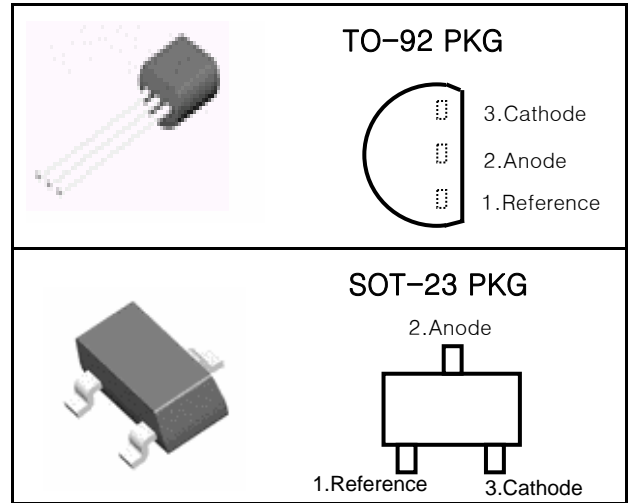


**PROGRAMMABLE PRECISION REFERENCES**

The TL431Z 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 0.2Ω. Active output circuitry provides a very sharp turn-on characteristic, making this device excellent replacement for zener diodes in many application.



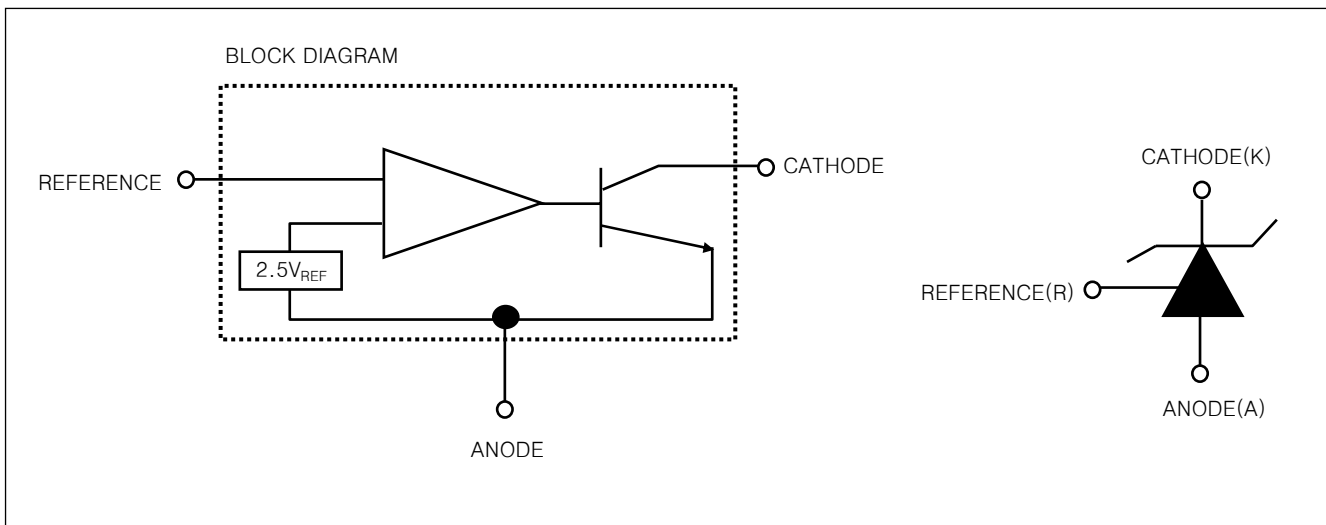
**FEATURES**

- Equivalent Full Range Temperature Coefficient 50PPM/°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 (0.2Ω Typ.) Dynamic Output Impedance
- Low Output Noise

**ORDERING INFORMATION**

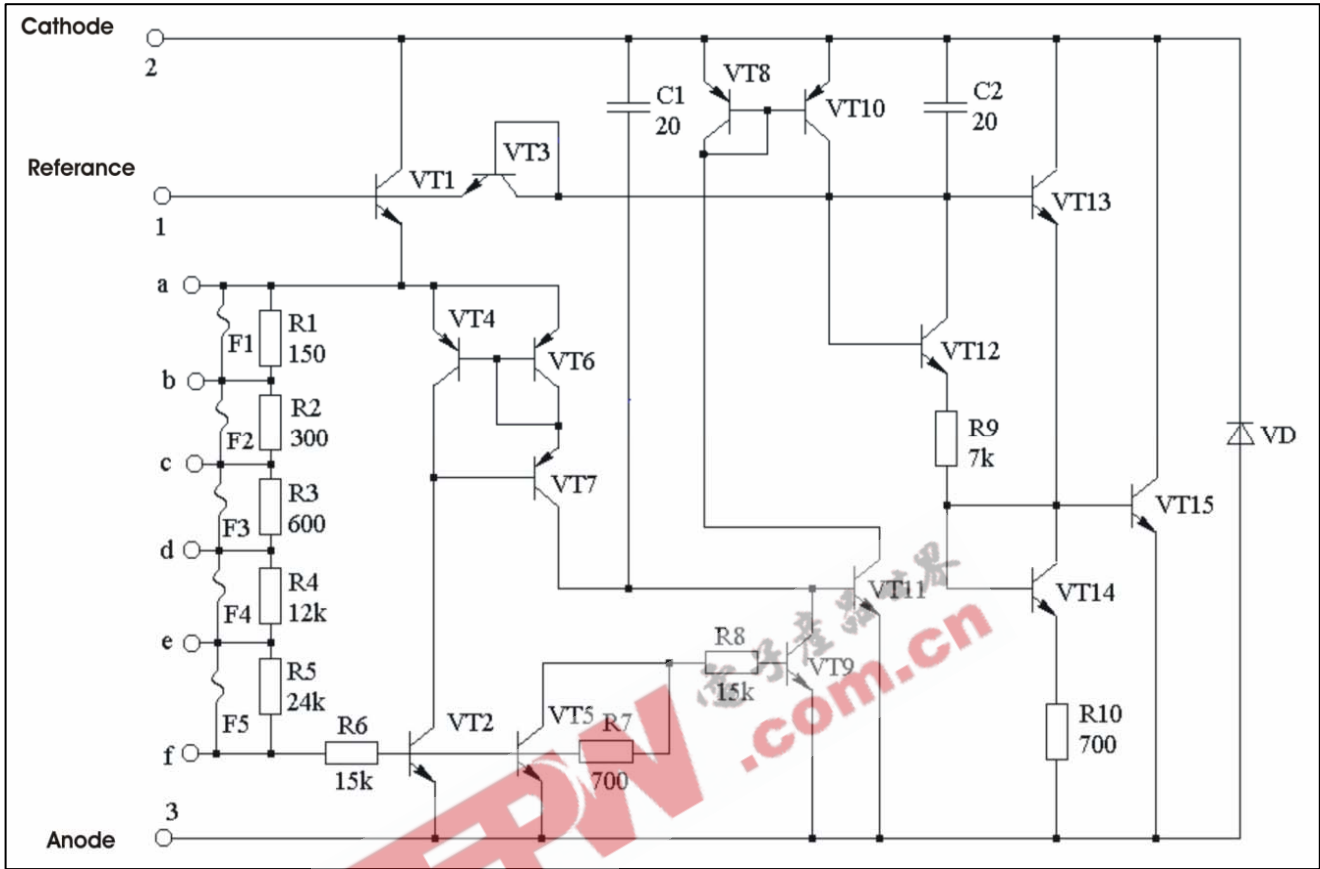
Device	Marking	Package
TL431Z	TL431Z	TO-92
TL431-AZ	TL431-AZ	
TL431-CZ	TL431-CZ	
TL431ZSF	431	SOT-23
TL431-AZSF	* Packing label is different as Vref	
TL431-CZSF		

**FUNCTION BLOCK DIAGRAM**



# PROGRAMMABLE PRECISION SHUNT REGULATOR TL431Z/AZ/ICZ

## 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	$T_A=25^\circ\text{C}$ Power Rating	Derating Factor Above $T_A=25^\circ\text{C}$	$T_A=70^\circ\text{C}$ Power Rating	$T_A=85^\circ\text{C}$ Power Rating	$T_A=125^\circ\text{C}$ Power Rating
TO-92	770mW	6.2mW/ $^\circ\text{C}$	491mW	398mW	-
SOT-23	230mW	1.8mW/ $^\circ\text{C}$	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	$I_{REF}$	2 ~ 4	$\mu A$
Junction Temperature	$T_J$	150	$^{\circ}C$
Operating Temperature	$T_{OPR}$	-40 ~ 85	$^{\circ}C$
Storage Temperature	$T_{STG}$	-65 ~ 150	$^{\circ}C$
Thermal Resistance Junction to Ambient	$\Theta_{JA}$	TO-92 PKG = 178 SOT-23 PKG = 625	$^{\circ}C/W$

**TL431Z ELECTRICAL CHARACTERISTICS**

( $T_A=25^{\circ}C$ , 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 Cathode Voltage	$\Delta V_{REF}/\Delta V_{KA}$	2	$I_K=10mA$		-1.4 -1	-2.7 -2	mV/V
			$\Delta V_{KA}=10V-V_{REF}$				
			$\Delta V_{KA}=36V-10V$				
Reference Input Current	$I_{REF}$	2	$I_{KA}=10mA, R1=10k\Omega, R2=\infty$		2.0	4	$\mu A$
Deviation of Reference Input Current Over Full Temperature Range	$\Delta I_{REF}/\Delta T$	2	$I_K=10mA, R1=10k\Omega, R2=\infty$ $T_A=Full\ Range$		0.4	1.2	$\mu A$
Minimum Cathode Current for Regulation	$I_{KA}MIN$	1	$\Delta V_{KA}=V_{REF}$		0.4	1	mA
Off-State Cathode Current	$I_{KA}OFF$	3	$V_{KA}=36V, V_{REF}=0$		0.1	1	$\mu A$
Dynamic Impedance	$Z_{KA}$	1	$V_{KA}=V_{REF}, I_K=1mA\sim 100mA,$ $f\leq 1kHz$		0.2	0.5	$\Omega$

**TL431AZ ELECTRICAL CHARACTERISTICS**

(T<sub>A</sub>=25°C, 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> =10mA	2.470	2.495	2.520	V
Deviation of Reference Input Voltage Over Full Temperature Range	ΔV <sub>REF</sub> /ΔT	1	V <sub>KA</sub> =V <sub>REF</sub> , I <sub>K</sub> =10mA T <sub>A</sub> =Full Range		3	17	mV
Ratio of Change in Reference Input Voltage to the Change in Cathode Voltage	ΔV <sub>REF</sub> /ΔV <sub>KA</sub>	2	I <sub>K</sub> =10mA	ΔV <sub>KA</sub> =10V-V <sub>REF</sub>	-1.4	-2.7	mV/V
				ΔV <sub>KA</sub> =36V-10V	-1	-2	
Reference Input Current	I <sub>REF</sub>	2	I <sub>KA</sub> =10mA, R1=10kΩ, R2=∞		2.0	4	μA
Deviation of Reference Input Current Over Full Temperature Range	ΔI <sub>REF</sub> /ΔT	2	I <sub>K</sub> =10mA, R1=10kΩ, R2=∞ T <sub>A</sub> =Full Range		0.4	1.2	μA
Minimum Cathode Current for Regulation	I <sub>KA</sub> MIN	1	ΔV <sub>KA</sub> =V <sub>REF</sub>		0.4	1	mA
Off-State Cathode Current	I <sub>KA</sub> OFF	3	V <sub>KA</sub> =36V, V <sub>REF</sub> =0		0.1	1	μA
Dynamic Impedance	Z <sub>KA</sub>	1	V <sub>KA</sub> =V <sub>REF</sub> , I <sub>K</sub> =1mA~100mA, f≤1kHz		0.2	0.5	Ω

**TL431CZ ELECTRICAL CHARACTERISTICS**

(T<sub>A</sub>=25°C, 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> =10mA	2.482	2.495	2.508	V
Deviation of Reference Input Voltage Over Full Temperature Range	ΔV <sub>REF</sub> /ΔT	1	V <sub>KA</sub> =V <sub>REF</sub> , I <sub>K</sub> =10mA T <sub>A</sub> =Full Range		3	17	mV
Ratio of Change in Reference Input Voltage to the Change in Cathode Voltage	ΔV <sub>REF</sub> /ΔV <sub>KA</sub>	2	I <sub>K</sub> =10mA	ΔV <sub>KA</sub> =10V-V <sub>REF</sub>	-1.4	-2.7	mV/V
				ΔV <sub>KA</sub> =36V-10V	-1	-2	
Reference Input Current	I <sub>REF</sub>	2	I <sub>KA</sub> =10mA, R1=10kΩ, R2=∞		2.0	4	μA
Deviation of Reference Input Current Over Full Temperature Range	ΔI <sub>REF</sub> /ΔT	2	I <sub>K</sub> =10mA, R1=10kΩ, R2=∞ T <sub>A</sub> =Full Range		0.4	1.2	μA
Minimum Cathode Current for Regulation	I <sub>KA</sub> MIN	1	ΔV <sub>KA</sub> =V <sub>REF</sub>		0.4	1	mA
Off-State Cathode Current	I <sub>KA</sub> OFF	3	V <sub>KA</sub> =36V, V <sub>REF</sub> =0		0.1	1	μA
Dynamic Impedance	Z <sub>KA</sub>	1	V <sub>KA</sub> =V <sub>REF</sub> , I <sub>K</sub> =1mA~100mA, f≤1kHz		0.2	0.5	Ω

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

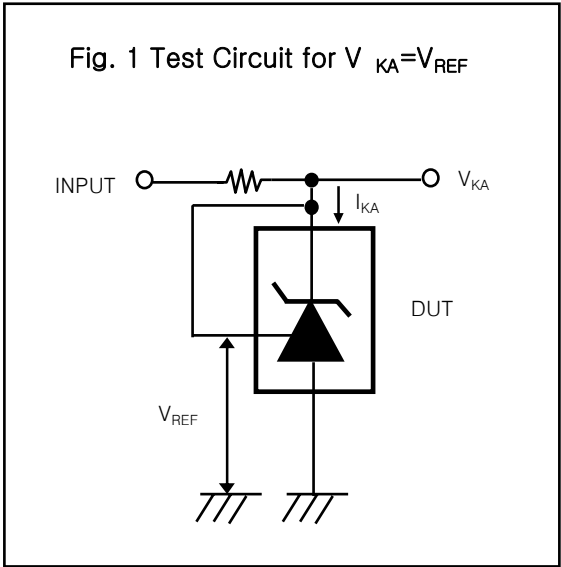


Fig. 2 Test Circuit for  $V_{KA} \geq V_{REF}$

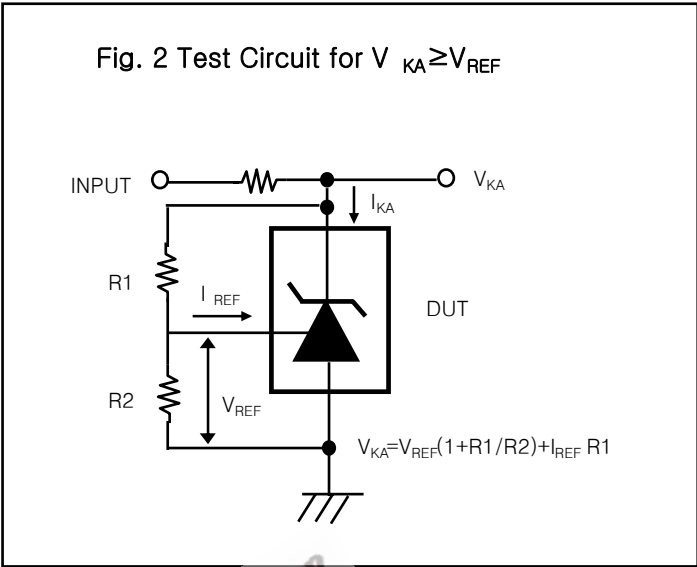
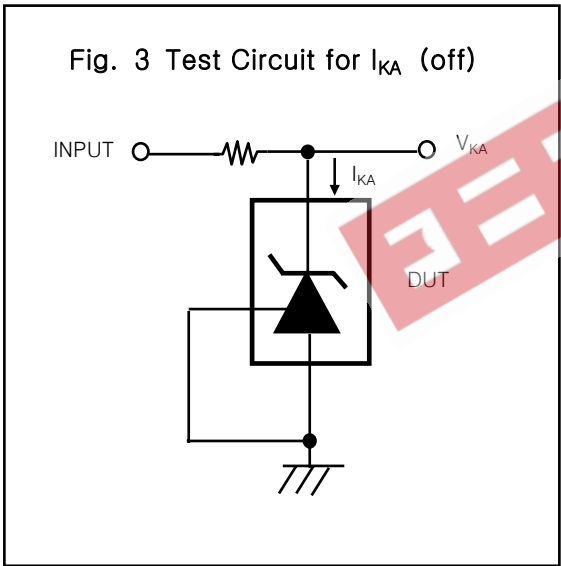


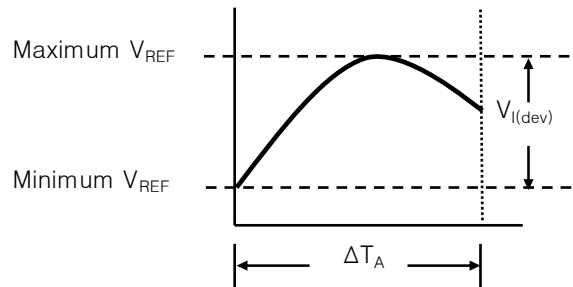
Fig. 3 Test Circuit for  $I_{KA}$  (off)



# PROGRAMMABLE PRECISION SHUNT REGULATOR TL431Z/AZ /CZ

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,  $\alpha V_{REF}$ , is defined as :

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



Where :

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

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

Example : Maximum  $V_{REF}=2496\text{mV}$  at  $30^\circ\text{C}$ , minimum  $V_{REF}=2492\text{mV}$  at  $0^\circ\text{C}$ ,  $V_{REF}=2495\text{mV}$  at  $25^\circ\text{C}$ ,  $\Delta T_A=70^\circ\text{C}$  for TL431CZ

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

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

### Calculating Dynamic Impedance

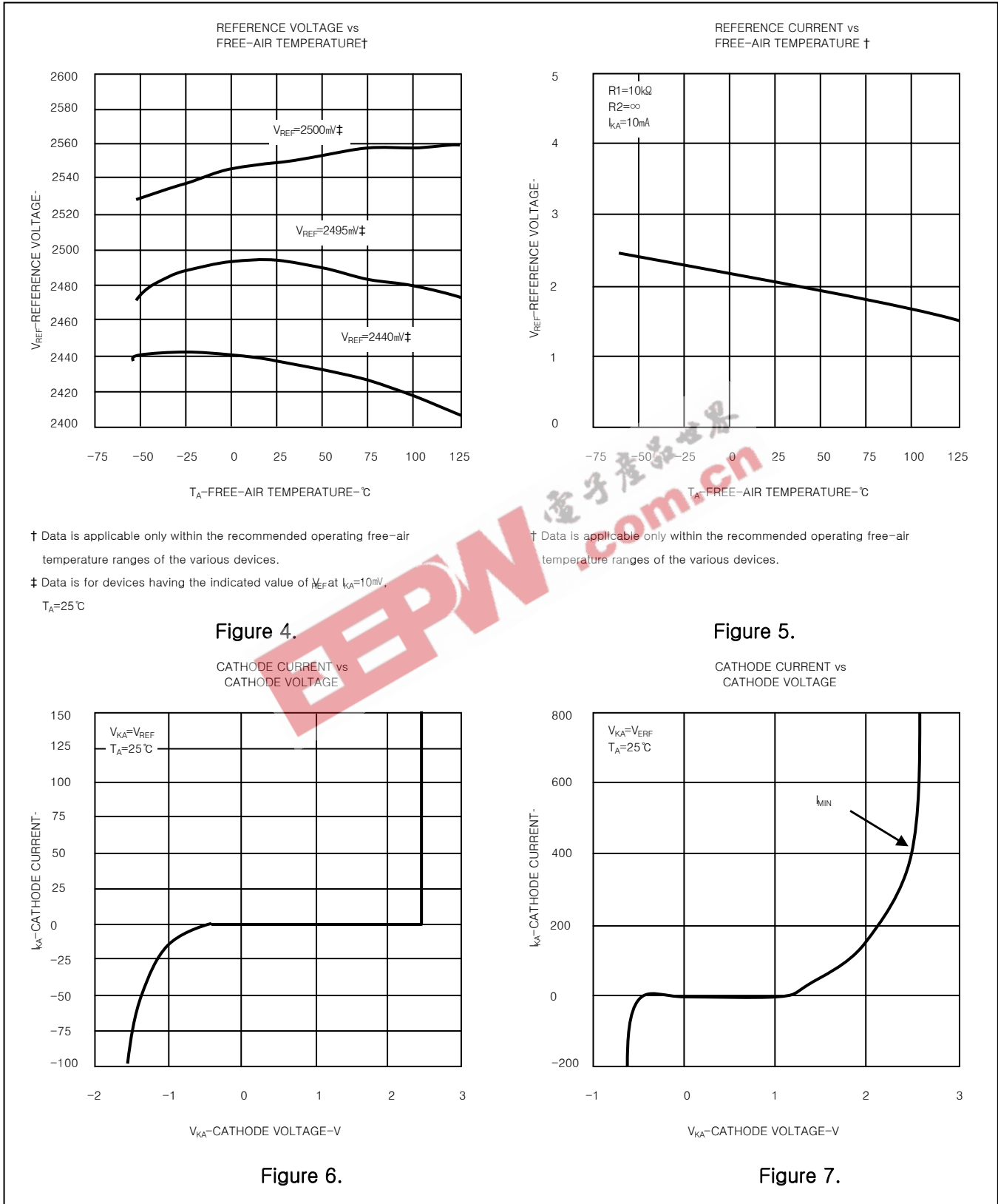
The dynamic impedance is defined as :  $|Z_{KA}| = \frac{\Delta V_{KA}}{\Delta I_{KA}}$

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



TYPICAL PERFORMANCE CHARACTERISTICS

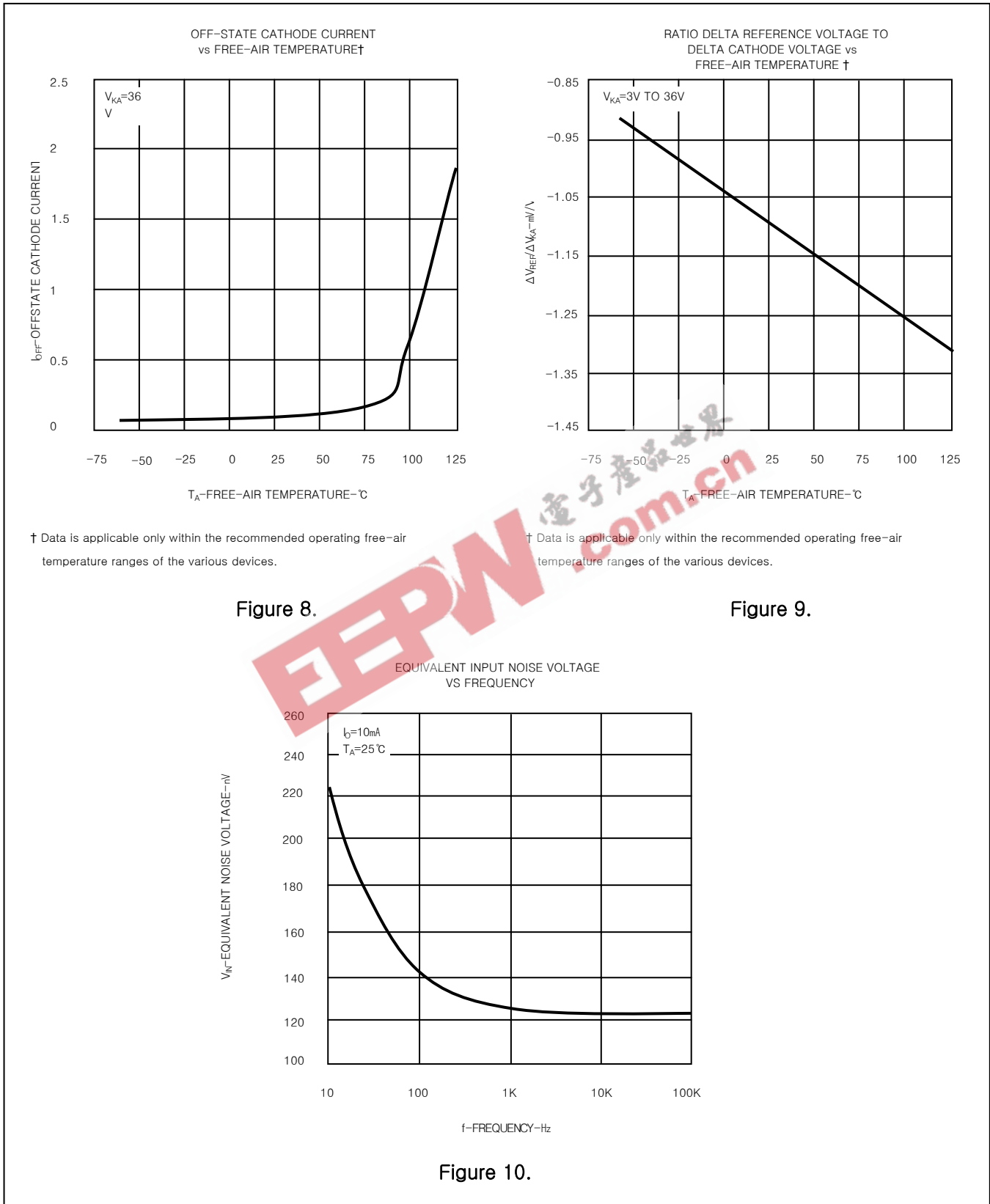


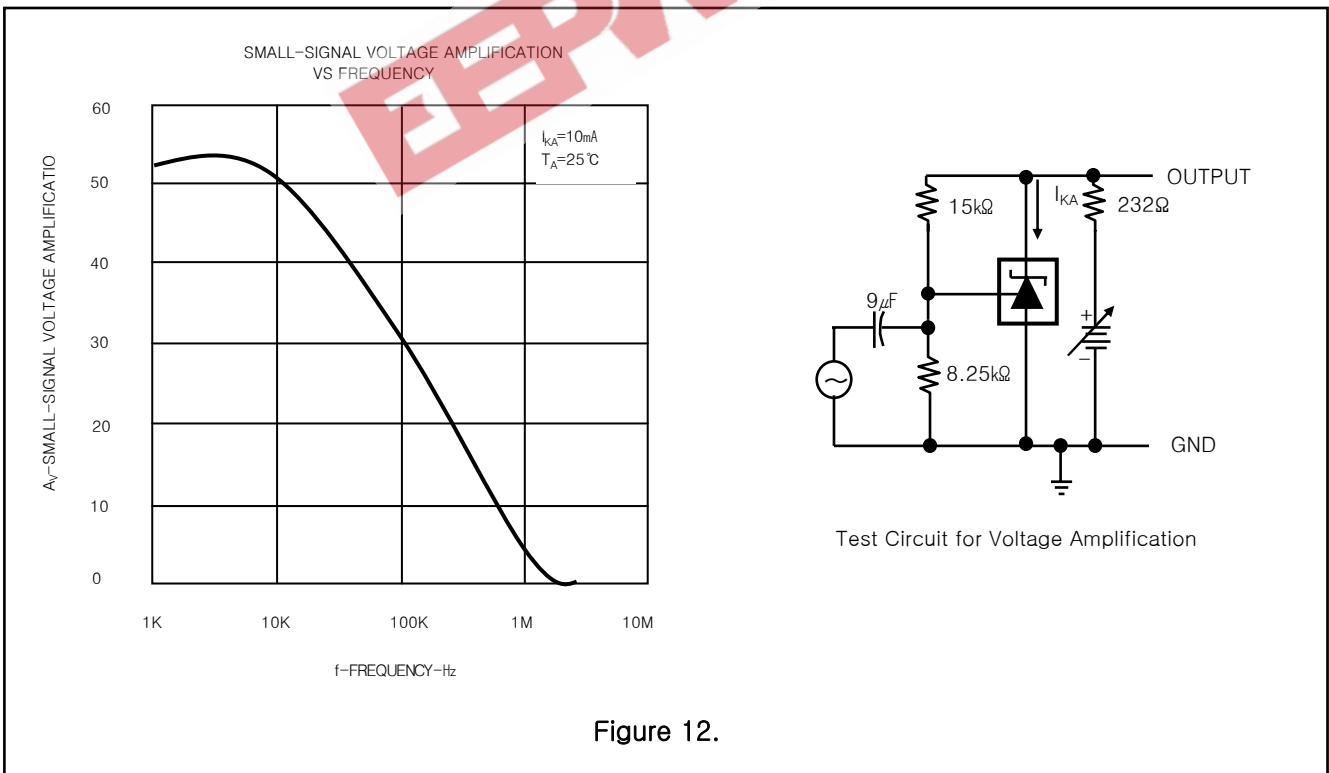
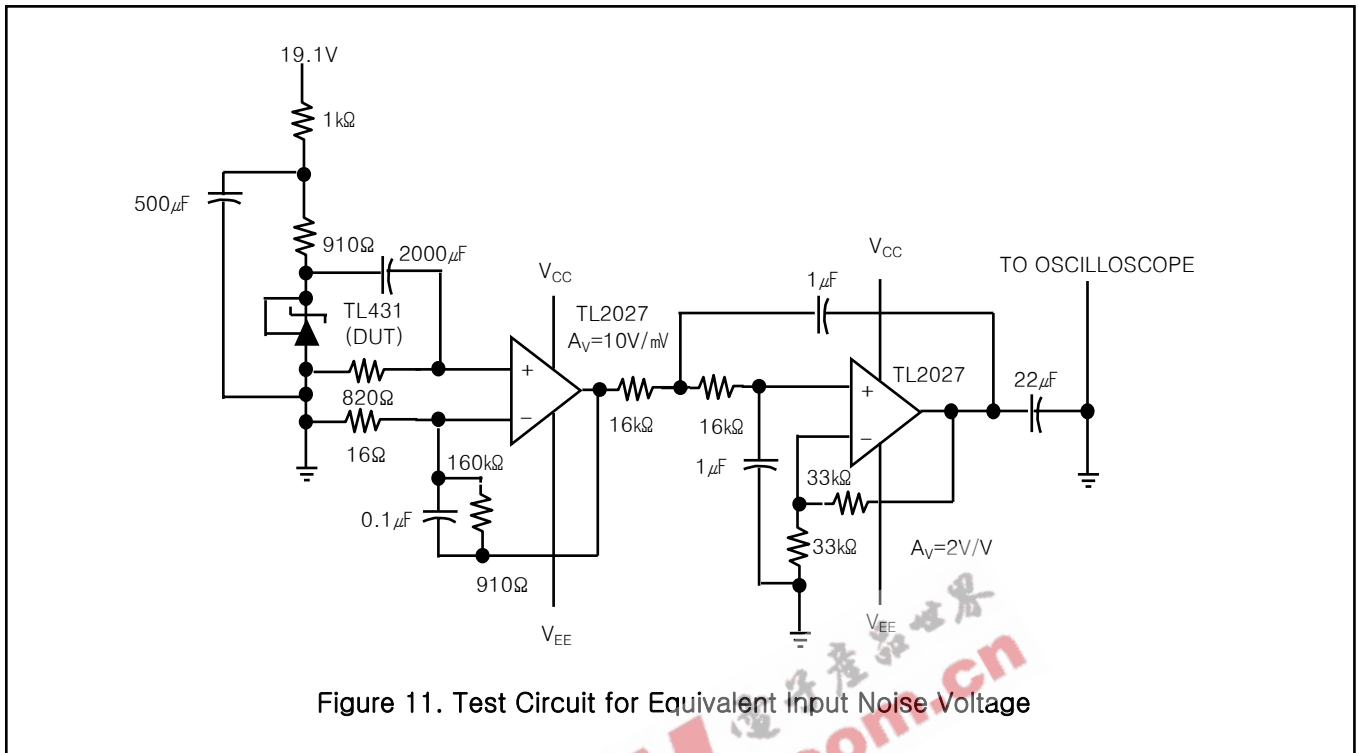
Figure 8.

Figure 9.

Figure 10.



TYPICAL PERFORMANCE CHARACTERISTICS



TYPICAL PERFORMANCE CHARACTERISTICS

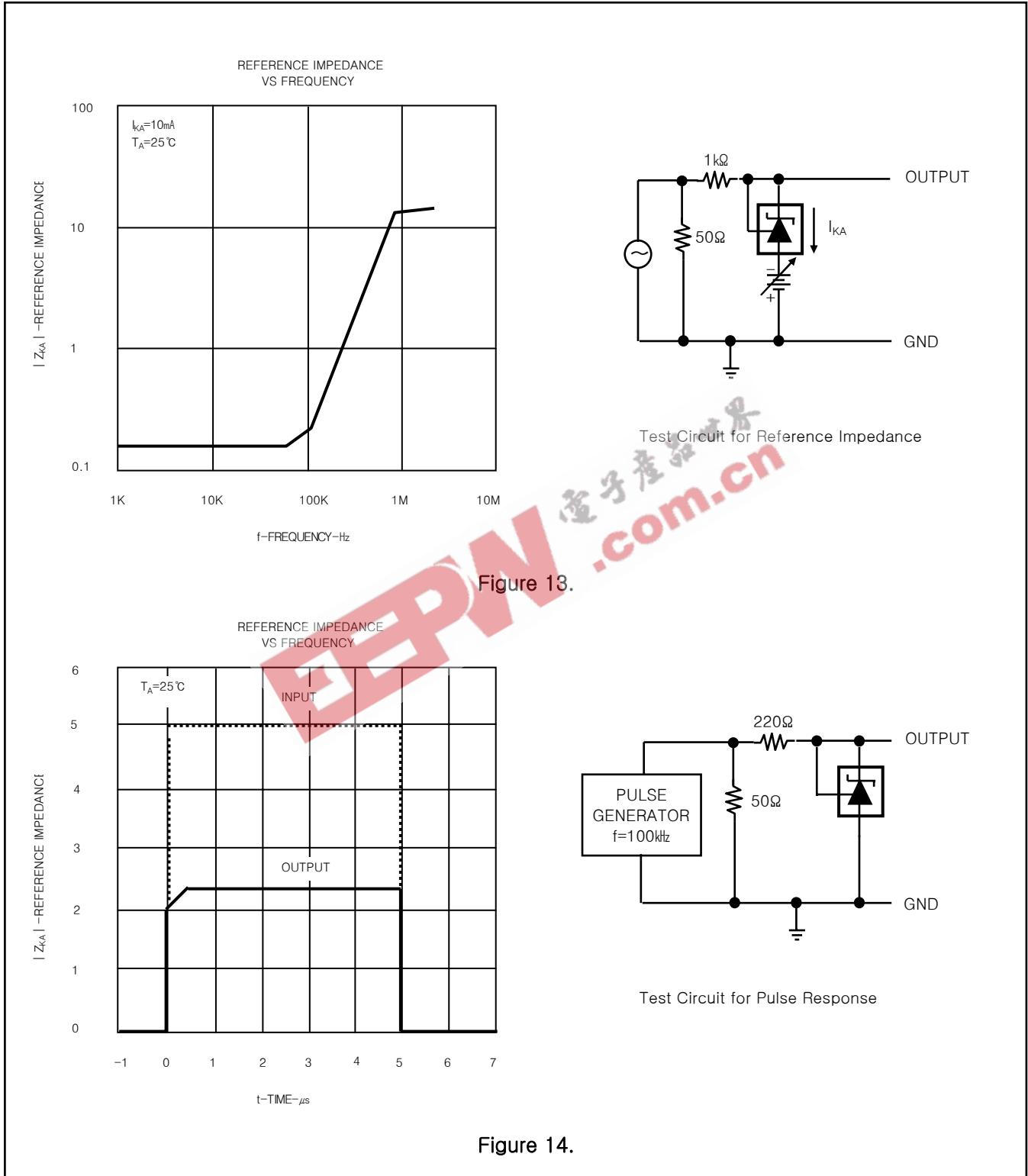


Figure 13.

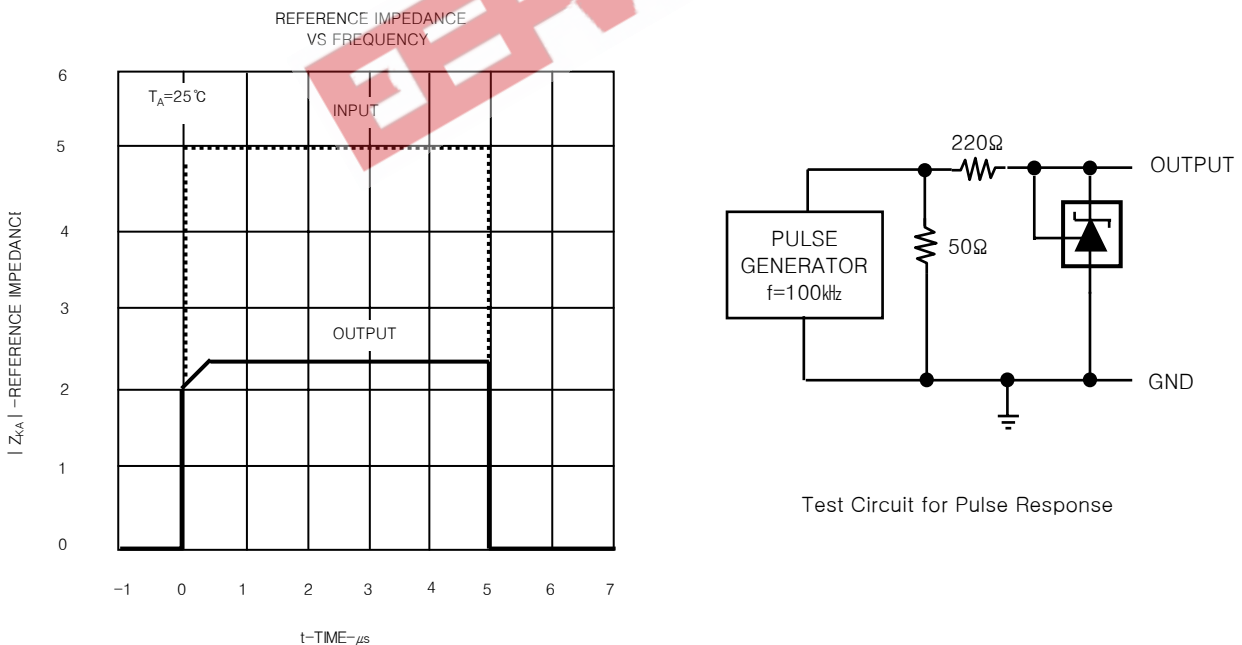
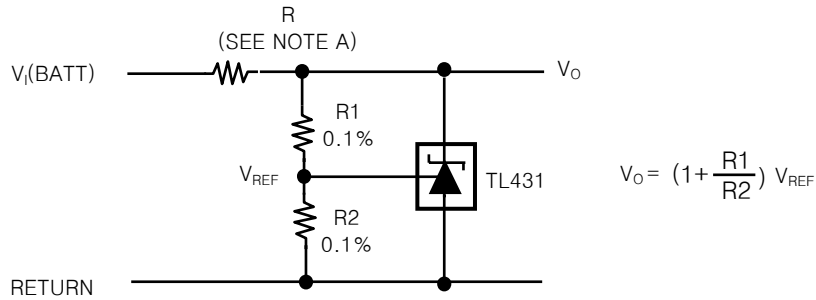
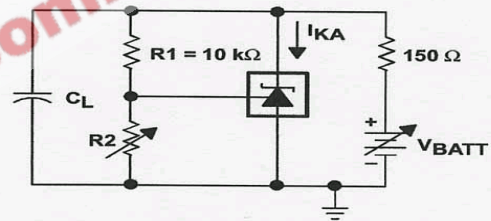
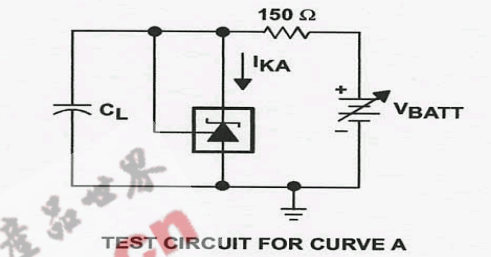
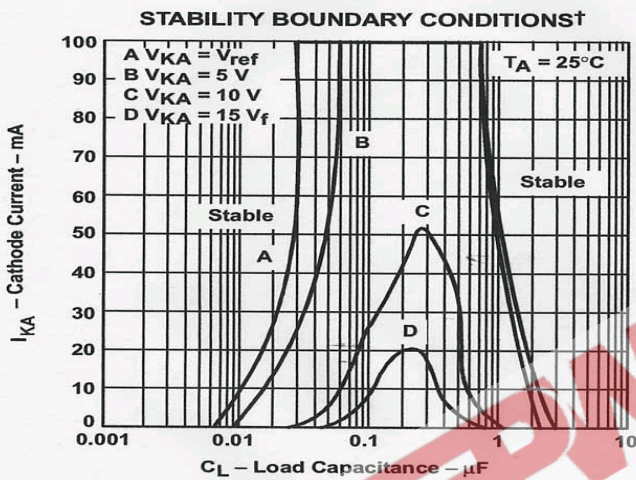


Figure 14.

APPLICATION INFORMATION

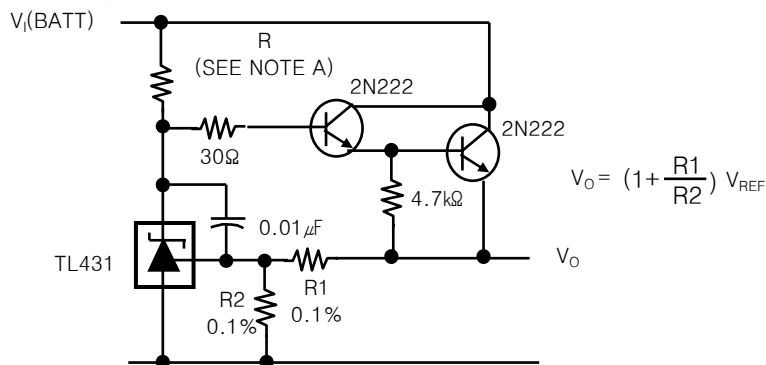


NOTE A : R Should provide cathode current  $\geq 1\text{mA}$  to the TL431 at minimum  $V_i(\text{BATT})$   
**Figure 15. Shunt Regulator**



† 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**



NOTE A : R Should provide cathode current  $\geq 1\text{mA}$  to the TL431 at minimum  $V_i(\text{BATT})$

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

APPLICATION INFORMATION

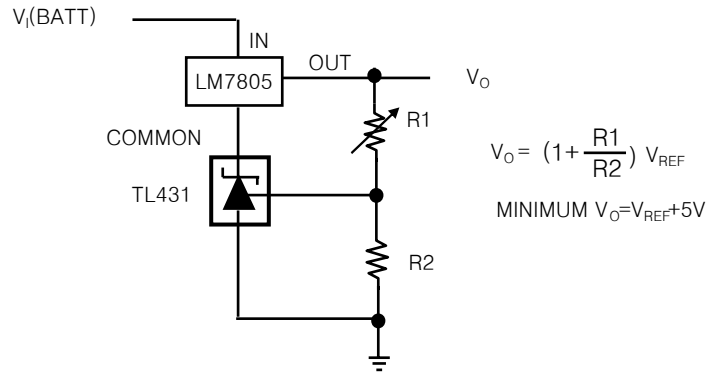


Figure 18. Output Control of a 3-Terminal Fixed Regulator

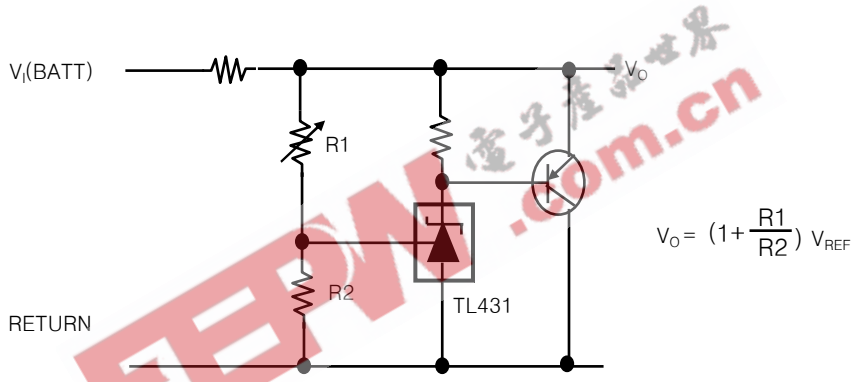
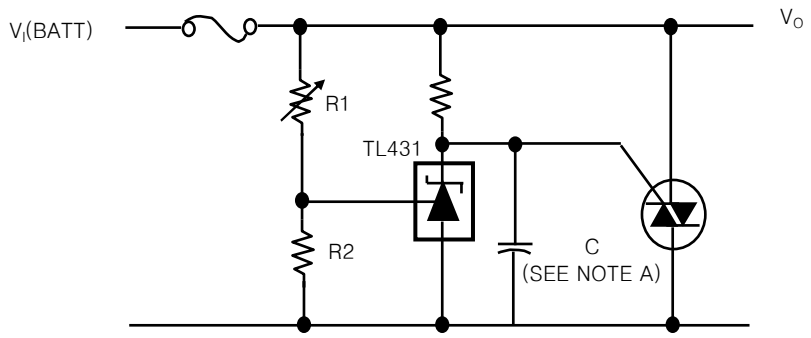


Figure 19. High-Current Shunt Regulator



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

Figure 20. Crowbar Circuit

APPLICATION INFORMATION

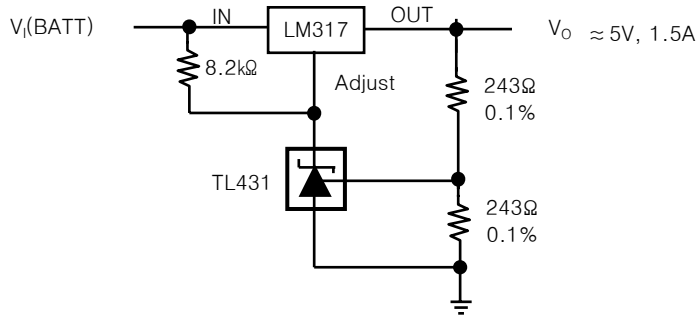
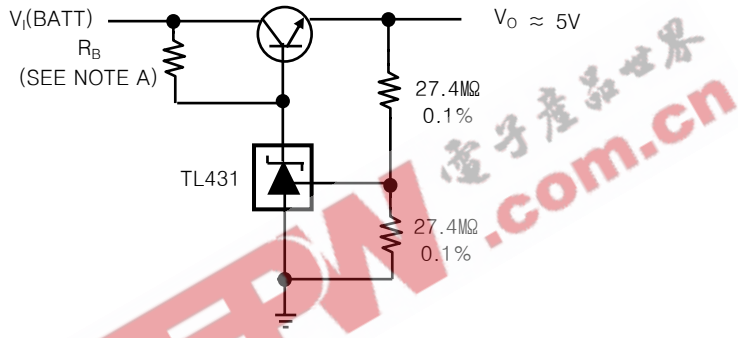


Figure 21. Precision 5-V 1.5A Regulator



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

Figure 22. Efficient 5-V Precision Regulator

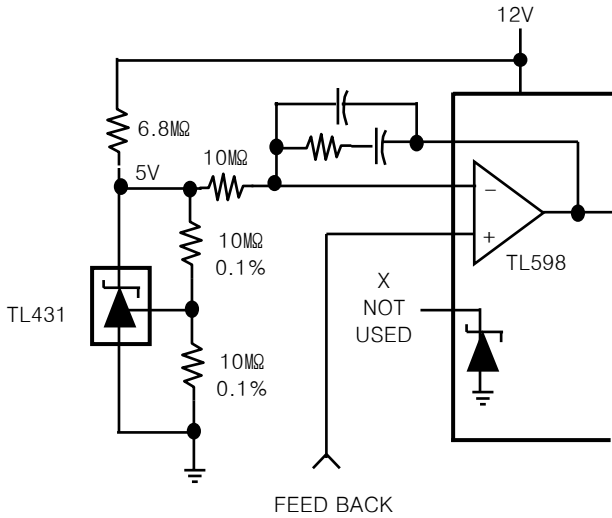
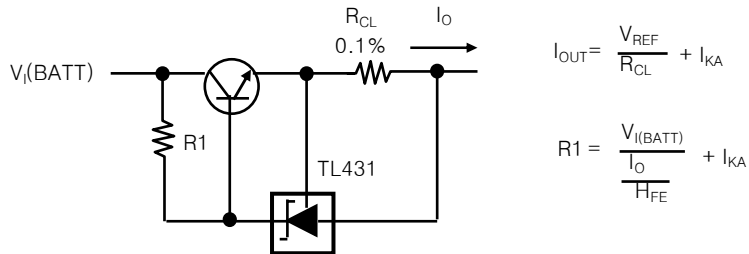
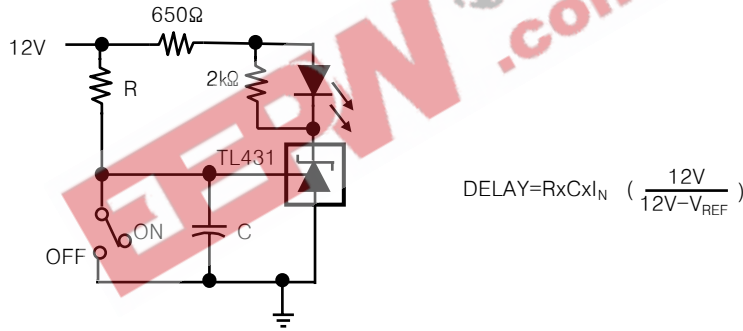
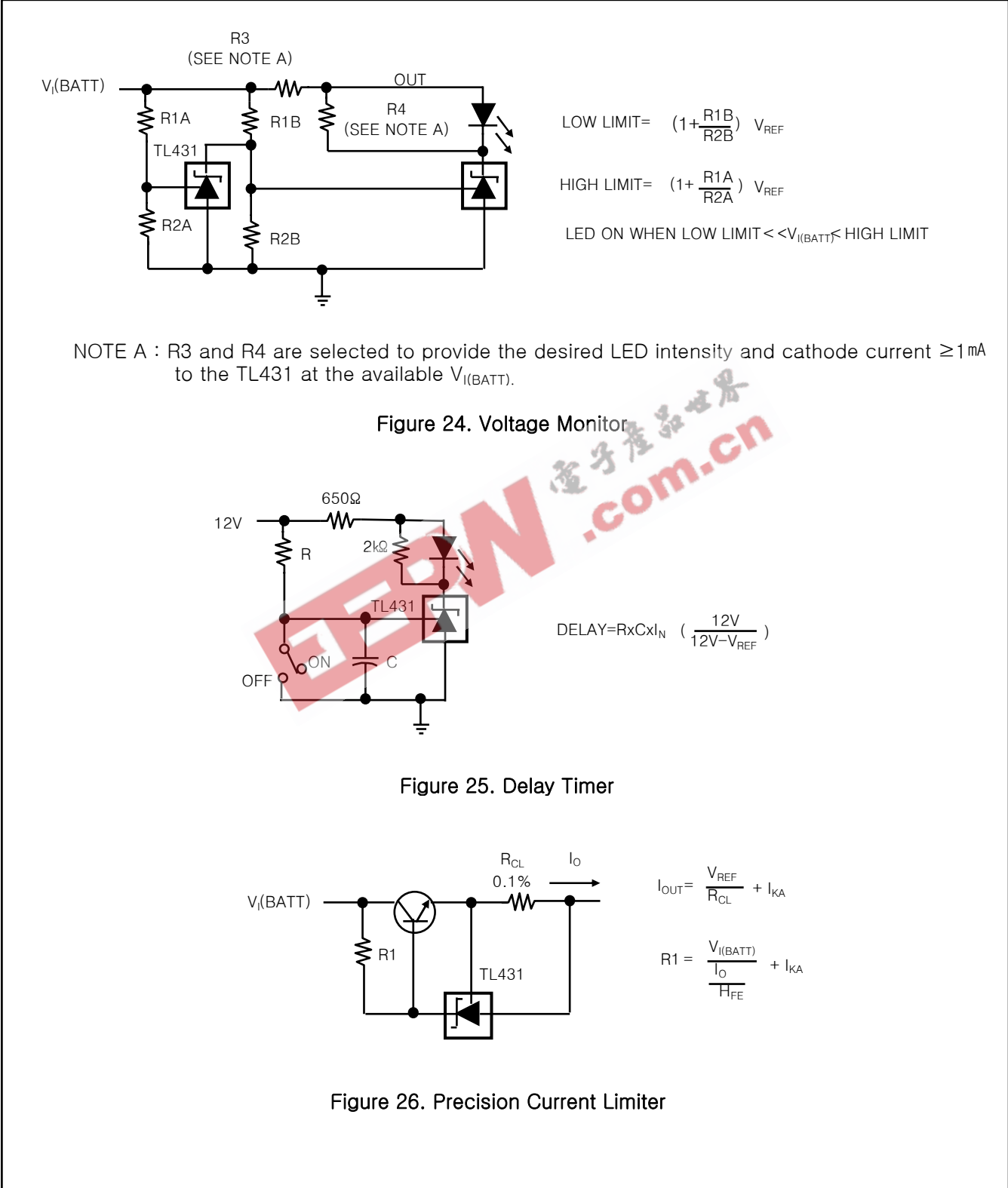


Figure 23. PWM Converter With Reference

APPLICATION INFORMATION



APPLICATION INFORMATION

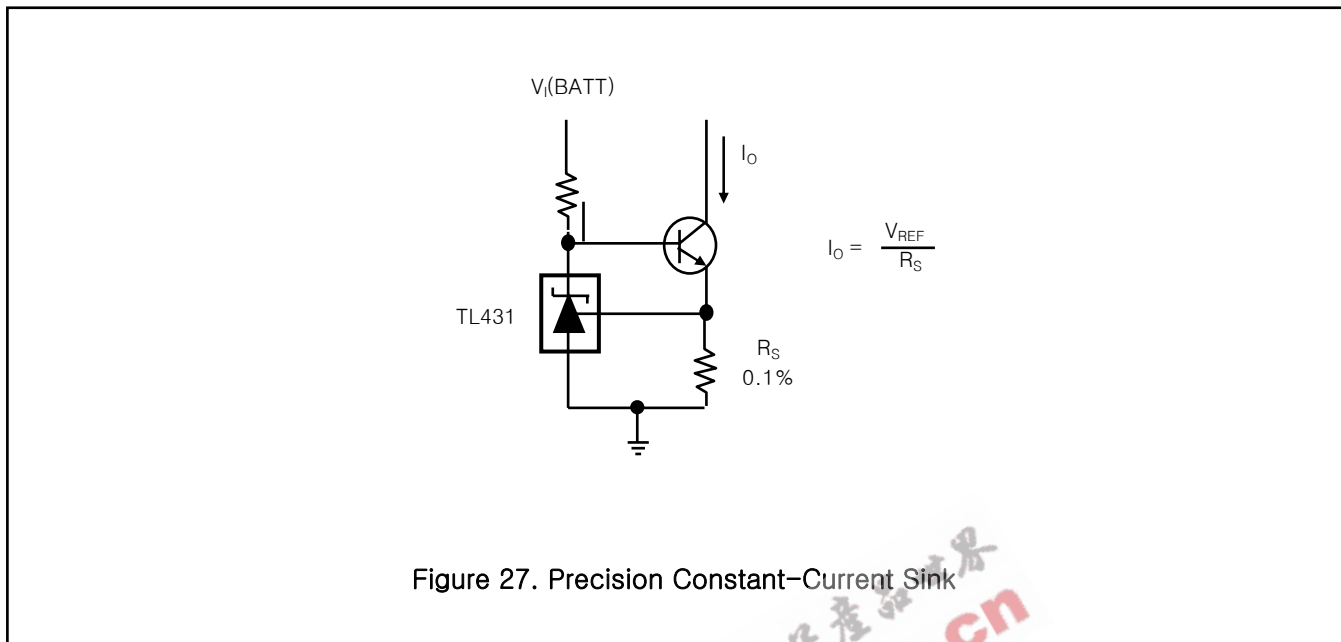


Figure 27. Precision Constant-Current Sink