MOTOROLA
SEMICONDUCTOR
TECHNICAL DATA

TL431, A, B Series

PROGRAMMABLE PRECISION REFERENCES

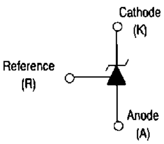
SILICON MONOLITHIC INTEGRATED CIRCUIT

Programmable Precision References

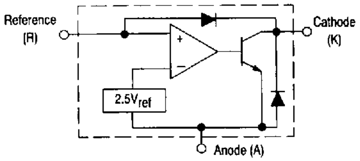
The TL431, A, B integrated circuits are three-terminal programmable shunt regulator diodes. These monolithic IC voltage references operate as a low temperature coefficient zener which is programmable from V_{ref} to 36 V with two external resistors. These devices exhibit a wide operating current range 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

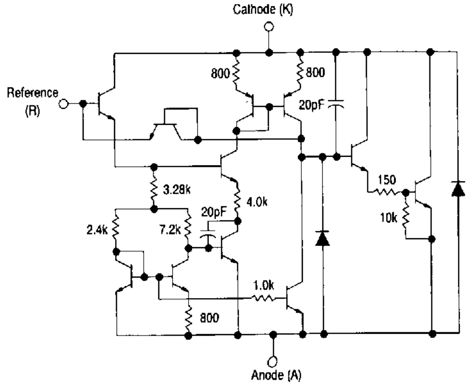
SYMBOL



FUNCTIONAL BLOCK DIAGRAM

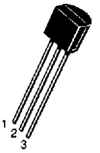


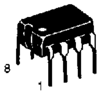
INTERNAL SCHEMATIC
Component values are nominal



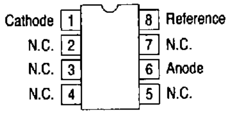
LP SUFFIX
CASE 29
(TO-92)

Pin 1. Reference
2. Anode
3. Cathode



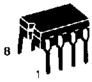


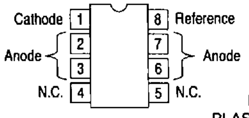
P SUFFIX
PLASTIC PACKAGE
CASE 626



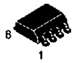
(Top View)

JG SUFFIX
CERAMIC PACKAGE
CASE 693





(Top View)



D SUFFIX
PLASTIC PACKAGE
CASE 751
(SOP-8)

ORDERING INFORMATION

Device	Temperature Range	Package
TL431CLP, ACLP, BCLP	0° to + 70°C	TO-92
TL431CP, ACP, BCP		Plastic
TL431CD, ACD, BCD		SOP-8
TL431CJG		Ceramic
TL431ILP, AILP, BILP	–40° to + 85°C	TO-92
TL431IP, AIP, BIP		Plastic
TL431ID, AID, BID		SOP-8
TL431IJG		Ceramic
TL431MJG	–55° to + 125°C	Ceramic

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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 Curent Range, Continuous	I_{ref}	–0.05 to +10	mA
Operating Junction Temperature	T_J	150	°C
Operating Ambient Temperature Range TL431M TL431I, TL431AI, TL431BI TL431C, TL431AC, TL431BC	T_A	 –55 to +125 –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 JG Suffix Ceramic Package	P_D	 0.70 1.10 1.25	W
Total Power Dissipation @ T_C = 25°C Derate above 25°C Case Temperature D, LP Suffix Plastic Package P Suffix Plastic Package JG Suffix Ceramic Package	P_D	 1.5 3.0 3.3	W

RECOMMENDED OPERATING CONDITIONS

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

THERMAL CHARACTERISTICS

Characteristics	Symbol	D, LP Suffix Package	P Suffix Package	JG Suffix Package	Unit
Thermal Resistance, Junction to Ambient	$R_{\theta JA}$	178	114	100	°C/W
Thermal Resistance, Junction to Case	$R_{\theta JC}$	83	41	38	°C/W

ELECTRICAL CHARACTERISTICS (Ambient temperature at 25°C, unless otherwise noted.)

Characteristics	Symbol	TL431M			TL431I			TL431C			Unit
		Min	Typ	Max	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 2.396	 2.495 —	 2.55 2.594	 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}	—	15	44	—	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	 — —	 –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 7.0	 — —	 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}	—	1.0	3.0	—	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	—	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	—	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	$\lvert Z_{ka} \rvert$	—	0.22	0.5	—	0.22	0.5	—	0.22	0.5	Ω

TL431, A, B Series

ELECTRICAL CHARACTERISTICS (Ambient temperature at 25°C, unless otherwise noted.)

Characteristics	Symbol	TL431AI			TL431AC			TL431B			Unit
		Min	Typ	Max	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}	V_{ref}	2.47 2.44	2.495 —	2.52 2.55	2.47 2.453	2.495 —	2.52 2.537	— 2.475	— 2.495	— 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}	—	2.6	1000	—	2.6	1000	—	0.23	0.5	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

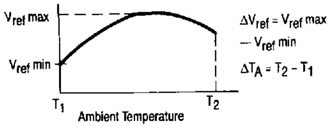
Note 1:

T_{low} = −55°C for TL431MG
= −40°C for TL431AIP TL431AILP, TL431IP, TL431ILP, TL431IJG
= 0°C for TL431ACP, TL431ACLP, TL431CP, TL431CLP, TL431CJG, TL431CD, TL431ACD

T_{high} = +125°C for TL431MJG
= +85°C for TL431AIP, TL431AILP, TL431IP, TL431ILP, TL431IJG
= +70°C for TL431ACP, TL431ACLP, TL431CP, TL431CLP, TL431CJG, TL431CD, TL431ACD

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:

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

αV_{ref} can be positive or negative depending on whether V_{ref} Min or V_{ref} Max occurs at the lower ambient temeperature. (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

$$\alpha V_{ref} = \frac{0.008 \times 10^6}{70\ (2.495)} = 45.8\ ppm/°C$$

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:

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

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

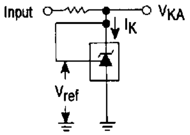
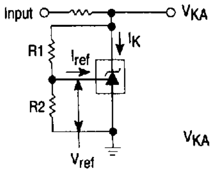
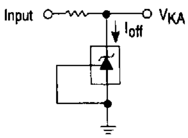


Figure 2. Test Circuit for $V_{KA} > V_{ref}$



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

Figure 3. Test Circuit for I_{off}



TL431, A, B Series

Figure 4. Cathode Current versus Cathode Voltage

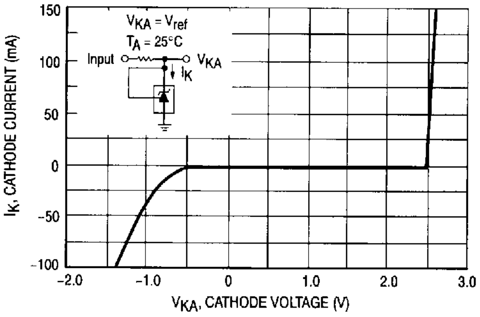


Figure 5. Cathode Current versus Cathode Voltage

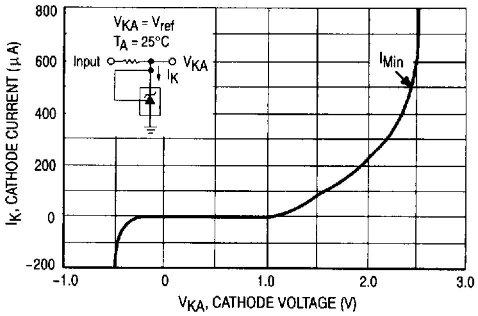


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Figure 6. Reference Input Voltage versus Ambient Temperature

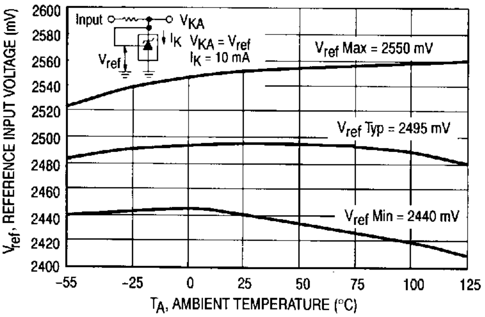


Figure 7. Reference Input Current versus Ambient Temperature

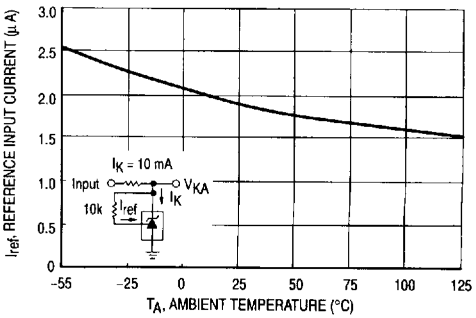


Figure 8. Change in Reference Input Voltage versus Cathode Voltage

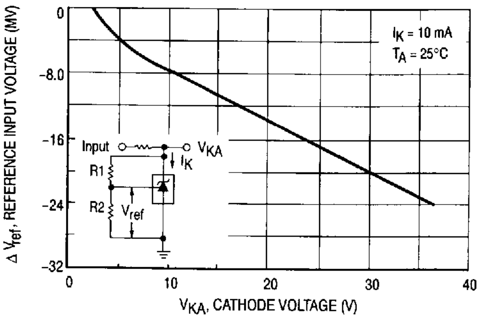


Figure 9. Off-State Cathode Current versus Ambient Temperature

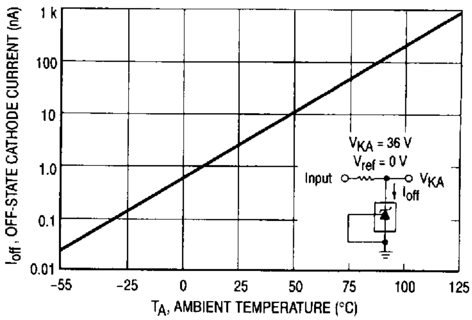


Figure 10. Dynamic Impedance versus Frequency

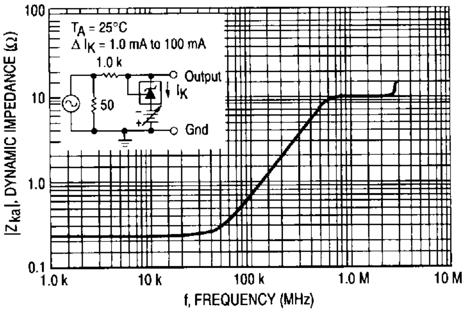


Figure 11. Dynamic Impedance versus Ambient Temperature

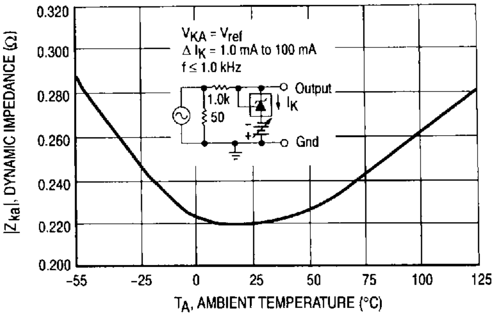


Figure 12. Open-Loop Voltage Gain versus Frequency

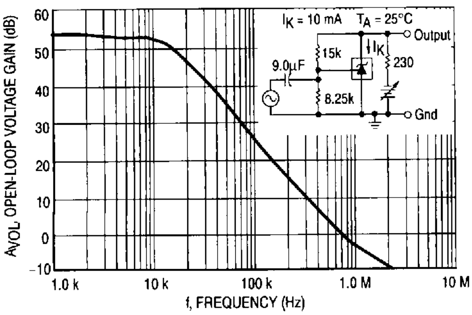


Figure 13. Spectral Noise Density

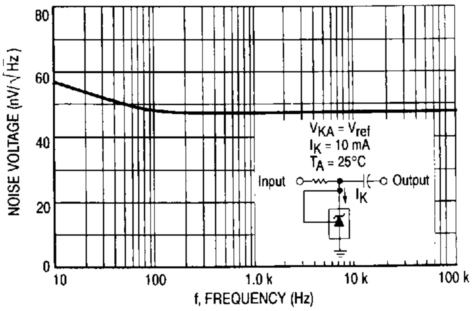


Figure 14. Pulse Response

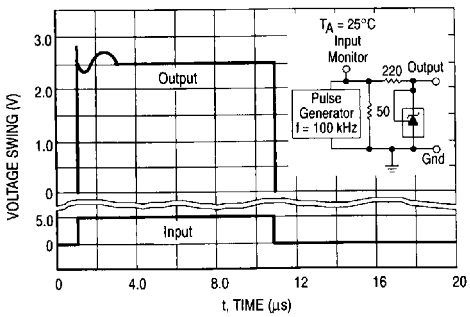


Figure 15. Stability Boundary Conditions

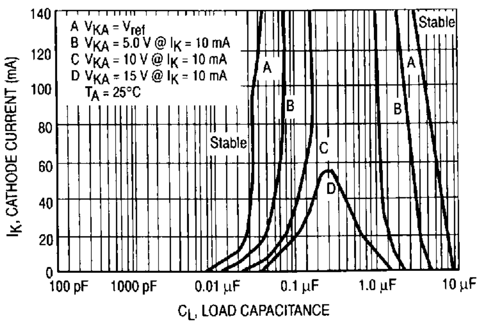


Figure 16. Test Circuit for Curve A of Stability Boundary Conditions

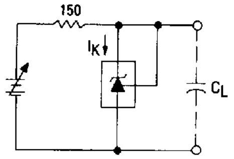
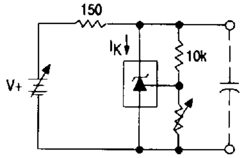
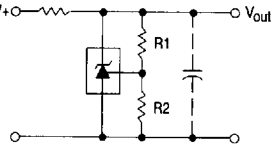


Figure 17. Test Circuit for Curves B, C, and D of Stability Boundary Conditions



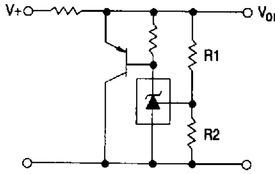
TYPICAL APPLICATIONS

Figure 18. Shunt Regulator



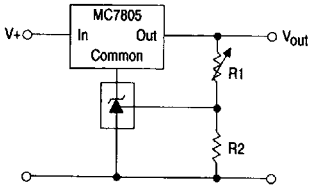
$$V_{out} = \left(1 + \frac{R1}{R2}\right) V_{ref}$$

Figure 19. High Current Shunt Regulator



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

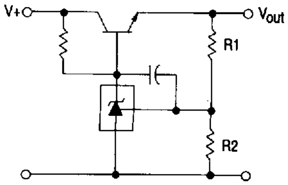
Figure 20. Output Control for a Three-Terminal Fixed Regulator



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

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

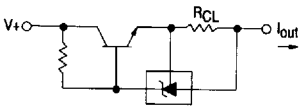
Figure 21. Series Pass Regulator



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

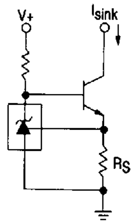
V_{out} min = $V_{ref} + V_{be}$

Figure 22. Constant Current Source



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

Figure 23. Constant Current Sink



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

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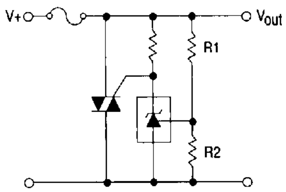
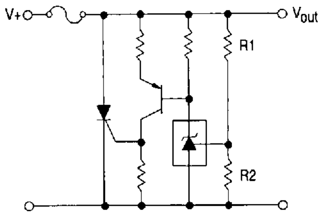
Figure 24. TRIAC Crowbar



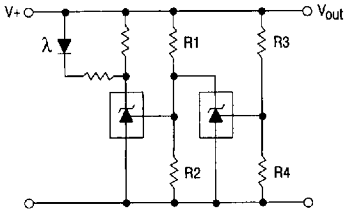
$$V_{out(trip)} = \left(1 + \frac{R1}{R2}\right) V_{ref}$$

Figure 25. SCR Crowbar



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

Figure 26. Voltage Monitor

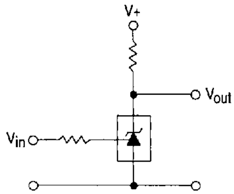


L.E.D. indicator is 'on' when V+ is between the upper and lower limits.

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

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

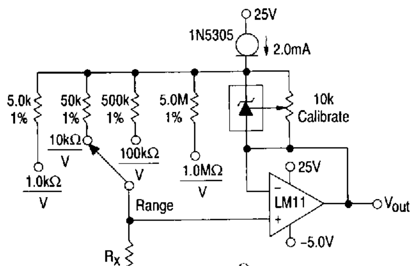
Figure 27. Single-Supply Comparator with Temperature-Compensated Threshold



$V_{th} = V_{ref}$

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

Figure 28. Linear Ohmmeter



$R_x = V_{out} \cdot \frac{\Omega}{V}$ Range

Figure 29. Simple 400 mW Phono Amplifier

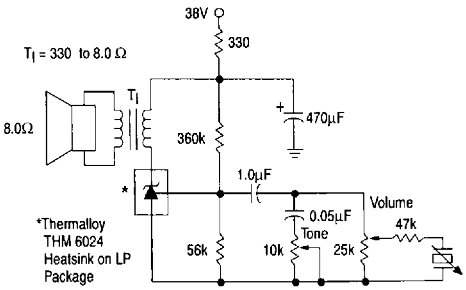
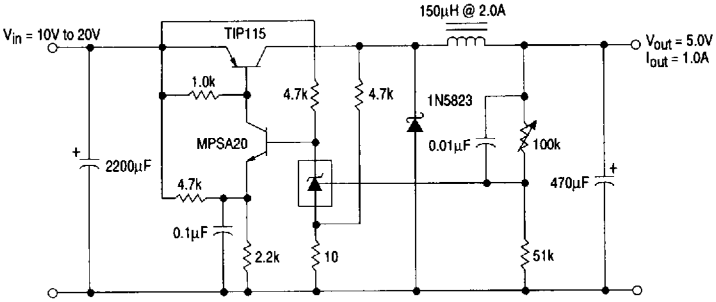


Figure 30. High Efficiency Step-Down Switching Converter



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 mV_{p-p} P.A.R.D.
Output Ripple	V_{in} = 20 V, I_O = 1.0 A	100 mV_{p-p} P.A.R.D.
Efficiency	V_{in} = 15 V, I_O = 1.0 A	82%

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