

## FEATURES

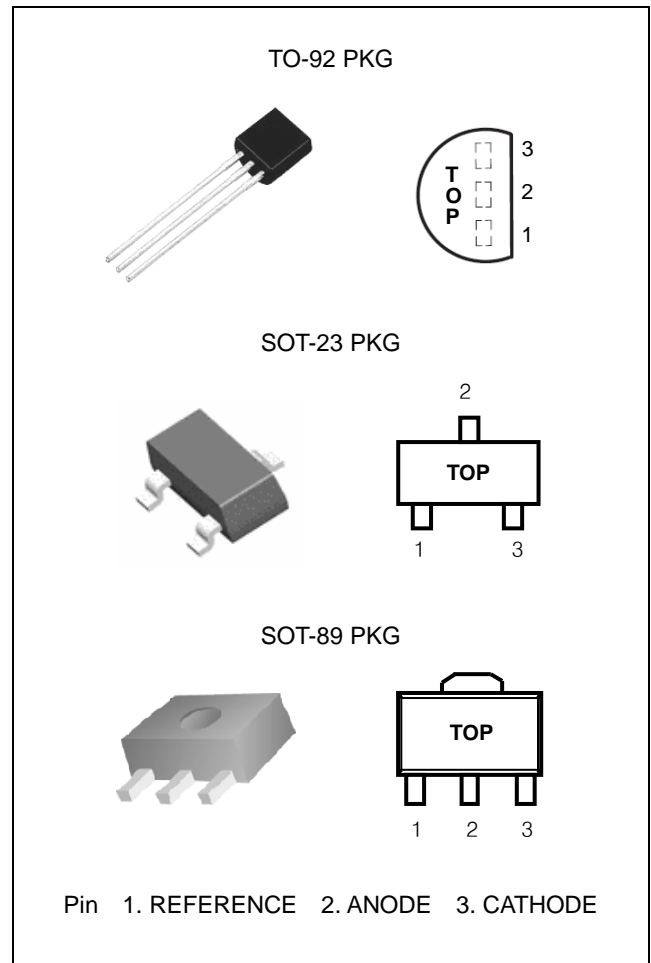
- Programmable Output Voltage to 40V
- Guaranteed 0.5% Reference Voltage Tolerance
- Low (0.2Ω Typ.) Dynamic Output Impedance
- Cathode Current Range (Continuous) – 100 ~ 150 mA
- Equivalent Full Range Temperature Coefficient of 50PPM/°C
- Temperature Compensated For Operation Over Full Rate Operating Temperature Range
- Low Output Noise Voltage
- Fast Turn-on Response
- Available in TO-92, SOT-89 and SOT-23-3L Packages

## APPLICATIONS

- Shunt Regulator
- Precision High-Current Series Regulator
- High-Current Shunt Regulator
- Crowbar Circuit
- PWM Converter With Reference
- Voltage Monitor
- Precision Current Limiter

## DESCRIPTION

The TL431 is a three-terminal adjustable shunt regulator with specified thermal stability over applicable temperature  $V_{REF}$  (2.495V) and 40V with two external resistors. This device has a typical dynamic output impedance of 0.2Ω. Active output circuitry provides a very sharp turn-on characteristic, making this device excellent replacement for Zener diodes in many applications. The TL431 is characterized for operation from -40°C to +125°C.



## ORDERING INFORMATION

| Device   | Package        |
|----------|----------------|
| TL431x   | TO-92 (Bulk)   |
| TL431xTA | TO-92 (Taping) |
| TL431xSF | SOT-23-3L      |
| TL431xF  | SOT-89-3L      |

\* Refer to the ordering information for the details.

## ABSOLUTE MAXIMUM RATINGS

(Full operating ambient temperature range applies unless otherwise noted.)

| PARAMETER                     | SYMBOL    | MIN.  | MAX. | UNIT |
|-------------------------------|-----------|-------|------|------|
| Cathode Voltage               | $V_{KA}$  | -     | 42   | V    |
| Cathode Current Range         | $I_{KA}$  | -100  | 150  | mA   |
| Reference Input Current Range | $I_{REF}$ | -0.05 | 10   | mA   |
| Junction Temperature Range    | $T_J$     | -40   | 150  | °C   |
| Storage Temperature Range     | $T_{STG}$ | -65   | 150  | °C   |

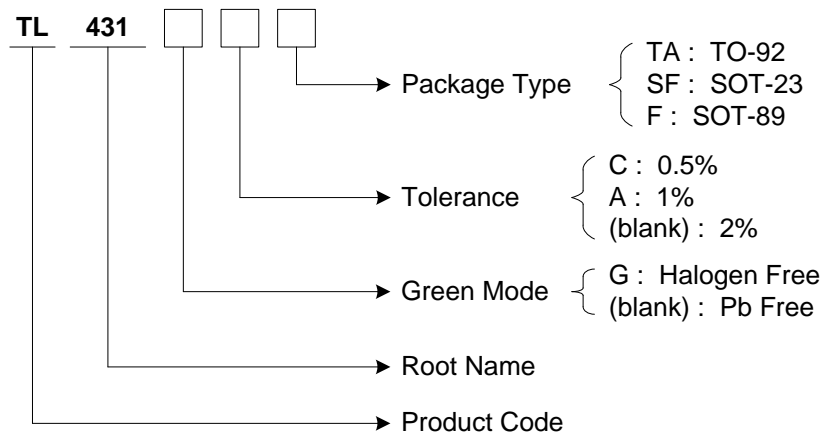
## RECOMMENDED OPERATING CONDITIONS

| PARAMETER                   | SYMBOL    | MIN.      | MAX. | UNIT |
|-----------------------------|-----------|-----------|------|------|
| Cathode Voltage             | $V_{KA}$  | $V_{REF}$ | 40   | V    |
| Cathode Current             | $I_{KA}$  | 0.5       | 100  | mA   |
| Operating Temperature Range | $T_{OPR}$ | -40       | 125  | °C   |

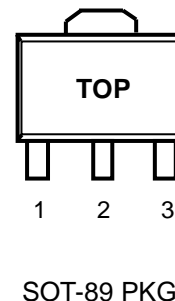
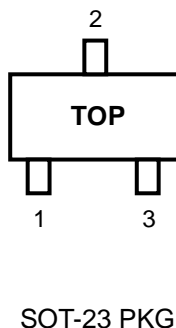
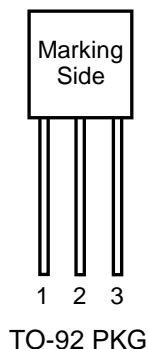
## ORDERING INFORMATION

| VREF   | Package | Tolerance | Order No. | Package Marking | Supplied As |
|--------|---------|-----------|-----------|-----------------|-------------|
| 2.495V | TO-92   | 0.5%      | TL431C    | TL431-C         | Bulk        |
|        |         |           | TL431GC   | TL431GC         |             |
|        |         |           | TL431CTA  | TL431-C         | Tape        |
|        |         |           | TL431GCTA | TL431GC         |             |
|        |         | 1%        | TL431A    | TL431-A         | Bulk        |
|        |         |           | TL431GA   | TL431GA         |             |
|        |         |           | TL431ATA  | TL431-A         | Tape        |
|        |         |           | TL431GATA | TL431GA         |             |
|        |         | 2%        | TL431     | TL431           | Bulk        |
|        |         |           | TL431G    | TL431G          |             |
|        |         |           | TL431TA   | TL431           | Tape        |
|        |         |           | TL431GTA  | TL431G          |             |
|        | SOT-23  | 0.5%      | TL431CSF  | 431             | Reel        |
|        |         |           | TL431GCSF | 431             |             |
|        |         | 1%        | TL431ASF  | 431             | Reel        |
|        |         |           | TL431GASF | 431             |             |
|        |         | 2%        | TL431SF   | 431             | Reel        |
|        |         |           | TL431GSF  | 431             |             |
|        | SOT-89  | 0.5%      | TL431CF   | 431             | Reel        |
|        |         | 1%        | TL431AF   | 431             | Reel        |
|        |         | 2%        | TL431F    | 431             | Reel        |

## ORDERING INFORMATION (continued)



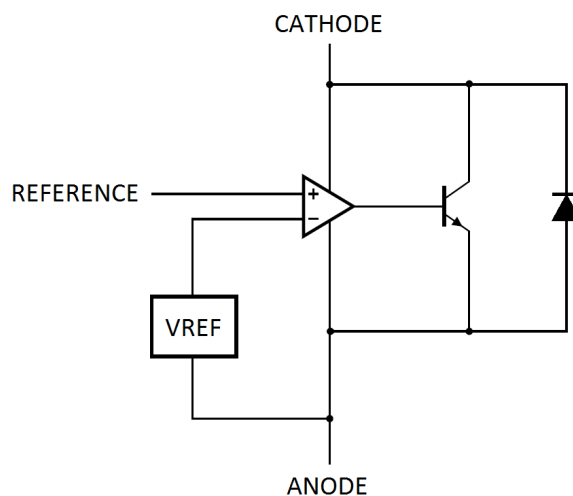
## PIN CONFIGURATION



## PIN DESCRIPTION

| Pin No. | TO-92 / SOT-23 / SOT-89 |                      |
|---------|-------------------------|----------------------|
|         | Pin Name                | Pin Description      |
| 1       | REFERENCE               | Reference Voltage    |
| 2       | ANODE                   | Ground               |
| 3       | CATHODE                 | Input Supply Voltage |

## BLOCK DIAGRAM



## ELECTRICAL CHARACTERISTICS

(T<sub>A</sub>=25°C, unless otherwise specified)

| PARAMETER                                                                   | SYMBOL                              | TEST CONDITIONS                                                                                 |                                            | MIN.  | TYP.  | MAX.  | UNIT |
|-----------------------------------------------------------------------------|-------------------------------------|-------------------------------------------------------------------------------------------------|--------------------------------------------|-------|-------|-------|------|
| Reference Input Voltage                                                     | V <sub>REF</sub>                    | V <sub>KA</sub> =V <sub>REF</sub> ,<br>I <sub>K</sub> =10mA                                     | TL431C                                     | 2.483 | 2.495 | 2.507 | V    |
|                                                                             |                                     |                                                                                                 | TL431A                                     | 2.470 | 2.495 | 2.520 |      |
|                                                                             |                                     |                                                                                                 | TL431                                      | 2.440 | 2.495 | 2.550 |      |
| Deviation of Reference Input Voltage (Note 1)                               | ΔV <sub>REF</sub> /ΔT               | V <sub>KA</sub> = V <sub>REF</sub> , I <sub>K</sub> = 10mA<br>T <sub>A</sub> = Full Range       |                                            |       | 15    | 30    | mV   |
| Ratio of Change in Reference Input Voltage to the Change in Cathode Voltage | ΔV <sub>REF</sub> /ΔV <sub>KA</sub> | I <sub>K</sub> = 10mA                                                                           | ΔV <sub>KA</sub> = 10V to V <sub>REF</sub> |       | -1.4  | -2.7  | mV/V |
|                                                                             |                                     |                                                                                                 | ΔV <sub>KA</sub> = 36V to 10V              |       | -1.0  | -2.0  |      |
| Reference Input Current                                                     | I <sub>REF</sub>                    | I <sub>KA</sub> = 10mA, R <sub>1</sub> = 10kΩ, R <sub>2</sub> = ∞                               |                                            |       | 1.8   | 4.0   | μA   |
| Deviation of Reference Input Current (Note 1)                               | ΔI <sub>REF</sub> /ΔT               | I <sub>K</sub> = 10mA, R <sub>1</sub> = 10kΩ, R <sub>2</sub> = ∞<br>T <sub>A</sub> = Full Range |                                            |       | 0.4   | 1.2   | μA   |
| Minimum Cathode Current for Regulation                                      | I <sub>K(MIN)</sub>                 | V <sub>KA</sub> = V <sub>REF</sub>                                                              |                                            |       |       | 0.5   | mA   |
| Off-State Cathode Current                                                   | I <sub>K(OFF)</sub>                 | V <sub>KA</sub> = 36V, V <sub>REF</sub> = 0                                                     |                                            |       | 0.17  | 0.90  | μA   |
| Dynamic Impedance (Note 2)                                                  | Z <sub>KA</sub>                     | V <sub>KA</sub> = V <sub>REF</sub> , I <sub>K</sub> = 1mA~100mA<br>f ≤ 1kHz                     |                                            |       | 0.27  | 0.50  | Ω    |

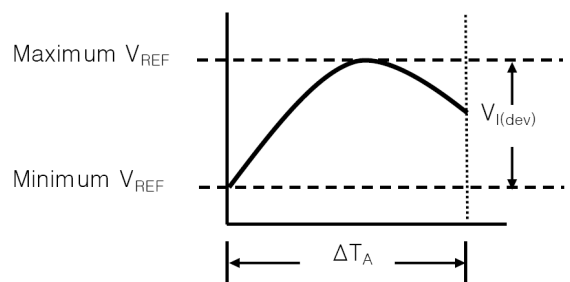
(Note 1) The deviation parameters ΔV<sub>REF</sub>/ΔT<sub>A</sub> and ΔI<sub>REF</sub>/ΔT<sub>A</sub> are defined as the differences between the maximum and minimum values obtained over the recommended temperature range. The average full-range temperature coefficient of the reference voltage, αV<sub>REF</sub>, is defined as:

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

Where:

ΔT<sub>A</sub> is the recommended operating free-air temperature range of the device.

αV<sub>REF</sub> can be positive or negative, depending on whether minimum V<sub>REF</sub> or maximum V<sub>REF</sub>, respectively, occurs at the lower temperature.



Example : Maximum V<sub>REF</sub>=2496mV at 30°C, minimum V<sub>REF</sub>=2492mV at 0°C, V<sub>REF</sub>=2495mV at 25°C, ΔT<sub>A</sub>=70°C for TL431C.

$$|\alpha V_{REF}| = \frac{\left( \frac{4\text{mV}}{2495\text{mV}} \right) \times 10^6}{70^\circ\text{C}} \approx 23\text{ppm/°C}$$

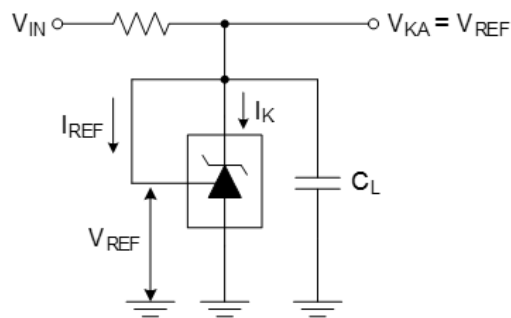
Because minimum V<sub>REF</sub> occurs at the lower temperature, the coefficient is positive.

(Note 2) The dynamic impedance is defined as:  $|Z_{KA}| = \frac{\Delta V_{KA}}{\Delta I_{KA}}$

When the device is operating with two external resistors, the total dynamic impedance of the circuit is given by:

$$|Z| = \frac{\Delta V}{\Delta I} \approx |Z_{KA}|(1 + R1/R2)$$

## TEST CIRCUITS



< Fig 1. Test circuit for  $V_{KA} = V_{REF}$  >

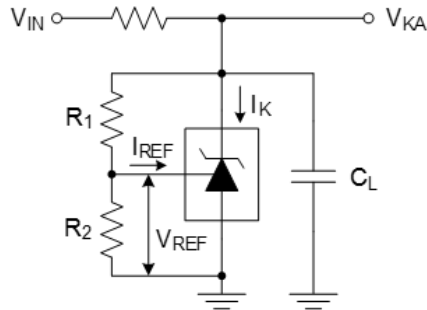
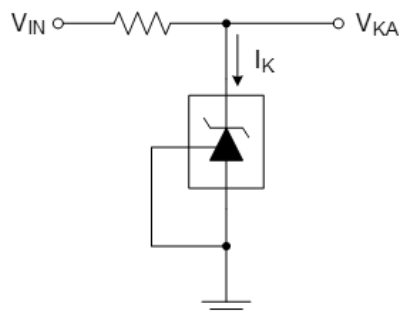


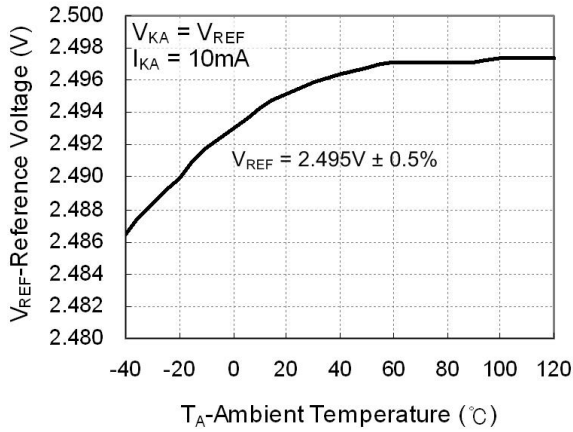
Fig 2. Test circuit for  $V_{KA} \geq V_{REF}$  >



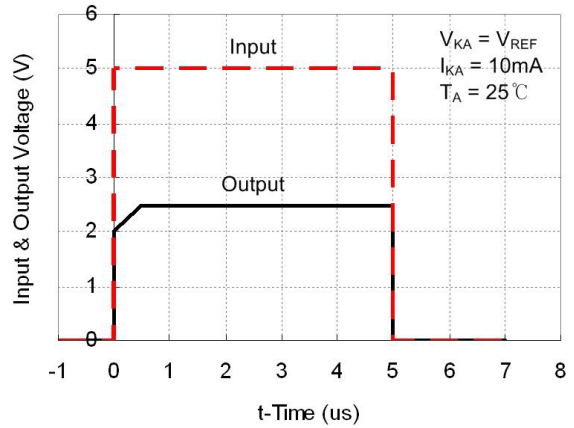
< Fig 3. Test circuit for  $I_{KA(OFF)}$  >

## TYPICAL OPERATING CHARACTERISTICS

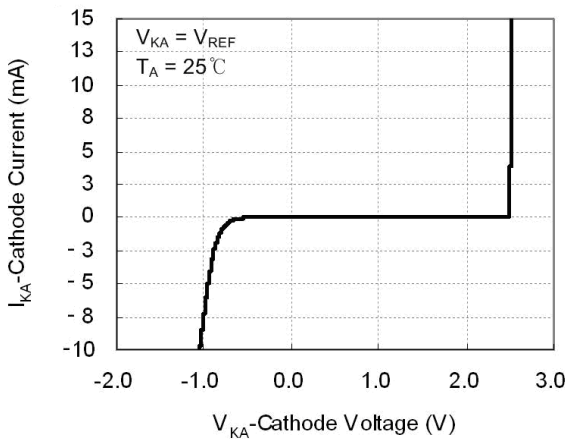
**Reference Voltage vs. Ambient Temperature**



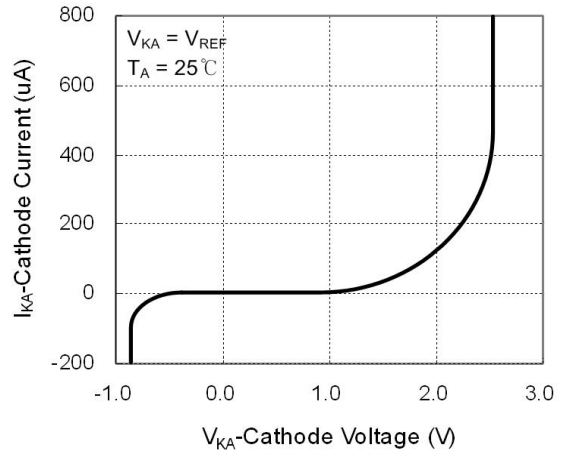
**Pulse Response**



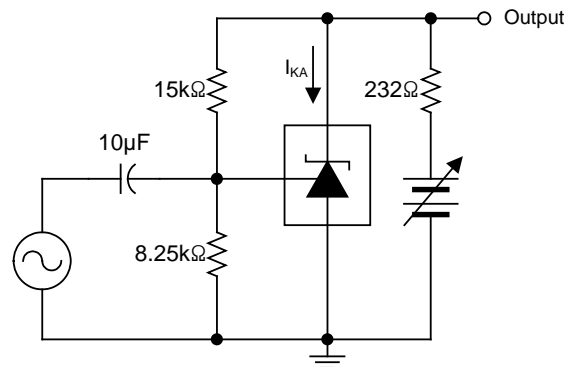
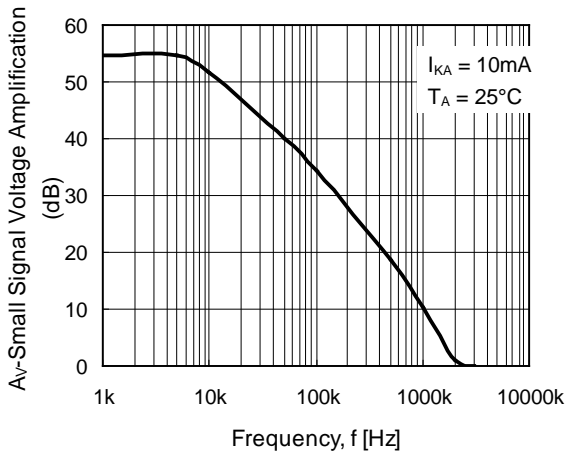
**Cathode Current vs. Cathode Voltage**



**Cathode Current vs. Cathode Voltage**



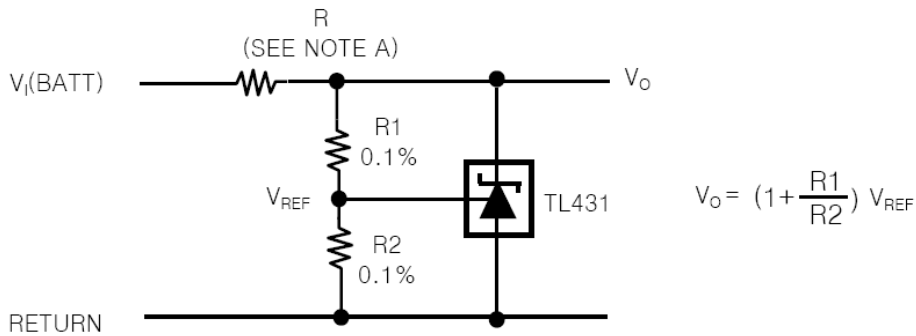
**Small Signal Voltage Amplification vs. Frequency**



< Fig 4. TEST Circuit for Voltage Amplification >

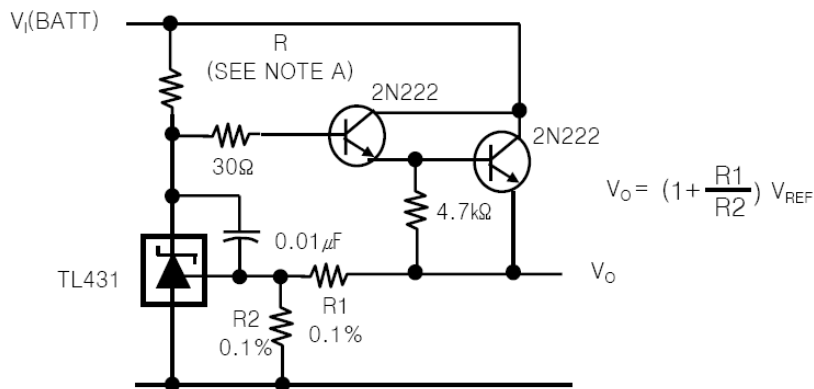
## APPLICATION INFORMATION

### 1. Shunt Regulator



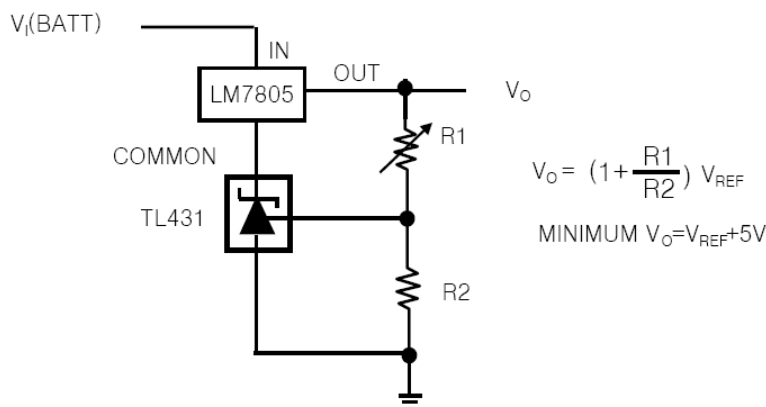
Note: R Should provide cathode current 1mA to the TL431 at minimum  $V_{I(BATT)}$

### 2. Precision High-Current Series Regulator



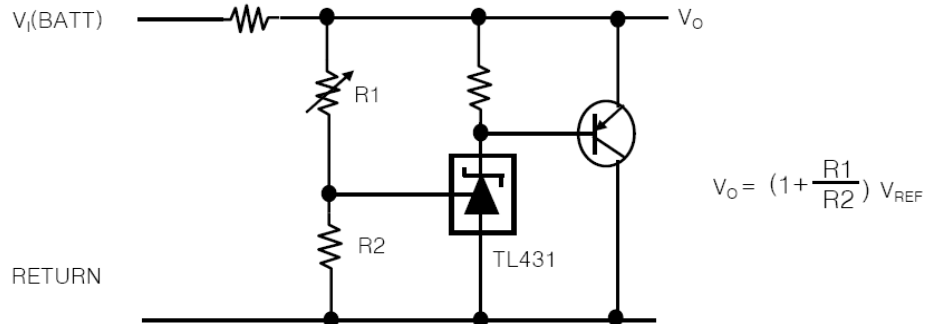
Note: R Should provide cathode current  $\geq 1$ mA to the TL431 at minimum  $V_{I(BATT)}$

### 3. Output Control of a Three-Terminal Fixed Regulator

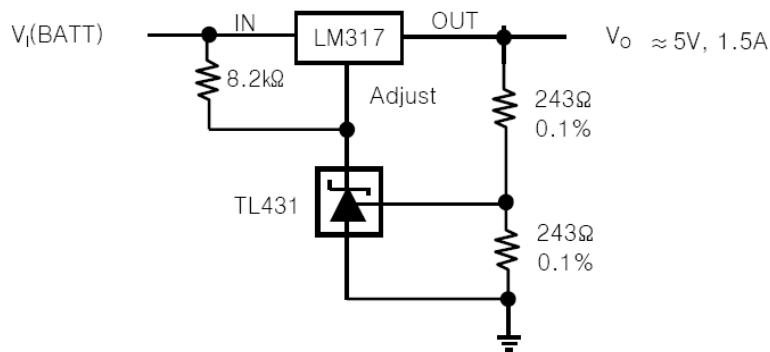




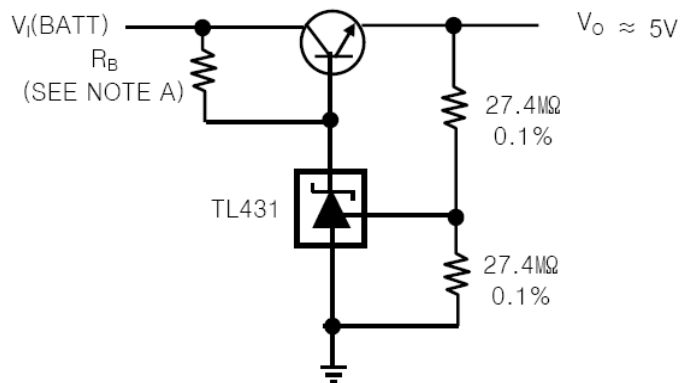
## 4. High-Current Shunt Regulator



## 5. Precision 5-V 1.5A Regulator

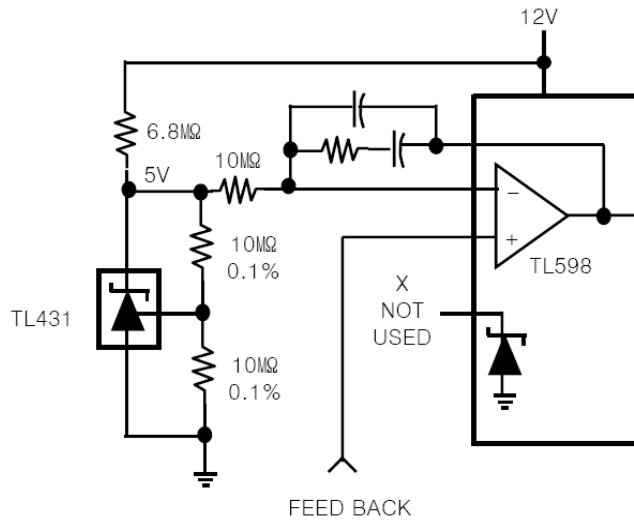


## 6. Efficient 5-V Precision Regulator

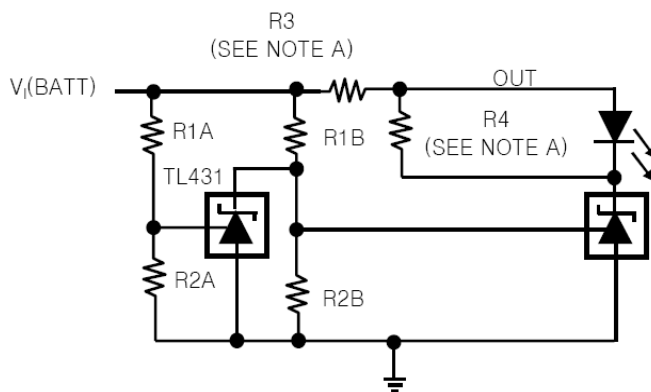


NOTE:  $R_B$  Should provide cathode current  $\geq 1mA$  to the TL431.

## 7. PWM Converter With Reference



## 8. Voltage Monitor



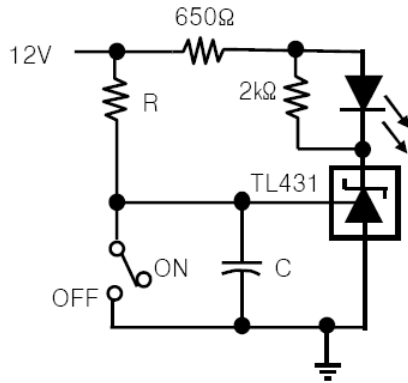
$$\text{LOW LIMIT} = \left(1 + \frac{R1B}{R2B}\right) V_{REF}$$

$$\text{HIGH LIMIT} = \left(1 + \frac{R1A}{R2A}\right) V_{REF}$$

LED ON WHEN  $\text{LOW LIMIT} < V_{I(BATT)} < \text{HIGH LIMIT}$

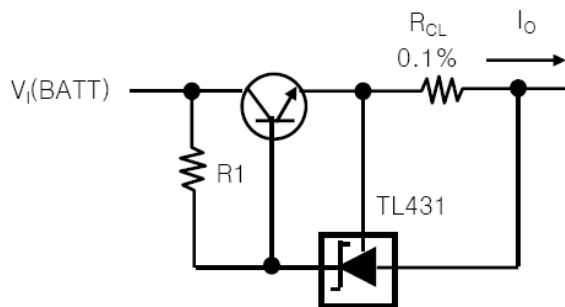
NOTE: R3 and R4 are selected to provide the desired LED intensity and cathode current  $\geq 1\text{mA}$  to the TL431 at the available  $V_{I(BATT)}$ .

## 9. Delay Timer



$$\text{DELAY} = R \times C \times I_N \left( \frac{12V}{12V - V_{REF}} \right)$$

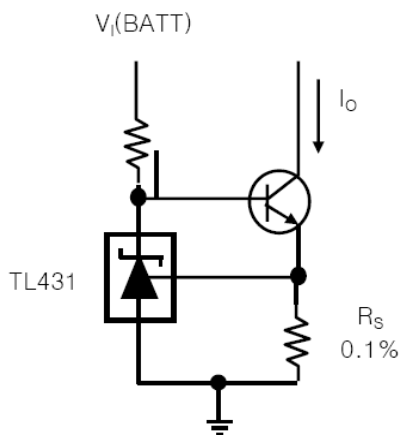
## 10. Precision Current Limiter



$$I_{OUT} = \frac{V_{REF}}{R_{CL}} + I_{KA}$$

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

## 11. Precision Constant-Current Sink



$$I_o = \frac{V_{REF}}{R_S}$$

## REVISION NOTICE

The description in this datasheet is subject to change without any notice to describe its electrical characteristics properly.