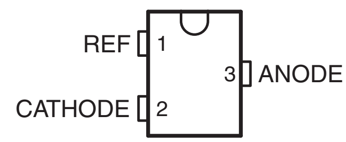
ADJUSTABLE PRECISION SHUNT REGULATORS

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.

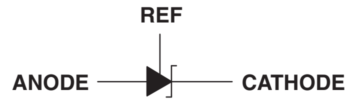
The devices are characterized for operation from –40°C to 125°C.

ORDERING INFORMATION(1)

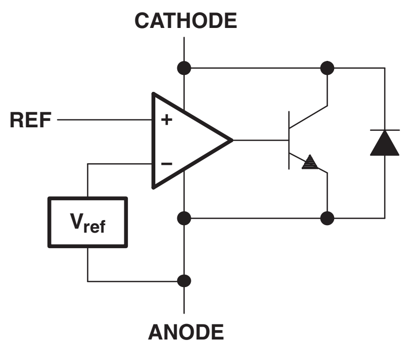
T_A	V_{ref} TOLERANCE (T_A = 25°C)	PACKAGE(2)		ORDERABLE PART NUMBER	TOP-SIDE MARKING
–40°C to 125°C	A Grade: 1%	SOT23 – DBZ	Reel of 3000	TL432AQDBZRQ1	TOIQ
	B Grade: 0.5 %			TL432BQDBZRQ1	TOHQ

(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.

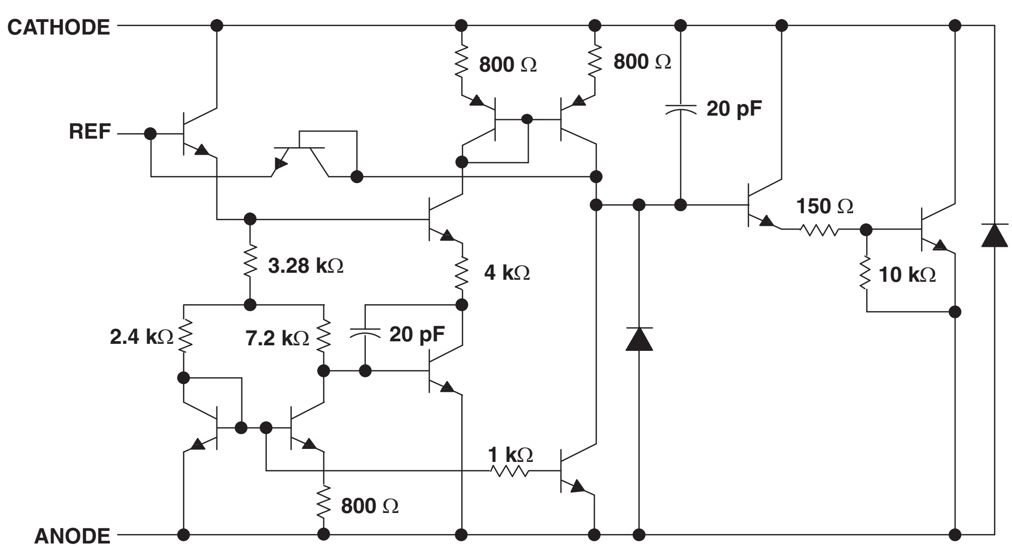
SYMBOL



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
$\lvert z_{KA} \rvert$	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

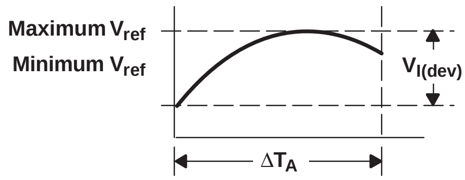
over recommended operating conditions, T_A = 25°C (unless otherwise noted)

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
$\lvert z_{KA} \rvert$	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:

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



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

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

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

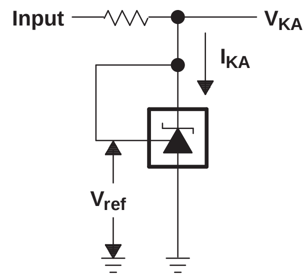


Figure 2. Test Circuit for $V_{KA} = V_{ref}$

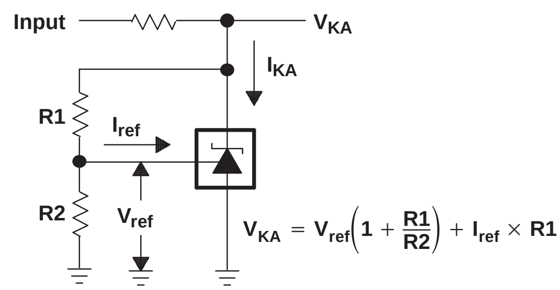


Figure 3. Test Circuit for $V_{KA} > V_{ref}$

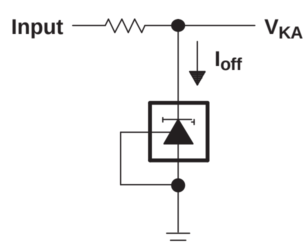


Figure 4. Test Circuit for I_{off}

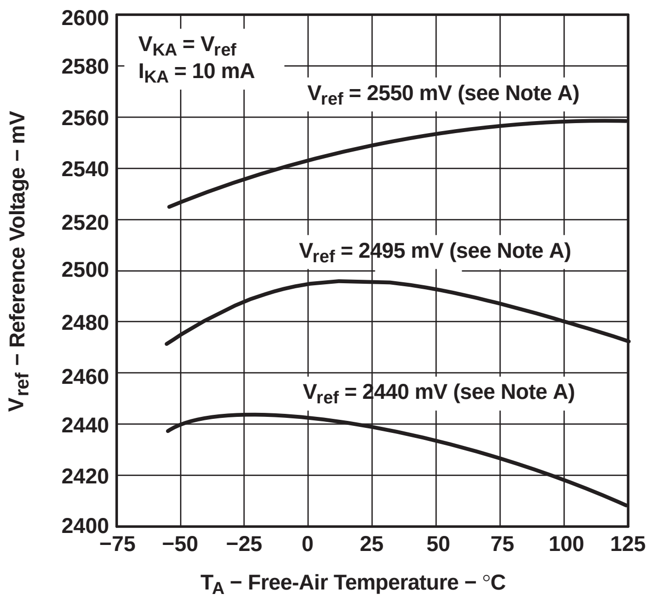
TYPICAL CHARACTERISTICS

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

REFERENCE VOLTAGE vs FREE-AIR TEMPERATURE



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

Figure 5.

REFERENCE CURRENT vs FREE-AIR TEMPERATURE

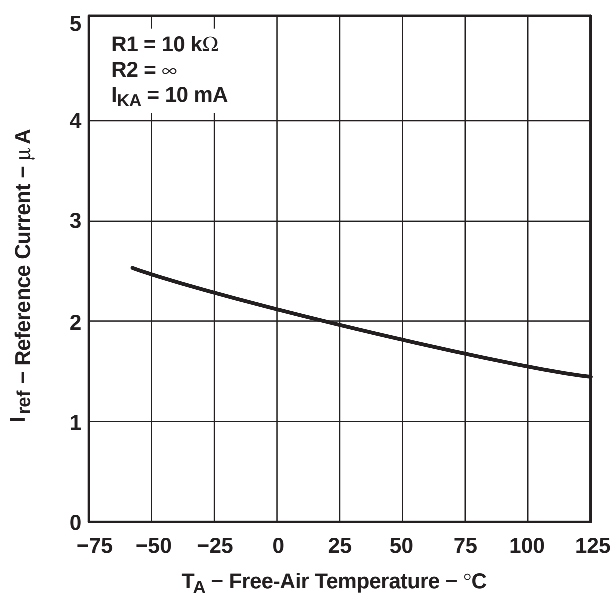


Figure 6.

CATHODE CURRENT
vs
CATHODE VOLTAGE

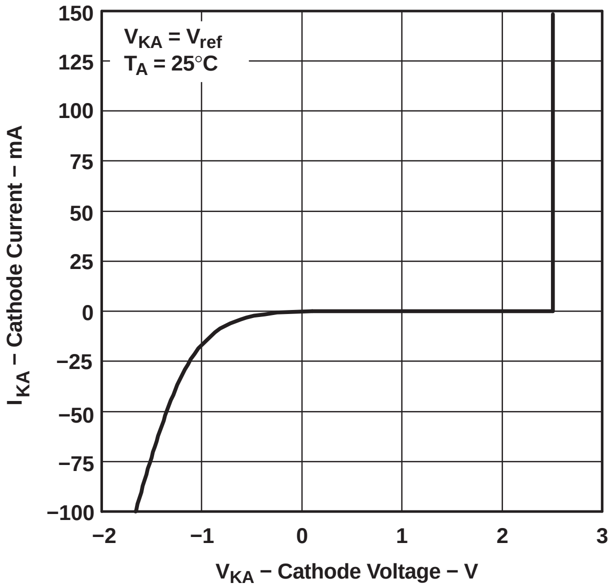


Figure 7.

CATHODE CURRENT
vs
CATHODE VOLTAGE

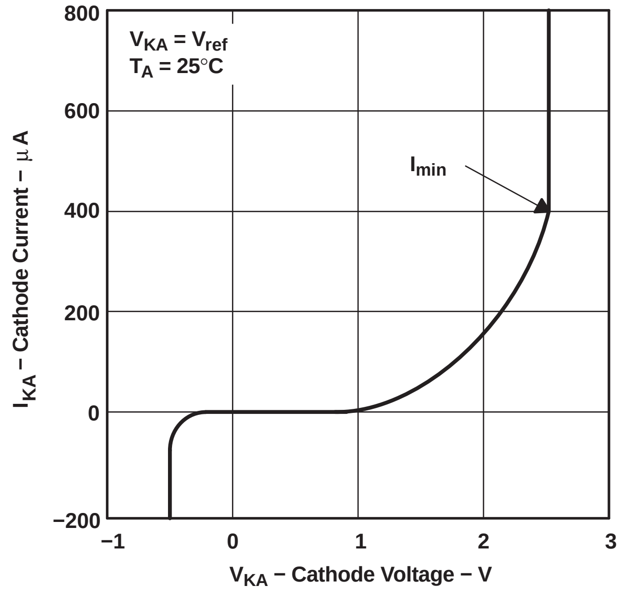


Figure 8.

OFF-STATE CATHODE CURRENT
vs
FREE-AIR TEMPERATURE

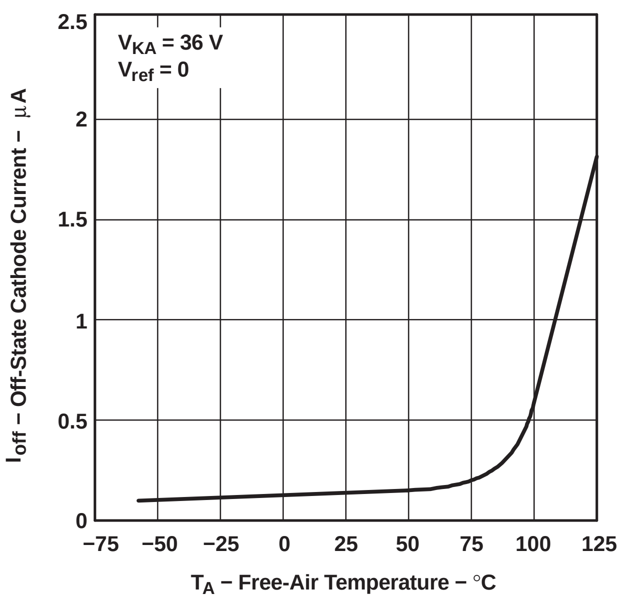


Figure 9.

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

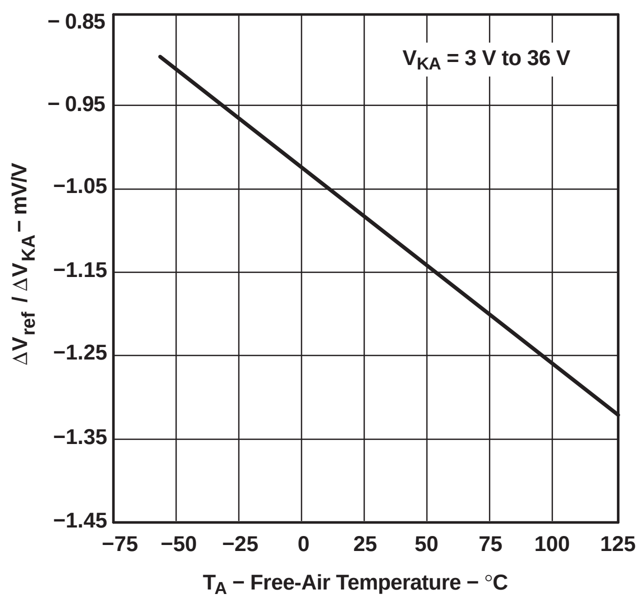


Figure 10.

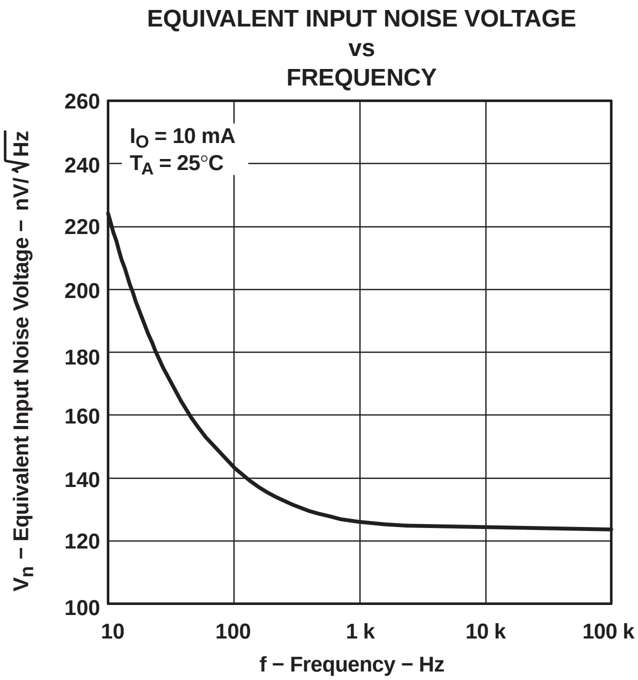
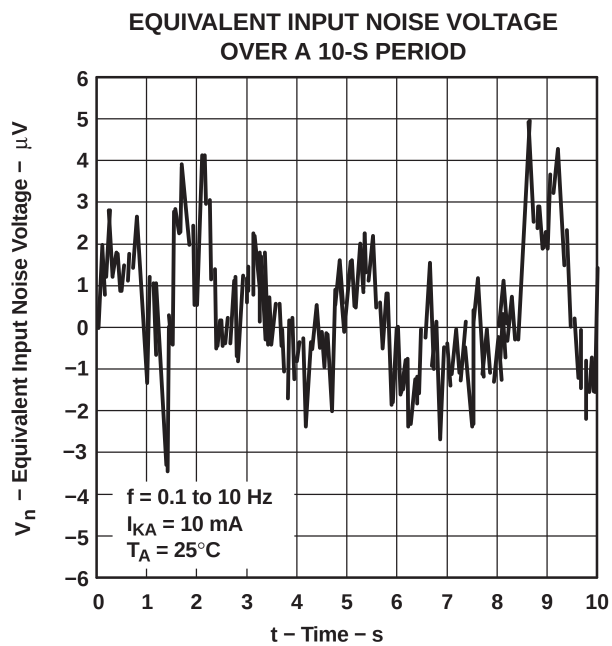

EQUIVALENT INPUT NOISE VOLTAGE
vs
FREQUENCY
I_O = 10 mA
T_A = 25°C
V_n – Equivalent Input Noise Voltage – nV/$\sqrt{Hz}$
260
240
220
200
180
160
140
120
100
10
100
1 k
10 k
100 k
f – Frequency – Hz

Figure 11.



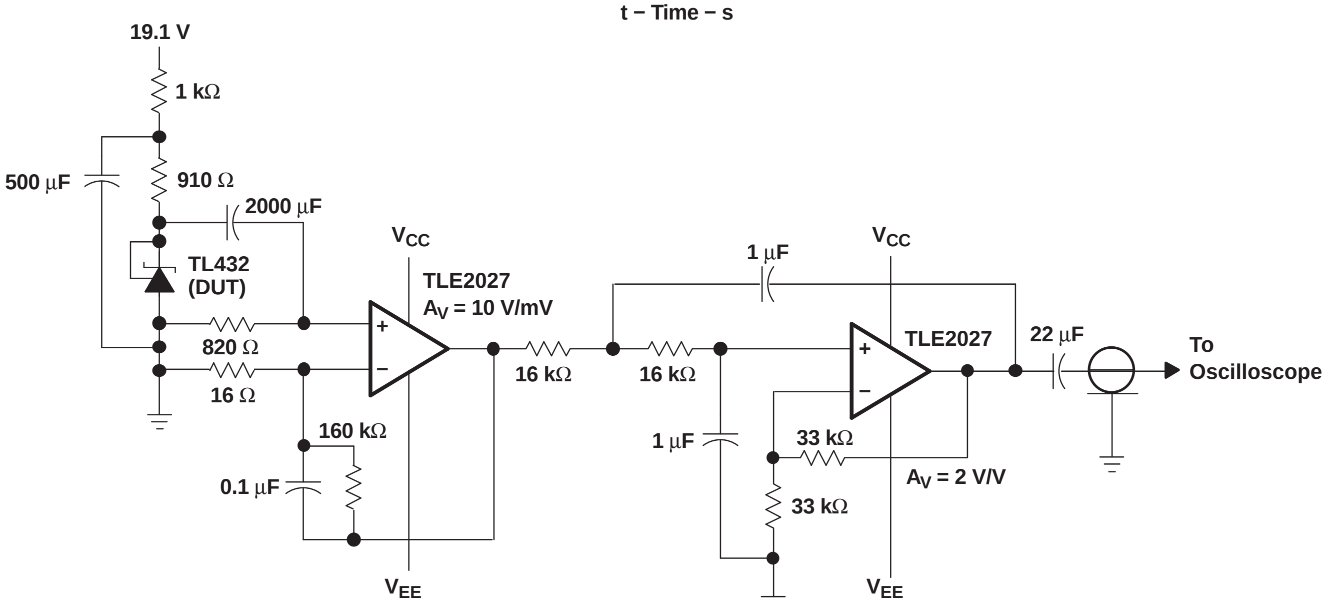
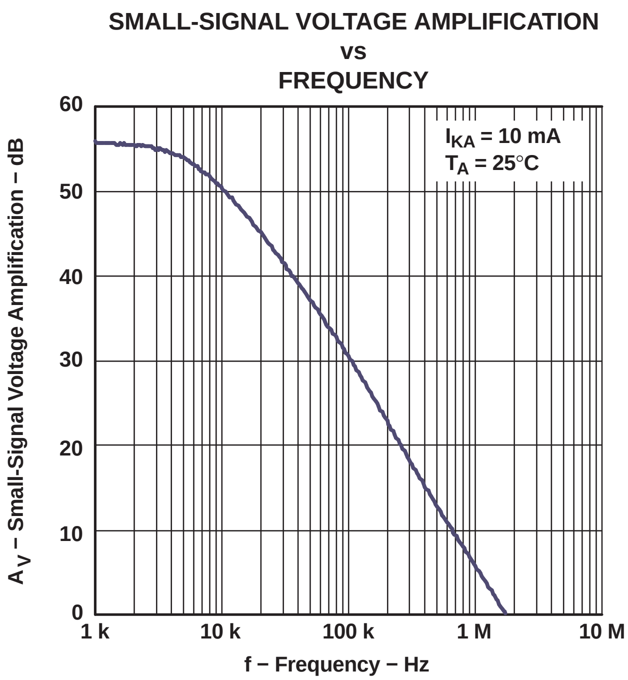
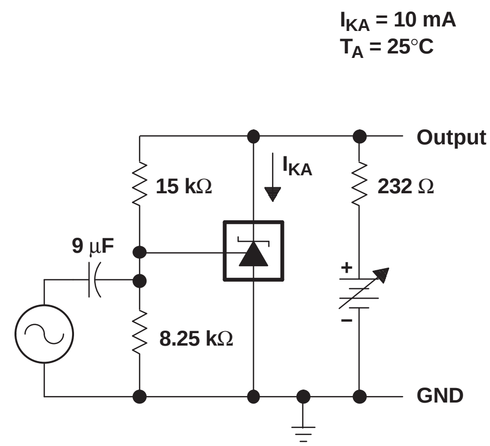


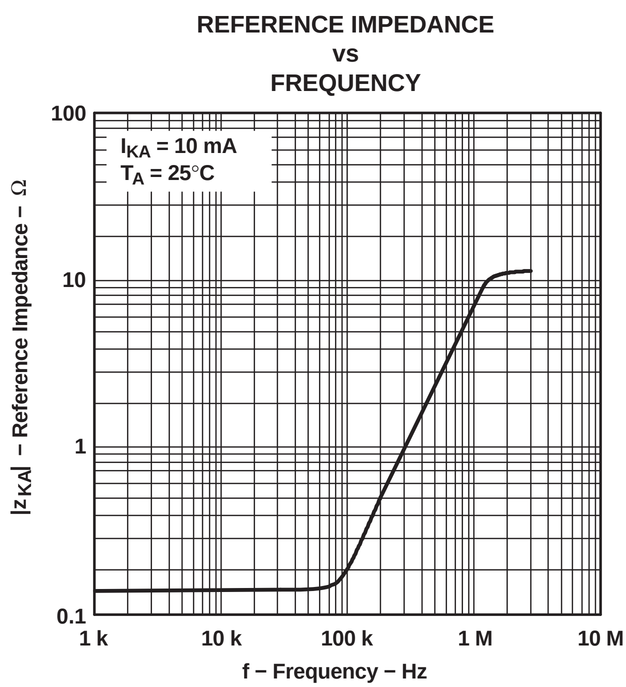
Figure 12. Test Circuit for Equivalent Input Noise Voltage

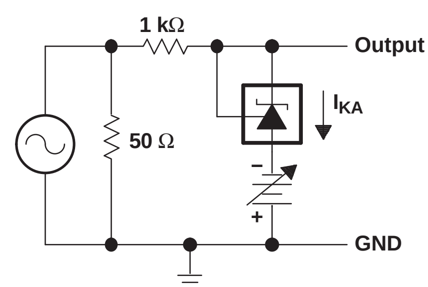




TEST CIRCUIT FOR VOLTAGE AMPLIFICATION

Figure 13.

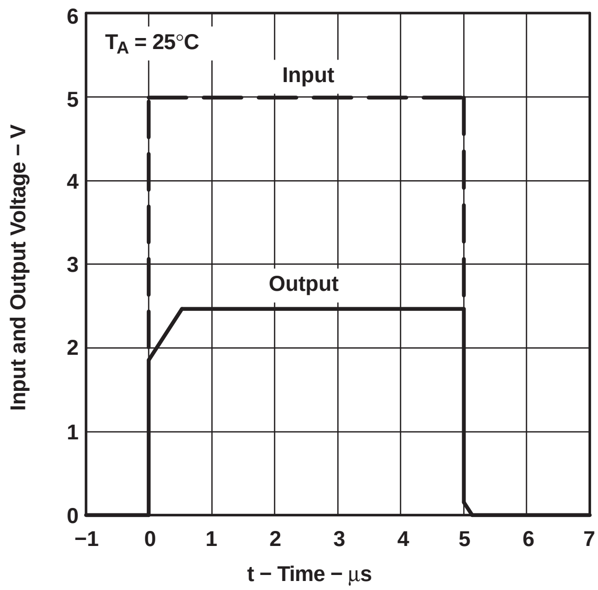


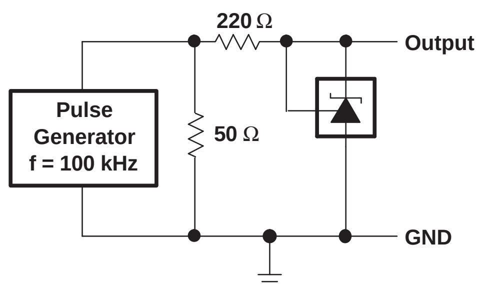


TEST CIRCUIT FOR REFERENCE IMPEDANCE

Figure 14.

PULSE RESPONSE

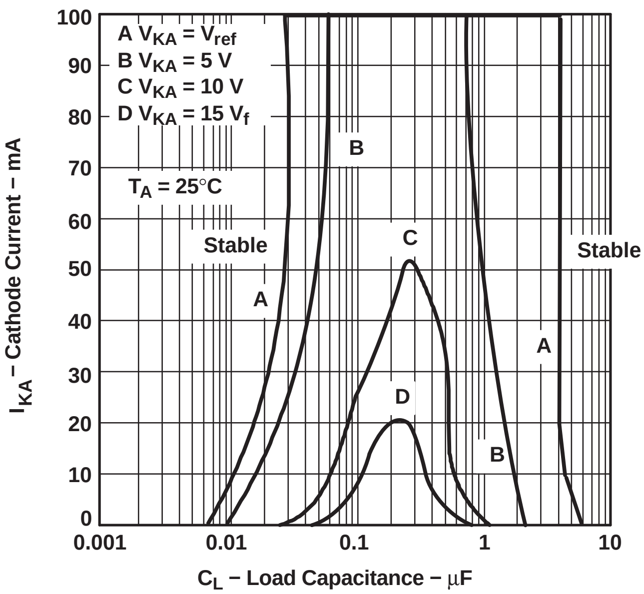


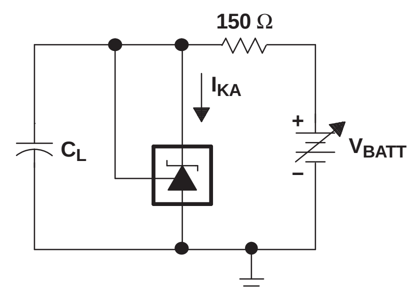


TEST CIRCUIT FOR PULSE RESPONSE

Figure 15.

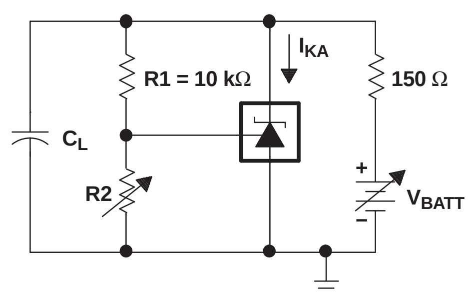
STABILITY BOUNDARY CONDITIONS†





TEST CIRCUIT FOR CURVE A

† 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.



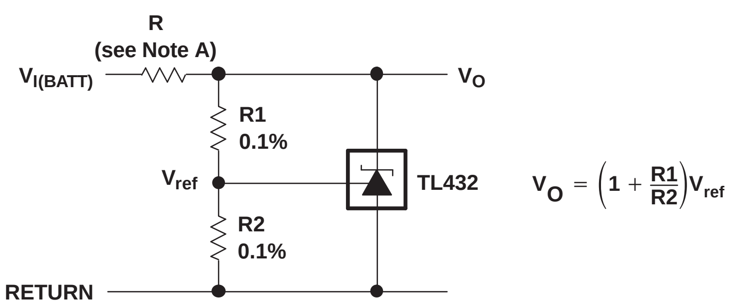
TEST CIRCUIT FOR CURVES B, C, AND D

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

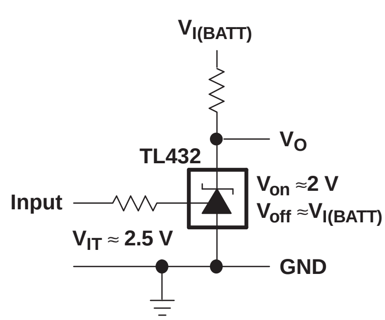
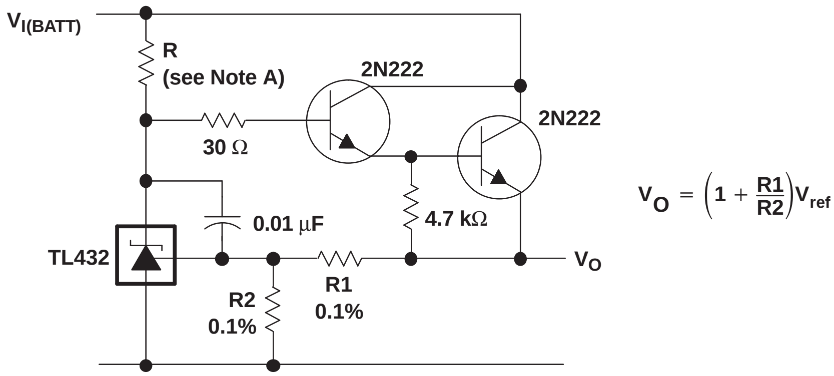


Figure 18. Single-Supply Comparator With Temperature-Compensated Threshold



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

Figure 19. Precision High-Current Series Regulator

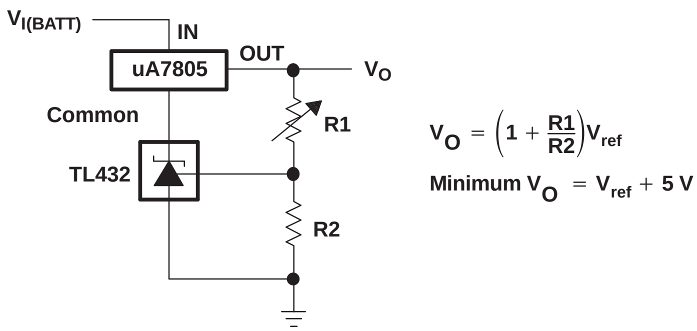


Figure 20. Output Control of a Three-Terminal Fixed Regulator

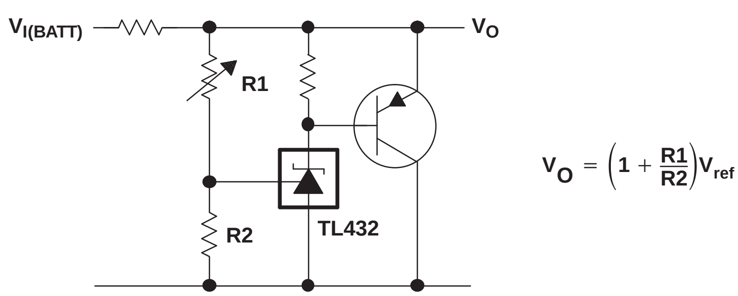
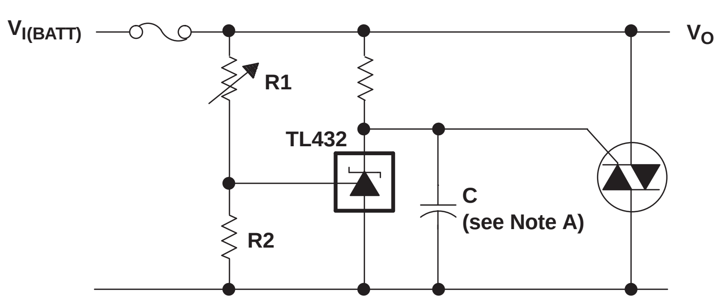


Figure 21. High-Current Shunt Regulator



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

Figure 22. Crowbar Circuit

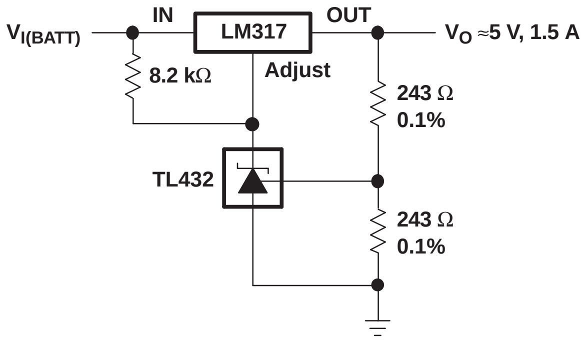
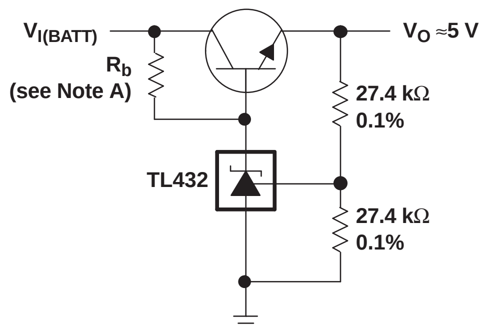


Figure 23. Precision 5-V 1.5-A Regulator



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

Figure 24. Efficient 5-V Precision Regulator

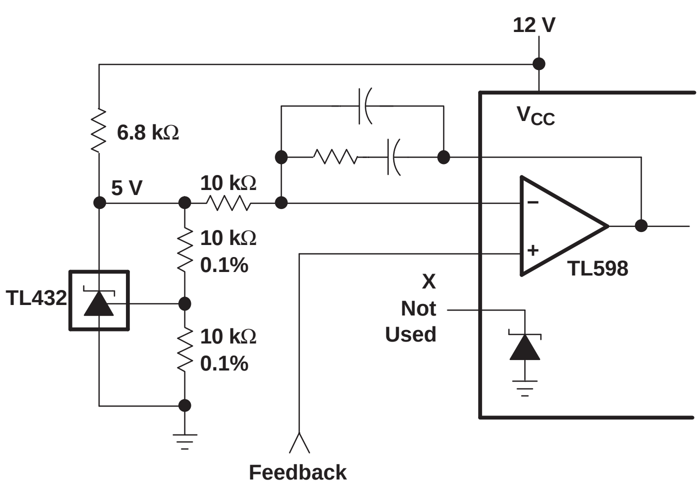
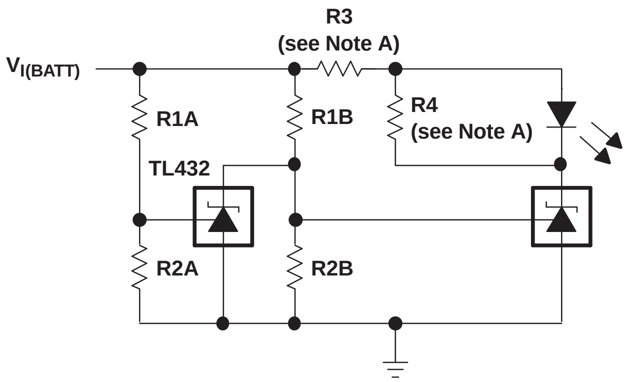


Figure 25. PWM Converter With Reference



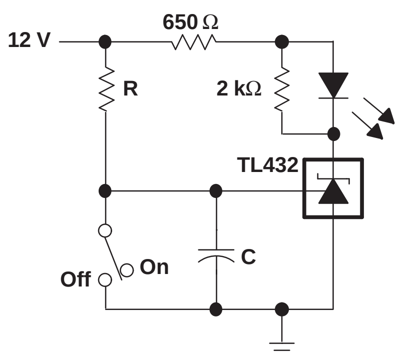
$$\text{Low Limit} = \left(1 + \frac{R1B}{R2B}\right)V_{ref}$$

$$\text{High Limit} = \left(1 + \frac{R1A}{R2A}\right)V_{ref}$$

LED on When Low Limit < $V_{I(BATT)}$ < High Limit

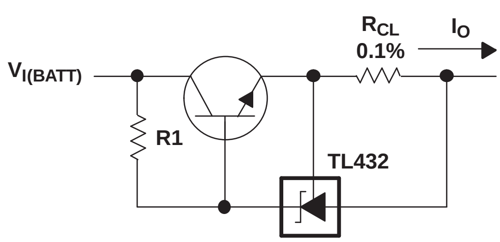
A. R3 and R4 are selected to provide the desired LED intensity and cathode current ≥1 mA to the TL432 at the available $V_{I(BATT)}$.

Figure 26. Voltage Monitor



$$\text{Delay} = R \times C \times l_n\left(\frac{12\ V}{12\ V - V_{ref}}\right)$$

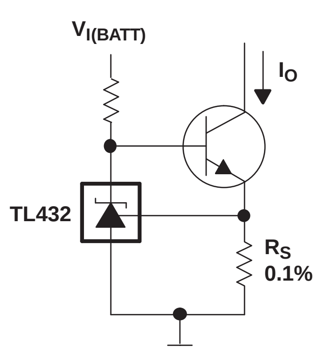
Figure 27. Delay Timer



$$I_{out} = \frac{V_{ref}}{R_{CL}} + I_{KA}$$

$$R1 = \frac{V_{I(BATT)}}{\frac{I_O}{h_{FE}} + I_{KA}}$$

Figure 28. Precision Current Limiter



$$I_O = \frac{V_{ref}}{R_S}$$

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.

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.

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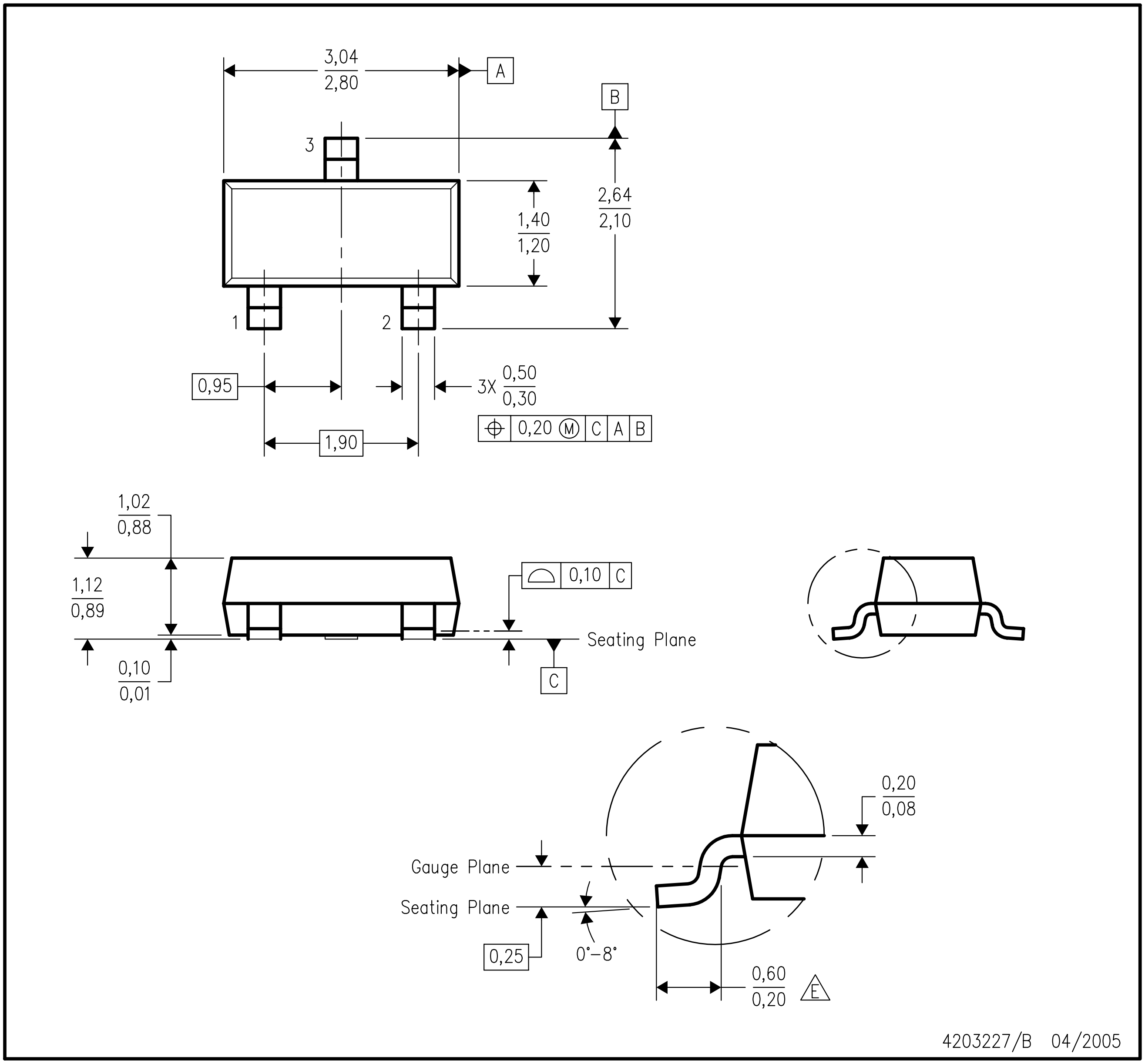
OTHER QUALIFIED VERSIONS OF TL432A-Q1, TL432B-Q1 :

- 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.