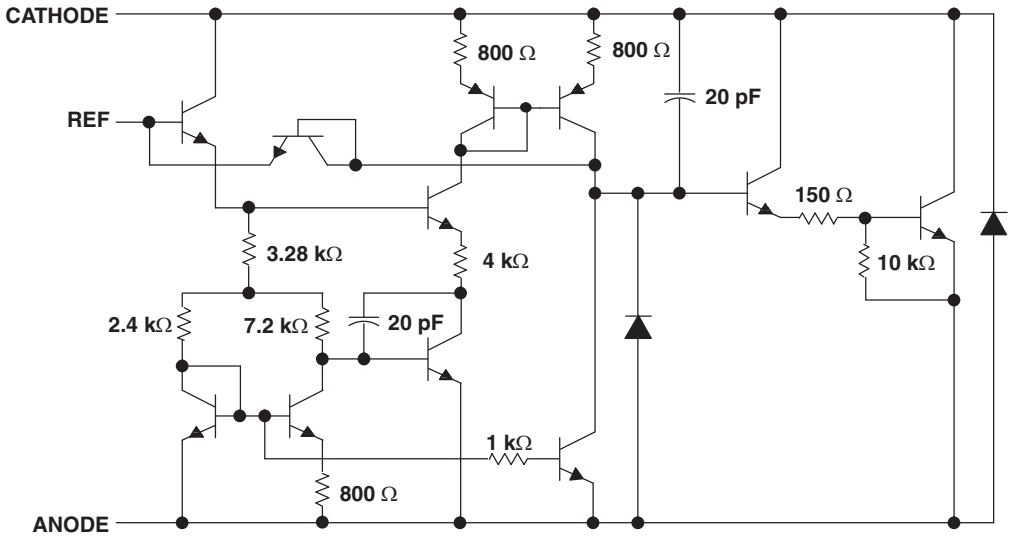
(1) For the most current package and ordering information, see the Package Option Addendum at the end of this document, or see the TI web site at www.ti.com.
(2) Package drawings, thermal data, and symbolization are available at www.ti.com/packaging.

SYMBOL

FUNCTIONAL BLOCK DIAGRAM



EQUIVALENT SCHEMATIC



NOTE: All component values are nominal.

ABSOLUTE MAXIMUM RATINGS(1)

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

V_{KA}	Cathode voltage(2)	37 V
I_{KA}	Continuous cathode current range	–100 mA to 150 mA
	Reference input current range	–50 μA to 10 mA
T_J	Operating virtual-junction temperature	150°C
T_{stg}	Storage temperature range	–65°C to 150°C

(1) Stresses beyond those listed under *absolute maximum ratings* may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under *recommended operating conditions* is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.
(2) Voltage values are with respect to the ANODE terminal, unless otherwise noted.

PACKAGE THERMAL DATA

PACKAGE	BOARD	θ_{JC}	θ_{JA}
SOT-23-3 (DBZ)	High K, JESD 51-7	76°C/W	206°C/W

RECOMMENDED OPERATING CONDITIONS

		MIN	MAX	UNIT
V_{KA}	Cathode voltage	V_{ref}	36	V
I_{KA}	Cathode current	1	100	mA
T_A	Operating free-air temperature	–40	125	°C

TL432A ELECTRICAL CHARACTERISTICS

over recommended operating conditions, T_A = 25°C (unless otherwise noted)

PARAMETER		TEST CIRCUIT	TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_{ref}	Reference voltage	Figure 2	V_{KA} = V_{ref}, I_{KA} = 10 mA		2470	2495	2520	mV
$V_{I(dev)}$	Deviation of reference voltage over full temperature range (see Figure 1)	Figure 2	V_{KA} = V_{ref}, I_{KA} = 10 mA, T_A = –40°C to 125°C			14	34	mV
$\Delta V_{ref}/\Delta V_{KA}$	Ratio of change in reference voltage to the change in cathode voltage	Figure 3	I_{KA} = 10 mA	ΔV_{KA} = 10 V – V_{ref}		–1.4	–2.7	mV/V
				ΔV_{KA} = 36 V – 10 V		–1	–2	
I_{ref}	Reference current	Figure 3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞			2	4	µA
$I_{I(dev)}$	Deviation of reference current over full temperature range (see Figure 1)	Figure 3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞, T_A = –40°C to 125°C			0.8	2.5	µA
I_{min}	Minimum cathode current for regulation	Figure 2	V_{KA} = V_{ref}			0.4	0.7	mA
I_{off}	Off-state cathode current	Figure 4	V_{KA} = 36 V, V_{ref} = 0			0.1	0.5	µA
$\|z_{KA}\|$	Dynamic impedance (see Figure 1)	Figure 2	I_{KA} = 1 mA to 100 mA, V_{KA} = V_{ref}, f ≤ 1 kHz			0.2	0.5	Ω

TL432B ELECTRICAL CHARACTERISTICS

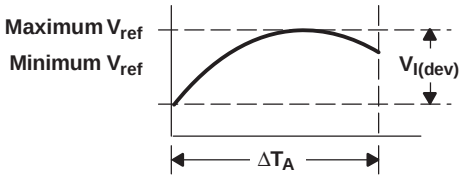
over recommended operating conditions, T_A = 25°C (unless otherwise noted)

PARAMETER		TEST CIRCUIT	TEST CONDITIONS		MIN	TYP	MAX	UNIT
V_{ref}	Reference voltage	Figure 2	V_{KA} = V_{ref}, I_{KA} = 10 mA		2483	2495	2507	mV
$V_{I(dev)}$	Deviation of reference voltage over full temperature range (see Figure 1)	Figure 2	V_{KA} = V_{ref}, I_{KA} = 10 mA, T_A = –40°C to 125°C			14	34	mV
$\Delta V_{ref}/\Delta V_{KA}$	Ratio of change in reference voltage to the change in cathode voltage	Figure 3	I_{KA} = 10 mA	ΔV_{KA} = 10 V – V_{ref}		–1.4	–2.7	mV/V
				ΔV_{KA} = 36 V – 10 V		–1	–2	
I_{ref}	Reference current	Figure 3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞			2	4	µA
$I_{I(dev)}$	Deviation of reference current over full temperature range (see Figure 1)	Figure 3	I_{KA} = 10 mA, R1 = 10 kΩ, R2 = ∞, T_A = –40°C to 125°C			0.8	2.5	µA
I_{min}	Minimum cathode current for regulation	Figure 2	V_{KA} = V_{ref}			0.4	0.7	mA
I_{off}	Off-state cathode current	Figure 4	V_{KA} = 36 V, V_{ref} = 0			0.1	0.5	µA
$\|z_{KA}\|$	Dynamic impedance (see Figure 1)	Figure 2	I_{KA} = 1 mA to 100 mA, V_{KA} = V_{ref}, f ≤ 1 kHz			0.2	0.5	Ω

Deviation Parameters

The deviation parameters $V_{ref(dev)}$ and $I_{ref(dev)}$ are defined as the differences between the maximum and minimum values obtained over the recommended temperature range. The average full-range temperature coefficient of the reference voltage, α_{Vref}, is defined as:

$$\left|\alpha_{V_{ref}}\right| \left(\frac{ppm}{°C}\right) = \frac{\left(\frac{V_{I(dev)}}{V_{ref\ at\ 25°C}}\right) \times 10^6}{\Delta T_A}$$



where:

ΔT_A is the recommended operating free-air temperature range of the device.

$\alpha_{V_{ref}}$ can be positive or negative, depending on whether minimum V_{ref} or maximum V_{ref}, respectively, occurs at the lower temperature.

Example: V_{ref} = 2495 mV at 25°C, $V_{I(dev)}$ = 14 mV, ΔT_A = 165°C for TL432B

$$\left|\alpha_{V_{ref}}\right| = \frac{\left(\frac{14\ mV}{2495\ mV}\right) \times 10^6}{165°C} \approx 34 \frac{ppm}{°C}$$

Because minimum V_{ref} occurs at the lower temperature, the coefficient is positive.

Dynamic Impedance

The dynamic impedance is defined as: $|z_{KA}| = \frac{\Delta V_{KA}}{\Delta I_{KA}}$

When the device is operating with two external resistors (see Figure 3), the total dynamic impedance of the circuit is given by:

$$|z'| = \frac{\Delta V}{\Delta I} \approx |z_{KA}| \left(1 + \frac{R1}{R2}\right)$$

Figure 1. Calculating Deviation Parameters and Dynamic Impedance

PARAMETER MEASUREMENT INFORMATION

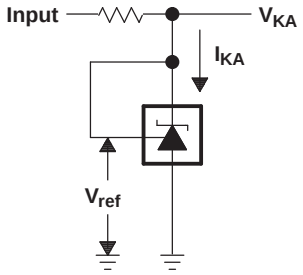


Figure 2. Test Circuit for $V_{KA} = V_{ref}$

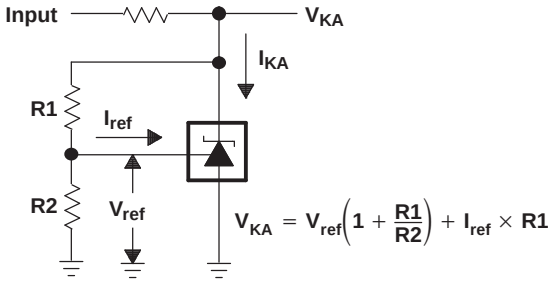


Figure 3. Test Circuit for $V_{KA} > V_{ref}$

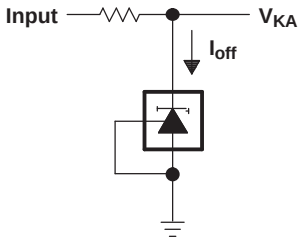


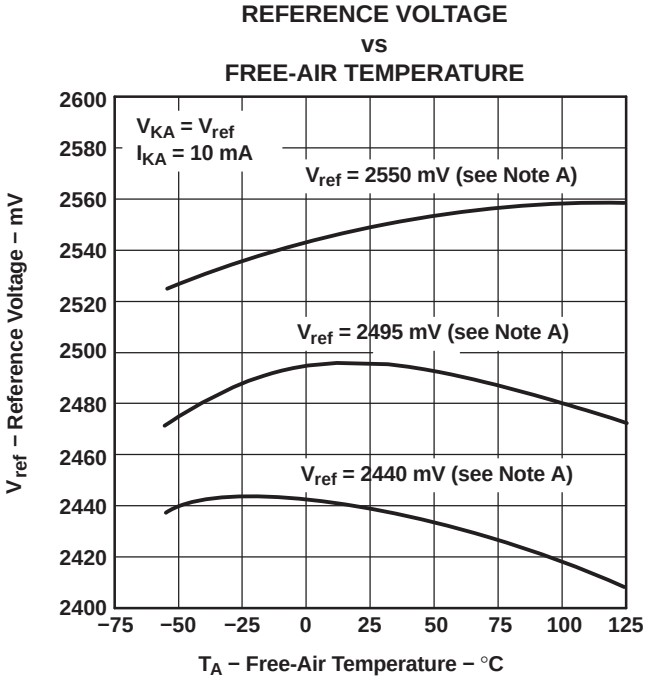
Figure 4. Test Circuit for I_{off}

TYPICAL CHARACTERISTICS

Data at high and low temperatures is applicable only within the recommended operating free-air temperature ranges of the various devices.

Table 1. Graphs

	FIGURE
Reference voltage vs Free-air temperature	Figure 5
Reference current vs Free-air temperature	Figure 6
Cathode current vs Cathode voltage	Figure 7, Figure 8
Off-state cathode current vs Free-air temperature	Figure 9
Ratio of delta reference voltage to delta cathode voltage vs Free-air temperature	Figure 10
Equivalent input noise voltage vs Frequency	Figure 11
Equivalent input noise voltage over a 10-s period	Figure 12
Small-signal voltage amplification vs Frequency	Figure 13
Reference impedance vs Frequency	Figure 14
Pulse response	Figure 15
Stability boundary conditions	Figure 16



A. Data is for devices having the indicated value of V_{ref} at I_{KA} = 10 mA, T_A = 25°C.

Figure 5.

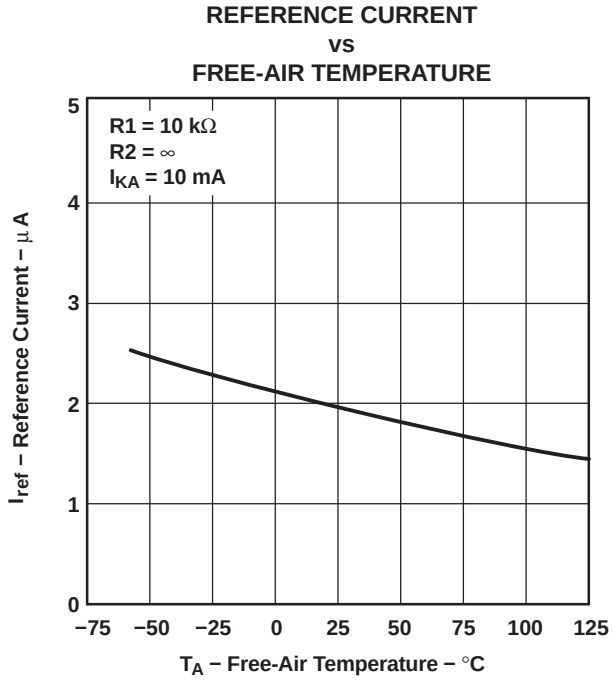


Figure 6.

CATHODE CURRENT
vs
CATHODE VOLTAGE

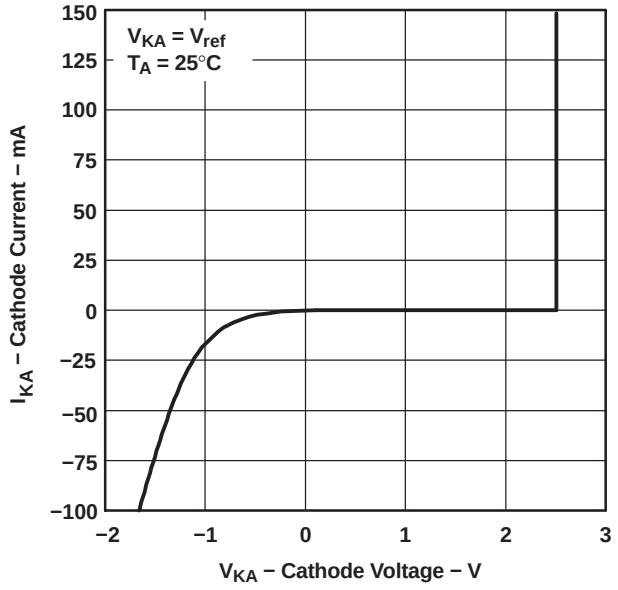


Figure 7.

CATHODE CURRENT
vs
CATHODE VOLTAGE

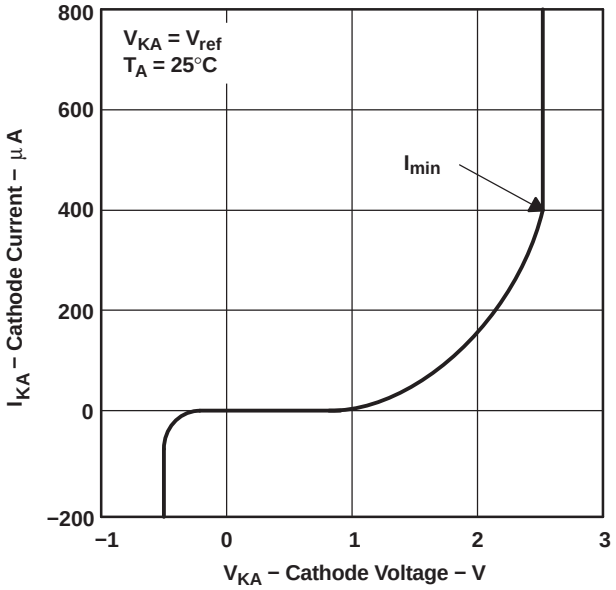


Figure 8.

OFF-STATE CATHODE CURRENT
vs
FREE-AIR TEMPERATURE

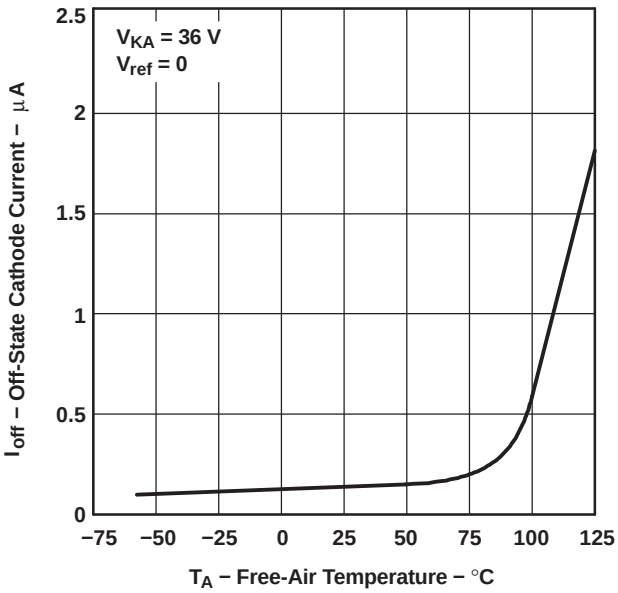


Figure 9.

RATIO OF DELTA REFERENCE VOLTAGE TO
DELTA CATHODE VOLTAGE
vs
FREE-AIR TEMPERATURE

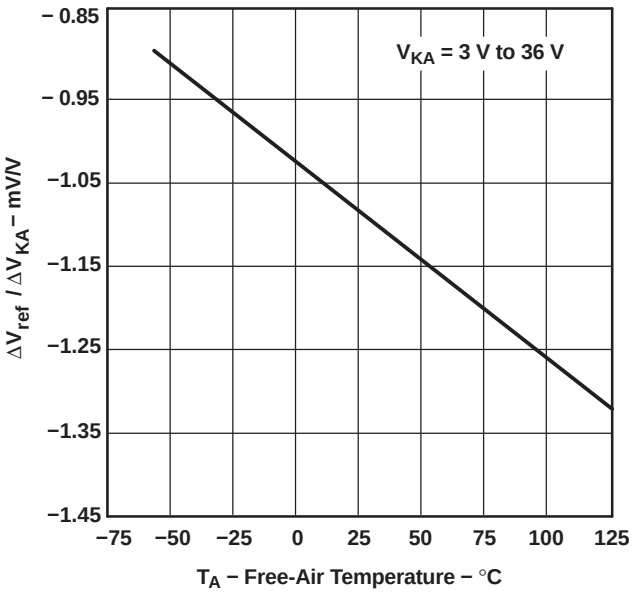


Figure 10.

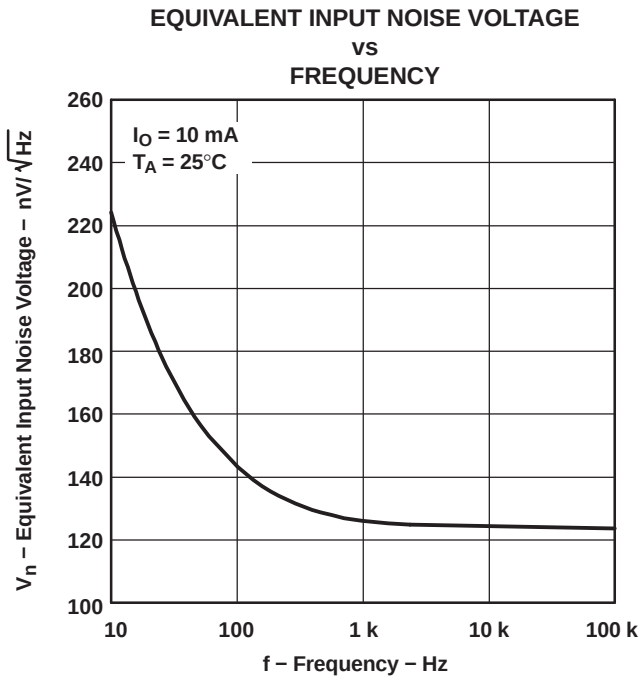


Figure 11.

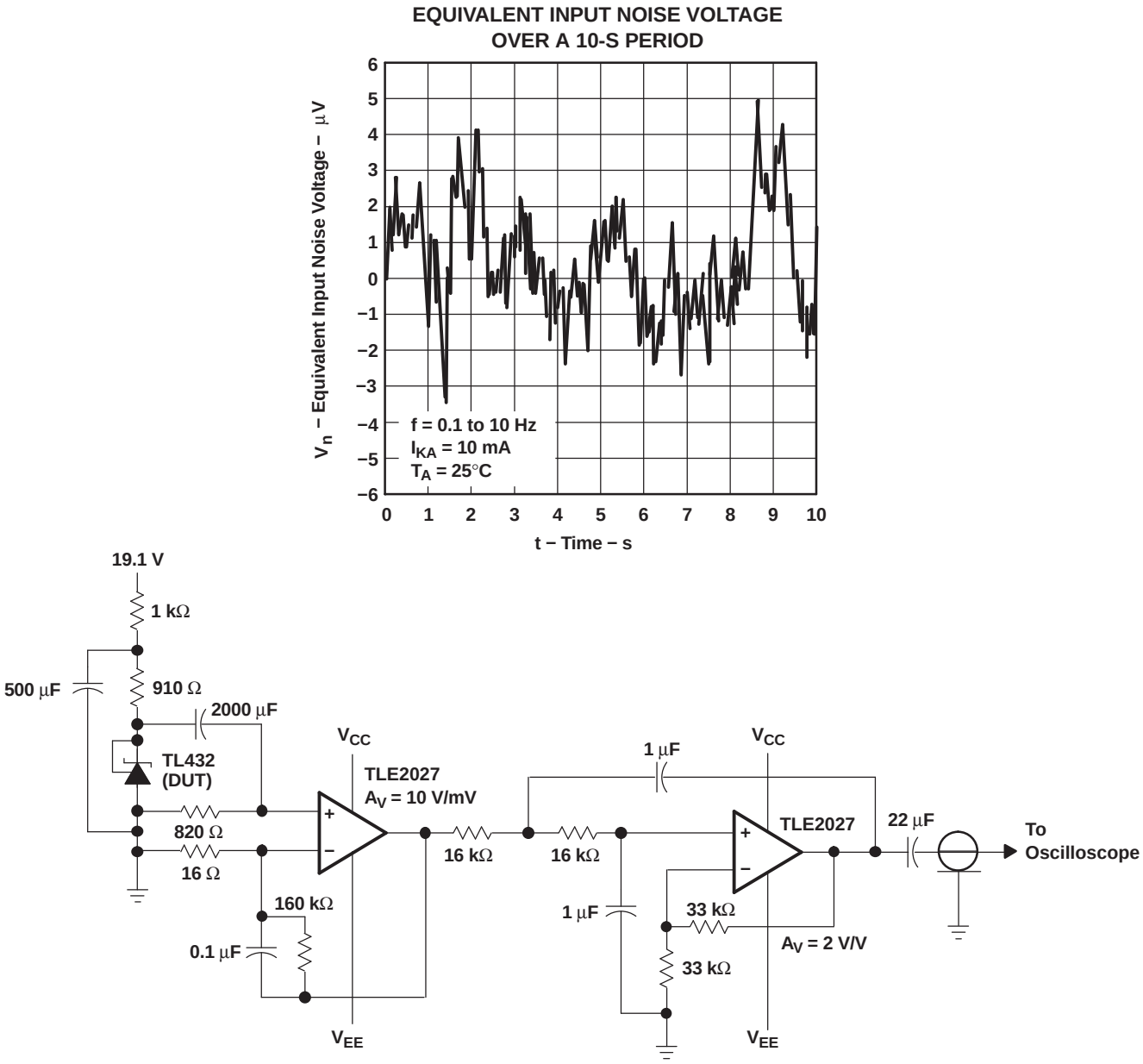
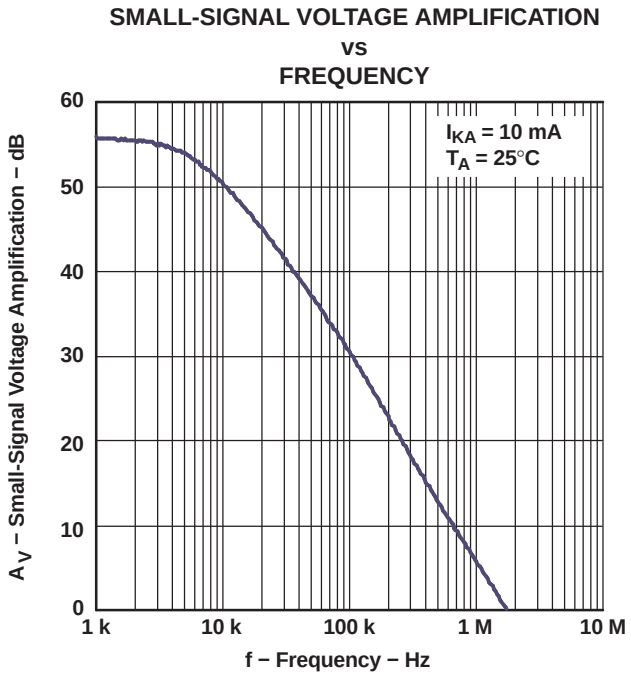
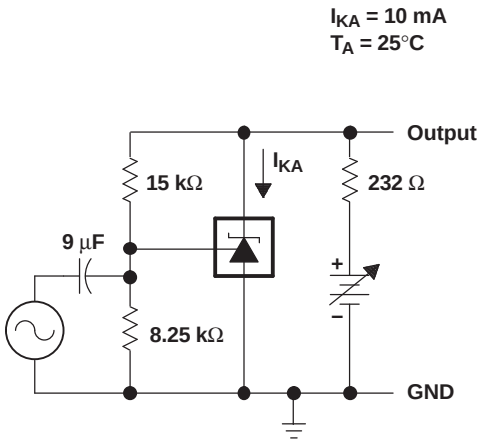


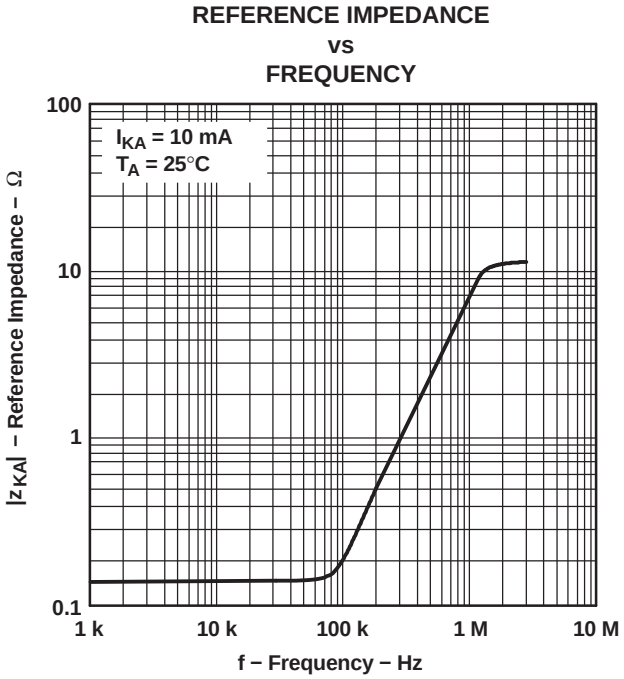
Figure 12. Test Circuit for Equivalent Input Noise Voltage

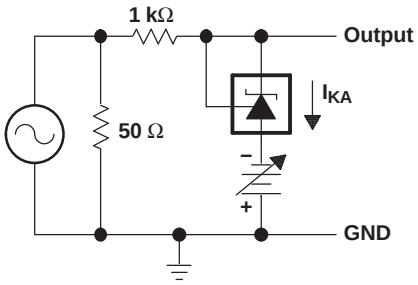




TEST CIRCUIT FOR VOLTAGE AMPLIFICATION

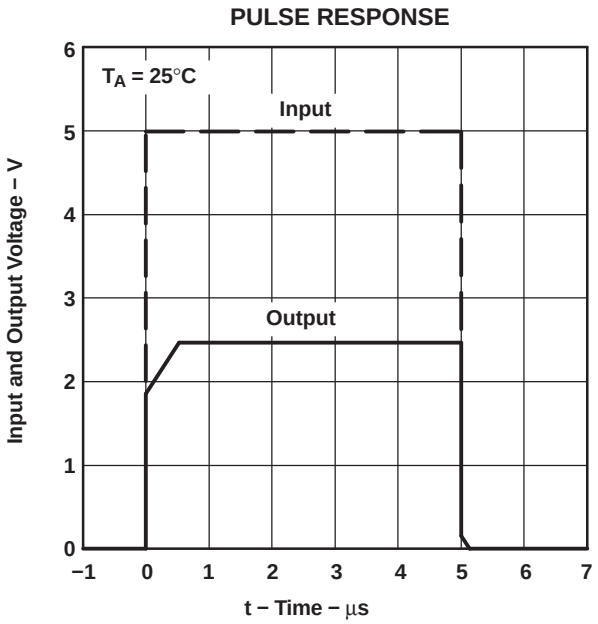
Figure 13.

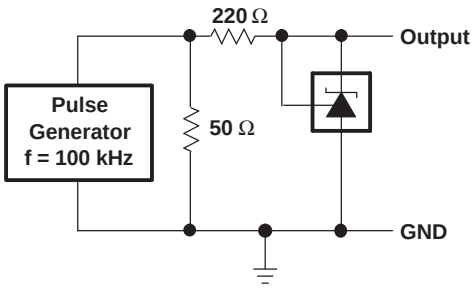




TEST CIRCUIT FOR REFERENCE IMPEDANCE

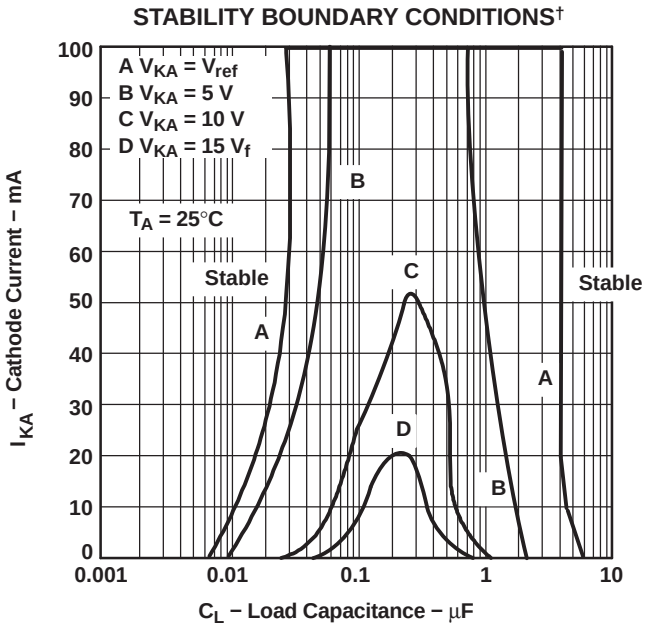
Figure 14.



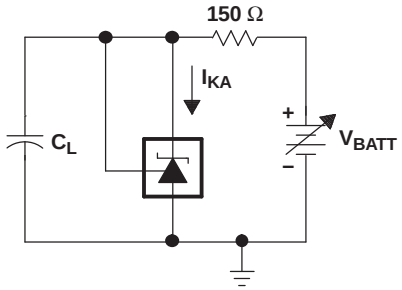


TEST CIRCUIT FOR PULSE RESPONSE

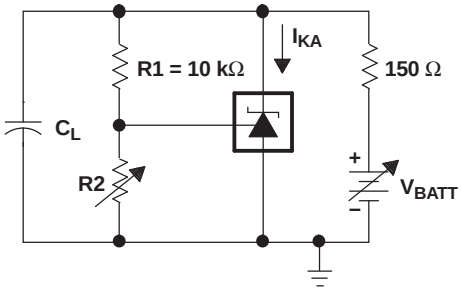
Figure 15.



† The areas under the curves represent conditions that may cause the device to oscillate. For curves B, C, and D, R2 and V+ were adjusted to establish the initial V_{KA} and I_{KA} conditions with C_L = 0. V_{BATT} and C_L then were adjusted to determine the ranges of stability.



TEST CIRCUIT FOR CURVE A



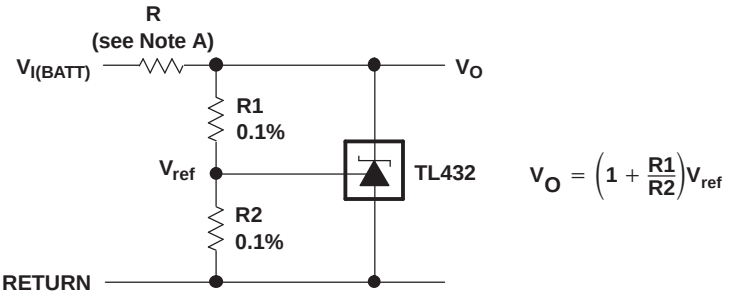
TEST CIRCUIT FOR CURVES B, C, AND D

Figure 16.

APPLICATION INFORMATION

Table 2. Application Circuits

	FIGURE
Shunt regulator	Figure 17
Single-supply comparator with temperature-compensated threshold	Figure 18
Precision high-current series regulator	Figure 19
Output control of a three-terminal fixed regulator	Figure 20
High-current shunt regulator	Figure 21
Crowbar circuit	Figure 22
Precision 5-V 1.5-A regulator	Figure 23
Efficient 5-V precision regulator	Figure 24
PWM converter with reference	Figure 25
Voltage monitor	Figure 26
Delay timer	Figure 27
Precision current limiter	Figure 28
Precision constant-current sink	Figure 29



A. R should provide cathode current ≥1 mA to the TL432 at minimum $V_{I(BATT)}$.

Figure 17. Shunt Regulator

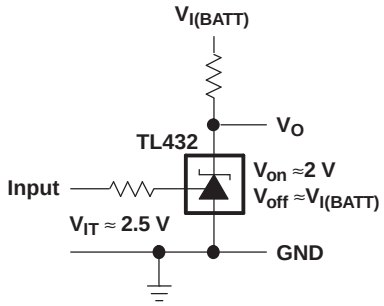
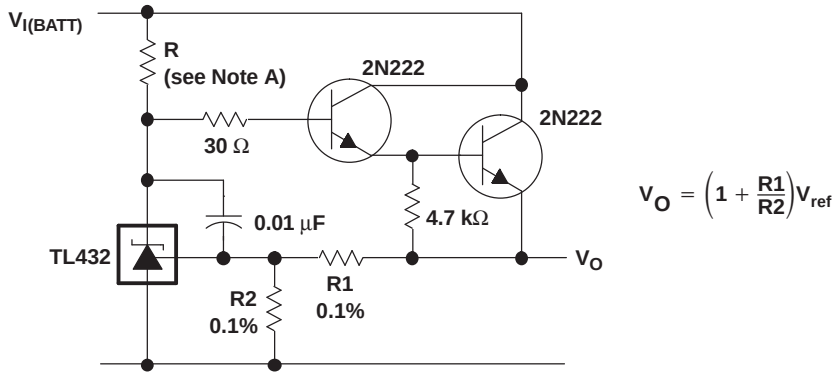


Figure 18. Single-Supply Comparator With Temperature-Compensated Threshold



A. R should provide cathode current ≥1 mA to the TL432 at minimum $V_{I(BATT)}$.

Figure 19. Precision High-Current Series Regulator

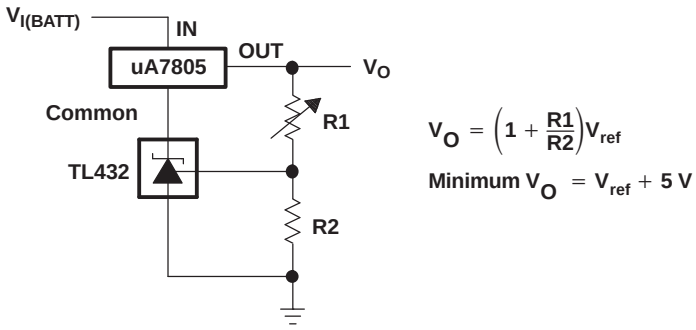


Figure 20. Output Control of a Three-Terminal Fixed Regulator

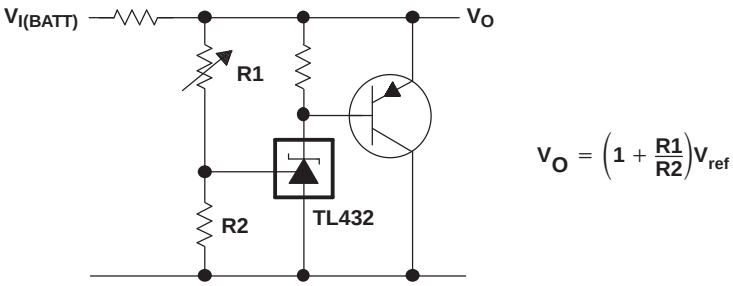
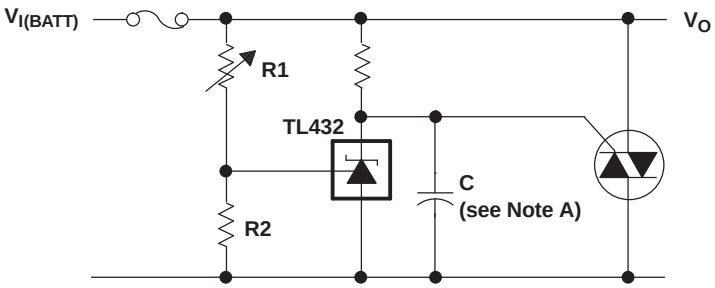


Figure 21. High-Current Shunt Regulator



A. See the stability boundary conditions in Figure 16 to determine allowable values for C.

Figure 22. Crowbar Circuit

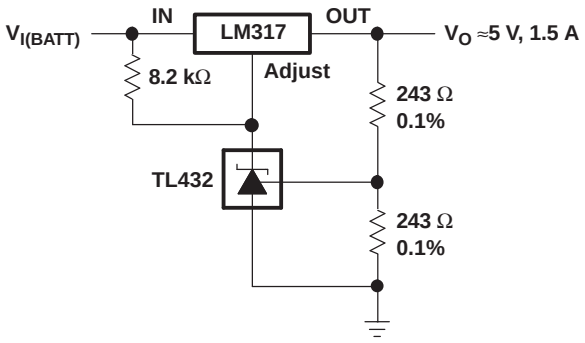
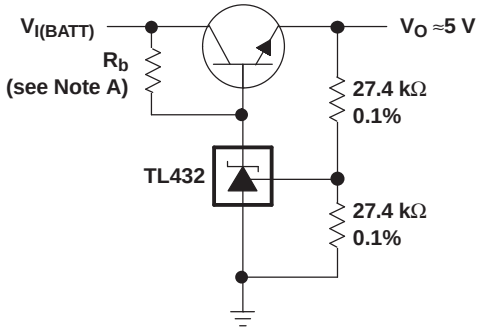


Figure 23. Precision 5-V 1.5-A Regulator



A. R_b should provide cathode current ≥1 mA to the TL432.

Figure 24. Efficient 5-V Precision Regulator

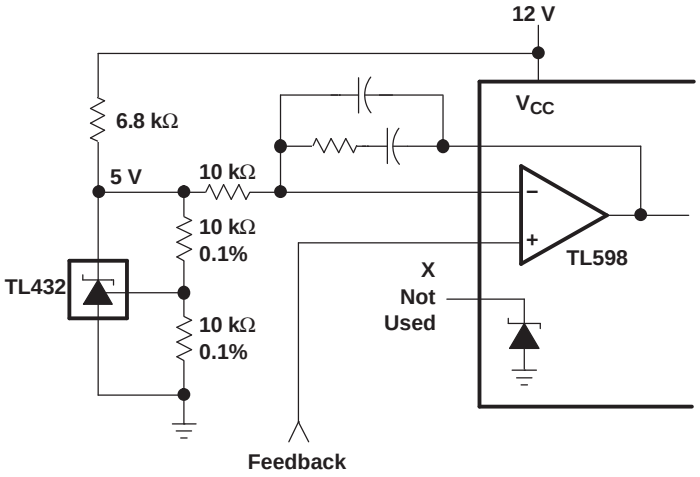
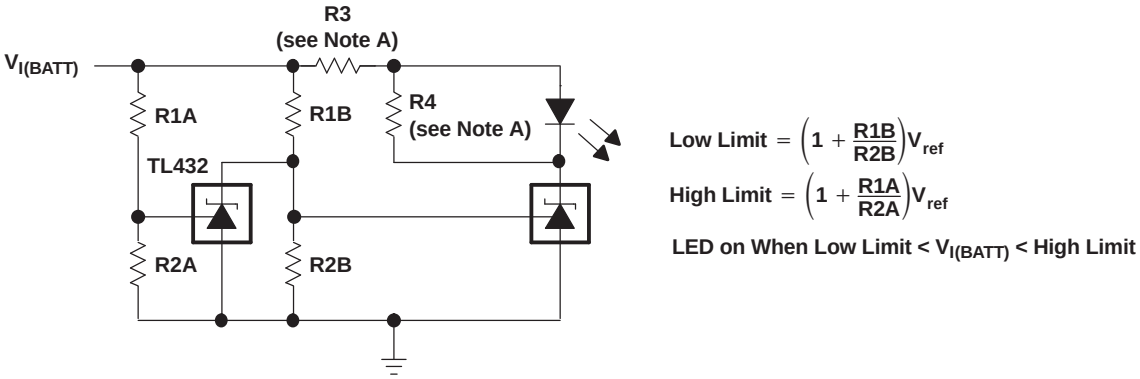


Figure 25. PWM Converter With Reference



A. R3 and R4 are selected to provide the desired LED intensity and cathode current ≥1 mA to the TL432 at the available $V_{I(BATT)}$.

Figure 26. Voltage Monitor

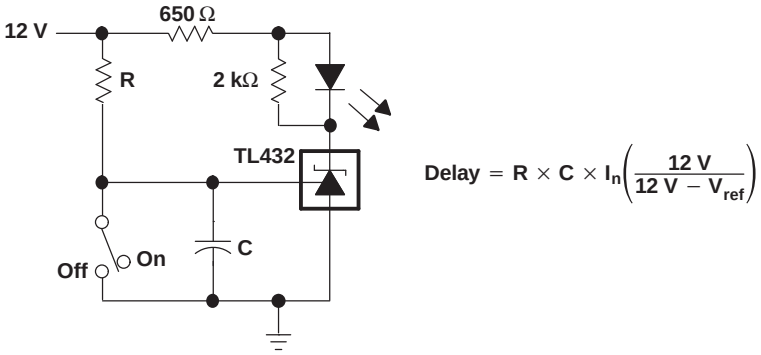


Figure 27. Delay Timer

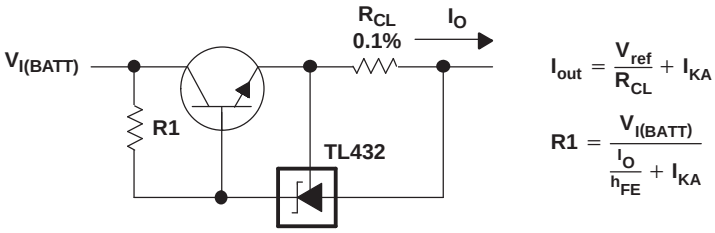


Figure 28. Precision Current Limiter

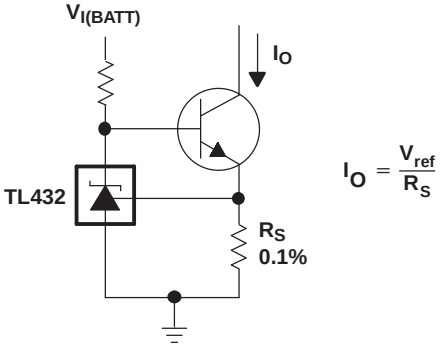


Figure 29. Precision Constant-Current Sink

PACKAGING INFORMATION

Orderable Device	Status (1)	Package Type	Package Drawing	Pins	Package Qty	Eco Plan (2)	Lead/Ball Finish	MSL Peak Temp (3)
TL432AQDBZRQ1	ACTIVE	SOT-23	DBZ	3	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM
TL432BQDBZRQ1	ACTIVE	SOT-23	DBZ	3	3000	Green (RoHS & no Sb/Br)	CU NIPDAU	Level-1-260C-UNLIM

(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.

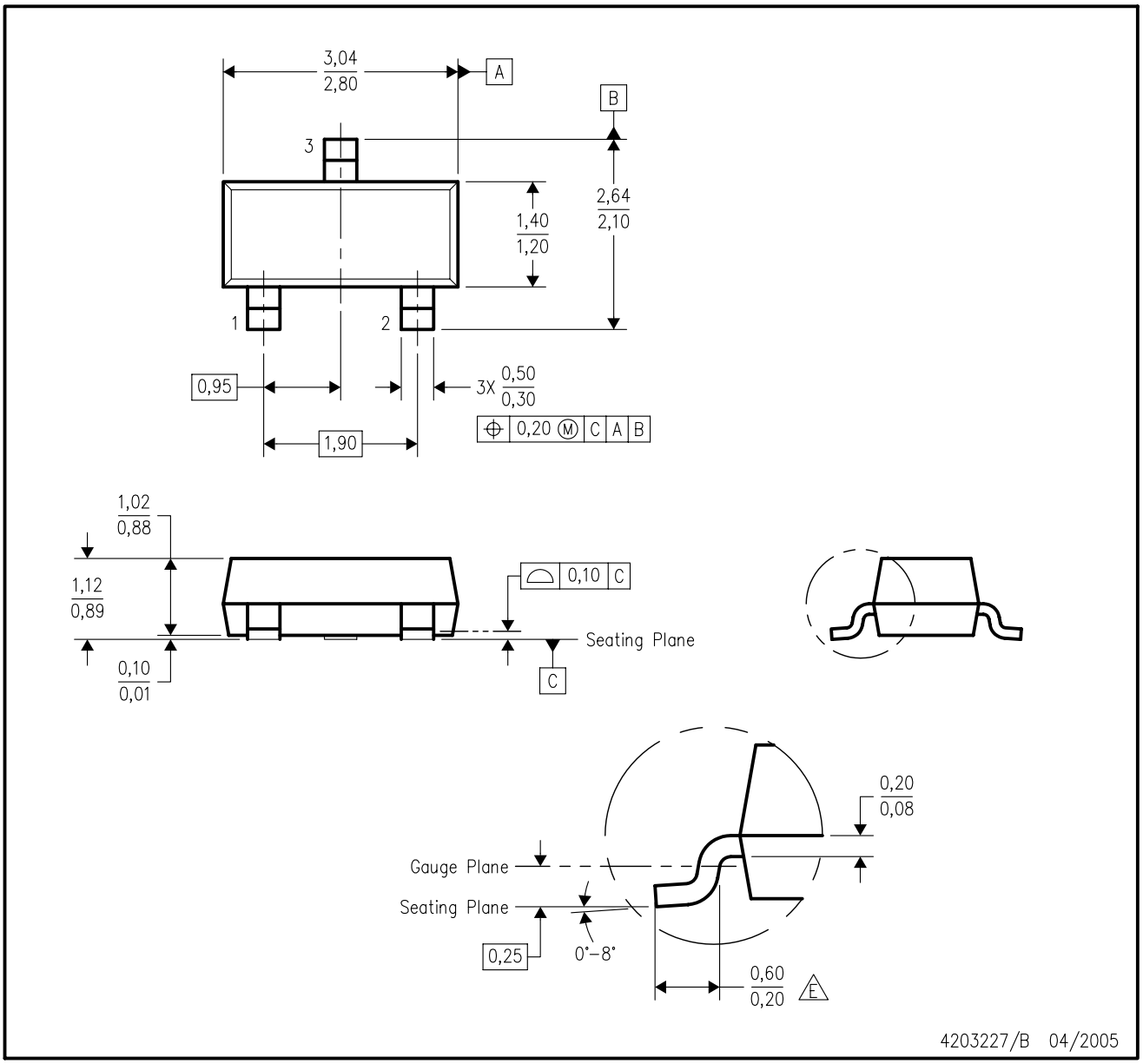
(2) Eco Plan - The planned eco-friendly classification: Pb-Free (RoHS), Pb-Free (RoHS Exempt), or Green (RoHS & no Sb/Br) - please check http://www.ti.com/productcontent for the latest availability information and additional product content details.
TBD: The Pb-Free/Green conversion plan has not been 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.

OTHER QUALIFIED VERSIONS OF TL432A-Q1, TL432B-Q1 :
- Catalog: TL432A, TL432B

NOTE: Qualified Version Definitions:
- Catalog - TI's standard catalog product

DBZ (R–PDSO–G3) PLASTIC SMALL–OUTLINE



NOTES:
A. All linear dimensions are in millimeters. Dimensioning and tolerancing per ASME Y14.5M–1994.
B. This drawing is subject to change without notice.
C. Lead dimensions are inclusive of plating.
D. Body dimensions are exclusive of mold flash and protrusion. Mold flash and protrusion not to exceed 0.25 per side.
E. Falls within JEDEC TO–236 variation AB, except minimum foot length.

IMPORTANT NOTICE

Texas Instruments Incorporated and its subsidiaries (TI) reserve the right to make corrections, modifications, enhancements, improvements, and other changes to its products and services at any time and to discontinue any product or service without notice. Customers should obtain the latest relevant information before placing orders and should verify that such information is current and complete. All products are sold subject to TI's terms and conditions of sale supplied at the time of order acknowledgment.

TI warrants performance of its hardware products to the specifications applicable at the time of sale in accordance with TI's standard warranty. Testing and other quality control techniques are used to the extent TI deems necessary to support this warranty. Except where mandated by government requirements, testing of all parameters of each product is not necessarily performed.

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

TI does not warrant or represent that any license, either express or implied, is granted under any TI patent right, copyright, mask work right, or other TI intellectual property right relating to any combination, machine, or process in which TI products or services are used. Information published by TI regarding third-party products or services does not constitute a license from TI 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 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. Reproduction of this information with alteration is an unfair and deceptive business practice. TI is not responsible or liable for such altered documentation. Information of third parties may be subject to additional restrictions.

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

TI products are not authorized for use in safety-critical applications (such as life support) where a failure of the TI product would reasonably be expected to cause severe personal injury or death, unless officers of the parties have executed an agreement specifically governing such use. Buyers represent that they have all necessary expertise in the safety and regulatory ramifications of their applications, and acknowledge and agree that they are solely responsible for all legal, regulatory and safety-related requirements concerning their products and any use of TI products in such safety-critical applications, notwithstanding any applications-related information or support that may be provided by TI. Further, Buyers must fully indemnify TI and its representatives against any damages arising out of the use of TI products in such safety-critical applications.

TI products are neither designed nor intended for use in military/aerospace applications or environments unless the TI products are specifically designated by TI as military-grade or "enhanced plastic." Only products designated by TI as military-grade meet military specifications. Buyers acknowledge and agree that any such use of TI products which TI has not designated as military-grade is solely at the Buyer's risk, and that they are solely responsible for compliance with all legal and regulatory requirements in connection with such use.

TI products are neither designed nor intended for use in automotive applications or environments unless the specific TI products are designated by TI as compliant with ISO/TS 16949 requirements. Buyers acknowledge and agree that, if they use any non-designated products in automotive applications, TI will not be responsible for any failure to meet such requirements.

Following are URLs where you can obtain information on other Texas Instruments products and application solutions:

Products		**Applications**	
Amplifiers	amplifier.ti.com	Audio	www.ti.com/audio
Data Converters	dataconverter.ti.com	Automotive	www.ti.com/automotive
DLP® Products	www.dlp.com	Broadband	www.ti.com/broadband
DSP	dsp.ti.com	Digital Control	www.ti.com/digitalcontrol
Clocks and Timers	www.ti.com/clocks	Medical	www.ti.com/medical
Interface	interface.ti.com	Military	www.ti.com/military
Logic	logic.ti.com	Optical Networking	www.ti.com/opticalnetwork
Power Mgmt	power.ti.com	Security	www.ti.com/security
Microcontrollers	microcontroller.ti.com	Telephony	www.ti.com/telephony
RFID	www.ti-rfid.com	Video & Imaging	www.ti.com/video
RF/IF and ZigBee® Solutions	www.ti.com/lprf	Wireless	www.ti.com/wireless

Mailing Address: Texas Instruments, Post Office Box 655303, Dallas, Texas 75265