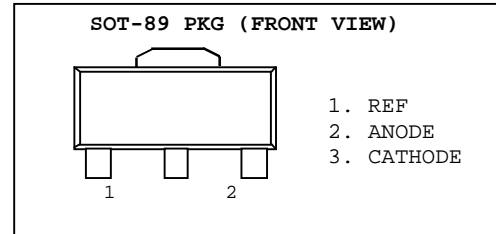
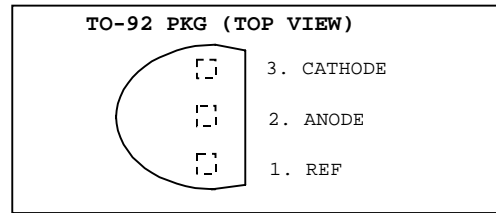


## PROGRAMMABLE PRECISION REFERENCES

The TL431 is three-terminal adjustable shunt regulator with specified thermal stability. The output voltage may be set to any value between  $V_{REF}$  (Approx. 2.5V) and 36V with two external resistors. This device has a typical output impedance of 0.2 $\Omega$ . Active output circuitry provides a very sharp turn-on characteristic, making this device excellent replacement for zener diodes in many applications.

## FEATURES

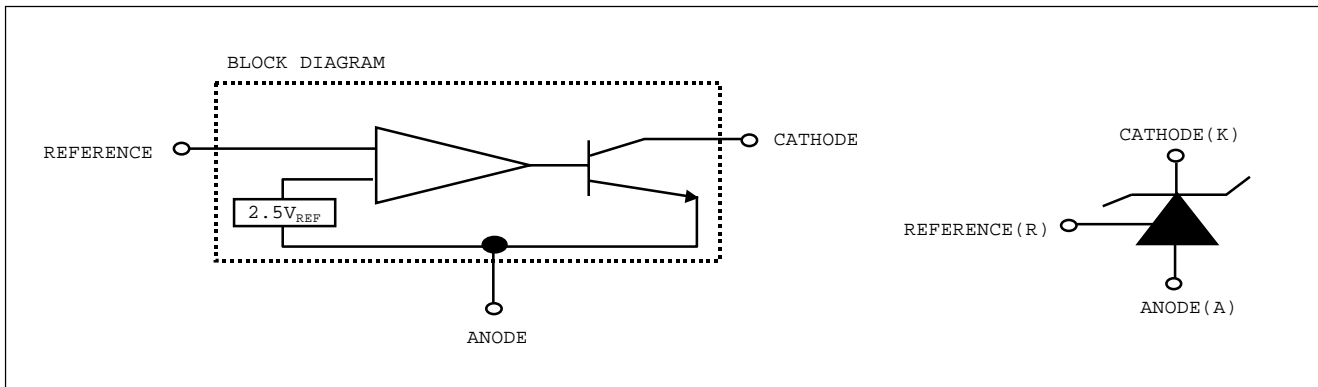
- Equivalent Full Range Temperature Coefficient 50PPM/ $^{\circ}C$
- Temperature Compensated For Operation Over Full Rate Operating Temperature Range
- Adjustable Output Voltage
- Fast Turn-on Response
- Sink Current Capability 1mA to 100mA
- Low (0.2 $\Omega$  Typ.) Dynamic Output Impedance
- Low Output Noise



## ORDERING INFORMATION

Device	Marking	Package
TL431	TL431	TO-92
TL431-A	TL431-A	
TL431-C	TL431-C	
TL431F	4N	SOT-89
TL431-AF	4A	
TL431-CF	4C	

## FUNCTION BLOCK DIAGRAM



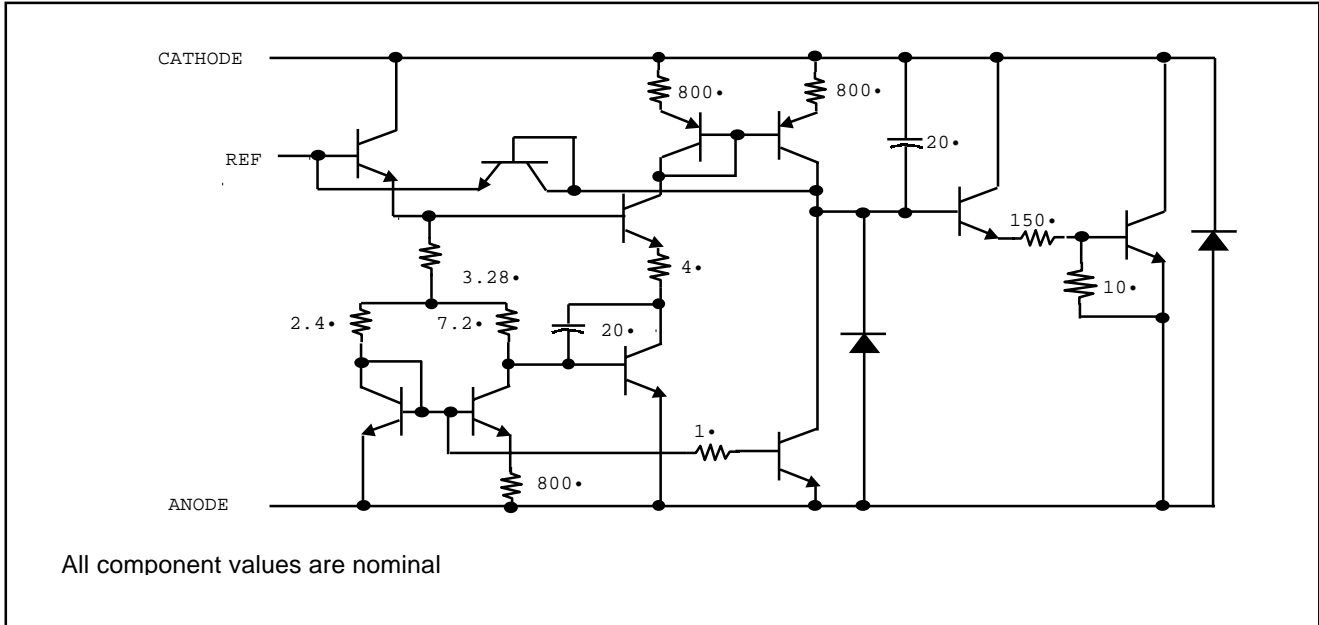
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# PROGRAMMABLE PRECISION SHUNT REGULATOR

TL431/A /C

## EQUIVALENT SCHEMATIC



## RECOMMENDED OPERATING CONDITIONS

CHARACTERISTIC	SYMBOL	MIN.	MAX.	UNIT
Cathode Voltage	$V_{KA}$	$V_{REF}$	36	V
Cathode Current	$I_K$	1	100	•

## DISSIPATION RATING TABLE1-FREE-AIR TEMPERATURE

Package	$T_A=25^\circ$ Power Rating	Derating Factor Above $T_A=25^\circ$	$T_A=70^\circ$ Power Rating	$T_A=85^\circ$ Power Rating	$T_A=125^\circ$ Power Rating
TO-92	775•	6.2•/•	496•	403•	-
SOT-89	500•	4.0•/•	320•	260•	-

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# PROGRAMMABLE PRECISION SHUNT REGULATOR

TL431/A /C

## ABSOLUTE MAXIMUM RATINGS

(Full Operating Ambient Temperature Range Applies Unless Otherwise Noted)

CHARACTERISTIC	SYMBOL	RATING	UNIT
Cathode Voltage	$V_{KA}$	37	V
Continuous Cathode Current Range	$I_{KA}$	-100~+150	•
Reference Input Current Range	$I_{REF}$	0.05~10	•
Junction Temperature	$T_J$	150	•
Operating Temperature	$T_{OPR}$	0~70	•
Storage Temperature	$T_{STG}$	-65~+150	•
Total Power Dissipation	$P_D$	700	•

## TL431 ELECTRICAL CHARACTERISTICS

( $T_A=25^\circ$ , unless otherwise specified)

CHARACTERISTIC	SYMBOL	CIR-CUIT	TEST CONDITION	MIN.	TYP.	MAX.	UNIT
Reference Input Voltage	$V_{REF}$	1	$V_{KA}=V_{REF}, I_K=10^\bullet$	2.440	2.495	2.550	V
Deviation of Reference			$V_{KA}=V_{REF}, I_K=10^\bullet$				
Input Voltage Over Full Temperature Range	$V_{REF}/ T$	1	$T_A=$ Full Range		4	17	•
Ratio of Change in Reference Input Voltage to the Change in Cathode Voltage	$V_{REF}/ V_{KA}$	2	$I_K=10^\bullet$ $V_{KA}=10V-V_{REF}$ $V_{KA}=36V-10V$		-1.4 -1	-2.7 -2	•/V
Reference Input Current	$I_{REF}$	2	$I_{KA}=10^\bullet, R1=10^\bullet, R2=^\bullet$		2	4	•
Deviation of Reference Input Current Over Full Temperature Range	$I_{REF}/ T$	2	$I_K=10^\bullet, R1=10^\bullet, R2=^\bullet$ $T_A=$ Full Range		0.4	1.2	•
Minimum Cathode Current for Regulation	$I_{KA}MIN$	1	$V_{KA}=V_{REF}$		0.4	1	•
Off-State Cathode Current	$I_{KA}OFF$	3	$V_{KA}=36V, V_{REF}=0$		0.1	1	•
Dynamic Impedance	$Z_{KA}$	1	$V_{KA}=V_{REF}, I_K=1^\bullet \sim 100^\bullet,$ $f \cdot 1^\bullet$		0.2	0.5	•

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# PROGRAMMABLE PRECISION SHUNT REGULATOR

TL431/A /C

## TL431A ELECTRICAL CHARACTERISTICS

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

CHARACTERISTIC	SYMBOL	CIR-CUIT	TEST CONDITION	MIN.	TYP.	MAX.	UNIT
Reference Input Voltage	V <sub>REF</sub>	1	V <sub>KA</sub> =V <sub>REF</sub> , I <sub>K</sub> =10•	2.470	2.495	2.520	V
Deviation of Reference Input Voltage Over Full Temperature Range	V <sub>REF</sub> / T	1	V <sub>KA</sub> =V <sub>REF</sub> , I <sub>K</sub> =10• T <sub>A</sub> =Full Range		4	17	•
Ratio of Change in Reference Input Voltage to the Change in Cathode Voltage	V <sub>REF</sub> / V <sub>KA</sub>	2	I <sub>K</sub> =10• V <sub>KA</sub> =10V-V <sub>REF</sub> V <sub>KA</sub> =36V-10V		-1.4	-2.7	•/V
Reference Input Current	I <sub>REF</sub>	2	I <sub>KA</sub> =10•, R1=10•, R2=•		2	4	•
Deviation of Reference Input Current Over Full Temperature Range	I <sub>REF</sub> / T	2	I <sub>K</sub> =10•, R1=10•, R2=• T <sub>A</sub> =Full Range		0.4	1.2	•
Minimum Cathode Current for Regulation	I <sub>KA</sub> MIN	1	V <sub>KA</sub> =V <sub>REF</sub>		0.4	1	•
Off-State Cathode Current	I <sub>KA</sub> OFF	3	V <sub>KA</sub> =36V, V <sub>REF</sub> =0		0.1	1	•
Dynamic Impedance	Z <sub>KA</sub>	1	V <sub>KA</sub> =V <sub>REF</sub> , I <sub>K</sub> =1•~100•, f•1•		0.2	0.5	•

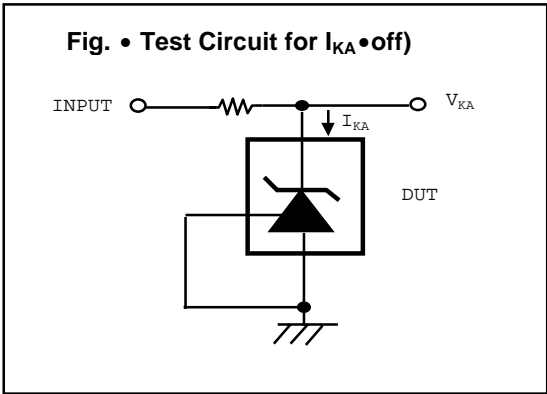
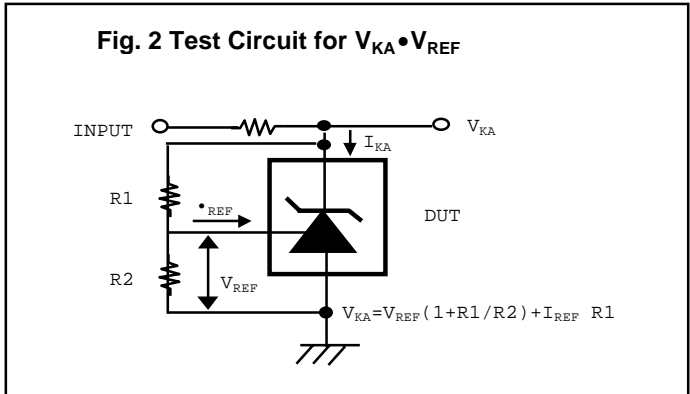
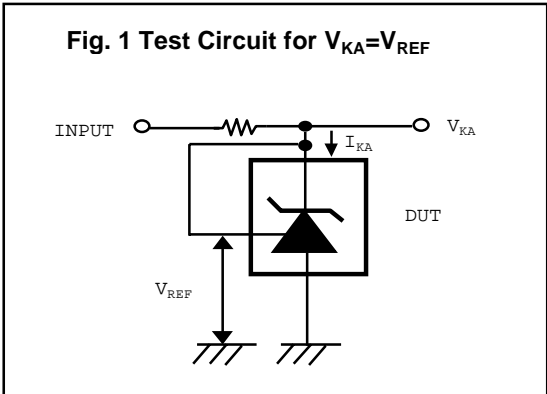
## TL431C ELECTRICAL CHARACTERISTICS

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

CHARACTERISTIC	SYMBOL	CIR-CUIT	TEST CONDITION	MIN.	TYP.	MAX.	UNIT
Reference Input Voltage	V <sub>REF</sub>	1	V <sub>KA</sub> =V <sub>REF</sub> , I <sub>K</sub> =10•	2.482	2.495	2.508	V
Deviation of Reference Input Voltage Over Full Temperature Range	V <sub>REF</sub> / T	1	V <sub>KA</sub> =V <sub>REF</sub> , I <sub>K</sub> =10• T <sub>A</sub> =Full Range		4	17	•
Ratio of Change in Reference Input Voltage to the Change in Cathode Voltage	V <sub>REF</sub> / V <sub>KA</sub>	2	I <sub>K</sub> =10• V <sub>KA</sub> =10V-V <sub>REF</sub> V <sub>KA</sub> =36V-10V		-1.4	-2.7	•/V
Reference Input Current	I <sub>REF</sub>	2	I <sub>KA</sub> =10•, R1=10•, R2=•		2	4	•
Deviation of Reference Input Current Over Full Temperature Range	I <sub>REF</sub> / T	2	I <sub>K</sub> =10•, R1=10•, R2=• T <sub>A</sub> =Full Range		0.4	1.2	•
Minimum Cathode Current for Regulation	I <sub>KA</sub> MIN	1	V <sub>KA</sub> =V <sub>REF</sub>		0.4	1	•
Off-State Cathode Current	I <sub>KA</sub> OFF	3	V <sub>KA</sub> =36V, V <sub>REF</sub> =0		0.1	1	•
Dynamic Impedance	Z <sub>KA</sub>	1	V <sub>KA</sub> =V <sub>REF</sub> , I <sub>K</sub> =1•~100•, f•1•		0.2	0.5	•

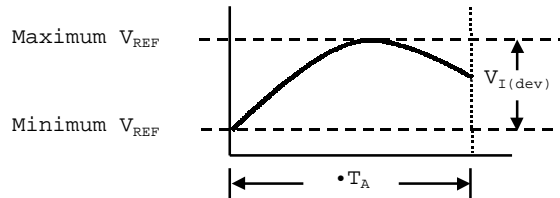
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The deviation parameters  $V_{REF(DEV)}$  and  $I_{REF(DEF)}$  are defined as the differences between the maximum and minimum values obtained over the recommended temperature range. The average full-range temperature coefficient of the reference voltage,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

$$\bullet V_{REF} \bullet \frac{ppm}{\bullet} = \frac{V_{T(dev)} \bullet x10^6}{\bullet T_A}$$



Where :

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

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

Example : Maximum  $V_{REF}=2496$  at  $30$ , maximum  $V_{REF}=2492$  at  $0$ ,  $V_{REF}=2495$  at  $25$ ,  $T_A=70$  for TL431C

$$\bullet V_{REF} \bullet = \frac{4 \bullet}{70 \bullet} \bullet x10^6 \sim 23PPM/\bullet$$

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

**Calculating Dynamic Impedance**

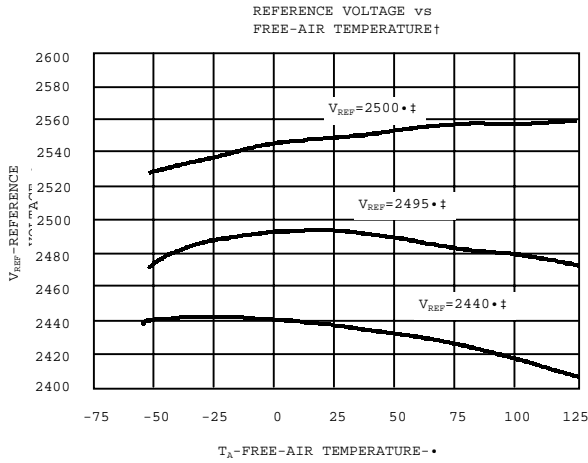
The dynamic impedance is defined as :  $\bullet Z_{KA} \bullet = \frac{\bullet V_{KA}}{\bullet I_{KA}}$

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

$$\bullet Z' \bullet = \frac{\bullet V}{\bullet I} \sim \bullet Z_{KA} \bullet \bullet 1 + \frac{R1}{R2} \bullet$$

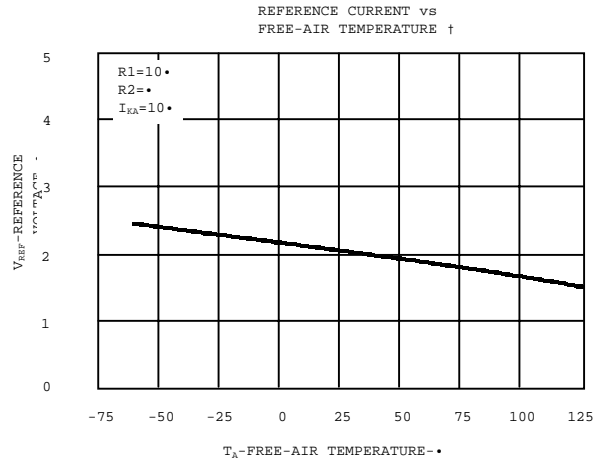
**Figure 1. Calculating deviation parameters and dynamic impedance**

TYPICAL PERFORMANCE CHARACTERISTICS



† Data is applicable only within the recommended operating free-air temperature ranges of the various devices.  
‡ Data is for devices having the indicated value of  $V_{REF}$  at  $I_{KA}=10$ ,  $T_A=25$ .

Figure 4.



† Data is applicable only within the recommended operating free-air temperature ranges of the various devices.

Figure 5.

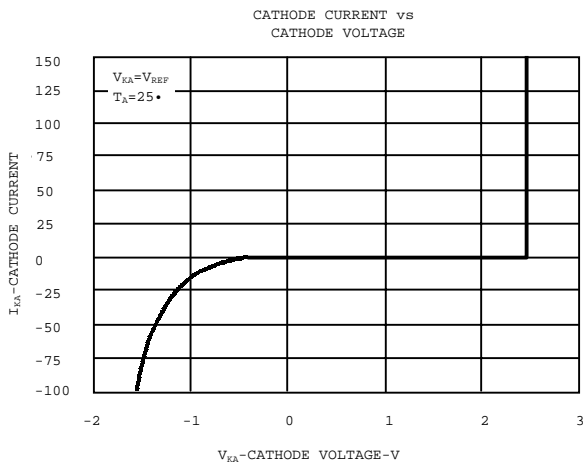


Figure 6.

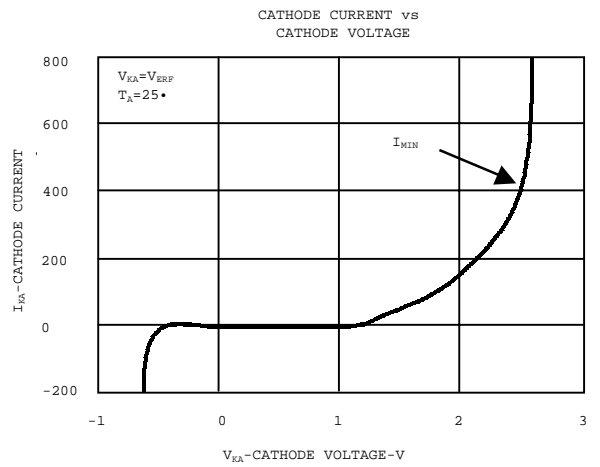
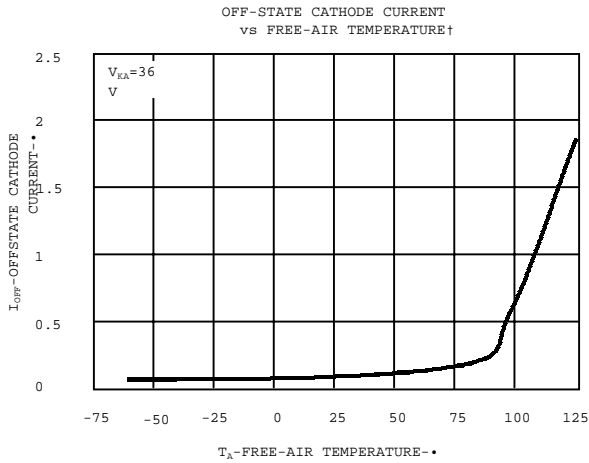


Figure 7.

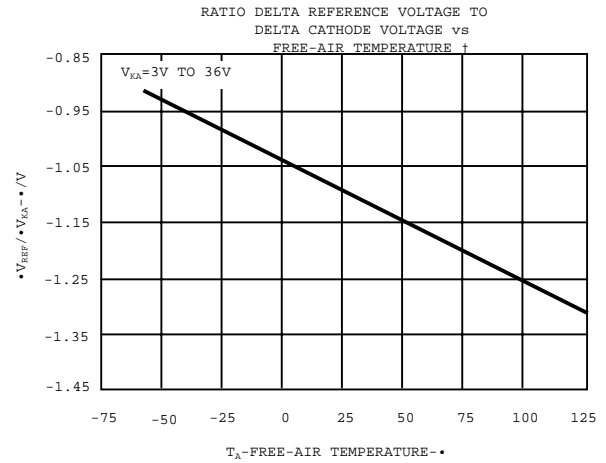
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**TYPICAL PERFORMANCE CHARACTERISTICS**



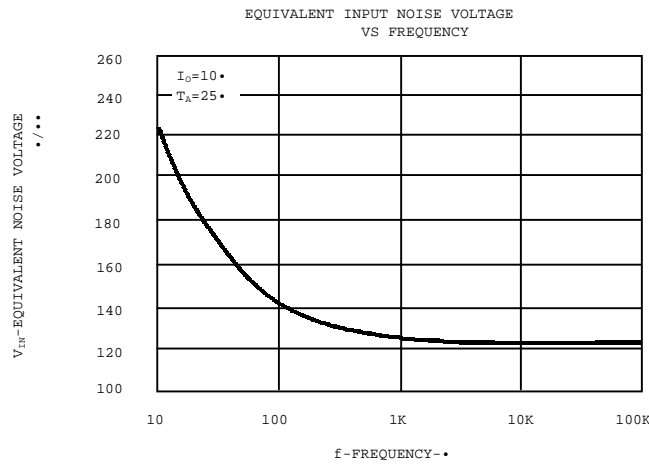
† Data is applicable only within the recommended operating free-air temperature ranges of the various devices.

**Figure 8.**



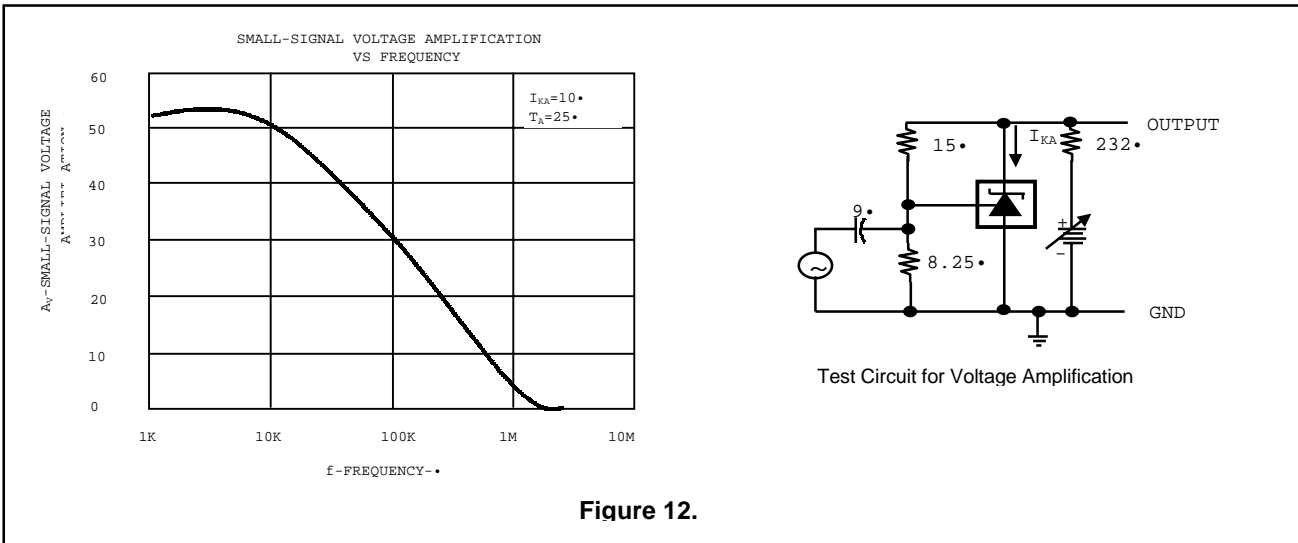
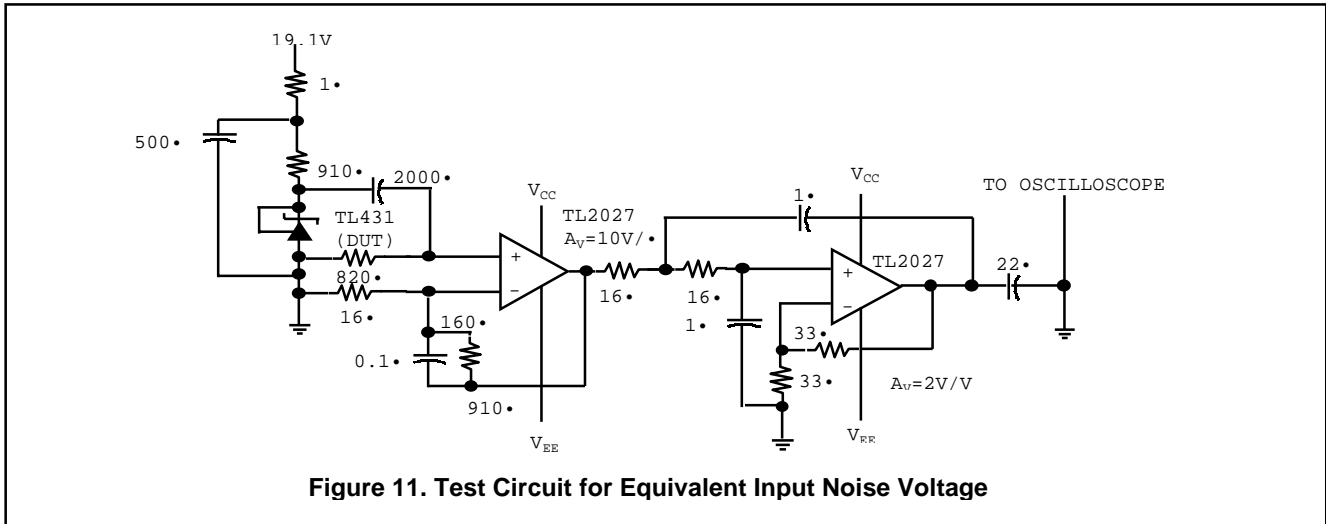
† Data is applicable only within the recommended operating free-air temperature ranges of the various devices.

**Figure 9.**



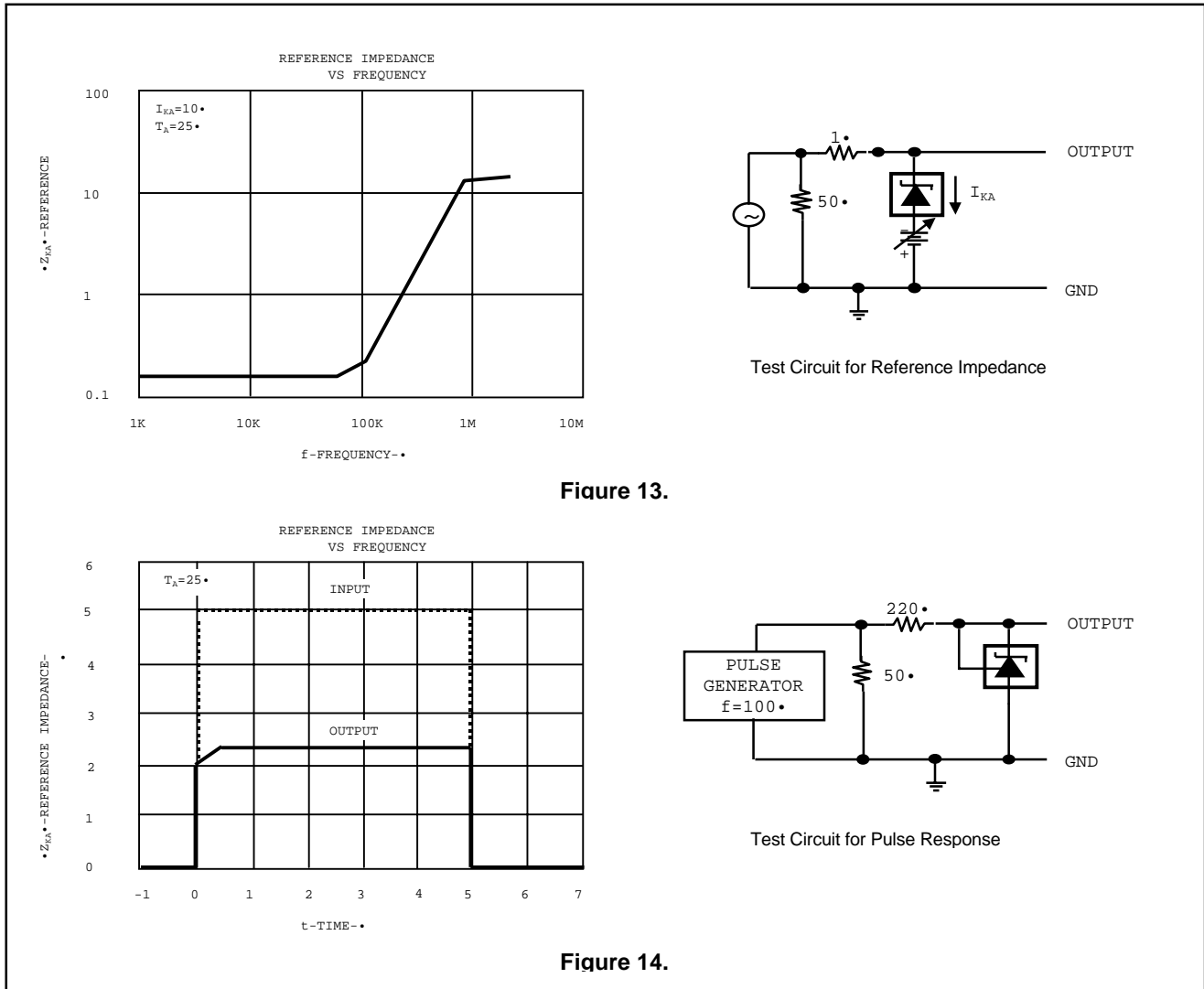
**Figure 10.**

**TYPICAL PERFORMANCE CHARACTERISTICS**

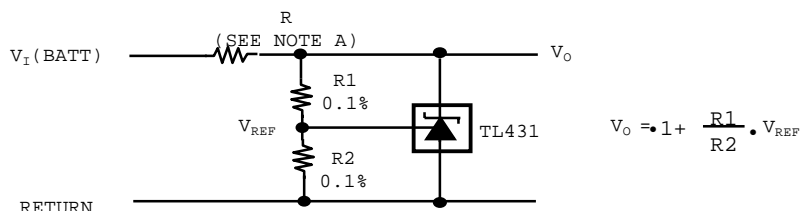


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**TYPICAL PERFORMANCE CHARACTERISTICS**

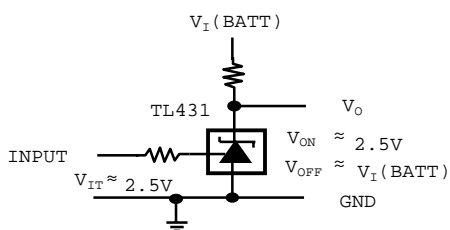


**APPLICATION INFORMATION**

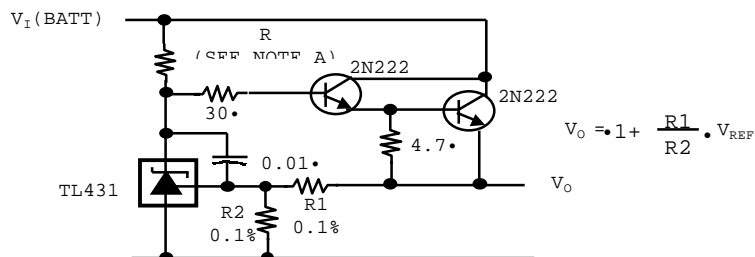


NOTE A : R Should provide cathode current  $\cdot 1 \cdot$  to the TL431 at minimum  $V_I(BATT)$

**Figure 15. Shunt Regulator**



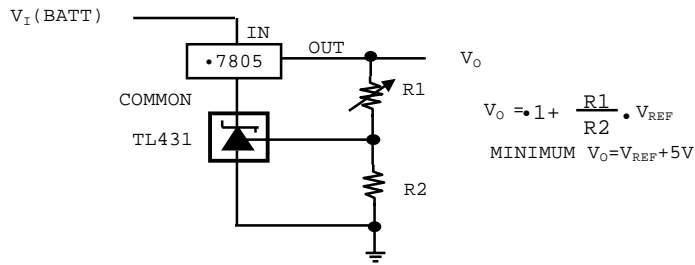
**Figure 16. Single-Supply Comparator With Temperature-Compensated Threshold**



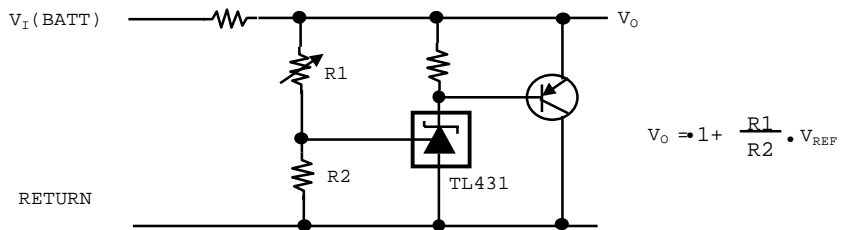
NOTE A : R Should provide cathode current  $\cdot 1 \cdot$  to the TL431 at minimum  $V_I(BATT)$

**Figure 17. Precision High-Current Series Regulator**

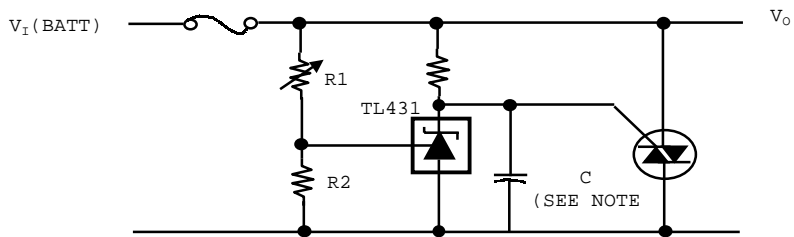
**APPLICATION INFORMATION**



**Figure 18. Output Control of a 3-Terminal Fixed Regulator**



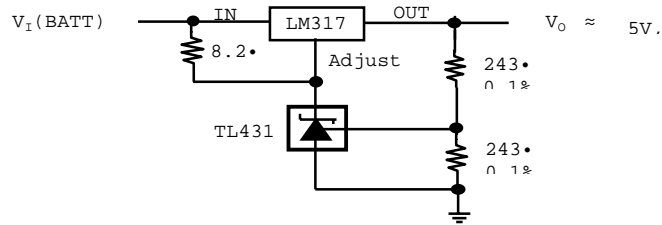
**Figure 19. High-Current Shunt Regulator**



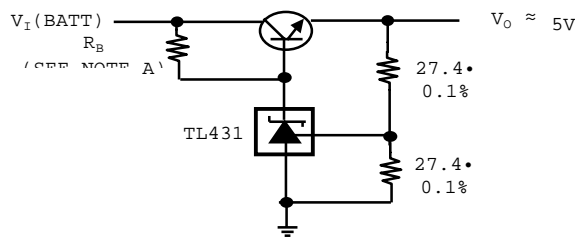
NOTE A : Refer to the stability boundary conditions in Figure 16 to determine allowable values for C.

**Figure 20. Crowbar Circuit**

**APPLICATION INFORMATION**

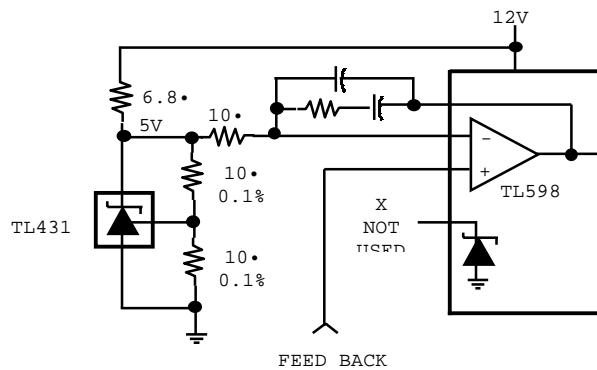


**Figure 21. Precision 5-V 1.5A Regulator**



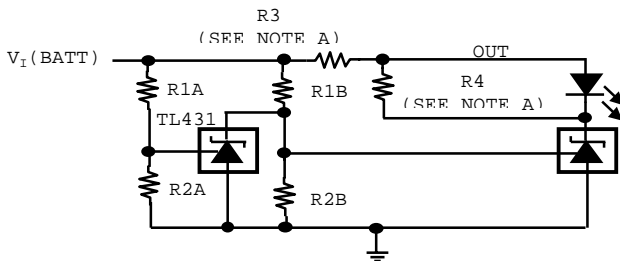
NOTE A :  $R_B$  should provide cathode current  $\cdot 1 \cdot$  to the TL431.

**Figure 22. Efficient 5-V Precision Regulator**



**Figure 23. PWM Converter With Reference**

APPLICATION INFORMATION



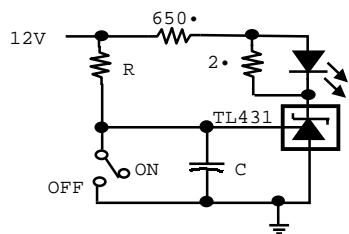
$$\text{LOW LIMIT} = \left(1 + \frac{R1B}{R2B}\right) \cdot V_{REF}$$

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

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

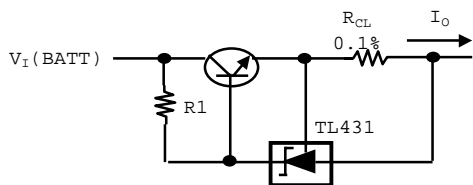
NOTE A : R3 and R4 are selected to provide the desired LED intensity and cathode current  $\cdot$  1  $\cdot$  to the TL431 at the available  $V_{I(BATT)}$

Figure 24. Voltage Monitor



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

Figure 25. Delay Timer

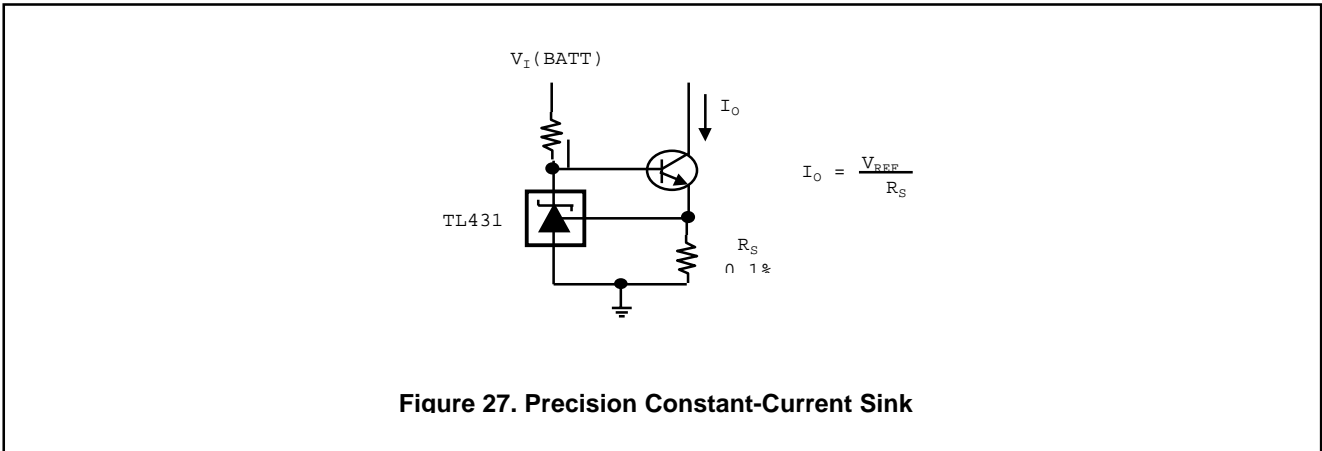


$$I_{OUT} = \frac{V_{REF}}{R_{CL}} + I_{KA}$$

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

Figure 26. Precision Current Limiter

**APPLICATION INFORMATION**



**Figure 27. Precision Constant-Current Sink**