ATL431LI-Q1/ATL432LI-Q1 高帯域幅、低 I_Q のプログラム可能なシャント・レギュレータ

1 特長

- 車載アプリケーション用に認定済み
- 下記内容で AEC-Q100 認定済み
  - デバイス温度グレード 1:動作時周囲温度 -40°C～+125°C
- 25℃での基準電圧の許容公差
  - 0.5% (B グレード)
  - 1% (A グレード)
- 出力電圧の最小値：2.5V (標準値)
- 可変出力電圧：V_{ref}～36V
- -40℃～+125℃で動作
- 最大温度ドリフト：27mV
- 出力インピーダンス：0.3Ω (標準値)
- シンク電流能力
  - I_{min} = 0.08mA (最大値)
  - I_{KA} = 15mA (最大値)
- 基準入力電流 I_{REF}：0.4μA (最大値)
- 全温度範囲にわたる基準入力電流の偏差、$I_{I(dev)}$：0.3μA (最大値)

2 アプリケーション

- インバータおよびモータ制御
- DC/DC コンバータ
- LED ライティング
- オンボード充電器 (OBC)
- インフォテインメント / クラスタ

3 概要

ATL43xLI-Q1 は 3 端子の可変シャント・レギュレータで、該当する車載、商業、軍事用の温度範囲全体にわたって熱的な安定性が規定されています。出力電圧は、2 つの外付け抵抗を使用して、V_{ref} (約 2.5V) から 36V までの範囲で任意の値に設定できます。このデバイスの出力インピーダンスは 0.3Ω (標準値) です。このデバイスは、アクティブ出力回路による非常に鋭い起動特性を備えているため、オンボード・レギュレーション、可変電源、スイッチング電源などの多くの用途でツェナー・ダイオードの優れた代替品となります。このデバイスは TL431LI-Q1 および TL432LI-Q1 とピン互換の代替品であり、最小動作電流が小さいため、システムの消費電力削減に役立ちます。ATL432LI-Q1 の機能と電気的仕様は ATL431LI-Q1 と完全に同じですが、DBZ パッケージのピン配置が異なります。

ATL431LI-Q1 は、初期公差 (25℃ 時) が 0.5% の B グレードと、1% の A グレードの 2 つのグレードで供給されます。ATL43xLI-Q1 は -40℃～+125℃ で動作が規定されており、温度に対する出力ドリフトが小さいため、温度範囲全体にわたって優れた安定性が得られます。

製品情報(1)

型番	パッケージ(ピン)	本体サイズ(公称)
ATL43xLI	SOT-23 (3)	2.90mm×1.30mm

(1) 提供されているすべてのパッケージについては、巻末の注文情報を参照してください。

概略回路図

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4 改訂履歴

資料番号末尾の英字は改訂を表しています。その改訂履歴は英語版に準じています。

2019年5月発行のものから更新 **Page**

- デバイスのステータスを「事前情報」から「量産データ」に変更 ... 1

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5 Device Comparison Table

DEVICE PINOUT	INITIAL ACCURACY	OPERATING FREE-AIR TEMPERATURE (T_A)
ATL431LI-Q1 ATL432LI-Q1	A: 1% B: 0.5%	Q: -40°C to 125°C

6 Pin Configuration and Functions

ATL431LI-Q1 DBZ Package
3-Pin SOT-23
Top View

ATL432LI-Q1 DBZ Package
3-Pin SOT-23
Top View

Pin Functions

NAME	PIN		TYPE	DESCRIPTION
	ATL431LI-Q1	ATL432LI-Q1		
	DBZ	DBZ		
ANODE	3	3	O	Common pin, normally connected to ground
CATHODE	1	2	I/O	Shunt Current/Voltage input
REF	2	1	I	Threshold relative to common anode

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7 Specifications

7.1 Absolute Maximum Ratings

over operating free-air temperature range (unless otherwise noted)[1]

		MIN	MAX	UNIT
V_{KA}	Cathode Voltage[2]		37	V
I_{KA}	Continuos Cathode Current Range	–10	18	mA
$I_{I(ref)}$	Reference Input Current	–5	10	mA
T_J	Operating Junction Temperature Range	–40	150	C
T_{stg}	Storage Temperature Range	–65	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) All voltage values are with respect to ANODE, unless otherwise noted.

7.2 ESD Ratings

			VALUE	UNIT
$V_{(ESD)}$	Electrostatic discharge	Human body model (HBM), per AEC Q100-002[1]	±4000	V
		Charged-device model (CDM), per AEC Q100-011	±1000	

(1) AEC Q100-002 indicates that HBM stressing shall be in accordance with the ANSI/ESDA/JEDEC JS-001 specification

7.3 Recommended Operating Conditions

			MIN	MAX	UNIT
V_{KA}	Cathode Voltage		V_{REF}	36	V
I_{KA}	Continuous Cathode Current Range		0.08	15	mA
T_A	Operating Free-Air Temperature[1]	ATL43xLIxQ	–40	125	C

(1) Maximum power dissipation is a function of $T_{J(max)}$, θ_{JA}, and T_A. The maximum allowable power dissipation at any allowable ambient temperature is $P_D = (T_{J(max)} – T_A)/\theta_{JA}$. Operating at the absolute maximum T_J can affect reliability. See the *Semiconductor and IC Package Thermal Metrics Application Report* for more information.

7.4 Thermal Information

THERMAL METRIC[1]		ATL43xLI DBZ 3 PINS	UNIT
$R_{\theta JA}$	Junction-to-ambient thermal resistance	371.7	C/W
$R_{\theta JC(top)}$	Junction-to-case (top) thermal resistance	145.9	C/W
$R_{\theta JB}$	Junction-to-board thermal resistance	104.7	C/W
ψ_{JT}	Junction-to-top characterization parameter	23.9	C/W
ψ_{JB}	Juction-to-board characterization parameter	102.9	C/W

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

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7.5 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	See 図 17	$V_{KA} = V_{ref}$, I_{KA} = 1 mA	ATL43xLIAx devices	2475	2500	2525	mV
				ATL43xLIBx devices	2487	2500	2512	mV
$V_{I(dev)}$	Deviation of reference input voltage over full temperature range (1)	See 図 17	$V_{KA} = V_{ref}$, I_{KA} = 1 mA	ATL43xLIxQ devices		10	27	mV
ΔV_{ref} / ΔV_{KA}	Ratio of change in reference voltage to the change in cathode voltage	See 図 18	I_{KA} = 1 mA	ΔV_{KA} = 10 V - V_{ref}		–1.4	–2.7	mV/V
				ΔV_{KA} = 36 V - 10 V		–1	–2	mV/V
I_{ref}	Reference Input Current	See 図 18	I_{KA} = 1 mA, R1 = 10kΩ, R2 = ∞			0.2	0.4	µA
$I_{I(dev)}$	Deviation of reference input current over full temperature range (1)	See 図 18	I_{KA} = 1 mA, R1 = 10kΩ, R2 = ∞			0.1	0.3	µA
I_{min}	Minimum cathode current for regulation	See 図 17	$V_{KA} = V_{ref}$			65	80	µA
I_{off}	Off-state cathode current	See 図 19	V_{KA} = 36 V, V_{ref} = 0			0.1	1	µA
$\lvert Z_{KA} \rvert$	Dynamic Impedance (2)	See 図 17	$V_{KA} = V_{ref}$, I_{KA} = 1 mA to 15 mA			0.65	0.75	Ω

(1) The deviation parameters $V_{I(dev)}$ and $I_{I(dev)}$ are defined as the differences between the maximum and minimum values obtained over the rated temperature range. For more details on $V_{I(dev)}$ and how it relates to the average temperature coefficient, see the *Temperature Coefficient* section.

(2) The dynamic impedance is defined by $|Z_{KA}| = \Delta V_{KA}/\Delta I_{KA}$. For more details on $|Z_{KA}|$ and how it relates to V_{out}, see the *Temperature Coefficient* section.

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7.6 Typical Characteristics

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

図 1. Reference Voltage versus Free-Air Temperature

図 2. Reference Current versus Free-Air Temperature

図 3. Cathode Current versus Cathode Voltage

図 4. Cathode Current versus Cathode Voltage

図 5. Off-State Cathode Current versus Free-Air Temperature

図 6. Ratio of Delta Reference Voltage to Delta Cathode Voltage versus Free-Air Temperature

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Typical Characteristics (continued)

図 7. Small-Signal Voltage Amplification versus Frequency

図 8. Test Circuit for Voltage Amplification

図 9. Reference Impedance versus Frequency

図 10. Test Circuit for Reference Impedance

図 11. Pulse Response

図 12. Test Circuit for Pulse Response

Typical Characteristics (continued)

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

図 13. Stability Boundary Conditions for All ATL431LI-Q1, ATL432LI-Q1 Devices Above 1 mA

図 14. Test Circuit for Stability Boundary Conditions

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

図 15. Stability Boundary Conditions for All ATL431LI-Q1, ATL432LI-Q1 Devices Below 1 mA

図 16. Test Circuit for Stability Boundary Conditions

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8 Parameter Measurement Information

図 17. Test Circuit for $V_{KA} = V_{ref}$

図 18. Test Circuit for $V_{KA} > V_{ref}$

図 19. Test Circuit for I_{off}

8.1 Temperature Coefficient

The deviation of the reference voltage, V_{ref}, over the full temperature range is known as $V_{I(dev)}$. The parameter of $V_{I(dev)}$ can be used to find the temperature coefficient of the device. The average full-range temperature coefficient of the reference input voltage, α_{Vref}, is defined as:

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

where:
ΔT_A is the rated operating temperature range of the device.

α_{Vref} is positive or negative, depending on whether minimum V_{ref} or maximum V_{ref}, respectively, occurs at the lower temperature. The full-range temperature coefficient is an average and, therefore, any subsection of the rated operating temperature range can yield a value that is greater or less than the average. For more details on temperature coefficient, refer to the *Voltage Reference Selection Basics White Paper*.

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8.2 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 図 18), the total dynamic impedance of the circuit is given by: $|z'| = \frac{\Delta V}{\Delta I}$, which is approximately equal to $|Z_{KA}|\left(1 + \frac{R1}{R2}\right)$.

The V_{KA} of the ATL431LI-Q1 can be affected by the dynamic impedance. The ATL431LI-Q1 test current I_{test} for V_{KA} is specified in the *Electrical Characteristics*. Any deviation from I_{test} can cause deviation on the output V_{KA}. 図 20 shows the effect of the dynamic impedance on the V_{KA}.

図 20. Dynamic Impedance

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9 Detailed Description

9.1 Overview

This standard device has proven ubiquity and versatility across a wide range of applications, ranging from power to signal path. This is due to its key components containing an accurate voltage reference and op amp, which are very fundamental analog building blocks. The ATL431LI-Q1 is used in conjunction with the key components to behave as the following:

- Single voltage reference
- Error amplifier
- Voltage clamp
- Comparator with integrated reference

ATL431LI-Q1 can be operated and adjusted to cathode voltages from 2.5 V to 36 V, making this part optimal for a wide range of end equipments in industrial, auto, telecom, and computing. For this device to behave as a shunt regulator or error amplifier, >80 µA (I_{min}(maximum)) must be supplied in to the cathode pin. Under this condition, feedback can be applied from the Cathode and Ref pins to create a replica of the internal reference voltage.

Various reference voltage options can be purchased with initial tolerances (at 25°C) of 0.5% and 1%. These reference options are denoted by B (0.5%) and A (1.0%) after the ATL431LI-Q1 or ATL432LI-Q1. ATL431LI-Q1 and ATL432LI-Q1 are both functionally the same, but have different pinout options. The ATL43xLI-Q1 devices are characterized for operation from –40°C to +125°C.

9.2 Functional Block Diagram

図 21. Equivalent Schematic

Functional Block Diagram (continued)

図 22. Detailed Schematic

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9.3 Feature Description

The ATL431LI-Q1 consists of an internal reference and amplifier that outputs a sink current based on the difference between the reference pin and the virtual internal pin. The sink current is produced by the internal Darlington pair, shown in 図 21. A Darlington pair is used for this device to be able to sink a maximum current of 15 mA.

When operated with enough voltage headroom (≥ 2.5 V) and cathode current (I_{KA}), the ATL431LI-Q1 forces the reference pin to 2.5 V. However, the reference pin cannot be left floating, as it needs I_{REF} ≥ 0.4 µA (see the *Specifications*). This is because the reference pin is driven into an NPN, which needs base current to operate properly.

When feedback is applied from the Cathode and Reference pins, the ATL431LI-Q1 behaves as a Zener diode, regulating to a constant voltage dependent on current being supplied into the cathode. This is due to the internal amplifier and reference entering the proper operating regions. The same amount of current needed in the above feedback situation must be applied to this device in open loop, servo, or error amplifying implementations for it to be in the proper linear region giving ATL431LI-Q1 enough gain.

Unlike many linear regulators, ATL431LI-Q1 is internally compensated to be stable without an output capacitor between the cathode and anode. However, if it is desired to use an output capacitor 図 13 can be used as a guide to assist in choosing the correct capacitor to maintain stability.

9.4 Device Functional Modes

9.4.1 Open Loop (Comparator)

When the cathode/output voltage or current of ATL431LI-Q1 is not being fed back to the reference/input pin in any form, this device is operating in open loop. With proper cathode current (Ika) applied to this device, the ATL431LI-Q1 has the characteristics shown in 図 21. With such high gain in this configuration, the ATL431LI-Q1 is typically used as a comparator. With the reference integrated makes ATL431LI-Q1 the preferred choice when users are trying to monitor a certain level of a single signal.

9.4.2 Closed Loop

When the cathode/output voltage or current of the ATL431LI-Q1 is being fed back to the reference/input pin in any form, this device is operating in closed loop. The majority of applications involving ATL431LI-Q1 use it in this manner to regulate a fixed voltage or current. The feedback enables this device to behave as an error amplifier, computing a portion of the output voltage and adjusting it to maintain the desired regulation. This is done by relating the output voltage back to the reference pin in a manner to make it equal to the internal reference voltage, which can be accomplished via resistive or direct feedback.

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10 Applications and Implementation

注

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.

10.1 Application Information

As this device has many applications and setups, there are many situations that this data sheet cannot characterize in detail. The linked application note will help the designer make the best choices when using this part.

Setting the Shunt Voltage on an Adjustable Shunt Regulator Application Note assists with setting the shunt voltage to achieve optimum accuracy for this device.

10.2 Typical Applications

10.2.1 Comparator With Integrated Reference

図 23. Comparator Application Schematic

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Typical Applications (continued)

10.2.2 Design Requirements

For this design example, use the parameters listed in 表 1 as the input parameters.

表 1. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
Input Voltage Range	0 V to 5 V
Input Resistance	10 kΩ
Supply Voltage	24 V
Cathode Current (Ik)	5 mA
Output Voltage Level	~2 V – V_{SUP}
Logic Input Thresholds VIH/VIL	V_L

10.2.3 Detailed Design Procedure

When using the ATL431LI-Q1 as a comparator with reference, determine the following:

- Input voltage range
- Reference voltage accuracy
- Output logic input high and low level thresholds
- Current source resistance

10.2.3.1 Basic Operation

In the configuration shown in 図 23, the ATL431LI-Q1 behaves as a comparator, comparing the V_{REF} pin voltage to the internal virtual reference voltage. When provided a proper cathode current (I_K), ATL431LI-Q1 has enough open-loop gain to provide a quick response. This can be seen in 図 24 where the R_{SUP} = 10 kΩ (I_{KA} = 500 µA) situation responds much slower than R_{SUP} = 1 kΩ (I_{KA} = 5 mA). With the ATL431LI-Q1 max operating current (I_{MIN}) being 1 mA, operation below that can result in low gain, leading to a slow response.

10.2.3.1.1 Overdrive

Slow or inaccurate responses can also occur when the reference pin is not provided enough overdrive voltage. This is the amount of voltage that is higher than the internal virtual reference. The internal virtual reference voltage is within the range of 2.5 V ±(0.5% or 1.0%) depending on which version is being used. The more overdrive voltage provided, the faster the ATL431LI-Q1 will respond.

For applications where ATL431LI-Q1 is being used as a comparator, it is best to set the trip point to greater than the positive expected error (that is +1.0% for the A version). For fast response, setting the trip point to >10% of the internal V_{REF} suffices.

For minimal voltage drop or difference from Vin to the ref pin, TI recommends to use an input resistor <10 kΩ to provide Iref.

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10.2.3.2 Output Voltage and Logic Input Level

For ATL431LI-Q1 to properly be used as a comparator, the logic output must be readable by the receiving logic device. This is accomplished by knowing the input high and low level threshold voltage levels, typically denoted by V_{IH} and V_{IL}.

As seen in 図 24, the output low level voltage of the ATL431LI-Q1 in open-loop/comparator mode is approximately 2 V, which is typically sufficient for 5 V supplied logic. However, this does not work for 3.3 V and 1.8 V supplied logic. To accommodate this, a resistive divider can be tied to the output to attenuate the output voltage to a voltage legible to the receiving low voltage logic device.

The output high voltage of the ATL431 is equal to V_{SUP} due to ATL431LI-Q1 being open-collector. If V_{SUP} is much higher than the maximum input voltage tolerance of the receiving logic, the output must be attenuated to accommodate the reliability of the outgoing logic.

When using a resistive divider on the output, make sure the sum of the resistive divider (R1 and R2 in 図 23) is much greater than R_{SUP} to not interfere with the ability of the ATL431LI-Q1 to pull close to V_{SUP} when turning off.

10.2.3.2.1 Input Resistance

The ATL431LI-Q1 requires an input resistance in this application to source the reference current (I_{REF}) needed from this device to be in the proper operating regions while turning on. The actual voltage seen at the ref pin is $V_{REF} = V_{IN} - I_{REF} \times R_{IN}$ because I_{REF} can be as high as 4 µA. TI recommends to use a resistance small enough that mitigates the error that I_{REF} creates from V_{IN}.

10.2.4 Application Curves

図 24. Output Response With Various Cathode Currents

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10.2.5 Precision LED Lighting Current Sink Regulator

図 25. LED Lighting Current Sink Regulator

10.2.5.1 Design Requirements

For this design example, use the parameters listed in 表 1 as the input parameters.

表 2. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
Supply Voltage ($V_{I(BATT)}$)	5 V
Sink Current (I_O)	100 mA
Cathode Current (Ik)	5 mA

10.2.5.2 Detailed Design Procedure

When using the ATL43xLI-Q1 as a constant current sink, determine the following:

- Output current range
- Output current accuracy
- Power consumption for the ATL43xLI-Q1

10.2.5.2.1 Basic Operation

In the configuration shown, the ATL43xLI-Q1 acts as a control component within a feedback loop of the constant current sink. Working with an external passing component such as a BJT, the ATL43xLI-Q1 provides precision current sink with accuracy set by itself and the sense resistor R_S. The LEDs are lit based on the desired current sink and regulated for accurate brightness and color.

10.2.5.2.1.1 Output Current Range and Accuracy

The output current range of the circuit is determined by the equation shown in the configuration. Keep in mind that the V_{REF} equals to 2.500 V. When choosing the sense resistor R_S, it needs to generate 2.500 V for the TL43xLI-Q1 when I_O reaches the target current. If the overhead voltage of 2.500 V is not acceptable, consider lower voltage reference devices such as the TLV43x-Q1 or TLVH43x-Q1.

The output current accuracy is determined by both the accuracy of the ATL43xLI-Q1 chosen, as well as the accuracy of the sense resistor R_S. The internal virtual reference voltage of ATL43xLI-Q1 is within the range of 2.500 V ±(0.5% or 1.0%), depending on which version is being used. Another consideration for the output current accuracy is the temperature coefficient of the ATL43xLI-Q1 and R_S. Refer to the for the specification of these parameters.

10.2.5.2.2 Power Consumption

For the ATL43xLI-Q1 to properly be used as a control component in this circuit, the minimum operating current needs to be reached. This is accomplished by setting the external biasing resistor in series with the ATL43xLI-Q1.

To achieve lower power consumption, the ATL43xLI-Q1 is used due to its 65 µA typical minimum cathode current, I_{min}.

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10.2.6 Shunt Regulator/Reference

図 26. Shunt Regulator Schematic

10.2.6.1 Design Requirements

For this design example, use the parameters listed in 表 1 as the input parameters.

表 3. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
Reference Initial Accuracy	1.0%
Supply Voltage	24 V
Cathode Current (Ik)	5 mA
Output Voltage Level	2.5 V–36 V
Load Capacitance	2 µF
Feedback Resistor Values and Accuracy (R1 and R2)	10 kΩ

10.2.6.2 Detailed Design Procedure

When using ATL431LI-Q1 as a shunt regulator, determine the following:

- Input voltage range
- Temperature range
- Total accuracy
- Cathode current
- Reference initial accuracy
- Output capacitance

10.2.6.2.1 Programming Output/Cathode Voltage

To program the cathode voltage to a regulated voltage, a resistive bridge must be shunted between the cathode and anode pins with the mid point tied to the reference pin. This can be seen in 図 26 with R1 and R2 being the resistive bridge. The cathode/output voltage in the shunt regulator configuration can be approximated by the equation shown in 図 26. The cathode voltage can be more accuratel, which can be determined by taking in to account the cathode current:

$$Vo = (1+R1/R2) \times V_{REF} - I_{REF} \times R1 \quad (1)$$

For this equation to be valid, the ATL431LI-Q1 must be fully biased so that it has enough open loop gain to mitigate any gain error. This can be done by meeting the Imin spec denoted in the *Specifications*.

10.2.6.2.2 Total Accuracy

When programming the output above unity gain (V_{KA} = V_{REF}), the ATL431LI-Q1 is susceptible to other errors that can effect the overall accuracy beyond V_{REF}. These errors include:

- R1 and R2 accuracies
- $V_{I(dev)}$: Change in reference voltage over temperature
- ΔV_{REF} / ΔV_{KA}: Change in reference voltage to the change in cathode voltage
- $|z_{KA}|$: Dynamic impedance, causing a change in cathode voltage with cathode current

Worst case cathode voltage can be determined taking all of the variables in to account. The *Setting the Shunt Voltage on an Adjustable Shunt Regulator Application Note* assists designers in setting the shunt voltage to achieve optimum accuracy for this device.

10.2.6.2.3 Stability

Though ATL431LI-Q1 is stable with no capacitive load, the device that receives the output voltage of the shunt regulator can present a capacitive load that is within the ATL431LI-Q1 region of stability, shown in 図 13. Also, designers can use capacitive loads to improve the transient response or for power supply decoupling. When using additional capacitance between Cathode and Anode, see 図 13. Also, *Understanding Stability Boundary Conditions Charts in TL431, TL432 Data Sheet Application Note* provides a deeper understanding of the stability characteristics of this device and aids the user in making the right choices when choosing a load capacitor.

10.2.6.2.4 Start-Up Time

As shown in 図 27, the ATL431LI-Q1 has a fast response up to approximately 2 V and then slowly charges to its programmed value. This is due to the compensation capacitance (shown in 図 13) the ATL43xLI-Q1 has to meet its stability criteria. Despite the secondary delay, ATL43xLI-Q1 still has a fast response suitable for many clamp applications.

10.2.6.3 Application Curves

図 27. ATL43xLI-Q1 Start-Up Response

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10.2.7 Isolated Flyback with Optocoupler

図 28. Isolated Flyback with Optocoupler

10.2.7.1 Design Requirements

The ATL431LI-Q1 is used in the feedback network on the secondary side for a isolated flyback with optocoupler design. 図 28 shows the simplified flyback converter that used the ATL431LI-Q1. For this design example, use the parameters in 表 4 as the input parameters.

表 4. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
Voltage Output	20 V
Feedback Network Quiescent Current (I_q)	<40 mW

10.2.7.1.1 Detailed Design Procedure

In this example, a simplified design procedure will be discussed. The compensation network for the feedback network is beyond the scope of this section. Details on compensation network can be found in *Compensation Design with TL431 for UCC28600 Application Report*.

The goal of this design is to design a low standby current feedback network to meet the Europe CoC Tier 2 and United States DoE Level VI requirements. To meet the design requirements, the system standby power needs to be below 75 mW. To meet this, the feedback network needs to consume less than 40 mW to allow margin for the power losses on the primary side controller and passive components. This can pose a challenge in systems greater than 10 V.

図 29. Feedback Quiescent Current

10.2.7.1.1.1 ATL431LI-Q1 Biasing

図 29 shows the simplified version of the feedback network. The standby I_q of the system is dependent on two paths: the ATL431LI-Q1 biasing path and the resistor feedback path. With the given design requirements, the total current through the feedback network cannot exceed 2 mA.

The design goal is to take full advantage of the I_{min} to set the I_{KA} of the ATL431LI-Q1. The benefit of the ATL431LI-Q1 is its low I_{min} of 80 µA which allows the I_{KA} to be lower at a full load condition compared to typical TL431LI-Q1 devices. This helps lower the I_{KA} at the no-load condition which is higher than the full load condition due to the dynamic changes in the I_{KA} as the system load varies. The I_{KA} at no-load, I_{OPTNL}, is dependent the value of Rs which is the biasing resistor. Rs is very application-specific and is dependent on variables such as the CTR of the optocoupler, voltage, and current at no-load. This can be seen in 式 2. It is possible to lower I_{OPTNL} to a value of 1.5 mA for a power loss of 30 mW by using an optocoupler with a high CTR.

$$Rs \approx (V_{OUT} - V_{OPTNL} - 2\,V) / I_{OPTNL}$$
$$V_{OPTNL} = \text{Optocoupler Voltage at No-Load Conditions}$$
$$I_{OPTNL} = \text{Optocoupler Current at No-Load Conditions} \quad (2)$$

10.2.7.1.1.2 Resistor Feedback Network

The feedback resistors set the output voltage of the secondary side and consume the same I_q at a fixed voltage. The design goal for the feedback resistor path is to minimize the resistor error while maintaining a low I_q. For this system example, the feedback network path in this design consumes 0.5 mA to allow enough current for ATL431LI-Q1 biasing. The resistors, R1 and R2, are sized based on a 0.5 mA budget for I_q and I_{ref}. By using the resistor values from 式 3 and 式 4, the total power consumption is 10 mW. This can be further decreased by using larger resistors.

$$R_1 = (V_{OUT} - V_{REF}) / I_{FB}$$
$$R_1 = (20\,V - 2.5\,V) / 0.5\,mA$$
$$R_1 = 35\,k\Omega \quad (3)$$
$$R_2 = V_{REF} / (I_{FB} - I_{REF})$$
$$R_2 = 2.5\,V / (0.5\,mA - 0.4\,\mu A)$$
$$R_2 = 5.004\,k\Omega \quad (4)$$

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10.2.8 Adjustable Reference for Tracking LDO

10.2.8.1 Design Requirements

The ATL431LI-Q1 is used as a reference voltage to help regulate a supply voltage off an LDO. By adjusting the cathode voltage, the output voltage of the LDO can vary. The TPS7B4250-Q1 is a voltage-tracking LDO with an adjustable pin which needs a precise reference voltage to change the regulate output voltage.

表 5. Design Parameters

DESIGN PARAMETER	EXAMPLE VALUE
Input Voltage	4 V to 40 V
ADJ Reference Voltage	2.500 V–18 V
Output Voltage	2.500 V–18 V
Output Current Rating	50 mA
Output Capacitor Range	1 µF to 50 µF
Output Capacitor ESR Range	1 mΩ to 20 Ω

10.2.8.2 Detailed Design Procedure

The goal of this design is to create a precision and stable output stage using an LDO that requires an external voltage reference such as the TPS7B4250-Q1. To begin the design process, the input and desired output voltage range is required. The ATL431LI-Q1 can be adjusted between 2.5 V and 36 V so it covers most of the output voltage rating of TPS7B42500-Q1. For reference voltage under 2.5 V, the TLV431-Q1 voltage reference can be used. The input and output capacitor must also be taken into consideration for decoupling and stability.

図 30. Feedback Quiescent Current

10.2.8.2.1 External Capacitors

An input capacitor, CI, is recommended to buffer line influences. Connect the capacitors close to the IC pins.

The output capacitor for the TPS7B4250-Q1 device is required for stability. Without the output capacitor, the regulator oscillates. The actual size and type of the output capacitor can vary based on the application load and temperature range. The effective series resistance (ESR) of the capacitor is also a factor in the IC stability. The worst case is determined at the minimum ambient temperature and maximum load expected. To ensure stability of TPS7B4250-Q1 device, the device requires an output capacitor between 1 µF and 50 µF with an ESR range between 0.001 Ω and 20 Ω that can cover most types of capacitor ESR variation under the recommend operating conditions. As a result, the output capacitor selection is flexible.

The capacitor must also be rated at all ambient temperature expected in the system. To maintain regulator stability down to –40°C, use a capacitor rated at that temperature.

10.3 System Examples

R should provide cathode current ≥ 80 µA to the ATL431LI-Q1 at minimum $V_{(BATT)}$.

図 31. Precision High-Current Series Regulator

図 32. Output Control of a Three-Terminal Fixed Regulator

図 33. High-Current Shunt Regulator

Refer to the stability boundary conditions in 図 13 to determine allowable values for C.

図 34. Crowbar Circuit

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System Examples (continued)

図 35. Precision 5-V, 1.5-A Regulator

R_b should provide cathode current ≥80 µA to the ATL431LI-Q1.

図 36. Efficient 5-V Low-Dropout (LDO) Regulator Configuration

図 37. PWM Converter With Reference

System Examples (continued)

Select R3 and R4 to provide the desired LED intensity and cathode current ≥80 µA to the ATL431LI-Q1 at the available $V_{I(BATT)}$.

図 38. Voltage Monitor

図 39. Delay Timer

図 40. Precision Current Limiter

図 41. Precision Constant-Current Sink

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11 Power Supply Recommendations

When using ATL43xLI-Q1 as a Linear Regulator to supply a load, designers typically uses a bypass capacitor on the output/cathode pin. When doing this, be sure that the capacitance is within the stability criteria shown in 図 13.

To not exceed the maximum cathode current, be sure that the supply voltage is current limited. Also, be sure to limit the current being driven into the Ref pin, so you do not exceed its absolute maximum rating.

For applications shunting high currents, pay attention to the cathode and anode trace lengths, adjusting the width of the traces to have the proper current density.

12 Layout

12.1 Layout Guidelines

Bypass capacitors must be placed as close to the part as possible. Current-carrying traces need to have widths appropriate for the amount of current they are carrying; in the case of the ATL43xLI-Q1, these currents are low.

12.2 Layout Example

図 42. DBZ Layout Example

13 デバイスおよびドキュメントのサポート

13.1 デバイス・サポート

13.1.1 デバイスの項目表記

TI は、ATL43xLI-Q1 ファミリのすべての組み合わせを区別するために、接尾辞と接頭辞を割り当てています。詳細および注文可能な組み合わせについては、「付録：パッケージ・オプション」を参照してください。

13.2 ドキュメントのサポート

13.2.1 関連資料

関連資料については、以下を参照してください。

テキサス・インスツルメンツ、*『Setting the Shunt Voltage on an Adjustable Shunt Regulator』(英語)*

13.3 関連リンク

次の表に、クイック・アクセス・リンクを示します。カテゴリには、技術資料、サポートおよびコミュニティ・リソース、ツールとソフトウェア、およびご注文へのクイック・アクセスが含まれます。

表 6. 関連リンク

製品	プロダクト・フォルダ	ご注文はこちら	技術資料	ツールとソフトウェア	サポートとコミュニティ
ATL431LI-Q1	ここをクリック	ここをクリック	ここをクリック	ここをクリック	ここをクリック
ATL432LI-Q1	ここをクリック	ここをクリック	ここをクリック	ここをクリック	ここをクリック

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13.5 サポート・リソース

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13.7 静電気放電に関する注意事項

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13.8 Glossary

SLYZ022 — *TI Glossary*.

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

14 メカニカル、パッケージ、および注文情報

以降のページには、メカニカル、パッケージ、および注文に関する情報が記載されています。この情報は、そのデバイスについて利用可能な最新のデータです。このデータは予告なく変更されることがあり、ドキュメントが改訂される場合もあります。本データシートのブラウザ版を使用されている場合は、画面左側の説明をご覧ください。

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)
ATL431LIAQDBZRQ1	Active	Production	SOT-23 (DBZ) | 3	3000 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	22XP
ATL431LIAQDBZRQ1.B	Active	Production	SOT-23 (DBZ) | 3	3000 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	22XP
ATL431LIBQDBZRQ1	Active	Production	SOT-23 (DBZ) | 3	3000 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	22ZP
ATL431LIBQDBZRQ1.B	Active	Production	SOT-23 (DBZ) | 3	3000 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	22ZP
ATL432LIAQDBZRQ1	Active	Production	SOT-23 (DBZ) | 3	3000 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	23AP
ATL432LIAQDBZRQ1.B	Active	Production	SOT-23 (DBZ) | 3	3000 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	23AP
ATL432LIBQDBZRQ1	Active	Production	SOT-23 (DBZ) | 3	3000 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	23BP
ATL432LIBQDBZRQ1.B	Active	Production	SOT-23 (DBZ) | 3	3000 | LARGE T&R	Yes	NIPDAU	Level-1-260C-UNLIM	-40 to 125	23BP

(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.

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OTHER QUALIFIED VERSIONS OF ATL431LI-Q1, ATL432LI-Q1 :

- Catalog : ATL431LI, ATL432LI

NOTE: Qualified Version Definitions:

- Catalog - TI's standard catalog product

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
ATL431LIAQDBZRQ1	SOT-23	DBZ	3	3000	178.0	9.0	3.15	2.77	1.22	4.0	8.0	Q3
ATL431LIBQDBZRQ1	SOT-23	DBZ	3	3000	178.0	9.0	3.15	2.77	1.22	4.0	8.0	Q3
ATL432LIAQDBZRQ1	SOT-23	DBZ	3	3000	178.0	9.0	3.15	2.77	1.22	4.0	8.0	Q3
ATL432LIBQDBZRQ1	SOT-23	DBZ	3	3000	178.0	9.0	3.15	2.77	1.22	4.0	8.0	Q3

TAPE AND REEL BOX DIMENSIONS

*All dimensions are nominal

Device	Package Type	Package Drawing	Pins	SPQ	Length (mm)	Width (mm)	Height (mm)
ATL431LIAQDBZRQ1	SOT-23	DBZ	3	3000	180.0	180.0	18.0
ATL431LIBQDBZRQ1	SOT-23	DBZ	3	3000	180.0	180.0	18.0
ATL432LIAQDBZRQ1	SOT-23	DBZ	3	3000	180.0	180.0	18.0
ATL432LIBQDBZRQ1	SOT-23	DBZ	3	3000	180.0	180.0	18.0

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NOTES:

1. All linear dimensions are in 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. Reference JEDEC registration TO-236, except minimum foot length.
4. Support pin may differ or may not be present.
5. Body dimensions do not include mold flash, protrusions, or gate burrs. Mold flash, protrusions, or gate burrs shall not exceed 0.25mm per side

LAND PATTERN EXAMPLE
SCALE:15X

SOLDER MASK DETAILS

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NOTES: (continued)

5. Publication IPC-7351 may have alternate designs.
6. Solder mask tolerances between and around signal pads can vary based on board fabrication site.

SOLDER PASTE EXAMPLE
BASED ON 0.125 THICK STENCIL
SCALE:15X

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NOTES: (continued)

7. Laser cutting apertures with trapezoidal walls and rounded corners may offer better paste release. IPC-7525 may have alternate design recommendations.
8. Board assembly site may have different recommendations for stencil design.

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