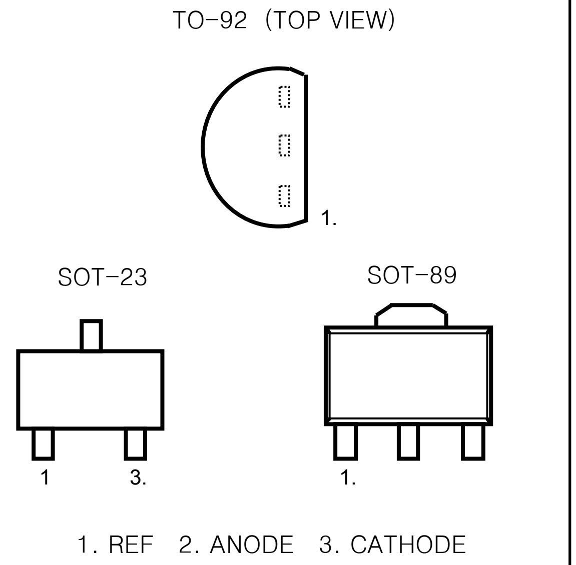
PROGRAMMABLE PRECISION SHUNT REGULATOR TL431/A /C

PROGRAMMABLE PRECISION REFERENCES

The TL431 is three-terminal adjustable shunt regulator with specified termal 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 inpedance of 0.2Ω.
Active output circuitry provides a very sharp turn-on characteristic, making this device excellent replacement for zener diodes in many application.



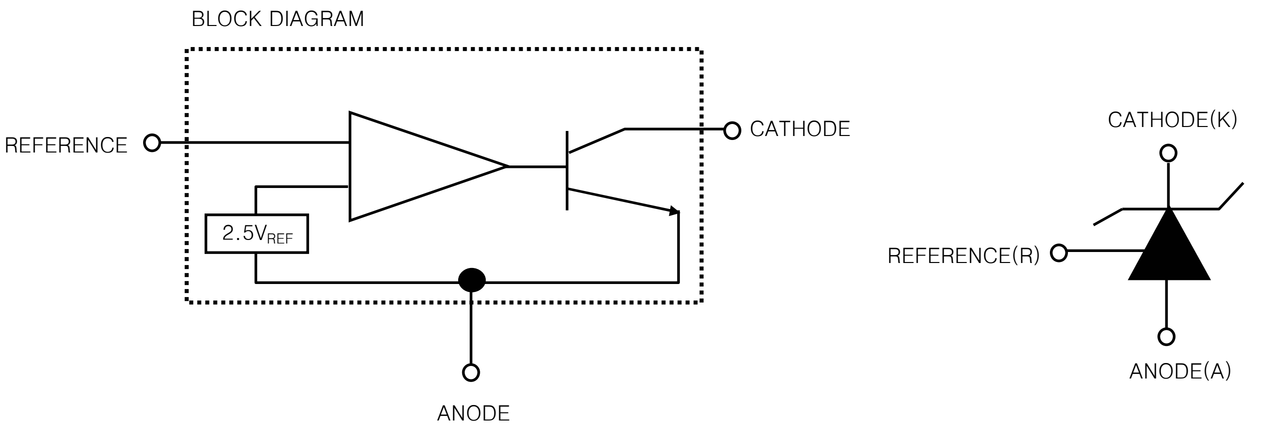
FEATURES

- Equivalent Full Range Temperature Coefficient 50PPM/℃
- Temperature Compensated For Operation Over Full Rate Operating Temperature Range
- Adjustable Output Voltage
- Fast Turn-on Response
- Sink Current Capability 1㎃ to 100㎃
- Low (0.2Ω Typ.) Dynamic Output Impedance
- Low Output Noise

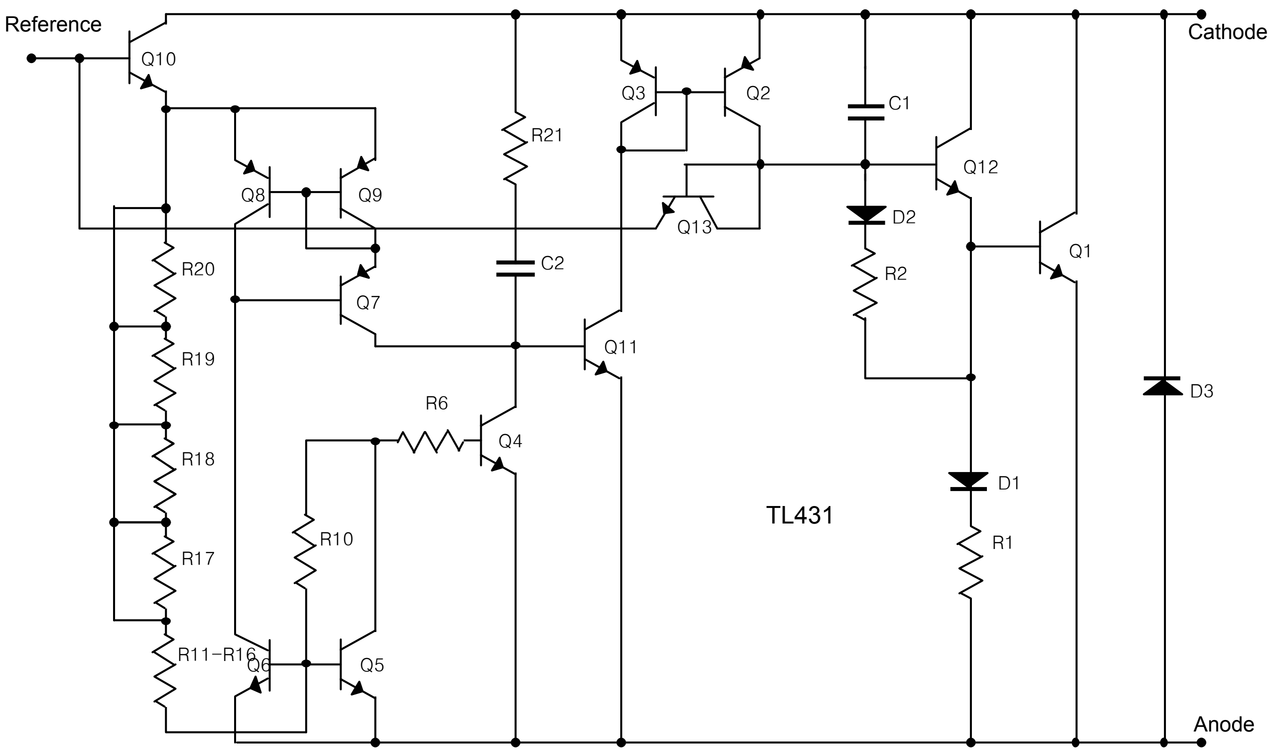
ORDERING INFORMATION

Device	Marking	Package
TL431	TL431	TO-92
TL431-A	TL431-A	
TL431-C	TL431-C	
TL431SF	431	SOT-23
TL431-ASF	* Packing label is different as Vref	
TL431-CSF		
TL431F	431	SOT-89
TL431-AF	* Packing label is different as Vref	
TL431-CF		

FUNCTION BLOCK DIAGRAM



EQUIVALENT SCHEMATIC



- All component values are nominal

RECOMMENDED OPERATING CONDITIONS

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

DISSIPATION RATING TABLE1-FREE-AIR TEMPERATURE

Package	T_A=25℃ Power Rating	Derating Factor Above T_A=25℃	T_A=70℃ Power Rating	T_A=85℃ Power Rating	T_A=125℃ Power Rating
TO-92	770mW	6.2mW/℃	491mW	398mW	-
SOT-89	500mW	4.0mW/℃	320mW	260mW	-
SOT-23	230mW	1.8mW/℃	149mW	122mW	-

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	mA
Reference Input Current Range	I_{REF}	0.05~10	mA
Junction Temperature	T_J	150	℃
Operating Temperature	T_{OPR}	−20 ~ 85	℃
Storage Temperature	T_{STG}	−65 ~ 150	℃
Total Power Dissipation	P_D	700	mW

TL431 ELECTRICAL CHARACTERISTICS
(T_A=25℃, 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=10mA		2.440	2.495	2.550	V
Deviation of Reference Input Voltage Over Full Temperature Range	$\Delta V_{REF}/\Delta T$	1	$V_{KA}=V_{REF}$, I_K=10mA T_A=Full Range			3	17	mV
Ratio of Change in Reference Input Voltage to the Change in Cathod Voltage	$\Delta V_{REF}/\Delta V_{KA}$	2	I_K=10mA	ΔV_{KA}=10V−V_{REF}		−1.4	−2.7	mV/V
				ΔV_{KA}=36V−10V		−1	−2	
Reference Input Current	I_{REF}	2	I_{KA}=10mA, R1=10kΩ, R2=∞			1.8	4	µA
Deviation of Reference Input Current Over Full Temperature Range	$\Delta I_{REF}/\Delta T$	2	I_K=10mA, R1=10kΩ, R2=∞ T_A=Full Range			0.4	1.2	µA
Minimum Cathode Current for Regulation	I_{KA}MIN	1	$\Delta V_{KA}=V_{REF}$			0.5	1	mA
Off-State Cathode Current	I_{KA}OFF	3	V_{KA}=36V, V_{REF}=0			0.2	1	µA
Dynamic Impedance	Z_{KA}	1	$V_{KA}=V_{REF}$, I_K=1mA~100mA, f≤1kHz			0.2	0.5	Ω

TL431A ELECTRICAL CHARACTERISTICS

(T_A=25℃, 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=10mA		2.470	2.495	2.520	V
Deviation of Reference Input Voltage Over Full Temperature Range	$\Delta V_{REF}/\Delta T$	1	$V_{KA}=V_{REF}$, I_K=10mA T_A=Full Range			3	17	mV
Ratio of Change in Reference Input Voltage to the Change in Cathod Voltage	$\Delta V_{REF}/\Delta V_{KA}$	2	I_K=10mA	ΔV_{KA}=10V−V_{REF}		−1.4	−2.7	mV/V
				ΔV_{KA}=36V−10V		−1	−2	
Reference Input Current	I_{REF}	2	I_{KA}=10mA, R1=10kΩ, R2=∞			1.8	4	μA
Deviation of Reference Input Current Over Full Temperature Range	$\Delta I_{REF}/\Delta T$	2	I_K=10mA, R1=10kΩ, R2=∞ T_A=Full Range			0.4	1.2	μA
Minimum Cathode Current for Regulation	$I_{KA}MIN$	1	$\Delta V_{KA}=V_{REF}$			0.5	1	mA
Off-State Cathode Current	$I_{KA}OFF$	3	V_{KA}=36V, V_{REF}=0			0.2	1	μA
Dynamic Impedance	Z_{KA}	1	$V_{KA}=V_{REF}$, I_K=1mA~100mA, f≤1kHz			0.2	0.5	Ω

TL431C ELECTRICAL CHARACTERISTICS

(T_A=25℃, 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=10mA		2.482	2.495	2.508	V
Deviation of Reference Input Voltage Over Full Temperature Range	$\Delta V_{REF}/\Delta T$	1	$V_{KA}=V_{REF}$, I_K=10mA T_A=Full Range			3	17	mV
Ratio of Change in Reference Input Voltage to the Change in Cathod Voltage	$\Delta V_{REF}/\Delta V_{KA}$	2	I_K=10mA	ΔV_{KA}=10V−V_{REF}		−1.4	−2.7	mV/V
				ΔV_{KA}=36V−10V		−1	−2	
Reference Input Current	I_{REF}	2	I_{KA}=10mA, R1=10kΩ, R2=∞			1.8	4	μA
Deviation of Reference Input Current Over Full Temperature Range	$\Delta I_{REF}/\Delta T$	2	I_K=10mA, R1=10kΩ, R2=∞ T_A=Full Range			0.4	1.2	μA
Minimum Cathode Current for Regulation	$I_{KA}MIN$	1	$\Delta V_{KA}=V_{REF}$			0.5	1	mA
Off-State Cathode Current	$I_{KA}OFF$	3	V_{KA}=36V, V_{REF}=0			0.2	1	μA
Dynamic Impedance	Z_{KA}	1	$V_{KA}=V_{REF}$, I_K=1mA~100mA, f≤1kHz			0.2	0.5	Ω

Fig. 1 Test Circuit for $V_{KA}=V_{REF}$

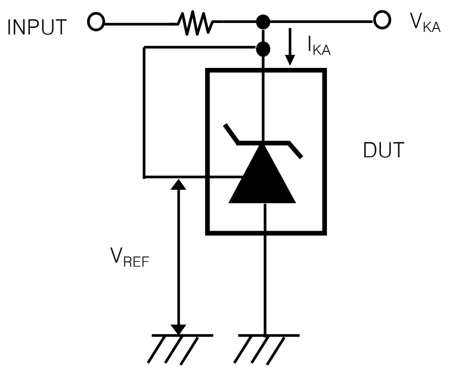


Fig. 2 Test Circuit for $V_{KA} \geq V_{REF}$

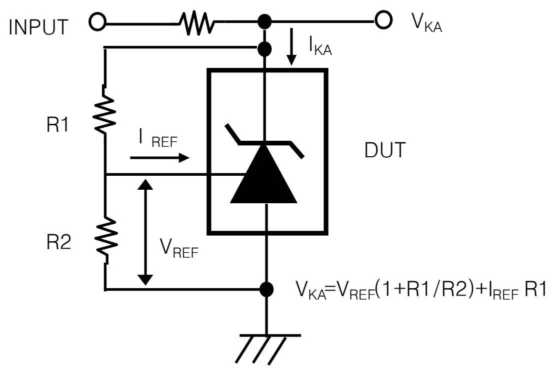
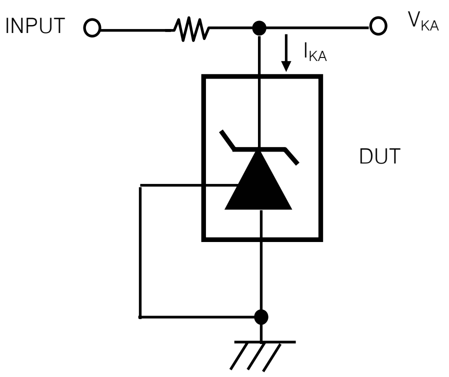
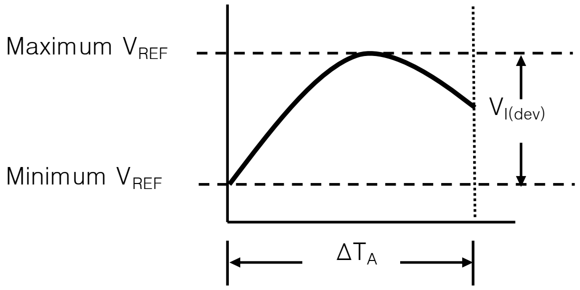


Fig. 3 Test Circuit for I_{KA} (off)



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, αV_{REF}, is defined as :

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



Where :

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

αV_{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℃, ΔT_A=70℃ for TL431C

$$|\alpha V_{REF}| = \frac{\left(\frac{4㎷}{2495㎷}\right) \times 10^6}{70℃} \approx 23PPM/℃$$

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

Calculating Dynamic Impedance

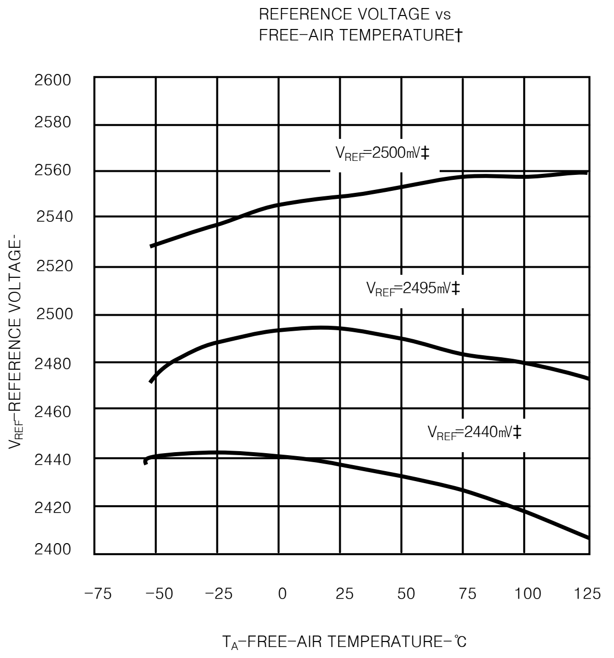
The dynamic impedance is defined as : $|Z_{KA}| = \frac{\Delta V_{KA}}{\Delta I_{KA}}$

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

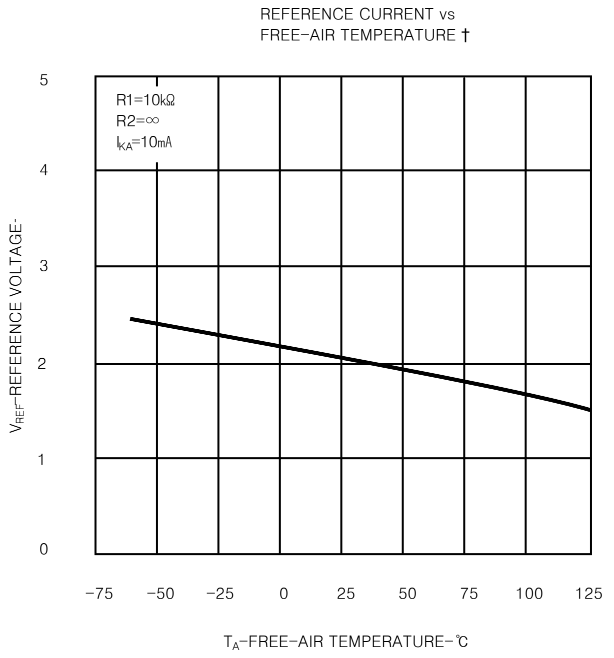
TYPICAL PERFORMANCE CHARACTERISTICS



† 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}=10mV, T_A=25℃

Figure 4.



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

Figure 5.

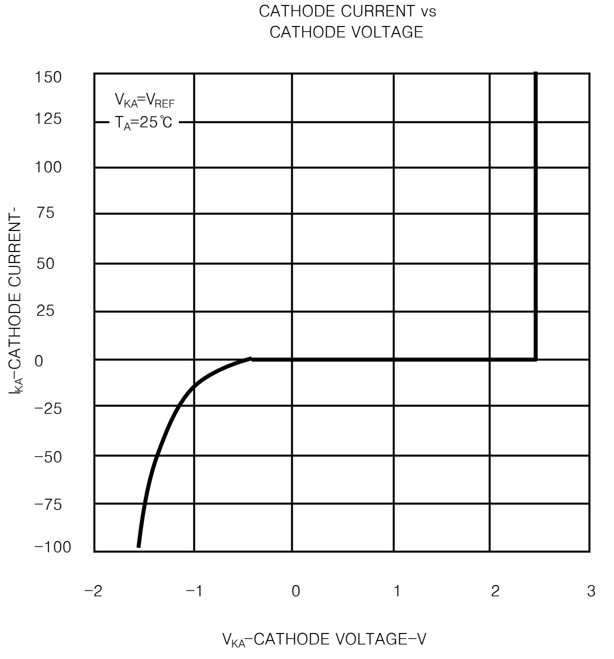


Figure 6.

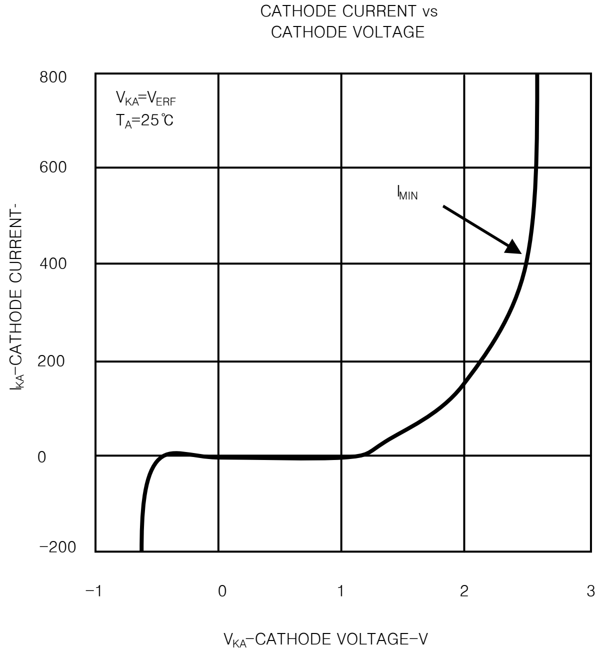
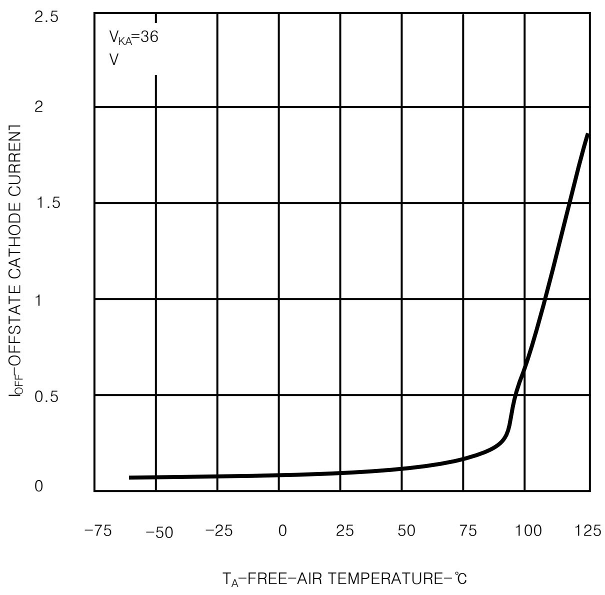


Figure 7.

TYPICAL PERFORMANCE CHARACTERISTICS

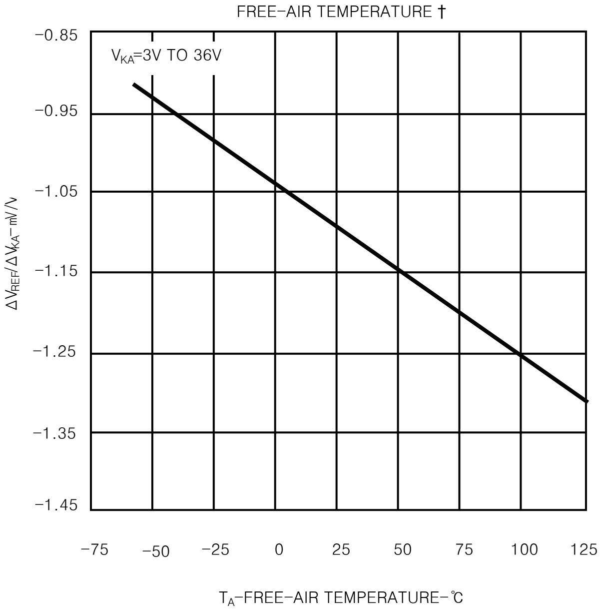
OFF-STATE CATHODE CURRENT
vs FREE-AIR TEMPERATURE†



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

Figure 8.

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



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

Figure 9.

EQUIVALENT INPUT NOISE VOLTAGE
VS FREQUENCY

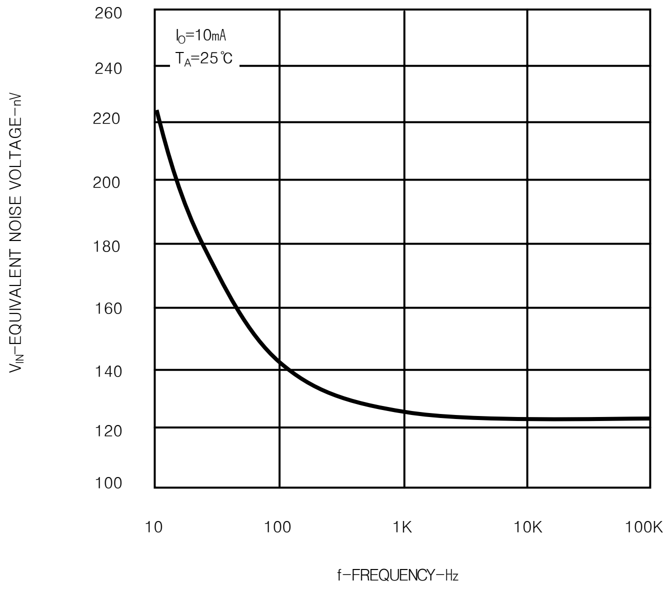


Figure 10.

TYPICAL PERFORMANCE CHARACTERISTICS

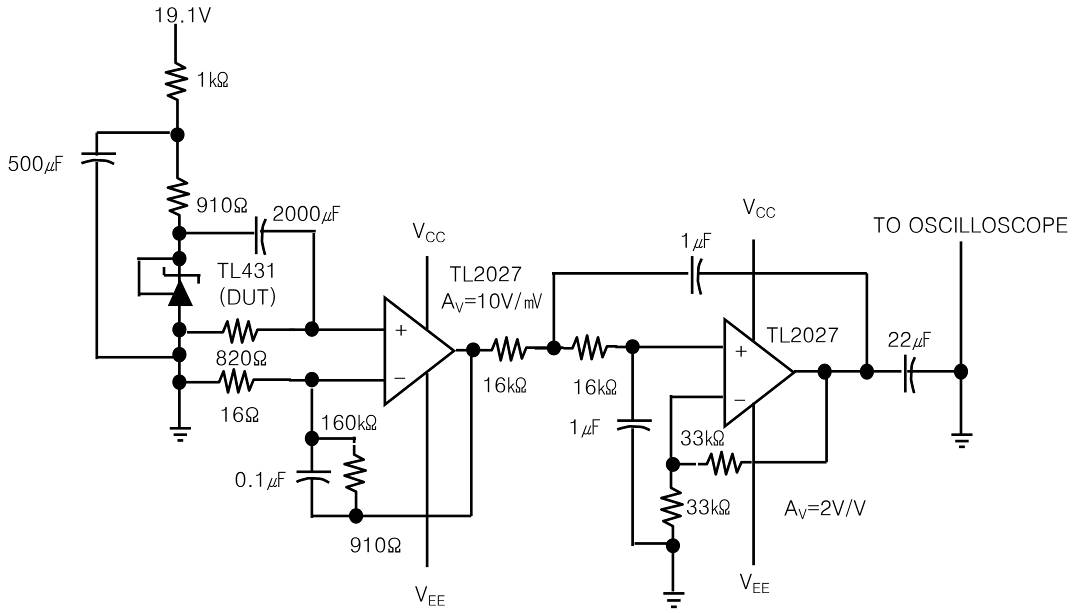
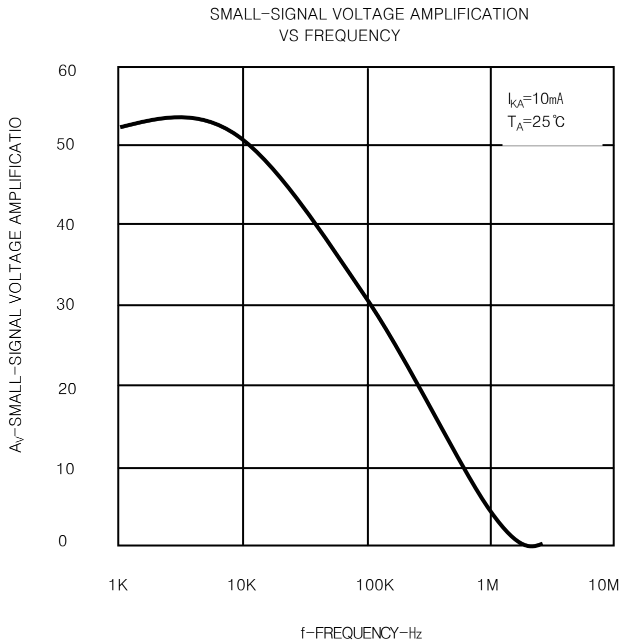
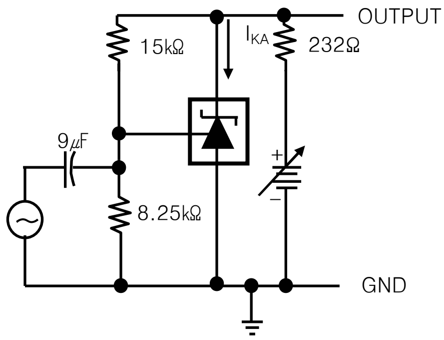


Figure 11. Test Circuit for Equivalent Input Noise Voltage

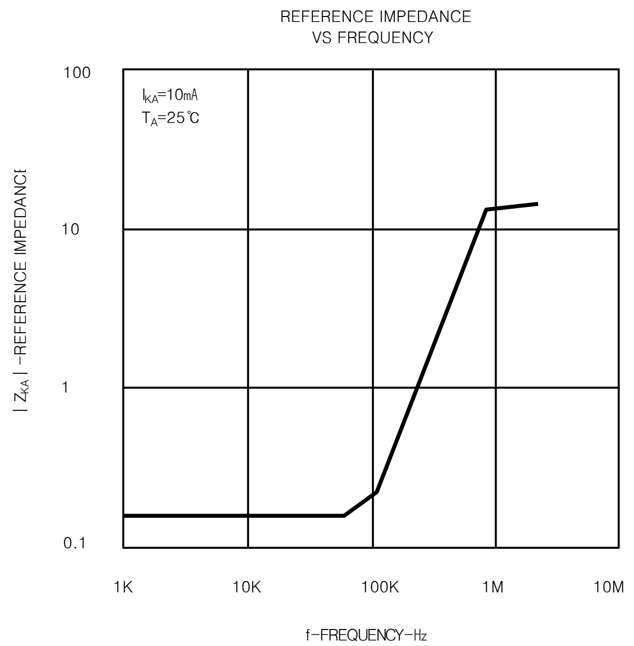


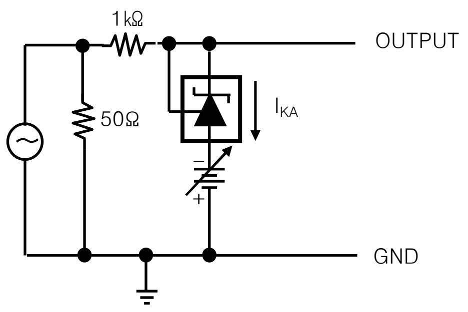


Test Circuit for Voltage Amplification

Figure 12.

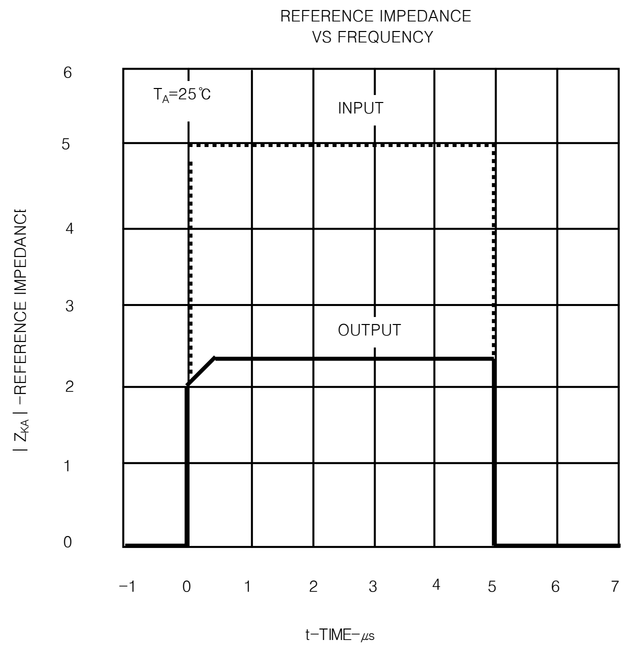
TYPICAL PERFORMANCE CHARACTERISTICS

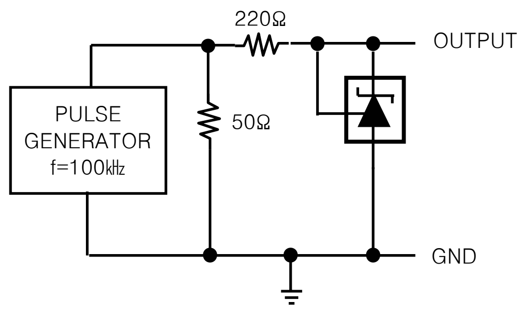




Test Circuit for Reference Impedance

Figure 13.

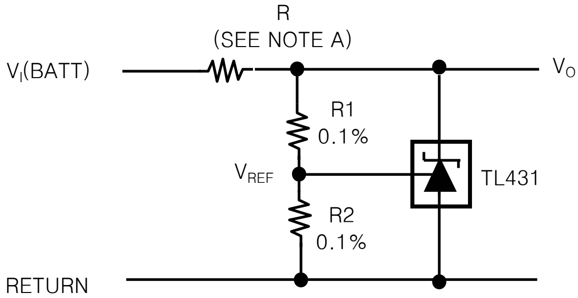




Test Circuit for Pulse Response

Figure 14.

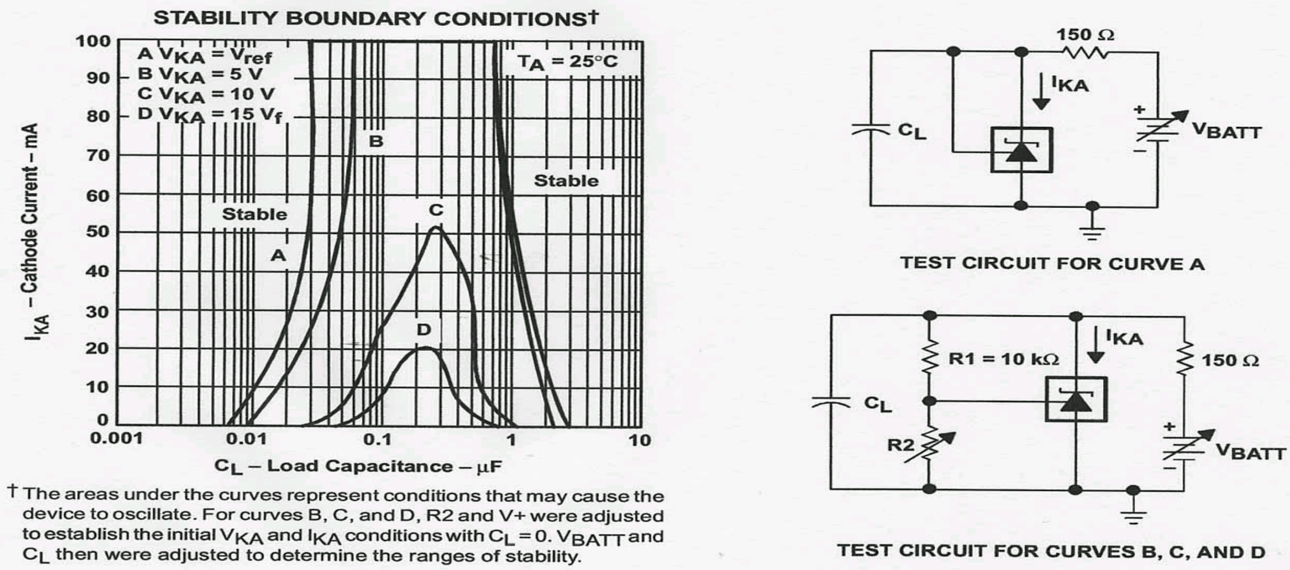
APPLICATION INFORMATION



$V_O = (1 + \frac{R1}{R2})\, V_{REF}$

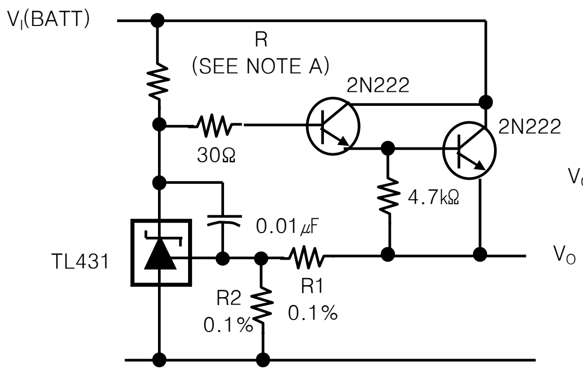
NOTE A : R Should provide cathode current≥1㎃ to the TL431 at minimum V_I(BATT)

Figure 15. Shunt Regulator



† 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.

Figure 16



$V_O = (1 + \frac{R1}{R2})\, V_{REF}$

NOTE A : R Should provide cathode current≥1㎃ to the TL431 at minimum V_I(BATT)

Figure 17. Precision High-Current Series Regulator

APPLICATION INFORMATION

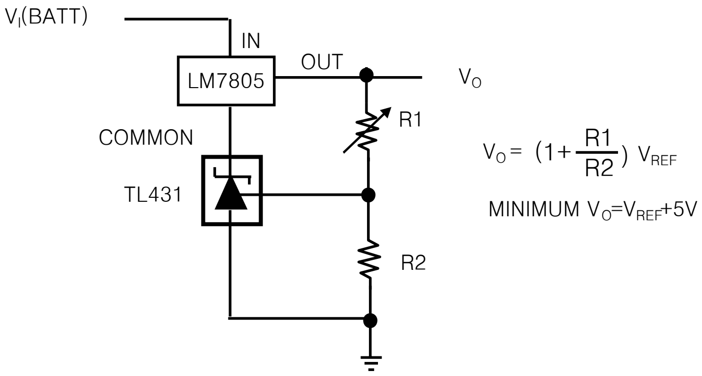


Figure 18. Output Control of a 3-Terminal Fixed Regulator

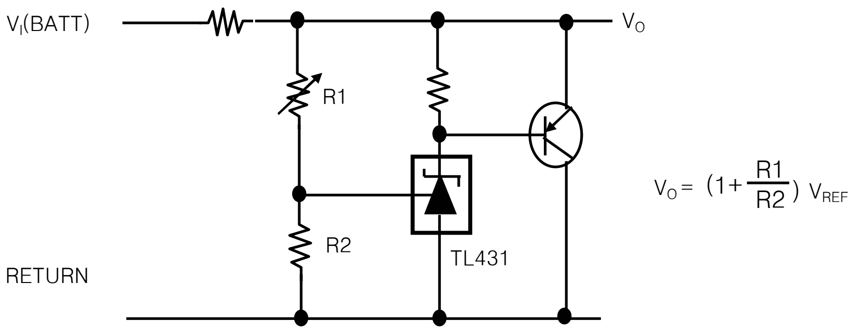
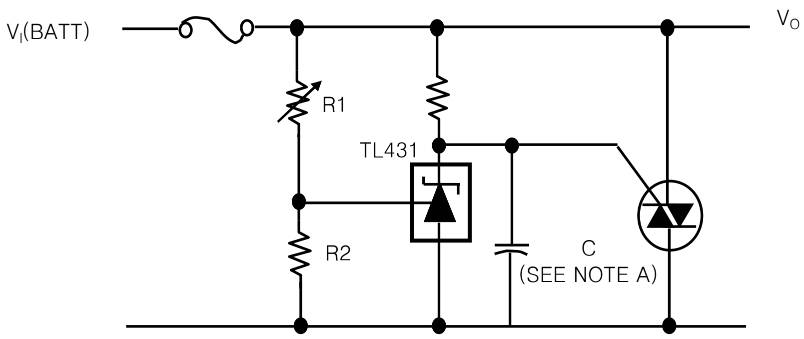


Figure 19. High-Current Shunt Regulator



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

Figure 20. Crowbar Circuit

APPLICATION INFORMATION

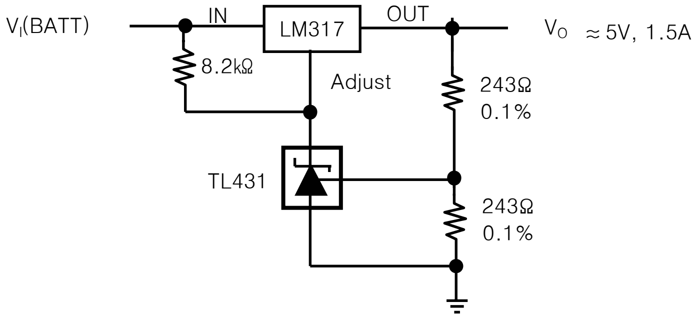
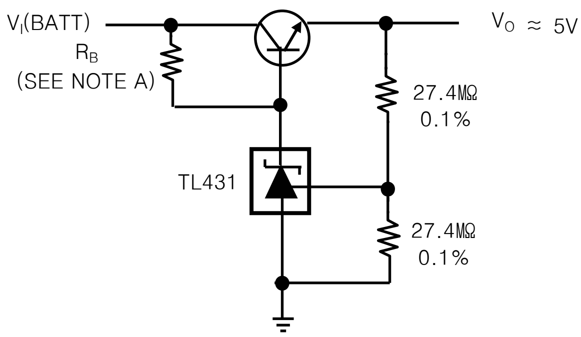


Figure 21. Precision 5-V 1.5A Regulator



NOTE A : R_B Should provide cathode current≥1㎃ to the TL431.

Figure 22. Efficient 5-V Precision Regulator

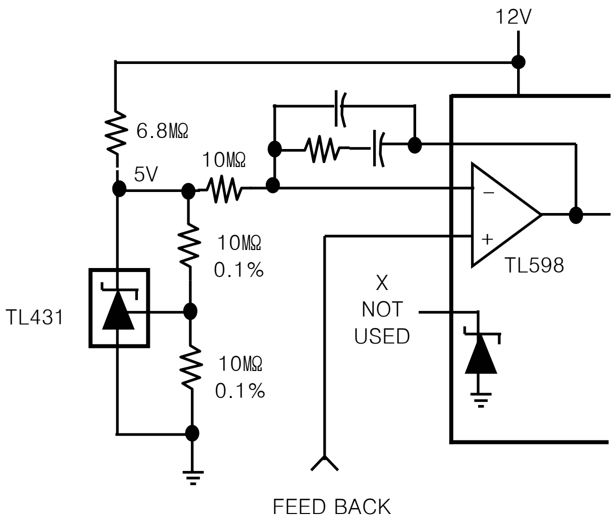
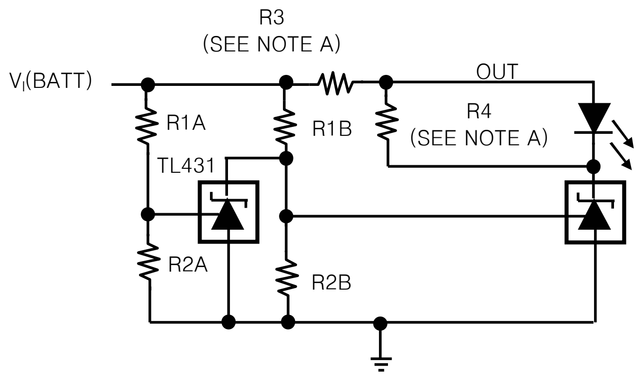


Figure 23. PWM Converter With Reference

APPLICATION INFORMATION



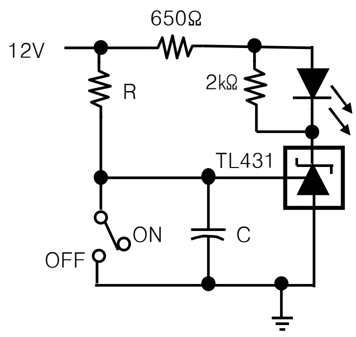
LOW LIMIT= $\left(1+\frac{R1B}{R2B}\right) V_{REF}$

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

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

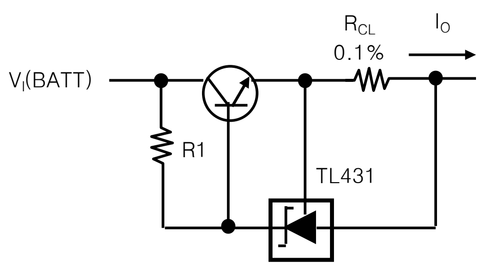
NOTE A : R3 and R4 are selected to provide the desired LED intensity and cathode current ≥1㎃ to the TL431 at the available $V_{I(BATT)}$.

Figure 24. Voltage Monitor



DELAY=RxCxI$_N$ $\left(\frac{12V}{12V-V_{REF}}\right)$

Figure 25. Delay Timer



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

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

Figure 26. Precision Current Limiter

APPLICATION INFORMATION

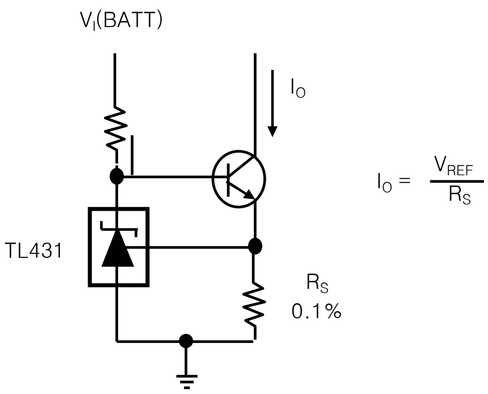


Figure 27. Precision Constant-Current Sink