

2.5V ADJUSTABLE SHUNT REGULATOR

Description

The GM431 is a three terminal adjustable shunt regulator with thermal stability guaranteed over temperature. Output voltage can be adjusted to any value between 2.5V (V_{ref}) and 36V by using two external resistors. The GM431 has a typical dynamic output impedance of 0.2 Ω . Active output circuitry provides a very unique turn on characteristic, making the GM431 an excellent replacement for zener diodes in many applications such as onboard regulation and adjustable power supplies. The GM431 is an ideal voltage reference for 3.0 to 3.3V switching power supplies.

The GM431 shunt regulator is available with 3 voltage tolerances 0.5%, 1.0% and 2.0% over $T_A = 0^\circ\text{C}$ to $+70^\circ\text{C}$, and four package options (SOT-23, TO-92, SOT-89 and SOP-8). Whatever your application is, the GM431 offers the optimum combination of performance, reliability, and economy.

Features

- ◆ Sink Current Capability 1 mA to 100mA
- ◆ Low dynamic output impedance, 0.2 Ω typ.
- ◆ Low output noise
- ◆ 0.5%, 1% or 2% reference voltage tolerance
- ◆ Alternate for TL431, TL431, LM431 & AS431
- ◆ Temperature range 0°C to $+70^\circ\text{C}$
- ◆ Available in SOT-23, TO-92, SOT-89 and SOP-8 packages

Application

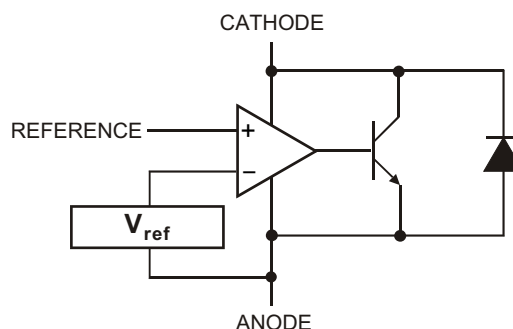
Switching power supplies
Linear regulators
Adjustable supplies

Battery-operated computers
Computer disk drives
Instrumentation

LOGIC SYMBOL

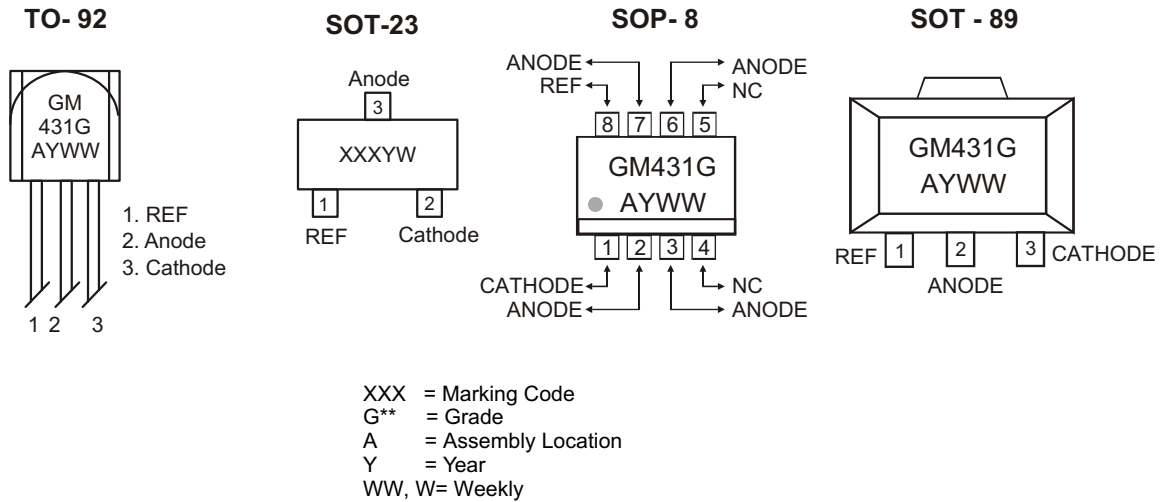


BLOCK DIAGRAM (POSITIVE LOGIC)



2.5V ADJUSTABLE SHUNT REGULATOR

◆ MARKING INFORMATION & PIN CONFIGURATIONS (TOP VIEW)



◆ ORDERING INFORMATION

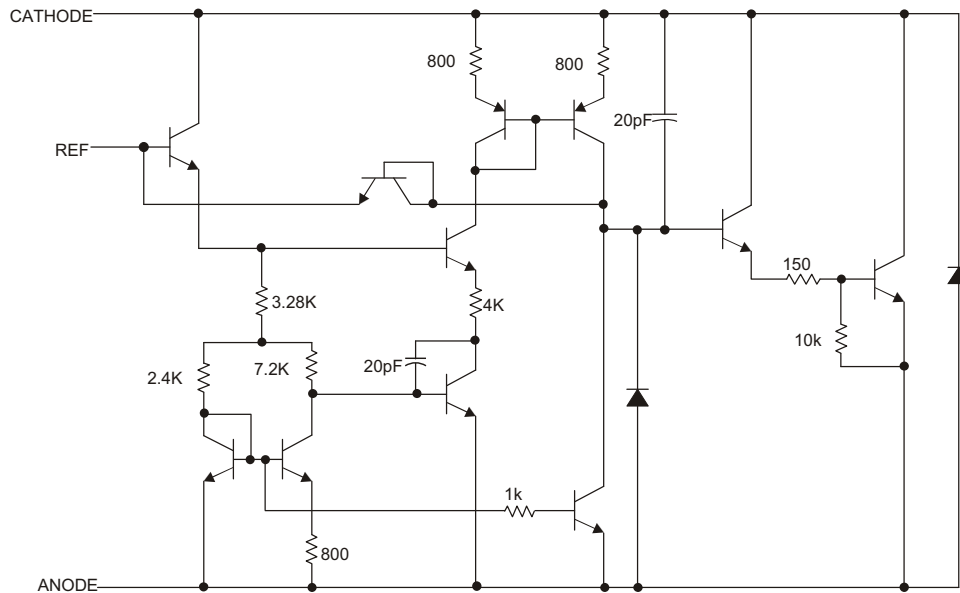
Ordering Number	Precision	Device code	Grade	Package	Shipping
GM431AT92B	0.5%		A	TO-92	1,000 Units/ ESD Bag
GM431AT92RL	0.5%		A	TO-92	2,000 Units/ Ammo Pack(Tape)
GM431AST23R	0.5%	AAA		SOT-23	3,000 Units/ Tape & Reel
GM431AS8T	0.5%		A	SOP-8	100 Units/ Tube
GM431AS8R	0.5%		A	SOP-8	2,500 Units/ Tape & Reel
GM431AST89R	0.5%		A	SOT-89	1,000 Units/ Tape & Reel
GM431BT92B	1%		B	TO-92	1,000 Units/ ESD Bag
GM431BT92RL	1%		B	TO-92	2,000 Units/ Ammo Pack(Tape)
GM431BST23R	1%	AAB		SOT-23	3,000 Units/ Tape & Reel
GM431BS8T	1%		B	SOP-8	100 Units/ Tube
GM431BS8R	1%		B	SOP-8	2,500 Units/ Tape & Reel
GM431BST89R	1%		B	SOT-89	1,000 Units/ Tape & Reel
GM431CT92B	2%		C	TO-92	1,000 Units/ ESD Bag
GM431CT92RL	2%		C	TO-92	2,000 Units/ Ammo Pack(Tape)
GM431CST23R	2%	AAC		SOT-23	3,000 Units/ Tape & Reel
GM431CS8T	2%		C	SOP-8	100 Units/ Tube
GM431CS8R	2%		C	SOP-8	2,500 Units/ Tape & Reel
GM431CST89R	2%		C	SOT-89	1,000 Units/ Tape & Reel

* For detail Ordering Number identification, please see last page.

**Grade A: indicates Precision of 0.5%, B: indicates Precision of 1%, C: indicates Precision of 2%

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◆ EQUIVALENT SCHEMATIC



* All component values are nominal.
Pin numbers shown are for the D package.

2.5V ADJUSTABLE SHUNT REGULATOR

◆ ABSOLUTE MAXIMUM RATINGS (over free-air temperature range except as noted)

PARAMETER	SYMBOL	Value	UNIT
Cathode Voltage ⁽¹⁾	V_{KA}	37	V
Continuous cathode current range	I_K	-100 to 150	mA
Reference input current range	I_{ref}	-50 μ A to 10mA	mA
Power dissipation at $T_A = 25^\circ\text{C}$ SOT-23 SOP-8 TO-92 SOT-89	P_D	0.23 0.60 0.78 0.80	W
Package thermal impedance ^(2, 3) SOT-23 TO-92 SOP-8 SOT-89	J_A	336 132 163 132	$^\circ\text{C/W}$
Operating ambient temperature range	T_A	0 to + 70	$^\circ\text{C}$
Lead temperature (soldering) 10 seconds	T_{LEAD}	260	$^\circ\text{C}$

These are stress ratings only. Functional operation of the device at these or any conditions beyond the "recommended operating conditions" is not implied. Exposure to absolute maximum rated conditions may affect device reliability.

NOTES:

1. Voltage values are with respect to the anode except as noted.

2. Maximum power dissipation is a function of $T_{J(max)}$, J_A and T_A . Maximum allowable power dissipation at any allowable ambient temperature is

$$P_D = (T_{J(max)} - T_A) / J_A$$

3. Package thermal impedance is calculated per JESD 51.

◆ RECOMMENDED OPERATING CONDITIONS

PARAMETER	SYMBOL	MINIMUM	MAXIMUM	UNIT
Cathode Voltage	V_{KA}	V_{ref}	36	V
Cathode Current	I_K	1.0	100	mA

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◆ ELECTRICAL CHARACTERISTICS ($T_A = 25^\circ\text{C}$ unless otherwise noted)

GM431A (0.5%)

PARAMETER	CONDITION	MIN	TYP	MAX	UNIT
Reference Voltage	V_{ref} $V_{KA} = V_{\text{ref}}, I_K = 10 \text{ mA}, T_A = 25^\circ\text{C}^{(1)}$ $V_{KA} = V_{\text{ref}}, I_K = 10 \text{ mA}, T_A = 0 \text{ to } 70^\circ\text{C}^{(1)}$	2.487	2.500	2.512	V
V_{ref} temp deviation	V_{dev} $V_{KA} = V_{\text{ref}}, I_K = 10 \text{ mA}^{(1)}, T_A = \text{full range}$		4	17	mV
Ratio of change in V_{ref} to change in V_{KA}	$\frac{V_{\text{ref}}}{V_{KA}}$ $I_K = 10 \text{ mA}$ $V_{KA} = 10 \text{ V to } V_{\text{ref}}$ $V_{KA} = 36 \text{ V to } 10 \text{ V}$	-2.7 -2.0	-1.0 -0.4		mV/V
Reference input current	I_{ref} $I_K = 10 \text{ mA}, R1 = 10 \text{ K}, R2 = \infty^{(2)}$		0.7	4.0	A
Deviation of reference input current over full temperature range	$I_{\text{ref(dev)}}$ $I_K = 10 \text{ mA}, R1 = 10 \text{ K}, R2 = \infty^{(2)}$ $T_A = \text{full range}$		0.4	1.2	A
Minimum operating current	$I_{K(\text{min})}$ $V_{KA} = V_{\text{ref}}^{(1)}$		0.4	1.0	mA
Off-state cathode current	$I_{K(\text{off})}$ $V_{KA} = 36 \text{ V}, V_{\text{ref}} = 0 \text{ V}^{(3)}$ $V_{KA} = 16 \text{ V}, V_{\text{ref}} = 0 \text{ V}^{(3)}$		0.1	1	A
Dynamic impedance	$ Z_{KA} $ $f \leq 1 \text{ kHz}, V_{KA} = V_{\text{ref}}, I_K = 1 \text{ mA to } 100 \text{ mA}^{(1)}$		0.2	0.50	

GM431B (1.0%)

PARAMETER	CONDITION	MIN	TYP	MAX	UNIT
Reference Voltage	V_{ref} $V_{KA} = V_{\text{ref}}, I_K = 10 \text{ mA}, T_A = 25^\circ\text{C}^{(1)}$ $V_{KA} = V_{\text{ref}}, I_K = 10 \text{ mA}, T_A = 0 \text{ to } 70^\circ\text{C}^{(1)}$	2.475	2.500	2.525	V
V_{ref} temp deviation	V_{dev} $V_{KA} = V_{\text{ref}}, I_K = 10 \text{ mA}^{(1)}, T_A = \text{full range}$		4	17	mV
Ratio of change in V_{ref} to change in V_{KA}	$\frac{V_{\text{ref}}}{V_{KA}}$ $I_K = 10 \text{ mA}$ $V_{KA} = 10 \text{ V to } V_{\text{ref}}$ $V_{KA} = 36 \text{ V to } 10 \text{ V}$	-2.7 -2.0	-1.0 -0.4		mV/V
Reference input current	I_{ref} $I_K = 10 \text{ mA}, R1 = 10 \text{ K}, R2 = \infty^{(2)}$		0.7	4.0	A
Deviation of reference input current over full temperature range	$I_{\text{ref(dev)}}$ $I_K = 10 \text{ mA}, R1 = 10 \text{ K}, R2 = \infty^{(2)}$ $T_A = \text{full range}$		0.4	1.2	A
Minimum operating current	$I_{K(\text{min})}$ $V_{KA} = V_{\text{ref}}^{(1)}$		0.4	1.0	mA
Off-state cathode current	$I_{K(\text{off})}$ $V_{KA} = 36 \text{ V}, V_{\text{ref}} = 0 \text{ V}^{(3)}$ $V_{KA} = 16 \text{ V}, V_{\text{ref}} = 0 \text{ V}^{(3)}$		0.1	1	A
Dynamic impedance	$ Z_{KA} $ $f \leq 1 \text{ kHz}, V_{KA} = V_{\text{ref}}, I_K = 1 \text{ mA to } 100 \text{ mA}^{(1)}$		0.2	0.50	

NOTES:

(1) See test circuit 1 on page 5.

(2) See test circuit 2 on page 5.

(3) See test circuit 3 on page 5.

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◆ ELECTRICAL CHARACTERISTICS ($T_A = 25^\circ\text{C}$ unless otherwise noted)

GM431C (2.0%)

PARAMETER	CONDITION	MIN	TYP	MAX	UNIT
Reference Voltage	$V_{KA} = V_{ref}$, $I_K = 10\text{ mA}$, $T_A = 25^\circ\text{C}^{(1)}$ $V_{KA} = V_{ref}$, $I_K = 10\text{ mA}$, $T_A = 0\text{ to }70^\circ\text{C}^{(1)}$	2.45	2.500	2.55	V
V_{ref} temp deviation	$V_{KA} = V_{ref}$, $I_K = 10\text{ mA}^{(1)}$, $T_A = \text{full range}$		4	17	mV
Ratio of change in V_{ref} to change in V_{KA}	$I_K = 10\text{ mA}$ $V_{KA} = 10\text{V to }V_{ref}$ $V_{KA} = 36\text{V to }10\text{V}$	-2.7 -2.0	-1.0 -0.4		mV/V
Reference input current	$I_K = 10\text{ mA}$, $R1 = 10\text{K}$, $R2 = \infty^{(2)}$		0.7	4.0	A
Deviation of reference input current over full temperature range	$I_K = 10\text{ mA}$, $R1 = 10\text{K}$, $R2 = \infty^{(2)}$ $T_A = \text{full range}$		0.4	1.2	A
Minimum operating current	$V_{KA} = V_{ref}^{(1)}$		0.4	1.0	mA
Off-state cathode current	$V_{KA} = 36\text{V}$, $V_{ref} = 0\text{V}^{(3)}$ $V_{KA} = 16\text{V}$, $V_{ref} = 0\text{V}^{(3)}$		0.1	1	A
Dynamic impedance	$f \leq 1\text{ kHz}$, $V_{KA} = V_{ref}$, $I_K = 1\text{ mA to }100\text{ mA}^{(1)}$		0.2	0.50	

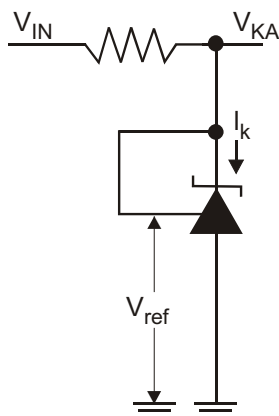
NOTES:

(1) See test circuit 1.

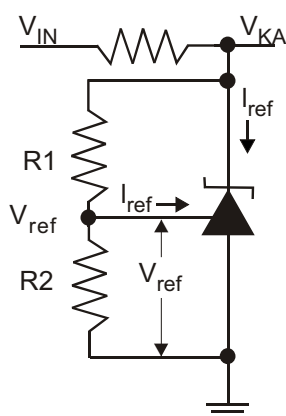
(2) See test circuit 2.

(3) See test circuit 3.

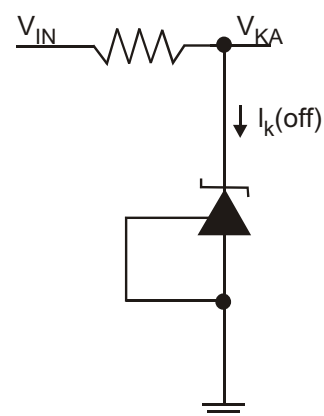
◆ TEST CIRCUITS



Test Circuit 1
 $V_{KA} = V_{ref}$



Test Circuit 2
 $V_{KA} > V_{ref}$



Test Circuit 3
Off-State

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◆ TYPICAL APPLICATIONS

GM431A, GM431B

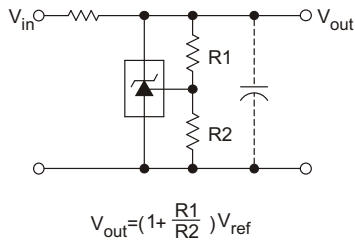


Figure 1. Shunt Regulator

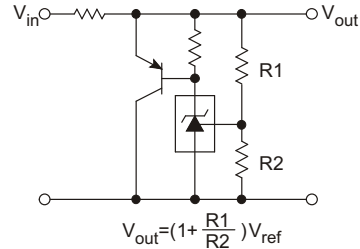


Figure 2. High Current Shunt Regulator

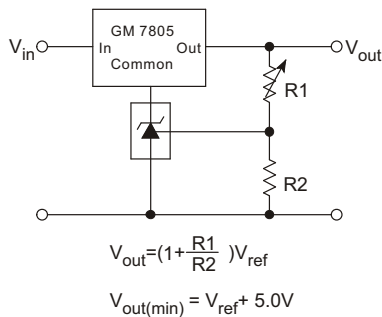


Figure 3. Output Control for a Three Terminal Fixed Regulator

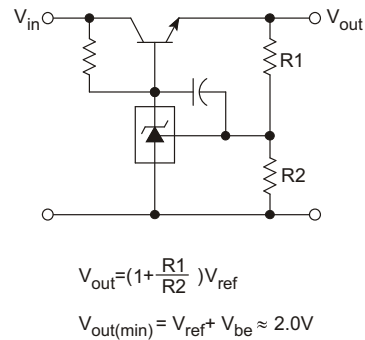


Figure 4. Series Pass Regulator

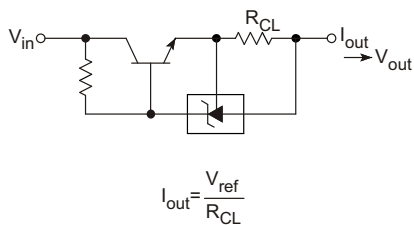


Figure 5. Constant Current Source

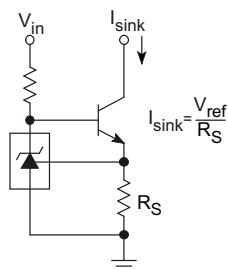


Figure 6. Constant Current Sink

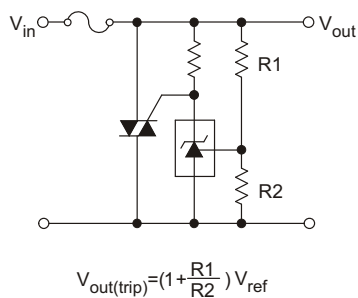


Figure 7. TRIAC Crowbar

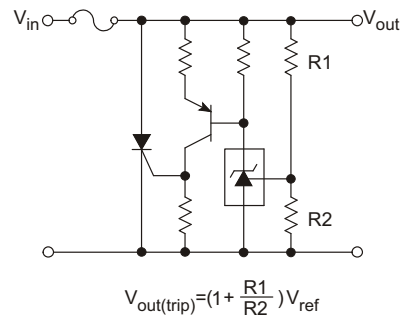


Figure 8. SCR Crowbar

◆ Typical Performance Characteristics

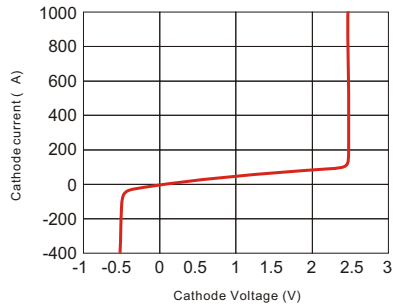


Figure 9. Cathode Current vs. Cathode Voltage

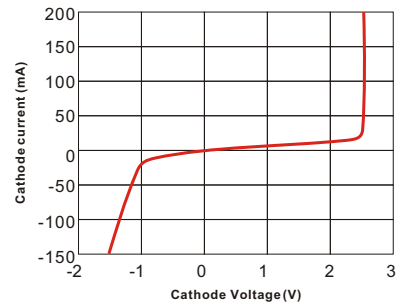


Figure 10. Cathode Current vs. Cathode Voltage

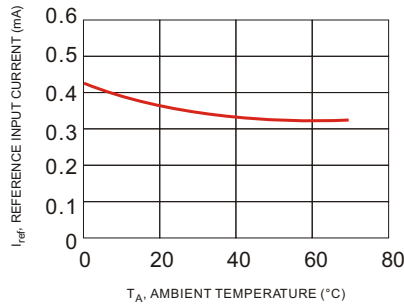


Figure 11. Reference Input Current versus Ambient Temperature

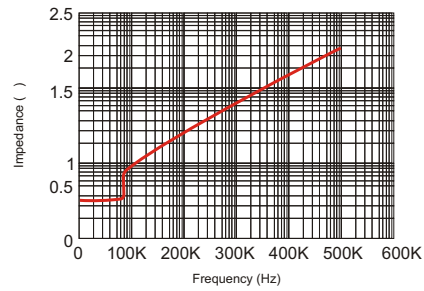


Figure 12. Dynamic Impedance Frequency

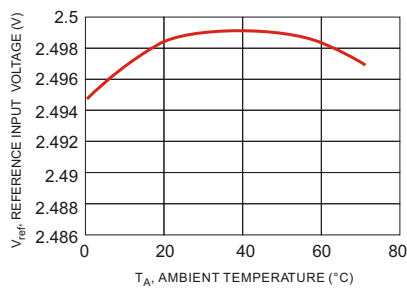


Figure 13. Reference Input Voltage versus Ambient Temperature

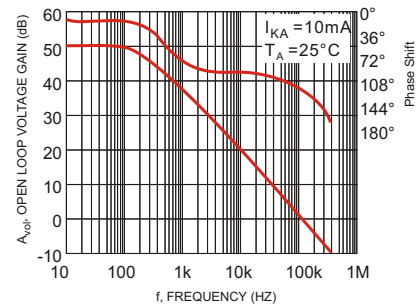


Figure 14. Open-Loop Voltage Gain vs. Frequency

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◆ Design Guide for AC-DCSMPS (Switching Mode Power Supply)

Use of Shunt Regulator in Transformer Secondary side Control

This example is applicable to both forward transformers and flyback transformers. A shunt regulator is used on the secondary side as an error amplifier, and feedback to the primary side is provided via a photocoupler.

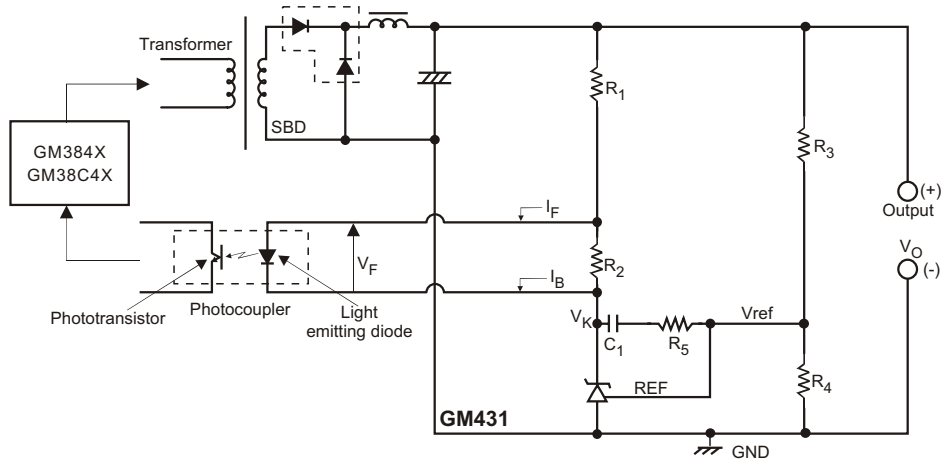


Figure 16. Typical Shunt Regulator/ Error Amplifier

Determination of External Constants for the Shunt Regulator

Dc characteristic determination: In figure 16, R_1 and R_2 are protection resistor for the light emitting diode in the photocoupler, and R_2 is a bypass resistor to feed I_K Minimum, and these are determined as shown below. The photocoupler specification should be obtained separately from the manufacturer. Using the parameters in figure 16, the following formulas are obtained:

$$R1 = \frac{V_O - V_F - V_K}{I_F + I_B}, R2 = \frac{V_F}{I_B}$$

V_K is the GM431 operating voltage, and is set at around 3V, taking into account a margin for fluctuation. R_2 is the current shunt resistance for the light emitting diode, in which a bias current I_B of around $1/5 I_F$ flows.

Next, the output voltage can be determined by R_3 and R_4 , and the following formula is obtained:

$$V_O = \frac{R3 + R4}{R4} \times V_{ref}, V_{ref} = 2.5V \text{ Typ}$$

The absolute values of R_3 and R_4 are determined by the GM431 reference input current I_{ref} and the AC characteristics described in the next section. The I_{ref} value is around $0.7\mu A$ Typ.

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◆ AC Characteristic Determination:

This refers to the determination of the gain frequency characteristic of the shunt regulator as an error amplifier. Taking the configuration in figure 16, the error amplifier characteristic is as shown in figure 17.

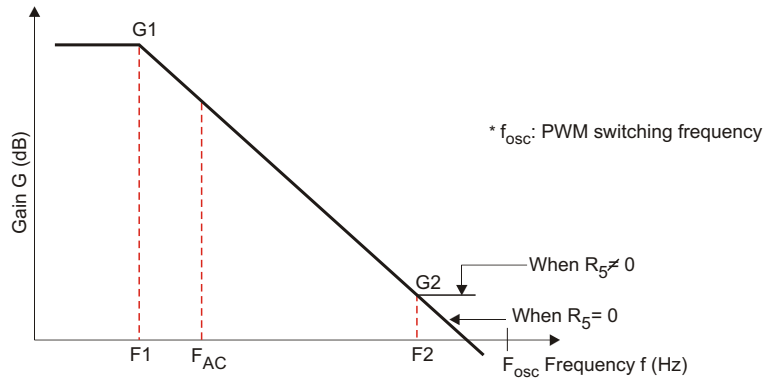


Figure 17. GM431 Error Amplification Characteristic

In Figure 17, the following formulas are obtained:

Gain

$$G_1 = G_0 \approx 50 \text{ dB to } 60 \text{ dB (determined by shunt regulator)}$$

$$G_2 = \frac{R_5}{R_3}$$

Corner frequencies

$$f_1 = 1/(2 \cdot C_1 \cdot G_0 \cdot R_3)$$

$$f_2 = 1/(2 \cdot C_1 \cdot R_5)$$

G_0 is the shunt regulator open-loop gain; this is given by the reciprocal of the reference voltage fluctuation V_{ref}/V_{KA} , and is approximately 50 dB.

Practical Example

Consider the example of a photocoupler, with an internal light emitting diode $V_F = 1.05 \text{ V}$ and $I_F = 2.5 \text{ mA}$, power supply output voltage $V_2 = 5 \text{ V}$, and bias resistance R_2 current of approximately $1/5 I_F$ at 0.5 mA . If the shunt regulator $V_K = 3 \text{ V}$, the following values are found.

$$R_1 = \frac{5V - 1.05V - 3V}{2.5mA + 0.5mA} = 316$$

$$R_2 = \frac{1.05V}{0.5mA} = 2.1 \text{ k}$$

Next, assume that $R_3 = R_4 = 10 \text{ k}$. This gives a 5 V output. If $R_5 = 3.3 \text{ k}$ and $C_1 = 0.022 \text{ }\mu\text{F}$, the following values are found.

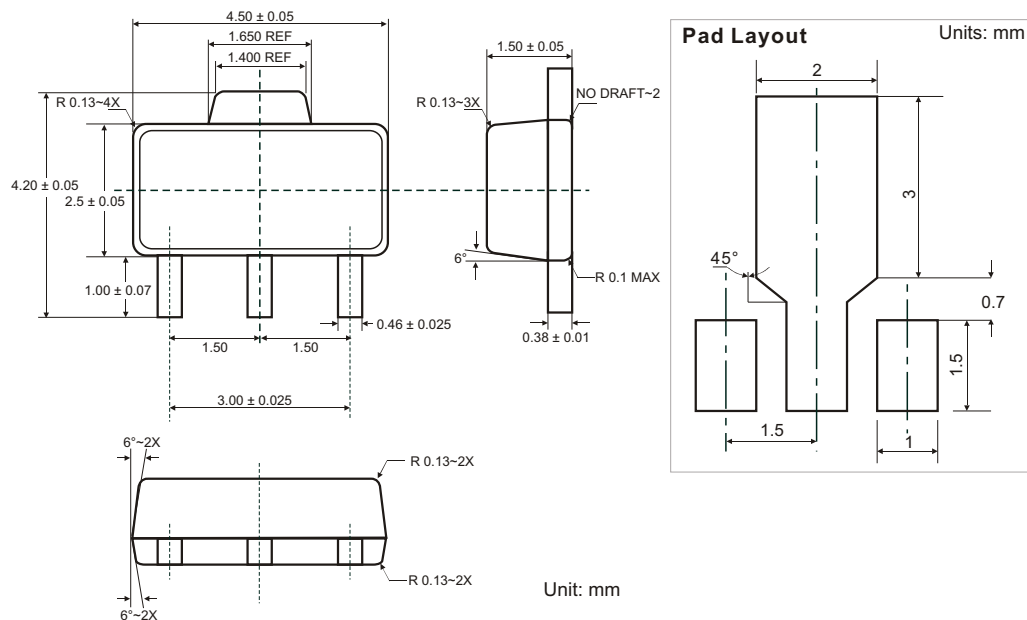
$$G_2 = 3.3 \text{ k} / 10 \text{ k} = 0.33 \text{ times } (-10 \text{ dB})$$

$$f_1 = 1 / (2 \times 0.022 \text{ }\mu\text{F} \times 316 \times 10 \text{ k}) = 2.3 \text{ (Hz)}$$

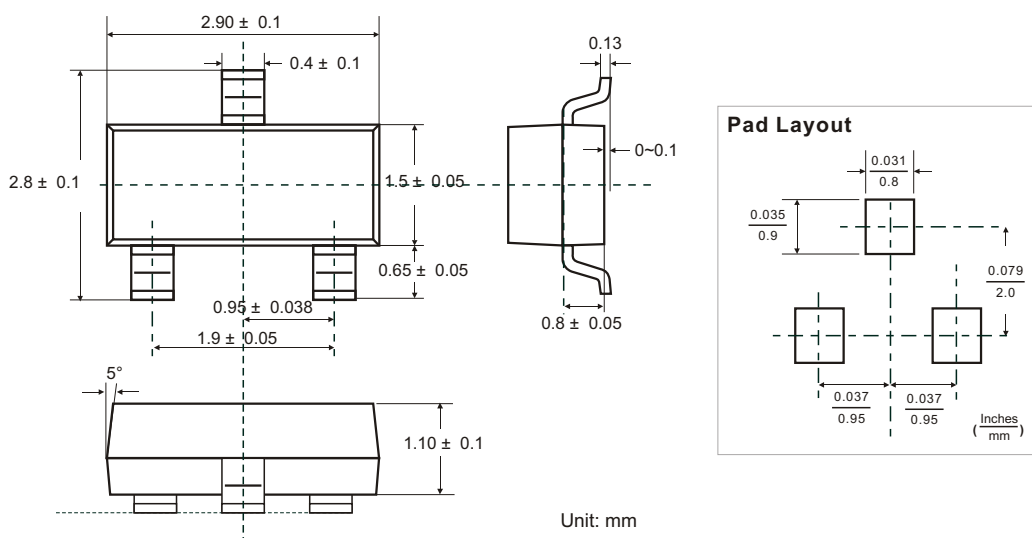
$$f_2 = 1 / (2 \times 0.022 \text{ }\mu\text{F} \times 3.3 \text{ k}) = 2.2 \text{ (kHz)}$$

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◆ SOT-89 PACKAGE OUTLINE DIMENSIONS

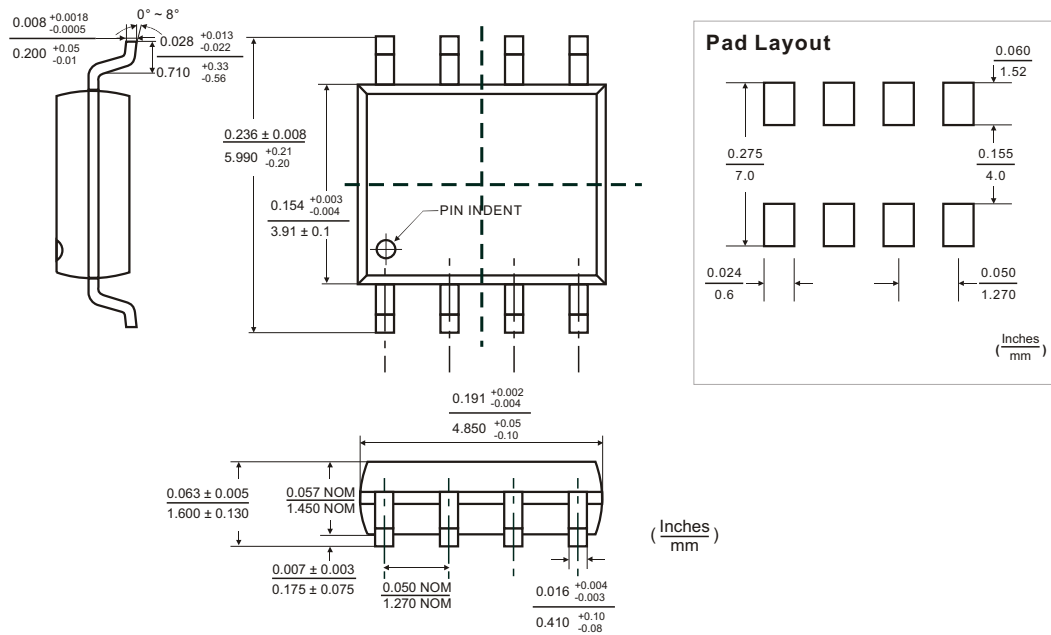


◆ SOT-23 PACKAGE OUTLINE DIMENSIONS

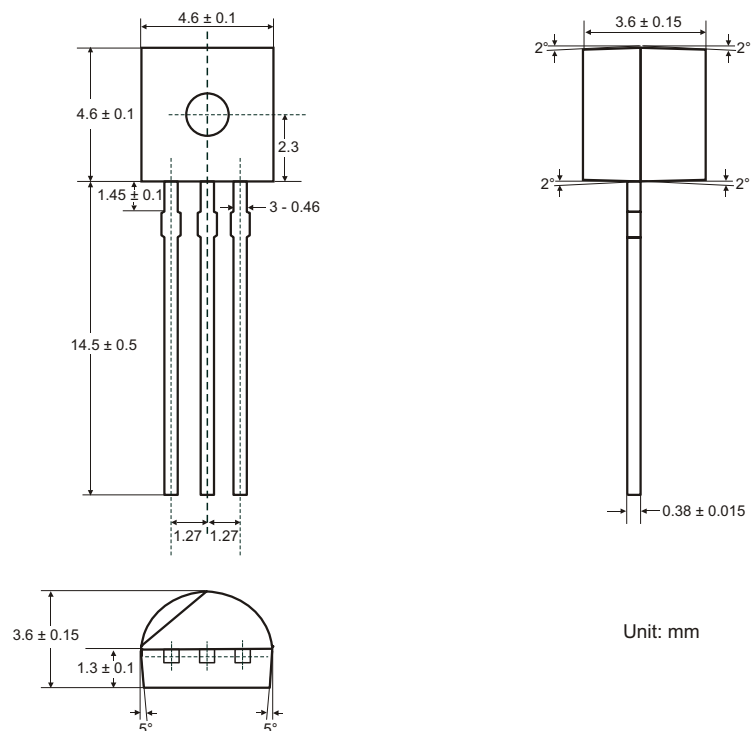


2.5V ADJUSTABLE SHUNT REGULATOR

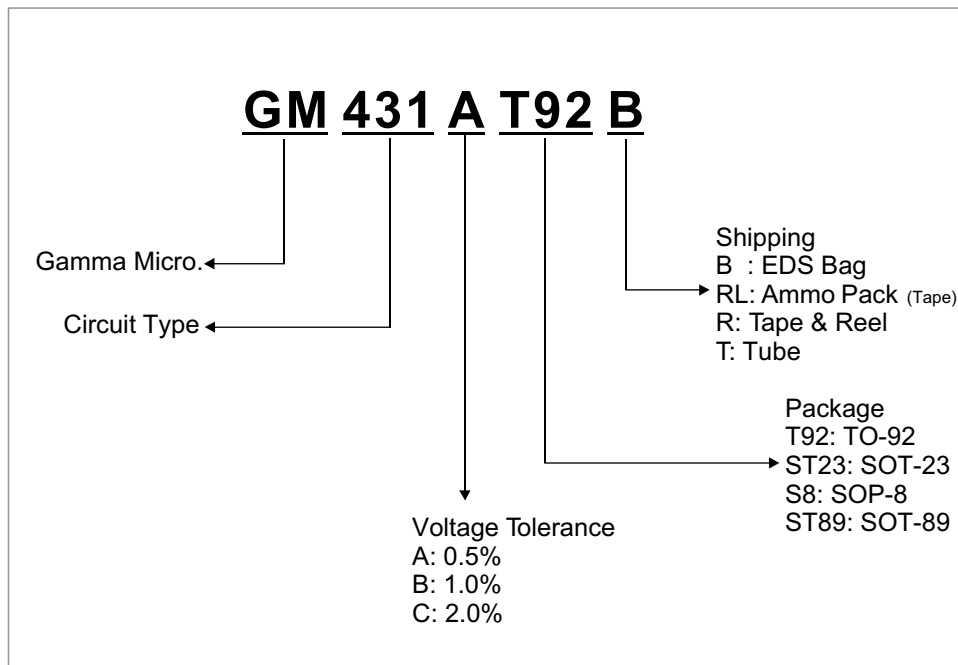
◆ SOP-8 PACKAGE OUTLINE DIMENSIONS



◆ TO-92 PACKAGE OUTLINE DIMENSIONS



◆ ORDERING NUMBER



2.5V ADJUSTABLE SHUNT REGULATOR

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