MOTOROLA

TL431, A, B Series

Programmable Precision References

The TL431, A, B integrated circuits are three–terminal programmable shunt regulator diodes. These monolithic IC voltage references operate as a low temperature coefficient zener which is programmable from V_{ref} to 36 V with two external resistors. These devices exhibit a wide operating current range of 1.0 mA to 100 mA with a typical dynamic impedance of 0.22 Ω. The characteristics of these references make them excellent replacements for zener diodes in many applications such as digital voltmeters, power supplies, and op amp circuitry. The 2.5 V reference makes it convenient to obtain a stable reference from 5.0 V logic supplies, and since the TL431, A, B operates as a shunt regulator, it can be used as either a positive or negative voltage reference.

- Programmable Output Voltage to 36 V
- Voltage Reference Tolerance: ±0.4%, Typ @ 25°C (TL431B)
- Low Dynamic Output Impedance, 0.22 Ω Typical
- Sink Current Capability of 1.0 mA to 100 mA
- Equivalent Full–Range Temperature Coefficient of 50 ppm/°C Typical
- Temperature Compensated for Operation over Full Rated Operating Temperature Range
- Low Output Noise Voltage

ORDERING INFORMATION

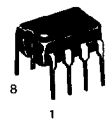
Device	Operating Temperature Range	Package
TL431CLP, ACLP, BCLP	T_A = 0° to +70°C	TO–92
TL431CP, ACP, BCP		Plastic
TL431CDM, ACDM, BCDM		Micro–8
TL431CD, ACD, BCD		SOP–8
TL431ILP, AILP, BILP	T_A = –40° to +85°C	TO–92
TL431IP, AIP, BIP		Plastic
TL431IDM, AIDM, BIDM		Micro–8
TL431ID, AID, BID		SOP–8

PROGRAMMABLE PRECISION REFERENCES

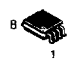
SEMICONDUCTOR TECHNICAL DATA

Z, LP SUFFIX
PLASTIC PACKAGE
CASE 29
(TO–92)

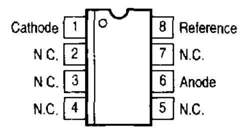
Pin 1. Reference
2. Anode
3. Cathode



P SUFFIX
PLASTIC PACKAGE
CASE 626

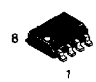


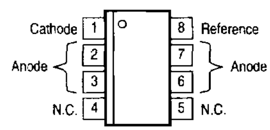
DM SUFFIX
PLASTIC PACKAGE
CASE 846A
(Micro–8)



(Top View)

D SUFFIX
PLASTIC PACKAGE
CASE 751
(SOP–8)

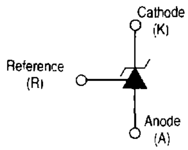




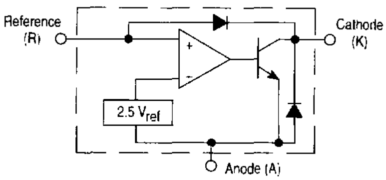
(Top View)

SOP–8 is an internally modified SO–8 package. Pins 2, 3, 6 and 7 are electrically common to the die attach flag. This internal lead frame modification decreases power dissipation capability when appropriately mounted on a printed circuit board. SOP–8 conforms to all external dimensions of the standard SO–8 package.

Symbol

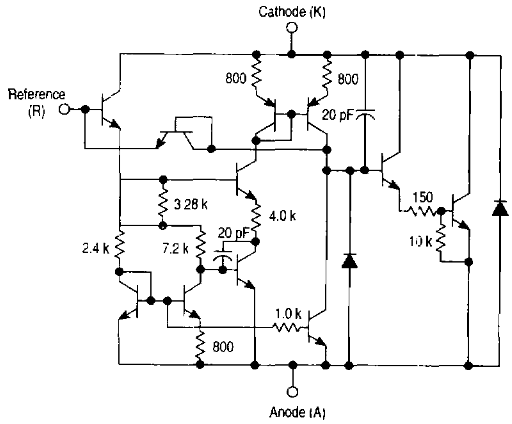


Representative Block Diagram



Representative Schematic Diagram

Component values are nominal



This device contains 12 active transistors.

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

Rating	Symbol	Value	Unit
Cathode to Anode Voltage	V_{KA}	37	V
Cathode Current Range, Continuous	I_K	–100 to +150	mA
Reference Input Current Range, Continuous	I_{ref}	–0.05 to +10	mA
Operating Junction Temperature	T_J	150	°C
Operating Ambient Temperature Range TL431I, TL431AI, TL431BI TL431C, TL431AC, TL431BC	T_A	 –40 to +85 0 to +70	°C
Storage Temperature Range	T_{stg}	–65 to +150	°C
Total Power Dissipation @ T_A = 25°C Derate above 25°C Ambient Temperature D, LP Suffix Plastic Package P Suffix Plastic Package DM Suffix Plastic Package	P_D	 0.70 1.10 0.52	W
Total Power Dissipation @ T_C = 25°C Derate above 25°C Case Temperature D, LP Suffix Plastic Package P Suffix Plastic Package	P_D	 1.5 3.0	W

NOTE: ESD data available upon request.

RECOMMENDED OPERATING CONDITIONS

Condition	Symbol	Min	Max	Unit
Cathode to Anode Voltage	V_{KA}	V_{ref}	36	V
Cathode Current	I_K	1.0	100	mA

THERMAL CHARACTERISTICS

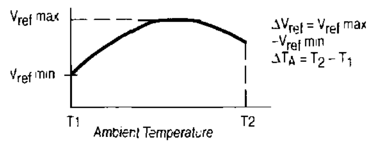
Characteristic	Symbol	D, LP Suffix Package	P Suffix Package	DM Suffix Package	Unit
Thermal Resistance, Junction–to–Ambient	$R_{\theta JA}$	178	114	240	°C/W
Thermal Resistance, Junction–to–Case	$R_{\theta JC}$	83	41	–	°C/W

ELECTRICAL CHARACTERISTICS *(T_A = 25°C, unless otherwise noted.)*

Characteristic	Symbol	TL431I			TL431C			Unit
		Min	Typ	Max	Min	Typ	Max	
Reference Input Voltage (Figure 1) $V_{KA} = V_{ref}$, I_K = 10 mA T_A = 25°C $T_A = T_{low}$ to T_{high} (Note 1)	V_{ref}	 2.44 2.41	 2.495 –	 2.55 2.58	 2.44 2.423	 2.495 –	 2.55 2.567	V
Reference Input Voltage Deviation Over Temperature Range (Figure 1, Notes 1, 2, 4) $V_{KA} = V_{ref}$, I_K = 10 mA	ΔV_{ref}	–	7.0	30	–	3.0	17	mV
Ratio of Change in Reference Input Voltage to Change in Cathode to Anode Voltage I_K = 10 mA (Figure 2), ΔV_{KA} = 10 V to V_{ref} ΔV_{KA} = 36 V to 10 V	$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	 – –	 –1.4 –1.0	 –2.7 –2.0	 – –	 –1.4 –1.0	 –2.7 –2.0	mV/V
Reference Input Current (Figure 2) I_K = 10 mA, R1 = 10 k, R2 = ∞ T_A = 25°C $T_A = T_{low}$ to T_{high} (Note 1)	I_{ref}	 – –	 1.8 –	 4.0 6.5	 – –	 1.8 –	 4.0 5.2	µA
Reference Input Current Deviation Over Temperature Range (Figure 2, Note 1, 4) I_K = 10 mA, R1 = 10 k, R2 = ∞	ΔI_{ref}	–	0.8	2.5	–	0.4	1.2	µA
Minimum Cathode Current For Regulation $V_{KA} = V_{ref}$ (Figure 1)	I_{min}	–	0.5	1.0	–	0.5	1.0	mA
Off–State Cathode Current (Figure 3) V_{KA} = 36 V, V_{ref} = 0 V	I_{off}	–	2.6	1000	–	2.6	1000	nA
Dynamic Impedance (Figure 1, Note 3) $V_{KA} = V_{ref}$, ΔI_K = 1.0 mA to 100 mA f ≤ 1.0 kHz	$\|Z_{KA}\|$	–	0.22	0.5	–	0.22	0.5	Ω

NOTE 1: T_{low} = –40°C for TL431AIP, TL431AILP, TL431IP, TL431ILP, TL431BID, TL431BIP, TL431BILP, TL431AIDM, TL431IDM, TL431BIDM
= 0°C for TL431ACP, TL431ACLP, TL431CP, TL431CLP, TL431CD, TL431ACD, TL431BCD, TL431BCP, TL431BCLP, TL431CDM, TL431ACDM, TL431BCDM
T_{high} = +85°C for TL431AIP, TL431AILP, TL431IP, TL431ILP, TL431BID, TL431BIP, TL431BILP, TL431IDM, TL431AIDM, TL431BIDM
= +70°C for TL431ACP, TL431ACLP, TL431CP, TL431ACD, TL431BCD, TL431BCP, TL431BCLP, TL431CDM, TL431ACDM, TL431BCDM

NOTE 2: The deviation parameter ΔV_{ref} is defined as the difference between the maximum and minimum values obtained over the full operating ambient temperature range that applies.



The average temperature coefficient of the reference input voltage, αV_{ref} is defined as.

$$V_{ref}\ \frac{ppm}{°C} = \frac{\left(\frac{\Delta V_{ref}}{V_{ref}\ @\ 25°C}\right) X\ 10^6}{\Delta T_A} = \frac{\Delta V_{ref} \times 10^6}{\Delta T_A\ (V_{ref}\ @\ 25°C)}$$

αV_{ref} can be positive or negative depending on whether V_{ref} Min or V_{ref} Max occurs at the lower ambient temperature. (Refer to Figure 6.)

Example : ΔV_{ref} = 8.0 mV and slope is positive.

V_{ref} @ 25°C = 2.495 V, ΔT_A = 70°C $\qquad \alpha V_{ref} = \frac{0.008 \times 10^6}{70\ (2.495)} = 45.8$ ppm/°C

NOTE 3 : The dynamic impedance Z_{KA} is defined as $|Z_{KA}| = \frac{\Delta V_{KA}}{\Delta I_K}$

When the device is programmed with two external resistors, R1 and R2, (refer to Figure 2) the total dynamic impedance of the circuit is defined as:

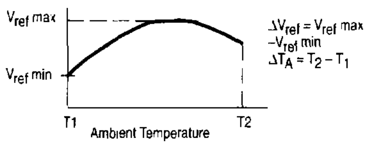
$$|Z_{KA}'| \approx |Z_{KA}| \left(1 + \frac{R1}{R2}\right)$$

ELECTRICAL CHARACTERISTICS (T_A = 25°C, unless otherwise noted.)

Characteristic	Symbol	TL431AI Min	TL431AI Typ	TL431AI Max	TL431AC Min	TL431AC Typ	TL431AC Max	TL431B Min	TL431B Typ	TL431B Max	Unit
Reference Input Voltage (Figure 1) $V_{KA} = V_{ref}$, I_K = 10 mA T_A = 25°C $T_A = T_{low}$ to T_{high}	V_{ref}	 2.47 2.44	 2.495 –	 2.52 2.55	 2.47 2.453	 2.495 –	 2.52 2.537	 2.483 2.475	 2.495 2.495	 2.507 2.515	V
Reference Input Voltage Deviation Over Temperature Range (Figure 1, Notes 1, 2, 4) $V_{KA} = V_{ref}$, I_K = 10 mA	ΔV_{ref}	–	7.0	30	–	3.0	17	–	3	17	mV
Ratio of Change in Reference Input Voltage to Change in Cathode to Anode Voltage I_K = 10 mA (Figure 2), ΔV_{KA} = 10 V to V_{ref} ΔV_{KA} = 36 V to 10 V	$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	 – –	 –1.4 –1.0	 –2.7 –2.0	 – –	 –1.4 –1.0	 –2.7 –2.0	 – –	 –1.4 –1.0	 –2.7 –2.0	mV/V
Reference Input Current (Figure 2) I_K = 10 mA, R1 = 10 k, R2 = ∞ T_A = 25°C $T_A = T_{low}$ to T_{high} (Note 1)	I_{ref}	 – –	 1.8 –	 4.0 6.5	 – –	 1.8 –	 4.0 5.2	 – –	 1.6 –	 3.0 4.0	μA
Reference Input Current Deviation Over Temperature Range (Figure 2, Note 1) I_K = 10 mA, R1 = 10 k, R2 = ∞	ΔI_{ref}	–	0.8	2.5	–	0.4	1.2	–	0.4	1.2	μA
Minimum Cathode Current For Regulation $V_{KA} = V_{ref}$ (Figure 1)	I_{min}	–	0.5	1.0	–	0.5	1.0	–	0.5	1.0	mA
Off–State Cathode Current (Figure 3) V_{KA} = 36 V, V_{ref} = 0 V	I_{off}	–	260	1000	–	260	1000	–	230	500	nA
Dynamic Impedance (Figure 1, Note 3) $V_{KA} = V_{ref}$, ΔI_K = 1.0 mA to 100 mA f ≤ 1.0 kHz	$\|Z_{KA}\|$	–	0.22	0.5	–	0.22	0.5	–	0.14	0.3	Ω

NOTE 1: T_{low} = –40°C for TL431AIP TL431AILP, TL431IP, TL431ILP, TL431BID, TL431BIP, TL431BILP, TL431AIDM, TL431IDM, TL431BIDM
= 0°C for TL431ACP, TL431ACLP, TL431CP, TL431CLP, TL431CD, TL431ACD, TL431BCD, TL431BCP, TL431BCLP, TL431CDM, TL431ACDM, TL431BCDM
T_{high} = +85°C for TL431AIP, TL431AILP, TL431IP, TL431ILP, TL431BID, TL431BIP, TL431BILP, TL431IDM, TL431AIDM, TL431BIDM
= +70°C for TL431ACP, TL431ACLP, TL431CP, TL431ACD, TL431BCD, TL431BCP, TL431BCLP, TL431CDM, TL431ACDM, TL431BCDM

NOTE 2: The deviation parameter ΔV_{ref} is defined as the difference between the maximum and minimum values obtained over the full operating ambient temperature range that applies.



The average temperature coefficient of the reference input voltage, αV_{ref} is defined as

$$V_{ref}\ \frac{ppm}{°C} = \frac{\left(\frac{\Delta V_{ref}}{V_{ref}\ @\ 25°C}\right) X\ 10^6}{\Delta T_A} = \frac{\Delta V_{ref} \times 10^6}{\Delta T_A\ (V_{ref}\ @\ 25°C)}$$

αV_{ref} can be positive or negative depending on whether V_{ref} Min or V_{ref} Max occurs at the lower ambient temperature. (Refer to Figure 6.)

Example : ΔV_{ref} = 8.0 mV and slope is positive,

V_{ref} @ 25°C = 2.495 V, ΔT_A = 70°C $\qquad \alpha\ V_{ref} = \frac{0.008 \times 10^6}{70\ (2.495)} = 45.8$ ppm/°C

NOTE 3 : The dynamic impedance Z_{KA} is defined as $|Z_{KA}| = \frac{\Delta V_{KA}}{\Delta I_K}$

When the device is programmed with two external resistors, R1 and R2, (refer to Figure 2) the total dynamic impedance of the circuit is defined as:

$$|Z_{KA}'| \approx |Z_{KA}| \left(1 + \frac{R1}{R2}\right)$$

NOTE 4: This test is not applicable to surface mount (D and DM suffix) devices.

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Figure 1. Test Circuit for $V_{KA} = V_{ref}$

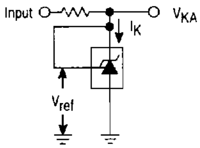
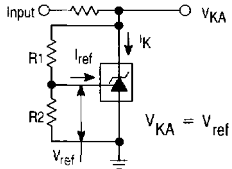


Figure 2. Test Circuit for $V_{KA} > V_{ref}$



$$V_{KA} = V_{ref}\left(1 + \frac{R1}{R2}\right) + I_{ref} \cdot R1$$

Figure 3. Test Circuit for I_{off}

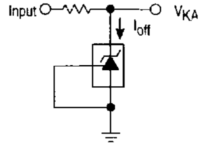


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Figure 4. Cathode Current versus Cathode Voltage

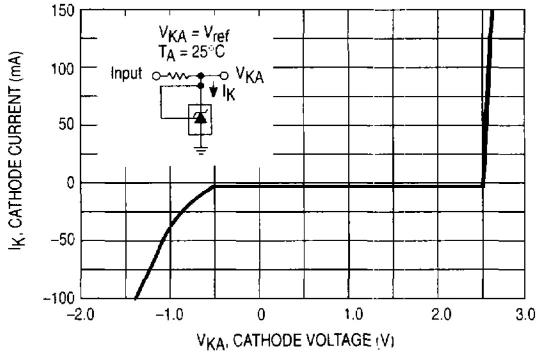

Figure 5. Cathode Current versus Cathode Voltage

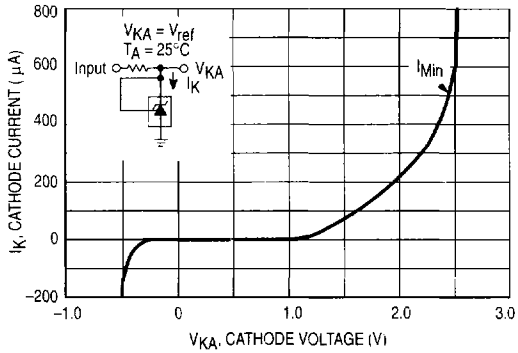

Figure 6. Reference Input Voltage versus Ambient Temperature

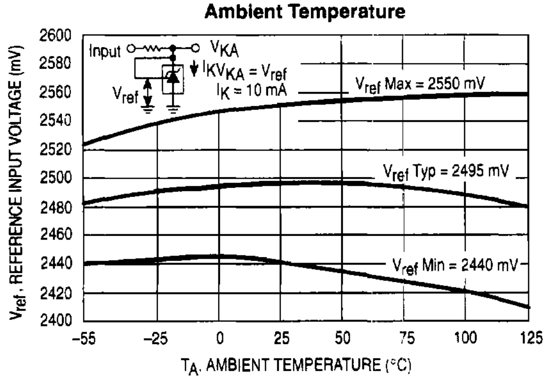

Figure 7. Reference Input Current versus Ambient Temperature

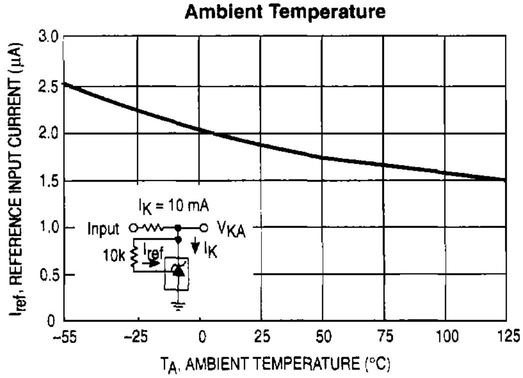

Figure 8. Change in Reference Input Voltage versus Cathode Voltage

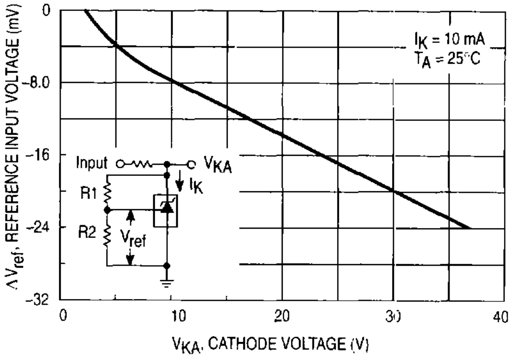

Figure 9. Off–State Cathode Current versus Ambient Temperature

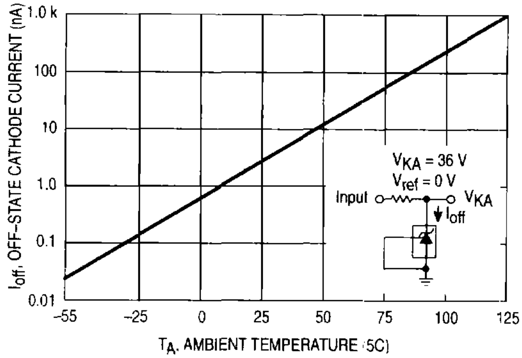

Figure 10. Dynamic Impedance versus Frequency

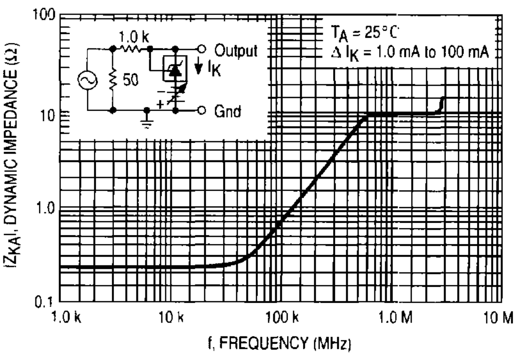

Figure 11. Dynamic Impedance versus Ambient Temperature

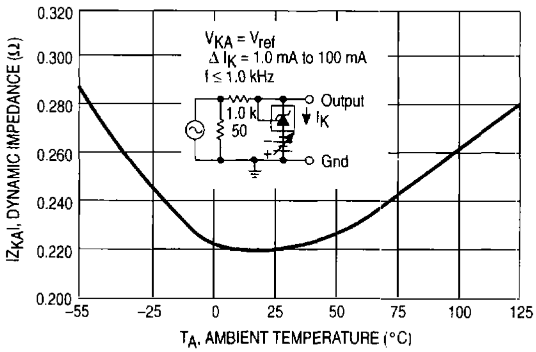

Figure 12. Open–Loop Voltage Gain versus Frequency

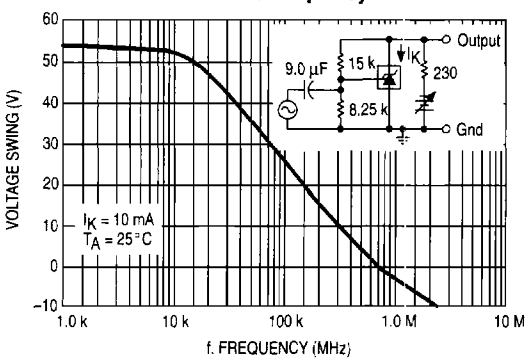

Figure 13. Spectral Noise Density

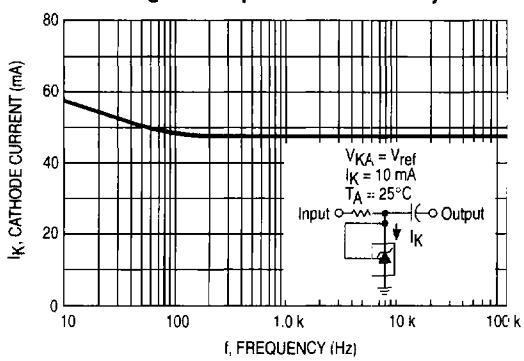

Figure 14. Pulse Response

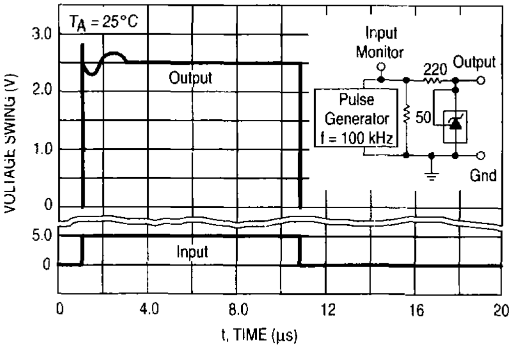

Figure 15. Stability Boundary Conditions

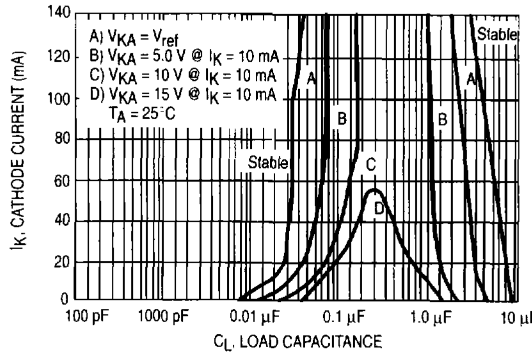

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Figure 16. Test Circuit For Curve A of Stability Boundary Conditions

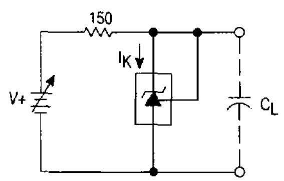
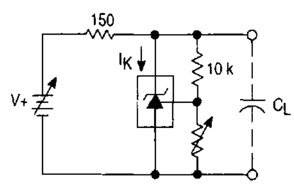
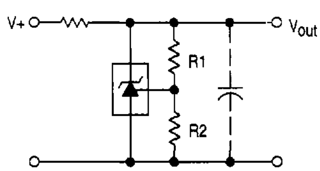


Figure 17. Test Circuit For Curves B, C, And D of Stability Boundary Conditions



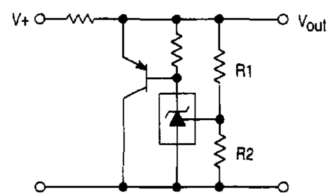
TYPICAL APPLICATIONS

Figure 18. Shunt Regulator



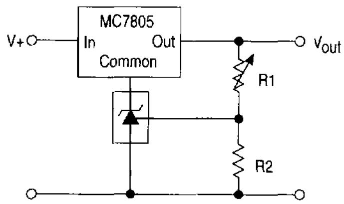
$$V_{out} = \left(1 + \frac{R1}{R2}\right) V_{ref}$$

Figure 19. High Current Shunt Regulator



$$V_{out} = \left(1 + \frac{R1}{R2}\right) V_{ref}$$

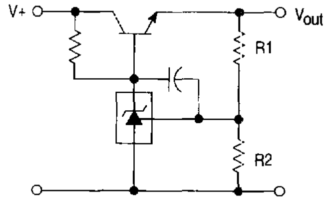
Figure 20. Output Control for a Three–Terminal Fixed Regulator



$$V_{out} = \left(1 + \frac{R1}{R2}\right) V_{ref}$$

$$V_{out}\ min = V_{ref} + 5.0V$$

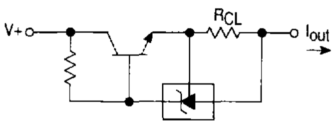
Figure 21. Series Pass Regulator



$$V_{out} = \left(1 + \frac{R1}{R2}\right) V_{ref}$$

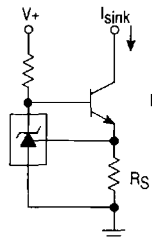
$$V_{out}\ min = V_{ref} + V_{be}$$

Figure 22. Constant Current Source



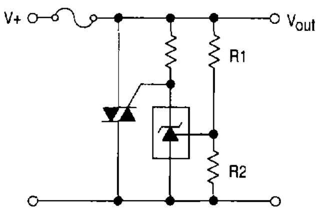
$$I_{out} = \frac{V_{ref}}{R_{CL}}$$

Figure 23. Constant Current Sink



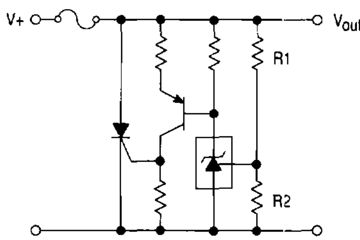
$$I_{Sink} = \frac{V_{ref}}{R_S}$$

Figure 24. TRIAC Crowbar



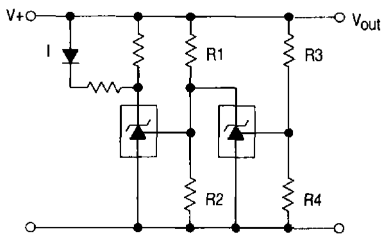
$$V_{out(trip)} = \left(1 + \frac{R1}{R2}\right) V_{ref}$$

Figure 25. SRC Crowbar



$$V_{out(trip)} = \left(1 + \frac{R1}{R2}\right) V_{ref}$$

Figure 26. Voltage Monitor

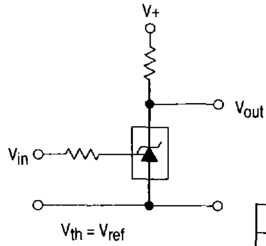


L.E.D. indicator is 'on' when V+ is between the upper and lower limits.

$$\text{Lower Limit} = \left(1 + \frac{R1}{R2}\right) V_{ref}$$

$$\text{Upper Limit} = \left(1 + \frac{R3}{R4}\right) V_{ref}$$

Figure 27. Single–Supply Comparator with Temperature–Compensated Threshold



V_{in}	V_{out}
< V_{ref}	V+
> V_{ref}	≈ 2.0 V

Figure 28. Linear Ohmmeter

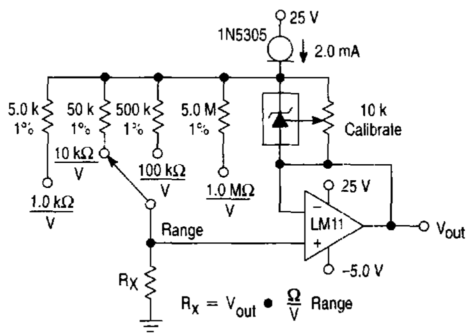


Figure 29. Simple 400 mW Phono Amplifier

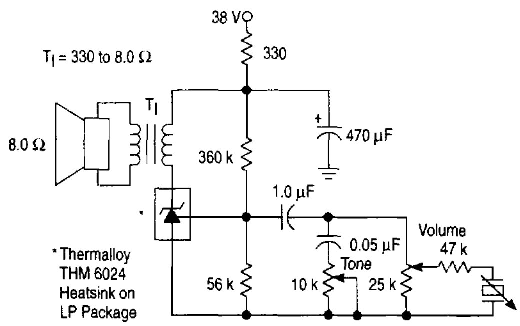
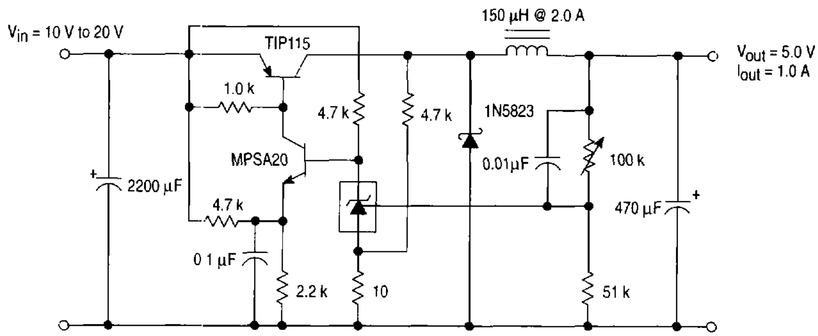


Figure 30. High Efficiency Step–Down Switching Converter



Test	Conditions	Results
Line Regulation	V_{in} = 10 V to 20 V, I_O = 1.0 A	53 mV (1.1%)
Load Regulation	V_{in} = 15 V, I_O = 0 A to 1.0 A	25 mV (0.5%)
Output Ripple	V_{in} = 10 V, I_O = 1.0 A	50 mVpp P.A.R.D.
Output Ripple	V_{in} = 20 V, I_O = 1.0 A	100 mVpp P.A.R.D.
Efficiency	V_{in} = 15 V, I_O = 1.0 A	82%