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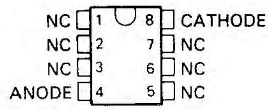
Contents

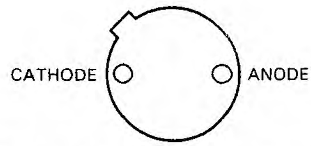
D3189, JANUARY 1989

- Operating Current Range . . . 20 μA to 20 mA
- 1.5% and 3% Initial Voltage Tolerance
- Reference Impedance . . .
  LM185 . . . 0.6 Ω Max at 25°C
  LM385 . . . 1 Ω Max at 25°C
  All Devices . . . 1.5 Ω Max Over Full Temperature Range
- Very Low Power Consumption
- Applications:
  Portable Meter References
  Portable Test Instruments
  Battery-Operated Systems
  Current-Loop Instrumentation
  Panel Meters
- Designed to be Interchangeable with National LM185-2.5, LM285-2.5, and LM385-2.5

D PACKAGE
(TOP VIEW)

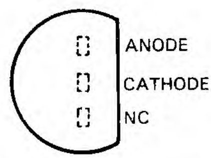


LD PACKAGE
(TOP VIEW)



The anode is in electrical contact with the case.

LP PACKAGE
(TOP VIEW)



NC—No internal connection

description

These micropower terminal bandgap voltage references operate over a 20-μA to 20-mA current range and feature exceptionally low dynamic impedance and good temperature stability. On-chip trimming provides tight voltage tolerance. The LM185-2.5 series bandgap reference has low noise and good long-term stability.

Careful design of the LM185-2.5 series has made the device exceptionally tolerant of capacitive loading, making it easy to use in almost any reference application. The wide dynamic operating temperature range allows its use with widely varying supplies with excellent regulation.

The extremely low-power drain of the LM185-2.5 series makes it useful for micropower circuitry. These voltage references can be used to make portable meters, regulators, or general-purpose analog circuitry with battery life approaching shelf life. Further, the wide operating current range allows them to replace older references with a tighter tolerance part.

The LM185-2.5 is characterized for operation over the full military temperature range of −55°C to 125°C. The LM285-2.5 is characterized for operation from −40°C to 85°C. The LM385-2.5 and LM385B-2.5 are characterized for operation from 0°C to 70°C.

symbol

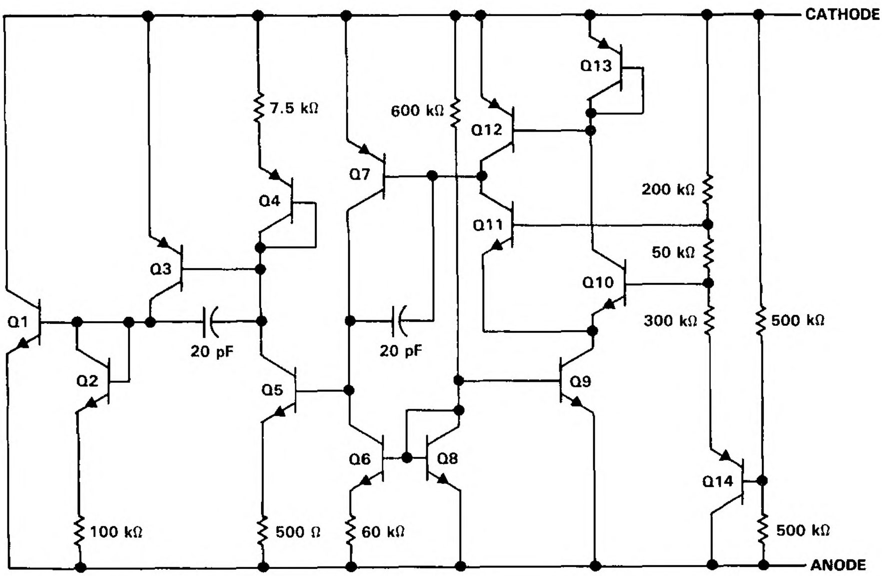
TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

AVAILABLE OPTIONS

T_A	V_Z TOLERANCE	PACKAGE SMALL OUTLINE (D)	PACKAGE METAL CAN (LD)	PACKAGE PLASTIC (LP)
0°C to 70°C	3%	LM385D-2.5		LM385LP-2.5
	1.5%	LM385BD-2.5		LM385BLP-2.5
−40°C to 85°C	1.5%	LM285D-2.5	LM285LD-2.5	LM285LP-2.5
−55°C to 125°C	1.5%		LM185LD-2.5	

The D package is available taped and reeled. Add the suffix R to the device type (i.e., LM385DR-2.5).

schematic



Component values shown are nominal.

TEXAS INSTRUMENTS
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absolute maximum ratings over operating free-air temperature range

Reverse current . . . . 30 mA
Forward current . . . . 10 mA
Operating free-air temperature range: LM185-2.5 . . . . −55°C to 125°C
LM285-2.5 . . . . −40°C to 85°C
LM385-2.5, LM385B-2.5 . . . . 0°C to 70°C
Storage temperature range . . . . −65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or LP package . . . . 260°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: LD package . . . . 300°C

electrical characteristics at specified free-air temperature

PARAMETER		TEST CONDITIONS	T_A†	LM185-2.5, LM285-2.5			LM385-2.5			LM385B-2.5			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	MIN	TYP	MAX	
V_Z	Reference voltage	I_Z = 20 µA to 20 mA	25°C	2.462	2.5	2.538	2.425	2.5	2.575	2.462	2.5	2.538	V
α_{VZ}	Average temperature coefficient of reference voltage‡	I_Z = 20 µA to 20 mA	25°C		±20			±20			±20		ppm/°C
ΔV_Z	Change in reference voltage with current	I_Z = 20 µA to 1 mA	25°C			1			2			2	mV
			Full range			1.5			2.5			2.5	
		I_Z = 1 mA to 20 mA	25°C			10			20			20	
			Full range			20			25			25	
$\Delta V_Z/\Delta t$	[illegible]erm change in [illegible]ce voltage	I_Z = 100 µA	25°C		±20			±20			±20		ppm/khr
$I_{Z(min)}$	Minimum reference current		Full range		8	20		8	20		8	20	µA
Z_Z	Reference impedance	I_Z = 100 µA	25°C		0.2	0.6		0.4	1		0.4	1	Ω
			Full range			1.5			1.5			1.5	
V_n	B[illegible]nd noise v[illegible]	I_Z = 100 µA, f = 10 Hz to 10 kHz	25°C		120			120			120		µV

† Full range is −55°C to 125°C for the LM185M-2.5, −40°C to 85°C for the LM285-2.5, and 0°C to 70°C for the LM385-2.5 and LM385B-2.5.
‡ The average temperature coefficient of reference voltage is defined as the total change in reference voltage divided by the specified temperature range.

2 Data Sheets

TYPICAL CHARACTERISTICS†

REVERSE CHARACTERISTICS

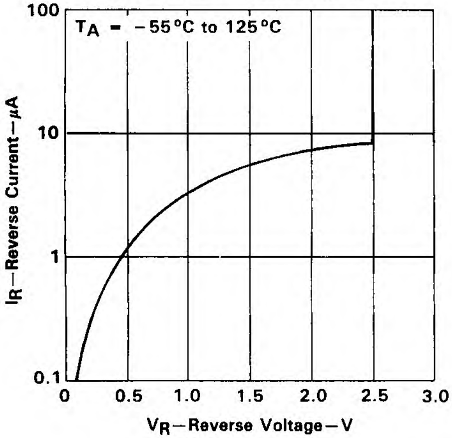

FIGURE 1

REFERENCE VOLTAGE CHANGE
WITH
REVERSE CURRENT

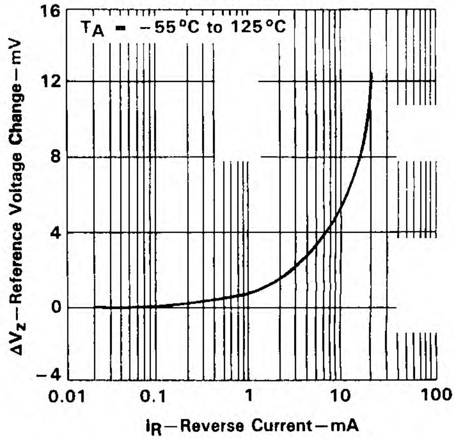

FIGURE 2

FORWARD CHARACTERISTICS

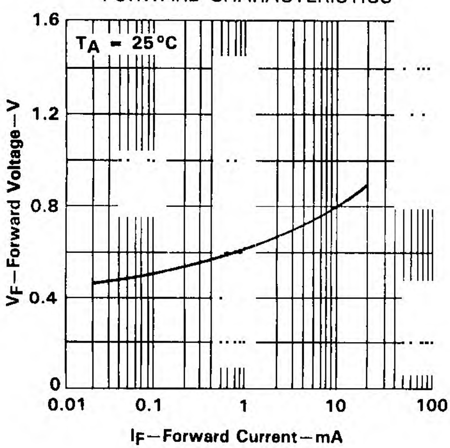

FIGURE 3

REFERENCE VOLTAGE
vs
FREE-AIR TEMPERATURE

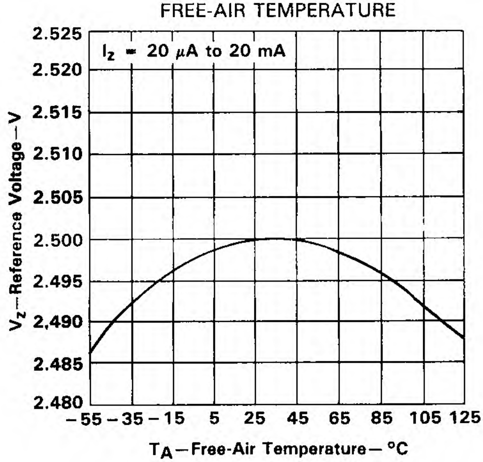

FIGURE 4

†Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS

REFERENCE IMPEDANCE
vs
REFERENCE CURRENT

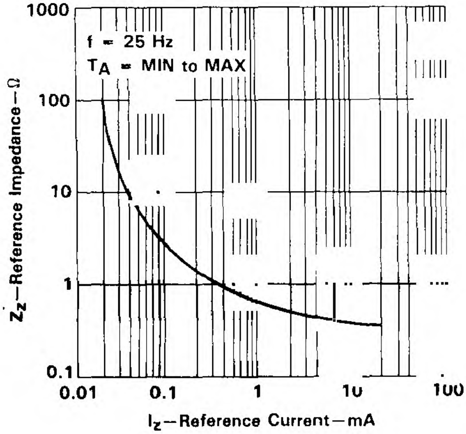

FIGURE 5

REFERENCE IMPEDANCE
vs
FREQUENCY

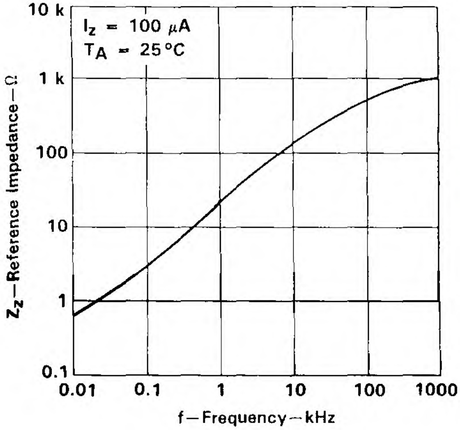

FIGURE 6

NOISE VOLTAGE
vs
FREQUENCY

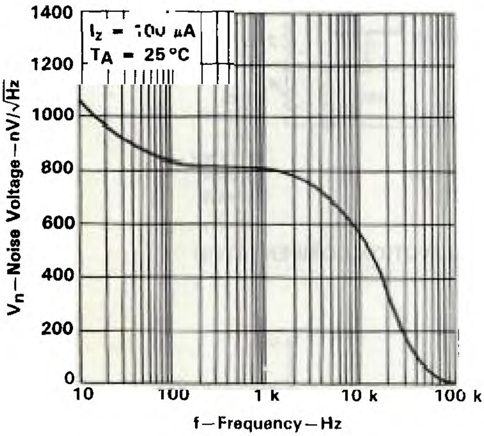

FIGURE 7

FILTERED RMS OUTPUT NOISE VOLTAGE
vs
FREQUENCY

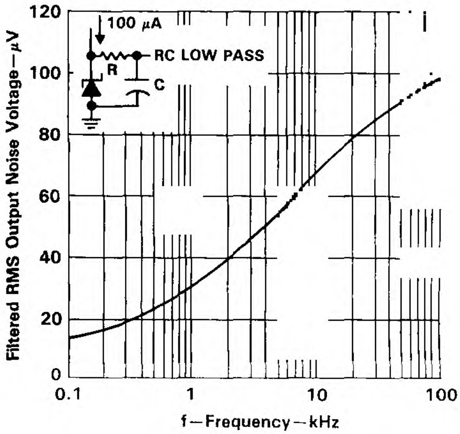

FIGURE 8

TYPICAL CHARACTERISTICS

TRANSIENT RESPONSE

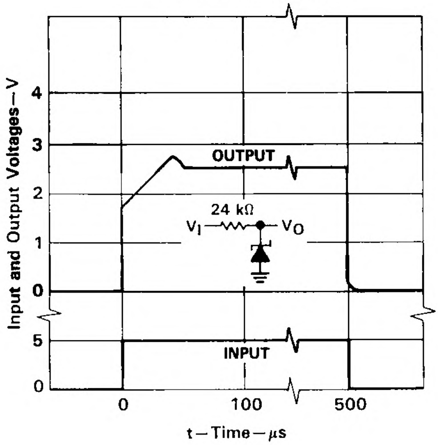

FIGURE 9

TYPICAL APPLICATION DATA

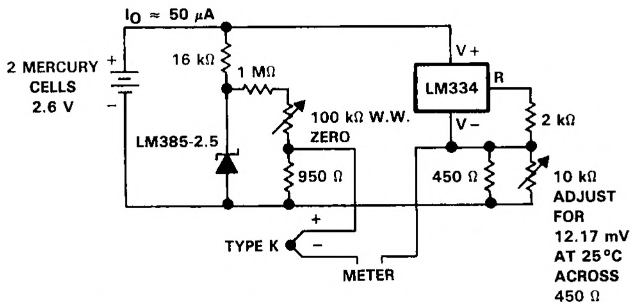

FIGURE 10. THERMOCOUPLE COLD-JUNCTION COMPENSATOR

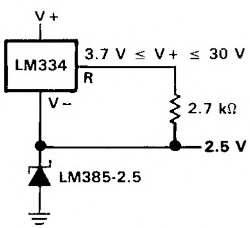

FIGURE 11. OPERATION OVER A WIDE SUPPLY RANGE

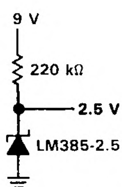

FIGURE 12. REFERENCE FROM A 9-V BATTERY

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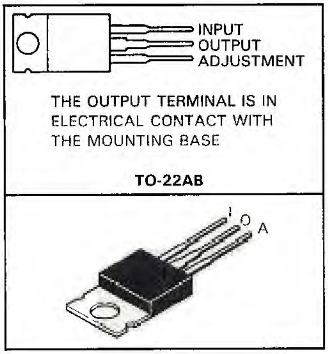
D2212, SEPTEMBER 1977—REVISED FEBRUARY 1988

- Output Voltage Range Adjustable from 1.2 V to 37 V
- Output Current Capability of 1.5 A Max
- Input Regulation Typically 0.01% Per Input-Volt Change
- Output Regulation Typically 0.1%
- Peak Output Current Constant Over Temperature Range of Regulator
- Popular 3-Lead TO-220AB Package
- Ripple Rejection Typically 80 dB
- Direct Replacement for National LM217 and LM317

terminal assignments

KC PACKAGE
(TOP VIEW)



description

The LM217 and LM317 are adjustable 3-terminal positive-voltage regulators capable of supplying 1.5 A over a differential voltage range of 3 V to 40 V. They are exceptionally easy to use and require only two external resistors to set the output voltage. Both input and output regulation are better than standard fixed regulators. The devices are packaged in a standard transistor package that is easily mounted and handled.

In addition to higher performance than fixed regulators, these regulators offer full overload protection available only in integrated circuits. Included on the chip are current limit, thermal overload protection, and safe-area protection. All overload protection circuitry remains fully functional even if the adjustment terminal is disconnected. Normally, no capacitors are needed unless the device is situated far from the input filter capacitors in which case an input bypass is needed. An optional output capacitor can be added to improve transient response. The adjustment terminal can be bypassed to achieve very high ripple rejection, which is difficult to achieve with standard 3-terminal regulators.

Besides replacing fixed regulators, these regulators are useful in a wide variety of other applications. The primary applications of each of these regulators is that of a programmable output regulator, but by connecting a fixed resistor between the adjustment terminal and the output terminal, each device can be used as a precision current regulator. Even though the regulator is floating and sees only the input-to-output differential voltage, use of these devices to regulate output voltages that would cause the maximum-rated differential voltage to be exceeded if the output became shorted to ground is not recommended. The TL783 is recommended for output voltages exceeding 37 V. Supplies with electronic shutdown can be achieved by clamping the adjustment terminal to ground, which programs the output to 1.2 V where most loads draw little current.

TEXAS INSTRUMENTS
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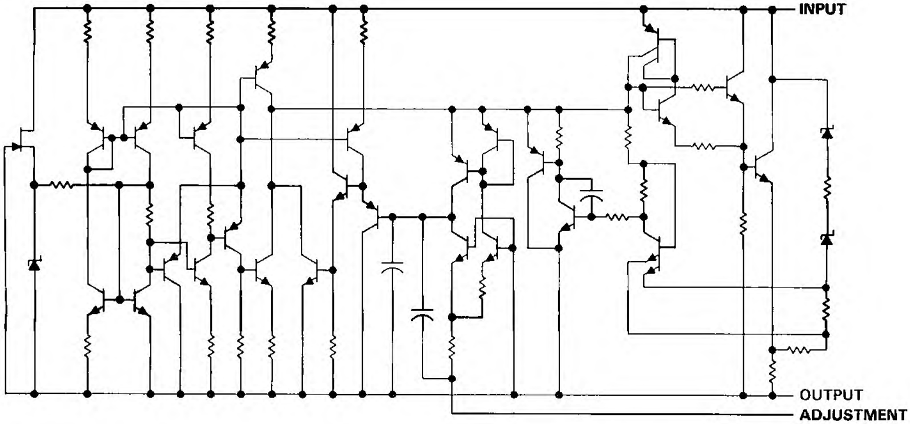
The LM217 and LM317 are characterized for operation from −25 °C to 150 °C and from 0 °C to 125 °C, respectively.

schematic



absolute maximum ratings over operating temperature range (unless otherwise noted)

	LM217	LM317	UNIT
Input-to-output differential voltage, $V_I - V_O$	40	40	V
Continuous total dissipation at 25 °C free-air temperature (see Note 1)	2000	2000	mW
Continuous total dissipation at (or below) 25 °C case temperature (see Note 1)	20	15	W
Operating free-air, case, or virtual junction temperature range	−25 to 150	0 to 125	°C
Storage temperature range	−65 to 150	−65 to [illegible]	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260	260	°C

NOTE 1: For operation above 25 °C free-air or case temperature, refer to Figures 15 and 16. To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variations in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

recommended operating conditions

	LM217		LM317		UNIT
	MIN	MAX	MIN	MAX	
Output current, I_O	5	1500	10	1500	mA
Operating virtual junction temperature, T_J	−25	150	0	125	°C

electrical characteristics over recommended ranges of operating virtual junction temperature (unless otherwise noted) (see Note 2)

PARAMETER	TEST CONDITIONS†		LM217 MIN	LM217 TYP	LM217 MAX	LM317 MIN	LM317 TYP	LM317 MAX	UNIT
Input regulation (See Note 3)	$V_I - V_O$ = 3 V to 40 V, See Note 4	T_J = MIN to MAX		0.01	0.02		0.01	0.04	%/V
		I_O = 10 mA to 1.5 A		0.02	0.05		0.02	0.07	
Ripple rejection	V_O = 10 V,	f = [illegible] Hz		65			65		dB
	V_O = 10 V, 10-μF capacitor between ADJ and ground	f = [illegible] Hz,	66	80		66	80		
Output regulation	I_O = 10 mA to 1.5 A, T_J = 25°C, See Note 4	$V_O \le 5$ V		5	15		5	25	mV
		$V_O > 5$ V		0.1	0.3		0.1	0.5	%
	I_O = 10 mA to 1.5 A, See Note 4	$V_O \le 5$ V		20	50		20	70	mV
		$V_O > 5$ V		0.3	1		0.3	1.5	%
Output voltage change with temperature	T_J = MIN to MAX			1			1		%
Output voltage long-term drift (see Note 5)	After 1000 h at T_J = MAX and $V_I - V_O$ = 40 V			0.3	1		0.3	1	%
Output noise voltage	f = 10 Hz to 10 kHz, T_J = 25°C			0.003			0.003		%
Minimum output current to maintain regulation	$V_I - V_O$ = 40 V			3.5	5		3.5	10	mA
Peak output current	$V_I - V_O \le 15$ V		1.5	2.2		1.5	2.2		A
	$V_I - V_O \le 40$ V, T_J = 25°C			0.4		0.15	0.4		
Adjustment-terminal current				50	100		50	100	μA
Change in adjustment-terminal current	$V_I - V_O$ = 2.5 V to 40 V, I_O = 10 mA to 1.5 A			0.2	5		0.2	5	μA
Reference voltage (output to ADJ)	$V_I - V_O$ = 3 V to 40 V, I_O = 10 mA to 1.5 A, P ≤ 15 W		1.2	1.25	1.3	1.2	1.25	1.3	V

†Unless otherwise noted, these specifications apply for the following test conditions; $V_I - V_O$ = 5 V and I_O = 0.5 A. For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.

NOTES: 2. All characteristics are measured with a 0.1-μF capacitor across the input and a 1-μF capacitor across the output.
3. Input regulation is expressed here as the percentage change in output voltage per 1-V change at the input.
4. Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.
5. Since long-term drift cannot be measured on the individual devices prior to shipment, this specification is not intended to be a guarantee or warranty. It is an engineering estimate of the average drift to be expected from lot to lot.

TYPICAL APPLICATION DATA

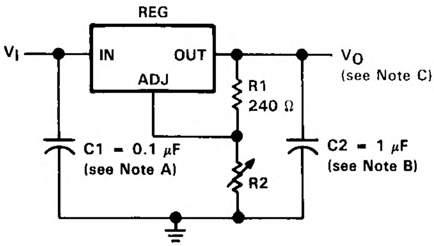


FIGURE 1. ADJUSTABLE VOLTAGE REGULATOR

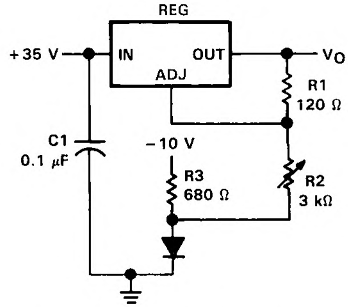
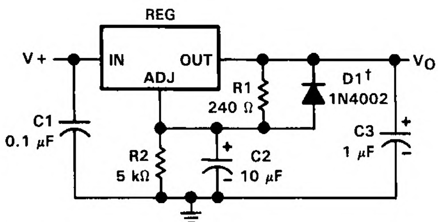


FIGURE 2. 0-V to 30-V REGULATOR CIRCUIT



†D1 discharges C2 if output is shorted to ground.

FIGURE 3. ADJUSTABLE REGULATOR CIRCUIT WITH IMPROVED RIPPLE REJECTION

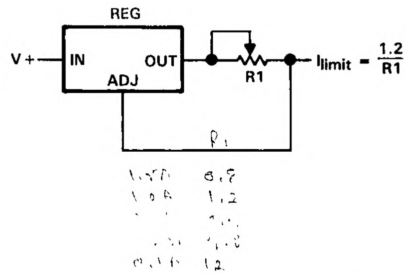


FIGURE 4. PRECISION CURRENT LIMITER CIRCUIT

NOTES: A. Use of an input bypass capacitor is recommended if regulator is far from filter capacitors.
B. Use of an output capacitor improves transient response but is optional.
C. Output voltage is calculated from the equation: $V_O = V_{ref}\left(1 + \frac{R2}{R1}\right)$
V_{ref} equals the difference between the output and adjustment terminal voltages.

TYPICAL APPLICATIONS

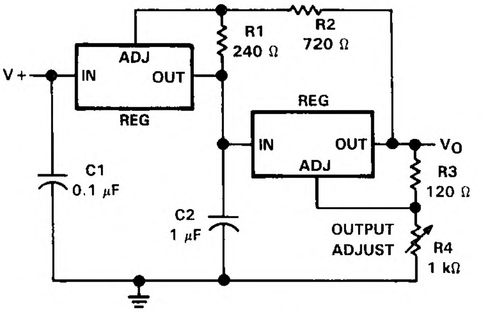


FIGURE 5. TRACKING PREREGULATOR CIRCUIT

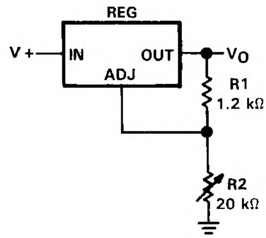
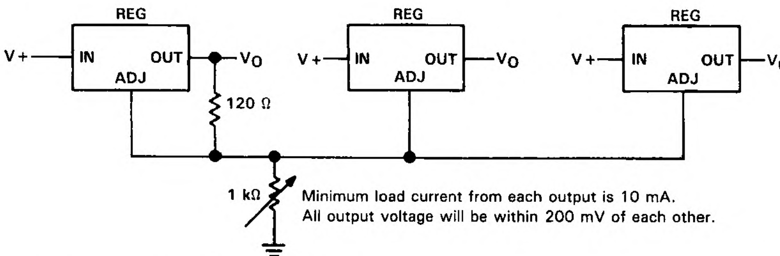
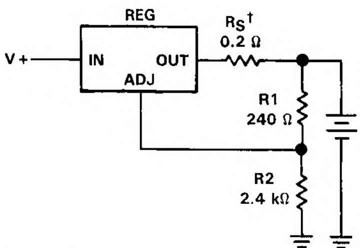


FIGURE 6. 1.2 to 20-V REGULATOR CIRCUIT WITH MINIMUM PROGRAM CURRENT



Minimum load current from each output is 10 mA.
All output voltage will be within 200 mV of each other.

FIGURE 7. ADJUSTING MULTIPLE ON-CARD REGULATORS WITH A SINGLE CONTROL



† R_S controls output impedance of charger

$$Z_{OUT} = R_S \left(1 + \frac{R2}{R1}\right)$$

The use of R_S allows low charging rates with a fully-charged battery.

FIGURE 8. BATTERY CHARGER CIRCUIT

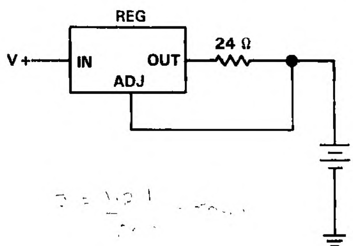


FIGURE 9. 50-mA CONSTANT-CURRENT BATTERY CHARGER CIRCUIT

2

Data Sheets

TYPICAL APPLICATIONS

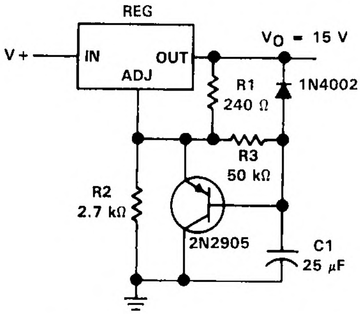


FIGURE 10. SLOW-TURN-ON 15-V REGULATOR CIRCUIT

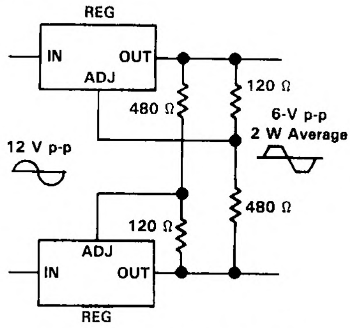
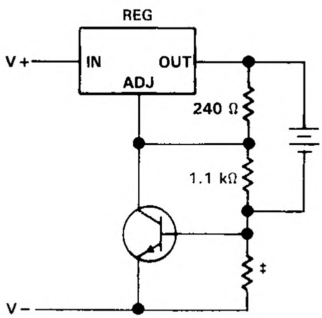


FIGURE 11. A-C VOLTAGE REGULATOR CIRCUIT



‡This resistor sets peak current (0.6 A for 1 Ω)

FIGURE 12. CURRENT-LIMITED 6-V CHARGER

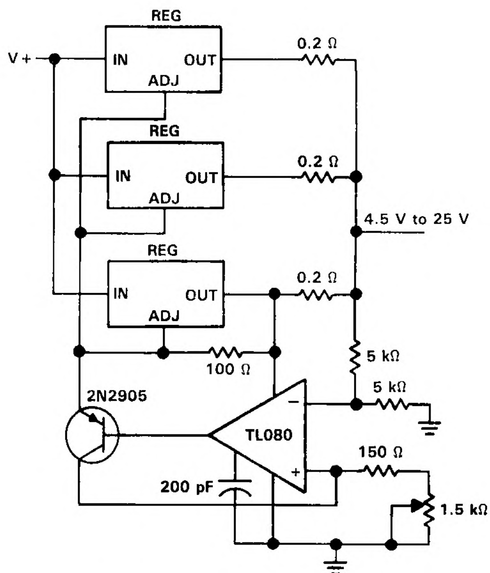


FIGURE 13. ADJUSTABLE 4-A REGULATOR

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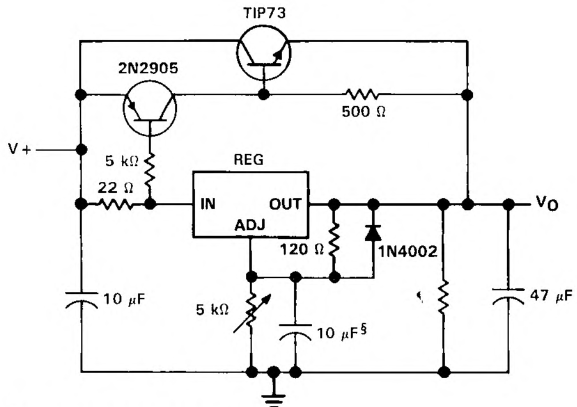
TYPICAL APPLICATIONS



¶Minimum load current is 30 mA.
§Optional capacitor improves ripple rejection

FIGURE 14. HIGH-CURRENT ADJUSTABLE REGULATOR

THERMAL INFORMATION

FREE-AIR TEMPERATURE DISSIPATION DERATING CURVE

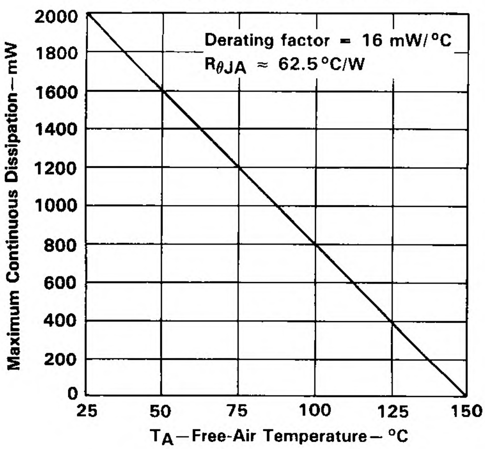


FIGURE 15

CASE TEMPERATURE DISSIPATION DERATING CURVE

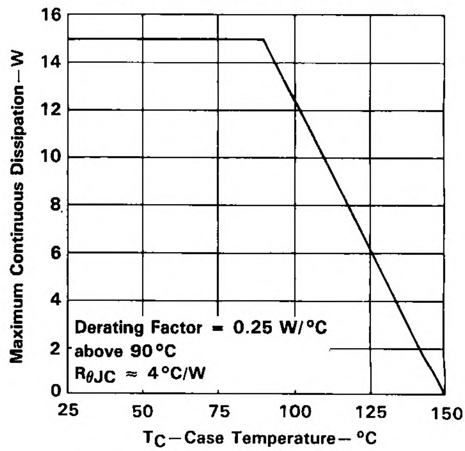


FIGURE 16

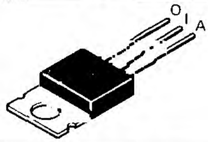
NOVEMBER 1981—REVISED FEBRUARY 1988

- Output Voltage Range Adjustable from −1.2 V to −37 V
- I_O Capability of 1.5 A Max
- Input Regulation Typically 0.01% per Input-Volt Change
- Output Regulation Typically 0.3%
- Peak Output Current Constant Over Temperature Range of Regulator
- Ripple Rejection Typically 77 dB
- Direct Replacement for National Semiconductor LM237, LM337

LM237, LM337 . . . KC PACKAGE
(TOP VIEW)

THE INPUT TERMINAL IS IN ELECTRICAL CONTACT WITH THE MOUNTING BASE

TO-220AB

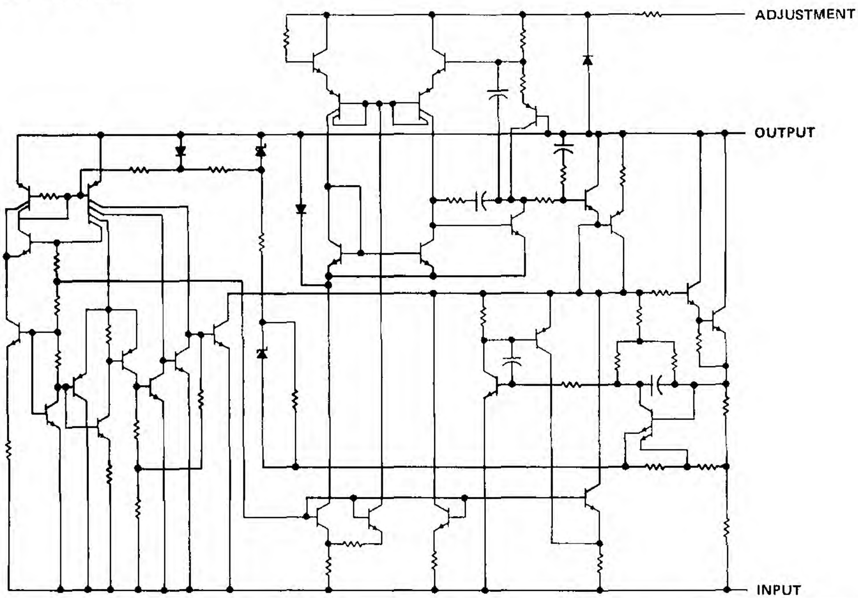


description

The LM237 and LM337 are adjustable 3-terminal negative-voltage regulators capable of supplying in excess of −1.5 A over an output voltage range of −1.2 V to −37 V. They are exceptionally easy to use, requiring only two external resistors to set the output voltage and one output capacitor for frequency compensation. The current design has been optimized for excellent regulation and low thermal transients. In addition, the LM237 and LM337 feature internal current limiting, thermal shutdown, and safe-area compensation, making them virtually immune to blowout by overloads.

The LM237 and LM337 serve a wide variety of applications including local on-card regulation, programmable output voltage regulation, or precision current regulation. They are ideal complements to the LM217 and LM317 adjustable positive-voltage regulators.

schematic diagram



absolute maximum ratings over operating temperature range (unless otherwise noted)

Input-to-output differential voltage, $V_I - V_O$	−40 V
Continuous total dissipation at 25 °C free-air temperature (see Note 1)	2 W
Continuous total dissipation at (or below) 25 °C case temperature (see Note 1)	15 W
Operating free-air, case, or virtual junction temperature range: LM237	−25 °C to 150 °C
LM337	0 °C to 125 °C
Storage temperature range	−65 °C to 150 °C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260 °C

NOTE 1: For operation above 25 °C free-air or case temperature, refer to Figures 1 and 2. To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variations in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

2 Data Sheets

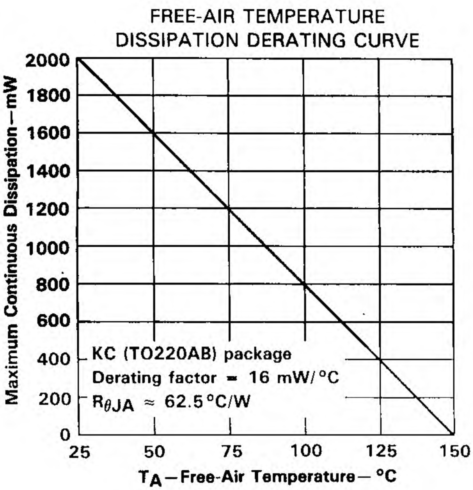


FIGURE 1

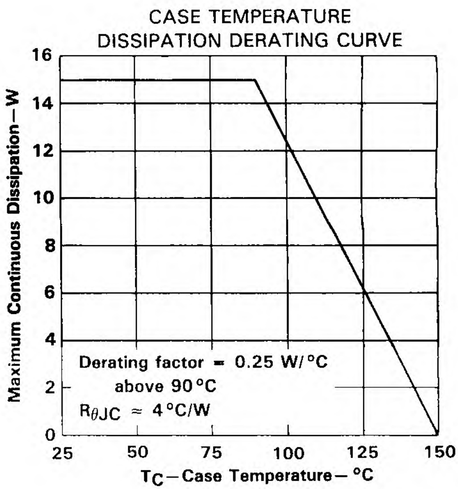


FIGURE 2

recommended operating conditions

		LM237		LM337		UNIT
		MIN	MAX	MIN	MAX	
Output current, I_O	$\lvert V_I - V_O \rvert \leq 40$ V, $P \leq 15$ W	10	1500	10	1500	mA
	$\lvert V_I - V_O \rvert \leq 10$ V, $P \leq 15$ W	6	1500	6	1500	
Operating virtual junction temperature, T_J		−25	150	0	125	°C

electrical characteristics over recommended ranges of operating virtual junction temperature (unless otherwise noted)

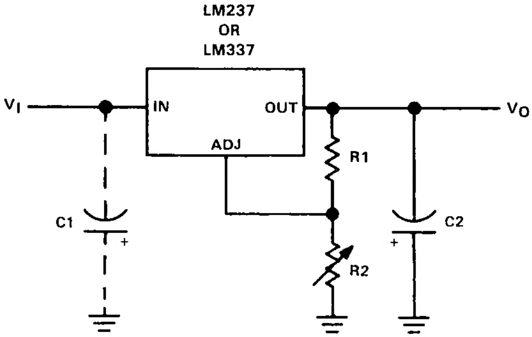
PARAMETER	TEST CONDITIONS†		LM237			LM337			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
Input regulation‡	$V_I - V_O = -3$ V to −40 V	$T_J = 25°C$		0.01	0[illegible]		0.01	0.04	%/V
		T_J = MIN to MAX		0.02	0[illegible]		0.02	0.07	
Ripple rejection	$V_O = -10$ V,	f = 120 Hz		60			60		dB
	$V_O = -10$ V, $C_{ADJ} = 10\ \mu F$	f = 120 Hz	66	77		66	77		
Output regulation	I_O = 10 mA to 1.5 A, $T_J = 25°C$	$\lvert V_O \rvert \leq 5$ V			[illegible]			50	mV
		$\lvert V_O \rvert \geq 5$ V			[illegible]			1	%
	I_O 10 mA to 1.5 A	$\lvert V_O \rvert \leq 5$ V			50			70	mV
		$\lvert V_O \rvert \geq 5$ V			1			1.5	%
Output voltage change with temperature	T_J = MIN to MAX			0.6			0.6		%
Output voltage long-term drift (see Note 2)	After 1000 h at T_J = MAX and $V_I - V_O = -40$ V			0.3	1		0.3	1	%
Output noise voltage	f = 10 Hz to 10 kHz,	$T_J = 25°C$		0.003			0[illegible]		%
Minimum output current to maintain regulation	$\lvert V_I - V_O \rvert \leq 40$ V			2.5	5		2.5	10	mA
	$\lvert V_I - V_O \rvert \leq 10$ V			1.2	3		1.5	6	
Peak output current	$\lvert V_I - V_O \rvert \leq 15$ V		1.5	2.2		1.5	2.2		A
	$\lvert V_I - V_O \rvert \leq 40$ V,	$T_J = 25°C$	0.24	0.4		0.15	0.4		
Adjustment-terminal current				65	100		65	100	μA
Change in adjustment terminal current	$V_I - V_O = -2.5$ V to −40 V, I_O = 10 mA to MAX,	$T_J = 25°C$		2	5		2	5	μA
Reference voltage (output to ADJ)	$V_I - V_O = -3$ to −40 V, I_O = 10 mA to 1.5 A, P ≤ rated dissipation	$T_J = 25°C$	−1.225	−1.250	−1.275	−1.213	−1.25	−1.287	V
		T_J = MIN to MAX	−1.2	−1.25	−1.3	−1.2	−1.25	−1.3	
Thermal regulation	Initial $T_J = 25°C$,	10-ms pulse		0.002	0.02		0.003	0.04	%/W

†Unless otherwise noted, these specifications apply for the following test conditions $\lvert V_I - V_O \rvert = 5$ V and $I_O = 0.5$ A. For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions. All characteristics are measured with a 0.1-μF capacitor across the input and a 1-μF capacitor across the output. Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.

‡Input regulation is expressed here as the percentage change in output voltage per 1-volt change at the input.

NOTE 2: Since long-term drift cannot be measured on the individual devices prior to shipment, this specification is not intended to be a guarantee or warranty. It is an engineering estimate of the average drift to be expected from lot to lot.

TYPICAL APPLICATION DATA



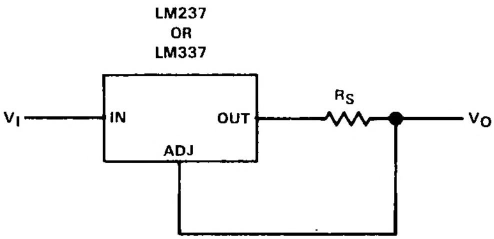
R1 is typically 120 Ω.

$$R2 = R1 \left(\frac{-V_O}{-1.25} - 1 \right)$$ where V_O is the output in volts.

C1 is a 1-μF solid tantalum required only if the regulator is more than 10 cm (4 in.) from the power supply filter capacitor.

C2 is a 1-μF solid tantalum or 10-μF aluminum electrolytic required for stability.

FIGURE 3. ADJUSTABLE NEGATIVE-VOLTAGE REGULATOR



$$R_S = \frac{1.25\ V}{I_{LIMIT}}$$

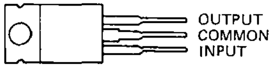
FIGURE 4. CURRENT-LIMITING CIRCUIT

D2700, APRIL 1983—REVISED

- Input-Output Differential Less than 0.6 V
- Output Current of 150 mA
- Reverse Polarity Protection
- Line Transient Protection
- Internal Short-Circuit Current Limiting
- Internal Thermal Overload Protection
- Mirror-Image Insertion Protection
- Direct Replacement for National LM330T-5.0

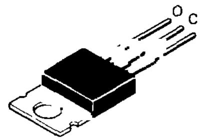
KC PACKAGE

(TOP VIEW)



THE COMMON TERMINAL IS IN ELECTRICAL CONTACT WITH THE MOUNTING BASE

TO-220AB



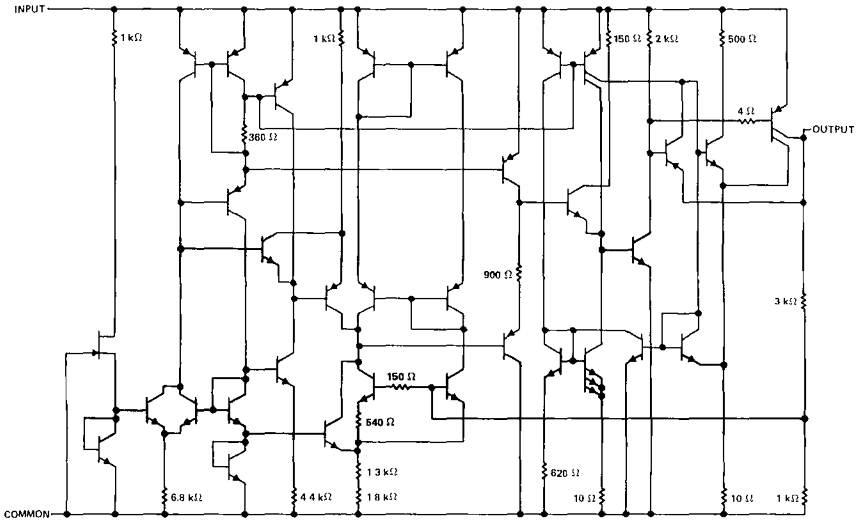
description

The LM330 3-terminal positive regulator features an ability to source 150 mA of output current with an input-output differential of 0.6 volt or less. Familar regulator features such as current limit and thermal overload protection are also provided.

The LM330 has low dropout voltage making it useful for certain battery applications. For example, since the low dropout voltage allows a longer battery discharge before the output falls out of regulation, a battery supplying the regulator input voltage may discharge to 5.6 V and still properly regulate the system and load voltage. The LM330 protects both itself and the regulated system from reverse installation of batteries.

Other protection features include line transient protection above 40 V, where the output actually shuts down to avoid damaging internal and external circuits. The LM330 regulator cannot be harmed by temporary mirror-image insertion.

schematic diagram



Resistor values shown are nominal.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Continuous input voltage	26 V
Transient input voltage t = 1 s	40 V
Continuous total dissipation at 25°C free-air temperature (see Note 1)	2 W
Continuous total dissipation at (or below) case temperature (see Note 1)	15 W
Operating free-air, case, or virtual junction temperature	−55°C to 150°C
Storage temperature	−65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C

NOTE 1: For operation above 25°C free-air or case temperature, refer to Figures 1 and 2. To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variations in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVE

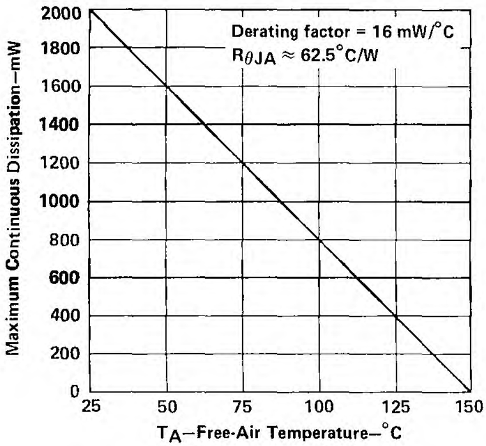


FIGURE 1

CASE TEMPERATURE
DISSIPATION DERATING CURVE

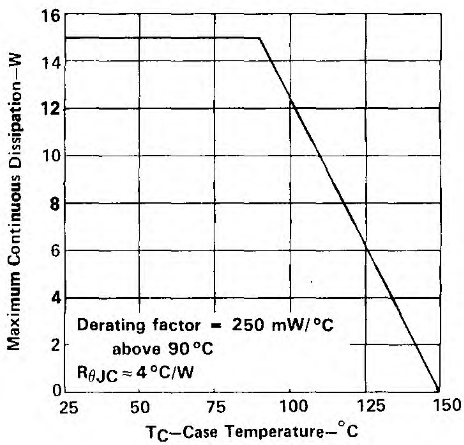


FIGURE 2

recommended operating conditions

		MIN	MAX	UNIT
I_O	Output current	5	150	mA
T_A	Operating virtual junction temperature	0	100	°C

electrical characteristics at 25°C virtual junction temperature, V_I = 14 V, I_O = 150 mA, (unless otherwise noted)

PARAMETERS	TEST CONDITIONS†		MIN	TYP	MAX	UNIT
Output voltage	V_I = 6 V to 26 V	I_O = 5 mA to 150 mA,	4.8	5	5.2	V
	T_J = 0°C to [illegible] C					
Input regulation		V_I = 9 V to 16 V		7	25	mV
		V_I = 6 V to 26 V		30	60	
Ripple rejection	f = 120 Hz			56		dB
Output regulation	I_O = 5 mA to 150 mA			14	50	mV
Output voltage long-term drift‡	After 1000 h at T_J = 150°C			20		mV
Dropout voltage	I_O = 150 mA			0.32	0.6	V
Output noise voltage	f = 10 Hz to 100 kHz			50		μV
Output voltage with input polarity reversed	R_L = 100 Ω	V_I = −30 V, t = 100 ms		>−0.3		V
		V_I = −12 V, DC		>−0.3		
Output voltage with input transient	V_I = 60 V,	t = 100 ms		<5.5		V
	V_I = 50 V,	t = 1 s		<5.5		
Bias current with input transient	R_L = 100 Ω	V_I = 40 V, t = 1 s		14		mA
		V_I = −6 V, t = 1 s		−80		
Overvoltage shutdown voltage			26	45		V
Output impedance	I_O = 100 mA, I_O = 10 mA (rms), f = 100 Hz to 10 kHz			[illegible]		mΩ
Bias current	I_O = 10 mA			[illegible]	7	mA
	I_O = 50 mA			5	11	
	I_O = 150 mA			18	40	
Bias current change	V_I = 6 V to 26 V			10		%
Peak output current			150	420	700	mA

† Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.1-μF capacitor across the input and a 10-μF capacitor across the output.

‡ Since long-term drift cannot be measured on the individual devices prior to shipment, this specification is not intended to be a guarantee or warranty. It is an engineering estimate of the average drift to be expected from lot to lot.

TYPICAL CHARACTERISTICS

OUTPUT VOLTAGE
vs
VIRTUAL JUNCTION TEMPERATURE

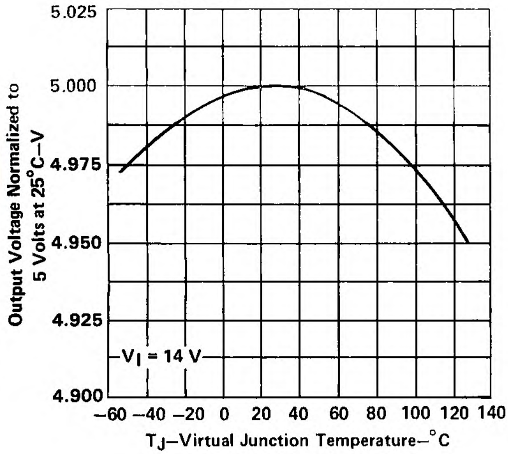


FIGURE 3

OUTPUT VOLTAGE
vs
INPUT VOLTAGE

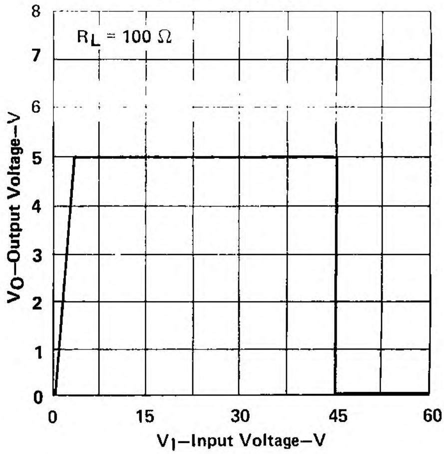


FIGURE 4

OUTPUT VOLTAGE
vs
INPUT VOLTAGE

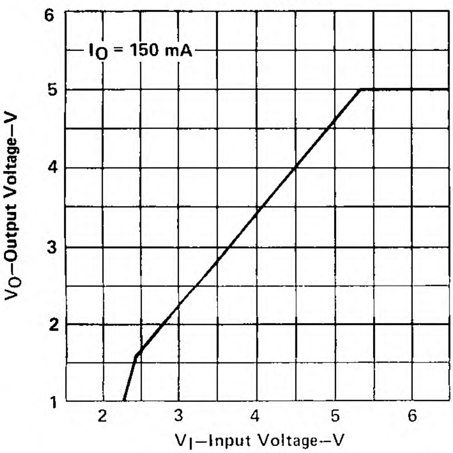


FIGURE 5

PEAK OUTPUT CURRENT
vs
INPUT VOLTAGE

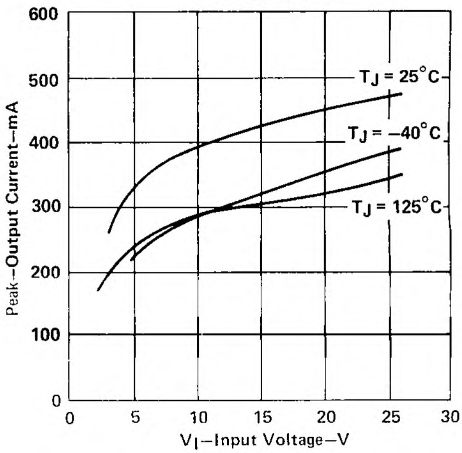


FIGURE 6

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

TYPICAL CHARACTERISTICS

RIPPLE REJECTION
vs
FREQUENCY

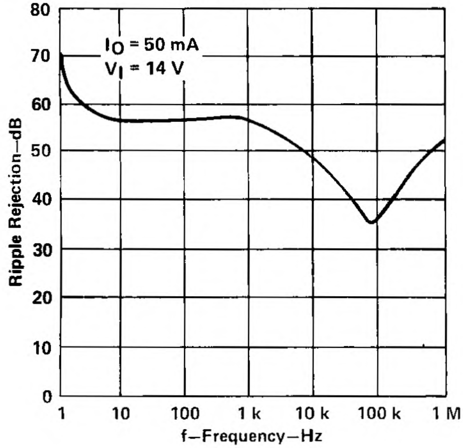


FIGURE 7

RIPPLE REJECTION
vs
OUTPUT CURRENT

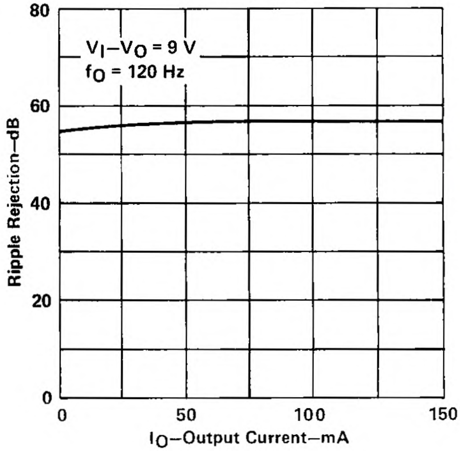


FIGURE 8

DROPOUT VOLTAGE
vs
VIRTUAL JUNCTION TEMPERATURE

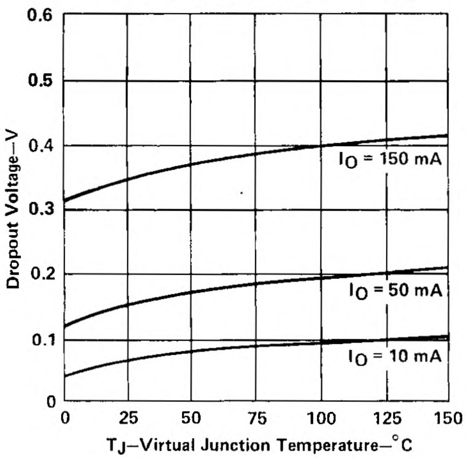


FIGURE 9

DROPOUT VOLTAGE
vs
OUTPUT CURRENT

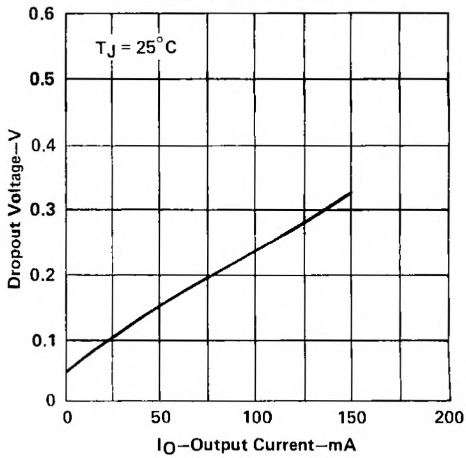


FIGURE 10

2 Data Sheets

TYPICAL CHARACTERISTICS

OUTPUT IMPEDANCE
vs
FREQUENCY

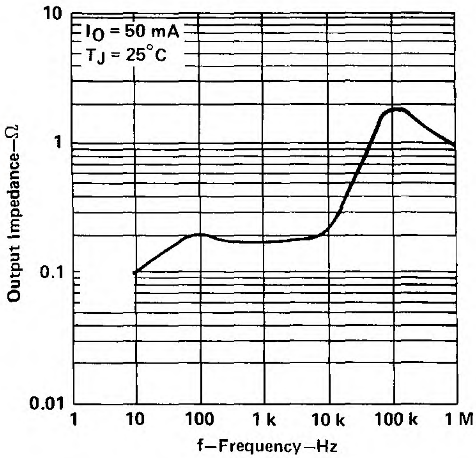


FIGURE 11

INPUT CURRENT
vs
INPUT VOLTAGE

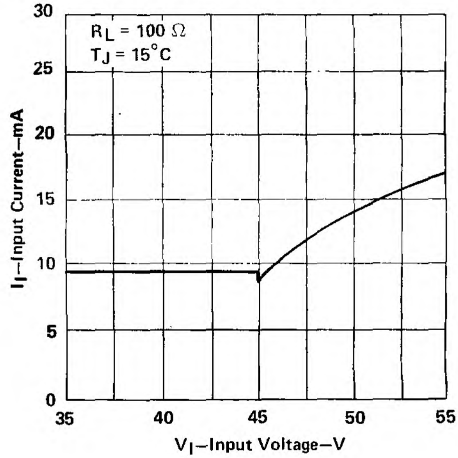


FIGURE 12

LINE TRANSIENT RESPONSE

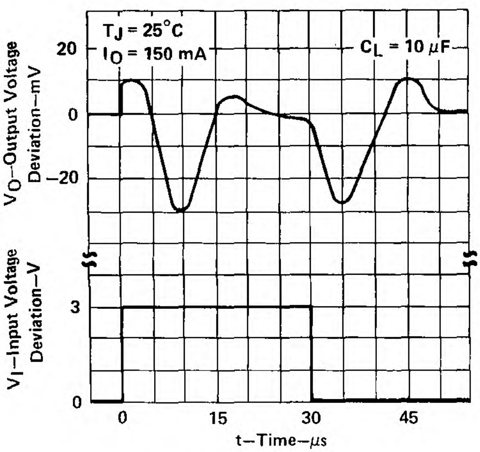


FIGURE 13

INPUT CURRENT
vs
REVERSE INPUT VOLTAGE

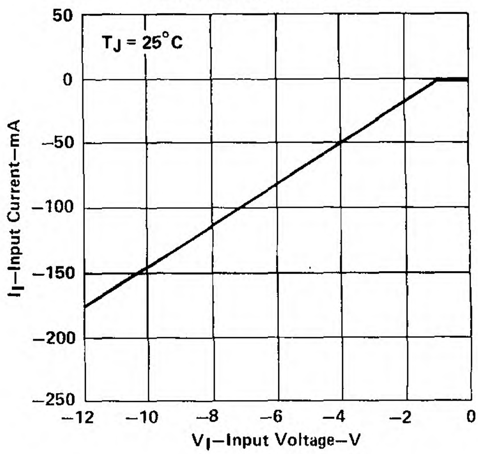


FIGURE 14

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

TYPICAL CHARACTERISTICS

OUTPUT VOLTAGE
vs
REVERSE INPUT VOLTAGE

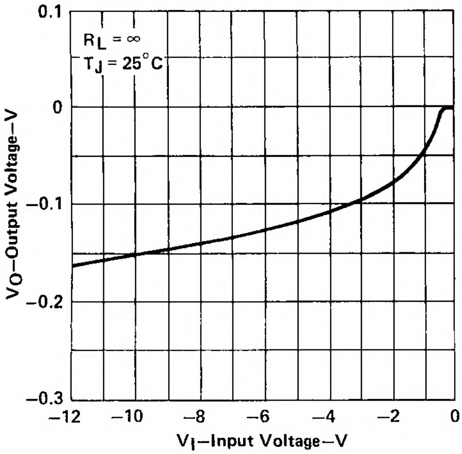


FIGURE 15

LOAD TRANSIENT RESPONSE

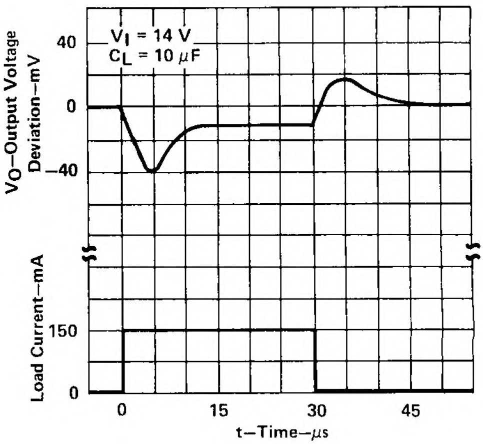


FIGURE 16

BIAS CURRENT
vs
OUTPUT CURRENT

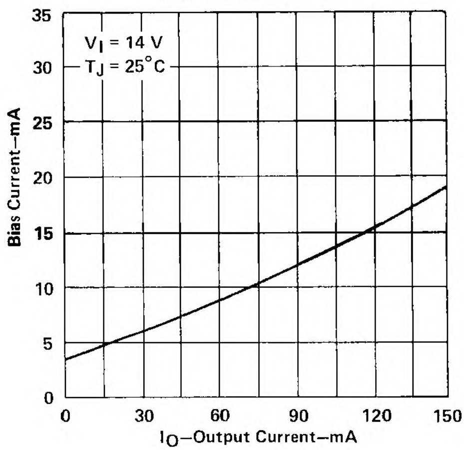


FIGURE 17

2 Data Sheets

TYPICAL CHARACTERISTICS

BIAS CURRENT
vs
VIRTUAL JUNCTION TEMPERATURE

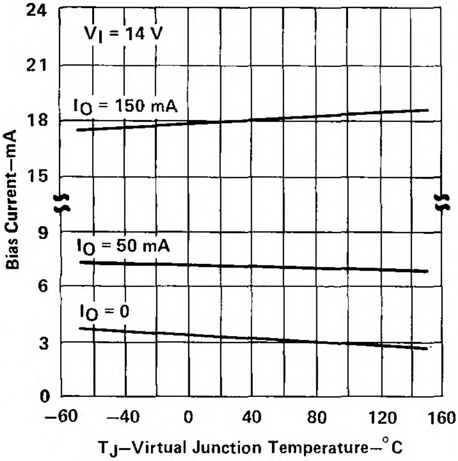


FIGURE 18

BIAS CURRENT
vs
INPUT VOLTAGE

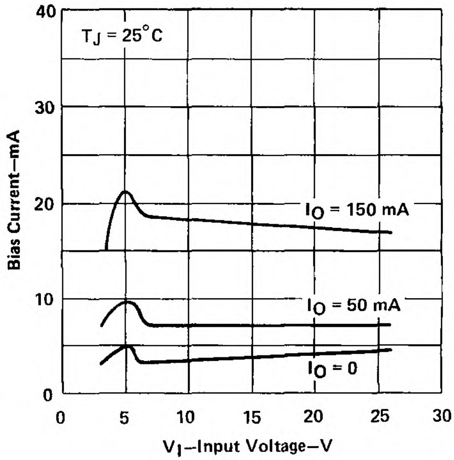
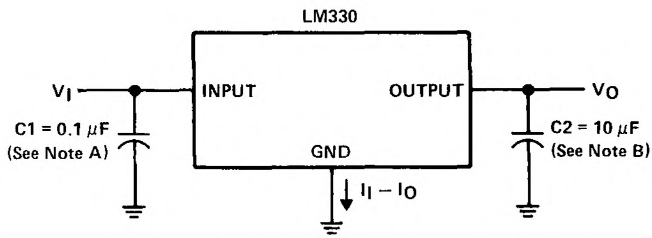


FIGURE 19

TYPICAL APPLICATION DATA



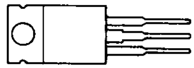
NOTES: A. Use of C1 is required if the regulator is not located in close proximity to the supply filter.
B. Capacitor C2 must be located as close as possible to the regulator and may be an aluminum or tantalum type capacitor. The minimum capacitance that will provide stability is 10-μF. The capacitor must be rated for operation at −40 °C to assure stability to that extreme.

FIGURE 20

D2733 APRIL 1983—REVISED JUNE 1988

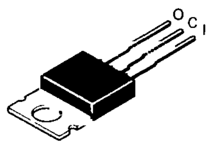
- **Input-Output Differential Less than 0.6 V**
- **Output Current of 150 mA**
- **Reverse Battery Protection**
- **Line Transient Protection**
- **40-V Load-Dump Protection**
- **Internal Short Circuit Current Limiting**
- **Internal Thermal Overload Protection**
- **Mirror-Image Insertion Protection**
- **Direct Replacement for National LM2930 Series**

KC PACKAGE
(TOP VIEW)

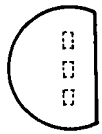


THE COMMON TERMINAL IS IN ELECTRICAL CONTACT WITH THE MOUNTING BASE

TO-220AB



LP
SILECT PACKAGE
(TOP VIEW)



TO-226AA

OCI

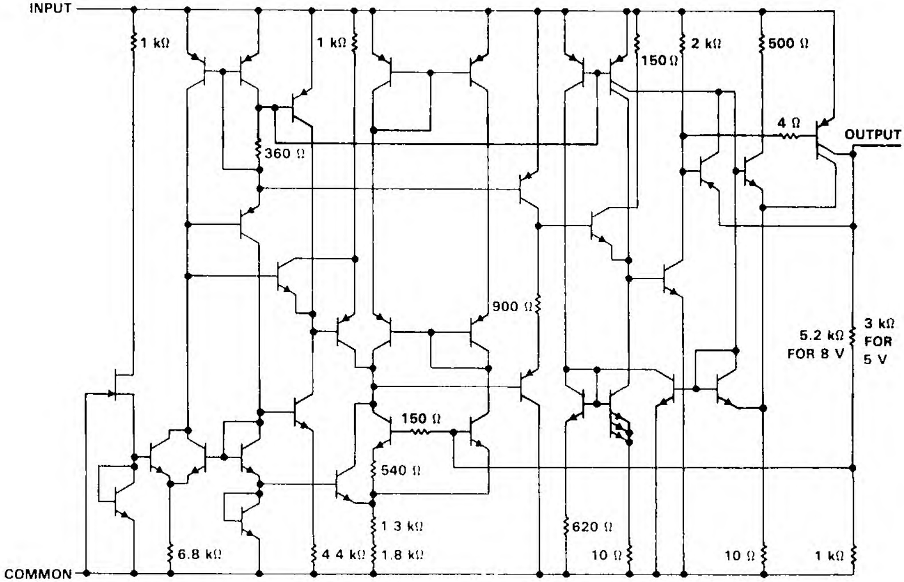
description

The LM2930-5 and LM2930-8 are 3-terminal positive regulators that provide fixed 5-V and 8-V regulated outputs. Each features the ability to source 150 mA of output current with an input-output differential of 0.6 V or less. Familiar regulator features such as current limit and thermal overload protection are also provided.

The LM2930 series has low voltage dropout making it useful for certain battery applications. For example, the low voltage dropout feature allows a longer battery discharge before the output falls out of regulation; the battery supplying the regulator input voltage may discharge to 5.6 V and still properly regulate the system and load voltage. Supporting this feature, the LM2930 series protects both itself and the regulated system from reverse battery installation or 2-battery jumps.

Other protection features include line transient protection for load-dump of up to 40 V. In this case, the regulator shuts down to avoid damaging internal and external circuits. The LM2930 series regulator cannot be harmed by temporary mirror-image insertion.

schematic diagram



All component values are nominal.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Continuous input voltage	26 V
Transient input voltage: t = 1 s	40 V
Continuous reverse input voltage	−6 V
Transient reverse input voltage: t = 100 ms	−12 V
Continuous total dissipation (see Note 1)	See Dissipation Rating Table 1
Continuous total dissipation (see Note 1)	See Dissipation Rating Table 2
Operating free-air, case, or virtual junction temperature	−40°C to 150°C
Storage temperature range	−65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C

NOTE 1: To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variation in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

DISSIPATION RATING TABLE 1—FREE-AIR TEMPERATURE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR	DERATE ABOVE T_A	$T_A = 70°C$ POWER RATING
KC	[illegible] mW	16 mW/°C	25°C	[illegible] mW
LP	775 mW	6.2 mW/°C	25°C	496 mW

DISSIPATION RATING TABLE 2—CASE TEMPERATURE

PACKAGE	$T_C \leq 25°C$ POWER RATING	DERATING FACTOR	DERATE ABOVE T_C	$T_C = 125°C$ POWER RATING
KC	20 W	0.25 W/°C	70°C	6.25 W
LP	1600 mW	28.6 mW/°C	94°C	715 mW

recommended operating conditions

		MIN	MAX	UNIT
I_O	Output current		[illegible]	mA
T_J	Operating virtual junction temperature	−40	125	°C

LM2930-5 electrical characteristics at 25°C virtual junction temperature, V_I = 14 V, I_O = 150 mA, (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		MIN	TYP	MAX	UNIT
Output voltage	V_I = 6 V to 26 V, T_J = −40°C to 125°C	I_O = 5 mA to 150 mA,	4.5	5	5.5	V
Input regulation	I_O = 5 mA	V_I = 9 V to 16 V		7	25	mV
		V_I = 6 V to 26 V		30	80	
Ripple rejection	f = 120 Hz			56		dB
Output regulation	I_O = 5 mA to 150 mA			14	50	mV
Output voltage long-term drift‡	After [illegible] h at T_J = 125°C			20		mV
Dropout voltage	I_O = [illegible] mA			0.32	0.6	V
Output noise voltage	f = 10 Hz to 100 kHz			60		μV
Output voltage during line transients	V_I = −12 V to 40 V,	R_L = 100 Ω	−0.3		5.5	V
Output impedance	I_O = [illegible] mA, I_O = 10 mA (rms), 100 Hz to 10 kHz			200		mΩ
Bias current	I_O = [illegible] mA			4	7	mA
	I_O = 150 mA			18	40	
Peak output current			150	300	700	mA

†Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.1-μF capacitor across the input and a 10-μF capacitor across the output.

‡Since long-term drift cannot be measured on the individual devices prior to shipment, this specification is intended to be an engineering estimate of the average drift to be expected from lot to lot.

LM2930-8 electrical characteristics at 25 °C virtual junction temperature, V_I = 14 V, I_O = 150 mA, (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		MIN	TYP	MAX	UNIT
Output voltage	V_I = 6 V to 26 V, I_O = 5 mA to 150 mA, T_J = −40 °C to 125 °C		7.2	8	8.8	V
Input regulation	I_O = 5 mA	V_I = 9.4 V to 16 V		12	50	mV
		V_I = 9.4 V to 26 V		50	100	
Ripple rejection	f = 120 Hz			52		dB
Output regulation	I_O = 5 mA to 150 mA			25	50	mV
Output voltage long-term drift‡	After 1000 h at T_J = 125 °C			30		mV
Dropout voltage	I_O = 150 mA			0.32	0.6	V
Output noise voltage	f = 10 Hz to [illegible] kHz			90		μV
Output voltage during line transients	V_I = −12 V to 40 V, R_L = 100 Ω		−0.3		8.8	V
Output impedance	I_O = 100 mA, I_O = 10 mA (rms), f = [illegible] Hz to 10 kHz			300		MΩ
Bias current	I_O = 10 mA			4	7	mA
	I_O = 150 mA			18	40	
Peak output current			[illegible]	[illegible]	700	mA

†Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.1-μF capacitor across the input and a 10-μF capacitor across the output.

‡Since long-term drift cannot be measured on the individual devices prior to shipment, this specification is intended to be an engineering estimate of the average drift to be expected from lot to lot.

TYPICAL CHARACTERISTICS

NORMALIZED OUTPUT VOLTAGE
vs
VIRTUAL JUNCTION TEMPERATURE

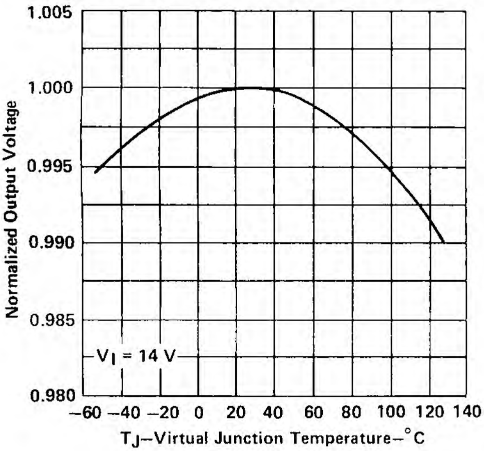


FIGURE 1

LM2930-5
OUTPUT VOLTAGE
vs
INPUT VOLTAGE

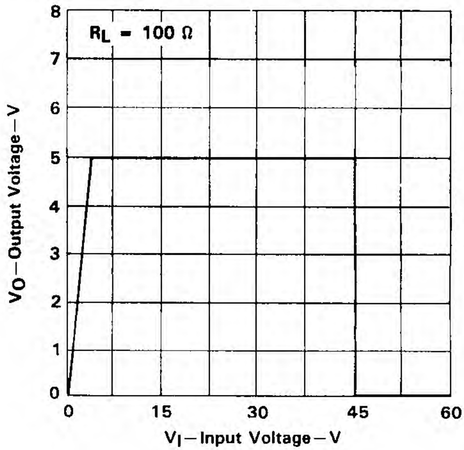


FIGURE 2

TYPICAL CHARACTERISTICS

LM2930-5
OUTPUT VOLTAGE
vs
INPUT VOLTAGE

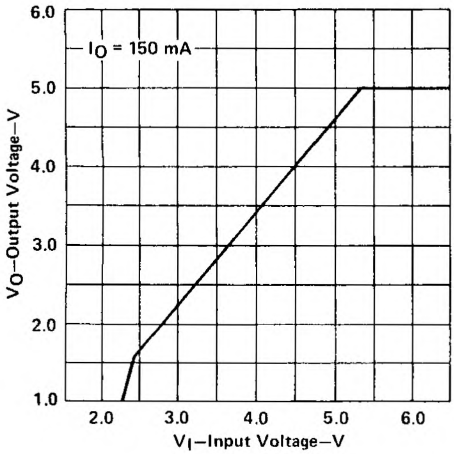


FIGURE 3

RIPPLE REJECTION
vs
FREQUENCY

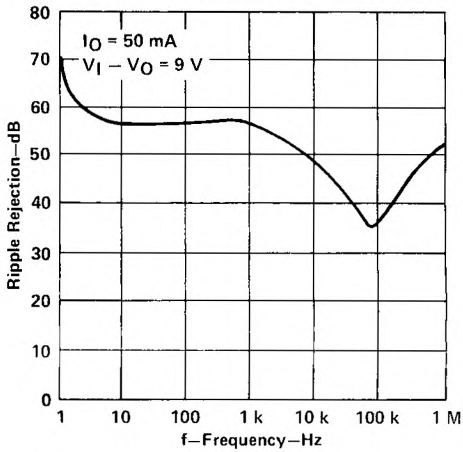


FIGURE 4

RIPPLE REJECTION
vs
OUTPUT CURRENT

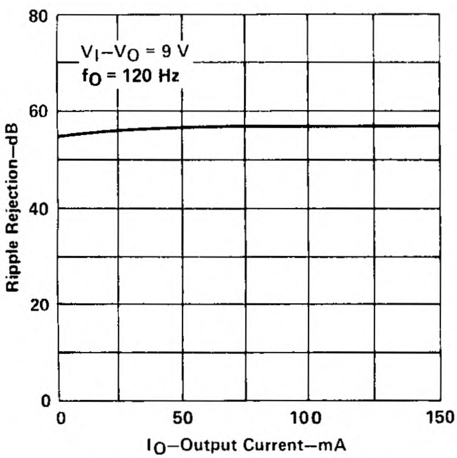


FIGURE 5

DROPOUT VOLTAGE
vs
VIRTUAL JUNCTION TEMPERATURE

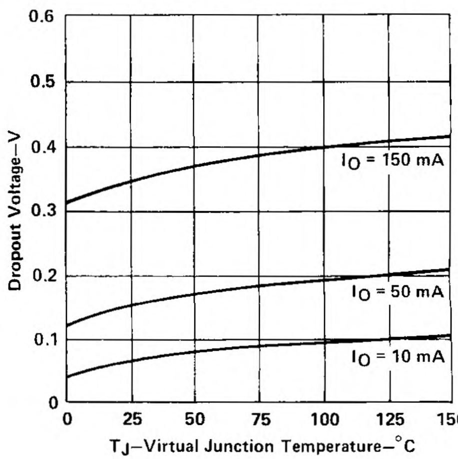


FIGURE 6

TYPICAL CHARACTERISTICS

DROPOUT VOLTAGE
vs
OUTPUT CURRENT

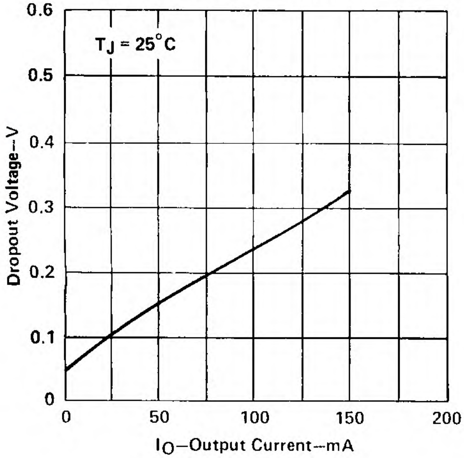


FIGURE 7

OUTPUT IMPEDANCE
vs
FREQUENCY

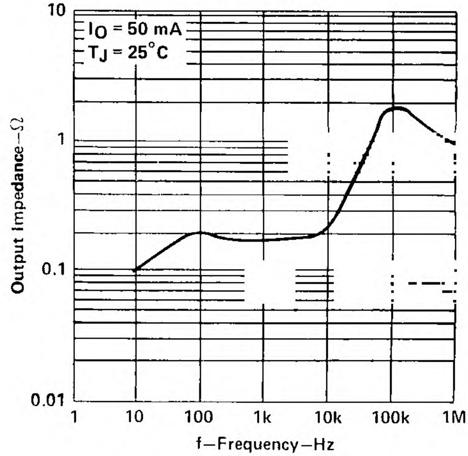


FIGURE 8

INPUT CURRENT
vs
INPUT VOLTAGE

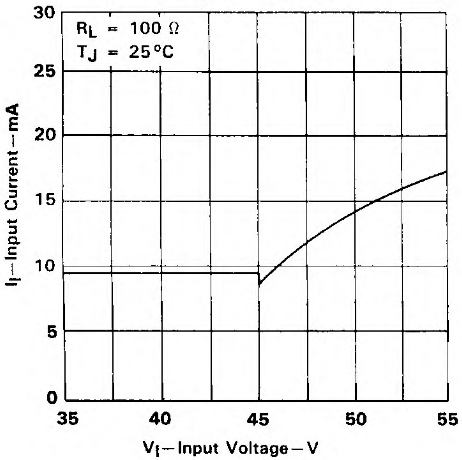


FIGURE 9

LINE TRANSIENT RESPONSE

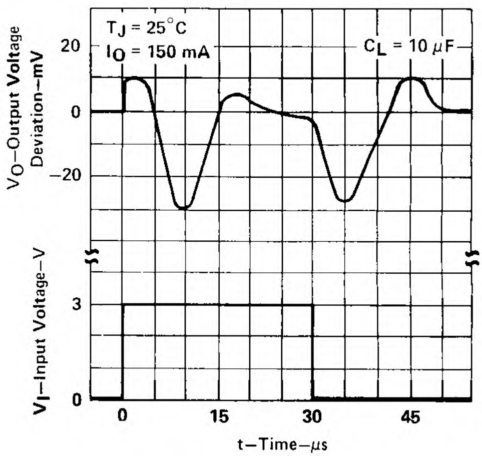


FIGURE 10

TYPICAL CHARACTERISTICS

INPUT CURRENT
vs
REVERSE INPUT VOLTAGE

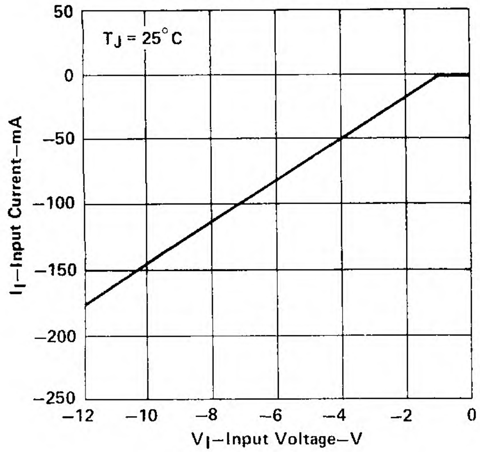


FIGURE 11

OUTPUT VOLTAGE
vs
REVERSE INPUT VOLTAGE

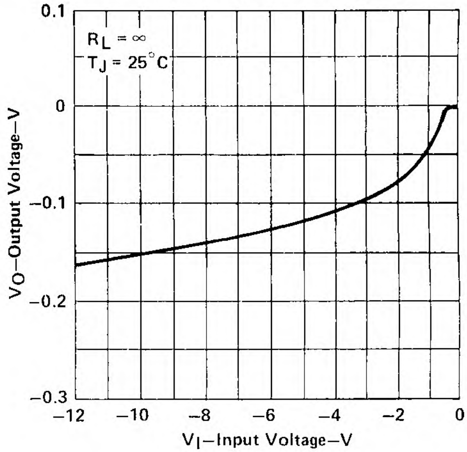


FIGURE 12

LOAD TRANSIENT RESPONSE

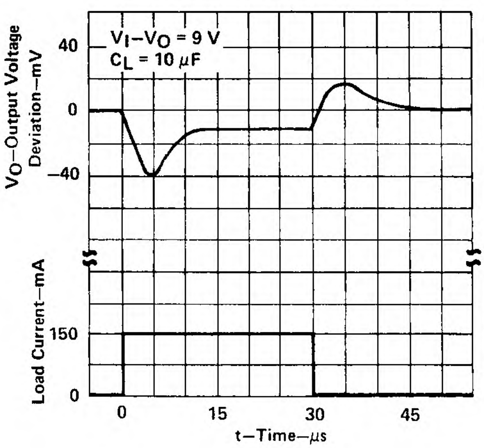


FIGURE 13

BIAS CURRENT
vs
OUTPUT CURRENT

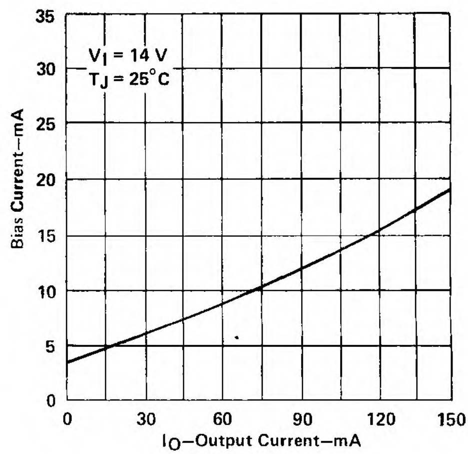


FIGURE 14

2

Data Sheets

TYPICAL CHARACTERISTICS

BIAS CURRENT
vs
VIRTUAL JUNCTION TEMPERATURE

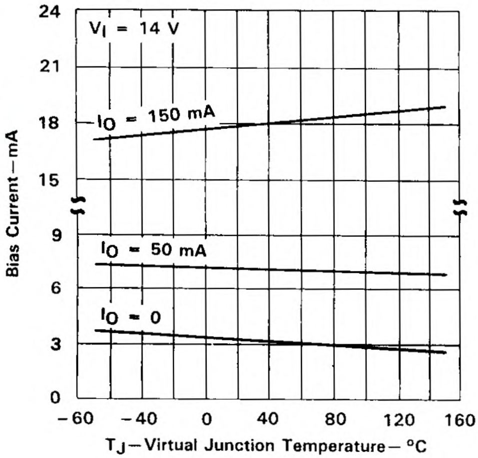


FIGURE 15

LM2905-5
BIAS CURRENT
vs
INPUT VOLTAGE

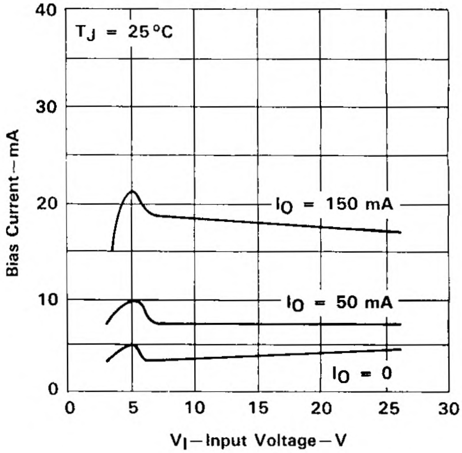
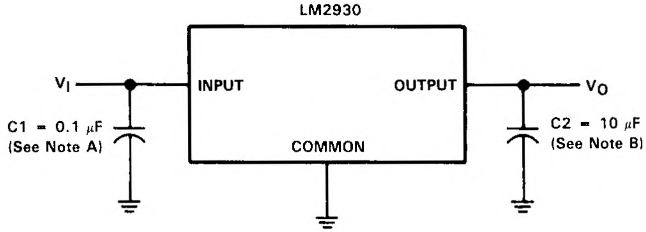


FIGURE 16

TYPICAL APPLICATION DATA



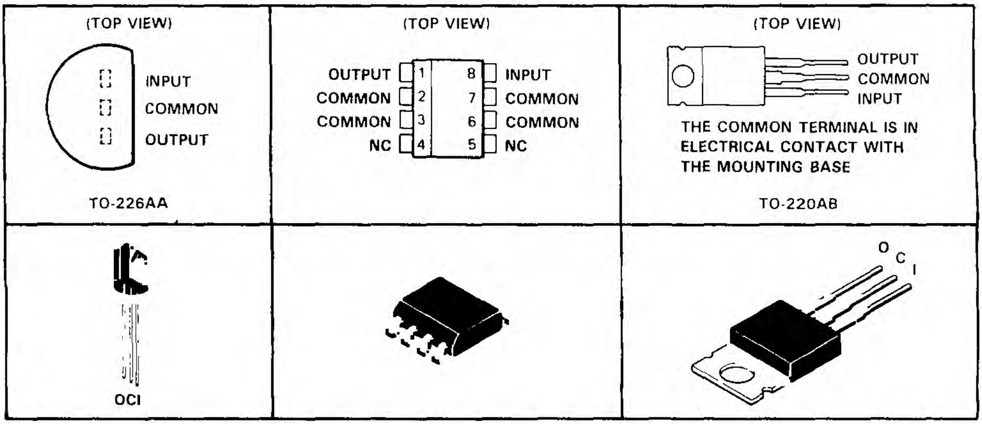
NOTES: A. Use of C1 is required if the regulator is not located in close proximity to the supply filter.
B. Capacitor C2 must be located as close as possible to the regulator and may be an aluminum or tantalum type capacitor. The minimum value required for stability is 10 μF. The capacitor must be rated for operation at −40 °C to guarantee stability to that extreme.

FIGURE 17

D2828, AUGUST 1988—REVISED OCTOBER 1988

- Input-Output Differential Less than 0.6 V
- Output Current of 150 mA
- Reverse Battery Protection
- Very Low Quiescent Current
- 60-V Load-Dump Protection
- Internal Short-Circuit Current Limiting
- Internal Thermal Overload Protection
- Mirror-Image Insertion Protection
- Reverse Transient Protection
- Direct Improved Replacement for National LM2931-5 and LM2931A-5

LP SILECT PACKAGE | D SMALL-OUTLINE PACKAGE | KC PACKAGE



description

The LM2931-5AQ is a 3-terminal positive voltage regulator that provides a 5-V regulated output. It features the ability to source 150 mA of output current with an input-output differential of 0.6 V or less. Familiar regulator features such as current limit and thermal overload protection are also provided.

This device also has a low dropout voltage making it useful for certain battery applications. For example, because the low dropout voltage allows a longer battery discharge before the output falls out of regulation, the battery supplying the regulator input voltage may discharge to 5.6 V and still properly regulate the 5-V load voltage. Supporting this feature, the LM2931-5AQ protects both itself and the regulated system from reverse battery installation or 2-battery jumps. The very low quiescent current feature is especially useful in battery-powered applications.

Other protection features include line transient protection from load-dump of up to 60 V. In this case, the regulator shuts down to avoid damaging internal and external circuits. The LM2931-5AQ regulator is virtually immune to temporary mirror-image insertion.

The Q suffix indicates that the device is characterized for operation from −40°C to 125°C.

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

absolute maximum ratings over operating junction temperature range (unless otherwise noted)

Continuous input voltage . . . . 26 V
Transient input voltage: t = 1 s . . . . 60 V
Continuous reverse input voltage . . . . −15 V
Transient reverse input voltage: t = 100 ms . . . . −50 V
Continuous total dissipation (see Note 1) . . . . See Dissipation Rating Tables 1 and 2
Operating virtual junction temperature . . . . −40°C to 125°C
Storage temperature range . . . . −65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds . . . . 260°C

NOTE 1: To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variation in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

DISSIPATION RATING TABLE 1 — FREE-AIR TEMPERATURE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25°C$	$T_A = 125°C$ POWER RATING
D	825 mW	6.6 mW/°C	165 mW
KC	2000 mW	16 mW/°C	400 mW
LP	775 mW	6.2 mW/°C	155 mW

DISSIPATION RATING TABLE 2 — CASE TEMPERATURE

PACKAGE	$T_C \le 25°C$ POWER RATING	DERATING FACTOR	DERATE ABOVE T_C	$T_C = 125°C$ PO[illegible]RATING
D	1600 mW	29.4 mW/°C	96°C	[illegible]mW
KC	20 W	0 18 W/°C	39°C	4.5 W
LP	1600 mW	28.6 mW/°C	94°C	715 mW

recommended operating conditions

	MIN	MAX	UNIT
Output current, I_O		150	mA
Operating virtual junction temperature, T_J	−40	125	°C

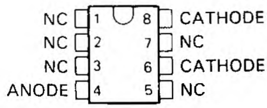
electrical characteristics at 25°C virtual junction temperature, $V_I = 14$ V (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		MIN	TYP	MAX	UNIT
Output voltage	V_I = 6 V to 26 V, $I_O \le$ 150 mA, T_J = −40°C to 125°C		4.75	5	5.25	V
Input regulation	I_O = 10 mA	V_I = 9 V to 16 V		2	10	mV
		V_I = 6 V to 26 V		4	30	
Ripple rejection	I_O = 10 mA, f = 120 hz		60	80		dB
Output regulation	I_O = 5 mA to [illegible]mA			14	50	mV
Output voltage long-term drift‡	I_O = 10 mA, After 1000 h at T_J = 125°C			20		mV
Dropout voltage	I_O = 10 mA			0.05	0.2	V
	I_O = 150 mA			0.3	0.6	
Output noise voltage	I_O = 10 mA, f = 10 Hz to 100 kHz			[illegible]		μV rms
Bias current	V_I = 6 V to 26 V, I_O = 10 mA, T_J = = −40°C to 125°C			0.4	1	mA
	V_I = 14 V, I_O = [illegible]mA, T_J = 25°C			10	12	

† Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.1-μF capacitor across the input to common and a 100-μF capacitor, with equivalent series resistance of less then 1 Ω, across the output to common.
‡ Since long-term drift cannot be measured on the individual devices prior to shipment, this specification is not intended to be a guarantee or warranty. It is an engineering estimate of the average drift to be expected from lot to lot.

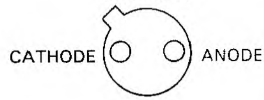
- **Initial Accuracy . . .**
  ±4 mV for LT1004-1.2
  ±20 mV for LT1004-2.5
- **Micropower Operation**
- **Operates Up to 20 mA**
- **Very Low Reference Impedance**
- **Applications:**
  Portable Meter References
  Portable Test Instruments
  Battery Operated Systems
  Current-Loop Instrumentation

LT1004C . . . D PACKAGE
(TOP VIEW)



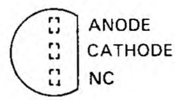
NC – No internal connection

LT1004M, LT1004C . . . LD PACKAGE
(TOP VIEW)



The anode is in electrical contact with the case.

LT1004C . . . LP PACKAGE
(TOP VIEW)



NC – No internal connection

description

The LT1004 micropower voltage references are two-terminal bandgap reference diodes designed to provide high accuracy and excellent temperature characteristics at very low operating currents. Optimizing the key parameters in the design, processing, and testing of the devices results in specifications previously attainable only with selected units.

The LT1004 is a pin-for-pin replacement for the LM185 series of references with improved specifications. The LT1004 is an attractive device for use in systems in which accuracy was previously attained at the expense of power consumption and trimming.

The LT1004M is characterized for operation over the full military temperature range of −55°C to 125°C. The LT1004C is characterized for operation from 0°C to 70°C.

symbol

2

Data Sheets

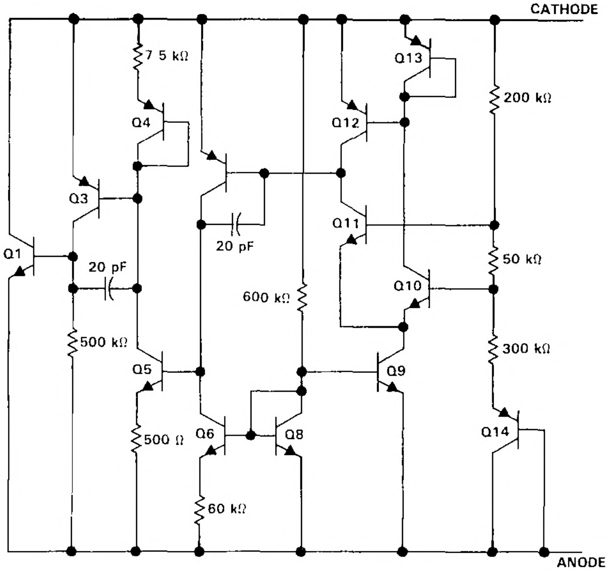
AVAILABLE OPTIONS

T_A	NOM V_Z	PACKAGE		
		SMALL OUTLINE (D)	METAL CAN (LD)	PLASTIC (LP)
0°C to 70°C	1.2 V	LT1004CD-1.2	LT1004CLD-1.2	LT1004CLP-1.2
	2.5 V	LT1004CD-2.5	LT1004CLD-2.5	LT1004CLP-2.5
−55°C to 125°C	1.2 V		LT1004MLD-1.2	
	2.5 V		LT1004MLD-2.5	

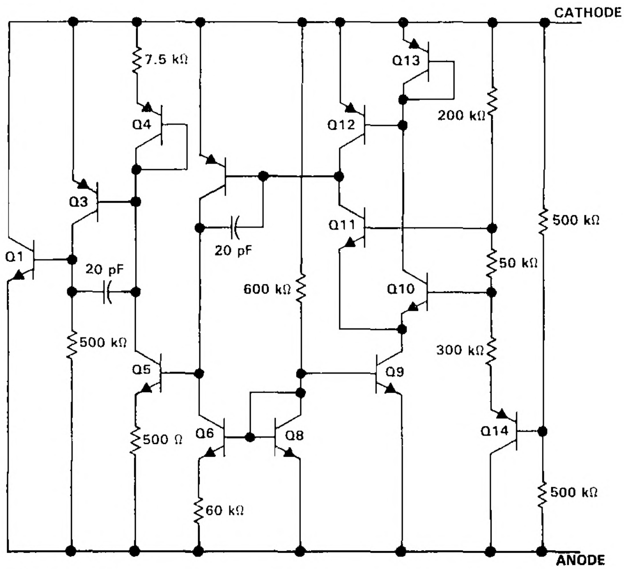
The D package is available taped and reeled. Add suffix R to the device type (i.e., LT1004CDR0.

schematic

LT1004-1.2



LT1004-2.5



All component values shown are nominal.

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

absolute maximum ratings over operating free-air temperature range

Reverse current . . . . 30 mA
Forward current . . . . 10 mA
Operating free-air temperature range: LT1004M . . . . −55°C to 125°C
LT1004C . . . . 0°C to 70°C
Storage temperature range . . . . −65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or LP package . . . . . . 260°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: LD package . . . . . . 300°C

electrical characteristics at specified free-air temperature

PARAMETER		TEST CONDITIONS	T_A†	LT1004-1.2			LT1004-2.5			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
V_Z	Reference voltage	I_Z = 100 µA, See Note 1	25°C	1.231	1.235	1.239	2.48	2.5	2.52	V
			0°C to 70°C	1.225		1.245	2.47		2.53	
			−55°C to 125°C	1.22		1.245	2.46		2.535	
α_{VZ}	Average temperature coefficient of reference voltage‡	I_Z = 10 µA	25°C		20					ppm/°C
		I_Z = 20 µA						20		
ΔV_Z	Change in reference voltage with current	I_Z = 10 µA to 1 mA	25°C			1			1	mV
			Full range			1.5			1.5	
		I_Z = 1 mA to 20 mA	25°C			10			10	
			Full range			20			20	
$\Delta V_Z/\Delta t$	Long-term change in reference voltage	I_Z = 100 µA	25°C		20			20		ppm/khr
$I_{Z(min)}$	Minimum reference current		Full range		8	10		12	20	µA
Z_Z	Reference impedance	I_Z = 100 µA	25°C		0.2	0.6		0.2	0.6	Ω
			Full range			1.5			1.5	
V_n	Broadband noise voltage	I_Z = 100 µA, f = 10 Hz to 10 kHz	25°C		60			120		µV

† Full range is −55°C to 125°C for the LT1004M and 0°C to 70°C for the LT1004C.
‡ The average temperature coefficient of reference voltage is defined as the total change in reference voltage divided by the specified temperature range.
NOTE 1: The 0°C to 70°C limits apply for both M- and C-suffix devices. The −55°C to 125°C limits apply only for M-suffix devices.

TYPICAL CHARACTERISTICS†

REVERSE CHARACTERISTICS

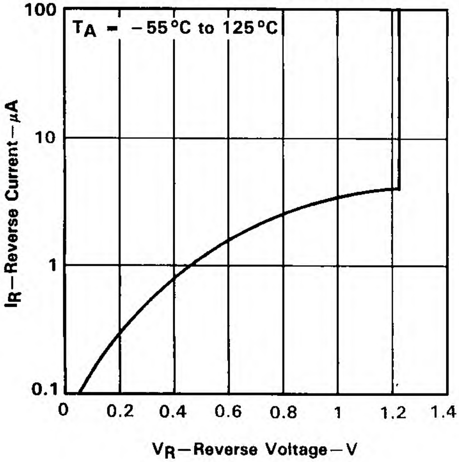


FIGURE 1

REFERENCE VOLTAGE CHANGE
vs
REVERSE CURRENT

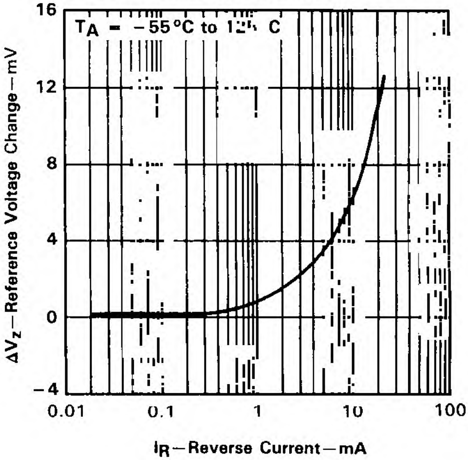


FIGURE 2

FORWARD CHARACTERISTICS

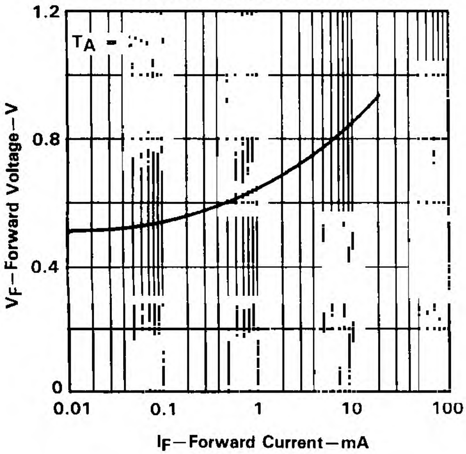


FIGURE 3

REFERENCE VOLTAGE
vs
FREE-AIR TEMPERATURE

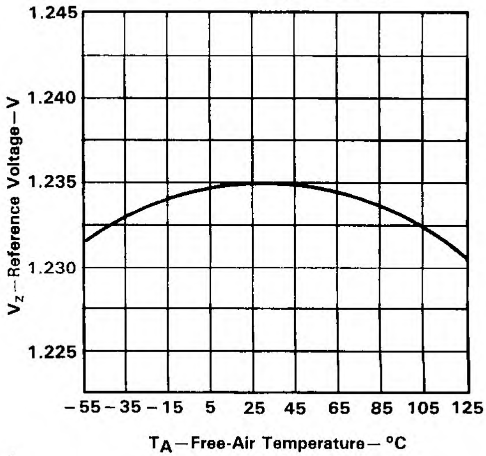


FIGURE 4

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TEXAS INSTRUMENTS
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TYPICAL CHARACTERISTICS

REFERENCE IMPEDANCE
vs
REFERENCE CURRENT

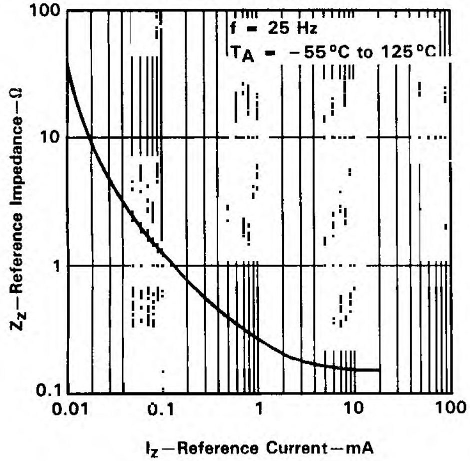

FIGURE 5

REFERENCE IMPEDANCE
vs
FREQUENCY

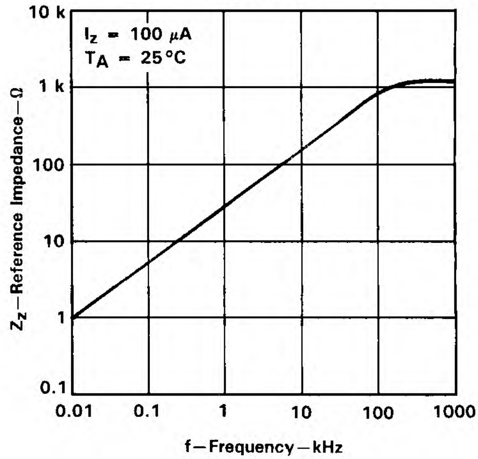

FIGURE 6

NOISE VOLTAGE
vs
FREQUENCY

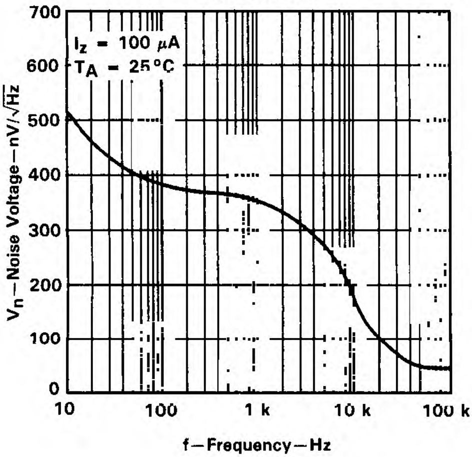

FIGURE 7

OUTPUT NOISE VOLTAGE
vs
CUTOFF FREQUENCY

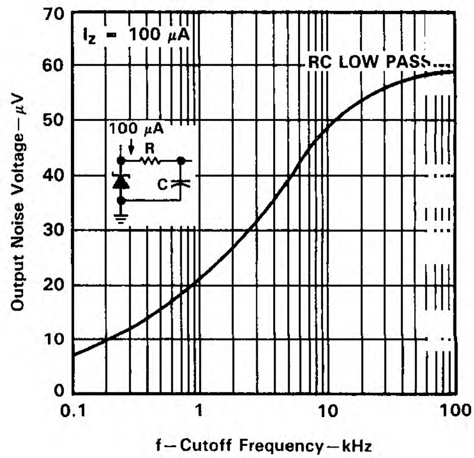

FIGURE 8

TEXAS INSTRUMENTS
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TYPICAL CHARACTERISTICS†

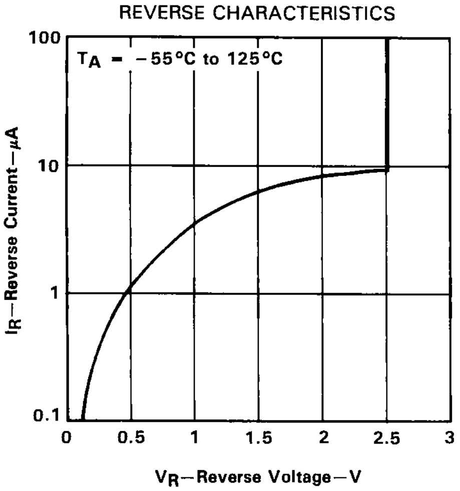

FIGURE 9

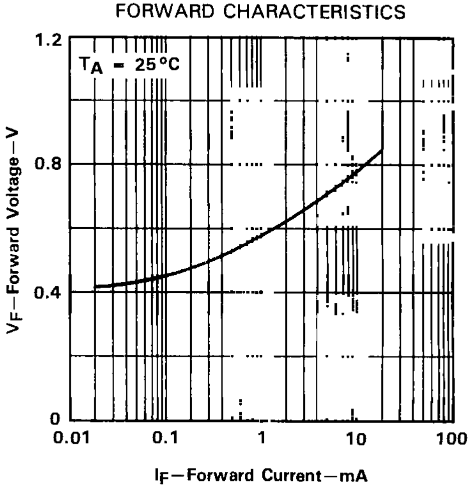

FIGURE 10

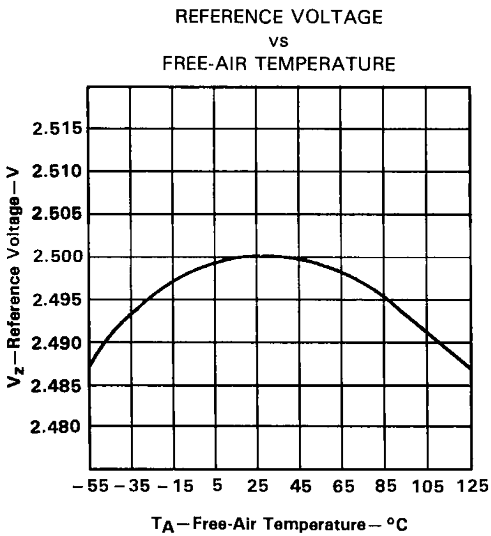

FIGURE 11

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS

REFERENCE IMPEDANCE
vs
REFERENCE CURRENT

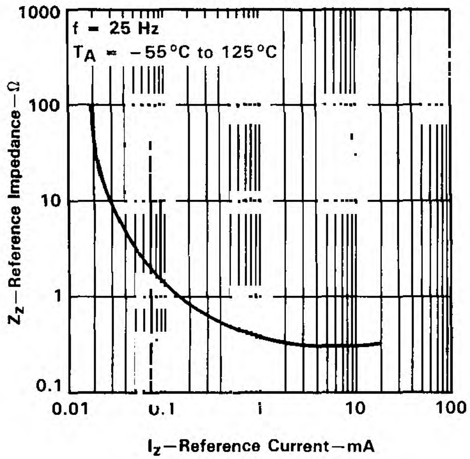

FIGURE 12

REFERENCE IMPEDANCE
vs
FREQUENCY

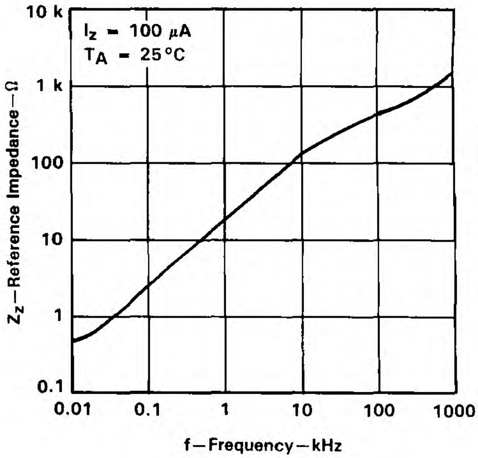

FIGURE 13

NOISE VOLTAGE
vs
FREQUENCY

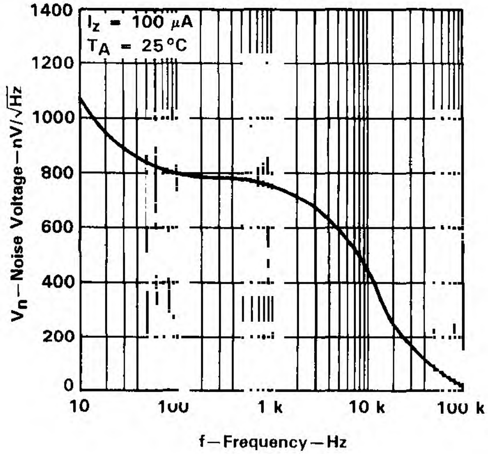

FIGURE 14

FILTERED OUTPUT NOISE VOLTAGE
vs
CUTOFF FREQUENCY

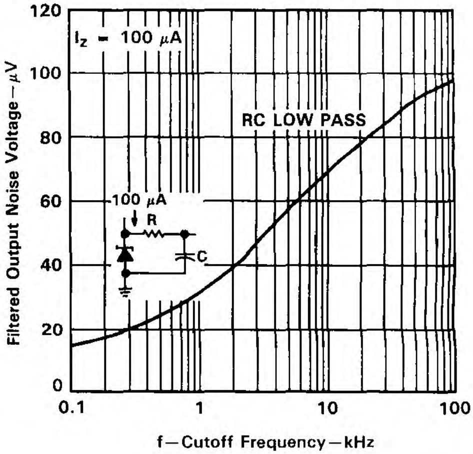

FIGURE 15

2

Data Sheets

TYPICAL CHARACTERISTICS

LT1004-1.2
TRANSIENT RESPONSE

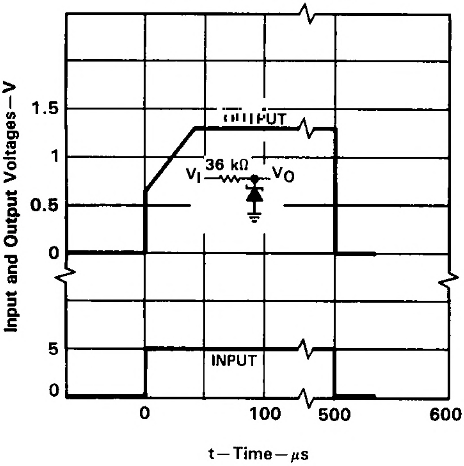

FIGURE 16

LT1004-2.5
TRANSIENT RESPONSE

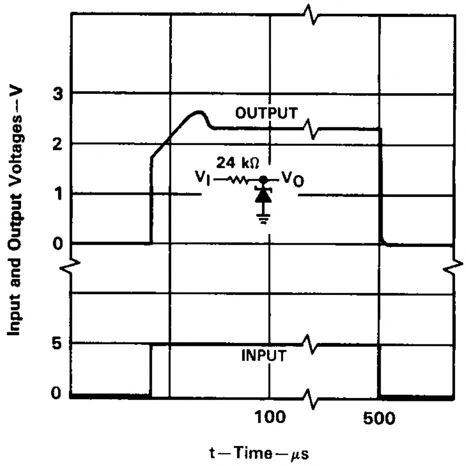

FIGURE 17

TEXAS INSTRUMENTS
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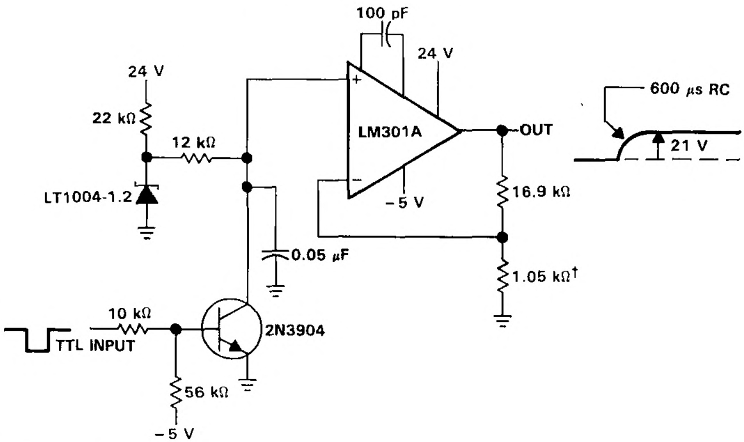
TYPICAL APPLICATION DATA



† 1% metal film resistors

FIGURE 18. Vpp GENERATOR FOR EPROMS (NO TRIM REQUIRED)

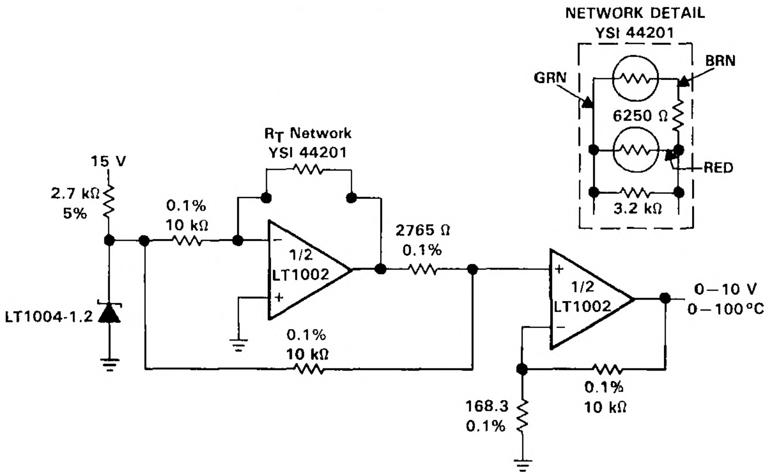


FIGURE 19. 0°C TO 100°C LINEAR OUTPUT THERMOMETER

TYPICAL APPLICATION DATA

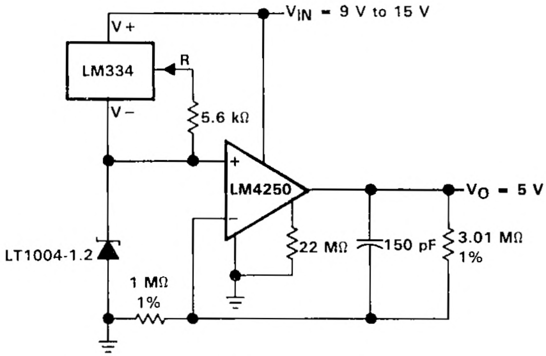


FIGURE 20. MICROPOWER 5-V REFERENCE

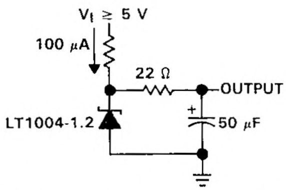


FIGURE 21. LOW-NOISE REFERENCE

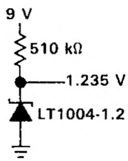
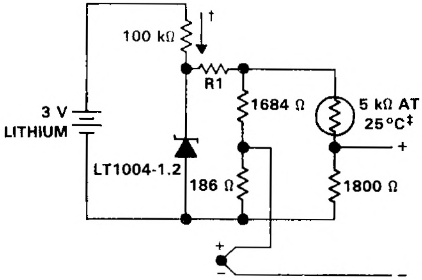


FIGURE 22. MICROPOWER REFERENCE FROM 9-V BATTERY



THERMOCOUPLE TYPE	R1
J	233 kΩ
K	299 kΩ
T	300 kΩ
S	2.1 MΩ

† Quiescent current ≅ 15 μA
‡ Yellow Springs Inst. Co., Part #44007
NOTE: This application compensates within ±1°C from 0°C to 60°C.

FIGURE 23. MICROPOWER COLD-JUNCTION COMPENSATION FOR THERMOCOUPLES

TYPICAL APPLICATION DATA

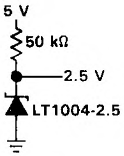


FIGURE 24. 2.5-V REFERENCE

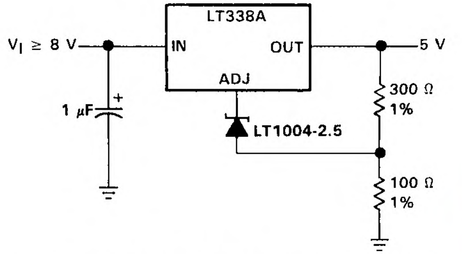
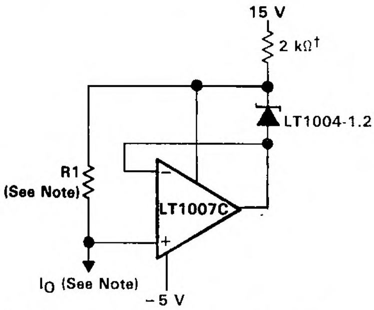


FIGURE 27. HIGH-STABILITY 5-V REGULATOR



† May be increased for small output currents.

NOTE: $R1 \approx \frac{2\ V}{I_O + 10\ \mu A}$, $I_O = \frac{1.235\ V}{R1}$.

FIGURE 25. GROUND-REFERENCED CURRENT SOURCE

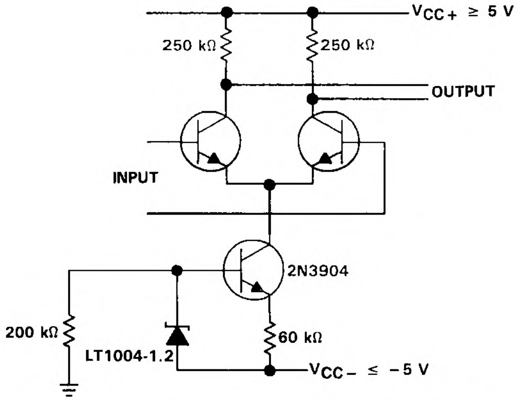
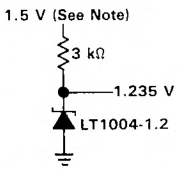
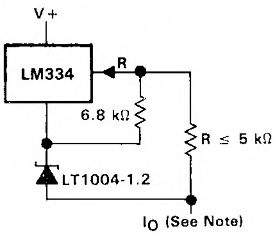


FIGURE 28. AMPLIFIER WITH CONSTANT GAIN OVER TEMPERATURE



NOTE: Output regulates down to 1.285 V for $I_O = 0$.

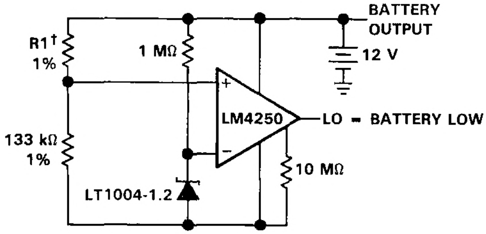
FIGURE 26. 1.2-V REFERENCE FROM 1.5-V BATTERY



NOTE: $I_O \approx \frac{1.3\ V}{R}$

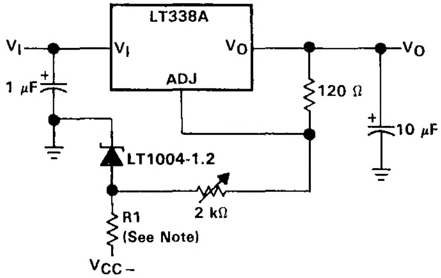
FIGURE 29. 2-TERMINAL CURRENT SOURCE WITH LOW TEMPERATURE COEFFICIENT

TYPICAL APPLICATION DATA



† R1 sets trip point, 60.4 kΩ per cell for 1.8 V per cell.

FIGURE 30. LEAD-ACID LOW-BATTERY-VOLTAGE DETECTOR



NOTE: $R1 \leq \frac{V_{CC} - 1\ V}{0.015}$

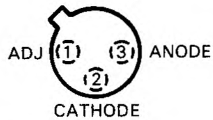
FIGURE 31. VARIABLE-VOLTAGE SUPPLY

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

D3191, MAY 1987—REVISED JANUARY 1989

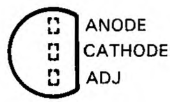
- **Excellent Temperature Stability**
- **Initial Tolerance . . . 0.2% Max**
- **Dynamic Impedance . . . 0.6 Ω Max**
- **Wide Operating Current Range**
- **Directly Interchangeable with LM136**
- **Needs No Adjustment for Minimum Temperature Coefficient**

LT1009M, LT1009C . . . LD PACKAGE
(TOP VIEW)



The anode is in electrical contact with the case.

LT1009C . . . LP PACKAGE
(TOP VIEW)



description

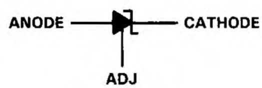
The LT1009 is a precision trimmed 2.5-V shunt regulator featuring a maximum initial tolerance of only ±5 mV, low dynamic impedance, and a wide operating current range. The 0.2% reference tolerance is achieved by on-chip trimming, which minimizes the initial voltage tolerance and the temperature coefficient α_{VZ}.

Even though the LT1009 needs no adjustments, a third terminal allows the reference voltage to be adjusted 5% to eliminate system errors. In many applications, the LT1009 can be used as a pin-for-pin replacement for the LM136H-2.5, which eliminates the external trim network.

The uses of the LT1009 include a 5-V system reference, an 8-bit ADC and DAC reference, or a power supply monitor. The LT1009 can also be used in applications such as digital voltmeters and current-loop measurement and control systems.

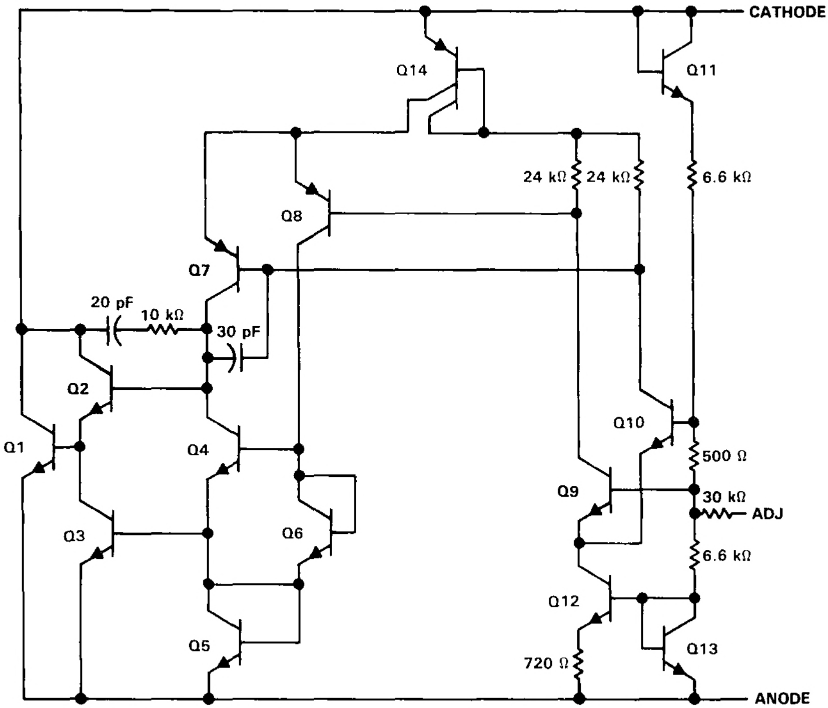
The LT1009M is characterized for operation over the full military temperature range of −55°C to 125°C. The LT1009C is characterized for operation from 0°C to 70°C.

symbol



TEXAS INSTRUMENTS

schematic



All component values shown are nominal.

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

absolute maximum ratings over operating free-air temperature range

Reverse current	20 mA
Forward current	10 mA
Operating free-air temperature range: LT1009M	−55°C to 125°C
LT1009C	0°C to 70°C
Storage temperature range	−65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or LP package	260°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: LD package	300°C

electrical characteristics at specified free-air temperature

PARAMETER		TEST CONDITIONS	T_A†	LT1009M			LT1009C			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
V_Z	Reference voltage	I_Z = 1 mA	25°C	2.495	2.5	2.505	2.495	2.5	2.505	V
$\Delta V_{Z(temp)}$	Change in reference voltage with temperature		MIN to MAX			15			4	mV
α_{VZ}	Average temperature coefficient of reference voltage‡		0°C to 70°C		15	25		15	25	ppm/°C
			−55°C to 125°C		25	35				
ΔV_Z	Change in reference voltage with current	I_Z = 400 µA to 10 mA	25°C		2.6	6		2.6	10	mV
			Full range			10			12	
$\Delta V_Z/\Delta t$	Long-term change in reference voltage	I_Z = 1 mA	25°C		20			20		ppm/khr
Z_Z	Reference impedance	I_Z = 1 mA	25°C		0.3	0.6		0.3	1	Ω
			Full range			1			1.4	

† Full range is −55°C to 125°C for the LT1009M and 0°C to 70°C for the LT1009C.
‡ The average temperature coefficient of reference voltage is defined as the total change in reference voltage divided by the specified temperature range.

TYPICAL CHARACTERISTICS†

REFERENCE VOLTAGE vs FREE-AIR TEMPERATURE

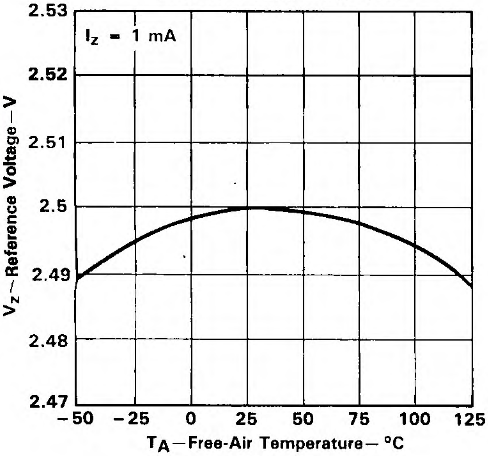


FIGURE 1

CHANGE IN REFERENCE VOLTAGE vs REFERENCE CURRENT

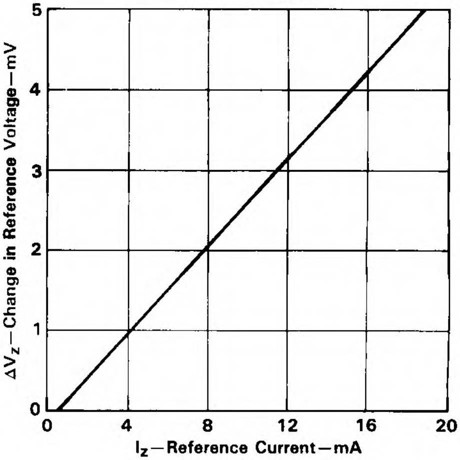


FIGURE 2

REVERSE CHARACTERISTICS

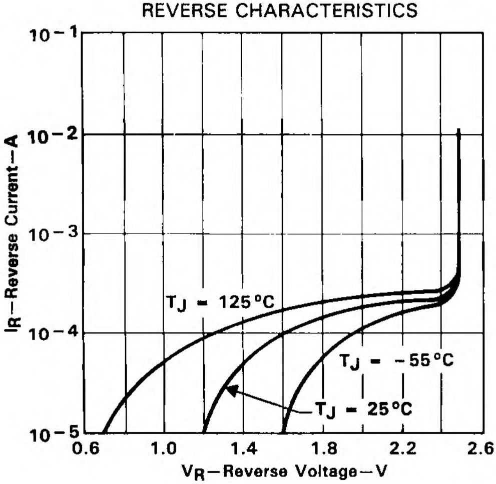


FIGURE 3

FORWARD CHARACTERISTICS

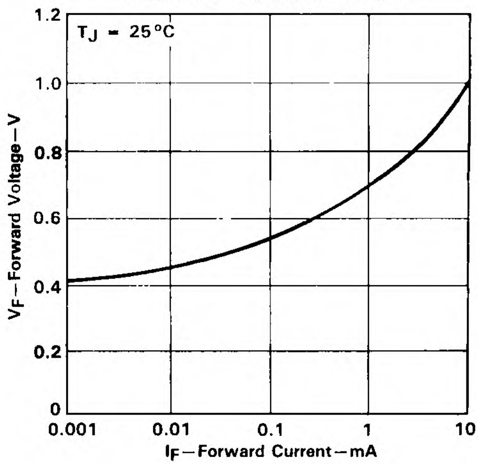


FIGURE 4

† Data at the high and low temperatures are applicable only within the rated operating free-air temperature ranges of the various devices.

TYPICAL CHARACTERISTICS

REFERENCE IMPEDANCE
vs
FREQUENCY

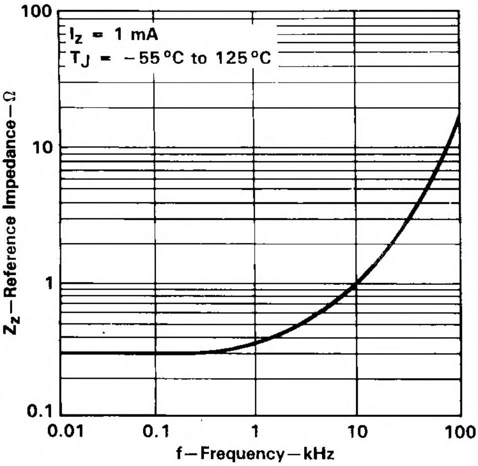


FIGURE 5

NOISE VOLTAGE
vs
FREQUENCY

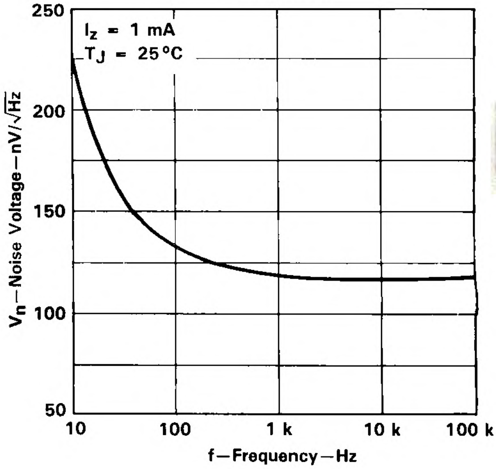


FIGURE 6

TRANSIENT RESPONSE

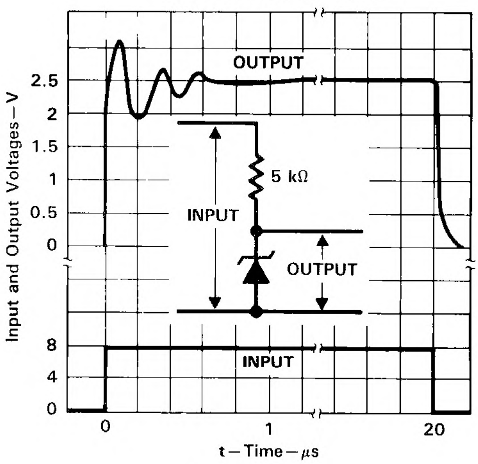
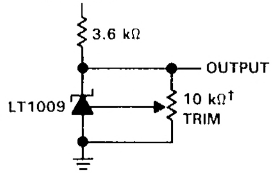


FIGURE 7

TYPICAL APPLICATION DATA



† Does not affect temperature coefficient. Provides ±5% trim range.

FIGURE 8. 2.5-V REFERENCE

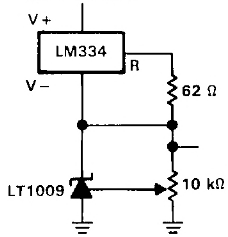


FIGURE 9. ADJUSTABLE REFERENCE WITH WIDE-SUPPLY RANGE

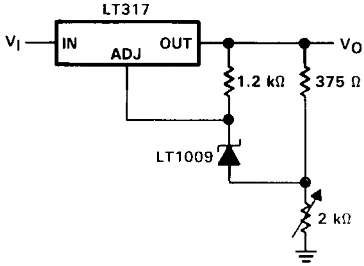


FIGURE 10. POWER REGULATOR WITH LOW TEMPERATURE COEFFICIENT

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

TYPICAL APPLICATION DATA

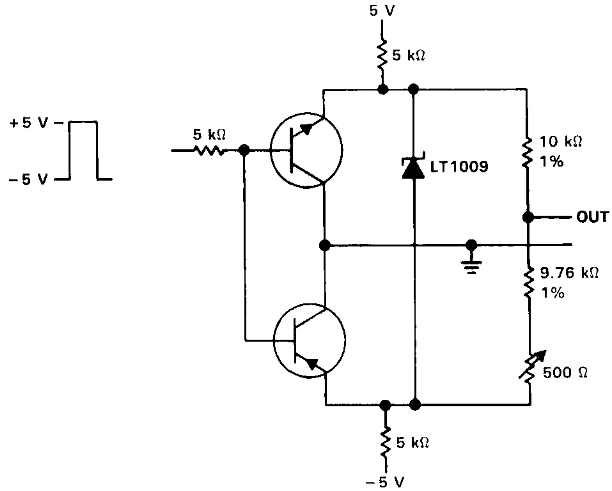


FIGURE 11. SWITCHABLE ±1.25-V BIPOLAR REFERENCE

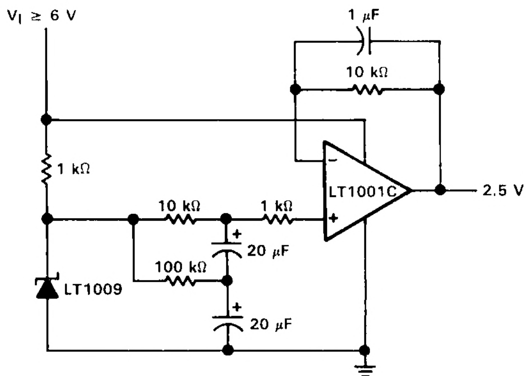
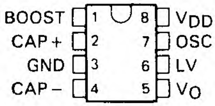


FIGURE 12. LOW-NOISE 2.5-V BUFFERED REFERENCE

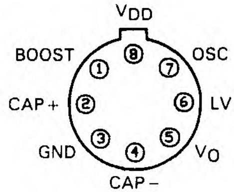
D3193, JANUARY 1989

- Plug-In Compatible with the 7660 with These Additional Features:
  - Operation to 9 V Over Full Temperature Range with No External Protection Diodes
  - Boost Pin for Higher Switching Frequency
  - 2 1/2 Times Lower Quiescent Power
  - Efficient Voltage Doubler
- No-Load Supply Current at 5 V . . . 200 μA Max
- Open-Circuit Voltage Conversion Efficiency . . . 97% Min
- Power Conversion Efficiency . . . 95% Min
- Operating Supply Voltage Range . . . 1.5 V to 9 V
- Commercial Device Operates from −40°C to 85°C

LTC1044M . . . JG PACKAGE
LTC1044C . . . D, JG, OR P PACKAGE
(TOP VIEW)



L PACKAGE
(TOP VIEW)



description

The LTC1044 is a monolithic CMOS switched-capacitor voltage converter manufactured using CMOS silicon-gate technology. The LTC1044 provides several voltage conversion functions; the input voltage can be inverted ($V_O = -V_I$), doubled ($V_O = 2V_I$), divided ($V_O = V_I/2$), or multiplied ($V_O = \pm nV_I$).

Designed to be pin-for-pin and functionally compatible with the 7660, the LTC1044 offers significant new design and performance advantages while still maintaining compatibility with existing 7660 designs.

The LTC1044M is characterized for operation over the full military temperature range of −55°C to 125°C. The LTC1044C is characterized for operation from −40°C to 85°C.

absolute maximum ratings over operating free-air temperature range†

Supply voltage, V_{DD} . . . 9.5 V
Input voltage range (pins 1, 6, and 7, see Note 1) . . . −0.3 V to V_{DD} + 0.3 V
Input current, I_I (pin 6) . . . 20 μA
Duration of output short circuit (V_{CC+} ≤ 5.5 V) . . . unlimited
Operating free-air temperature range: LTC1044M . . . −55°C to 125°C
LTC1044C . . . −40°C to 85°C
Storage temperature range . . . −65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package . . . 300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package . . . 260°C
L package . . . 300°C

† Stresses beyond those listed under "absolute maximum ratings" may cause permanent damage to the device. These are stress ratings only, and functional operation of the device at these or any other conditions beyond those indicated under "recommended operating conditions" is not implied. Exposure to absolute-maximum-rated conditions for extended periods may affect device reliability.

2

Data Sheets

recommended operating conditions

		LTC1044M		LTC1044C		UNIT
		MIN	MAX	MIN	MAX	
V_{DD}	Supply voltage (R_L = 10 kΩ, see Note 1)	1.5	9	1.5	9	V
V_I	Input voltage (pins 1, 6, and 7, see Note 2)	−0.3	V_{DD}+0.3	−0.3	V_{DD}+0.3	V
T_A	Operating free-air temperature	−55	125	−40	85	°C

NOTES: 1. The LTC1044 operates with alkaline, mercury, or NiCad 9-V batteries, even when the initial battery voltage is slightly higher than 9 V.
2. Connecting any input terminal to voltages substantially greater than V_{DD} or less than ground may cause destructive latch-up. It is recommended that no inputs from sources operating from external supplies be applied prior to power-up of the LTC1044.

electrical characteristics at specified free-air temperature, V_{DD} = 5 V (unless otherwise noted, see Figure 1)

PARAMETER		TEST CONDITIONS	T_A†	LTC1044M MIN	LTC1044M TYP	LTC1044M MAX	LTC1044C MIN	LTC1044C TYP	LTC1044C MAX	UNIT
r_o	Output resistance	I_O = 20 mA, f_{osc} = 5 kHz	25°C			100			100	Ω
			Full range			150			130	
		V_{DD} = 2 V, I_L = 3 mA, f_{osc} = 1 kHz	Full range			400			325	
f_{osc}	Oscillator frequency	V_{DD} = 5 V, C_{osc} = 1 pF, See Note 3	Full range	5			5			kHz
		V_{DD} = 2 V, C_{osc} = 1 pF, See Note 3		1			1			
η_P	Power efficiency	R_L = 5 kΩ, f_{osc} = 5 kHz	25°C	95	98		95	98		%
n_{VO}	Voltage conversion efficiency	R_L = ∞	25°C	97	99.9		97	99.9		%
I_{osc}	Oscillator sink or source current	V_{osc} = 0 or V_{DD}, Pin 1 at 0 V	Full range			3			3	µA
		V_{osc} = 0 or V_{DD}, Pin 1 at V_{DD}				20			20	
I_{DD}	Supply current	R_L = ∞, Pins 1 and 7 no connection	25°C		60	200		60	200	µA
		R_L = ∞, Pins 1 and 7 V_{DD} = 3 V			20			20		

† Full range is −55°C to 125°C for the LTC1044M and −40°C to 85°C for the LTC1044C.

NOTE 3: f_{osc} is tested with C_{osc} at 100 pF to minimize the effects of test fixture capacitance loading. The 1-pF frequency is correlated to this 100-pF test point and is intended to simulate the capacitance at pin 7 when the device is plugged into a test socket and no external capacitor is used.

PARAMETER MEASUREMENT INFORMATION

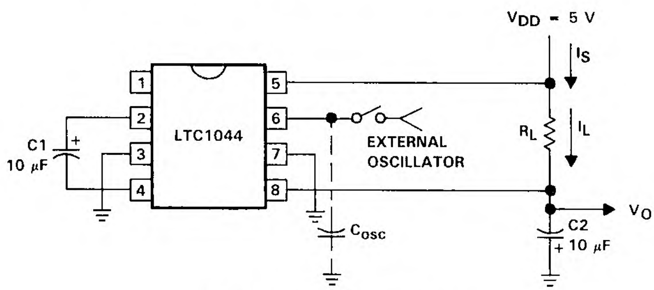


FIGURE 1. TEST CIRCUIT

TYPICAL CHARACTERISTICS†

SUPPLY CURRENT
vs
SUPPLY VOLTAGE

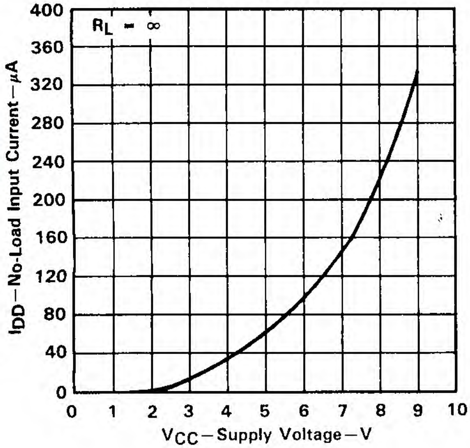


FIGURE 2

OUTPUT RESISTANCE
vs
SUPPLY VOLTAGE

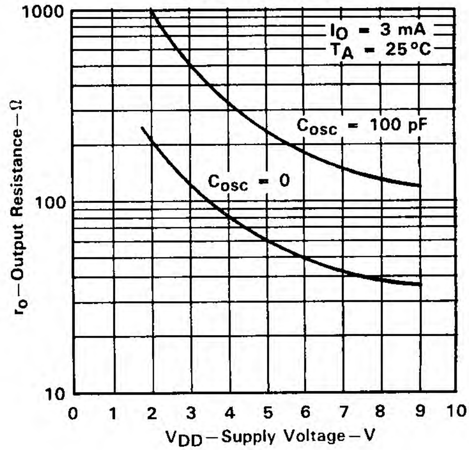


FIGURE 3

OUTPUT RESISTANCE
vs
FREE-AIR TEMPERATURE

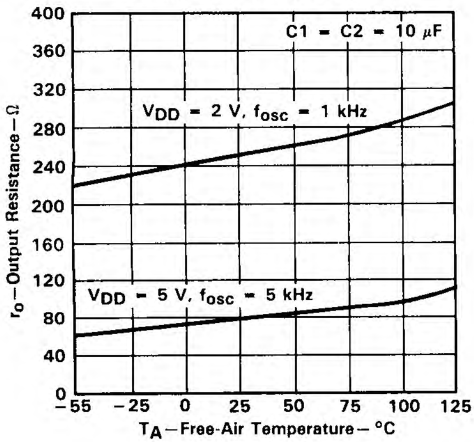


FIGURE 4

OUTPUT RESISTANCE
vs
OSCILLATOR FREQUENCY

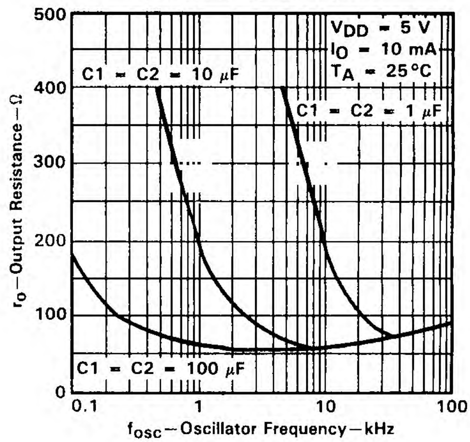


FIGURE 5

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the two devices.

TYPICAL CHARACTERISTICS†

OSCILLATOR FREQUENCY
vs
EXTERNAL CAPACITOR

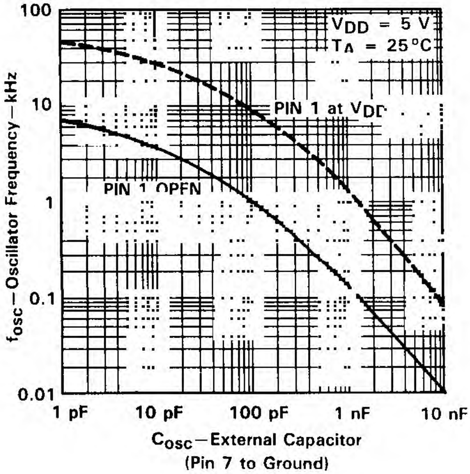


FIGURE 6

OSCILLATOR FREQUENCY
vs
SUPPLY VOLTAGE

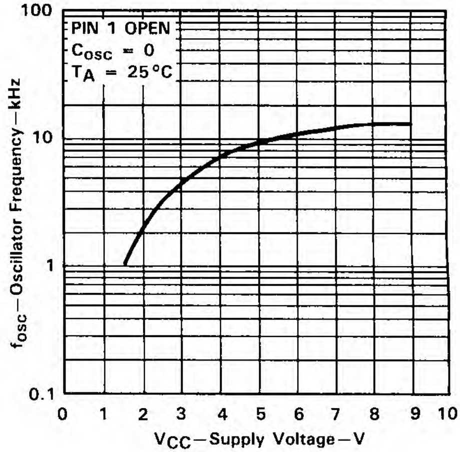


FIGURE 7

OSCILLATOR FREQUENCY
vs
FREE-AIR TEMPERATURE

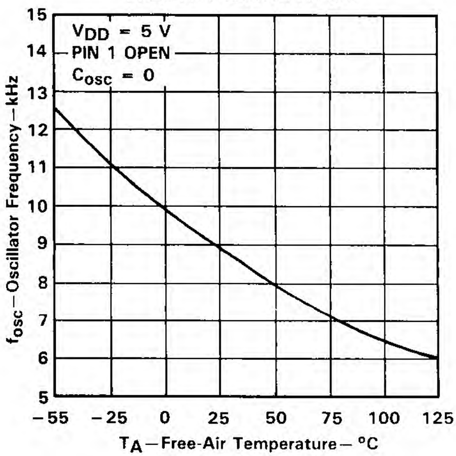


FIGURE 8

POWER CONVERSION EFFICIENCY
vs
OSCILLATOR FREQUENCY

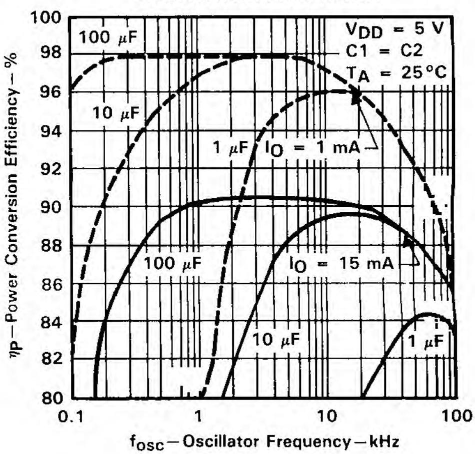


FIGURE 9

† Data at high and low temperatures are applicable only within the rated operating free-air temperature ranges of the two devices.

TYPICAL CHARACTERISTICS

POWER CONVERSION EFFICIENCY
and SUPPLY CURRENT
vs
OUTPUT CURRENT

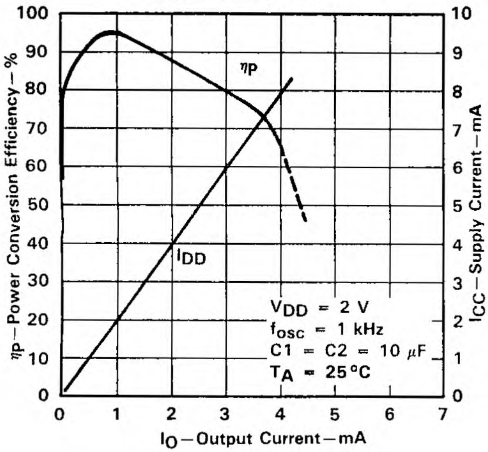


FIGURE 10

POWER CONVERSION EFFICIENCY
and SUPPLY CURRENT
vs
OUTPUT CURRENT

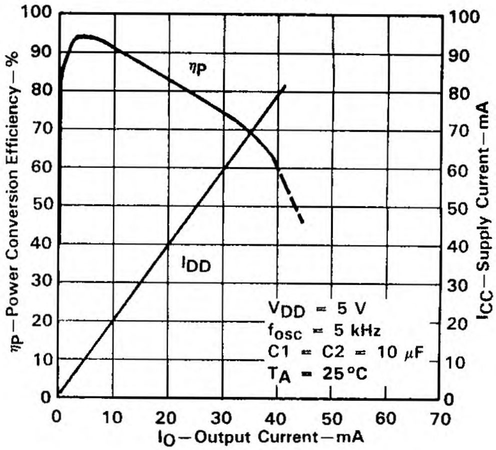


FIGURE 11

OUTPUT VOLTAGE
vs
OUTPUT CURRENT

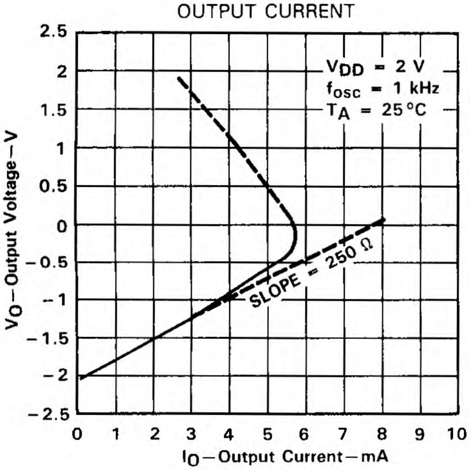


FIGURE 12

OUTPUT VOLTAGE
vs
OUTPUT CURRENT

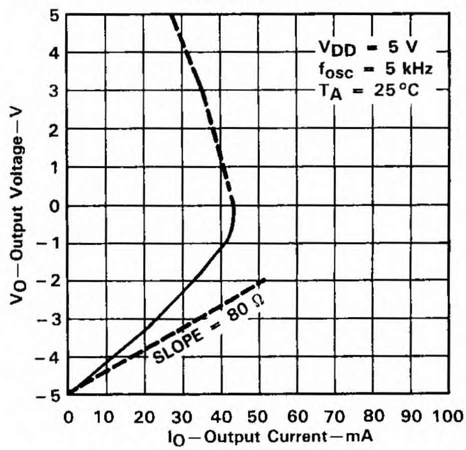


FIGURE 13

TYPICAL APPLICATION DATA

theory of operation

To understand the theory of operation of the LTC1044, a review of a basic switched-capacitor building block is helpful. In Figure 14, when the switch is in the left position, capacitor C1 charges to voltage V1. The total charge on C1 is $q1 = C1 \cdot V1$. The switch then moves to the right, discharging C1 to voltage V2. After this discharge time, the charge on C1 is $q2 = C1 \cdot V2$. Note that charge has been transferred from the source, V1, to the output, V2. The amount of charge transferred is calculated as follows:

$$\Delta q = q1 - q2 = C1(V1 - V2).$$

If the switch is cycled f times per second, the charge transfer per unit time (i.e., current) is calculated as follows:

$$I = f \times \Delta q = f \times C1(V1 - V2).$$

Rewriting in terms of voltage and impedance equivalence,

$$I = \frac{V1 - V2}{(1/fC1)} = \frac{V1 - V2}{R_{eq}}$$

where R_{eq} is defined as $R_{eq} = 1/fC1$. The equivalent circuit for the switched-capacitor network is shown in Figure 15.

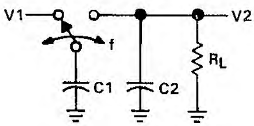


FIGURE 14. SWITCHED-CAPACITOR BUILDING BLOCK

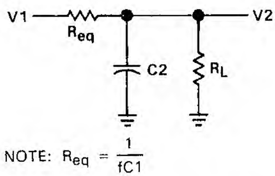


FIGURE 15. SWITCHED-CAPACITOR EQUIVALENT CIRCUIT

Examination of Figure 16 shows that the LTC1044 has the same switching action as the basic switched-capacitor building block, with the addition of finite switch on-state resistance and output voltage ripple.

The simple theory, although not exact, helps illustrate how the device operates. For example, it explains how the LTC1044 behaves in Figure 9. The loss, and hence the efficiency, is determined by the output impedance. As frequency is decreased, the output impedance is eventually dominated by the 1/fC1 term, and power efficiency drops. Figure 9 shows this effect for various capacitor values.

Note also that power efficiency decreases as frequency increases. This is caused by internal switching losses that occur because some finite charge is lost in each switching cycle. This charge loss per unit cycle, when multiplied by the switching frequency, becomes a current loss. At high frequency, this loss becomes significant, and the power efficiency starts to decrease.

TYPICAL APPLICATION DATA

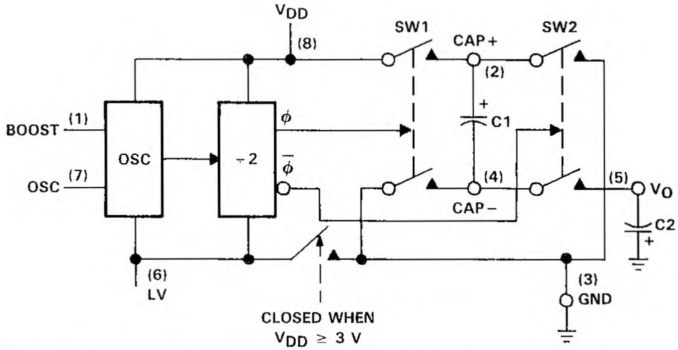


FIGURE 16. LTC1044 SWITCHED-CAPACITOR VOLTAGE CONVERTER BLOCK DIAGRAM

LV (pin 6)

The internal logic of the LTC1044 runs between V_{DD} and LV (pin 6). For $V_{DD} \geq 3$ V, an internal switch shorts LV to GND (pin 3). The LV pin can be tied to ground or left floating. For $V_{DD} \leq 3$ V, the LV pin should be tied to GND.

OSC (pin 7) and BOOST (pin 1)

The switching frequency can be raised, lowered, or driven from an external source. Figure 17 shows a functional diagram of the oscillator circuit. By connecting the boost pin (pin 1) to V_{DD}, the charge and discharge current is increased, thereby increasing the frequency by a factor of approximately 7. Increasing the frequency decreases output impedance and ripple for higher load currents. Loading pin 7 with more capacitance lowers the frequency. Using the boost pin (pin 1) in conjunction with external capacitance on pin 7 allows the user to select the frequency over a wide range.

Driving the LTC1044 from an external frequency source can easily be achieved by driving pin 7 and leaving the boost pin open, as shown in Figure 18. The output current from pin 7 is small, typically 0.5 µA, so a logic gate can drive this current. Using a CMOS logic gate is preferable because it can operate over a wide supply voltage range (3 V to 15 V) and has enough voltage swing to drive the internal Schmitt trigger shown in Figure 17. For 5-V applications, a TTL logic gate can be used by simply adding an external pull-up resistor (see Figure 18).

TYPICAL APPLICATION DATA

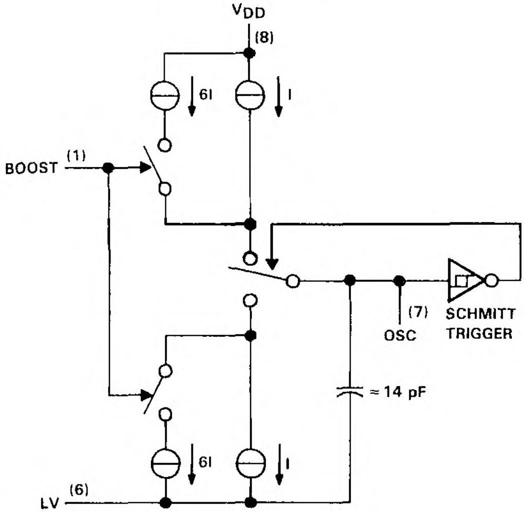


FIGURE 17. OSCILLATOR

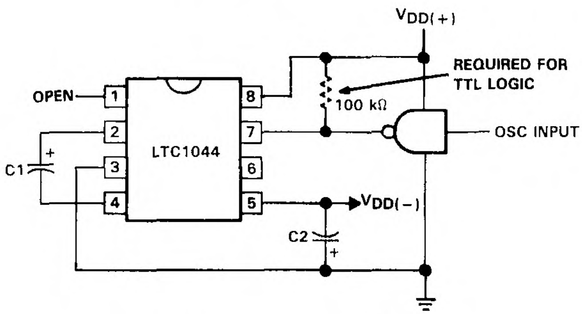


FIGURE 18. EXTERNAL CLOCKING

external diode (D_X)

Previous circuits of this type have required a diode between V_O (pin 5) and the external capacitor C2 for voltages above 6.5 V (5 V for military temperature range). The improvements in the LTC1044 circuit design and Texas Instruments LinCMOS™ silicon-gate process have eliminated the need for this diode. The LTC1044 operates from 1.5 V to 9 V without the protection diode over all temperature ranges. The LTC1044 will operate without any problems in existing LTC7660 designs that use the protection diode as long as the maximum recommended supply voltage of 9 V is not exceeded.

LinCMOS is a trademark of Texas Instruments Incorporated.

TYPICAL APPLICATION DATA

capacitor selection

External capacitors C1 and C2 are not critical. They do not have to be high quality or have tight tolerance, nor is matching required. Aluminum or tantalum electrolytics are excellent choices, with cost and size being the only consideration.

negative voltage converter

Figure 19 shows a typical connection that provides a negative supply from an available positive supply. This circuit operates over full temperature and power supply ranges without the need for external diodes. The LV pin (pin 6) is shown grounded, but for $V_{DD} \geq 3$ V, it may be floated, since LV is internally switched to ground (pin 3) for $V_{DD} \geq 3$ V.

The output voltage (pin 5) characteristics of the circuit are those of a nearly ideal voltage source in series with an 80-Ω resistor. The 80-Ω output impedance is composed of two terms—the equivalent switched-capacitor resistance (see Theory of Operation) and a term related to the on-state resistance of the MOS switches. At an oscillator frequency of 10 kHz and C1 = 10 µF, the first term is:

$$R_{eq} = \frac{1}{(f_{osc}/2) \times C1} = \frac{1}{5 \times 10^3 \times 10 \times 10^{-6}} = 20\ \Omega$$

Notice that the equation for R_{eq} is not a capacitive reactance equation ($X_C = 1/\omega C$) and does not contain a 2π term. While the exact expression for output impedance is extremely complex, the dominant effect of the capacitor is clearly shown in the typical curves of output impedance and power efficiency versus frequency. For C1 = C2 = 10 µF, the output impedance goes from 60 Ω at f_{osc} = 10 kHz to 200 Ω at f_{osc} = 1 kHz. As the 1/fC term becomes large compared to the switch on-state resistance term, the output resistance is determined by 1/fC only.

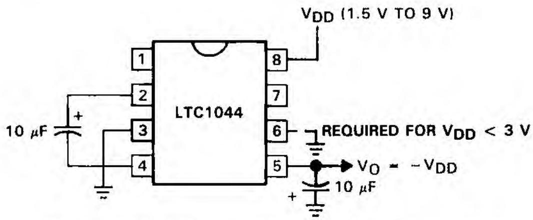


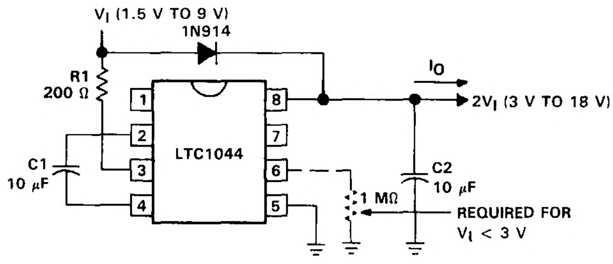
FIGURE 19. NEGATIVE VOLTAGE CONVERTER

voltage doubling

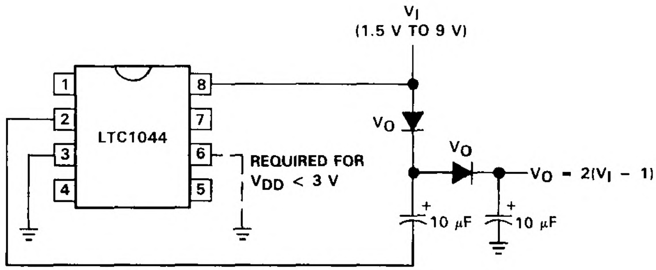
Figure 20 illustrates two methods of voltage doubling. In Figure 20(a), doubling is achieved by simply rearranging the connection of the two external capacitors. When the input voltage is less than 3 V, an external 1-MΩ resistor is required to ensure that the oscillator starts; it is not required for higher input voltages.

In this application, the ground input (pin 3) is taken above V_{DD} (pin 8) during power-on, making it prone to latch-up. The latch-up, while not destructive, prevents the circuit from doubling. Resistor R1 is added to eliminate this problem; in most cases, 200 Ω is sufficient. It may be necessary in a particular application to increase this value to guarantee start-up. The voltage drop across R1 is $V_{R1} = 2 \times I_O \times R2$. If this voltage exceeds two diode drops (1.4 V for silicon, 0.8 V for Schottky), the circuit in Figure 20(a) is recommended because it will never have a start-up problem.

TYPICAL APPLICATION DATA



(a)

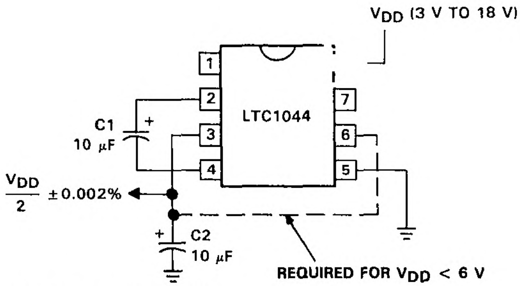


(b)

FIGURE 20. VOLTAGE DOUBLER

ultra-precision voltage divider

An ultra-precision voltage divider is shown in Figure 21. To achieve the 0.0002% accuracy indicated, the load current should be kept below 100 nA. However, with a slight loss in accuracy, the load current can be increased.



NOTE: T_A = MIN to MAX, $I_O \leq$ 100 nA

FIGURE 21. ULTRA-PRECISION VOLTAGE DIVIDER

TYPICAL APPLICATION DATA

battery splitter

Obtaining positive and negative supplies from a single battery or single power supply is a common need in many systems. Where current requirements are small, the circuit shown in Figure 22 is a simple solution. It provides symmetrical positive and negative output voltages, both equal to one half the input voltage. The output voltages are both referenced to pin 3 (output common). If the input voltage between pin 8 and pin 5 is less than 6 V, pin 6 should also be connected to pin 3, as shown by the dashed line.

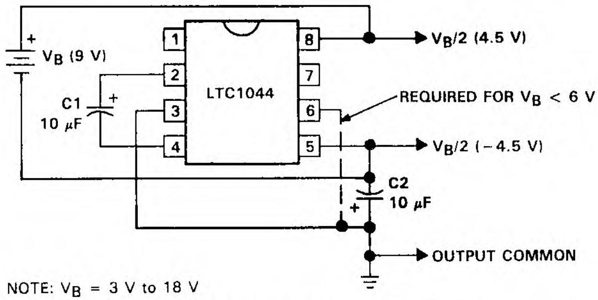
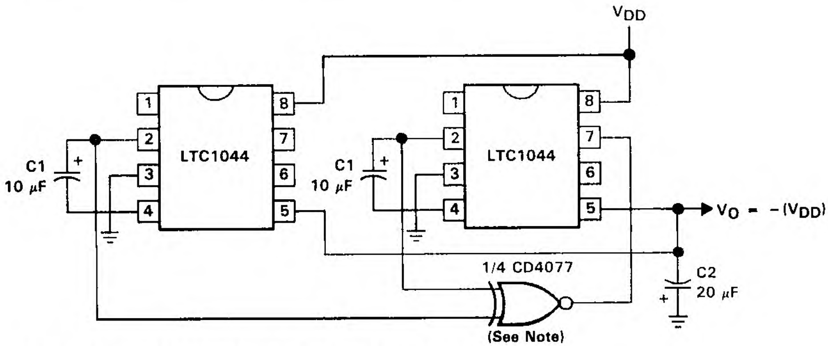


FIGURE 22. BATTERY SPLITTER

paralleling for lower output resistance

Figures 23, 24, and 25 illustrate the flexibility of the LTC1044. Figure 23 shows two LTC1044s connected in parallel to provide a lower effective output resistance. If, however, the output resistance is dominated by 1/fC1, increasing the size of C1 or increasing the frequency is more beneficial than the paralleling circuit shown.



NOTE: The exclusive NOR gate synchronizes both LTC1044s to minimize ripple.

FIGURE 23. PARALLELING FOR LOWER OUTPUT RESISTANCE

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TYPICAL APPLICATION DATA

Figures 24 and 25 "stack" two LTC1044s to provide even higher voltages. As shown schematically in Figure 24, a negative voltage doubler or tripler can be achieved depending upon how pin 8 of the second LTC1044 is connected. Figure 25 illustrates a similar circuit that can be used to obtain positive tripling, or even quadrupling [the doubler circuit appears in Figure 20(a)]. In both of these circuits, the available output *current* is a function of the product of the individual power conversion efficiencies and the voltage step-up ratio.

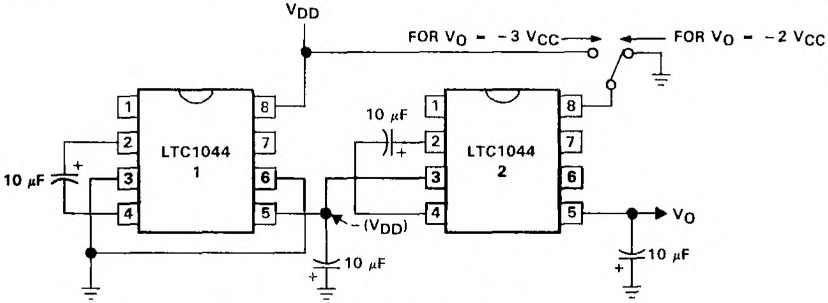


FIGURE 24. STACKING FOR HIGHER VOLTAGE

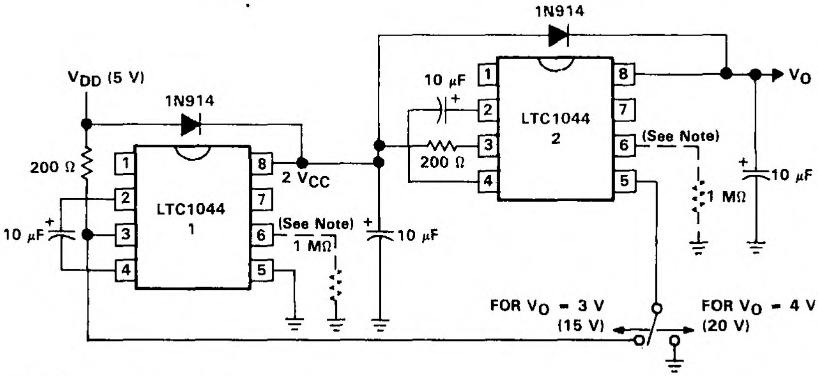
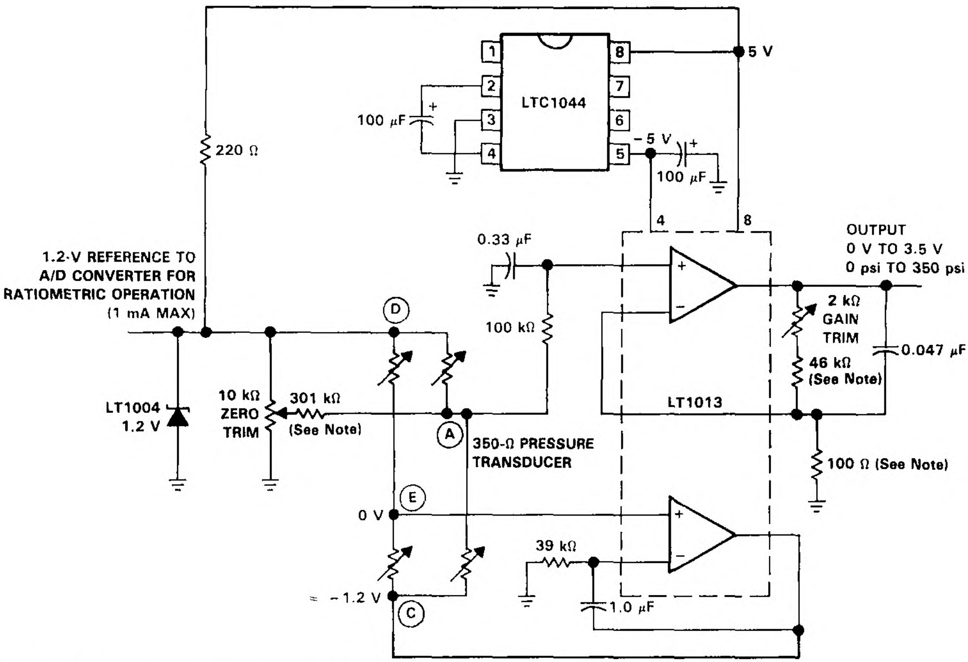


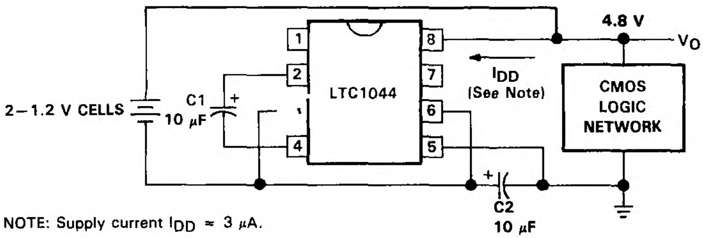
FIGURE 25. VOLTAGE TRIPLER/QUADRUPLER

TYPICAL APPLICATION DATA



NOTE: 1% film resistor pressure transducer BLH/DHF-350 (Circled letter is pin number)

FIGURE 26. SINGLE 5-V STRAIN GAUGE BRIDGE SIGNAL CONDITIONER



NOTE: Supply current I_{DD} ≈ 3 μA.

FIGURE 27. GENERATING CMOS LOGIC SUPPLY FROM 2 MERCURY BATTERIES

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TYPICAL APPLICATION DATA

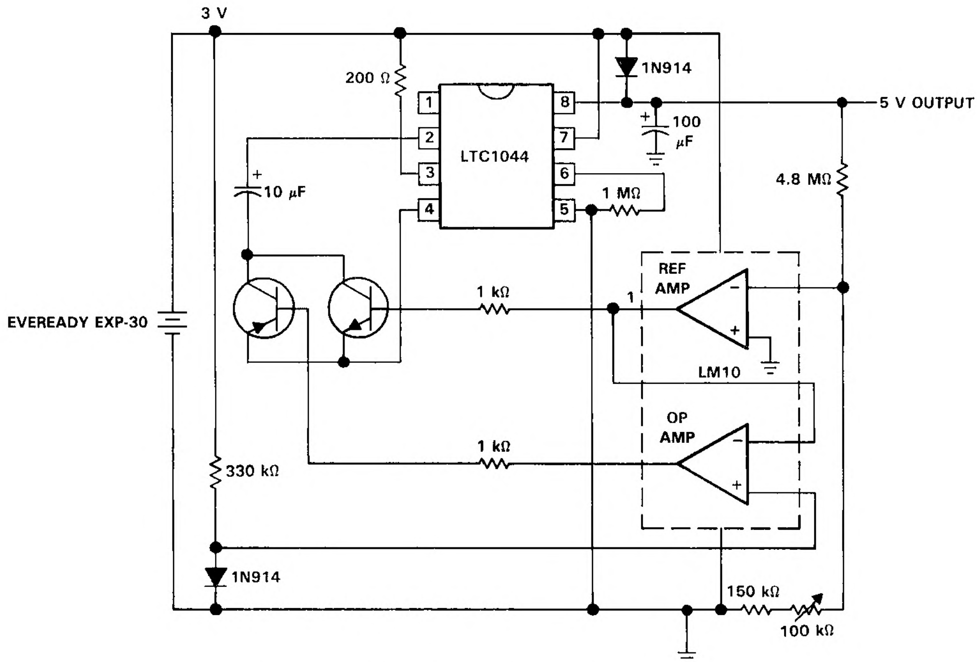
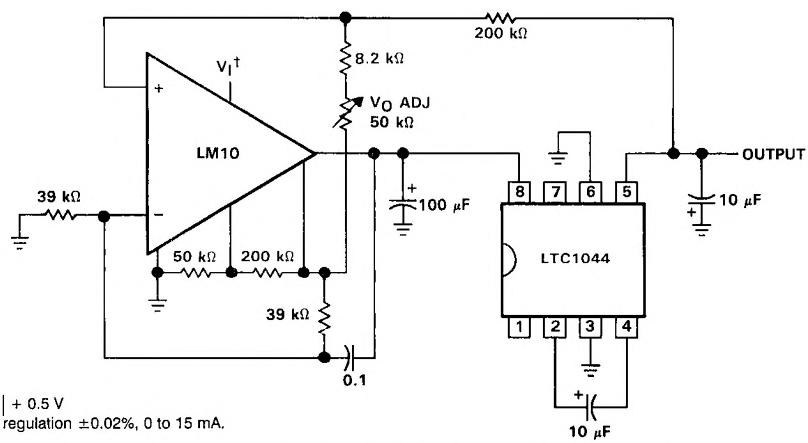


FIGURE 28. REGULATED OUTPUT 3-V TO 5-V CONVERTER



†$V_I \geq |-V_O| + 0.5$ V
NOTE: Load regulation ±0.02%, 0 to 15 mA.

FIGURE 29. LOW-OUTPUT-IMPEDANCE VOLTAGE CONVERTER

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TYPICAL APPLICATION DATA

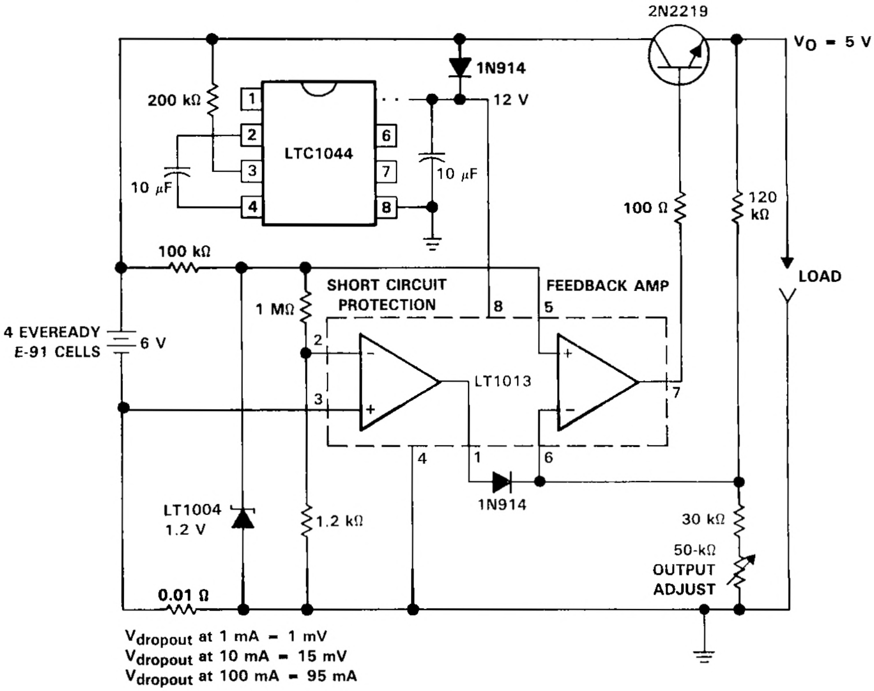
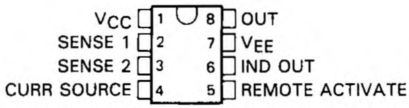


FIGURE 30. LOW-DROPOUT 5-V REGULATOR

D2439, APRIL 1978—REVISED MARCH 1988

- **Separate Outputs for "Crowbar" and Logic Circuitry**
- **Programmable Time Delay to Eliminate Noise Triggering**
- **TTL-Level Activation Isolated from Voltage-Sensing Inputs**
- **2.6-Volt Internal Voltage Reference with Temperature Coefficient Typically 0.08%/°C**

D, JG, OR P PACKAGE
(TOP VIEW)

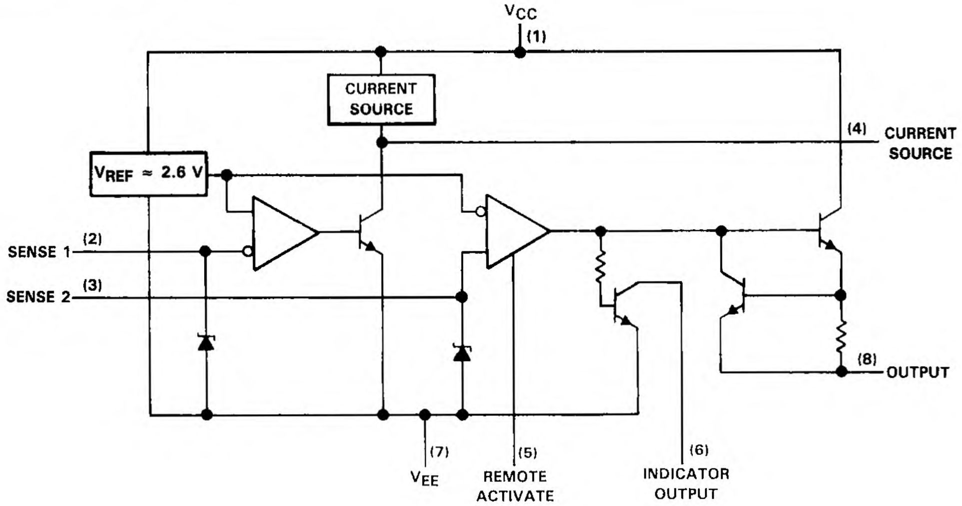


description

The MC3423 overvoltage-sensing circuit is designed to protect sensitive electronic circuitry by monitoring the supply rail and triggering an external "crowbar" SCR in the event of a voltage transient or loss of regulation. The protective mechanism may be activated by an overvoltage condition at the Sense 2 input or by application of a TTL high level to the Remote Activate terminal. Separate outputs are available to trigger the crowbar circuit and to provide a logic pulse to indicator or power supply control circuitry. The Sense 2 input provides a direct control of the output circuitry. The Sense 1 input controls an internal current source that may be utilized to implement a delayed trigger by connecting its output to an external capacitor and the Sense 2 input. This protects against false triggering due to noise at the Sense 1 input.

The MC3423 is characterized for operation from 0°C to 70°C.

functional block diagram



absolute maximum ratings

Supply voltage, V_{CC} (see Note 1) .... 40 V
Sense 1 voltage .... 6.5 V
Sense 2 voltage .... 6.5 V
Remote activate input voltage .... 7 V
Output current, I_O .... 300 mA
Continuous total dissipation: .... See Dissipation Rating Table
Operating free-air temperature range .... 0°C to 70°C
Storage temperature range .... −65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or P package .... 260°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package .... 300°C

NOTE 1: Voltage values are measured with respect to the V_{EE} terminal.

DISSIPATION RATING TABLE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25°C$	$T_A = 70°C$ POWER RATING
D	725 mW	5 8 mW/°C	464 mW
JG	825 mW	6.6 mW/°C	528 mW
P	1000 mW	8.0 mW/°C	640 mW

recommended operating conditions

	MIN	MAX	UNIT
Supply voltage, V_{CC}	4.5	40	V
High-level input voltage, remote activate input	2		V
Low-level input voltage, remote activate input		0.5	V

electrical characteristics over operating free-air temperature range, V_{CC} = 5 V to 36 V (unless otherwise noted)

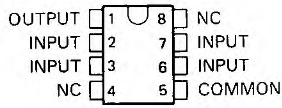
PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Output voltage	Remote Activate at 2 V, I_O = 100 mA	$V_{CC}-2.2$	$V_{CC}-1.8$		V
Indicator low-level output voltage	Remote Activate at 2 V, I_O = 1.6 mA		0.1	0.4	V
Threshold voltage of either sense input	T_A = 25°C	2.45	2.6	2.75	V
Temperature coefficient of input threshold voltage			0.06		%/°C
Source current (pin 4)	Sense 1 at 3 V, Pin 4 at 1.3 V	0.1	0.22	0.3	mA
High-level input current, Remote Activate input	V_{CC} = 5 V, V_I = 2 V		5	40	μA
Low-level input current, Remote Activate input	V_{CC} = 5 V, V_I = 0.8 V		−120	−180	μA
Supply current	Outputs open		6	10	mA
Propagation delay time, Remote Activate input to output	T_A = 25°C		0.5		μs
Output current rate of rise	T_A = 25°C		400		mA/μs

D2565, OCTOBER 1982—REVISED APRIL 1988

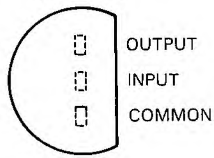
- 3-Terminal Regulators
- Output Current Up to 100 mA
- No External Components Required
- Internal Thermal Overload Protection
- Internal Short Circuit Current Limiting
- Direct Replacement for Motorola MC79L00 Series
- Available in 5% or 10% Selections

NOMINAL OUTPUT VOLTAGE	5% OUTPUT VOLTAGE TOLERANCE	10% OUTPUT VOLTAGE TOLERANCE
−5 V	MC79L05AC	MC79L05C
−12 V	MC79L12AC	MC79L12C
−15 V	MC79L15AC	MC79L15C

D PACKAGE
(TOP VIEW)



LP SILECT PACKAGE
(TOP VIEW)

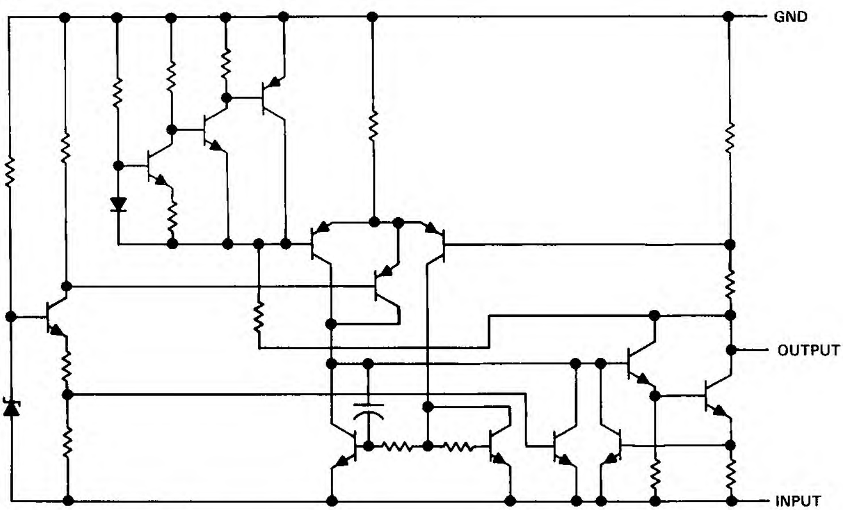


NC-No internal connection

description

This series of fixed-voltage monolithic integrated-circuit voltage regulators is designed for a wide range of applications. These include on-card regulation for elimination of noise and distribution problems associated with single-point regulation. In addition, they can be used to control series pass elements to make high-current voltage-regulator circuits. One of these regulators can deliver up to 100 mA of output current. The internal current-limiting and thermal-shutdown features make them essentially immune to overload. When used as a replacement for a Zener-diode and resistor combination, these devices can provide an effective improvement in output impedance of two orders of magnitude and lower bias current.

schematic



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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	MC79L05	MC79L12 MC79L15	UNIT
Input voltage	−30	−35	V
Continuous total dissipation	See Dissipation Rating Tables 1 and 2		
Operating free-air, case, or virtual junction temperature range	0 to 150	0 to 150	°C
Storage temperature range	−65 to [illegible]	−65 to 150	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260	260	°C

DISSIPATION RATING TABLE 1—FREE AIR TEMPERATURE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR	DERATE ABOVE T_A	$T_A = 70°C$ POWER RATING
D	825 mW	6.6 [illegible]	25°C	528 mW
LP†	775 mW	6.2 mW/°C	25°C	496 mW

†The LP package dissipation rating is based on thermal resistance measured in still air with the device mounted in an Augat socket. The bottom of the package was 10 mm (0.375 in.) above the socket.

DISSIPATION RATING TABLE 2—CASE TEMPERATURE

PACKAGE	$T_C \le 25°C$ POWER RATING	DERATING FACTOR	DERATE ABOVE T_C	$T_C = 125°C$ POWER RATING
D	1600 mW	29.0 mW/°C	95°C	725 mW
LP	1600 mW	28.6 mW/°C	94°C	715 mW

recommended operating conditions

		MIN	MAX	UNIT
Input voltage, V_I	MC79L05	−7	−20	V
	MC79L12	−14.5	−27	
	MC79L15	−17.5	−30	
Output current, I_O			[illegible]	mA
Operating virtual junction temperature, T_J		0	[illegible]	°C

MC79L05 electrical characteristics at specified virtual junction temperature, $V_I = -10$ V, $I_O = 40$ mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		MC[illegible]C			MC[illegible]AC			UNIT
			MIN	[illegible]	MAX	MIN	[illegible]	MAX	
Output voltage‡		25°C	−4.6	−5	−5.4	−4.8	−5	−5.2	V
	V_I = −7 V to −20 V, I_O = 1 mA to 40 mA	0°C to 125°C	−4.5		−5.5	−4.75		−5.25	
	V_I = −10 V, I_O = 1 mA to 70 mA	0°C to 125°C	−4.5		−5.5	−4.75		−5.25	
Input regulation	V_I = −7 V to −20 V	25°C			[illegible]			[illegible]	mV
	V_I = −8 V to −20 V				[illegible]			[illegible]	
Ripple rejection	V_I = −8 V to −18 V, f = 120 Hz	25°C	40	49		41	49		dB
Output regulation	I_O = 1 mA to 100 mA	25°C			60			60	mV
	I_O = 1 mA to 40 mA				30			30	
Output noise voltage	f = 10 Hz to 100 kHz	25°C		40			40		μV
Dropout voltage	I_O = 40 mA	25°C		1.7			1.7		V
Bias current		25°C			6			6	mA
		125°C			5.5			5.5	
Bias current change	V_I = −8 V to −20 V	0°C to 125°C			1.5			1.5	mA
	I_O = 1 mA to 40 mA				0.2			0.1	

MC79L12 electrical characteristics at specified virtual junction temperature, $V_I = -19$ V, $I_O = 40$ mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		MC79L12C			MC79L12AC			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
Output voltage‡		25°C	[illegible]	−12	−12.9	−11.5	−12	−12.5	V
	V_I = −14.5 V to −27 V, I_O = 1 mA to 40 mA	0°C to 125°C	−10.8		−13.2	−11.4		−12.6	
	V_I = −19 V, I_O = 1 mA to 70 mA	0°C to 125°C	−10.8		−13.2	−11.4		−12.6	
Input regulation	V_I = −14.5 V to −27 V	25°C			[illegible]			250	mV
	V_I = −16 V to −27 V				[illegible]			200	
Ripple rejection	V_I = −15 V to −25 V, f = 120 Hz	25°C	36	42		37	42		dB
Output regulation	I_O = 1 mA to 100 mA	25°C			100			100	mV
	I_O = 1 mA to 40 mA				50			50	
Output noise voltage	f = 10 Hz to 100 kHz	25°C		80			80		μV
Dropout voltage	I_O = 40 mA	25°C		1.7			1.7		V
Bias current		25°C			6.5			6.5	mA
		125°C			6			6	
Bias current change	V_I = −16 V to −27 V	0°C to 125°C			1.5			1.5	mA
	I_O = 1 mA to 40 mA				0.2			0.1	

†All characteristics are measured with a 0.33-μF capacitor across the input and a 0.1-μF capacitor across the output. Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.

‡This specification applies only for dc power dissipation permitted by absolute maximum ratings.

2 Data Sheets

MC79L15 electrical characteristics at specified virtual junction temperature, $V_I = -23\ V$, $I_O = 40\ mA$ (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		MC[illegible]C			MC79L15AC			UNIT
			[illegible]	[illegible]	MAX	[illegible]	TYP	MAX	
Output voltage‡		25°C	[illegible]	−15	−16.2	[illegible]	−15	−15.6	V
	$V_I = -17.5\ V$ to $-30\ V$, $I_O = 1\ mA$ to $40\ mA$	0°C to 125°C	−13.5		−16.5	−14.25		−15.75	
	$V_I = -23\ V$, $I_O = 1\ mA$ to $70\ mA$	0°C to 125°C	−13.5		−16.5	−14.25		−15.75	
Input regulation	$V_I = -17.5\ V$ to $-30\ V$	25°C			300			300	mV
	$V_I = -20\ V$ to $-30\ V$				[illegible]			250	
Ripple rejection	$V_I = -18.5\ V$ to $-28.5\ V$, f = 120 Hz	25°C	33	39		34	39		dB
Output regulation	$I_O = 1\ mA$ to $100\ mA$	25°C			150			150	mV
	$I_O = 1\ mA$ to $40\ mA$				75			75	
Output noise voltage	f = 10 Hz to [illegible] kHz	25°C		90			90		μV
Dropout voltage	$I_O = 40\ mA$	25°C		1.7			1.7		V
Bias current		25°C			6.5			6.5	mA
		125°C			6			6	
Bias current change	$V_I = -20\ V$ to $-30\ V$	0°C to 125°C			1.5			1.5	mA
	$I_O = 1\ mA$ to $40\ mA$				0.2			0.1	

†All characteristics are measured with a 0.33-μF capacitor across the input and a 0.1-μF capacitor across the output. Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.

‡This specification applies only for dc power dissipation permitted by absolute maximum ratings.

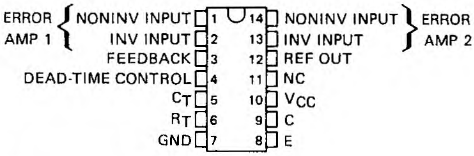
2

Data Sheets

D2714, MARCH 1983—REVISED FEBRUARY 1988

- **Complete PWM Power Control Circuitry**
- **Uncommitted Output for 200-mA Sink or Source Current**
- **Variable Dead-Time Provides Control Over Total Range**
- **Internal Regulator Provides a Stable 5-V Reference Supply**
- **Circuit Architecture Provides Easy Synchronization**
- **Direct Replacement for Motorola MC34060**

D OR N PACKAGE
(TOP VIEW)



NC—No internal connections

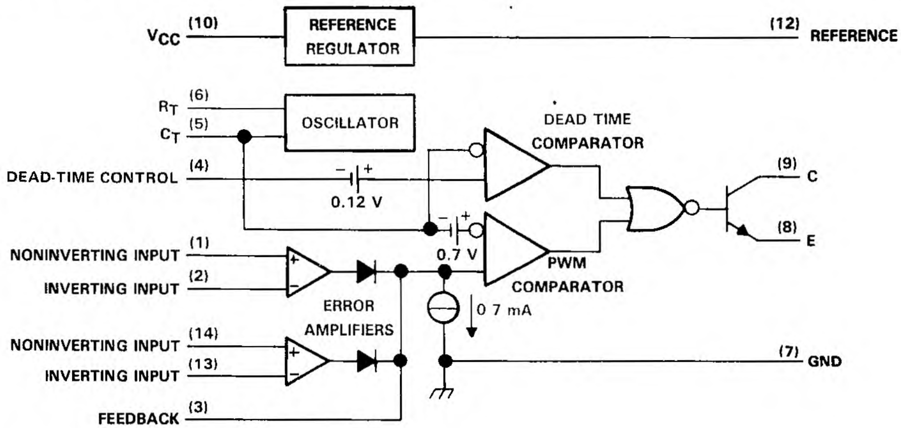
2
Data Sheets

description

The MC34060 incorporates on a single monolithic chip all the functions required in the construction of a pulse-width-modulation control circuit. Designed primarily for power supply control, the device contains an on-chip 5-V regulator, two error amplifiers, an adjustable oscillator, and a dead-time control comparator. The uncommitted output transistor provides either common-emitter or emitter-follower output capability. The internal amplifiers exhibit a common-mode voltage range from −0.3 V to V_{CC} − 2 V. The dead-time control comparator has a fixed offset that provides approximately 5% dead time unless externally altered. The on-chip oscillator may be bypassed by terminating R_T (pin 6) to the reference output and providing a sawtooth input to C_T (pin 5), or it may be used to drive the common MC34060 circuitry and provide a sawtooth input for associated control circuitry in multiple rail power supplies.

The MC34060 is characterized for operation from 0°C to 70°C.

functional block diagram



All voltage and current values shown are nominal.

TEXAS INSTRUMENTS
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absolute maximum ratings over operating temperature range (unless otherwise noted)

		UNIT
Supply voltage, V_{CC} (see Note 1)	42	V
Amplifier input voltages	$V_{CC}+0.3$	V
Collector output voltage	42	V
Collector output current	250	mA
Continuous total dissipation	See Dissipation Rating Table	
Operating free-air temperature range	0 to 70	°C
Storage temperature range	−65 to 1[illegible]	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or N package	260	°C

NOTE 1: All voltage values except differential voltages are with respect to the network ground terminal.

DISSIPATION RATING TABLE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR	DERATE ABOVE T_A	$T_A = 70°C$ POWER RATING
D	900 mW	7.6 mW/°C	31°C	608 mW
N	1000 mW	9.2 mW/°C	41°C	736 mW

recommended operating conditions

	MIN	MAX	UNIT
Supply voltage, V_{CC}	7	40	V
Amplifier input voltages, V_I	−0.3	$V_{CC}-2$	V
Collector output voltage, V_O		40	V
Collector output current (each transistor)		[illegible]	mA
Reference output current		10	mA
Current into feedback terminal		0.3	mA
Timing capacitor, C_T	0.47	[illegible]	nF
Timing resistor, R_T	1.8	[illegible]	kΩ
Oscillator frequency	1	[illegible]	kHz
Operating free-air temperature, T_A	0	70	°C

electrical characteristics over recommended operating free-air temperature range, V_{CC} = 15 V, f = 25 kHz (unless otherwise noted)

reference section

PARAMETER	TEST CONDITIONS†	MIN	TYP‡	MAX	UNIT
Output voltage (V_{ref})	I_O = 1 mA	4.75	5	5.25	V
Input regulation	V_{CC} = 7 V to 40 V, T_A = 25°C		2	25	mV
Output regulation	I_O = 1 to 10 mA, T_A = 25°C		1	15	mV
Output voltage change with temperature	ΔT_A = MIN to MAX		0.2%	2.6%	
Short-circuit output current§	V_{ref} = 0, T_A = 25°C		35		mA

oscillator section

PARAMETER	TEST CONDITIONS†	MIN	TYP‡	MAX	UNIT
Frequency	C_T = 0.001 μF, R_T = 47 kΩ		25		kHz
Standard deviation of frequency¶	C_T = 0.001 μF, R_T = 47 kΩ		3%		
Frequency change with voltage	V_{CC} = 7 V to 40 V, T_A = 25°C		0.1%		
Frequency change with temperature	C_T = 0.001 μF, R_T = 47 kΩ, ΔT_A = MIN to MAX			±2%	

dead-time control-section (see Figure 1)

PARAMETER	TEST CONDITIONS		MIN	TYP‡	MAX	UNIT
Input bias current (pin 4)	V_I = 0 to 5.25 V			−2	−10	μA
Maximum duty cycle	V_I (pin 4) = 0	C_T = 0.1 μF, R_T = 12 kΩ	90%	96%	100%	
		C_T = 0.001 μF, R_T = 47 kΩ		92%	100%	
Input threshold voltage (pin 4)	Zero duty cycle			3	3.3	V
	Maximum duty cycle		0			

error-amplifier sections

PARAMETER	TEST CONDITIONS	MIN	TYP‡	MAX	UNIT
Input offset voltage	V_O (pin 3) = 2.5 V		2	10	mV
Input offset current	V_O (pin 3) = 2.5 V		25	250	nA
Input bias current	V_O (pin 3) = 2.5 V		0.2	1	μA
Common-mode input voltage range	V_{CC} = 7 V to 40 V			−0.3 to V_{CC}−2	V
Open-loop voltage amplification	ΔV_O = 3 V, R_L = 2 kΩ, V_O = 0.5 V to 3.5 V	70	95		dB
Unity gain bandwidth	V_O = 0.5 V to 3.5 V, R_L = 2 kΩ		800		kHz
Phase margin at unity gain	V_O = 0.5 V to 3.5 V, R_L = 2 kΩ		65°		
Common-mode rejection ratio	V_{CC} = 40 V	65	80		dB
Output sink current (pin 3)	V_{ID} = −15 mV to −5 V, $V_{(pin\ 3)}$ = 0.7 V	0.3	0.7		mA
Output source current (pin 3)	V_{ID} = 15 mV to 5 V, $V_{(pin\ 3)}$ = 3.5 V	−2			mA

† For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.
‡ All typical values except for "change with temperature" characteristics are at T_A = 25°C.
§ Duration of the short-circuit should not exceed one second.
¶ Standard deviation is a measure of the statistical distribution about the mean as derived from the formula $\sigma = \sqrt{\frac{\sum_{n=1}^{N}(x_n - \overline{X})^2}{N-1}}$

electrical characteristics over recommended operating free-air temperature range, V_{CC} = 15 V, f = 25 kHz (unless otherwise noted) (continued)

output section

PARAMETER		TEST CONDITIONS	MIN	TYP†	MAX	UNIT
Collector off-state current		V_{CE} = 40 V, V_{CC} = 40 V		2	100	μA
Emitter off-state current		V_{CC} = V_C = 40 V, V_E = 0			−100	μA
Collector-emitter saturation voltage	Common-emitter	V_E = 0, I_C = 200 mA		1.1	1.3	V
	Emitter follower	V_C = 15 V, I_E = −200 mA		1.5	2.5	V

pwm comparator section (see Figure 1)

PARAMETER	TEST CONDITIONS	MIN	TYP†	MAX	UNIT
Input threshold voltage (pin 3)	Zero duty cycle		4	4.5	V
Input sink current (pin 3)	$V_{(pin\ 3)}$ = 0.7 V	0.3	0.7		mA

total device

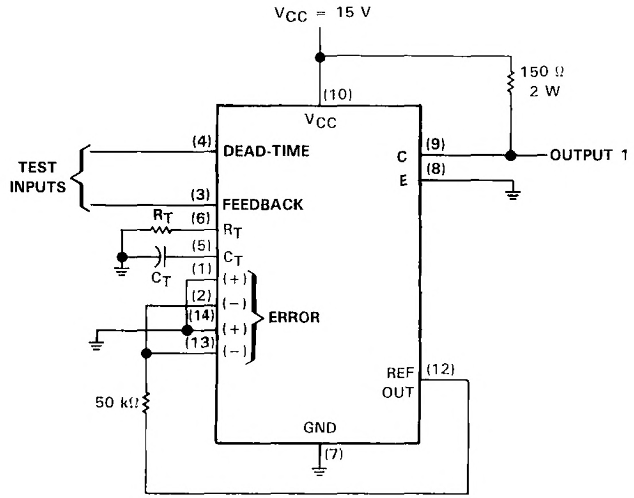
PARAMETER	TEST CONDITIONS		MIN	TYP†	MAX	UNIT
Standby supply current	Pin 6 at V_{ref}, All other inputs and outputs open	V_{CC} = 15 V		6	10	mA
		V_{CC} = 40 V		9	15	mA
Average supply current	$V_{(pin\ 4)}$ = 2 V, C_T = 0.001 μF,	R_T = 47 kΩ, See Figure 1		7.5		mA

switching characteristics, T_A = 25 °C

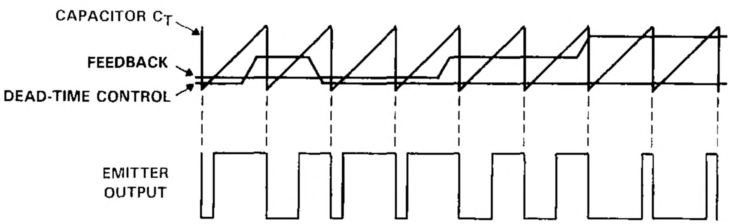
PARAMETER	TEST CONDITIONS	MIN	TYP†	MAX	UNIT
Output voltage rise time	Common-emitter configuration, See Figure 3		100	200	ns
Output voltage fall time	Common-emitter configuration, See Figure 3		25	[illegible]	ns
Output voltage rise time	Emitter-follower configuration, See Figure 4		100	200	ns
Output voltage fall time	Emitter-follower configuration, See Figure 4		40	100	ns

†All typical values are at T_A = 25 °C.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



TIMING WAVEFORMS

FIGURE 1. DEAD-TIME AND FEEDBACK CONTROL

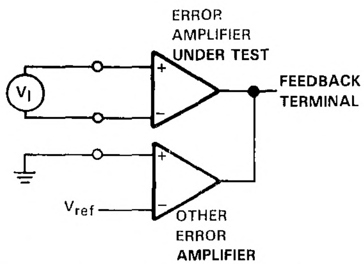


FIGURE 2. ERROR-AMPLIFIER CHARACTERISTICS

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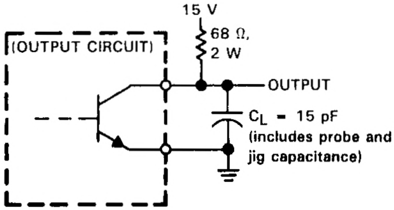
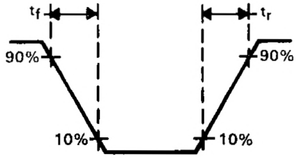
PARAMETER MEASUREMENT INFORMATION

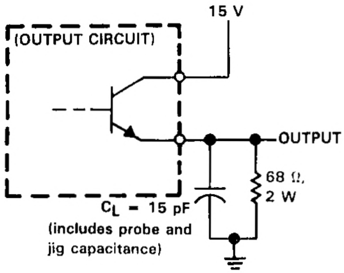


TEST CIRCUIT

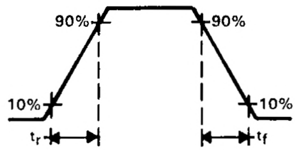


OUTPUT VOLTAGE WAVEFORM

FIGURE 3. COMMON-EMITTER CONFIGURATION



TEST CIRCUIT



OUTPUT VOLTAGE WAVEFORM

FIGURE 4. EMITTER-FOLLOWER CONFIGURATION

TYPICAL CHARACTERISTICS

OSCILLATOR FREQUENCY and
FREQUENCY VARIATION† vs
TIMING RESISTANCE

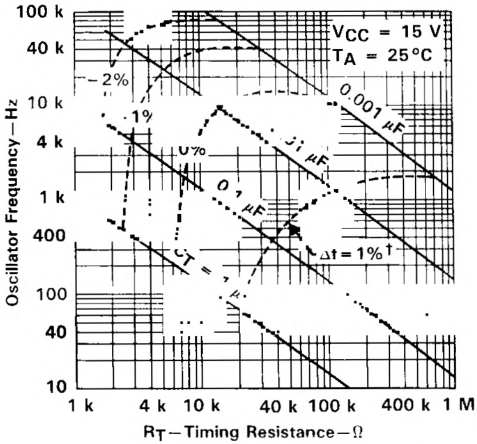


FIGURE 5

AMPLIFIER VOLTAGE AMPLIFICATION
vs
FREQUENCY

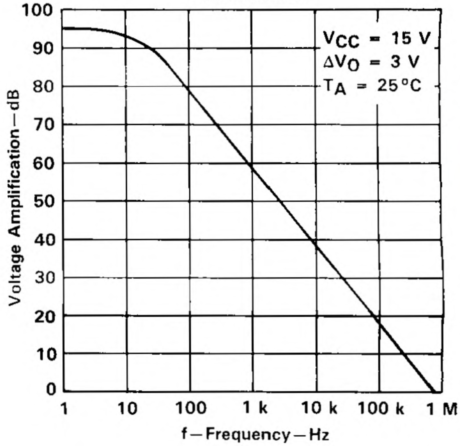


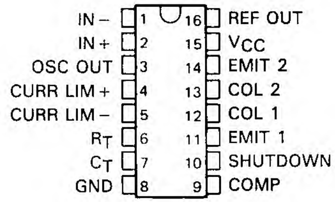
FIGURE 6

†Frequency variation (Δf) is the change in oscillator frequency that occurs over the full temperature range.

D2294, APRIL 1977—REVISED OCTOBER 1988

- **Complete PWM Power Control Circuitry**
- **Uncommitted Outputs for Single-Ended or Push-Pull Applications**
- **Low Standby Current . . . 8 mA Typ**
- **Interchangeable with Silicon General SG2524 and SG3524**

J OR N PACKAGE
(TOP VIEW)



description

The SG2524 and SG3524 incorporate on single monolithic chips all the functions required in the construction of a regulating power supply, inverter, or switching regulator. They can also be used as the control element for high-power-output applications. The SG2524 and SG3524 were designed for switching regulators of either polarity, transformer-coupled dc-to-dc converters, transformerless voltage doublers, and polarity converter applications employing fixed-frequency, pulse-width-modulation techniques. The complementary output allows either single-ended or push-pull application. Each device includes an on-chip regulator, error amplifier, programmable oscillator, pulse-steering flip-flop, two uncommitted pass transistors, a high-gain comparator, and current-limiting and shut-down circuitry.

The SG2524 is characterized for operation from −25 °C to 85 °C, and the SG3524 is characterized for operation from 0 °C to 70 °C.

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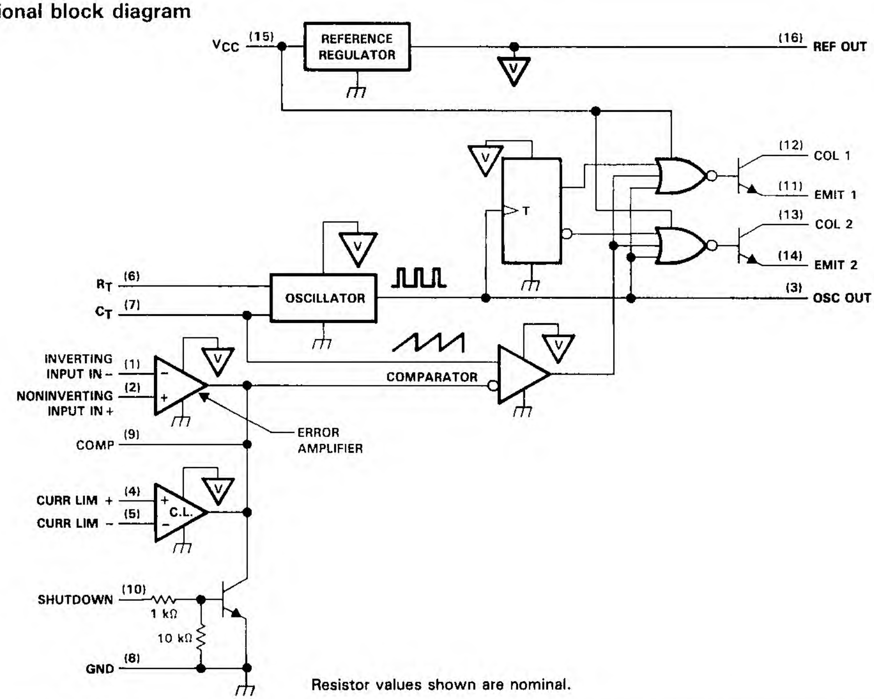
functional block diagram



Resistor values shown are nominal.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, V_{CC} (see Notes 1 and 2) . . . . 40 V
Collector output current . . . . 100 mA
Reference output current . . . . 50 mA
Current through C_T terminal . . . . −5 mA
Continuous total dissipation . . . . See Dissipation Rating Table
Operating free-air temperature range: SG2524 . . . . −25°C to 85°C
SG3524 . . . . 0°C to 70°C
Storage temperature range . . . . −65°C to 150°C

NOTES: 1. All voltage values are with respect to network ground terminal.
2. The reference regulator may be bypassed for operation from a fixed 5-V supply by connecting the V_{CC} and reference output pins both to the supply voltage. In this configuration, the maximum supply voltage is 6 V.

DISSIPATION RATING TABLE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR	DERATE ABOVE T_A	$T_A = 70°C$ POWER RATING	$T_A = 85°C$ POWER RATING
J	[illegible] mW	8.2 [illegible]	28°C	[illegible] mW	[illegible] mW
N	1000 mW	9.2 mW/°C	41°C	736 mW	598 mW

recommended operating conditions

	SG2524		SG3524		UNIT
	MIN	MAX	MIN	MAX	
Supply voltage, V_{CC}	8	40	8	40	V
Reference output current	0	50	0	50	mA
Current thru C_T terminal	−0.03	−2	−0.03	−2	mA
Timing resistor, R_T	1.8	100	1.8	100	kΩ
Timing capacitor, C_T	0[illegible]	0.1	0.001	0.1	μF
Operating free-air temperature	[illegible]	85	0	70	°C

electrical characteristics over recommended operating free-air temperature range, V_{CC} = 20 V (unless otherwise noted)

reference section

PARAMETER	TEST CONDITIONS†	SG2524			SG3524			UNIT
		MIN	TYP‡	MAX	MIN	TYP‡	MAX	
Output voltage		4.8	5	5.2	4.6	5	[illegible]	V
Input regulation	V_{CC} = 8 to 40 V		10	20		10	30	mV
Ripple rejection	f = 120 Hz		66			66		dB
Output regulation	I_O = 0 to 20 mA		20	50		20	50	mV
Output voltage change with temperature	T_A = MIN to MAX		0.3	1		0.3	1	%
Short-circuit output current§	V_{ref} = 0		100			100		mA

†For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.
‡All typical values, except output voltage change with temperature, are at T_A = 25°C.
§Duration of the short circuit should not exceed one second.

electrical characteristics over recommended operating free-air temperature range, V_{CC} = 20 V, f = 20 kHz (unless otherwise noted)

oscillator section

PARAMETER	TEST CONDITIONS†		MIN	TYP‡	MAX	UNIT
Frequency	C_T = 0.001 μF,	R_T = 2 kΩ		450		kHz
Standard deviation of frequency§	All values of voltage, temperature, resistance, and capacitance constant			5		%
Frequency change with voltage	V_{CC} = 8 to 40 V,	T_A = 25°C			1	%
Frequency change with temperature	T_A = MIN to MAX				2	%
Output amplitude at pin 3	T_A = 25°C			3.5		V
Output pulse duration (width) at pin 3	C_T = 0.01 μF,	T_A = 25°C		0.5		μs

error amplifier section

PARAMETER	TEST CONDITIONS	SG2524			SG3524			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
Input offset voltage	V_{IC} = 2.5 V		0.5	5		2	10	mV
Input bias current	V_{IC} = 2.5 V		2	10		2	10	μA
Open-loop voltage amplification		72	80		60	80		dB
Common-mode input voltage range	T_A = 25°C	1.8 to 3.4			1.8 to 3.4			V
Common-mode rejection ratio			70			70		dB
Unity-gain bandwidth			3			3		MHz
Output swing	T_A = 25°C	0.5		3.8	0.5		3.8	V

output section

PARAMETER	TEST CONDITIONS		MIN	TYP‡	MAX	UNIT
Collector-emitter breakdown voltage			40			V
Collector off-state current	V_{CE} = 40 V			0.01	50	μA
Collector-emitter saturation voltage	I_C = 50 mA			1	2	V
Emitter output voltage	V_C = 20 V,	I_E = −250 μA	17	18		V
Turn-off voltage rise time	R_C = 2 kΩ			0.2		μs
Turn-on voltage fall time	R_C = 2 kΩ			0.1		μs

comparator section

PARAMETER	TEST CONDITIONS	MIN	TYP‡	MAX	UNIT
Maximum duty cycle, each output		45			%
Input threshold voltage at pin 9	Zero duty cycle		1		V
	Maximum duty cycle		3.5		
Input bias current			−1		μA

†For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.
‡All typical values, except for temperature coefficients, are at T_A = 25°C.
§Standard deviation is a measure of the statistical distribution about the mean as derived from the formula $\sigma = \sqrt{\frac{\sum_{n=1}^{N}(X_n - \overline{X})^2}{N-1}}$.

electrical characteristics over recommended operating free-air temperature range, V_{CC} = 20 V, f = 20 kHz (unless otherwise noted)

current limiting section

PARAMETER	TEST CONDITIONS	SG2524			SG3524			UNIT
		MIN	TYP†	MAX	MIN	TYP†	MAX	
Input voltage range (either input)		−1 to +1			−1 to +1			V
Sense voltage at T_A = 25°C	$V_{(pin\ 2)} - V_{(pin\ 1)} \ge 50$ mV, $V_{(pin\ 9)}$ = 2 V	190	200	210	180	200	220	mV
Temperature coefficient of sense voltage			0.2			0.2		mV/°C

total device

PARAMETER	TEST CONDITIONS	MIN	TYP†	MAX	UNIT
Standby current	V_{CC} = 40 V, Pins 1,4,7,8,9,11,14 gronded, Pin 2 at 2 V, All other inputs and outputs open		8	10	mA

†All typical values, except for temperature coefficients, are at T_A = 25°C.

PARAMETER MEASUREMENT INFORMATION

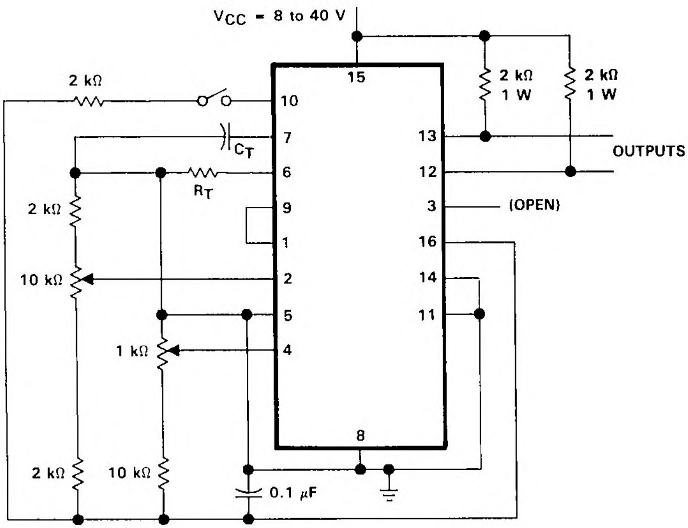
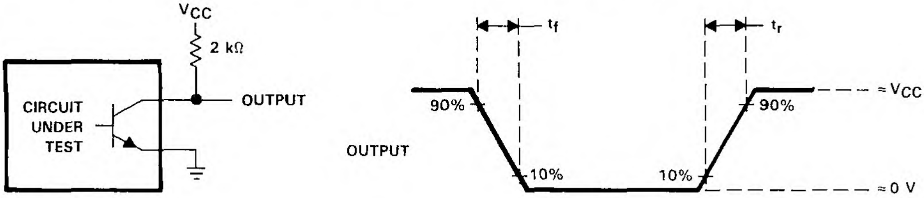


FIGURE 1. GENERAL TEST CIRCUIT

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT

VOLTAGE WAVEFORMS

FIGURE 2. SWITCHING TIMES

TYPICAL CHARACTERISTICS

OPEN-LOOP VOLTAGE AMPLIFICATION
OF ERROR AMPLIFIER
vs
FREQUENCY

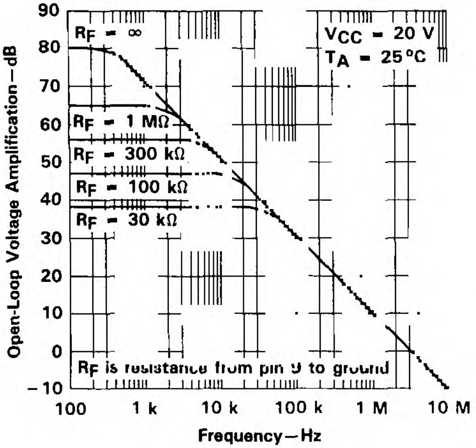


FIGURE 3

OSCILLATOR FREQUENCY
vs
TIMING RESISTANCE

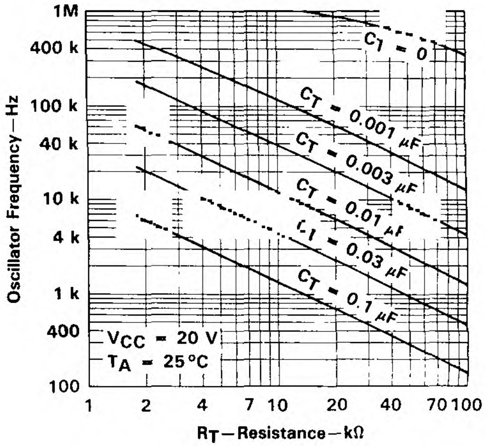


FIGURE 4

TYPICAL CHARACTERISTICS

OUTPUT DEAD TIME
vs
TIMING CAPACITANCE VALUE

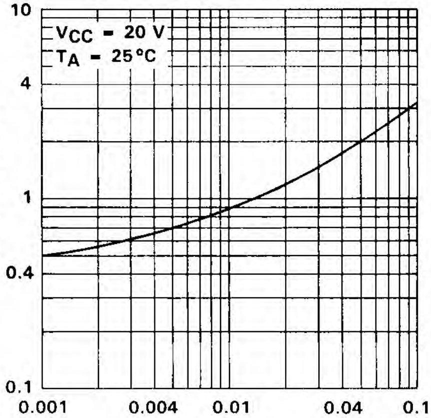


FIGURE 5

PRINCIPLES OF OPERATION†

The SG2524 is a fixed-frequency pulse-width-modulation voltage-regulator control circuit. The regulator operates at a fixed frequency that is programmed by one timing resistor R_T and one timing capacitor C_T. R_T establishes a constant charging current for C_T. This results in a linear voltage ramp at C_T, which is fed to the comparator providing linear control of the output pulse duration (width) by the error amplifier. The SG2524 contains an on-board 5-V regulator that serves as a reference as well as supplying the SG2524 internal regulator control circuitry. The internal reference voltage is divided externally by a resistor ladder network to provide a reference within the common-mode range of the error amplifier as shown in Figure 6, or an external reference may be used. The output is sensed by a second resistor divider network and the error signal is amplified. This voltage is then compared to the linear voltage ramp at C_T. The resulting modulated pulse out of the high-gain comparator is then steered to the appropriate output pass transistor (Q1 or Q2) by the pulse-steering flip-flop, which is synchronously toggled by the oscillator output. The oscillator output pulse also serves as a blanking pulse to assure both outputs are never on simultaneously during the transition times. The duration of the blanking pulse is controlled by the value of C_T. The outputs may be applied in a push-pull configuration in which their frequency is half that of the base oscillator, or paralleled for single-ended applications in which the frequency is equal to that of the oscillator. The output of the error amplifier shares a common input to the comparator with the current-limiting and shut-down circuitry and can be overridden by signals from either of these inputs. This common point is also available externally and may be employed to control the gain of, or to compensate the error amplifier, or to provide additional control to the regulator.

†Throughout these discussions, references to the SG2524 apply also to the SG3524.

TYPICAL APPLICATION DATA†

oscillator

The oscillator controls the frequency of the SG2524 and is programmed by R_T and C_T as shown in Figure 4.

$$f \approx \frac{1.15}{R_T\, C_T}$$

where R_T is in kΩ
C_T is in μF
f is in kHz

Practical values of C_T fall between 0.001 and 0.1 μF. Practical values of R_T fall between 1.8 and 100 kΩ. This results in a frequency range typically from 140 Hz to 500 kHz.

blanking

The output pulse of the oscillator is used as a blanking pulse at the output. This pulse duration is controlled by the value of C_T as shown in Figure 5. If small values of C_T are required, the oscillator output pulse duration may still be maintained by applying a shunt capacitance from pin 3 to ground.

synchronous operation

When an external clock is desired, a clock pulse of approximately 3 V can be applied directly to the oscillator output terminal. The impedance to ground at this point is approximately 2 kΩ. In this configuration, R_T C_T must be selected for a clock period slightly greater than that of the external clock.

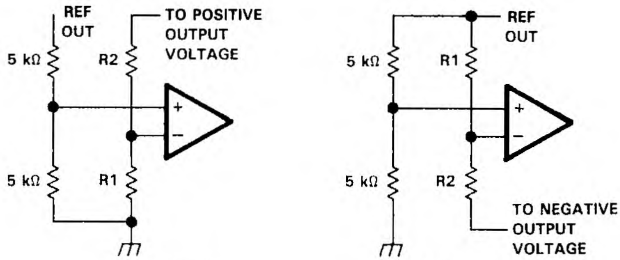
If two or more SG2524 regulators are to be operated synchronously, all oscillator output terminals should be tied together. The oscillator programmed for the minimum clock period will be the master from which all the other SG2524s operate. In this application, the C_T R_T values of the slaved regulators must be set for a period approximately 10% longer than that of the master regulator. In addition, C_T (master) = 2 C_T (slave) to ensure that the master output pulse, which occurs first, has a longer pulse duration and will subsequently reset the slave regulators.

†Throughout these discussions, references to the SG2524 apply also to the SG3524.

TYPICAL APPLICATION DATA†

voltage reference

The 5-V internal reference may be employed by use of an external resistor divider network to establish a reference within the error amplifiers common-mode voltage range (1.8 to 3.4 V) as shown in Figure 6, or an external reference may be applied directly to the error amplifier. For operation from a fixed 5-V supply, the internal reference may be bypassed by applying the input voltage to both the V_{CC} and V_{REF} terminals. In this configuration, however, the input voltage is limited to a maximum of 6 V.



$$V_O = 2.5\ \text{V}\ \frac{R1 + R2}{R1} \qquad \frac{R1\ R2}{R1 + R2} = 2.5\ \text{k}\Omega$$

FIGURE 6. ERROR AMPLIFIER BIAS CIRCUITS

error amplifier

The error amplifier is a differential-input transconductance amplifier. The output is available for dc gain control or ac phase compensation. The compensation node (pin 9) is a high-impedance node (R_L = 5 MΩ). The gain of the amplifier is $A_V = (0.002\ \Omega^{-1})\ R_L$ and can easily be reduced from a nominal 10,000 by an external shunt resistance from pin 9 to ground. Refer to Figure 3 for data.

compensation

Pin 9, as discussed above, is made available for compensation. Since most output filters will introduce one or more additional poles at frequencies below 200 Hz, which is the pole of the uncompensated amplifier, introduction of a zero to cancel one of the output filter poles is desirable. This can best be accomplished with a series RC circuit from pin 9 to ground in the range of 50 kΩ and 0.001 μF. Other frequencies can be canceled by use of the formula $f \approx 1/RC$.

shut-down circuitry

Pin 9 can also be employed to introduce external control of the SG2524. Any circuit that can sink 200 μA can pull the compensation terminal to ground and thus disable the SG2524.

In addition to constant-current limiting, pins 4 and 5 may also be used in transformer-coupled circuits to sense primary current and shorten an output pulse should transformer saturation occur. Pin 5 may also be grounded to convert pin 4 into an additional shut-down terminal.

†Throughout these discussions, references to the SG2524 also apply to the SG3524.

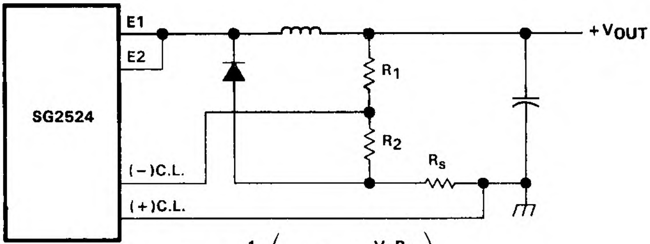
TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

TYPICAL APPLICATION DATA†

current limiting

A current-limiting sense amplifier is provided in the SG2524. The current-limiting sense amplifier exhibits a threshold of 200 mV and must be applied in the ground line since the voltage range of the inputs is limited to +1 V to −1 V. Caution should be taken to ensure the −1 V limit is not exceeded by *either* input, otherwise damage to the device may result.

Fold-back current limiting can be provided with the network shown in Figure 7. The current-limit schematic is shown in Figure 8.



$$I_{O(max)} = \frac{1}{R_s}\left(V_{(sense)} + \frac{V_O R_2}{R_1 + R_2}\right)$$

$$I_{OS} = \frac{V_{(sense)}}{R_s} \quad \text{where } V_{(sense)} = 20 \text{ mV}$$

FIGURE 7. FOLDBACK CURRENT LIMITING FOR SHORTED OUTPUT CONDITIONS

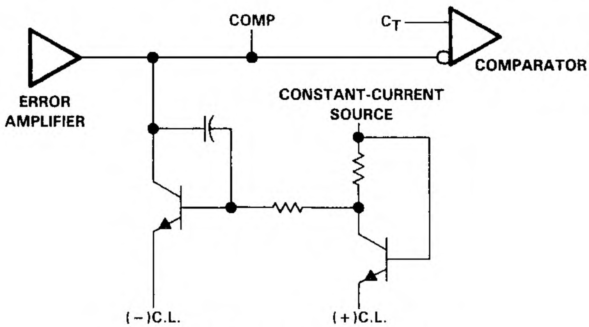


FIGURE 8. CURRENT-LIMIT SCHEMATIC

output circuitry

The SG2524 contains two identical n-p-n transistors, the collectors and emitters of which are uncommitted. Each transistor has antisaturation circuitry that limits the current through that transistor to a maximum of 100 mA for fast response.

†Throughout these discussions, references to the SG2524 also apply to the SG3524.

TYPICAL APPLICATION DATA†

general

There are a wide variety of output configurations possible when considering the application of the SG2524 as a voltage regulator control circuit. They can be segregated into three basic categories:

1. Capacitor-diode-coupled voltage multipliers
2. Inductor-capacitor-implemented single-ended circuits
3. Transformer-coupled circuits

Examples of these categories are shown in Figures 9, 10 and 11, respectively. Detailed diagrams of specific applications are shown in Figures 12 through 15.

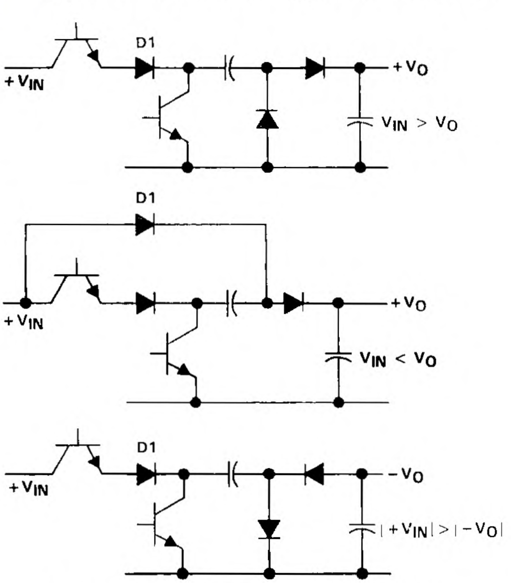


FIGURE 9. CAPACITOR-DIODE-COUPLED VOLTAGE-MULTIPLIER OUTPUT STAGES

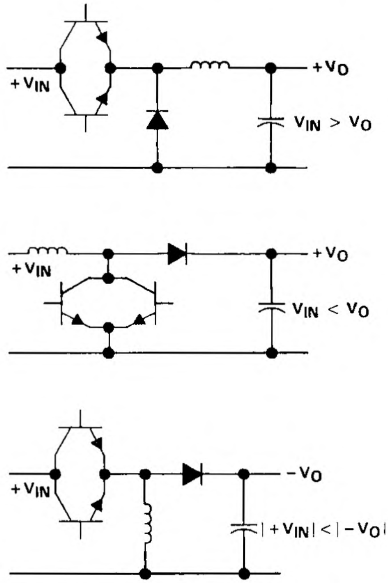
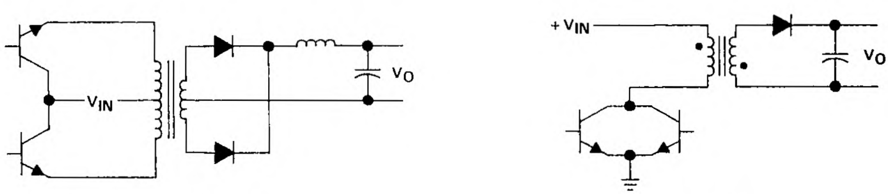


FIGURE 10. SINGLE-ENDED INDUCTOR CIRCUIT



PUSH-PULL

FLYBACK

FIGURE 11. TRANSFORMER-COUPLED OUTPUTS

†Throughout these discussions, references to the SG2524 also apply to the SG3524.

TYPICAL APPLICATION DATA†

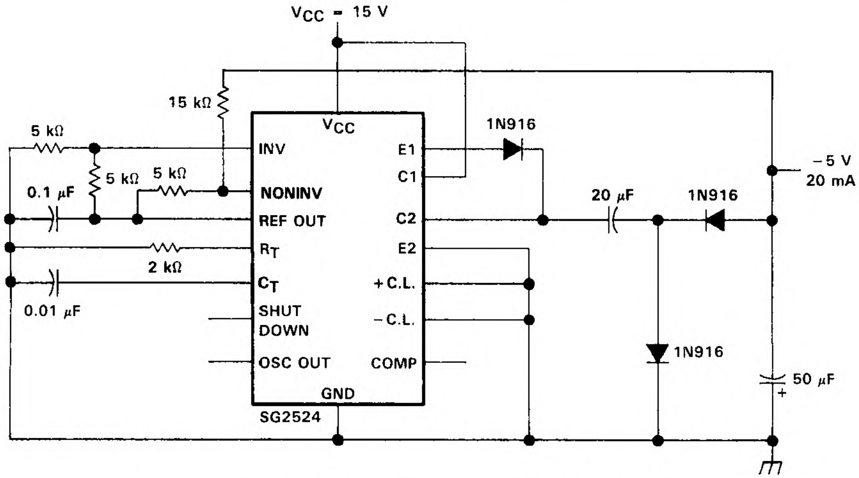


FIGURE 12. CAPACITOR-DIODE OUTPUT CIRCUIT

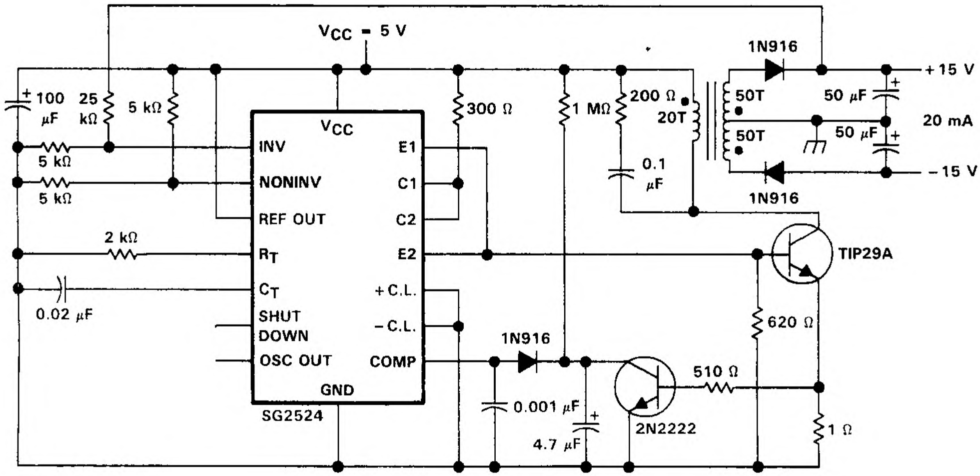


FIGURE 13. FLYBACK CONVERTER CIRCUIT

†Throughout these discussions, references to the SG2524 also apply to the SG3524.

TYPICAL APPLICATION DATA†

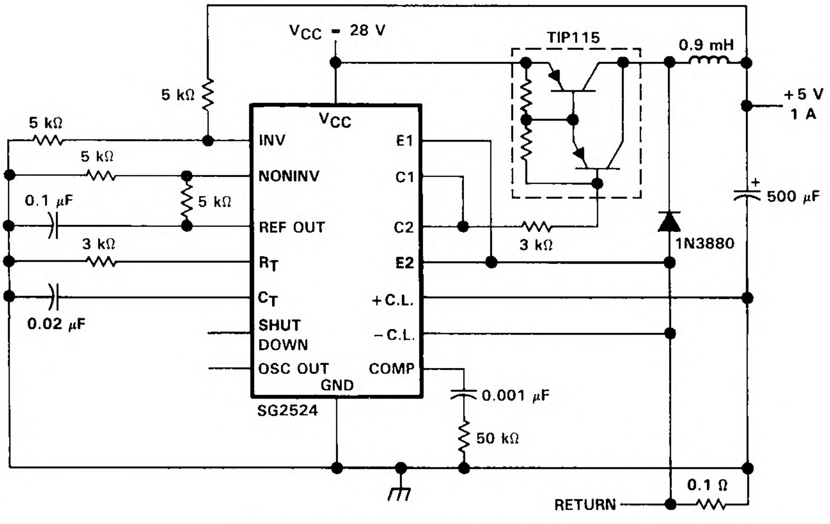


FIGURE 14. SINGLE-ENDED LC CIRCUIT

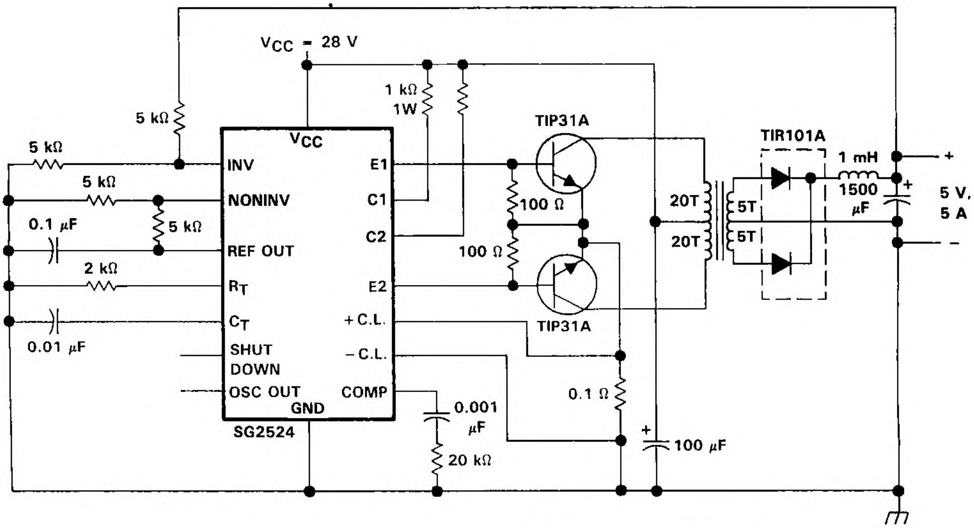


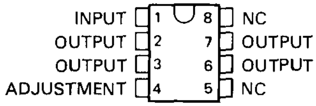
FIGURE 15. PUSH-PULL TRANSFORMER-COUPLED CIRCUIT

†Throughout these discussions, references to the SG2524 also apply to the SG3524.

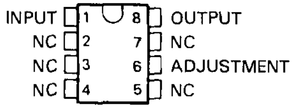
D2527, APRIL 1979—REVISED MAY 1988

- **Output Voltage Range Adjustable from 1.2 V to 32 V**
- **Output Current Capability of 100 mA**
- **Input Regulation Typically 0.01% Per Input-Volt Change**
- **Output Regulation Typically 0.5%**
- **Ripple Rejection Typically 80 dB**

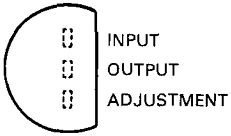
TL317C . . . D PACKAGE
(TOP VIEW)



TL317M . . . JG PACKAGE
(TOP VIEW)



TL317C . . . LP SILECT PACKAGE
(TOP VIEW)



NC—No internal connection

description

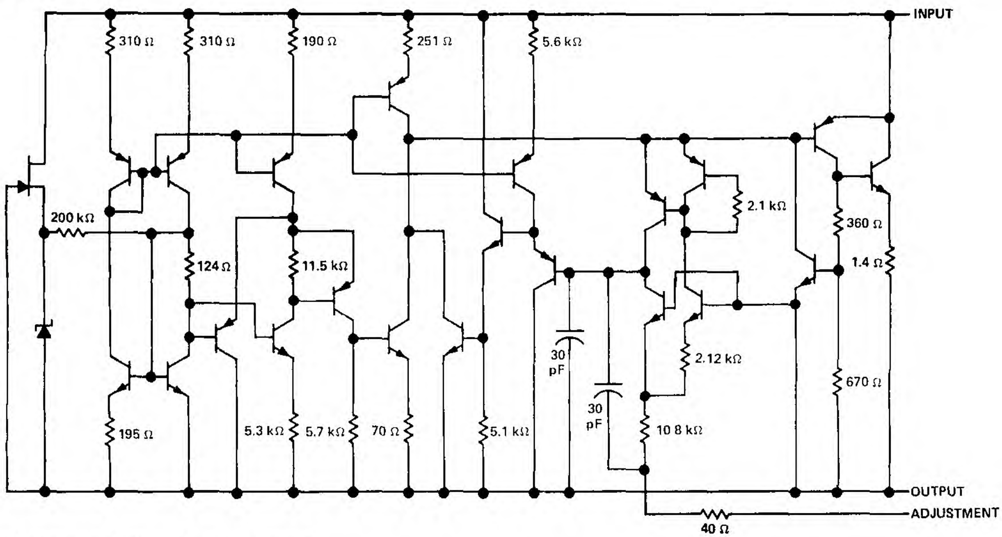
The TL317 is an adjustable 3-terminal positive-voltage regulator capable of supplying 100 mA over an output-voltage range of 1.2 V to 32 V. It is exceptionally easy to use and requires only two external resistors to set the output voltage. Both input and output regulation are better than standard fixed regulators. The device is packaged in standard packages that are easily mounted and handled.

In addition to higher performance than fixed regulators, this regulator offers full overload protection available only in integrated circuits. Included on the chip are current limiting and thermal overload protection. All overload protection circuitry remains fully functional even if the adjustment terminal is disconnected. Normally, no capacitors are needed unless the device is situated far from the input filter capacitors, in which case an input bypass is needed. An optional output capacitor can be added to improve transient response. The adjustment terminal can be bypassed to achieve very high ripple rejection, which is difficult to achieve with standard 3-terminal regulators.

In addition to replacing fixed regulators, the TL317 regulator is useful in a wide variety of other applications. Since the regulator is floating and sees only the input-to-output differential voltage, supplies of several hundred volts can be regulated as long as the maximum input-to-output differential is not exceeded. Its primary application is that of a programmable output regulator, but by connecting a fixed resistor between the adjustment terminal and the output terminal, this device can be used as a precision current regulator. Supplies with electronic shutdown can be achieved by clamping the adjustment terminal to ground, programming the output to 1.2 V where most loads draw little current.

The TL317M is characterized for operation over the full military temperature range from −55°C to 125°C. The TL317C is characterized for operation from 0°C to 125°C.

schematic



All component values shown are nominal

absolute maximum ratings over operating temperature range (unless otherwise noted)

Input-to-output differential voltage, $V_I - V_O$ . . . . 35 V
Continuous total dissipation . . . . See Dissipation Rating Table
Operating free-air, case, or virtual junction temperature range: TL317M . . . . −55°C to 150°C
TL317C . . . . 0°C to 150°C
Storage temperature range . . . . −65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: JG package . . . . 300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or LP package . . . . 260°C

DISSIPATION RATING TABLE 1—FREE-AIR TEMPERATURE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25°C$	$T_A = 125°C$ POWER RATING
D	725 mW	5.8 mW/°C	145 mW
JG	1050 mW	8.4 mW/°C	210 mW
LP†	775 mW	6.2 mW/°C	155 mW

†The LP package dissipation rating is based on thermal resistance measured in still air with the device mounted in an Augat socket. The bottom of the package was 10 mm (0.375 in.) above the socket.

DISSIPATION RATING TABLE 2—CASE TEMPERATURE

PACKAGE	$T_C \le 25°C$ POWER RATING	DERATING FACTOR	DERATE ABOVE T_C	$T_C = 125°C$ POWER RATING
D	[illegible] mW	29.6 mW/°C	96°C	[illegible] mW
JG	1600 mW	38.4 mW/°C	108°C	960 mW
LP	1600 mW	28.6 mW/°C	94°C	715 mW

recommended operating conditions

	TL317M		TL317C		UNIT
	MIN	MAX	MIN	MAX	
Output current, I_O	2.5	100	2.5	100	mA
Operating virtual junction temperature, T_J	−55	125	0	125	°C

electrical characteristics over recommended operating virtual junction temperature range (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		MIN	TYP	MAX	UNIT
Input regulation (see Note 2)	$V_I - V_O$ = 3 V to 35 V	T_J = 25°C		0.01	0.02	%/V
		I_O = 2.5 mA to 100 mA		0.02	0.05	
Ripple rejection	V_O = 10 V,	f = 120 Hz		65		dB
	V_O = 10 V, 10-μF capacitor between ADJ and ground	f = 120 Hz,	66	80		
Output regulation	I_O = 2.5 mA to 100 mA, T_J = 25°C,	$V_O \le 5$ V		25		mV
		$V_O \ge 5$ V		0.5		%
	I_O = 2.5 mA to 100 mA,	$V_O \le 5$ V		50		mV
		$V_O \ge 5$ V		1		%
Output voltage change with temperature	T_J = 0°C to 125°C			1		%
Output voltage long-term drift (see Note 3)	After 1000 h at T_J = 125°C and $V_I - V_O$ = 35 V			0.3	1	%
Output noise voltage	f = 10 Hz to 10 kHz, T_J = 25°C			0.003		%
Minimum output current to maintain regulation	$V_I - V_O$ = 35 V			1.5	2.5	mA
Peak output current	$V_I - V_O \le 35$ V		100	200		mA
Adjustment-terminal current				50	100	μA
Change in adjustment-terminal current	$V_I - V_O$ = 2.5 V to 35 V, I_O = 2.5 mA to [illegible] mA			0.2	5	μA
Reference voltage (output to ADJ)	$V_I - V_O$ = 3 V to 35 V, I_O = 2.5 mA to [illegible] mA, P ≤ rated dissipation		1.2	1.25	1.3	V

† Unless otherwise noted, these specifications apply for the following test conditions: $V_I - V_O$ = 5 V and I_O = 40 mA. Pulse testing techniques must be used that will maintain the junction temperature as close to the ambient temperature as possible. All characteristics are measured with a 0.1-μF capacitor across the input and a 1-μF capacitor across the output.

NOTES: 2. Input regulation is expressed here as the percentage change in output voltage per 1-volt change at the input.
3. Since long-term drift cannot be measured on the individual devices prior to shipment, this specification is not intended to be a guarantee or warranty. It is an engineering estimate of the average drift to be expected from lot to lot.

TYPICAL APPLICATION DATA

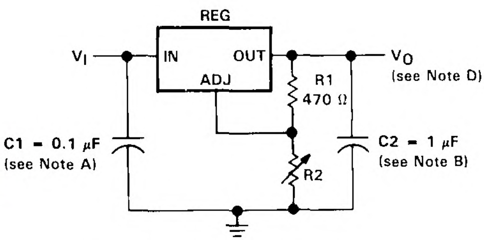


FIGURE 1. ADJUSTABLE VOLTAGE REGULATOR

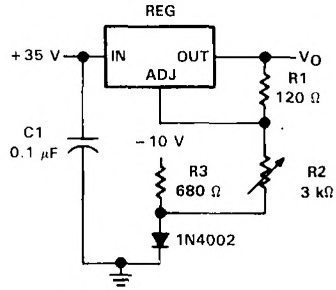
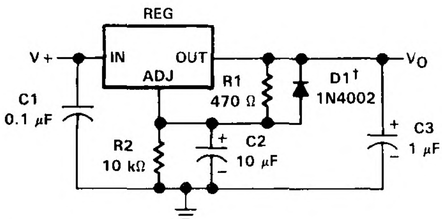


FIGURE 2. 0-V TO 30-V REGULATOR CIRCUIT



† D1 discharges C2 if output is shorted to ground.

FIGURE 3. ADJUSTABLE REGULATOR CIRCUIT WITH IMPROVED RIPPLE REJECTION

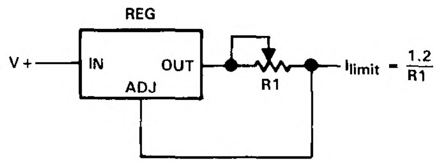


FIGURE 4. PRECISION CURRENT LIMITER CIRCUIT

NOTES: A. Use of an input bypass capacitor is recommended if regulator is far from filter capacitors.

B. Use of an output capacitor improves transient response but is optional.

C. V_{ref} equals the difference between the output and adjustment terminal voltages.

D. Output voltage is calculated from the equation: $V_O = V_{ref}\left(1 + \frac{R2}{R1}\right)$

TYPICAL APPLICATION DATA

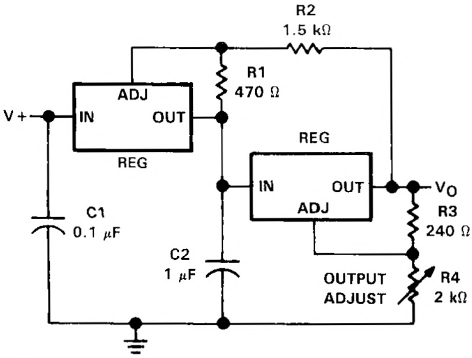


FIGURE 5. TRACKING PREREGULATOR CIRCUIT

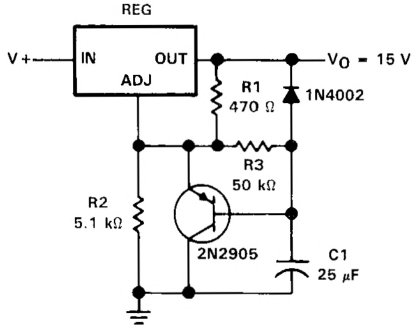


FIGURE 6. SLOW-TURN-ON 15-V REGULATOR CIRCUIT

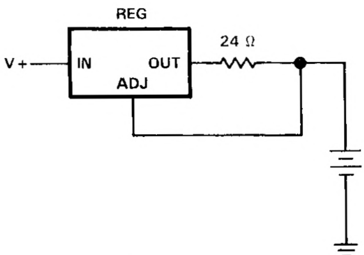
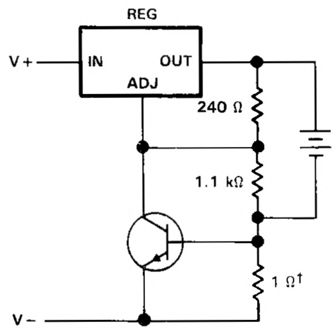


FIGURE 7. 50-mA CONSTANT-CURRENT BATTERY CHARGER CIRCUIT

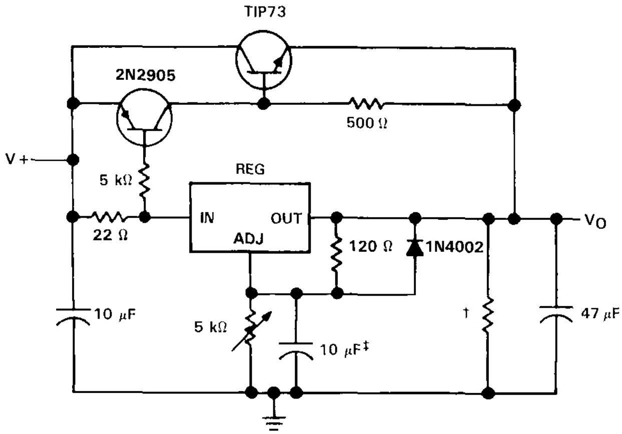


†This resistor sets peak current (100 mA for 6 Ω).

FIGURE 8. CURRENT-LIMITED 6-V CHARGER

2 Data Sheets

TYPICAL APPLICATION DATA



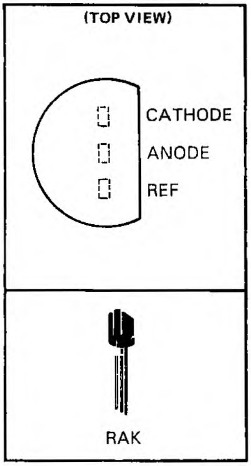
†Minimum load current is 30 mA.
‡Optional capacitor improves ripple rejection

FIGURE 9. HIGH-CURRENT ADJUSTABLE REGULATOR

D2165, JUNE 1976—REVISED MARCH 1988

- Temperature Compensated
- Programmable Output Voltage
- Low Output Resistance
- Low Output Noise
- Sink Capability to 100 mA

LP
SILECT PACKAGE
(TOP VIEW)

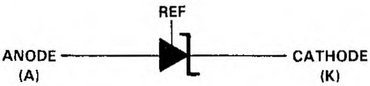


description

The TL430 is a three-terminal adjustable shunt regulator featuring excellent temperature stability, wide operating current range, and low output noise. The output voltage may be set by two external resistors to any desired value between 3 volts and 30 volts. The TL430 can replace zener diodes in many applications providing improved performance.

The TL430I is characterized for operation from −40°C to 85°C, and the TL430C is characterized for operating from 0°C to 70°C.

functional block diagram



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Regulator voltage (see Note 1) . . . . 30 V
Continuous regulator current . . . . 150 mA
Continuous dissipation at (or below) 25°C free-air temperature (see Note 2) . . . . 775 mW
Operating free-air temperature range: TL430I . . . . −40°C to 85°C
TL430C . . . . 0°C to 70°C
Storage temperature range . . . . −65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds . . . . 260°C

recommended operating conditions

	MIN	MAX	UNIT
Regulator voltage, V_Z	V_{ref}	30	V
Regulator current, I_Z	2	100	mA

Notes: 1. All voltage values are with respect to the anode terminal.
2. For operation above 25°C free-air temperature, derate at 6.2 mW/°C.

electrical characteristics at 25 °C free-air temperature (unless otherwise noted)

PARAMETER		TEST FIGURE	TEST CONDITIONS		TL430I MIN	TL430I TYP	TL430I MAX	TL430C MIN	TL430C TYP	TL430C MAX	UNIT
V_{ref}	Reference input voltage	1	$V_Z = V_{ref}$, I_Z = 10 mA		2.6	2.75	2.9	2.5	2.75	3	V
αV_{ref}	Temperature coefficient of reference input voltage	1	$V_Z = V_{ref}$, I_Z = 10 mA, T_A = 0 °C to 70 °C			120	200		120		ppm/°C
I_{ref}	Reference input current	2	I_Z = 10 mA, R1 = 10 kΩ, R2 = ∞			3	10		3	10	μA
I_{ZK}	Regulator current near lower knee of regulation range	1	$V_Z = V_{ref}$			0.5	2		0.5	2	mA
I_{ZM}	Regulator current at maximum limit of regulation range	1	$V_Z = V_{ref}$		50			50			mA
		2	V_Z = 5 V to 30 V, See Note 3		100			100			
r_z	Differential regulator resistance (see Note 4)	1	$V_Z = V_{ref}$, ΔI_Z = (52 − 2) mA			1.5	3		1.5	3	Ω
V_{nz}	Noise voltage	2	f = 0.1 Hz to 10 Hz	V_Z = 3 V		50			50		μV
				V_Z = 12 V		200			200		
				V_Z = 30 V		650			650		

NOTES: 3. The average power dissipation, $V_Z \cdot I_Z \cdot$ duty cycle, must not exceed the maximum continuous rating in any 10-ms interval.
4. The regulator resistance for $V_Z > V_{ref}$, r_z, is given by:

$$r_z' = r_z \left(1 + \frac{R1}{R2}\right)$$

PARAMETER MEASUREMENT INFORMATION

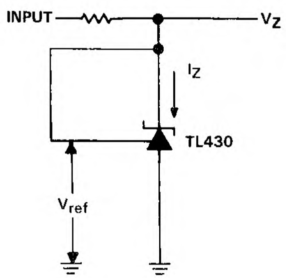
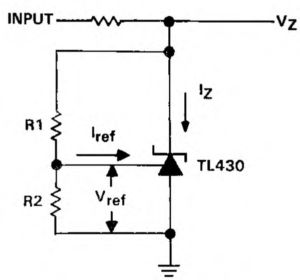


FIGURE 1. TEST CIRCUIT FOR $V_Z = V_{ref}$



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

FIGURE 2. TEST CIRCUIT FOR $V_Z > V_{ref}$

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TYPICAL CHARACTERISTICS

SMALL-SIGNAL REGULATOR IMPEDANCE
vs
FREQUENCY

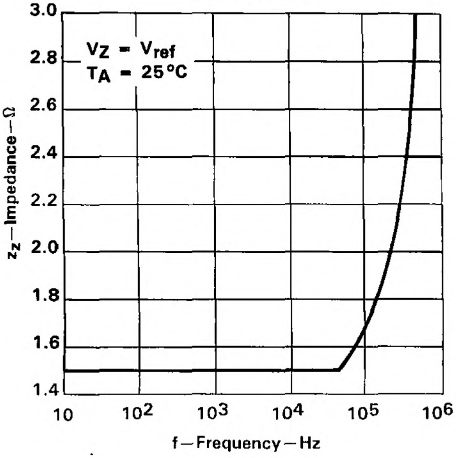


FIGURE 3

CURRENT
vs
VOLTAGE

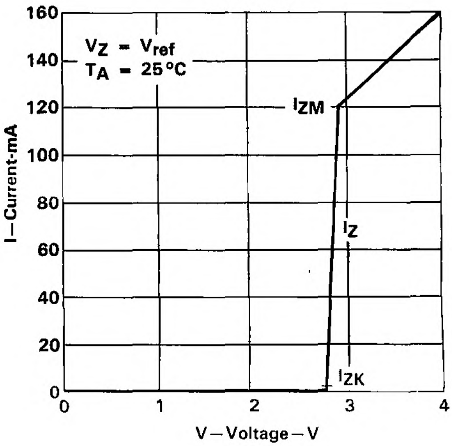
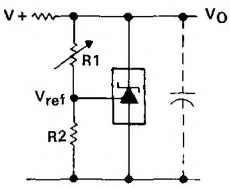


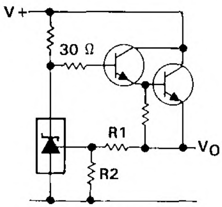
FIGURE 4

TYPICAL APPLICATION DATA



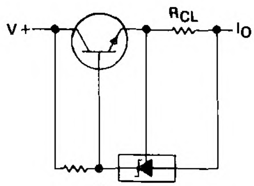
$$V_O \approx \left(1 + \frac{R1}{R2}\right) V_{ref}$$

FIGURE 5. SHUNT REGULATOR



$$V_O \approx \left(1 + \frac{R1}{R2}\right) V_{ref}$$

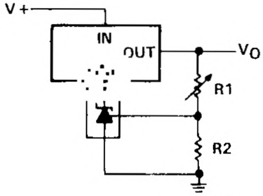
FIGURE 6. SERIES REGULATOR



$$I_O \approx \frac{V_{ref}}{R_{CL}}$$

FIGURE 7. CURRENT LIMITER

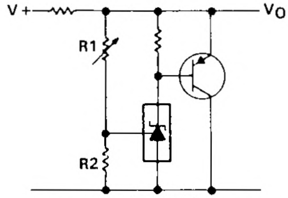
TYPICAL APPLICATION DATA



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

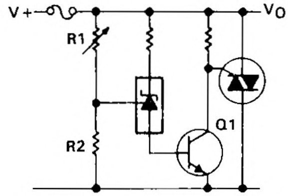
$$\text{Min } V_O = V_{ref} + 5$$

FIGURE 8. OUTPUT CONTROL OF A THREE-THERMAL FIXED REGULATOR



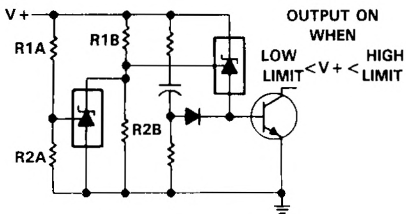
$$V_O \approx \left(1 + \frac{R1}{R2}\right) V_{ref}$$

FIGURE 9. HIGHER-CURRENT APPLICATIONS



$$V_{limit} \approx \left(1 + \frac{R1}{R2}\right)\left(V_{ref} + V_{BE(Q1)}\right)$$

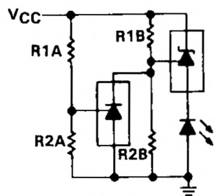
FIGURE 10. CROW BAR



$$\text{Low limit} \approx V_{ref}\left(1 + \frac{R1B}{R2B}\right) + V_{BE}$$

$$\text{High limit} \approx V_{ref}\left(1 + \frac{R1A}{R2A}\right)$$

FIGURE 11. OVER-VOLTAGE/ UNDER-VOLTAGE PROTECTION CIRCUIT



$$\text{Low limit} \approx V_{ref}\left(1 + \frac{R1B}{R2B}\right) + V_{BE}$$

$$\text{High limit} \approx V_{ref}\left(1 + \frac{R1A}{R2A}\right)$$

FIGURE 12. V_{CC} MONITOR

ADJUSTABLE PRECISION SHUNT REGULATORS

D2410, JULY 1978 – REVISED AUGUST 1988

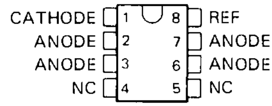
- **Equivalent Full-Range Temperature Coefficient . . . 30 ppm/°C**
- **Temperature Compensated for Operation Over Full Rated Operating Temperature Range**
- **Adjustable Output Voltage**
- **Fast Turn-On Response**
- **Sink Current Capability . . . 1 mA to 100 mA**
- **Low (0.2 Ω Typ) Dynamic Output Impedance**
- **Low Output Noise**

description

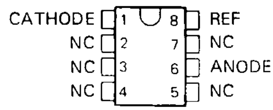
The TL431 and TL431A are three-terminal adjustable shunt regulators with specified thermal stability over applicable industrial and commercial temperature ranges. The output voltage may be set to any value between V_{ref} (approximately 2.5 V) and 36 V with two external resistors (see Figure 16). These devices have a typical output impedance of 0.2 Ω. Active output circuitry provides a very sharp turn-on characteristic, making these devices excellent replacements for zener diodes in many applications.

The TL431M is characterized for operation over the full military temperature range of −55°C to 125°C. The TL431I and TL431AI are characterized for operation from −40°C to 85°C, and the TL431C and TL431AC are characterized for operation from 0°C to 70°C.

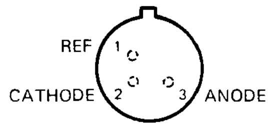
TL431I, TL431AI, TL431C, TL431AC . . . D PACKAGE
(TOP VIEW)



TL431M . . . JG PACKAGE
(TOP VIEW)

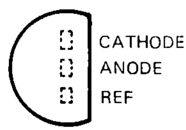


TL431M . . . LD PACKAGE
(TOP VIEW)

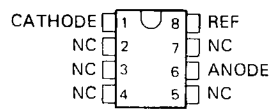


THE ANODE IS IN ELECTRICAL CONTACT WITH THE CASE.

TL431I, TL431AI, TL431C, TL431AC . . . LP PACKAGE
(TOP VIEW)

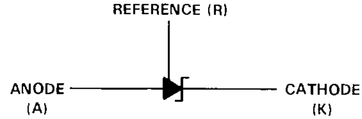


TL431I, TL431AI, TL431C, TL431AC . . . P PACKAGE
(TOP VIEW)



NC—No internal connection

symbol



TEXAS INSTRUMENTS

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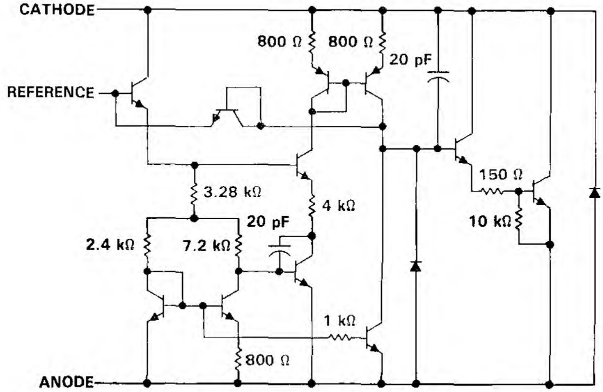
schematic



Component values are nominal.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Cathode voltage (see Note 1) . . . . 37 V
Continuous cathode current range . . . . −100 mA to 150 mA
Reference input current range . . . . −50 μA to 10 mA
Continuous power dissipation . . . . See Dissipation Rating Tables 1 and 2
Operating free-air temperature range: TL431C, TL431AC . . . . 0°C to 70°C
TL431I, TL431AI . . . . −40°C to 85°C
TL431M . . . . −55°C to 125°C
Storage temperature range . . . . −65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: LD or JG package . . . . 300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D, LP, or P package . . . . . 260°C

NOTE 1: Voltage values are with respect to the anode terminal unless otherwise noted.

DISSIPATION RATING TABLE 1—FREE-AIR TEMPERATURE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25°C$	$T_A = 70°C$ POWER RATING	$T_A = 85°C$ POWER RATING	$T_A = 125°C$ POWER RATING
D	825 mW	6.6 mW/°C	528 mW	429 mW	
JG	1050 mW	8.4 mW/°C	672 mW	546 mW	210 mW
LD	275 mW	2.2 mW/°C	176 mW	143 mW	55 mW
LP	775 mW	6.2 mW/°C	496 mW	403 mW	
P	1000 mW	8.0 mW/°C	640 mW	520 mW	

DISSIPATION RATING TABLE 2—CASE TEMPERATURE

PACKAGE	$T_C \le 25°C$ POWER RATING	DERATING FACTOR ABOVE $T_C = 25°C$	$T_C = 125°C$ POWER RATING
LD	1550 mW	12.4 mW/°C	[illegible] mW

recommended operating conditions

	MIN	MAX	UNIT
Cathode voltage, V_{KA}	V_{ref}	36	V
Cathode current, I_K (for regulation)	1	100	mA

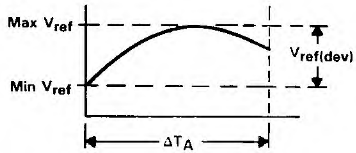
electrical characteristics at 25 °C free-air temperature (unless otherwise noted)

PARAMETER		TEST CIRCUIT	TEST CONDITIONS	TL431M MIN	TL431M TYP	TL431M MAX	TL431I MIN	TL431I TYP	TL431I MAX	TL431C MIN	TL431C TYP	TL431C MAX	UNIT
V_{ref}	Reference input voltage	1	$V_{KA} = V_{ref}$, $I_K = 10$ mA	2400	2495	2600	244[illegible]	2495	2550	2440	2495	2550	mV
$V_{ref(dev)}$	Deviation of reference input voltage over full temperature range‡	1	$V_{KA} = V_{ref}$, $I_K = 10$ mA, T_A = full range†		22			5	30		4	17	mV
$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	Ratio of change in reference input voltage to the change in cathode voltage	2	$I_K = 10$ mA, $\Delta V_{KA} = 10\text{ V} - V_{ref}$		−1.4	−3		−1.4	−2.7		−1.4	−2.7	$\frac{mV}{V}$
			$I_K = 10$ mA, $\Delta V_{KA} = 36\text{ V} - 10\text{ V}$		−1	−2.3		−1	−2		−1	−2	
I_{ref}	Reference input current	2	$I_K = 10$ mA, $R1 = 10$ kΩ, $R2 = \infty$		2	8		2	4		2	4	μA
$I_{ref(dev)}$	Deviation of reference input current over full temperature range‡	2	$I_K = 10$ mA, $R1 = 10$ kΩ, $R2 = \infty$, T_A = full range†		1			0.8	2.5		0.4	1.2	μA
I_{min}	Minimum cathode current for regulation	1	$V_{KA} = V_{ref}$		0.4	1.5		0.4	1		0.4	1	mA
I_{off}	Off-state cathode current	3	$V_{KA} = 36$ V, $V_{ref} = 0$		0.1	3		0.1	1		0.1	1	μA
$\|z_{ka}\|$	Dynamic impedance§	1	$V_{KA} = V_{ref}$, $I_K = 1$ mA to 100 mA, $f \le 1$ kHz		0.2	0.9		0.2	0.5		0.2	0.5	Ω

† Full temperature range is −55 °C to 125 °C for the TL431M, −40 °C to 85 °C for the TL431I, and 0 °C to 70 °C for the TL431C.

‡ The deviation parameters $V_{ref(dev)}$ and $I_{ref(dev)}$ are defined as the differences between the maximum and minimum values obtained over the rated temperature range. The average full-range temperature coefficient of the reference input voltage, $\alpha_{V_{ref}}$, is defined as:

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



where ΔT_A is the rated 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 (see Figure 8).

Example: Max V_{ref} = 2496 mV @ 30 °C, Min V_{ref} = 2492 mV @ 0 °C, V_{ref} = 2495 mV @ 25 °C, ΔT_A = 70 °C for TL431C

$$|\alpha_{V_{ref}}| = \frac{\left(\frac{4\text{ mV}}{2495\text{ mV}}\right) \times 10^6}{70\,°C} \approx 23\text{ ppm/°C}$$

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

§ The dynamic impedance is defined as

$$|z_{ka}| = \frac{\Delta V_{KA}}{\Delta I_K}$$

When the device is operated with two external resistors (see Figure 2), the total dynamic impedance of the circuit is given by:

$$|z'| = \frac{\Delta V}{\Delta I} \approx |z_{ka}| \left(1 + \frac{R1}{R2}\right)$$

Data Sheets 2

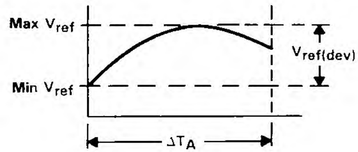
electrical characteristics at 25°C free-air temperature (unless otherwise noted)

PARAMETER		TEST CIRCUIT	TEST CONDITIONS		TL431AI MIN	TL431AI TYP	TL431AI MAX	TL431AC MIN	TL431AC TYP	TL431AC MAX	UNIT
V_{ref}	Reference input voltage	1	$V_{KA} = V_{ref}$, $I_K = 10$ mA		2470	2495	2520	2470	2495	2520	mV
$V_{ref(dev)}$	Deviation of reference input voltage over full temperature range‡	1	$V_{KA} = V_{ref}$, $I_K = 10$ mA, T_A = full range†			5	25		4	15	mV
$\frac{\Delta V_{ref}}{\Delta V_{KA}}$	Ratio of change in reference input voltage to the change in cathode voltage	2	$I_K = 10$ mA	$\Delta V_{KA} = 10\text{ V} - V_{ref}$		−1.4	−2.7		−1.4	−2.7	mV/V
				$\Delta K_{VA} = 36\text{ V} - 10\text{ V}$		−1	−2		−1	−2	
I_{ref}	Reference input current	2	$I_K = 10$ mA, R1 = 10 kΩ, R2 = ∞			2	4		2	4	μA
$I_{ref(dev)}$	Deviation of reference input current over full temperature range‡	2	$I_K = 10$ mA, R1 = 10 kΩ, R2 = ∞, T_A = full range†			0.8	2.5		0.8	1.2	μA
I_{min}	Minimum cathode current for regulation	1	$V_{KA} = V_{ref}$			0.4	0.7		0.4	0.6	mA
I_{off}	Off-state cathode current	3	$V_{KA} = 36$ V, $V_{ref} = 0$			0.1	0.5		0.1	0.5	μA
$\lvert z_{ka} \rvert$	Dynamic impedance§	1	$V_{KA} = V_{ref}$, $I_K = 1$ mA to 100 mA, $f \le 1$ kHz			0.2	0.5		0.2	0.5	Ω

†Full temperature range is −40°C to 85°C for TL431AI and 0°C to 70°C for TL431AC.

‡The deviation parameters $V_{ref(dev)}$ and $I_{ref(dev)}$ are defined as the differences between the maximum and minimum values obtained over the rated temperature range. The average full-range temperature coefficient of the reference input voltage, αV_{ref}, is defined as:

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



where ΔT_A is the rated 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.

§The dynamic impedance is defined as: $\lvert z_{ka} \rvert = \frac{\Delta V_{KA}}{\Delta I_K}$

When the device is operating with two external resistors, see figure 2, the total dynamic impedance of the circuit is given by:

$$\lvert z' \rvert = \frac{\Delta V}{\Delta I}, \text{ which is approximately equal to } \lvert z_{ka} \rvert \left(1 + \frac{R1}{R2}\right)$$

PARAMETER MEASUREMENT INFORMATION

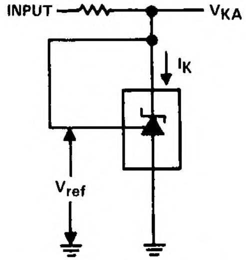
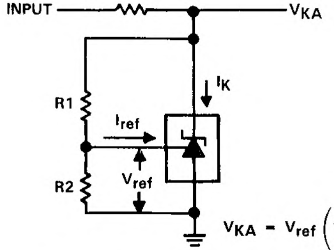


FIGURE 1. TEST CIRCUIT FOR $V_{KA} = V_{ref}$



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

FIGURE 2. TEST CIRCUIT FOR $V_{KA} > V_{ref}$

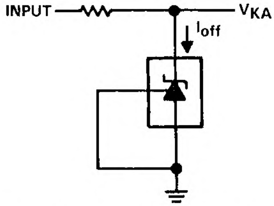


FIGURE 3. TEST CIRCUIT FOR I_{off}

TYPICAL CHARACTERISTICS

CATHODE CURRENT
vs
CATHODE VOLTAGE

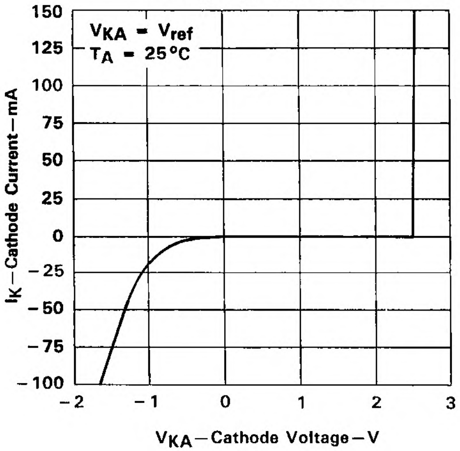


FIGURE 4

CATHODE CURRENT
vs
CATHODE VOLTAGE

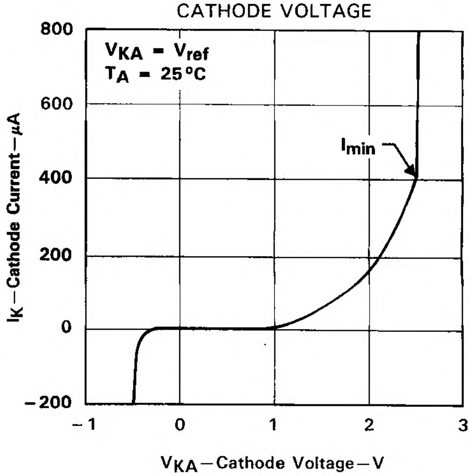


FIGURE 5

TYPICAL CHARACTERISTICS

OFF-STATE CATHODE CURRENT
vs
FREE-AIR TEMPERATURE†

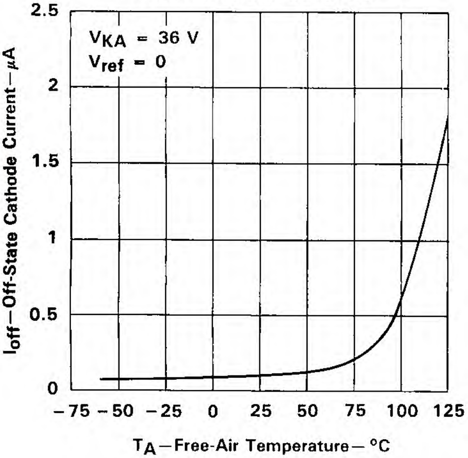


FIGURE 6

NOISE VOLTAGE
vs
FREQUENCY

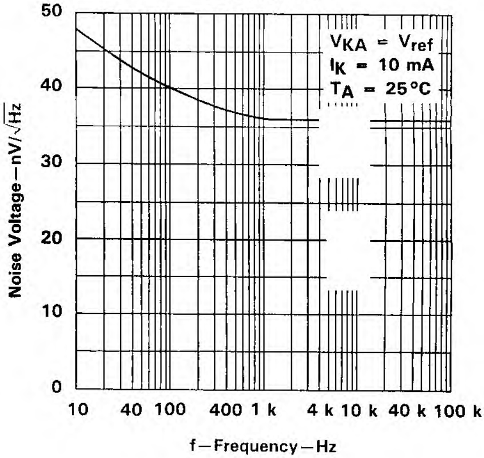


FIGURE 7

REFERENCE INPUT VOLTAGE
vs
FREE-AIR TEMPERATURE†

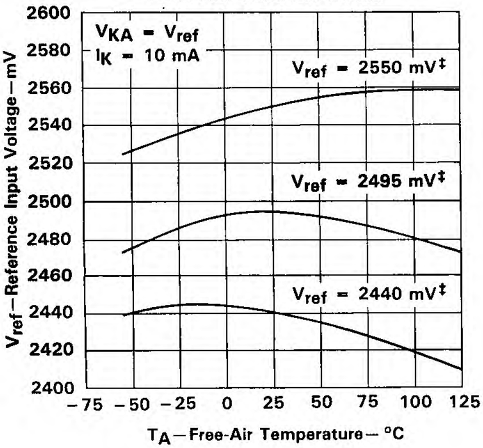


FIGURE 8

REFERENCE INPUT CURRENT
vs
FREE-AIR TEMPERATURE†

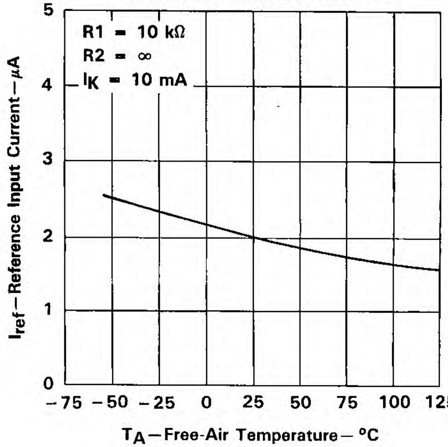


FIGURE 9

†For TL431I, TL431AI, TL431C, and TL431AC, the data applies only for the portions of the curves that lie within their recommended operating temperature ranges.
‡Data is for devices having the indicated value of V_{ref} at I_K = 10 mA, T_A = 25°C.

TYPICAL CHARACTERISTICS

CHANGE IN REFERENCE INPUT VOLTAGE
vs
CATHODE VOLTAGE

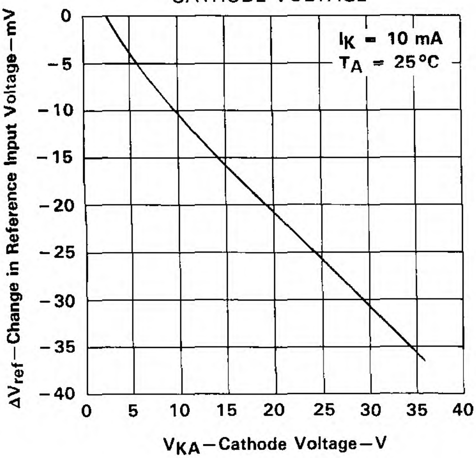


FIGURE 10

DYNAMIC IMPEDANCE
vs
FREE-AIR TEMPERATURE†

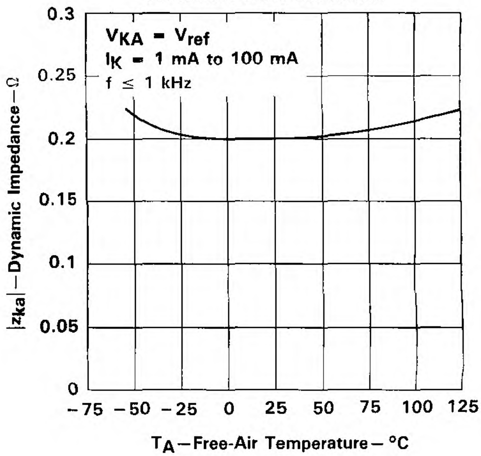


FIGURE 11

DYNAMIC IMPEDANCE
vs
FREQUENCY

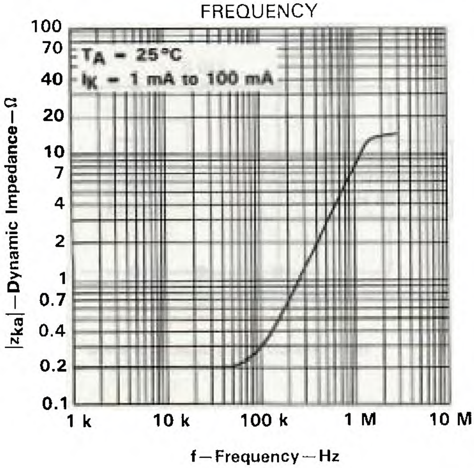
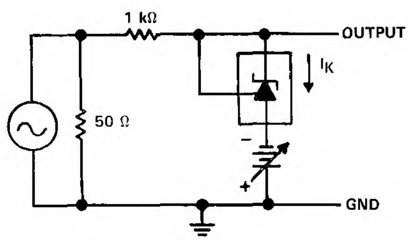


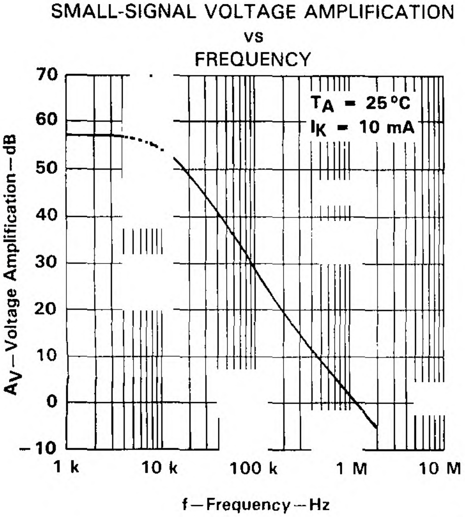
FIGURE 12

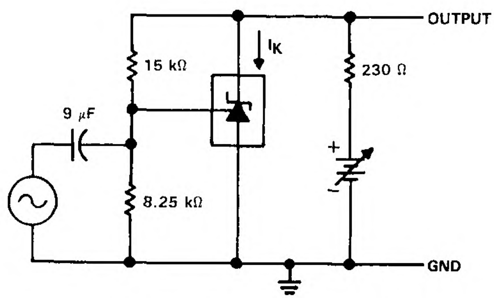


TEST CIRCUIT FOR DYNAMIC IMPEDANCE

†For TL431I, TL431AI, TL431C, and TL431AC, the data applies only for the portions of the curves that lie within their recommended operating temperature ranges.

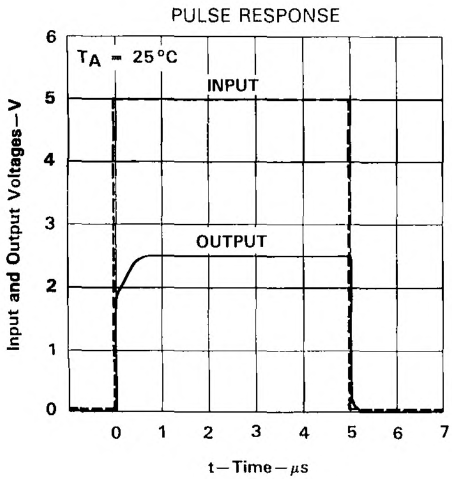
TYPICAL CHARACTERISTICS

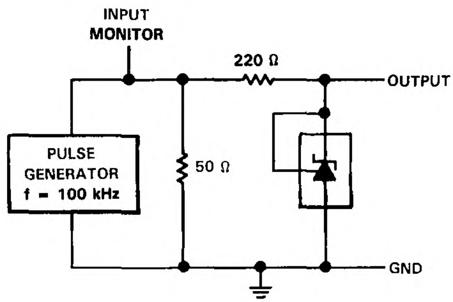




TEST CIRCUIT FOR VOLTAGE AMPLIFICATION

FIGURE 13

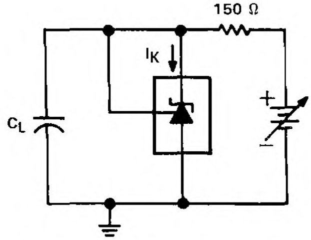




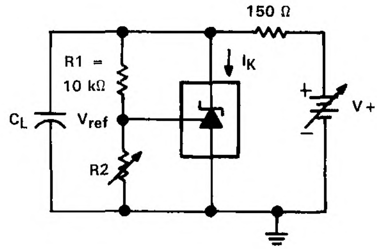
TEST CIRCUIT FOR PULSE RESPONSE

FIGURE 14

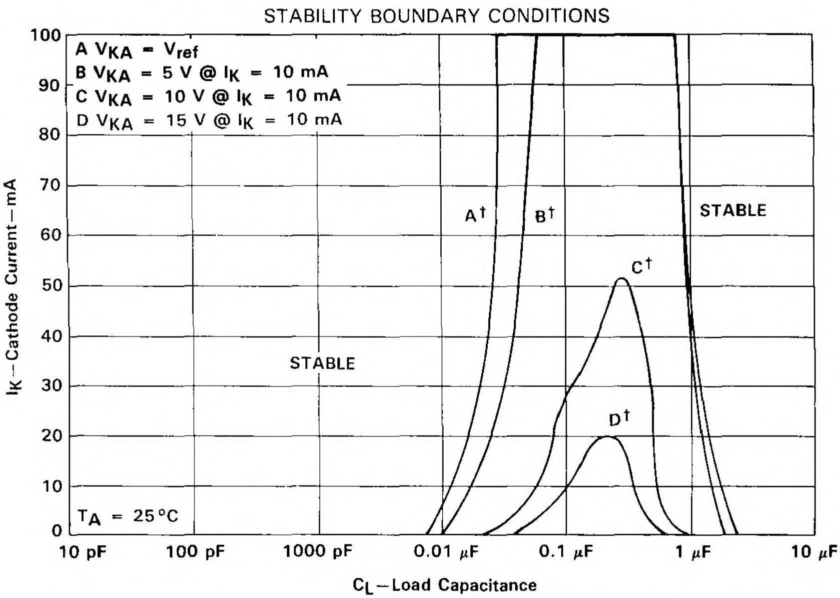
TYPICAL CHARACTERISTICS



TEST CIRCUIT FOR CURVE A BELOW



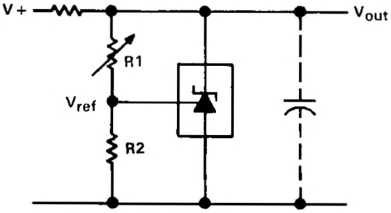
TEST CIRCUIT FOR CURVES B, C, AND D BELOW



† 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_K conditions with C_L = 0. V+ and C_L were then adjusted to determine the ranges of stability.

FIGURE 15

TYPICAL APPLICATIONS



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

FIGURE 16. SHUNT REGULATOR

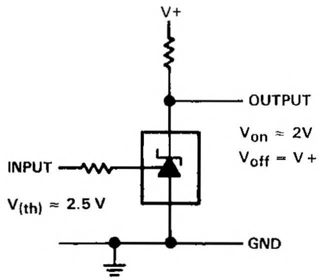
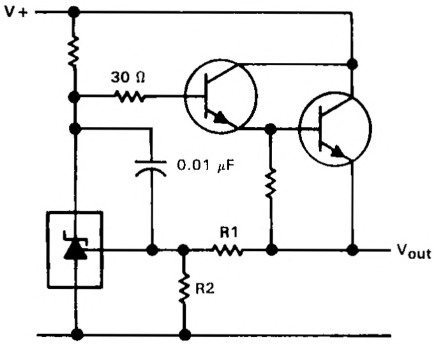
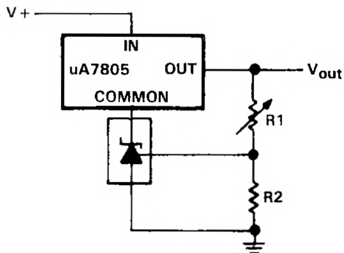


FIGURE 17. SINGLE-SUPPLY COMPARATOR WITH TEMPERATURE-COMPENSATED THRESHOLD



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

FIGURE 18. SERIES REGULATOR

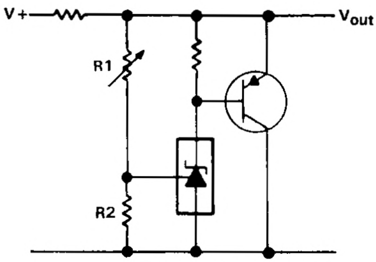


$$V_{out} = V_{ref} \left(1 + \frac{R1}{R2}\right)$$

$$\text{Min } V_{out} = V_{ref} + 5\ \text{V}$$

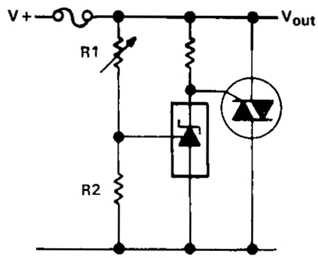
FIGURE 19. OUTPUT CONTROL OF A THREE-TERMINAL FIXED REGULATOR

TYPICAL APPLICATIONS



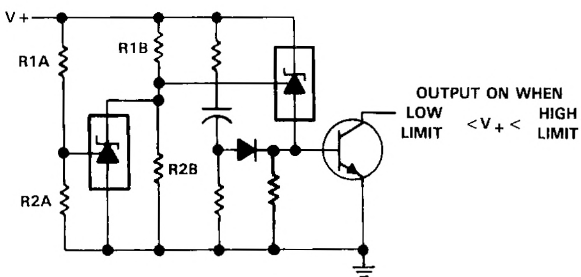
$$V_{out} = \left(1 + \frac{R1}{R2}\right)V_{ref}$$

FIGURE 20. HIGHER-CURRENT SHUNT REGULATOR



$$V_{limit} \approx \left(1 + \frac{R1}{R2}\right)V_{ref}$$

FIGURE 21. CROW BAR

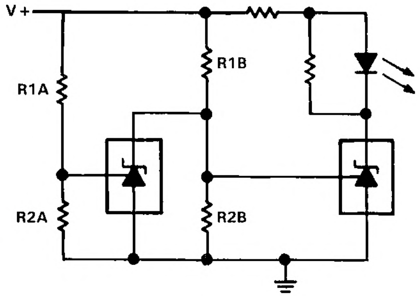


$$\text{Low limit} \approx V_{ref}\left(1 + \frac{R1B}{R2B}\right) + V_{BE}$$

$$\text{High limit} \approx V_{ref}\left(1 + \frac{R1A}{R2A}\right)$$

FIGURE 22. OVER-VOLTAGE/UNDER-VOLTAGE PROTECTION CIRCUIT

TYPICAL APPLICATIONS

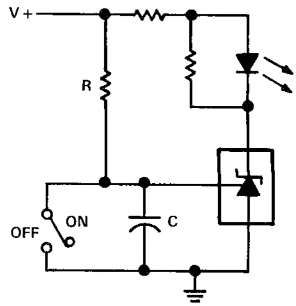


Low limit $\approx V_{ref}\left(1 + \frac{R1B}{R2B}\right)$

High limit $\approx V_{ref}\left(1 + \frac{R1A}{R2A}\right)$

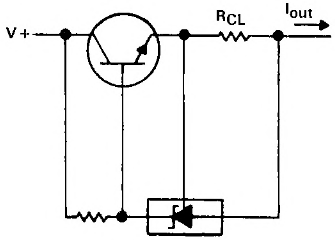
LED ON WHEN LOW LIMIT < V+ < HIGH LIMIT

FIGURE 23. VOLTAGE MONITOR



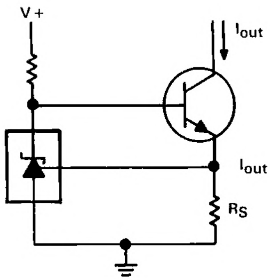
$$\text{Delay} = R \cdot C \cdot \ln \frac{V+}{(V+) - V_{ref}}$$

FIGURE 24. DELAY TIMER



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

FIGURE 25. CURRENT LIMITER OR CURRENT SOURCE



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

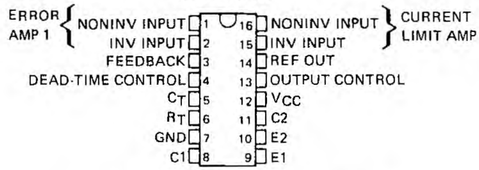
FIGURE 26. CONSTANT-CURRENT SINK

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

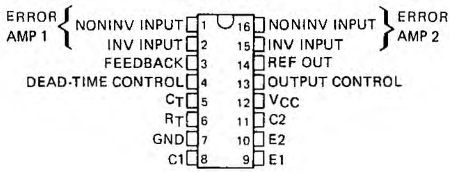
D2535, JANUARY 1983—REVISED OCTOBER 1988

- Complete PWM Power Control Circuitry
- Uncommitted Outputs for 200-mA Sink or Source Current
- Output Control Selects Single-Ended or Push-Pull Operation
- Internal Circuitry Prohibits Double Pulse at Either Output
- Variable Dead-Time Provides Control over Total Range
- Internal Regulator Provides a Stabie 5-V Reference Supply, 5%
- Circuit Architecture Allows Easy Synchronization
- TL493 has Output Current-Limit Sensing
- TL495 has On-Chip 39-V Zener and External Control of Output Steering

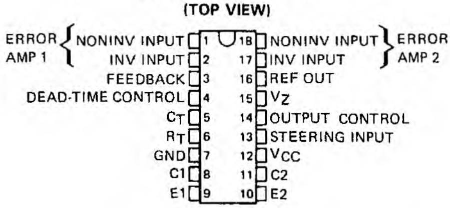
TL493C . . . D OR N PACKAGE
(TOP VIEW)



TL494I, TL494C . . . D, J, OR N PACKAGE
(TOP VIEW)



TL495C . . . N PACKAGE
(TOP VIEW)



description

The TL493, TL494, and TL495 each incorporate on a single monolithic chip all the functions required in the construction of a pulse-width-modulation control circuit. Designed primarily for power supply control, these devices offer the systems engineer the flexibility to tailor the power supply control circuitry to his application.

The TL493 contains an error amplifier, current-limiting amplifier, an on-chip adjustable oscillator, a dead-time control comparator, pulse-steering control flip-flop, a 5-volt, 5%-precision regulator, and output-control circuits.

The error amplifier exhibits a common-mode voltage range from −0.3 volts to V_{CC} −2 volts. The current-limit amplifier exhibits a common-mode voltage range from −0.3 volts to 3 volts with an offset voltage of approximately 80 millivolts in series with the inverting input to ease circuit design requirements. The dead-time control comparator has a fixed offset that provides approximately 5% dead time when externally altered. The on-chip oscillator may be bypassed by terminating R_T (pin 6) to the reference output and providing a sawtooth input to C_T (pin 5), or it may be used to drive the common circuits in synchronous multiple-rail power supplies.

DEVICE TYPES, SUFFIX VERSIONS, AND PACKAGES

	TL493	TL494	TL495
TL49−I	*	D,J,N	*
TL49−C	D,N	D,J,N	N

*These combinations are not defined by this data sheet.

FUNCTION TABLE

INPUTS		
OUTPUT CONTROL	STEERING INPUT (TL495 only)	OUTPUT FUNCTION
$V_I = 0$	Open	Single-ended or parallel output
$V_I = V_{ref}$	Open	Normal push-pull operation
$V_I = V_{ref}$	$V_I = 0$	PWM Output at Q1
$V_I = V_{ref}$	$V_I = V_{ref}$	PWM Output at Q2

TEXAS INSTRUMENTS

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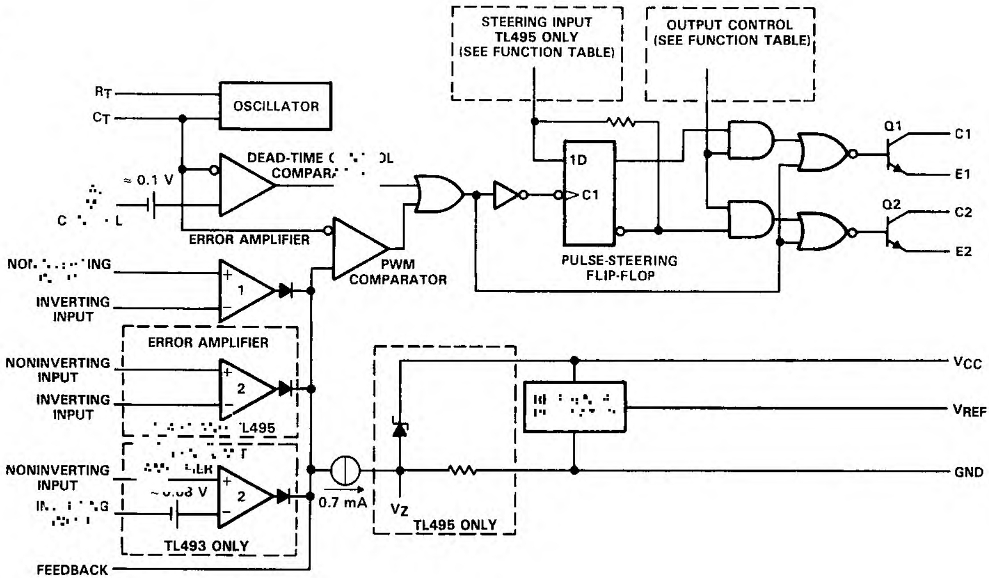
description (continued)

The uncommited output transistors provide either common-emitter or emitter-follower output capability. Each device provides for push-pull or single-ended output operation, which may be selected through the output-control function. The architecture of these devices prohibits the possibility of either output being pulsed twice during push-pull operation.

The TL493 and TL494 are similar except that an additional error amplifier is included in the TL494 instead of a current-limiting amplifier. The TL495 provides the identical functions found in the TL494. In addition, it contains an on-chip 39-volt diode for high-voltage applications where V_{CC} is greater than 40 volts, and an output-steering control that overrides the internal control of the pulse-steering flip-flop.

The TL494I is characterized for operation from −25°C to 85°C. The TL493C, TL494C, and TL495C are characterized for operation from 0°C to 70°C.

functional block diagram



TEXAS INSTRUMENTS
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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	TL494I	TL493C TL494C	TL495C	UNIT
Supply voltage, V_{CC} (see Note 1)	41	41	41	V
Amplifier input voltage	$V_{CC}+0.3$	$V_{CC}+0.3$	$V_{CC}+0.3$	V
Collector output voltage	41	41	41	V
Collector output current	250	[illegible]	250	mA
Continuous total dissipation	See Dissipation Rating Table			
Operating free-air temperature range	−25 to 85	0 to 70	0 to 70	°C
Storage temperature range	−65 to 150	−65 to 150	−65 to 150	°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package	300	300	300	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or N package	260	260	260	°C

NOTE 1: All voltage values, except differential voltages, are with respect to the network ground terminal.

DISSIPATION RATING TABLE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR	DERATE ABOVE T_A	$T_A = 70°C$ POWER RATING	$T_A = 85°C$ POWER RATING
D	900	7.6 mW/°C	25°C	608 mW	494 mW
J	1000	8.2 mW/°C	28°C	656 mW	533 mW
N	1000	9.2 mW/°C	41°C	736 mW	598 mW

recommended operating conditions

	TL494I		TL493C TL494C TL495C		UNIT
	MIN	MAX	MIN	MAX	
Supply voltage, V_{CC}	7	40	[illegible]	40	V
Amplifier input voltages, V_I	−0.3	$V_{CC}-2$	−0.3	$V_{CC}-2$	V
Collector output voltage, V_O		40		40	V
Collector output current (each transistor)		200		200	mA
Current into feedback terminal		0.3		0.3	mA
Timing capacitor, C_T	0.47	10 000	0.47	10 000	nF
Timing resistor, R_T	1.8		1.8		kΩ
Oscillator frequency	1		1		kHz
Operating free-air temperature, T_A	−25	85	0	70	°C

electrical characteristics over recommended operating free-air temperature range, V_{CC} = 15 V, f = 10 kHz (unless otherwise noted)

reference section

PARAMETER	TEST CONDITIONS†	TL493C, TL494I, TL494C, TL495C MIN	TYP‡	MAX	UNIT
Output voltage (V_{ref})	I_O = 1 mA	4.75	5	5.25	V
Input regulation	V_{CC} = 7 V to 40 V		2	25	mV
Output regulation	I_O = 1 to 10 mA		1	15	mV
Output voltage change with temperature	ΔT_A = MIN to MAX		0.2%	1%	
Short-circuit output current§	V_{ref} = 0		35		mA

oscillator section (see Figure 1)

PARAMETER	TEST CONDITIONS†	TL493C, TL494I, TL494C, TL495C MIN	TYP‡	MAX	UNIT
Frequency	C_T = 0.01 μF, R_T = 12 kΩ		10		kHz
Standard deviation of frequency¶	All values of V_{CC}, C_T, R_T, and T_A constant		10%		
Frequency change with voltage	V_{CC} = 7 V to 40 V, T_A = 25°C		0.1%		
Frequency change with temperature#	C_T = 0.01 μF, R_T = 12 kΩ, ΔT_A = MIN to MAX			1%	

amplifier sections (see Figure 2)

PARAMETER		TEST CONDITIONS	MIN	TYP‡	MAX	UNIT
Input offset voltage	Error	V_O (pin 3) = 2.5 V		2	10	mV
	Current-limit (TL493 only)			80		
Input offset current		V_O (pin 3) = 2.5 V		25	[illegible]	nA
Input bias current		V_O (pin 3) = 2.5 V		0.2	[illegible]	μA
Common-mode input voltage range	Error	V_{CC} = 7 V to 40 V	−0.3 to $V_{CC}-2$			V
	Current limit (TL493 only)		−0.3 to 3			
Open-loop voltage amplification	Error	ΔV_O = 3 V, R_L = 2 kΩ V_O = 0.5 V to 3.5 V	70	95		dB
	Current-limit (TL493 only)			90		
Unity-gain bandwidth		V_O = 0.5 V to 3.5 V R_L = 2 kΩ		[illegible]		kHz
Common-mode rejection ratio	Error	ΔV_O = 40 V, T_A = 25°C	65	[illegible]		dB
	Current-limit (TL493 only)			70		
Output sink current (pin 3)		V_{ID} = −15 mV to −5 V, $V_{(pin\ 3)}$ = 0.7 V	0.3	0.7		mA
Output source current (pin 3)		V_{ID} = 15 mV to 5 V, $V_{(pin\ 3)}$ = 3.5 V	−2			mA

† For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.
‡ All typical values except for parameter changes with temperature are at T_A = 25°C.
§ Duration of the short-circuit should not exceed one second.
¶ Standard deviation is a measure of the statistical distribution about the mean as derived from the formula $\sigma = \sqrt{\frac{\sum_{n=1}^{N} (x_n - \overline{X})^2}{N-1}}$
# Temperature coefficient of timing capacitor and timing resistor not taken into account.

electrical characteristics over recommended operating free-air temperature range, V_{CC} = 15 V, f = 10 kHz (unless otherwise noted)

output section

PARAMETER		TEST CONDITIONS	TL493C TL494I, TL494C TL495C MIN	TYP†	MAX	UNIT
Collector off-state current		V_{CE} = 40 V, V_{CC} = 40 V		2		μA
Emitter off-state current		V_{CC} = V_C = 40 V, V_E = 0			−100	μA
Collector-emitter saturation voltage	Common-emitter	V_E = 0, I_C = [illegible] mA		1.1	1.3	V
	Emitter-follower	V_C = 15 V, I_E = −[illegible] mA		1.5	2.5	V
Output control input current		V_I = V_{ref}			3.5	mA

dead-time control-section (see Figure 1)

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
Input bias current (pin 4)	V_I = 0 to 5.25 V		−2	−10	μA
Maximum duty cycle, each output	V_I (pin 4) = 0, C_T = 0.1 μF, R_T = 12 kΩ		45%		
Input threshold voltage (pin 4)	Zero duty cycle		3	3.3	V
	Maximum duty cycle	0			

pwm comparator section (see Figure 1)

PARAMETER	TEST CONDITIONS	MIN	TYP†	MAX	UNIT
Input threshold voltage (pin 3)	Zero duty cycle		4	4.5	V
Input sink current (pin 3)	$V_{(pin\ 3)}$ = 0.7 V	0.3	0.7		mA

steering control (TL495 only)

PARAMETER	TEST CONDITIONS	MIN	MAX	UNIT
Input current	V_I = 0.4 V		[illegible]	μA
	V_I = 2.4 V		200	

zener-diode circuit (TL495 only)

PARAMETER	TEST CONDITIONS	MIN	TYP†	MAX	UNIT
Breakdown voltage	V_{CC} = 41 V, I_Z = 2 mA		39		V
Sink current	$V_{I(pin\ 15)}$ = 1 V		0.3		mA

total device

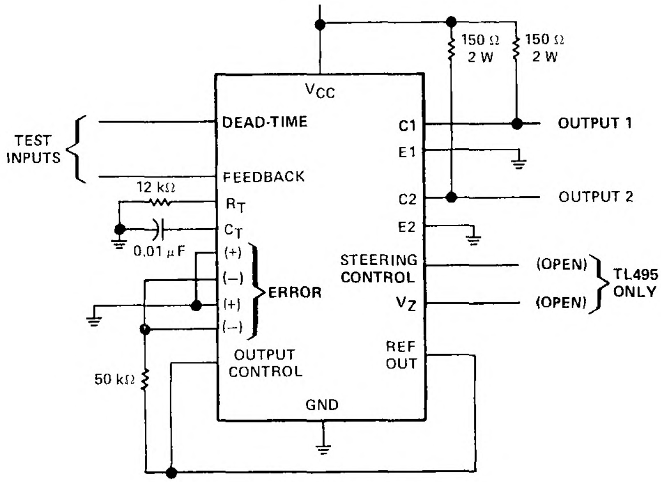
PARAMETER	TEST CONDITIONS		MIN	TYP†	MAX	UNIT
Standby supply current	Pin 6 at V_{ref}, All other inputs and outputs open	V_{CC} = 15 V		6	10	mA
		V_{CC} = 40 V		9	15	
Average supply current	$V_{I(pin\ 4)}$ = 2 V,	See Figure 1		7.5		mA

switching characteristics, T_A = 25°C

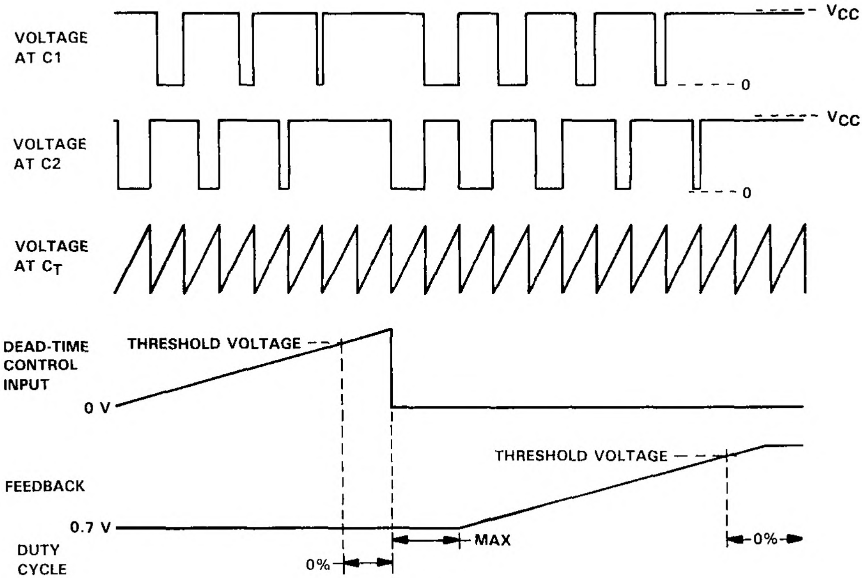
PARAMETER	TEST CONDITIONS	MIN	TYP†	MAX	UNIT
Output voltage rise time	Common-emitter configuration, See Figure 3		100	200	ns
Output voltage fall time			25	100	ns
Output voltage rise time	Emitter-follower configuration, See Figure 4		100	[illegible]	ns
Output voltage fall time			40	[illegible]	ns

†All typical values except for temperature coefficient are at T_A = 25°C.

PARAMETER MEASUREMENT INFORMATION



TEST CIRCUIT



VOLTAGE WAVEFORMS

FIGURE 1. OPERATIONAL TEST CIRCUIT AND WAVEFORMS

PARAMETER MEASUREMENT INFORMATION

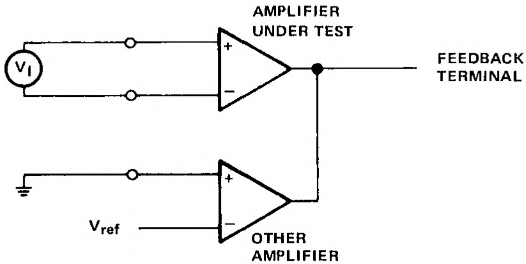


FIGURE 2. AMPLIFIER CHARACTERISTICS

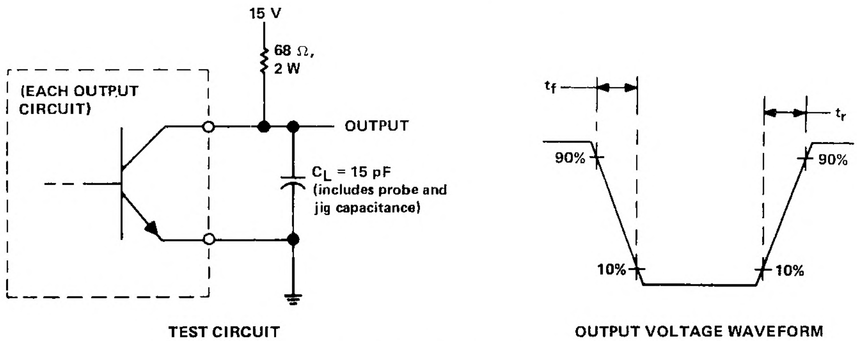


FIGURE 3. COMMON-EMITTER CONFIGURATION

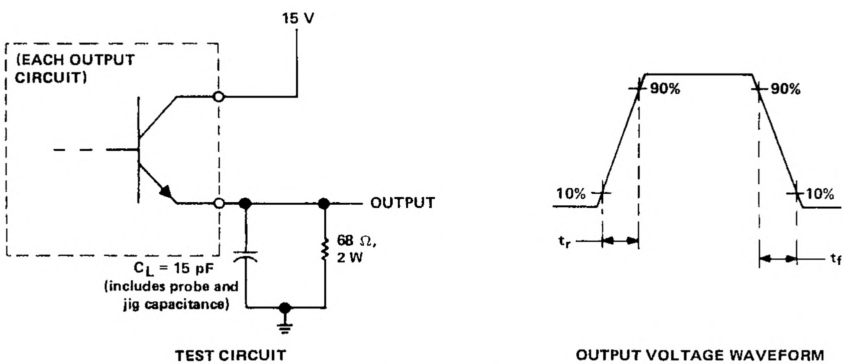


FIGURE 4. EMITTER-FOLLOWER CONFIGURATION

TYPICAL CHARACTERISTICS

OSCILLATOR FREQUENCY AND
FREQUENCY VARIATION† vs
TIMING RESISTANCE

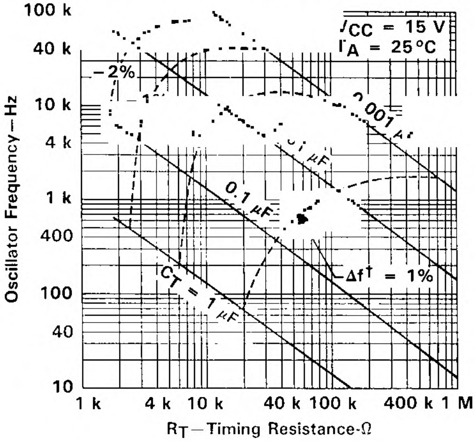


FIGURE 5

AMPLIFIER VOLTAGE AMPLIFICATION
vs
FREQUENCY

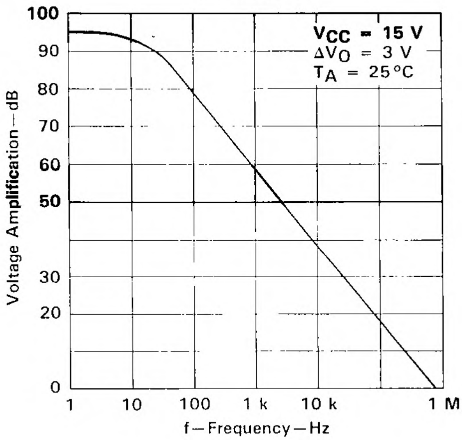


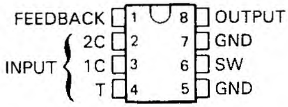
FIGURE 6

†Frequency variation (Δf) is the change in oscillator frequency that occurs over the full temperature range.

D2486, AUGUST 1978—REVISED FEBRUARY 1988

- **Internal Step-Up Switching Regulator**
- **Fixed 9-Volt Output**
- **Charges Battery Source During Transformer-Coupled-Input Operation**
- **Minimum External Components Required (1 Inductor, 1 Capacitor, 1 Diode)**
- **1- or 2-Cell-Input Operation**

D OR P PACKAGE
(TOP VIEW)



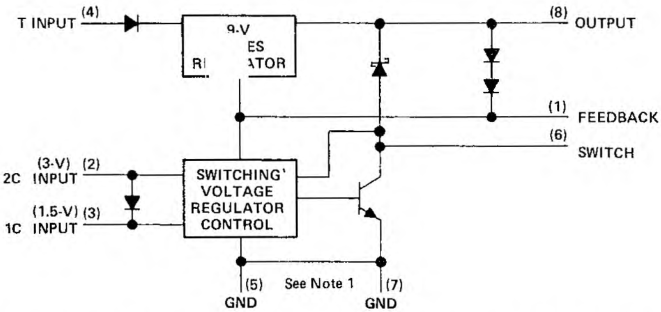
Pins 5 and 7 are connected together internally.

description

The TL496 power supply control circuit is designed to provide a 9-volt regulated supply from a variety of input sources. Operable from a 1- or 2-cell battery input, the TL496 performs as a switching regulator with the addition of a single inductor and filter capacitor. When ac coupled with a step-down transformer, the TL496 operates as a series regulator to maintain the regulated output voltage and, with the addition of a single catch diode, time shares to recharge the input batteries.

The design of the TL496 allows minimal supply current drain during stand-by operation (125 μA typical). With most battery sources this allows a constant bias to be maintained on the power supply. This makes power instantly available to the system thus eliminating power-up sequencing problems.

functional block diagram



NOTE 1: Pins 5 and 7, though connected together internally, must both be terminated to ground to ensure proper circuit operation.

absolute maximum ratings

Input voltage:
- Pin 2 . . . . 3.5 V
- Pin 3 . . . . 2.5 V
- Pin 4 . . . . 20 V

Output voltage (Pin 6) . . . . 12 V
Diode reverse voltage (Pin 8) . . . . 12 V
Switch current (Pin 6) . . . . 1.2 A
Diode current (Pin 8) . . . . 1.2 A
Continuous total dissipation . . . . See Dissipation Rating Table
Operating free-air temperature range . . . . 0°C to 70°C
Storage temperature range . . . . −65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds . . . . 260°C

DISSIPATION RATING TABLE

PACKAGE	$T_A \leq 25°C$ POWER RATING	DERATING FACTOR	$T_A = 70°C$ POWER RATING
D	[illegible] mW	5.8 [illegible]	464 mW
P	1000 mW	8.0 mW/°C	640 mW

recommended operating conditions

	MIN	MAX	UNIT
Input voltage, one-cell operation (pins 2 and 3 to ground)	1.1	1.5	V
Input voltage, two-cell operation (pin 2 to ground)	2.3	3	V
Input voltage, one-cell or two-cell operation (pin 4 to ground)	$V_O + 2$	20	V

electrical characteristics at 25°C free-air temperature

series regulator section (input is pin 4)

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
Dropout voltage	$V_I = 5$ V,	$I_O = -50$ mA		1.5	2	V
Regulated output voltage	$V_I = 20$ V	$I_O = -50$ μA	9.5	10.1	11.2	V
		$I_O = -80$ mA	9.0	10.0	11.0	
	$V_I = 20$ V, Pin 1 shorted to pin 8	$I_O = -50$ μA	8.5	9.0	9.7	
		$I_O = -80$ mA	6.7	8.6	9.5	
Standby current (pin 4)	$V_I = 20$ V,	Pin 8 at 12 V			400	μA
Reverse current thru pin 4	$V_I = -1.5$ V,	1 mA into pin 8			−25	μA

output switch

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	MAX
$V_{CE(sat)}$	Collector-emitter saturation voltage	800 mA into pin 6, Pin 2 at 2.25 V		0.35	0.6	V

diode (pin 6 to pin 8)

PARAMETER		TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_F	Forward voltage	$I_F = 1.5$ A		1.6	2.5	V
I_R	Reverse current thru pin 6	Pin 6 at 0 V, 1 mA into pin 8			−20	μA

control section

PARAMETER	TEST CONDITIONS	MIN	TYP	MAX	UNIT
On-state current (pin 2)	Pins 1 and 8 at 0 V, Pin 2 at 3 V		60	100	mA
Standby current (pin 1)	Pin 1 at 8.65 V, Pins 2 and 6 at 3 V			40	μA
Standby current (pin 2 and 6)	Pin 1 at 8.65 V, Pins 2 and 6 at 3 V			400	μA
Start-up current (current into pin 6 to initiate cycle)	Pins 1, 2, 6 and 8 at 2.25 V	16			mA

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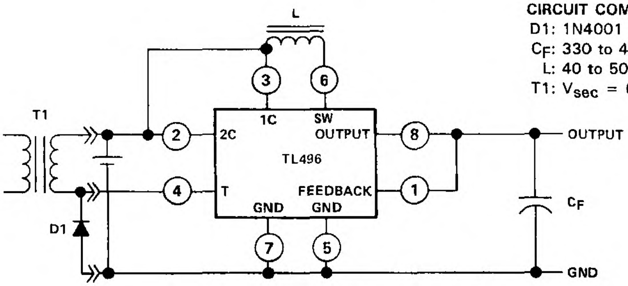
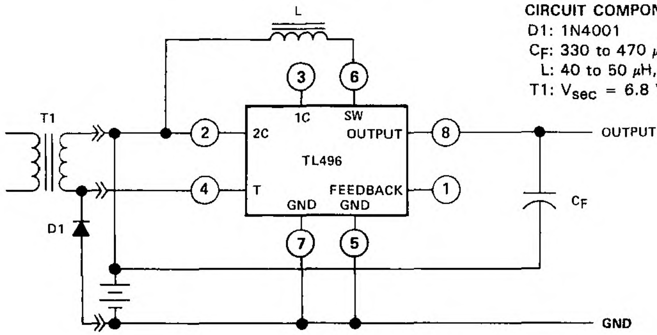
TYPICAL APPLICATION DATA



CIRCUIT COMPONENT INFORMATION
D1: 1N4001
C_F: 330 to 470 μF, 10 V, electrolytic
L: 40 to 50 μH, Q ≈ 3, R < 0, 15 Ω
T1: V_{sec} = 6.8 V RMS typ., R_{sec} = 11 Ω typ.

FIGURE 1. ONE-CELL OPERATION



CIRCUIT COMPONENT INFORMATION
D1: 1N4001
C_F: 330 to 470 μF, 10 V, electrolytic
L: 40 to 50 μH, Q ≈ 3, R < 0, 15 Ω
T1: V_{sec} = 6.8 V RMS typ., R_{sec} = 11 Ω typ.

FIGURE 2. TWO-CELL OPERATION

typical electrical characteristics for circuits above

PARAMETER		ONE-CELL OPERATION (FIGURE 1)	TWO-CELL OPERATION (FIGURE 2)
Input current	No load	125 uA	125 uA
	R_L = 120 Ω	525 mA	405 mA
Output voltage	Without T1	7.2 V	8.6 V
	With T1	8.6 V	10 V
Output current capability		40 mA	80 mA
Efficiency		66%	66%
Battery life (AA NiCad) no load		60 days	166 days

functional description

The TL496 is designed to operate from either a single-cell or two-cell source. To operate the device from a single-cell (1.1 V to 1.5 V) the source must be connected to both inputs 1C and 2C as shown in Figure 1. For two-cell operation (2.3 V to 3.0 V), the input is applied to the 2C input only and the 1C input is left open (see Figure 2).

battery operation

The TL496 operates as a switching regulator from a battery input. The cycle is initiated when a low voltage condition is sensed by the internal feedback (the thresholds at pin 1 and pin 8 are approximately 7.2 and 8.6 volts respectively). An internal latch is set and the output transistor is turned "on." This causes the current in the external inductor (L) to increase linearly until it reaches a peak value of approximately 1 ampere. When the peak current is sensed the internal latch is reset and the output transistor is turned "off." The energy developed in the inductor is then delivered to the output storage capacitor through the blocking diode. The latch remains in the off state until the feedback signal indicates the output voltage is again deficient.

transformer-coupled operation

The TL496 operates on alternate half cycles of the ac input during transformer-coupled operation to, first, sustain the output voltage and, second, recharge the batteries. The TL496 performs like a series regulator to supply charge to the output filter/storage capacitor during the first half cycle. The output voltage of the series regulator is slightly higher voltage than that created by the switching circuit; this maintains the feedback voltage above the switching regulator control circuit threshold. This effectively inhibits the switching control circuitry. During the second half cycle an external diode (1N4001) is used to clamp the negative going end of the transformer secondary to ground thus allowing the positive-going end (end connected to V+side of battery) to pump charge into the stand-by batteries.

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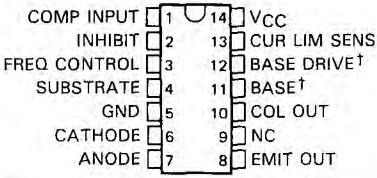
D2225, JUNE 1976—REVISED OCTOBER 1988

- **High Efficiency . . . 60% or Greater**
- **Output Current . . . 500 mA**
- **Input Current Limit Protection**
- **TTL Compatible Inhibit**
- **Adjustable Output Voltage**
- **Input Regulation . . . 0.2% Typ**
- **Output Regulation . . . 0.4% Typ**
- **Soft Start-up Capability**

TL497AM . . . J PACKAGE
TL497AI, TL497AC . . . D, J, OR N PACKAGE
(TOP VIEW)



NC—No internal connection

† The Base pin (#11) and Base Drive pin (#12) are used for device testing only. They are not normally used in circuit applications of the device.

description

The TL497A incorporates on a single monolithic chip all the active functions required in the construction of a switching voltage regulator. It can also be used as the control element to drive external components for high-power-output applications. The TL497A was designed for ease of use in step-up, step-down, or voltage inversion applications requiring high efficiency.

The TL497A is a fixed-on-time variable-frequency switching voltage regulator control circuit. The on-time is programmed by a single external capacitor connected between the frequency control pin and ground. This capacitor, C_T, is charged by an internal constant-current generator to a predetermined threshold. The charging current and the threshold vary proportionally with V_{CC}, thus the one time remains constant over the specified range of input voltage (5 to 12 V). Typical on-times for various values of C_T are as follows:

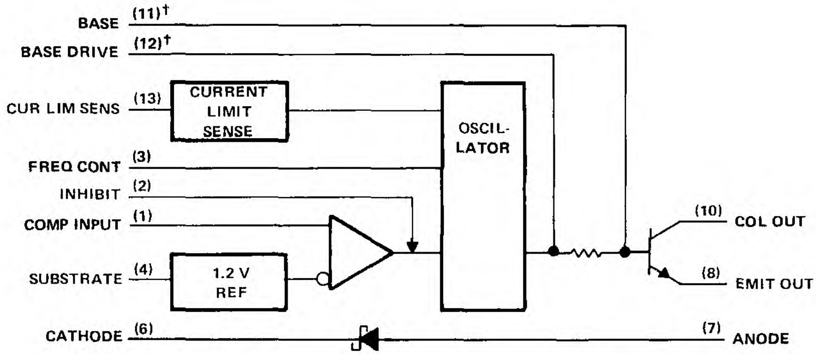
TIMING CAPACITOR, C_T (pF)	200	250	350	400	500	750	1000	1500	2000
ON-TIME (μs)	19	22	26	32	44	56	80	120	180

The output voltage is controlled by an external resistor ladder network (R1 and R2 in Figures 1, 2, and 3) that provides a feedback voltage to the comparator input. This feedback voltage is compared to the reference voltage of 1.2 V (relative to the substrate pin) by the high-gain comparator. When the output voltage decays below the value required to maintain 1.2 V at the comparator input, the comparator enables the oscillator circuit, which charges and discharges C_T as described above. The internal pass transistor is driven on during the charging of C_T. The internal transistor may be used directly for switching currents up to 500 mA. Its collector and emitter are uncommitted and it is current driven to allow operation from the positive supply voltage or ground. An internal Schottky diode matched to the current characteristics of the internal transistor is also available for blocking or commutating purposes. The TL497A also has on-chip current-limit circuitry that senses the peak currents in the switching regulator and protects the inductor against saturation and the pass transistor against overstress. The current limit is adjustable and is programmed by a single sense resistor, R_{CL}, connected between pin 14 and pin 13. The current-limit circuitry is activated when 0.7 V is developed across R_{CL}. External gating is provided by the inhibit input. When the inhibit input is high, the output is turned off.

Simplicity of design is a primary feature of the TL497A. With only six external components (three resistors, two capacitors, and one inductor), the TL497A will operate in numerous voltage conversion applications (step-up, step-down, invert) with as much as 85% of the source power delivered to the load. The TL497A replaces the TL497 in all applications.

The TL497AM is characterized for operation over the full military temperature range of −55°C to 125°C, the TL497AI is characterized for operation from −25°C to 85°C, and the TL497AC from 0°C to 70°C.

functional block diagram



† The Base pin (#11) and Base Drive pin (#12) are used for device testing only. They are not normally used in circuit applications of the device.

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Input voltage, V_{CC} (see Note 1)	15 V
Output voltage	35 V
Comparator input voltage	5 V
Inhibit input voltage	5 V
Diode reverse voltage	35 V
Power switch current	750 mA
Diode forward current	750 mA
Continuous total dissipation	See Dissipation Rating Table
Operating free-air temperature range: TL497AM	−55°C to 125°C
TL497AI	−25°C to 85°C
TL497AC	0°C to 70°C
Storage temperature range	−65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package	300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or N package	260°C

NOTE 1. All voltage values except diode voltages are with respect to network ground terminal.

DISSIPATION RATING TABLE

PACKAGE	$T_A \leq 25°C$ POWER RATING	DERATING FACTOR	DERATE ABOVE T_A	T_A = 70°C POWER RATING	T_A = 85°C POWER RATING	T_A = 125°C POWER RATING
D	950 mW	7.6 mW/°C	25°C	[illegible] mW	494 mW	
J (TL _ AM)	1000 mW	11.0 mW/°C	59°C	880 mW	715 mW	275 mW
J (TL _ AI)	1000 mW	8.2 mW/°C	28°C	656 mW	533 mW	
N	1000 mW	9.2 mW/°C	41°C	736 mW	598 mW	

recommended operating conditions

		MIN	MAX	UNIT
Input voltage, V_I		4.5	12	V
High-level inhibit input voltage, V_{IH}		2.5		V
Low-level inhibit input voltage, V_{IL}			0.8	V
Output voltage	Step-up configuration (see Figure 1)	$V_I + 2$	30	V
	Step-down configuration (see Figure 2)	V_{ref}	$V_I - 1$	
	Inverting regulator (see Figure 3)	$-V_{ref}$	−25	
Power switch current			[illegible]	mA
Diode forward current			[illegible]	mA

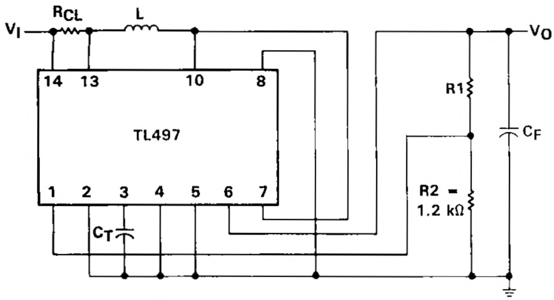
electrical characteristics at specified free-air temperature, V_I = 6 V (unless otherwise noted)

PARAMETER	TEST CONDITIONS†			TL497AM, TL497AI			TL497AC			UNIT
				MIN	TYP‡	MAX	MIN	TYP‡	MAX	
High-level inhibit input current	$V_{I(I)}$ = 5 V		Full range		0.8	1.5		0.8	1.5	mA
Low-level inhibit input current	$V_{I(I)}$ = 0 V		Full range		5	20		5	10	μA
Comparator reference voltage	V_I = 4.5 V to 6 V		Full range	1.14	1.20	1.26	1.08	1.20	1.32	V
Comparator input bias current	V_I = 6 V		Full range		40	100		40	100	μA
Switch on-state voltage	V_I = 4.5 V	I_O = 100 mA	25°C		0.13	0.2		0.13	0.2	V
		I_O = 500 mA	Full range			1			0.85	
Switch off-state current	V_I = 4.5 V, V_O = 30 V		25°C		10	50		10	50	μA
			Full range			500			[illegible]	
Current-limit sense voltage	V_I = 6 V		25°C	0.45		1	0.45		[illegible]	V
Diode forward voltage	I_O = 10 mA		Full range		0.75	0.95		0.75	0.85	V
	I_O = 100 mA		Full range		0.9	1.1		0.9	1	
	I_O = 500 mA		Full range		1.33	1.75		1.33	1.55	
Diode reverse voltage	I_O = 500 μA		Full range	30						V
	I_O = 200 μA		Full range				30			
On-state supply current			25°C		11	14		11	14	mA
			Full range			16			15	
Off-state supply current			25°C		6	9		6	9	mA
			Full range			11			10	

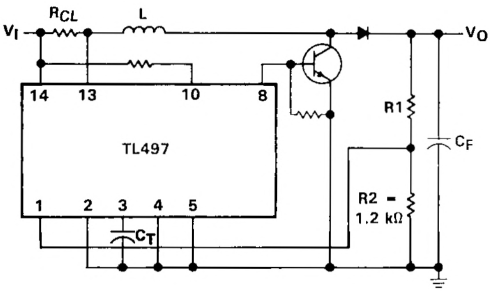
† Full range for TL497AM is −55°C to 125°C, for TL497AI is −25°C to 85°C, and for TL497AC is 0°C to 70°C.
‡ All typical values are at T_A = 25°C.

2 Data Sheets

TYPICAL APPLICATION DATA



BASIC CONFIGURATION
(I_{PK} < 500 mA)



EXTENDED POWER CONFIGURATION
(USING EXTERNAL TRANSISTOR)

FIGURE 1. POSITIVE REGULATOR, STEP-UP CONFIGURATIONS

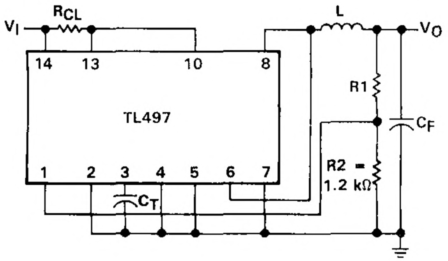
DESIGN EQUATIONS

- $I_{PK} = 2\, I_O \max \left[\frac{V_O}{V_I}\right]$
- $L\,(\mu H) = \frac{V_I}{I_{PK}}\, t_{on}(\mu s)$

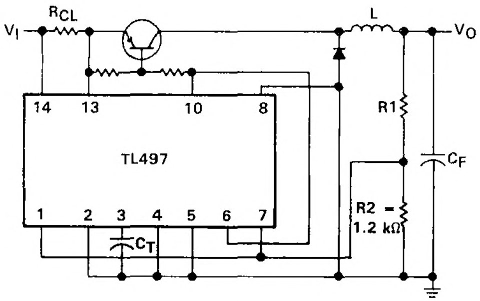
Choose L (50 to 500 µH), calculate t_{on} (25 to 150 µs)

- $C_T(pF) \approx 12\, t_{on}(\mu s)$
- $R1 = (V_O - 1.2)\ k\Omega$
- $R_{CL} = \frac{0.5\ V}{I_{PK}}$
- $C_F\,(\mu F) \approx t_{on}(\mu s)\, \frac{\left[\frac{V_I}{V_O} I_{PK} + I_O\right]}{V_{ripple}\,(PK)}$

TYPICAL APPLICATION DATA



BASIC CONFIGURATION
$I_{PK} < 500$ mA)



EXTENDED POWER CONFIGURATION
(USING EXTERNAL TRANSISTOR)

DESIGN EQUATIONS

- $I_{PK} = 2\ I_O$ max
- $L\ (\mu H) = \frac{V_I - V_O}{I_{PK}}\ t_{on}(\mu s)$

Choose L (50 to 500 μH), calculate t_{on} (10 to 150 μs)

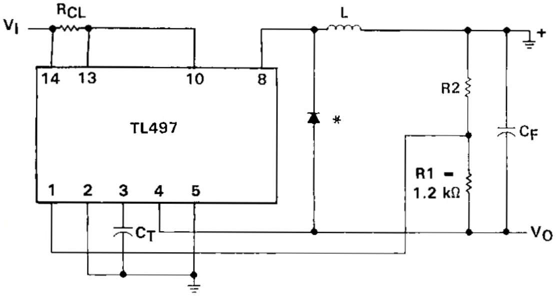
- $C_T(pF) \approx 12\ t_{on}(\mu s)$
- $R1 = (V_O - 1.2)\ k\Omega$
- $R_{CL} = \frac{0.5\ V}{I_{PK}}$
- $C_F(\mu F) \approx t_{on}(\mu s) \frac{\left[\frac{V_I}{V_O} I_{PK} + I_O\right]}{V_{ripple\ (PK)}}$

FIGURE 2. POSITIVE REGULATOR, STEP-DOWN CONFIGURATIONS

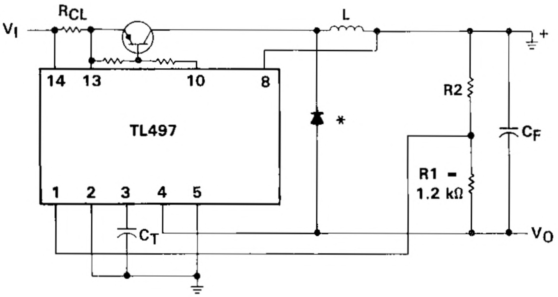
2

Data Sheets

TYPICAL APPLICATION DATA



BASIC CONFIGURATION
(I_{PK} < 500 mA)



EXTENDED POWER CONFIGURATION
(USING EXTERNAL TRANSISTOR)

- $I_{PK} = 2\, I_O \max \left[1 + \frac{|V_O|}{V_I}\right]$
- $L\ (\mu H) = \frac{V_I}{I_{PK}}\, t_{on}(\mu s)$

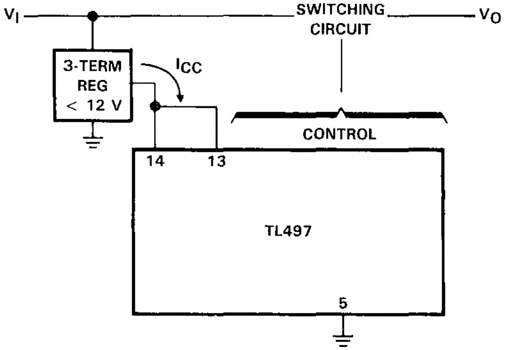
Choose L (50 to 500 μH), calculate t_{on} (25 to 150 μs)

- $C_T(pF) \approx 12\, t_{on}(\mu s)$
- $R2 = (V_O - 1.2)\ k\Omega$
- $R_{CL} = \frac{0.5\ V}{I_{PK}}$
- $C_F\ (\mu F) \approx t_{on}(\mu s)\ \frac{\left[\frac{V_I}{V_O}\ I_{PK} + I_O\right]}{V_{ripple\ (PK)}}$

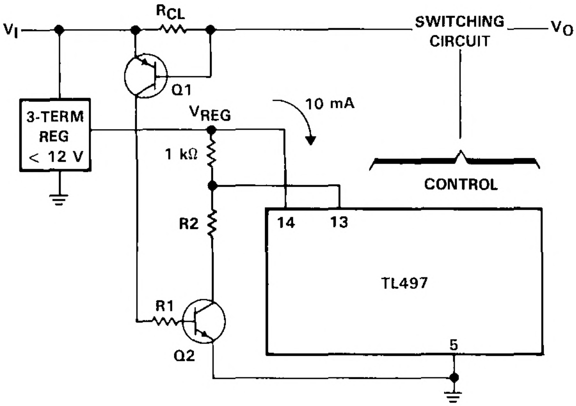
*Use external catch-diode, e.g., 1N4001, when building an inverting supply with the TL497A.

FIGURE 3. INVERTING APPLICATIONS

TYPICAL APPLICATION DATA



EXTENDED INPUT CONFIGURATION WITHOUT CURRENT LIMIT



CURRENT LIMIT FOR EXTENDED INPUT CONFIGURATION

DESIGN EQUATIONS

$$R_{CL} = \frac{V_{BE(Q1)}}{I_{limit\ (PK)}}$$

$$R1 = \frac{V_I}{I_{B(Q2)}}$$

$$R2 = (V_{reg} - 1)\ 10\ k\Omega$$

FIGURE 4. EXTENDED INPUT VOLTAGE RANGE (V_I > 15 V)

D2712, APRIL 1983 – REVISED OCTOBER 1988

- Complete PWM Power Control Circuitry
- Uncommitted Outputs for 200-mA Sink or Source Current
- Output Control Selects Single-Ended or Push-Pull Operation
- Internal Circuitry Prohibits Double Pulse at Either Output
- Variable Dead-Time Provides Control Over Total Range
- Internal Regulator Provides a Stable 5-V Reference Supply Trimmed to 1%
- Circuit Architecture allows Easy Synchronization
- Under-Voltage Lockout for Low V_{CC} Conditions
- TL595 has On-Chip 39-V Zener and External Control of Output Steering

TL594I, TL594C . . . D, J, OR N PACKAGE
(TOP VIEW)

ERROR AMP 1	NONINV INPUT	1	16	NONINV INPUT	ERROR AMP 2
	INV INPUT	2	15	INV INPUT	
	FEEDBACK	3	14	REF OUT	
	DEAD-TIME CONTROL	4	13	OUTPUT CONTROL	
	C_T	5	12	V_{CC}	
	R_T	6	11	C2	
	GND	7	10	E2	
	C1	8	9	E1	

TL595C . . . N
DUAL-IN-LINE PACKAGE
(TOP VIEW)

ERROR AMP 1	NONINV INPUT	1	18	NONINV INPUT	ERROR AMP 2
	INV INPUT	2	17	INV INPUT	
	FEEDBACK	3	16	REF OUT	
	DEAD-TIME CONTROL	4	15	V_Z	
	C_T	5	14	OUTPUT CONTROL	
	R_T	6	13	STEERING INPUT	
	GND	7	12	V_{CC}	
	C1	8	11	C2	
	E1	9	10	E2	

FUNCTION TABLE

INPUTS		OUTPUT FUNCTION
OUTPUT CONTROL	STEERING INPUT (TL595 ONLY)	
$V_I \leq 0$	Open	Single-ended or parallel output
$V_I \geq V_{ref}$	Open	Normal push-pull operation
$V_I \geq V_{ref}$	$V_I < 0$	PWM Output at Q1
$V_I \geq V_{ref}$	$V_I \geq V_{ref}$	PWM Output at Q2

description

The TL594 and TL595 devices each incorporates on a single monolithic chip all the functions required in the construction of a pulse-width-modulation control circuit. Designed primarily for power supply control, these devices offer the systems engineer the flexibility to tailor the power supply control circuitry to his application.

The TL594 contains two error amplifiers, an on-chip adjustable oscillator, a dead-time control comparator, pulse-steering control flip-flop, 5-V regulator with a precision of 1%, an under-voltage lockout control circuit, and output control circuitry.

The error amplifiers exhibit a common-mode voltage range from −0.3 V to V_{CC} −2 V. The dead-time control comparator has a fixed offset that provides approximately 5% dead time when externally altered. The on-chip oscillator may be bypassed by terminating R_T (pin 6) to the reference output and providing a sawtooth input to C_T (pin 5), or it may be used to drive the common circuitry in synchronous multiple-rail power supplies.

The uncommitted output transistors provide either common-emitter or emitter-follower output capability. Each device provides for push-pull or single-ended output operation with selection by

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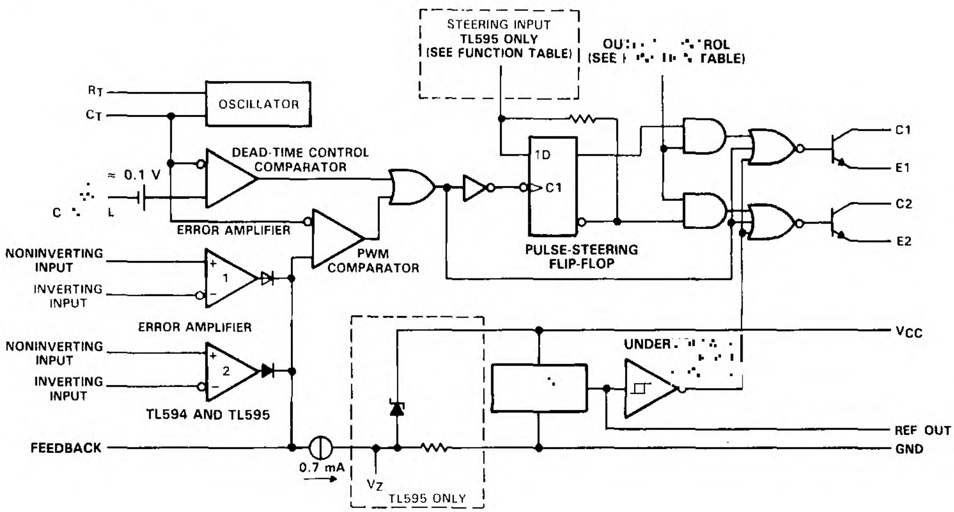
description (continued)

means of the output-control function. The architecture of these devices prohibits the possibility of either output being pulsed twice during push-pull operation. The undervoltage lockout control circuit locks the outputs off until the internal circuitry is operational.

The TL595 provides the identical functions found in the TL594. In addition, the TL595 also contains an on-chip 39-V zener diode for high-voltage applications where V_{CC} is greater than 40 V, and an output steering control that overrides the internal control of the pulse-steering flip-flop.

The TL594I is characterized for operation from −25°C to 85°C. The TL594C and TL595C are characterized for operation from 0°C to 70°C.

functional block diagram



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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

	TL594I	TL594C TL595C	UNIT
Supply voltage, V_{CC} (see Note 1)	41	41	V
Amplifier input voltages	$V_{CC}+0.3$	$V_{CC}+0.3$	V
Collector output voltage	41	41	V
Collector output current	250	250	mA
Continuous total dissipation	See Dissipation Rating Table		
Operating free-air temperature range	−25 to 85	0 to 70	°C
Storage temperature range	−65 to 150	−65 to 150	°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package	300	300	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or N package	260	260	°C

NOTE 1: All voltage values, except differential voltages, are with respect to the network ground terminal.

DISSIPATION RATING TABLE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR	DERATE ABOVE T_A	$T_A = 70°C$ POWER RATING	$T_A = 85°C$ POWER RATING
D	950 mW	7.6 mW/°C	25°C	608 mW	494 mW
J	1000 mW	8.2 mW/°C	28°C	656 mW	533 mW
N	1000 mW	9.2 mW/°C	41°C	736 mW	598 mW

recommended operating conditions

	TL594I		TL594C TL595C		UNIT
	MIN	MAX	MIN	MAX	
Supply voltage, V_{CC}	7	40	7	40	V
Amplifier input voltages, V_I	−0.3	$V_{CC}-2$	−0.3	$V_{CC}-2$	V
Collector output voltage, V_O		40		40	V
Collector output current (each transistor)		200		200	mA
Current into feedback terminal		0.3		0.3	mA
Timing capacitor, C_T	0.47	10 000	0.47	10 000	nF
Timing resistor, R_T	1.8	500	1.8	500	kΩ
Oscillator frequency	1	300	1	300	kHz
Operating free-air temperature, T_A	−25	85	0	70	°C

electrical characteristics over recommended operating free-air temperature range, V_{CC} = 15 V (unless otherwise noted)

reference section

PARAMETER	TEST CONDITIONS†		MIN	TYP‡	MAX	UNIT
Output voltage (V_{ref})	I_O = 1 mA,	T_A = 25°C	4.95	5	5.05	V
Input regulation	V_{CC} = 7 V to 40 V,	T_A = 25°C		2	25	mV
Output regulation	I_O = 1 to 10 mA,	T_A = 25°C		14	35	mV
Output voltage change with temperature	ΔT_A = MIN to MAX			0.2%	1%	
Short-circuit output current§	V_{ref} = 0		10	35	50	mA

oscillator section (see Figure 2)

PARAMETER	TEST CONDITIONS†		MIN	TYP‡	MAX	UNIT
Frequency				10		kHz
Standard deviation of frequency¶	All values of V_{CC}, C_T, R_T, T_A constant			10%		
F[illegible] voltage	V_{CC} = 7 V to 40 V,	T_A = 25°C		0.1%		
F[illegible] temperature	ΔT_A = MIN to MAX					

amplifier sections (see Figure 1)

PARAMETER	TEST CONDITIONS		MIN	TYP‡	MAX	UNIT
Input offset voltage, error amplifier	Feedback pin at 2.5 V			2	10	mV
Input offset current	Feedback control at 2.5 V			25	250	nA
Input bias current	Feedback control at 2.5 V			0.2	1	µA
Common-mode input voltage range, error amplifier	V_{CC} = 7 V to 40 V		−0.3 to V_{CC}−2			V
Open-loop voltage amplification, error amplifier	ΔV_O = 3 V, R_L = 2 kΩ	V_O = 0.5 V to 3.5 V	70	95		dB
Unity-gain bandwidth	V_O = 0.5 V to 3.5 V,	R_L = 2 kΩ		800		kHz
Common-mode rejection ratio, error amplifier	V_{CC} = 40 V,	T_A = 25°C	65	80		dB
Output sink current (pin 3)	V_{ID} = −15 mV to −5 V,	Feedback control at 0.5 V	0.3	0.7		mA
Output cource current (pin 3)	V_{ID} = 15 mV to 5 V,	Feedback at 3.5 V	−2			mA

† For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.
‡ All typical values except for parameter changes with temperature are at T_A = 25°C.
§ Duration of the short-circuit should not exceed one second.
¶ Standard deviation is a measure of the statistical distribution about the mean as derived from the formula

$$\sigma = \sqrt{\frac{\sum_{n=1}^{N}(x_n - \overline{X})^2}{N-1}}$$

electrical characteristics over recommended operating free-air temperature range, V_{CC} = 15 V (unless otherwise noted)

dead-time control section (see Figure 2)

PARAMETER	TEST CONDITIONS	MIN	TYP†	MAX	UNIT
Input bias current (pin 4)	V_I = 0 to 5.25 V		−2	−10	µA
Maximum duty cycle, each output	Dead-time control at 0 V	45%			
Input threshold voltage (pin 4)	Zero duty cycle		3	3.3	V
	Maximum duty cycle	0			

output section

		TEST CONDITIONS		MIN	TYP†	MAX	UNIT
Collector off-state current		V_{CE} = 40 V,	V_{CC} = 40 V		2	100	µA
		V_C = 15 V, V_{CC} = 1 to 3 V, Dead-time and output control pins at 0 V	V_E = 0 V,		4	200	
Emitter off-state current		V_{CC} = V_C = 40 V,	V_E = 0			−100	µA
Collector-emitter saturation voltage	Common-emitter	V_E = 0,	I_C = 200 mA		1.1	1.3	V
	Emitter-follower	V_C = 15 V,	I_E = −200 mA		1.5	2.5	
Output control input current		V_I = V_{ref}				3.5	mA

pwm comparator section (see Figure 2)

PARAMETER	TEST CONDITIONS	MIN	TYP†	MAX	UNIT
Input threshold voltage (pin 3)	Zero duty cycle		4	4.5	V
Input sink current (pin 3)	$V_{(pin\ 3)}$ = 0.5 V	0.3	0.7		mA

under-voltage lockout section (see Figure 2)

PARAMETER	TEST CONDITION‡	MIN	MAX	UNIT
Threshold voltage	T_A = 25°C		6	V
	ΔT_A = MIN to MAX	3.5	6.9	
Hysteresis§		100		mV

total device (see Figure 2)

PARAMETER	TEST CONDITIONS		MIN	TYP†	MAX	UNIT
Standby supply current	Pin 6 at V_{ref}, All other inputs and outputs open	V_{CC} = 15 V		9	15	mA
		V_{CC} = 40 V		11	18	
Average supply current	Dead-time Control at 2 V, See Figure 2			12.4		mA

† All typical values except for parameter changes with temperature are at T_A = 25°C.
‡ For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.
§ Hysteresis is the difference between the positive-going input threshold voltage and the negative-going input threshold voltage.

switching characteristics, $T_A = 25°C$

PARAMETER	TEST CONDITIONS	MIN	TYP†	MAX	UNIT
Output voltage rise time	Common-emitter configuration,		100	200	ns
Output voltage fall time	See Figure 3		30	100	
Output voltage rise time	Emitter-follower configuration,		200	400	ns
Output voltage fall time	See Figure 4		45	100	

† All typical values are at $T_A = 25°C$.

PARAMETER MEASUREMENT INFORMATION

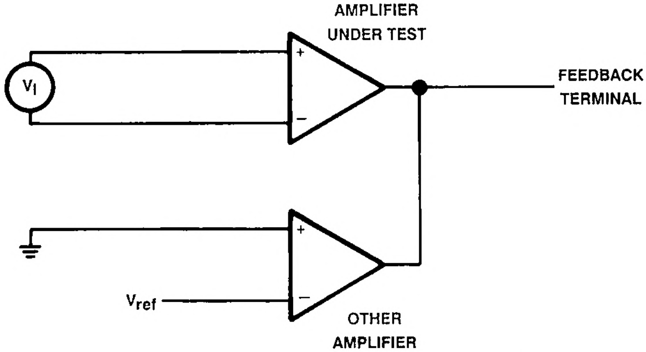

FIGURE 1. AMPLIFIER CHARACTERISTICS

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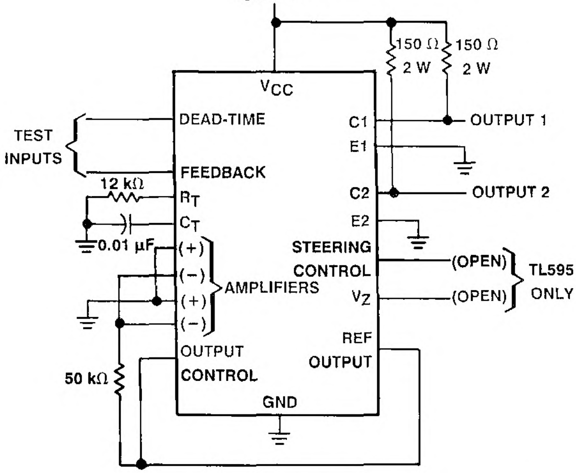
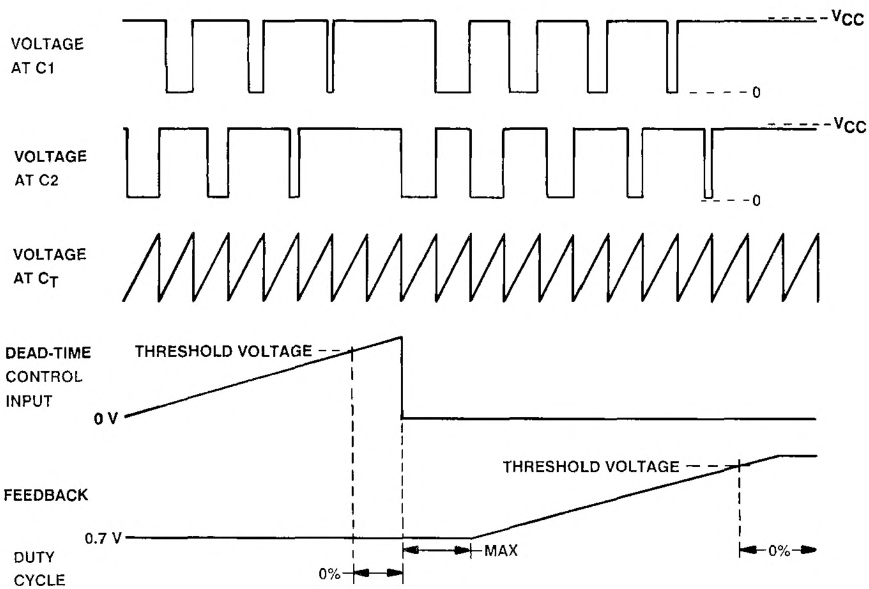
PARAMETER MEASUREMENT INFORMATION



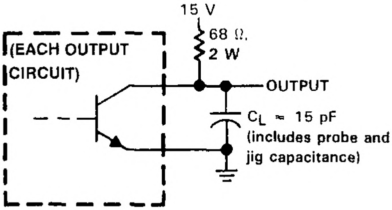
TEST CIRCUIT



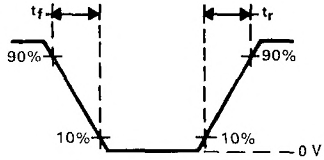
VOLTAGE WAVEFORMS

FIGURE 2. OPERATIONAL TEST CIRCUIT AND WAVEFORMS

PARAMETER MEASUREMENT INFORMATION

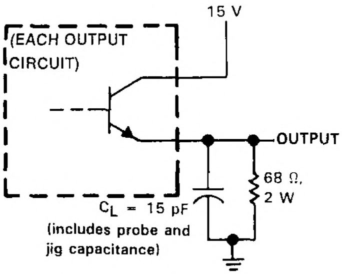


TEST CIRCUIT

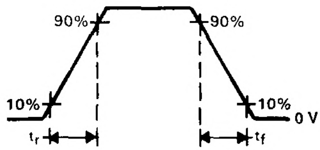


OUTPUT VOLTAGE WAVEFORM

FIGURE 3. COMMON-EMITTER CONFIGURATION



TEST CIRCUIT



OUTPUT VOLTAGE WAVEFORM

FIGURE 4. EMITTER-FOLLOWER CONFIGURATION

TYPICAL CHARACTERISTICS

OSCILLATOR FREQUENCY and FREQUENCY VARIATION† vs TIMING RESISTANCE

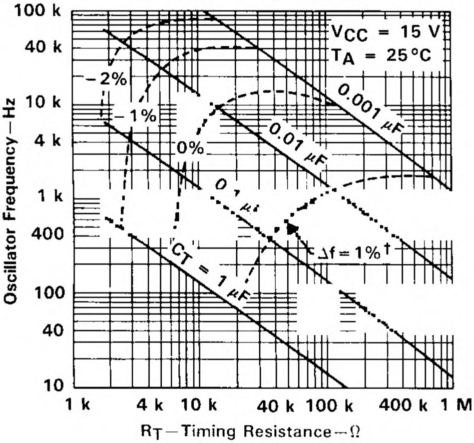


FIGURE 5

AMPLIFIER VOLTAGE AMPLIFICATION vs FREQUENCY

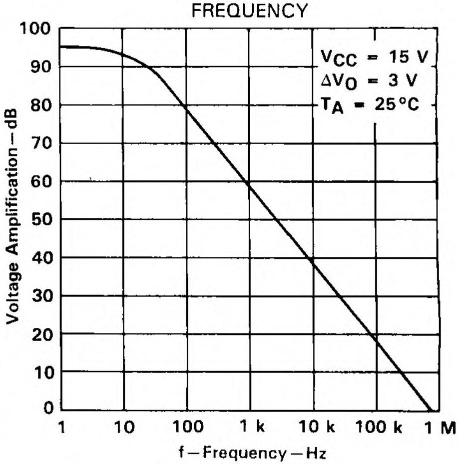


FIGURE 6

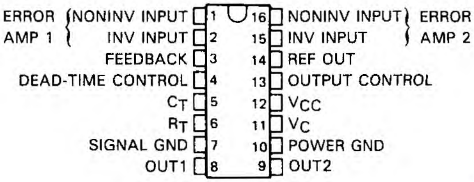
† Frequency variation (Δf) is the change in oscillator frequency that occurs over the full temperature range.

2 Data Sheets

D3026, FEBRUARY 1988—REVISED OCTOBER 1988

- **Complete PWM Power Control Function**
- **Totem-Pole Outputs for 200-mA Sink or Source Current**
- **Output Control Selects Parallel or Push-Pull Operation**
- **Internal Circuitry Prohibits Double Pulse at Either Output**
- **Variable Dead-Time Provides Control Over Total Range**
- **Internal Regulator Provides a Stable 5-V Reference Supply, Trimmed to 1% Tolerance**
- **On-Board Output Current-Limiting Protection**
- **Under-Voltage Lockout for Low V_{CC} Conditions**
- **Independent Power and Signal Grounds**
- **TL598Q Has Extended Temperature Range . . . −40°C to 125°C**

D, J, OR N PACKAGE
(TOP VIEW)



FUNCTION TABLE

INPUT OUTPUT CONTROL	OUTPUT FUNCTION
V_I = GND	Single-ended or parallel output
V_I = V_{ref}	Normal push-pull operation

description

The TL598 incorporates all the functions required in the construction of pulse-width-modulated controlled systems on a single monolithic chip. Designed primarily for power supply control, the TL598 provides the systems engineer with the flexibility to tailor the power supply control circuits to a specific application.

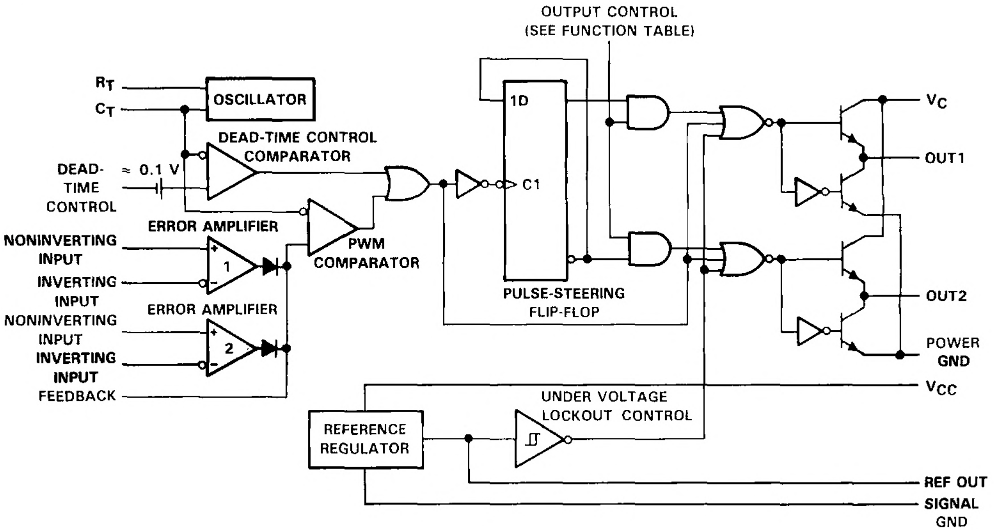
The TL598 contains two error amplifiers, an internal oscillator (externally adjustable), a dead-time control comparator, a pulse-steering flip-flop, a 5-V precision reference, an under-voltage lockout control, and output control circuits. Two totem-pole outputs provide exceptional rise and fall time performance for power FET control. The outputs are designed with the collectors sharing a common source supply and common power grounds and are independent of V_{CC} and signal ground.

The error amplifier has a common-mode voltage range from −0.3 V to V_{CC} −2 V. The dead-time control comparator has a fixed offset that prevents overlap of the outputs during push-pull operation. Synchronous multiple supply operation may be achieved by connecting pin 6 to the reference output and providing a sawtooth input to pin 5.

The TL598 device provides an output control function to select either push-pull or parallel operation. Circuit architecture prevents either output from being pulsed twice during push-pull operation.

The TL598Q is characterized for operation from −40°C to 125°C. The TL598C is characterized for operation from 0°C to 70°C.

logic diagram (positive logic)



2

Data Sheets

absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, V_{CC} (see Note 1)	41 V
Amplifier input voltage, V_I	$V_{CC}+0.3$ V
Collector voltage	41 V
Output current (each output), sink or source, I_O	250 mA
Continuous total dissipation	See Dissipation Rating Table
Operating virtual junction temperature range, T_J: TL598Q	−40°C to 150°C
TL598C	0°C to 150°C
Storage temperature range	−65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package	300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or N package	260°C

NOTE 1: All voltage values, except differential voltages, are with respect to the network ground terminal.

DISSIPATION RATING TABLE

PACKAGE	POWER RATING	DERATING FACTOR	ABOVE T_A	T_A = 70°C POWER RATING	T_A = 125°C POWER RATING
D	950 mW	7.6 mW/°C	25°C	608 mW	190 mW
N	1200 mW	13 mW/°C	58°C	1040 mW	325 mW

recommended operating conditions

		MIN	MAX	UNIT
Supply voltage, V_{CC}		7	40	V
Amplifier input voltage, V_I		−0.3	$V_{CC}-2$	V
Collector voltage			40	V
Output current (each output), sink or source, I_O			200	mA
Current into feedback terminal, I_{IL}			0.3	mA
Timing capacitor, C_T		[illegible]	10	µF
Timing resistor, R_T		1.8	500	kΩ
Oscillator frequency, f_{osc}		1	300	kHz
Free-air temperature, T_A	TL598Q	−40	[illegible]	°C
	TL598C	0	70	°C

2 Data Sheets

electrical characteristics over recommended operating free-air temperature range, V_{CC} = 15 V, f = 10 kHz (unless otherwise noted), see Note 2

reference section

PARAMETER	TEST CONDITIONS†		[illegible]			TL598C			UNIT
			MIN	[illegible]	[illegible]	[illegible]	TYP‡	[illegible]	
Output voltage (V_{ref})	I_O = 1 mA,	T_A = 25°C	4.95	5	[illegible]	[illegible]	5	[illegible]	V
		T_A = MIN to MAX	4.9		5.1	4.9		5.1	
Input regulation	V_{CC} = 7 V to 40 V,	T_A = [illegible]		2	22		2	25	mV
Output regulation	I_O = 1 to 10 mA,	T_A = 25°C		1	15		1	15	mV
		T_A = MIN to MAX			80				
Output voltage change with temperature	ΔT_A = MIN to MAX			0.2	1		0.2	1	%
Short-circuit output current§	V_{ref} = 0		−10	−35		−10	−35		mA

oscillator section (see Figure 1) C_T = 0.001 μF, R_T = 12 kΩ

PARAMETER	TEST CONDITIONS†	MIN	TYP‡	MAX	UNIT
Frequency			[illegible]		kHz
Standard deviation of frequency¶	All values of V_{CC}, C_T, R_T, T_A constant		10		%
Frequency change with voltage	V_{CC} = 7 V to 40 V, T_A = 25°C		0.1	1	%
Frequency change with temperature#	ΔT_A = MIN to MAX		2	5	%

error amplifier section

PARAMETER	TEST CONDITIONS		MIN	TYP‡	MAX	UNIT
Input offset voltage	Feedback pin at 2.5 V			2	10	mV
Input offset current	Feedback pin at 2.5 V			25	250	nA
Input bias current	Feedback pin at 2.5 V			0.2	1	μA
Common-mode input voltage range	V_{CC} = 7 V to 40 V		−0.3 to $V_{CC}-2$			V
Open-loop voltage amplification	ΔV_O (pin 3) = 3 V,	V_O (pin 3) = 0.5 V to 3.5 V	70	95		dB
Unity-gain bandwidth				800		kHz
Common-mode rejection ratio	V_{CC} = 40 V,	ΔV_{IC} = 36.5 V, T_A = 25°C	65	80		dB
Output sink current (pin 3)	Feedback pin at 0.5 V		0.3	0.7		mA
Output source current (pin 3)	Feedback pin at 3.5 V		−2			mA
Phase margin at unity gain	Feedback pin = 0.5 V to 3.5 V, R_L = 2 kΩ			65°		
Supply voltage rejection ratio	Feedback pin at 2.5 V,	ΔV_{CC} = 33 V, R_L = 2 kΩ		[illegible]		dB

† For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.
‡ All typical values except for parameter changes with temperature are at T_A = 25°C.
§ Duration of the short-circuit should not exceed one second.
¶ Standard deviation is a measure of the statistical distribution about the mean as derived from the formula $\sigma = \sqrt{\frac{\sum_{n=1}^{N} (x_n - X)^2}{N-1}}$
# Effects of temperature on external R_T and C_T are not taken into account.

NOTE 2: Pulse testing techniques must be used that will maintain the junction temperature as close to the ambient temperature as possible.

electrical characteristics over recommended operating free-air temperature range, V_{CC} = 15 V, f = 10 kHz (unless otherwise noted), see Note 2

under-voltage lockout section

PARAMETER	TEST CONDITIONS†	TL598Q		TL598C		UNIT
		MIN	MAX	MIN	MAX	
Threshold voltage	T_A = 25°C	4	6	4	6	V
	ΔT_A = MIN to MAX	3.8	6.9	3	6.9	
Hysteresis‡	T_A = 25°C	100		100		mV
	T_A = MIN to MAX	30		50		

output section

PARAMETER	TEST CONDITIONS		MIN	TYP§	MAX	UNIT
Collector off-state current	V_{CE} = 40 V, Dead-time pin is connected to REF	V_{CC} = 40 V,		2	100	µA
High-level output voltage	V_{CC} = 15 V,	I_O = −200 mA	12			V
	V_C = 15 V,	I_O = −20 mA	13			
Low-level output voltage	V_{CC} = 15 V,	I_O = 200 mA			2	V
	V_C = 15 V,	I_O = 20 mA			0.4	
Output control input current	V_I = V_{ref}				3.5	mA
	V_I = 0.4 V				100	µA

dead-time control section (see Figure 1)

PARAMETER	TEST CONDITIONS	TL598Q			TL598C			UNIT
		MIN	TYP§	MAX	MIN	TYP§	MAX	
Input bias current (pin 4)	V_I = 0 to 5.25 V		−2	−25		−2	−10	µA
Maximum duty cycle, each output	Dead-time control at 0 V	45			45			%
Input threshold voltage (pin 4)	Zero duty cycle		3	3.2		3	3.3	V
	Maximum duty cycle	0			0			

pwm comparator section

PARAMETER	TEST CONDITIONS	MIN	UNIT
Input threshold voltage (pin 3)	Zero duty cycle		V
Input sink current (pin 3)	$V_{(pin\ 3)}$ = 0.5 V	0.3	mA

total device (see Figure 1)

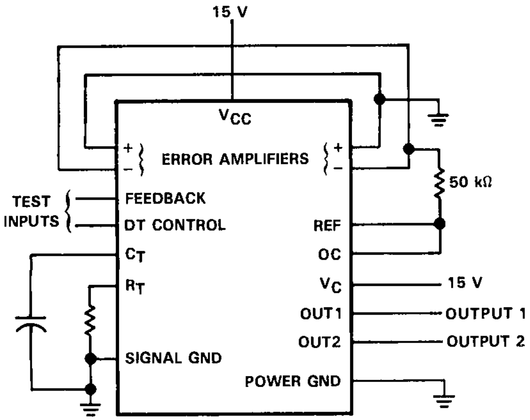
PARAMETER	TEST CONDITIONS		MIN	TYP§	MAX	UNIT
Standby supply current	Pin 6 at V_{ref}, All other inputs and outputs open	V_{CC} = 15 V		15	21	mA
		V_{CC} = 40 V		17	23	
Average supply current	Dead-time control at 2 V			15		mA

†For conditions shown as MIN or MAX, use the appropriate value specified under recommended operating conditions.
‡Hysteresis is the difference between the positive-going input threshold voltage and the negative-going input threshold voltage.
§All typical values except for parameter changes with temperature are at T_A = 25°C
NOTE 2: Pulse testing techniques must be used that will maintain the junction temperature as close to the ambient temperature as possible.

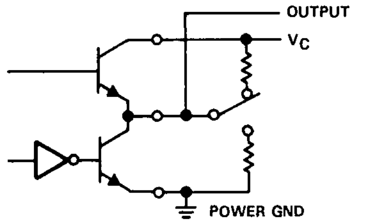
switching characteristics, T_A = 25°C

PARAMETER	TEST CONDITIONS		MIN	TYP	MAX	UNIT
Output voltage rise time	C_L = 1500 pF,			100	150	ns
Output voltage fall time	V_C = 15 V,	V_{CC} = 15 V, See Figure 2		50	75	ns

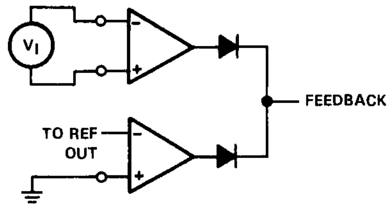
PARAMETER MEASUREMENT INFORMATION



MAIN DEVICE TEST CIRCUIT

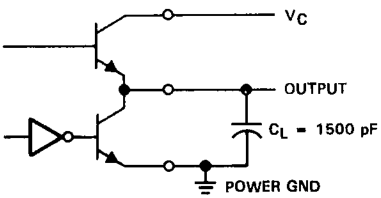


OUTPUT CONFIGURATION

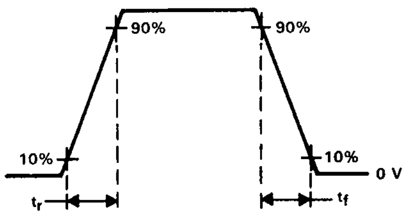


ERROR AMPLIFIER TEST CIRCUIT

FIGURE 1. TEST CIRCUITS



OUTPUT CONFIGURATION



OUTPUT VOLTAGE WAVEFORM

FIGURE 2. SWITCHING OUTPUT CONFIGURATION AND VOLTAGE WAVEFORM

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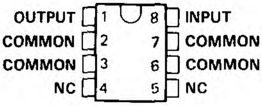
D3017, SEPTEMBER 1987—REVISED FEBRUARY 1988

- Very Low Dropout Voltage, Less than 0.6 V at 150 mA
- Very Low Quiescent Current
- TTL- and CMOS-Compatible Enable On TL751L Series
- 60-V Load-Dump Protection
- Reverse Transient Protection to −50 V
- Internal Thermal Overload Protection
- Over-Voltage Protection
- Internal Over-Current Limiting Circuitry

terminal assignments

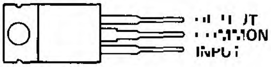
TL750L . . . D
SMALL OUTLINE PACKAGE

(TOP VIEW)



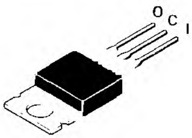
TL750L . . . KC
HEAT-SINK-MOUNTED PACKAGE

(TOP VIEW)



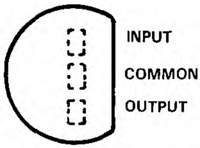
THE COMMON TERMINAL IS IN ELECTRICAL CONTACT WITH THE MOUNTING BASE

TO-220AB



TL750L . . . LP
SILECT™ PACKAGE

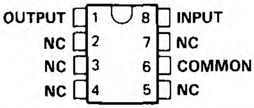
(TOP VIEW)

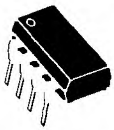


TO-226AA

TL750L . . . P
DUAL-IN-LINE PACKAGE

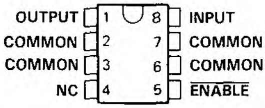
(TOP VIEW)





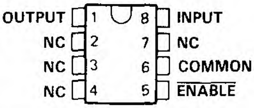
TL751L . . . D
SMALL OUTLINE PACKAGE

(TOP VIEW)



TL751L . . . P
DUAL-IN-LINE PACKAGE

(TOP VIEW)



NC—No internal connection
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description

The TL750L and TL751L series are low-dropout positive voltage regulators specifically designed for battery-powered systems. The TL750L and the TL751L incorporate over-voltage and current-limiting protection circuitry along with internal reverse-battery protection circuitry to protect both itself and the regulated system. Both series are fully protected against 60-volt load-dump and reverse-battery conditions. Extremely low quiescent current during full-load conditions makes the TL750L and TL751L series ideal for standby power systems.

The TL750L series of fixed-output voltage regulators offer 5-volt, 8-volt, 10-volt, and 12-volt options. They are available in TO-226AA (formerly TO-92) (LP) packages, TO-220AB (KC) packages, 8-pin "small outline" plastic packages (D), and 8-pin plastic dual-in-line packages (P).

The TL751L series of fixed-output voltage regulators also offer 5-volt, 8-volt, 10-volt, and 12-volt options with the addition of an enable input. The enable input, when taken high, places the regulator output in a high-impedance state. This gives the designer complete control over power up, power down, or emergency shut down. This series is offered in the 8-pin "small outline" plastic package and the 8-pin plastic dual-in-line package.

absolute maximum ratings over operating junction temperature range (unless otherwise noted)

		TL750L	TL751L	UNIT
Continuous input voltage		26	26	V
Transient input voltage, T_A = 25°C (see Note 1)		60	60	V
Continuous reverse input voltage		−15	−15	V
Transient reverse input voltage: t ≤ 100 ms		−50	−50	V
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 1):	D package	[illegible]	825	mW
	KC package	[illegible]		
	LP package	[illegible]		
	P package	1000	1000	
Operating virtual junction temperature range		−40 to 150	−40 to 150	°C
Storage temperature range		−65 to [illegible]	−65 to 150	°C
Lead temperature 1,6 mm (1/16 inch) for 10 seconds		[illegible]	[illegible]	°C

NOTES: 1. The transient input voltage rating applies for the waveform described in Figure 1.
2. For operation above 25°C free-air temperature, linearly derate the D package at the rate of 6.6 mW/°C, the KC package at 15.2 mW/°C, the LP package at 6.2 mW/°C, and the P package at 8 mW/°C.

recommended operating conditions over recommended operating junction temperature range (unless otherwise noted)

		MIN	MAX	UNITS
Input voltage, V_I	TL75_[illegible]	6	26	V
	TL75_L08	9	26	
	TL75_L10	11	26	
	TL75_L12	13	26	
High-level $\overline{\text{ENABLE}}$ input voltage, V_{IH}	TL751L	2	15	V
Low-level $\overline{\text{ENABLE}}$ voltage, V_{IL}†	TL751L	−0.3	0.8	V
Output current, I_O	TL75_L	0	[illegible]	mA
Operating virtual junction temperature, T_J	TL75_L_C	0	[illegible]	°C
	TL75_L_Q	−40	[illegible]	

†The algebraic convention, in which the least positive (most negative) value is designated minimum, is used in this data sheet for $\overline{\text{ENABLE}}$ voltage levels and temperature only.

TL750L05 and TL751L05 electrical characteristics at 25 °C virtual junction temperature, V_I = 14 V, I_O = 10 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		MIN	TYP	MAX	UNIT
Output voltage	V_I = 6 V to 26 V,	T_J = 25 °C	4.80	5	5.2	V
	I_O = 0 to 150 mA	T_J = T_J min to 125 °C	4.75		5.25	
Input regulation	V_I = 9 V to 16 V			5	10	mV
	V_I = 6 V to 26 V			6	30	
Ripple rejection	V_I = 8 V to 1[illegible] V	f = 120 Hz	60	65		dB
Output regulation	I_O = 5 mA t[illegible] mA			20	50	mV
Dropout voltage	I_O = 10 mA				0.2	V
	I_O = 150 mA				0.6	
Output noise voltage	f = 1[illegible] H[illegible] to 100 kHz			[illegible]		μV
Bias current	I_O = [illegible] mA			[illegible]	12	mA
	V_I = 6 V to 26 V, I_O = 10 mA,	T_J = T_J min to 125 °C		1	2	

TL750L08 and TL751L08 electrical characteristics at 25 °C virtual junction temperature, V_I = 14 V, I_O = 10 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		MIN	TYP	MAX	UNIT
Output voltage	V_I = 9 V to 26 V,	T_J = 25 °C	7.8	8	8.2	V
	I_O = 0 to 150 mA	T_J = T_J min to [illegible] C	7.6		8.4	
Input regulation	V_I = 10 V to 17 V			10	20	mV
	V_I = 9 V to 26 V			25	50	
Ripple rejection	V_I = 11 V to 21 V,	f = 120 Hz	60	65		dB
Output regulation	I_O = 5 mA to 150 mA			40	80	mV
Dropout voltage	I_O = 1[illegible] mA				0.2	V
	I_O = [illegible] mA				0.6	
Output noise voltage	f = 1[illegible] to 100 kHz					μV
Bias current	I_O = 150 mA			[illegible]	12	mA
	V_I = 9 V to 26 V, I_O = 10 mA,	T_J = T_J min to 125 °C		1	2	

TL750L10 and TL751L10 electrical characteristics at 25 °C virtual junction temperature, V_I = 14 V, I_O = 10 mA (unless otherwise noted)

PARAMETER	TEST CON[illegible]NS†		MIN	TYP	MAX	UNIT
Output voltage	V_I = 11 V to 26 V,	T_J = [illegible]	9.75	10	10.25	V
	I_O = 0 to 150 mA	T_J = T_J min to [illegible] C	9.50		10.50	
Input regulation	V_I = 12 V to 19 V			10	25	mV
	V_I = 11 V to 26 V			30	60	
Ripple rejection	V_I = 12 V to [illegible] V	f = 120 Hz	60	65		dB
Output regulation	I_O = 5 mA to [illegible] mA			50	100	mV
Dropout voltage	I_O = 10 mA				0.2	V
	I_O = 150 mA				0.6	
Output noise voltage	f = 1[illegible] H[illegible] to [illegible] kHz			700		μV
Bias current	I_O [illegible] mA			10	12	mA
	V_I = [illegible] to 26 V, I_O = 10 mA,	T_J = T_J min 125 °C		1	2	

†Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.1-μF capacitor across the input and a 10-μF capacitor, with equivalent series resistance of less than 1 ohm, across the output.

TL750L12 and TL751L12 electrical characteristics at 25 °C virtual junction temperature, V_I = 14 V, I_O = 10 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		MIN	TYP	MAX	UNIT
Output voltage	V_I = 13 V to 26 V,	T_J = [illegible]	[illegible]	12	12.3	V
	I_O = 0 to 150 mA	T_J = T_J min to 125 °C	11.4		12.6	
Input regulation	V_I = 14 V to 19 V			15	30	mV
	V_I = 13 V to 26 V			20	40	
Ripple rejection	V_I = 13 V to 23 V,	f = 120 Hz	50	55		dB
Output regulation	I_O = 5 mA to 150 mA			50	120	mV
Dropout voltage	I_O = 10 mA				0.2	V
	I_O = [illegible] mA				0.6	
Output noise voltage	f = [illegible] to 100 kHz			700		μV
Bias current	I_O = 150 mA			10	12	mA
	V_I = 13 V to 26 V, I_O = 10 mA,	T_J = T_J min to 125 °C		1	2	

†Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.1-μF capacitor across the input and a 10-μF capacitor, with equivalent series resistance of less than 1 ohm, across the output.

ABSOLUTE MAXIMUM RATINGS

TRANSIENT INPUT VOLTAGE
vs
TIME

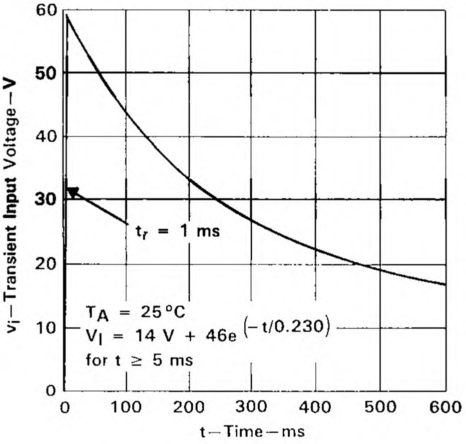


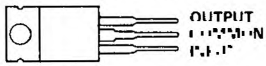
FIGURE 1

D3017, JANUARY 1988—REVISED OCTOBER 1988

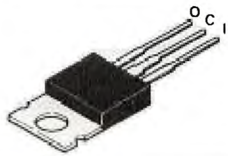
- Very Low Dropout Voltage, Less than 0.6 V at 750 mA
- Low Quiescent Current
- TTL- and CMOS-Compatible Enable on TL751M Series
- 60-V Load-Dump Protection
- Over-Voltage Protection
- Internal Thermal Overload Protection
- Internal Over-Current Limiting Circuitry

3-LEAD KC (TO-220AB) PACKAGE

(TOP VIEW)

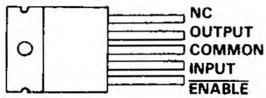


THE COMMON TERMINAL IS IN ELECTRICAL CONTACT WITH THE MOUNTING BASE



5-LEAD KC PACKAGE

(TOP VIEW)



GROUND TERMINAL IS IN ELECTRICAL CONTACT WITH MOUNTING BASE

description

The TL750M and TL751M series are low-dropout positive voltage regulators specifically designed for battery-powered systems. The TL750M and TL751M incorporate on-board over-voltage and current-limit protection circuitry to protect both themselves and the regulated system. Both series are fully protected against 60-V load-dump and reverse battery conditions. Extremely low quiescent current, even during full-load conditions, makes the TL750M and TL751M series ideal for standby power systems.

The TL750M series of fixed-output voltage regulators offer 5-V, 8-V, 10-V, and 12-V options available in 3-lead KC (TO-220AB) plastic packages.

The TL751M series of fixed-output voltage regulators also offer 5-V, 8-V, 10-V, and 12-V options with the addition of an enable input. The enable input gives the designer complete control over power-up, allowing for sequential power-up or emergency shutdown. When taken high, the enable input places the regulator output in a high-impedance state. It is completely TTL- and CMOS-compatible. The TL751M series is offered in 5-lead KC plastic packages.

The TL750M and TL751M series are characterized for operation from −40°C to 125°C free-air temperature.

TEXAS INSTRUMENTS

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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Continuous input voltage	26 V
Transient input voltage (see Figure 1)	60 V
Continuous reverse input voltage	−15 V
Transient reverse input voltage: t = 100 ms	−50 V
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 1)	2 W
Continuous total dissipation at (or below) 25°C case temperature (see Note 1)	20 W
Operating free-air, case, or virtual junction temperature	−40°C to 150°C
Storage temperature range	−65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C

Note 1: For operation above 25°C free-air temperature, refer to Figures 2 and 3. To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variation in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

recommended operating conditions over recommended operating free-air temperature range (unless otherwise noted)

	DEVICE	MIN	MAX	UNITS
Input voltage range, V_I	TL75_M05	6	26	V
	TL75_[illegible]	9	26	
	TL75_M1[illegible]	11	26	
	TL75_M12	13	26	
High-level ENABLE input voltage, V_{IH}	TL751M_	2	15	V
Low-level [illegible]BLE input voltage, V_{IL} (see Note 2)	TL751M_	−0.3	0.8	
Output current range, I_O	TL75_M		750	mA
Operating virtual junction temperature range, T_J	TL75_M_C	0	[illegible]	°C
	TL75_M_Q	−40	[illegible]	

Note 2: The [illegible]ic convention, in which the least positive (most negative) value is designated minimum, is used in this data sheet for [illegible] voltage levels and temperature only.

TL750M05 and TL751M05 electrical characteristics at 25°C free-air temperature, V_I = 14 V, I_O = 300 mA, ENABLE at 0 V for TL751M05 (unless otherwise noted)

PARAMETER	TEST CONDITIONS (see Note 3)		MIN	TYP	MAX	UNIT
Output voltage	V_I = 6 V to 26 V, I_O = 0 to 750 mA	T_A = 25°C	4.95	5	5.05	V
		T_A = T_J min to 125°C	4.9		5.1	
Input regulation	V_I = 9 V to 16 V, I_O = 2[illegible] mA			10	25	mV
	V_I = 6 V to 26 V, I_O = [illegible] mA			12	50	
Ripple rejection	V_I = 8 V to 18 V, f = [illegible] Hz			55		dB
Output regulation	I_O = [illegible] mA to 750 mA			20	50	mV
Dropout voltage	I_O = [illegible] mA				0.5	V
	I_O = [illegible] mA				0.6	
Output noise voltage	f = 10 Hz to 100 kHz			500		μV
Bias current	I_O = 750 mA			60	75	mA
	I_O = 10 mA				5	

NOTE 3: Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.1-μF capacitor across the input and a 10-μF capacitor on the output with equivalent series resistance within the guidelines shown in Figure 4.

TL750M08 and TL751M08 electrical characteristics at 25°C free-air temperature, V_I = 14 V, I_O = 300 mA, $\overline{ENABLE}$ at 0 V for TL751M08 (unless otherwise noted)

PARAMETER	TEST CONDITIONS (see Note 3)		MIN	TYP	MAX	UNIT
Output voltage	V_I = 9 V to 26 V, I_O = 0 to 750 mA	T_A = 25°C	7.92	8	8.08	V
		T_A = T_J min to 125°C	7.84		8.16	
Input regulation	V_I = 10 V to 17 V, I_O = 250 mA			12		mV
	V_I = 9 V to 26 V, I_O = 250 mA			15		
Ripple rejection	V_I = 11 V to 21 V, f = 120 Hz			55		dB
Output regulation	I_O = 5 mA to 750 mA			24		mV
Dropout voltage	I_O = [illegible] mA				0.5	V
	I_O = [illegible] mA				0.6	
Output noise voltage	f = 10 Hz to 100 kHz			500		µV
Bias current	I_O = 750 mA			60	75	mA
	I_O = 10 mA				5	

TL750M10 and TL751M10 electrical characteristics at 25°C free-air temperature, V_I = 14 V, I_O = 300 mA, $\overline{ENABLE}$ at 0 V for TL751M10 (unless otherwise noted)

PARAMETER	TEST CONDITIONS (see Note 3)		MIN	TYP	MAX	UNIT
Output voltage	V_I = 11 V to 26 V, I_O = 0 to 750 mA	T_A = 25°C	9.9	10	10.1	V
		T_A = T_J min to 125°C	9.8		10.2	
Input regulation	V_I = 12 V to 18 V, I_O = [illegible] mA			15		mV
	V_I = 11 V to 26 V, I_O = [illegible] mA			20		
Ripple rejection	V_I = 13 V to 23 V, f = [illegible]		55	60		dB
Output regulation	I_O = 5 mA to 750 mA			30		mV
Dropout voltage	I_O = [illegible] mA				0.5	V
	I_O = [illegible] mA				0.6	
Output noise voltage	f = 10 Hz to 100 kHz			1000		µV
Bias current	I_O = 750 mA			60	75	mA
	I_O = 10 mA				5	

TL750M12 and TL751M12 electrical characteristics at 25°C free-air temperature, V_I = 14 V, I_O = 300 mA, $\overline{ENABLE}$ at 0 V for TL751M12 (unless otherwise noted)

PARAMETER	TEST CONDITIONS (see Note 3)		MIN	TYP	MAX	UNIT
Output voltage	V_I = 13 V to 26 V, I_O = 0 to 750 mA	T_A = 25°C	[illegible]	12	12.12	V
		T_A = T_J min to 125°C	11.76		12.24	
Input regulation	V_I = 14 V to 19 V, I_O = [illegible] mA			15		mV
	V_I = 13 V to 26 V, I_O = [illegible] mA			20		
Ripple rejection	V_I = 13 V to 23 V, f = [illegible]		55	60		dB
Output regulation	I_O = 5 mA to 750 mA			30		mV
Dropout voltage	I_O = 500 mA				0.5	V
	I_O = 750 mA				0.6	
Output noise voltage	f = [illegible] to 100 kHz			1000		µV
Bias current	I_O = [illegible] mA			60	75	mA
	I_O = [illegible] mA				5	

NOTE 3: Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.1-µF capacitor across the input and a 10-µF capacitor on the output with equivalent series resistance within the guidelines shown in Figure 4.

TL751Mxx electrical characteristics at 25°C free-air temperature, V_I = 14 V, I_O = 300 mA

PARAMETER	MIN	TYP	MAX	UNIT
Response time, $\overline{ENABLE}$ to output		50		µs

2

Data Sheets

2

Data Sheets

MAXIMUM RATINGS

TRANSIENT INPUT VOLTAGE
vs
TIME

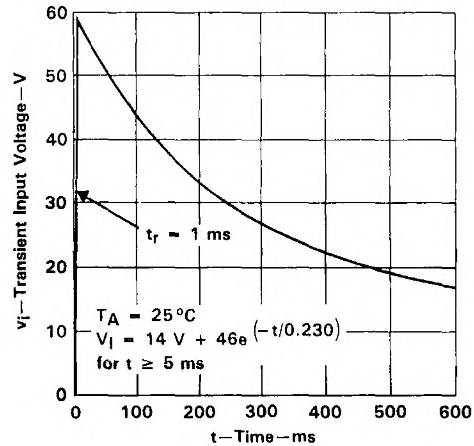


FIGURE 1

FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVE

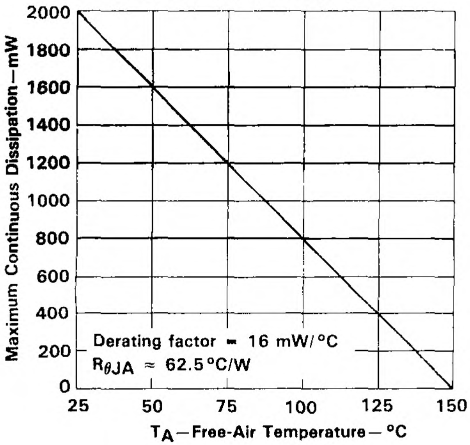


FIGURE 2

CASE TEMPERATURE
DISSIPATION DERATING CURVE

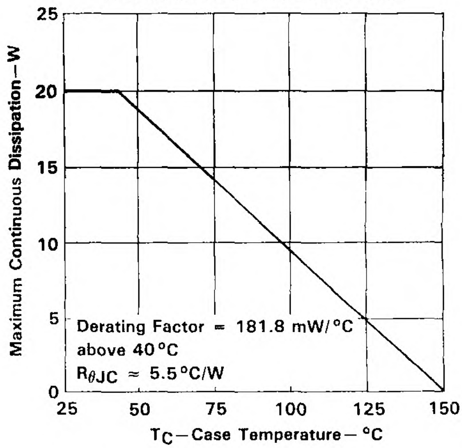
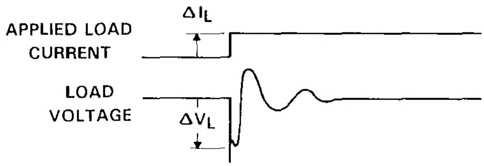


FIGURE 3

TRANSIENT RESPONSE



EQUIVALENT SERIES RESISTANCE OF OUTPUT CAPACITOR
vs
LOAD CURRENT RANGE

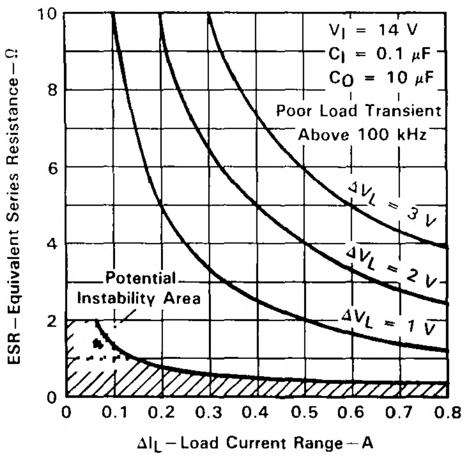


FIGURE 4

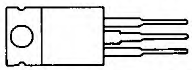
D2643, APRIL 1981–REVISED AUGUST 1988

- ±1% Output Tolerance at 25°C
- ±2% Output Tolerance Over Full Operating Range
- Thermal Shutdown
- Internal Short-Circuit Current Limiting
- Pinout Identical to uA7800 Series
- Improved Version of uA7800 Series

NOMINAL OUTPUT VOLTAGE	REGULATOR
5 V	TL780-05C
12 V	TL780-12C
15 V	TL780-15C

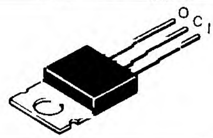
KC PACKAGE

(TOP VIEW)



THE COMMON TERMINAL IS IN ELECTRICAL CONTACT WITH THE MOUNTING BASE

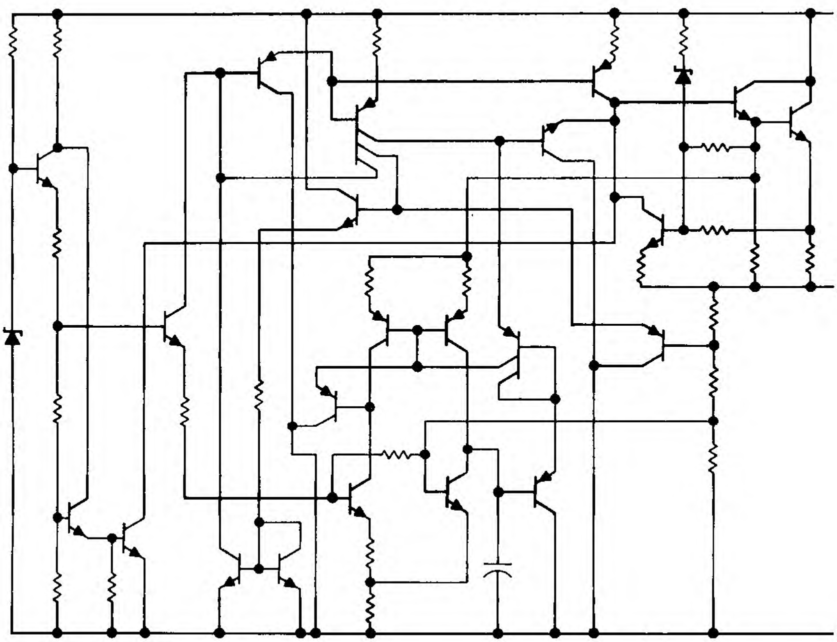
TO-220AB



description

Each fixed-voltage precision regulator in this series is capable of supplying 1.5 amperes of load current. A unique temperature-compensation technique coupled with an internally trimmed bandgap reference has resulted in improved accuracy when compared to other three-terminal regulators. Advanced layout techniques provide excellent line, load, and thermal regulation. The internal current limiting and thermal shutdown features make the devices essentially immune to overload.

schematic



absolute maximum ratings over operating temperature range (unless otherwise noted)

Input voltage	35 V
Continuous total dissipation at 25 °C free-air temperature (see Note 1)	2 W
Continuous total dissipation at (or below) 25 °C case temperature (see Note 1)	15 W
Operating free-air, case, or virtual junction temperature range	0 to 150 °C
Storage temperature range	−65 to 150 °C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260 °C

NOTE 1: For operation above 25 °C free-air or case temperature, refer to Figures 1 and 2. To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variations in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVE

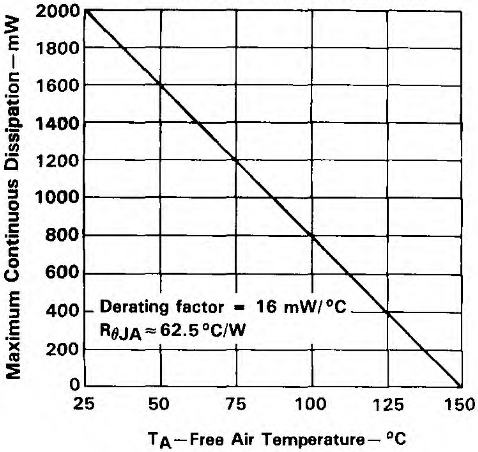


FIGURE 1

CASE TEMPERATURE
DISSIPATION DERATING CURVE

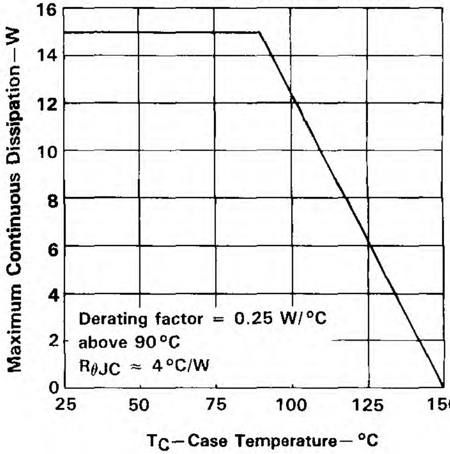


FIGURE 2

recommended operating conditions

		MIN	MAX	UNIT
Input voltage, V_I	TL780-05C	7	25	V
	TL780-[illegible]	14.5	30	
	TL780-15C	17.5	30	
Output current, I_O			1.5	A
Operating virtual junction temperature, T_J		0	125	°C

TL780-05C electrical characteristics at specified virtual junction temperature, V_I = 10 V, I_O = 500 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		MIN	TYP	MAX	UNIT
Output voltage	I_O = 5 mA to 1A, P ≤ 15 W, V_I = 7 V to 20 V	25°C	4.95	5	5.05	V
		0°C to 125°C	4.9		5.1	
Input regulation	V_I = 7 V to 25 V	25°C		0.5	5	mV
	V_I = 8 V to 12 V			0.5	5	
Ripple rejection	V_I = 8 V to 18 V, f = 120 Hz	0°C to [illegible] C	70	85		db
Output regulation	I_O = 5 mA to 1.5 A	25°C		4	25	mV
	I_O = 250 mA to 750 mA			1.5	15	
Output resistance	f = 1 kHz	0°C to 125°C		[illegible]		Ω
Temperature coefficient of output voltage	I_O = 5 mA	0°C to 125°C		0.25		mV/°C
Output noise voltage	f = 10 Hz to 100 kHz	25°C		75		μV
Dropout voltage	I_O = 1 A	25°C		2		V
Bias current		25°C		5	8	mA
Bias current change	V_I = 7 V to 25 V	0°C to 125°C		0.7	1.3	mA
	I_O = 5 mA to 1 A			0.03	0.5	
Short-circuit output current	V_I = 35 V	25°C		[illegible]		mA
Peak output current		25°C		2.2		A

TL780-12C electrical characteristics at specified virtual junction temperature, V_I = 19 V, I_O = 500 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		MIN	TYP	MAX	UNIT
Output voltage	I_O = 5 mA to 1 A, P ≤ 15 W, V_I = 14.5 V to 27 V	25°C	11.88	12	12.12	V
		0°C to 125°C	11.76		12.24	
Input regulation	V_I = 14.5 V to 30 V	25°C		1.2	12	mV
	V_I = 16 V to 22 V			1.2	12	
Ripple rejection	V_I = 15 V to 25 V, f = 120 Hz	0°C to 125°C	65	80		dB
Output regulation	I_O = 5 mA to 1.5 A	25°C		6.5	60	mV
	I_O 250 mA to 750 mA			2.5	36	
Output resistance	f = 1 kHz	0°C to 125°C		0.0035		Ω
Temperature coefficient of output voltage	I_O = 5 mA	0°C to 125°C		0.6		mV/°C
Output noise voltage	f = 10 Hz to 100 kHz	25°C		[illegible]		μV
Dropout voltage	I_O = 1 A	25°C		[illegible]		V
Bias current		25°C		5.5	8	mA
Bias current change	V_I = 14.5 V to 30 V	0°C to 125°C		0.4	1.3	mA
	I_O = 5 mA to 1 A			0.03	0.5	
Short-circuit output current	V_I = 35 V	25°C		350		mA
Peak output current		25°C		2.2		A

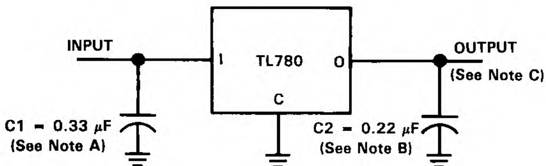
†Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with 0.33 μF capacitor across the input and a 0.22 μF capacitor across the output.

TL780-15C electrical characteristics at specified virtual junction temperature, V_I = 23 V, I_O = 500 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		MIN	TYP	MAX	UNIT
Output voltage	I_O = 5 mA to 1 A, P ≤ 15 W, V_I = 17.5 V to 30 V	25°C	14.85	15	[illegible]	V
		0°C to 125°C	14.7		[illegible]	
Input regulation	V_I = 17.5 V to 30 V	25°C		1.5	15	mV
	V_I = 20 V to [illegible]			1.5	15	
Ripple rejection	V_I = 18.5 V to [illegible] V, f = [illegible] Hz	0°C to [illegible]°C	60	75		dB
Output regulation	I_O = 5 mA to 1.5 A	25°C		7	75	mV
	I_O = 250 mA to 750 mA			2.5	45	
Output resistance	f = 1 kHz	0°C to 125°C		0.0035		Ω
Temperature coefficient of output voltage	I_O = 5 mA	0°C to 125°C		0.62		mV/°C
Output noise voltage	f = 10 Hz to 100 kHz	25°C		225		μV
Dropout voltage	I_O = 1 A	25°C		2		V
Bias current		25°C		5.5	8	mA
Bias current change	V_I = 17.5 V to 30 V	0°C to 125°C		0.4	1.3	mA
	I_O = 5 mA to 1 A			[illegible]	0.5	
Short-circuit output current	V_I = 35 V	25°C		[illegible]		mA
Peak output current		25°C		2.2		A

†Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.33 μF capacitor across the input and a 0.22 μF capacitor across the output.

TYPICAL APPLICATION DATA

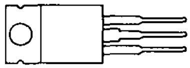


Notes: A. C1 required if regulator is far from power supply filter.
B. C2 not required for stability, however transient response is improved.
C. Permanent damage can occur if output is pulled below ground.

D2659, SEPTEMBER 1981—REVISED SEPTEMBER 1988

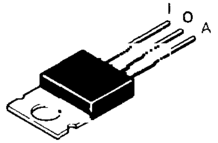
- Output Adjustable from 1.25 V to 125 V
- 700-mA Output Current
- Full Short-Circuit, Safe-Operating-Area, and Thermal Shutdown Protection
- 0.001 %/V Typical Input Regulation
- 0.15% Typical Output Regulation
- 76-dB Typical Ripple Rejection
- Standard TO-220AB Package

KC PACKAGE
(TOP VIEW)



THE OUTPUT TERMINAL IS IN ELECTRICAL CONTACT WITH THE MOUNTING BASE

TO-220AB



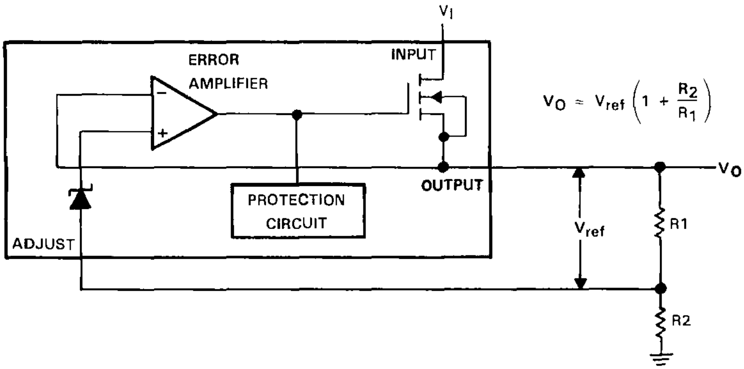
description

The TL783C is an adjustable three-terminal positive-voltage regulator with an output range of 1.25 V to 125 V and a DMOS output transistor capable of sourcing more than 700 mA. It is designed for use in high-voltage applications where standard bipolar regulators cannot be used. Excellent performance specifications . . . superior to those of most bipolar regulators . . . are achieved through circuit design and advanced layout techniques.

As a state-of-the-art regulator, the TL783C combines standard bipolar circuitry with high-voltage double-diffused MOS transistors on one chip to yield a device capable of withstanding voltages far higher than standard bipolar integrated circuits. Because of its lack of secondary breakdown and thermal runaway characteristics usually assoicated with bipolar outputs, the TL783C maintains full overload protection while operating at up to 125 V from input to output. Other features of the device include current limiting, safe-operating-area (SOA) protection, and thermal shutdown. Even if the adjustment pin is inadvertently disconnected, the protection circuitry remains functional.

Only two external resistors are required to program the output voltage. An input bypass capacitor is necessary only when the regulator is situated far from the input filter. An output capacitor, although not required, will improve transient response and protection from instantaneous output short-circuits. Excellent ripple rejection can be achieved without a bypass capacitor at the adjustment terminal.

functional block diagram



absolute maximum ratings over operating temperature range (unless otherwise noted)

Input-to-output differential voltage, $V_I - V_O$	125 V
Continuous total dissipation at (or below) 25°C free-air temperature (see Note 1)	2 W
Continuous total dissipation at (or below) 25°C case temperature (see Note 1)	20 W
Operating free-air, case, or virtual junction temperature range	0°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C

NOTE 1: For operation above 25°C free-air or case temperature, refer to Figures 1 and 2. To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variations in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVE

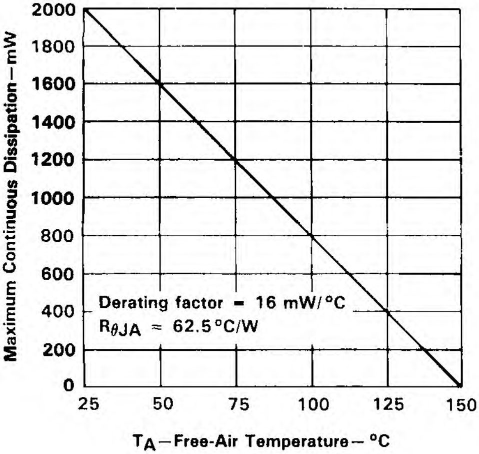


FIGURE 1

CASE TEMPERATURE
DISSIPATION DERATING CURVES

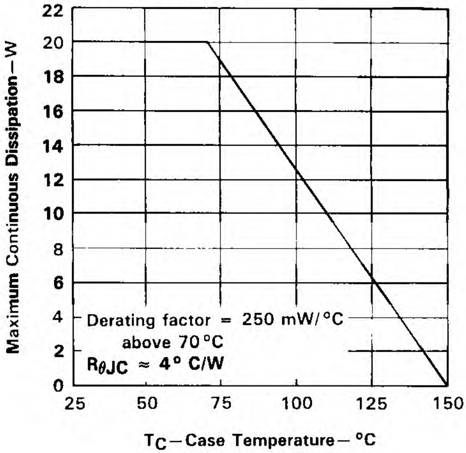


FIGURE 2

recommended operating conditions

	MIN	MAX	UNIT
Input-to-output voltage differential, $V_I - V_O$		125	V
Output current, I_O	15	700	mA
Operating virtual junction temperature, T_J	0	125	°C

TEXAS INSTRUMENTS
POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

electrical characteristics at $V_I - V_O = 25$ V, $I_O = 0.5$ A, $T_J = 0°C$ to 125°C (unless otherwise noted)

PARAMETER	TEST CONDITIONS†			MIN	TYP	MAX	UNIT
Input regulation‡	$V_I - V_O = 20$ V to 125 V,	P ≤ rated dissipation	$T_J = 25°C$		0.001	0.01	%/V
			$T_J = 0°C$ to 125°C		0.004	0.02	
Ripple rejection	$\Delta V_{I(p-p)} = 10$ V,	$V_O = 10$ V,	f = 120 Hz	66	76		dB
Output regulation	$I_O = 15$ mA to 700 mA,	$T_J = 25°C$	$V_O \le 5$ V		7.5	25	mV
			$V_O \ge 5$ V		0.15	0.5	%
	$I_O = 15$ mA to 700 mA,	P ≤ rated dissipation	$V_O \le 5$ V		20	70	mV
			$V_O \ge 5$ V		0.3	1.5	%
Output voltage change with temperature					0.4		%
Output voltage long-term drift	1000 h at $T_J = 125°C$, See Note 2	$V_I - V_O = 125$ V,			0.2		%
Output noise voltage	f = 10 Hz to 10 kHz,	$T_J = 25°C$					%
Minimum output current to maintain regulation	$V_I - V_O = 125$ V					15	mA
Peak output current	$V_I - V_O = 25$ V,	t = 1 ms			1100		mA
	$V_I - V_O = 15$ V,	t = 30 ms			715		
	$V_I - V_O = 25$ V,	t = 30 ms		700	900		
	$V_I - V_O = 125$ V,	t = 30 ms		100	250		
Adjustment-terminal current					83	110	μA
Change in adjustment-terminal current	$V_I - V_O = 15$ V to 125 V,	$I_O = 15$ mA to 700 mA,	P ≤ rated dissipation		0.5	5	μA
Reference voltage (output to ADJ)	$V_I - V_O = 10$ V to 125 V,	$I_O = 15$ mA to 700 mA,	P ≤ rated dissipation	1.2	1.27	1.3	V

† Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.

‡ Input regulation is expressed here as the percentage change in output voltage per 1-volt change at the input.

NOTE 2: Since long-term drift cannot be measured on the individual devices prior to shipment, this specification is not intended to be a guarantee or warranty. It is an engineering estimate of the average drift to be expected from lot to lot.

TYPICAL CHARACTERISTICS

OUTPUT CURRENT LIMIT
vs
INPUT-TO-OUTPUT VOLTAGE DIFFERENTIAL

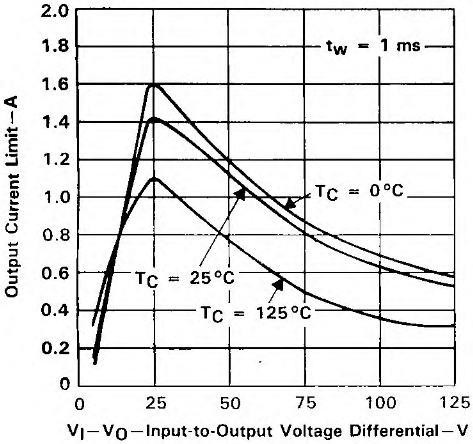


FIGURE 3

OUTPUT CURRENT LIMIT
vs
INPUT-TO-OUTPUT VOLTAGE DIFFERENTIAL

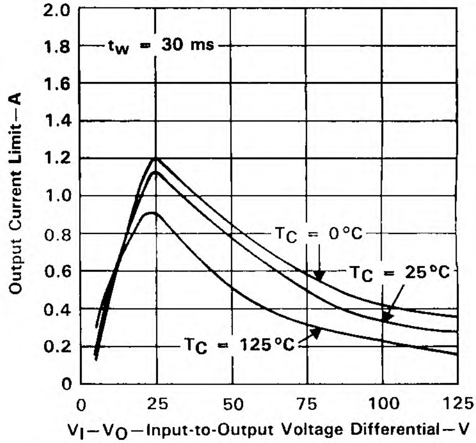


FIGURE 4

OUTPUT CURRENT LIMIT
vs
TIME

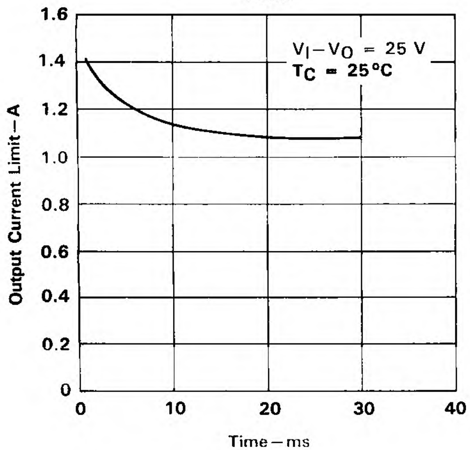


FIGURE 5

RIPPLE REJECTION
vs
OUTPUT VOLTAGE

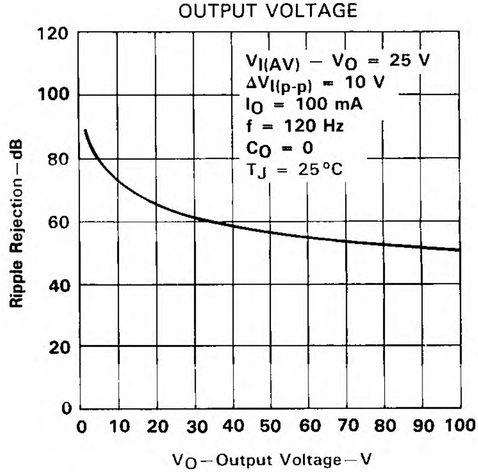


FIGURE 6

TYPICAL CHARACTERISTICS

RIPPLE REJECTION
vs
OUTPUT CURRENT

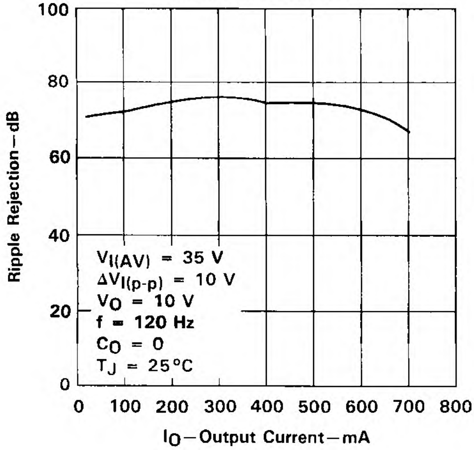


FIGURE 7

RIPPLE REJECTION
vs
FREQUENCY

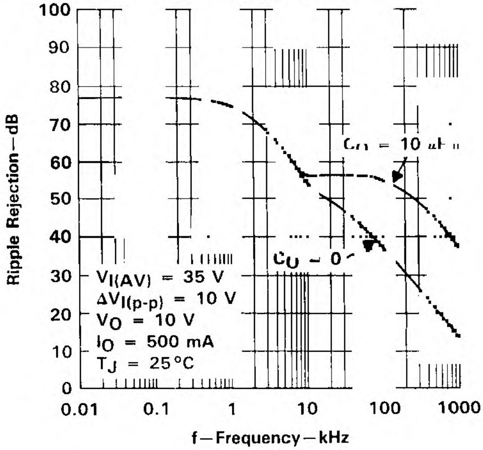


FIGURE 8

OUTPUT IMPEDANCE
vs
FREQUENCY

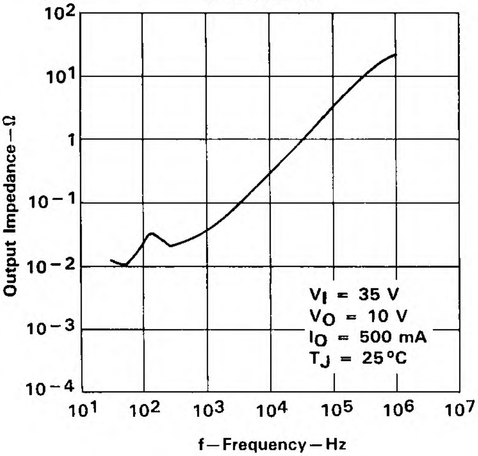


FIGURE 9

REFERENCE VOLTAGE
vs
VIRTUAL JUNCTION TEMPERATURE

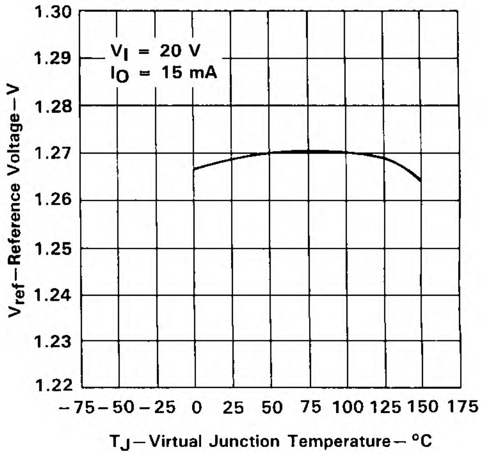


FIGURE 10

2 Data Sheets

TYPICAL CHARACTERISTICS

ADJUSTMENT-TERMINAL CURRENT
vs
VIRTUAL JUNCTION TEMPERATURE

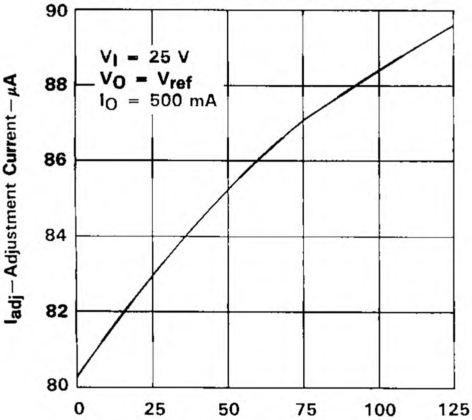


FIGURE 11

DROPOUT VOLTAGE
vs
VIRTUAL JUNCTION TEMPERATURE

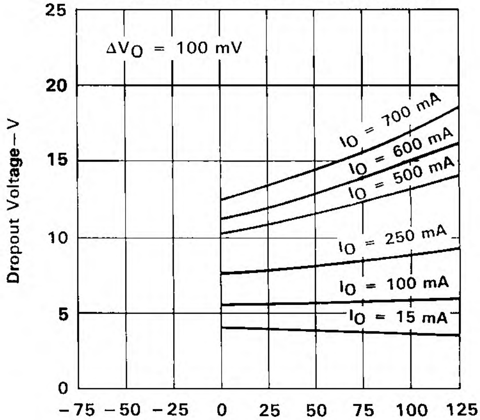


FIGURE 12

LOAD REGULATION
vs
VIRTUAL JUNCTION TEMPERATURE

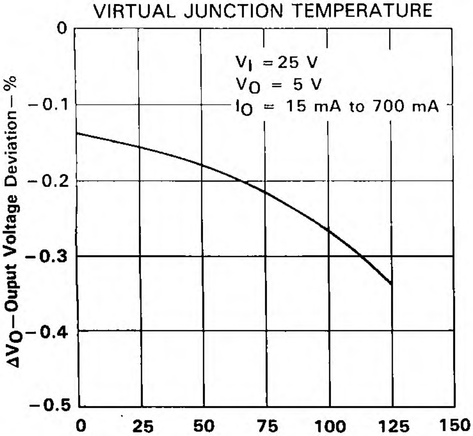


FIGURE 13

MINIMUM OUTPUT CURRENT
TO MAINTAIN REGULATION
vs
INPUT VOLTAGE

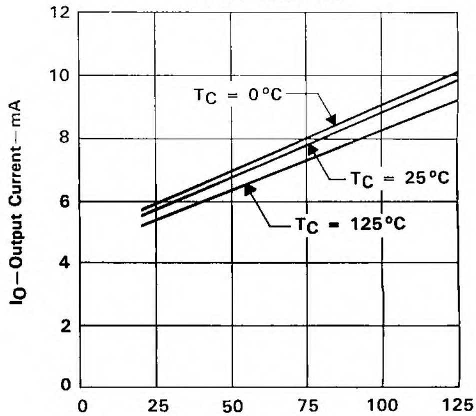


FIGURE 14

TYPICAL CHARACTERISTICS

LINE TRANSIENT RESPONSE

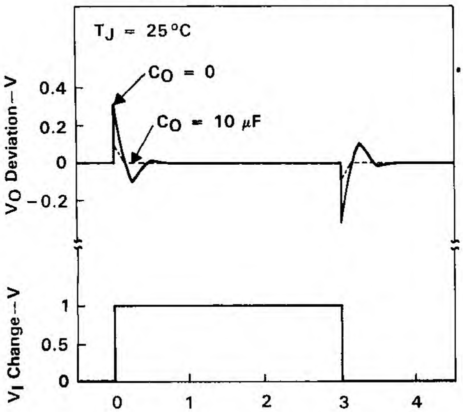


FIGURE 15

LOAD TRANSIENT RESPONSE

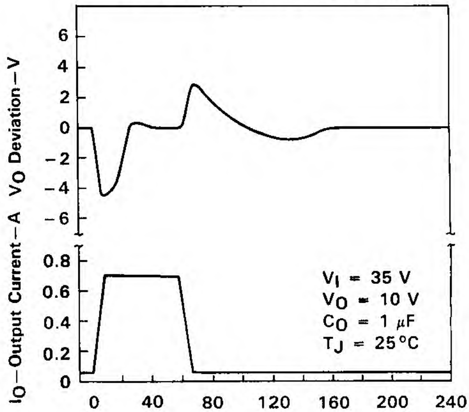


FIGURE 16

DESIGN CONSIDERATIONS

The internal reference (see functional block diagram) is used to generate 1.25 V nominal (V_{ref}) between the output and adjustment terminals. This voltage is developed across R1 and causes a constant current to flow through R1 and the programming resistor R2, giving an output voltage of:

$$V_O = V_{ref}(1 + R2/R1) + I_{adj}(R2)$$

or

$$V_O \sim V_{ref}(1 + R2/R1).$$

The TL783C was designed to minimize I_{adj} and maintain consistency over line and load variations, thereby minimizing the I_{adj} (R2) error term.

To maintain I_{adj} at a low level, all quiescent operating current is returned to the output terminal. This quiescent current must be sunk by the external load and is the minimum load current necessary to prevent the output from rising. The recommended R1 value of 82 Ω will provide a minimum load current of 15 mA. Larger values may be used if the input-to-output differential voltage is less than 125 V (see minimum operating current curve) or if the load will sink some portion of the minimum current.

bypass capacitors

The TL783C regulator is stable without bypass capacitors; however, any regulator will become unstable with certain values of output capacitance if an input capacitor is not used. Therefore, the use of input bypassing is recommended whenever the regulator is located more than four inches from the power-supply filter capacitor. A 1-μF tantalum or electrolytic capacitor is usually sufficient.

Adjustment-terminal capacitors are not recommended for use on the TL783C because they can seriously degrade load transient response as well as create a need for extra protection circuitry. Excellent ripple rejection is presently achieved without this added capacitor.

Due to the relatively low gain of the MOS output stage, output voltage drop-out may occur under large load transient conditions. Addition of an output bypass capacitor will greatly enhance load transient response as well as prevent drop-out. For most applications, it is recommended that an output bypass capacitor be used with a minimum value of:

$$C_O\ (\mu F) = 15/V_O$$

Larger values will provide proportionally better transient response characteristics.

protection circuitry

The TL783C regulator includes built-in protection circuits capable of guarding the device against most overload conditions encountered in normal operation. These protective features are current limiting, safe-operating-area protection, and thermal shutdown. These circuits are meant to protect the device under occasional fault conditions only. Continuous operation in the current limit or thermal shutdown mode is not recommended.

The internal protection circuits of the TL783C will protect the device up to maximum rated V_I as long as certain precautions are taken. If V_I is instantaneously switched on, transients exceeding maximum input ratings may occur, which can destroy the regulator. These are usually caused by lead inductance and bypass capacitors causing a ringing voltage on the input. In addition, if rise times in excess of 10 V/ns are applied to the input, a parasitic n-p-n transistor in parallel with the DMOS output can be turned on causing the device to fail. If the device is operated over 50 V and the input is switched on rather than ramped on, a low-Q capacitor, such as a tantalum or electrolytic should be used rather than ceramic, paper, or plastic bypass capacitors. A Q factor of 0.015 or greater will usually provide adequate damping to suppress ringing. Normally, no problems will occur if the input voltage is allowed to ramp upward through the action of an ac line rectifier and filter network.

Similarly, if an instantaneous short circuit is applied to the outputs, both ringing and excessive fall times can result. A tantalum or electrolytic bypass capacitor is recommended to eliminate this problem. However, if a large output capacitor is used and the input is shorted, addition of a protection diode may be necessary to prevent capacitor discharge through the regulator. The amount of discharge current delivered is dependent on output voltage, size of capacitor, and fall time of V_I. A protective diode (see Figure 17) is required only for capacitance values greater than

$$C_O\ (\mu F) = 3 \times 10^4/(V_O)^2.$$

Care should always be taken to prevent insertion of regulators into a socket with power on. Power should be turned off before removing or inserting regulators.

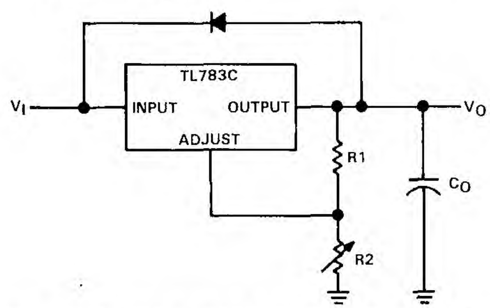


FIGURE 17. REGULATOR WITH PROTECTIVE DIODE

load regulation

The current set resistor (R1) should be located close to the regulator output terminal rather than near the load. This eliminates long line drops from being amplified through the action of R1 and R2 to degrade load regulation. To provide remote ground sensing, R2 should be near the load ground.

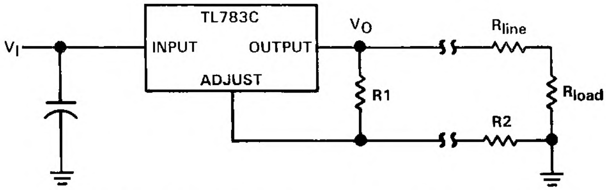
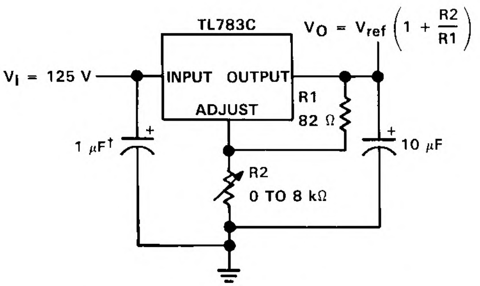


FIGURE 18. REGULATOR WITH CURRENT-SET RESISTOR

TYPICAL APPLICATION DATA



†NEEDED IF DEVICE IS MORE THAN 4 INCHES FROM FILTER CAPACITOR

FIGURE 19. 1.25-V TO 115-V ADJUSTABLE REGULATOR

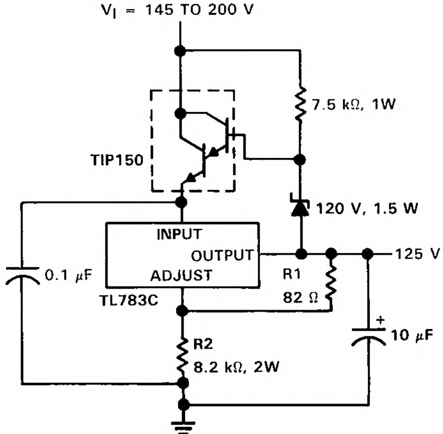


FIGURE 20. 125-V SHORT-CIRCUIT-PROTECTED OFF-LINE REGULATOR

TYPICAL APPLICATION DATA

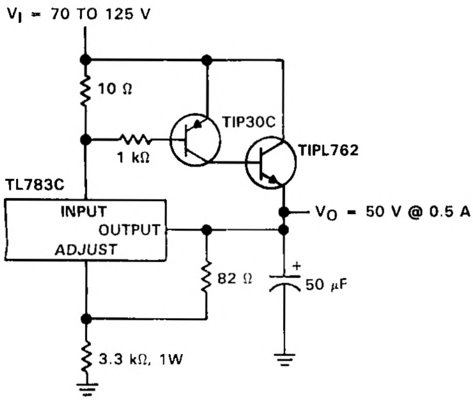


FIGURE 21. 50-V REGULATOR WITH CURRENT BOOST

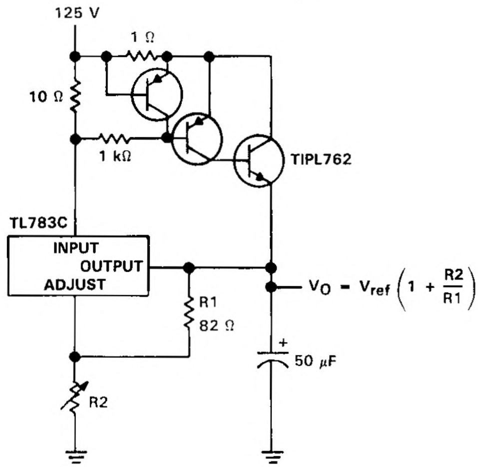


FIGURE 22. ADJUSTABLE REGULATOR WITH CURRENT BOOST AND CURRENT LIMIT

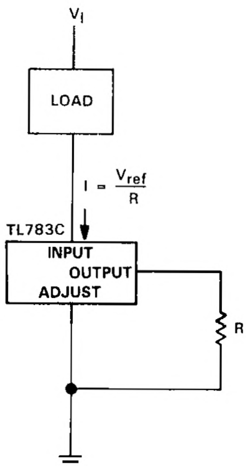


FIGURE 23. CURRENT-SINKING REGULATOR

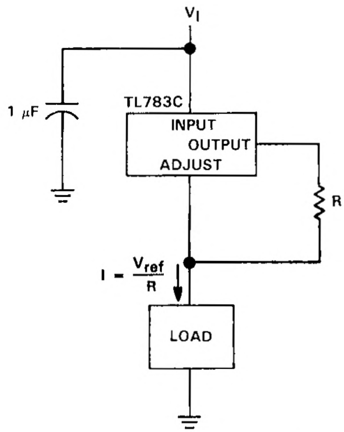


FIGURE 24. CURRENT SOURCING REGULATOR

TYPICAL APPLICATION DATA

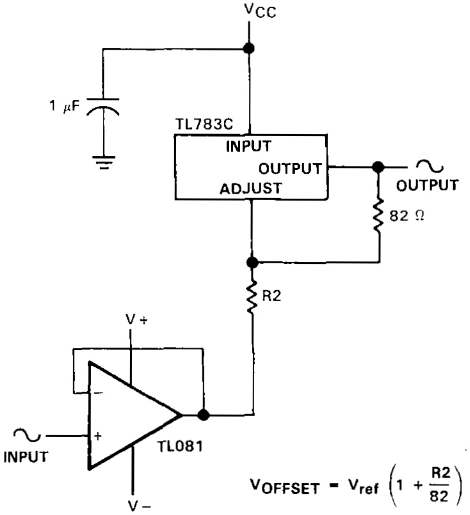


FIGURE 25. HIGH-VOLTAGE UNITY-GAIN OFFSET AMPLIFIER

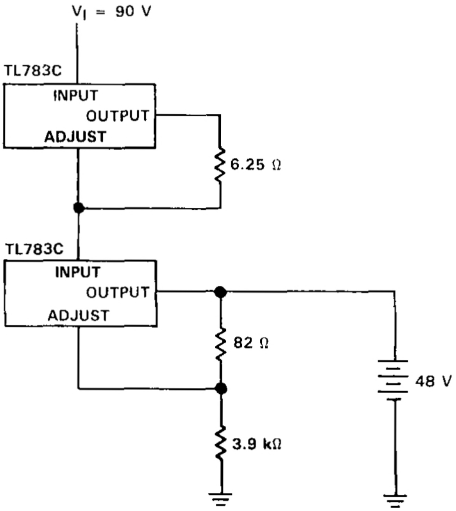
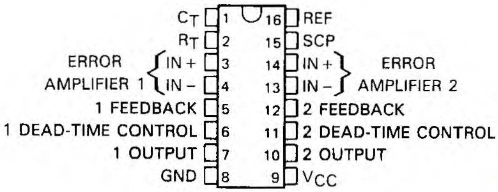


FIGURE 26. 48-V, 200-mA FLOAT CHARGER

D2730, FEBRUARY 1983 – REVISED OCTOBER 1988

- Complete PWM Power Control Circuitry
- Completely Synchronized Operation
- Internal Undervoltage Lockout Protection
- Wide Supply Voltage Range
- Internal Short-Circuit Protection
- Oscillator Frequency . . . 500 kHz Max
- Variable Dead Time Provides Control Over Total Range
- Internal Regulator Provides a Stable 2.5-V Reference Supply

D OR N PACKAGE
(TOP VIEW)



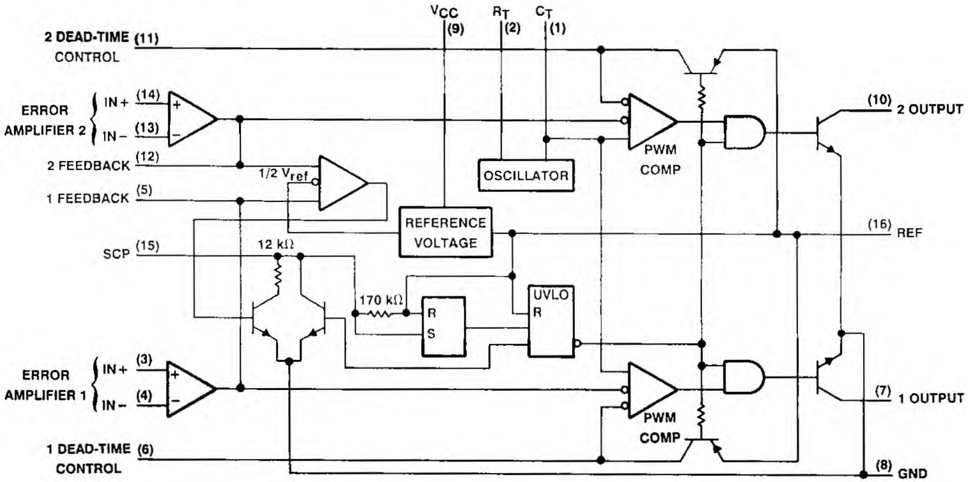
description

The TL1451AC incorporates on a single monolithic chip all the functions required in the construction of two pulse-width-modulation control circuits. Designed primarily for power supply control, the TL1451AC contains an on-chip 2.5-V regulator, two error amplifiers, an adjustable oscillator, two dead-time comparators, undervoltage lockout circuitry, and dual common-emitter output transistor circuits.

The uncommitted output transistors provide common-emitter output capability for each controller. The internal amplifiers exhibit a common-mode voltage range from 1.04 V to 1.45 V. The dead-time control comparator has no offset unless externally altered and may be used to provide 0% to 100% dead time. The on-chip oscillator may be operated by terminating R_T (pin 2) and C_T (pin 1). During low V_{CC} conditions, the undervoltage lockout control circuit feature locks the outputs off until the internal circuitry is operational.

The TL1451AC is characterized for operation from −20°C to 85°C.

functional block diagram



absolute maximum ratings over operating free-air temperature range

Supply voltage, V_{CC}	41 V
Amplifier input voltage	20 V
Collector output voltage	51 V
Collector output current	21 mA
Continuous total dissipation	See Dissipation Rating Table
Operating free-air temperature range	−20°C to 85°C
Storage temperature range	−65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260°C

DISSIPATION RATING TABLE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25°C$	$T_A = 70°C$ POWER RATING	$T_A = 85°C$ POWER RATING
D	500 mW	4.0 mW/°C	320 mW	260 mW
N	1000 mW	8.0 mW/°C	640 mW	520 mW

recommended operating conditions

	MIN	MAX	UNIT
Supply voltage, V_{CC}	3.6	40	V
Amplifier input voltage, V_I	1.05	1.45	V
Collector output voltage, V_O		50	V
Collector output current		20	mA
Current into feedback terminal		45	µA
Feedback resistor, R_F	100		kΩ
Timing capacitor, C_T	150	15000	pF
Timing [illegible] R_T	5.1	100	kΩ
Oscillator frequency	1	500	kHz
Operating free-air temperature, T_A	−20	85	°C

electrical characteristics over recommended operating free-air temperature range, $V_{CC} = 6$ V, f = 200 kHz (unless otherwise noted)

reference section

PARAMETER	TEST CONDITIONS	MIN	TYP†	MAX	UNIT
Output voltage (pin 16)	$I_O = 1$ mA	2.4	2.5	2.6	V
Output voltage change with temperature	$T_A = -20°C$ to 25°C		[illegible]	±1%	
	$T_A = 25°C$ to 85°C		[illegible]	±1%	
Input regulation	$V_{CC} = 3.6$ V to 40 V		2	12.5	mV
Output regulation	$I_O = 0.1$ mA to 1 mA		1	7.5	mV
Short-circuit output current	$V_O = 0$	3	10	30	mV

undervoltage lockout section

PARAMETER	TEST CONDITIONS		MIN	TYP†	MAX	UNIT
[illegible] (pin 9)	$I_{Oref} = 0.1$ mA,	$T_A = 25°C$		2.72		V
[illegible] voltage (pin 9)	$I_{Oref} = 0.1$ mA,	$T_A = 25°C$		2.6		V
H[illegible]is (pin 9)	$I_{Oref} = 0.1$ mA,	$T_A = 25°C$	80	120		mV
Reset threshold voltage (pin 9)	$I_{Oref} = 0.1$ mA,	$T_A = 25°C$	1.5	1.8		V

† All typical values are at $T_A = 25°C$.

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electrical characteristics over recommended operating free-air temperature range, V_{CC} = 6 V, f = 200 kHz (unless otherwise noted) (continued)

protection control section

PARAMETER	TEST CONDITIONS	MIN	TYP†	MAX	UNIT
[illegible] voltage (pin 15)	T_A = 25°C	0.65	0.7	0.75	V
Standby voltage (pin 15)	No pullup	140	185	230	mV
Latched input voltage (pin 15)	[illegible] pullup		60	120	mV
Input (source) current	[illegible] − 0.7 V, T_A = 25°C	−10	−15	−20	µA
Comparator threshold voltage (pins 5 and 12)			1.18		V

oscillator section

PARAMETER	TEST CONDITIONS	MIN	TYP†	MAX	UNIT
Frequency	C_T = [illegible]F, R_T = 10 kΩ		200		kHz
Standard deviation of frequency	C_T = [illegible]F, R_T = 10 kΩ		10%		
Frequency c[illegible] with voltage	V_{CC} = 3.6 V to 40 V		1%		
Frequency change with temperature	T_A = −20°C to 25°C		−0.4%	±2%	
	T_A = 25°C to 85°C		−0.2%	±2%	

dead-time control section

PARAMETER	TEST CONDITIONS	MIN	TYP†	MAX	UNIT
Input bias current (pins 6 and 11)				1	µA
Latch mode (source) current (pins 6 and 11)	T_A = 25°C	−80	−145		µA
Latched input voltage (pins 6 and 11)	I_O = 40 µA	2.3			V
Input threshold voltage at f = 10 kHz (pins 6 and 11)	Zero duty cycle		2.05	2.25	V
	Maximum duty cycle	1.2	1.45		

error-amplifier section

PARAMETER	TEST CONDITIONS	MIN	TYP†	MAX	UNIT
Input offset voltage	V_O (pins 5 and 12) = 1.25 V			±6	mV
Input offset current	V_O [illegible] and 12) = 1.25 V			±100	nA
Input bias current	V_O [illegible] and 12) = 1.25 V		160	500	nA
Common-mode input voltage range	V_{CC} = 3.6 V to 40 V	1.05 to 1.45			V
Open-loop voltage amplification	R_F = 200 kΩ	70	80		dB
Unity-gain bandwidth			1.5		MHz
Common-mode rejection ratio		60	80		dB
Positive output voltage swing		V_{ref}−0.1			V
N[illegible] output voltage swing				1	V
C[illegible] sink) current (pins 5 and 12)	V_{ID} = −0.1 V, V_O = 1.25 V	0.5	1.6		mA
O[illegible] source) current (pins 5 and 12)	V_{ID} = 0.1 V, V_O = 1.25 V	−45	−70		µA

† All typical values are at T_A = 25°C

electrical characteristics over recommended operating free-air temperature range, V_{CC} = 6 V, f = 200 kHz (unless otherwise noted) (continued)

output section

PARAMETER	TEST CONDITIONS	MIN	TYP†	MAX	UNIT
Collector off-state current	V_O = 50 V			10	µA
Output saturation voltage	I_O = 10 mA		1.2	2	V
Short-circuit output current	V_O = 6 V		90		mA

pwm comparator section

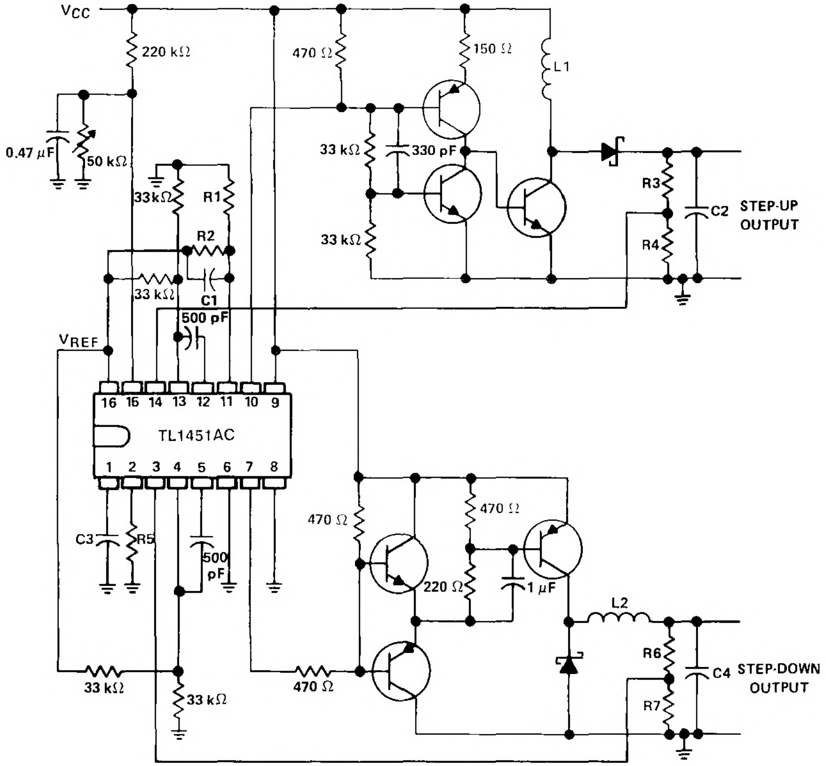
PARAMETER	TEST CONDITIONS	MIN	TYP†	MAX	UNIT
Input threshold voltage at f = 10 kHz (pins 5 and 12)	Zero duty cycle		2.05	2.25	V
	Maximum duty cycle	1.2	1.45		
Input (sink) current (pins 5 and 12)	V_I = 1.25 V	0.5	1.6		mA
Input (source) current (pins 5 and 12)	V_I = 1.25 V	−45	−70		µA

total device

PARAMETER	TEST CONDITIONS	MIN	TYP†	MAX	UNIT
Standby supply current	Off-state		1.3	1.8	mA
Average supply current	R_T = 10 kΩ		1.7	2.4	mA

† All typical values are at T_A = 25°C.

TYPICAL APPLICATION DATA

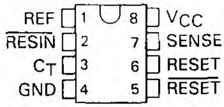


Values for R1 through R7, C1 through C4, and L1 and L2 depend upon inidividual application.

D2722, APRIL 1983—REVISED OCTOBER 1988

- **Power-On Reset Generator**
- **Automatic Reset Generation After Voltage Drop**
- **Wide Supply Voltage Range . . . 3 V to 18 V**
- **Precision Voltage Sensor**
- **Temperature-Compensated Voltage Reference**
- **True and Complement Reset Outputs**
- **Externally Adjustable Pulse Width**

D OR P PACKAGE
(TOP VIEW)



description

The TL7702A series are monolithic integrated circuit supply voltage supervisors specifically designed for use as reset controllers in microcomputer and microprocessor systems. To ensure that the microcomputer system has reset, the TL7702A series initiates an internal time delay that delays the return of the reset outputs to their inactive states. Since the time delay for most microcomputers and microprocessors is in the order of several machine cycles, the device internal time delay is determined by an external capacitor connected to the C_T input (pin 3).

$$t_d = 1.3 \times 10^4 \times C_T$$

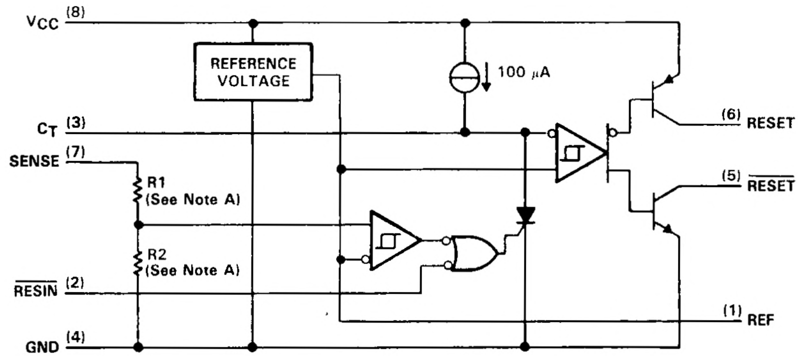
Where: C_T is in farads (F) and t_d is in seconds(s)

During power-up, the outputs are undefined until the supply voltage V_{CC} reaches a minimum value of 3.6 V. During power-down, with the SENSE input below the threshold voltage, the outputs remain active until the supply voltage V_{CC} falls below a maximum of 2 V after which the outputs are undefined. See Timing Diagram. Suggested circuits to eliminate undefined states are shown in Figures 3 and 4.

In addition, when the supply voltage drops below the nominal value, the outputs will be active until the supply voltage returns to the nominal value. An external capacitor (typically 0.1 μF) must be connected to the REF output (pin 1) to reduce the influence of fast transients in the supply voltage.

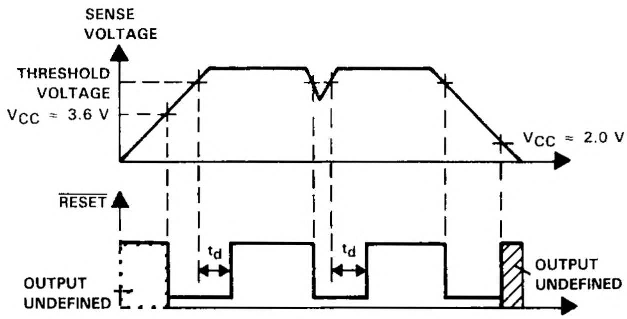
The TL7702AI series is characterized for operation from −25°C to 85°C; the TL7702AC series is characterized from 0°C to 70°C.

functional block diagram



NOTE A: TL7702A: R1 = 0 Ω, R2 = open
TL7705A: R1 = 7.8 kΩ, R2 = 10 kΩ
TL7709A: R1 = 19.7 kΩ, R2 = 10 kΩ
TL7712A: R1 = 32.7 kΩ, R2 = 10 kΩ
TL7715A: R1 = 43.4 kΩ, R2 = 10 kΩ

timing diagram



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absolute maximum ratings over operating free-air temperature (unless otherwise noted)

Supply voltage, V_{CC} ([illegible] Note 1)		20 V
Input voltage range at [illegible]IN		−0.3 V to 20 V
Input voltage at SENSE:	TL7702A (see Note 2)	−0.3 V to 6 V
	TL7705A	−0.3 V to 10 V
	TL7709A	−0.3 V to 15 V
	TL7712A	−0.3 V to 20 V
	TL7715A	−0.3 V to 20 V
High-level output current at [illegible]T		−30 mA
Low-level output current at [illegible]T		30 mA
Continuous total dissipation		See Dissipation Rating Table
Operating free-air temperature range:	TL77_I	−25°C to 85°C
	TL77_C	0°C to 70°C
Storage temperature range		−65°C to 150°C

NOTE 1: All voltage values are with respect to the network ground terminal.

DISSIPATION RATING TABLE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25°C$	$T_A = 70°C$ POWER RATING	$T_A = 85°C$ PO[illegible] RATING
D	725 mW	5.8 mW/°C	464 mW	[illegible] mW
P	1000 mW	8.0 mW/°C	640 mW	520 mW

recommended operating conditions

		MIN	NOM	MAX	UNIT
Supply voltage, V_{CC}		3.6		18	V
High-level input voltage at $\overline{RESIN}$, V_{IH}		2			V
Low-level input voltage at $\overline{RESIN}$, V_{IL}				0.6	V
Voltage at SENSE, V_I	TL[illegible]	0		See Note 2	V
	TL[illegible]	0		10	
	TL7709A	0		15	
	TL7712A	0		20	
	TL7715A	0		20	
High-level output current at RESET, I_{OH}				−16	mA
Low-level output current at $\overline{RESET}$, I_{OL}				16	mA
Operating free-air temperature range, T_A	TL77_I	−25		85	°C
	TL77_C	0		70	

NOTE 2: For proper operation of the TL7702A, the voltage applied to the SENSE terminal should not exceed V_{CC} − 1 V or 6 V, whichever is less.

2 Data Sheets

electrical characteristics over recommended ranges of supply voltage, input voltage, output current, and free-air temperature (unless otherwise noted)

PARAMETER			TEST CONDITIONS†	MIN	TYP	MAX	UNIT
V_{OH}	High-level output voltage at [illegible]		I_{OH} = −16 mA	$V_{CC}-1.5$			V
V_{OL}	Low-level output voltage at [illegible]		I_{OL} = 16 mA			0.4	V
V_{ref}	Reference voltage		T_A = 25°C	2.48	2.53	2.58	V
V_{T-}	Negative-going threshold voltage at SENSE input	TL7702A	V_{CC} = 3.6 V to 18 V, T_A = 25°C	2.48	2.53	2.58	V
		TL7705A		4.5	4.55	4.6	
		TL7709A		7.5	7.6	7.7	
		TL7712A		10.6	10.8	11	
		TL7715A		13.2	13.5	13.8	
V_{hys}	Hysteresis‡ at SENSE input	TL7[illegible]	V_{CC} = 3.6 V to 18 V, T_A = 25°C		10		mV
		TL7[illegible]			15		
		TL7[illegible]			20		
		TL7712A			35		
		TL7715A			45		
I_I	Input current at $\overline{RESIN}$ input		V_I = 2.4 V to V_{CC}			20	μA
			V_I = 0.4 V			−100	
I_I	Input current at SENSE inp[illegible]	TL7702A	$V_{ref} < V_I < V_{CC} - 1.5$ V		0.5	2	μA
I_{OH}	High-level output current at [illegible]		V_O = 18 V			50	μA
I_{OL}	Low-level output current at [illegible]		V_O = 0			−50	μA
I_{CC}	Supply current		All inputs and outputs open		1.8	3	mA

†All electrical characteristics are measured with 0.1-μF capacitors connected at pins 1, 3, and 8 to GND.
‡Hysteresis is the difference between the positive-going input threshold voltage, V_{T+}, and the negative-going input threshold voltage, V_{T-}.

switching characteristics over recommended ranges of supply voltage, input voltage, output current, and free-air temperature (unless otherwise noted)

PARAMETER		TEST CONDITIONS§	MIN	TYP	MAX	UNIT
$t_{wS(min)}$	Minimum pulse duration at SENSE input to switch outputs	$V_{IH} = V_{T-}$ +200 mV, $V_{IL} = V_{T-}$ −200 mV			2	μs
t_{pd}	Propagation delay time from [illegible] to $\overline{RESET}$	V_{CC} = 5 V		1.5		μs
t_r	[illegible]	V_{CC} = 5 V, See Note 3			0.2	μs
	[illegible]				3.5	
t_f	[illegible]				0.2	μs
	[illegible]				3.5	

§All switching characteristics are measured with 0.1-μF capacitors connected at pins 1 and 8 to GND.
NOTE 3: The rise and fall times are measured with a 4.7-kΩ load resistor at $\overline{RESET}$ (pin 5) and RESET (pin 6).

PARAMETER MEASUREMENT INFORMATION

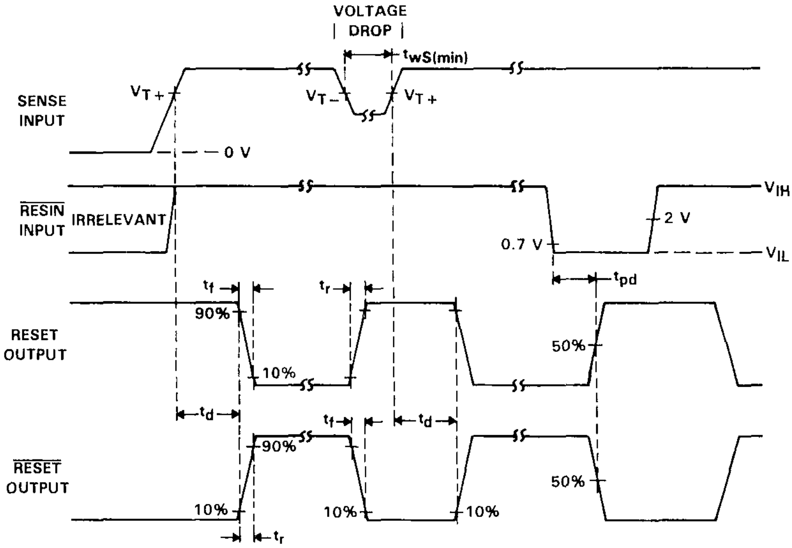

FIGURE 1. SWITCHING DIAGRAM

TYPICAL APPLICATION DATA

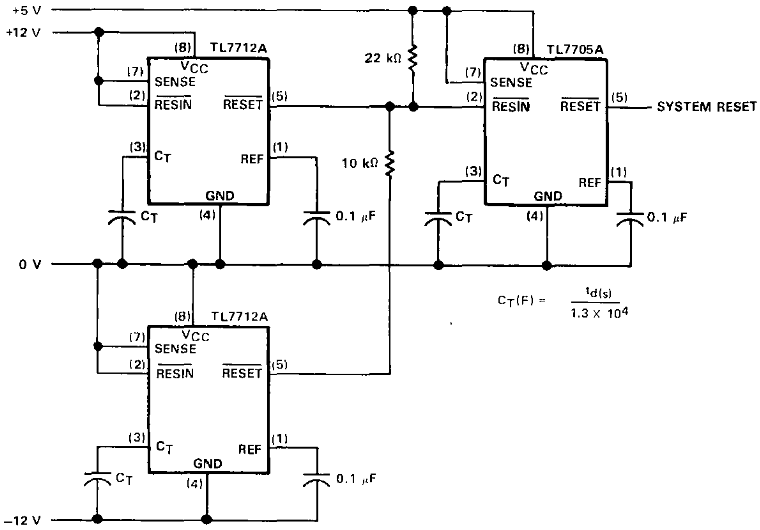

FIGURE 2. MULTIPLE POWER SUPPLY SYSTEM RESET GENERATION

TYPICAL APPLICATION DATA

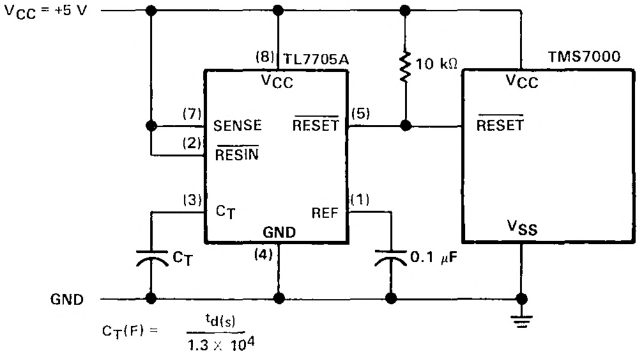

FIGURE 3. RESET CONTROLLER FOR TMS7000 SYSTEM

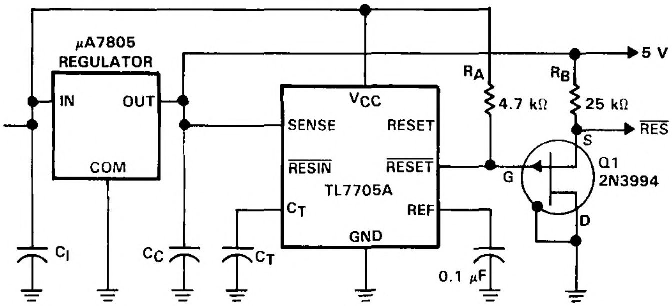

FIGURE 4. ELIMINATING UNDEFINED STATES USING A P-CHANNEL JFET

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TYPICAL APPLICATION DATA

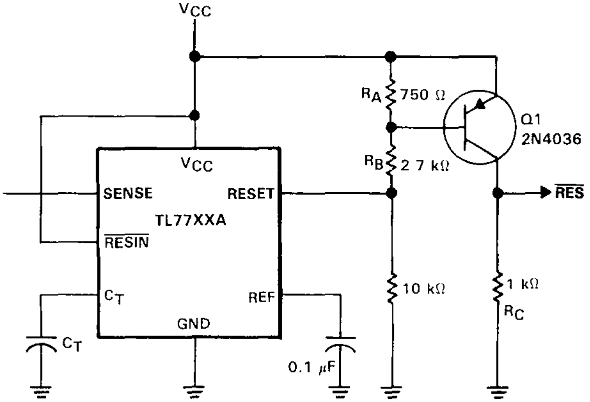
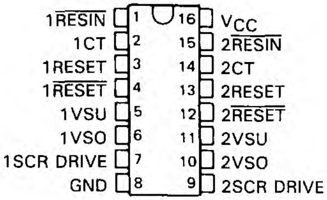


FIGURE 5. ELIMINATING UNDEFINED STATES USING A P-N-P TRANSISTOR

D3035, OCTOBER 1987—REVISED MAY 1988

- Power-On Reset Generator
- Automatic Reset Generation After Voltage Drop
- $\overline{\text{RESET}}$ Defined When V_{CC} Exceeds 1 V
- Wide Supply Voltage Range . . . 3.5 V to 18 V
- Precision Overvoltage and Undervoltage Sensing
- 250-mA Peak Output Current for Driving SCR Gates
- 2-mA Active-Low SCR Gate Drive for False Trigger Protection
- Temperature-Compensated Voltage Reference
- True and Complementary Reset Outputs
- Externally Adjustable Output Pulse Duration

DW OR N PACKAGE
(TOP VIEW)



description

The TL7770 is a monolithic integrated circuit system supervisor designed for use as a reset controller in microcomputer and microprocessor power supply systems. This device contains two independent supply-voltage supervisors that monitor the supplies for overvoltage and undervoltage conditions at the VSO and VSU pins, respectively. When V_{CC} attains the minimum voltage of 1 V during power-up, the $\overline{\text{RESET}}$ output becomes active (low). As V_{CC} approaches 3.5 V, the delay timer function activates latching RESET and $\overline{\text{RESET}}$ active (high and low respectively) for a time delay, t_d, after system voltages have achieved normal levels. Above V_{CC} = 3.5 V, taking $\overline{\text{RESIN}}$ low will activate the time delay function, RESET and $\overline{\text{RESET}}$, during normal system voltage levels. To ensure that the microcomputer system has reset, the outputs remain active until the voltage at VSU exceeds the threshold value V_{T+} for a time delay, t_d, which is determined by an external timing capacitor such that:

$$t_d \approx 20 \times 10^3 \times \text{capacitance}$$

where t_d is in seconds and capacitance is in farads.

The overvoltage-detection circuit is programmable for a wide range of user designs. During an overvoltage condition, an internal SCR is triggered, providing 250 mA peak instantaneous current and 25 mA continuous current to the SCR gate drive pin, which can be used to drive an external high-current SCR gate or an overvoltage warning circuit.

The TL7770Q series is characterized for operation from −40°C to 125°C. The TL7770C series is characterized for operation from 0°C to 70°C.

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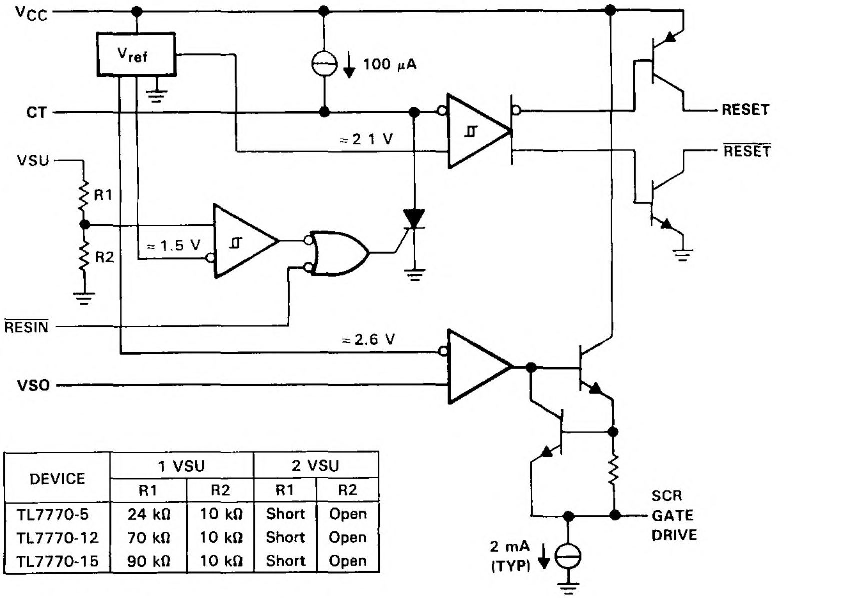
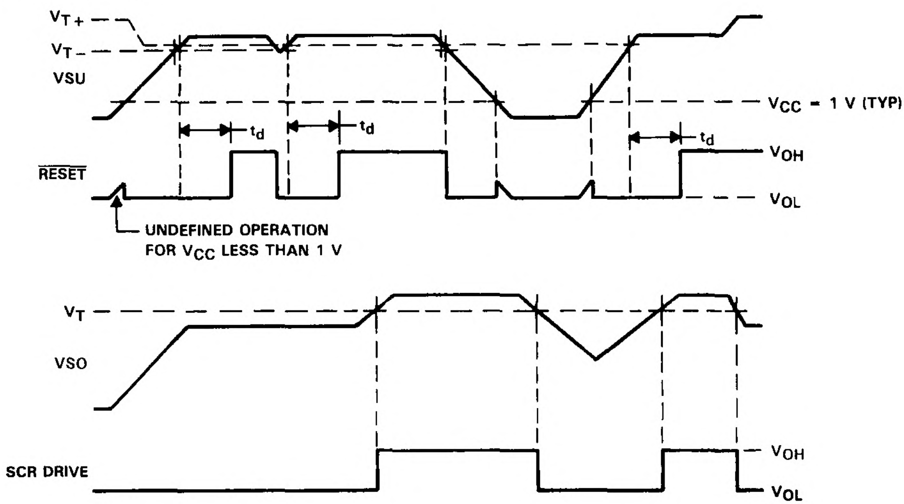
logic diagram (each channel)



DEVICE	1 VSU		2 VSU	
	R1	R2	R1	R2
TL7770-5	24 kΩ	10 kΩ	Short	Open
TL7770-12	70 kΩ	10 kΩ	Short	Open
TL7770-15	90 kΩ	10 kΩ	Short	Open

typical timing diagram



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absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, V_{CC} (see Note 1) . . . . 20 V
Input voltage range, V_I: 1VSU, 2VSU, 1VSO, and 2VSO . . . . −0.3 V to 18 V
Low-level output current ($1\overline{RESET}$ and $2\overline{RESET}$), I_{OL} . . . . 20 mA
High-level output current (1RESET and 2RESET), I_{OH} . . . . −20 mA
Continuous total dissipation . . . . See Dissipation Rating Table
Operating virtual junction temperature range (see Note 2) . . . . −40°C to 150°C
Storage temperature range . . . . −65°C to 150°C
Lead temperature 1,6 mm (1/16 in) from case for 10 seconds . . . . 260°C

NOTE 1: All voltage values are with respect to the network ground terminal.

DISSIPATION RATING TABLE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR	DERATE ABOVE T_A	$T_A = 70°C$ POWER RATING	$T_A = 125°C$ POWER RATING
DW	1000 mW	8.2 mW/°C	25°C	[illegible] mW	205 mW
N	1000 mW	12.4 mW/°C	69°C	992 mW	310 mW

recommended operating conditions

		MIN	MAX	UNIT
Supply voltage, V_{CC}		3.5	18	V
Input voltage range, V_I (see Note 2)	1[illegible], 1VSU, 2VSU, 2VSO, 1VSO	0	18	V
Output voltage (1CT and 2CT), V_O			5	V
Output sink current (1CT [illegible]), I_O			50	μA
High-level output current [illegible] and 2RESET), I_{OH}			−16	mA
Low-level output current ($1\overline{RESET}$ and $2\overline{RESET}$), I_{OL}			16	mA
Continuous output current (1SCR GATE DRIVE [illegible] 2SCR GATE DRIVE), I_O			25	mA
Operating free-air temperature, T_A	TL77[illegible] Series	−40	[illegible]	°C
	TL7770C Series	0	[illegible]	°C

NOTE 2: The algebraic convention, in which the least positive (most negative) value is designated minimum, is used in this data sheet for logic voltage levels and temperature only.

electrical characteristics over recommended ranges of supply voltage, input voltage, output current, and free-air temperature (unless otherwise noted)

supply supervisor section

PARAMETER			TEST CONDITIONS†	MIN	TYP‡	MAX	UNIT
V_{OH}	High-level output voltage	[illegible]	I_{OH} = −15 mA	V_{CC}−1.5			V
		[illegible]ATE DRIVE	I_{OH} = −20 mA	V_{CC}−1.5			
V_{OL}	Low-level output voltage	[illegible]	I_{OL} = 15 mA			0.4	V
V_{T-}	Undervoltage threshold (negative-going)	[illegible]70-5 (5-V sense, 1[illegible]	T_A = 25°C	4.5	4.55	4.6	V
		TL7770-12 (12-V sense, [illegible])		10.8	10.9	11.02	
		TL7770-15 (15-V sense, 1VSU)		13.5	13.64	13.77	
		TL7770-5, TL7770-12, TL7770-15 (programmable sense, 2VSU)		1.485	1.5	1.515	
		TL7770-5 (5-V sense, 1VSU)		4.46		4.64	
		TL7770-12 (12-V sense, 1VSU)		10.68		11.12	
		TL7770-15 (15-V sense, 1VSU)		13.36		13.91	
		TL7770-5, TL7770-12, TL7770-15 (pr[illegible]mable sense, 2VSU)		1.47		1.53	
V_T	Overvoltage threshold	TL[illegible]5, TL7770-12, TL7770-15 (VSO)	T_A = 25°C	2.53	2.58	2.63	V
			T_A = MIN to MAX	2.48		2.68	
V_{hys}	Hysteresis (V_{T+} − V_{T-}) at VSU	T[illegible]-5 (5-V sense, 1[illegible]	T_A = 25°C		15		mV
		TL7770-12 (12-V sense, [illegible])			36		
		TL7770-15 (15-V sense, 1VSU)			45		
		TL7770-5, TL7770-12, TL7770-15 (programmable sense, 2VSU)			5		
I_I	Input current	$\overline{\text{RESIN}}$	V_I = 5.5 V or 0.4 V			−10	μA
		VSO	V_I = 2.4 V		0.5	2	
I_{OH}	High-level output current	[illegible]	V_O = 18 V			50	μA
I_{OL}	Low-level output current	[illegible]	V_O = 0			−50	μA
I_{OH}	Peak output current	SCR GATE DRIVE	Duration ≈ 1 ms	250			mA

total device

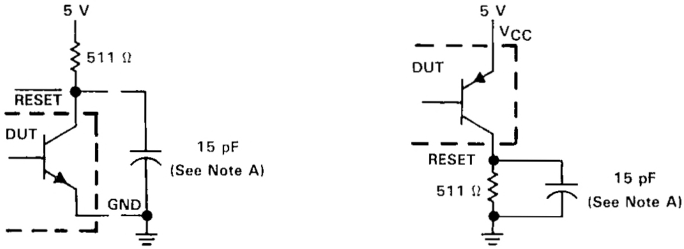
PARAMETER		TEST CONDITIONS†		MIN	TYP‡	MAX	UNIT
I_{CC}	Supply current	1VSU and 2VSU at > V_{T+}, [illegible] at V_{CC}, 1VSO and 2VSO at 0 V	T_A = 25°C			5	mA
			T_A = MIN to MAX			6.5	

†For conditions shown as MIN or MAX, use the appropriate value specified in the recommended operating conditions.
‡Typical values are at V_{CC} = 5 V, T_A = 25°C.

switching characteristics, V_{CC} = 5 V, CT open, T_A = 25°C

PARAMETER		FROM (INPUT)	TO (OUTPUT)	TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_{PLH}	Propagation delay time, low-to-high-level output	$\overline{RESIN}$	RESET	See Figure 1		270	500	ns
t_{PHL}	Propagation delay time, high-to-low-level output	$\overline{RESIN}$	RESET			270	500	ns
t_{PLH}	Propagation delay time, low-to-high-level output	$\overline{RESIN}$	$\overline{RESET}$			270	500	ns
t_{PHL}	Propagation delay time, high-to-low-level output	$\overline{RESIN}$	$\overline{RESET}$			270	500	ns
t_r	Rise time		RESET				75	ns
t_f	Fall time					150		
t_r	Rise time		$\overline{RESET}$			75		ns
t_f	Fall time						50	
$t_{w(min)}$	Minimum effective pulse duration	$\overline{RESIN}$		See Figure 2(a)		150		ns
		VSU		See Figure 2(b)		100		

PARAMETER MEASUREMENT INFORMATION

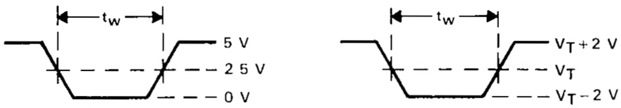


$\overline{\text{RESET}}$ OUTPUT CONFIGURATION

RESET OUTPUT CONFIGURATION

NOTE A: Includes jig and probe capacitance.

FIGURE 1. RESET AND $\overline{\text{RESET}}$ OUTPUT CONFIGURATIONS



(a) $\overline{\text{RESIN}}$

(b) VSU

WAVEFORMS

FIGURE 2. INPUT PULSE DEFINITION

TEXAS INSTRUMENTS
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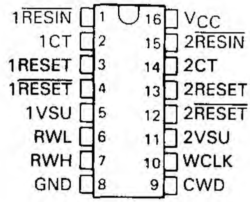
D3016, I

- Power-On Reset Generator
- Automatic Reset Generation After Voltage Drop
- Wide Supply Voltage Range . . . 3.5 V to 18 V
- Dual Precision Undervoltage Comparators
- Temperature-Compensated Voltage Reference
- True and Complementary Reset Outputs
- Externally Adjustable Pulse Duration
- Outputs Valid When V_{CC} Exceeds 1 V
- Precision Watchdog Function
- Externally Set Timing Window
- Externally Set Delay

D OR N PACKAGE
(TOP VIEW)



2 Data Sheets

description

The TL7780 is a monolithic integrated circuit system supervisor designed for use as a reset controller in microcomputer and microprocessor power supply systems. This device contains two independent supply-voltage supervisors and one watchdog function. The voltage supervisors monitor the supply . s at the VSU pins. When V_{CC} attains the minimum voltage of 1 V during power-up, the RESET and ·: :-· outputs become active (high and low, respectively) to prevent undefined operation. Taking $\overline{\text{RESIN}}$ low has the same effect. To ensure that the microcomputer system has reset, the outputs remain active after the voltage at VSU exceeds the threshold value V_{T+} for a time delay (t_d) determined by an external timing capacitor such that:

$$t_d = \text{(constant to be determined) X capacitance}$$

where t_d is in seconds and capacitance is in farads

The "watchdog" function monitors the system activity by sensing the positive edge of a programmer-generated signal at WCLK. An on-board current source generates a voltage ramp v_{cwd} across the external capacitor connected to CWD, which is compared to a timing window (set by external resistors connected to RWL and RWH) at the instant of the occurrence of the positive edge of the programmer-generated signal WCLK. If the positive edge of WCLK occurs before v_{cwd} reaches the voltage at RWL or after v_{cwd} reaches the voltage at RWH, then 1RESET and 1$\overline{\text{RESET}}$ become active, resetting the system for a period t_d. A precision current source, which tracks with the CWD charging current, allows RWL and RWH to be set by external resistors, creating a temperature-compensated "watchdog" window.

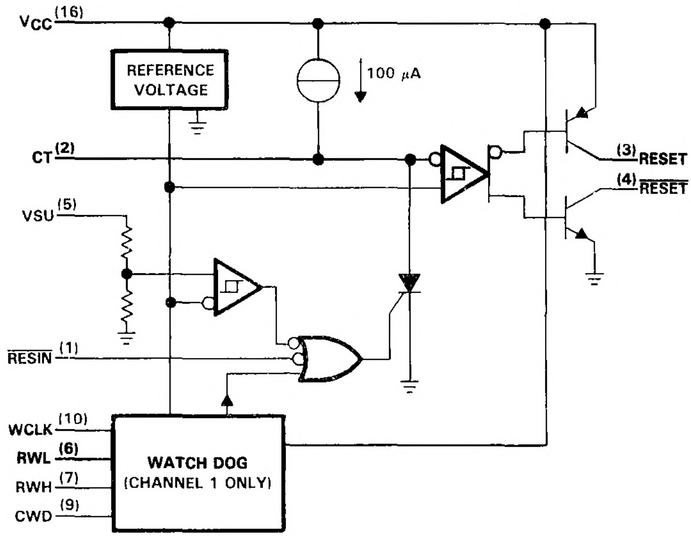
To set up the required frequency window for WCLK, the following conditions must exist:

1) $C_{WD} > 100$ pF, $R_{WL} > 10$ kΩ, $R_{WH} > 40$ kΩ

2) $f_L = \frac{1}{R_{WH}} \times C_{WD}$, $f_H = \frac{1}{R_{WL}} \times C_{WD}$

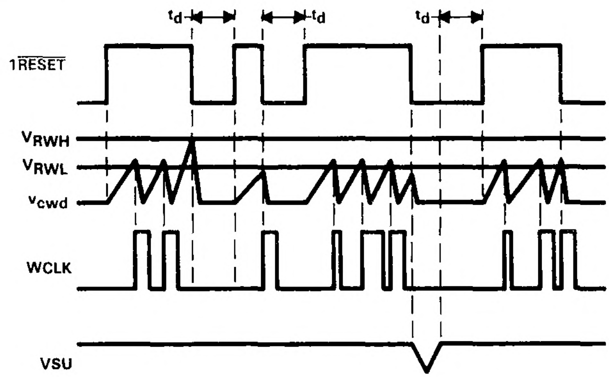
The TL7780Q series is characterized for operation from −40°C to 125°C. The TL7780C series is characterized for operation from 0°C to 70°C.

logic diagram (each channel)†



† Pin numbers for channel 1 are shown; pin 16 is common to both channels.

functional timing diagram



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Supply voltage, V_{CC} (see Note 1) . . . . 20 V
Input voltage range 1$\overline{RESIN}$, 2$\overline{RESIN}$, 1VSU, 2VSU) . . . . −0.3 V to V_{CC}
High-level output current 1RESET and 2RESET, I_{OH}: . . . . −20 mA
Low-level output current 1$\overline{RESET}$ and 2$\overline{RESET}$, I_{OL}: . . . . 20 mA
Continuous total dissipation . . . . See Dissipation Rating Table
Operating virtual junction temperature range . . . . −40°C to 150°C
Storage temperature range . . . . −65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds . . . . 260°C

NOTE 1: All voltage values are with respect to network ground terminal.

DISSIPATION RATING TABLE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR ABOVE T_A = 25°C	T_A = 70°C POWER RATING	T_A = 125°C POWER RATING
D	950 mW	7.6 mW/°C	608 mW	190 mW
N	1000 mW	12.5 mW/°C	1000 mW	312 mW

recommended operating conditions

		MIN	MAX	UNIT
Supply v[illegible], V_{CC}		3.5	18	V
Input voltage, V_I	1$\overline{RESIN}$, 2$\overline{RESIN}$, 1VSU, 2VSU, V_I, See Note 2	−0.3	18	V
Output voltage (1CT and 2CT), V_O			5	V
Output sink current (1CT and 2CT), I_O			50	µA
High-level output current (1RESET and 2RESET), I_{OH}			−16	mA
Low-level output current (1$\overline{RESET}$ and 2$\overline{RESET}$), I_{OL}			16	mA
Operating free-air temperature, T_A	TL7780Q Series	−40	125	°C
	TL7780C Series	0	70	

NOTE 2: The algebraic convention, in which the least positive (most negative) value is designated minimum, is used in this data sheet for input voltage levels and temperature only.

2 Data Sheets

electrical characteristics over recommended ranges of supply voltage, input voltage, output current, and operating free-air temperature (unless otherwise noted)

supply supervisor section

PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
V_{OH}	High-level output voltage	RESET	I_{OH} = −15 mA	V_{CC}−1.5			V
V_{OL}	Low-level output voltage	$\overline{RESET}$	I_{OL} = 15 mA			0.4	V
V_{T-}	Undervoltage threshold (negative-going)	TL7780-5 (5-V sense, 1VSU)	T_A = 25°C	4.5	4.55	4.6	V
		TL7780-12 (12-V sense, 1VSU)		10.8	10.9	11.02	
		TL7780-15 (15-V sense, 1VSU)		13.5	13.64	13.77	
		TL7780-5, TL7780-12, TL7780-15 (programmable sense, 2VSU)		1.485	1.5	1.515	
		TL7780-5 (5-V sense, 1VSU)		4.46		4.64	
		TL7780-12 (12-V sense, 1VSU)		10.68		11.12	
		TL7780-15 (15-V sense, 1VSU)		13.36		13.91	
		TL7780-5, TL7780-12, TL7780-15 (programmable sense, 2VSU)		1.47		1.53	
V_{hys}	Hysteresis (V_{T+} − V_{T-}) at VSU	TL7780-5 (5-V sense, 1VSU)	T_A = 25°C		15		mV
		TL7780-12 (12-V sense, 1VSU)			36		
		TL7780-15 (15-V sense, 1VSU)			45		
		TL7780-5, TL7780-12, TL7780-15 (p[illegible]nmable sense, 2VSU)			5		
I_I	Input current	[illegible]	V_I = 5.5 V or 0.4 V			−10	µA
I_{OH}	High-level output current	$\overline{RESET}$	V_O = 18 V			50	µA
I_{OL}	Low-level output current	RESET	V_O = 0			−50	µA

electrical characteristics over recommended ranges of supply voltage, input voltage, output current, and operating free-air temperature, Ct at 0.1 µF to GND (unless otherwise noted)

"watchdog" section

PARAMETER			TEST CONDITIONS†	MIN	TYP	MAX	UNIT
V_T	Input threshold voltage	WCLK	V_{CC} = 3.5 V to 18 V	0.4		1.8	V
I_I	Input current	WCLK	V_I = 2.4 V			100	µA
			V_I = 0.4 V			200	
	Charging current	CWD	V_{CC} = 3.5 V to 18 V	45		55	µA
I_O	Output current	RWL and RWH	V_{CC} = 3.5 V to 18 V	45		55	µA

total device

PARAMETER			TEST CONDITIONS	MIN	TYP	MAX	UNIT
I_{CC}	Supply current	VSU and $\overline{RESIN}$ at V_{CC}	T_A = 25°C			5	mA
			T_A = MIN to MAX			6.5	

† For conditions shown as MIN or MAX, use the appropriate value specified in the recommended operating conditions.

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switching characteristics, V_{CC} = 5 V, Cr open, T_A = 25°C (see Figure 1)

supply supervisor section

PARAMETER		FROM (INPUT)	TO (OUTPUT)	TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_{PLH}	Propagation delay time, low-to-high-level output	[illegible]	1RESET	C_L = 15 pF		100	500	ns
t_{PHL}	Propagation delay time, high-to-low-level output	[illegible]	2RESET			100	500	ns
t_{PLH}	Propagation delay time, low-to-high-level output	2 [illegible]	2$\overline{\text{RESET}}$			100	500	ns
t_{PHL}	Propagation delay time, high-to-low-level output	1$\overline{\text{RESIN}}$	1$\overline{\text{RESET}}$			100	500	ns
t_r	Rise time	1RESET or 2RESET					75	ns
t_f	Fall time						50	
t_r	Rise time	1$\overline{\text{RESET}}$ or 2$\overline{\text{RESET}}$					75	ns
t_f	Fall time						50	

"watchdog" section

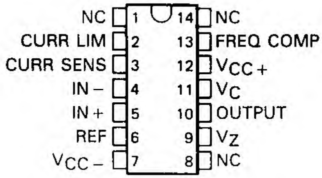
PARAMETER		FROM (INPUT)	TO (OUTPUT)	TEST CONDITIONS	MIN	TYP	MAX	UNIT
t_{PLH}	Propagation delay time, low-to-high-level output	WCLK	1RESET	C_L = 15 pF,		100	500	ns
t_{PHL}	Propagation delay time, high-to-low-level output	WCLK	1RESET	R_{WL} = 60 kΩ,		100	500	ns
t_{PLH}	Propagation delay time, low-to-high-level output	WCLK	1$\overline{\text{RESET}}$	R_{WH} = 60 kΩ,		100	500	ns
t_{PHL}	Propagation delay time, high-to-low-level output	WCLK	1$\overline{\text{RESET}}$	CWD = 2 V		100	500	ns
t_{PLH}	Propagation delay time, low-to-high-level output	WCLK	CWD	C_{WD} = 15 pF		100	500	ns
t_{PHL}	Propagation delay time, high-to-low-level output	WCLK	CWD	(probe capacitance)		100	500	ns

2

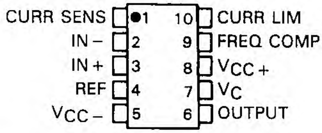
Data Sheets

- **150-mA Load Current Without External Power Transistor**
- **Typically 0.02% Input Regulation and 0.03% Load Regulation (uA723M)**
- **Adjustable Current Limiting Capability**
- **Input Voltages to 40 V**
- **Output Adjustable from 2 to 37 V**
- **Direct Replacement for Fairchild μA723M and μA723C**

uA723M . . . J PACKAGE
uA723C . . . D, J, OR N PACKAGE
(TOP VIEW)



uA723M . . . U PACKAGE
(TOP VIEW)



NC—No internal connection

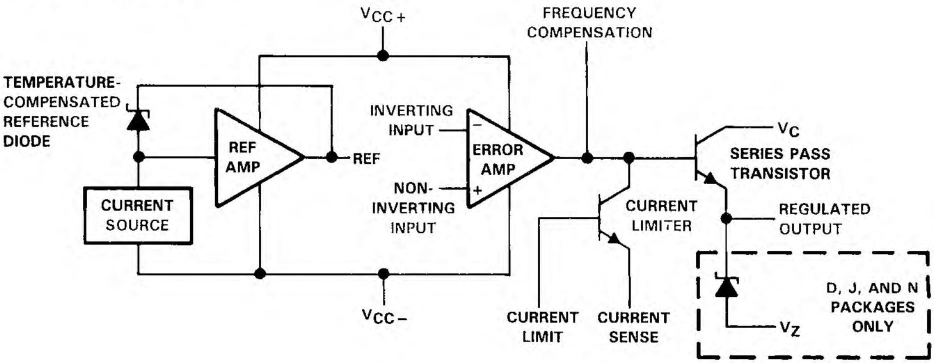
description

The uA723M and uA723C are monolithic integrated circuit voltage regulators featuring high ripple rejection, excellent input and load regulation, excellent temperature stability, and low standby current. The circuit consists of a temperature-compensated reference voltage amplifier, an error amplifier, a 150-mA output transistor, and an adjustable output current limiter.

The uA723M and uA723C are designed for use in positive or negative power supplies as a series, shunt, switching, or floating regulator. For output currents exceeding 150 mA, additional pass elements may be connected as shown in Figures 4 and 5.

The uA723M is characterized for operation over the full military temperature range of −55°C to 125°C. The uA723C is characterized for operation from 0°C to 70°C.

functional block diagram



absolute maximum ratings over operating free-air temperature range (unless otherwise noted)

Peak voltage from V_{CC+} to V_{CC-} ($t_w \leq 50$ ms)	50 V
Continuous voltage from V_{CC+} to V_{CC-}	40 V
Input-to-output voltage differential	40 V
Differential input voltage to error amplifier	±5 V
Voltage between noninverting input and V_{CC-}	8 V
Current from V_Z	25 mA
Current from REF	15 mA
Continuous total dissipation (see Note 1)	See Dissipation Rating Table
Operating free-air temperature range: uA723M Circuits	−55°C to 125°C
uA723C Circuits	0°C to 70°C
Storage temperature range	−65°C to 150°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J or U package	300°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: D or N package	260°C

NOTE 1: Power dissipation = $[I_{(standby)} + I_{(ref)}] V_{CC} + [V_C - V_O] I_O$.

DISSIPATION RATING TABLE

PACKAGE	$T_A \leq 25°C$ POWER RATING	DERATING FACTOR	DERATE ABOVE T_A	$T_A = 70°C$ POWER RATING	$T_A = 125°C$ POWER RATING
D	950 mW	7.6 mW/°C	25°C	608 mW	
J (uA-M)	1000 mW	11.0 mW/°C	59°C	880 mW	275 mW
J (uA-C)	1000 mW	8.2 mW/°C	28°C	656 mW	
N	1000 mW	9.2 mW/°C	41°C	736 mW	
U	675 mW	5.4 mW/°C	25°C	432 mW	135 mW

recommended operating conditions

	MIN	MAX	UNIT
Input voltage, V_I	9.5	40	V
Output voltage, V_O	2	37	V
Input-to-output voltage differential, $V_C - V_O$	3	38	V
Output current, I_O		150	mA

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electrical characteristics at specified free-air temperature (see Notes 2 and 3)

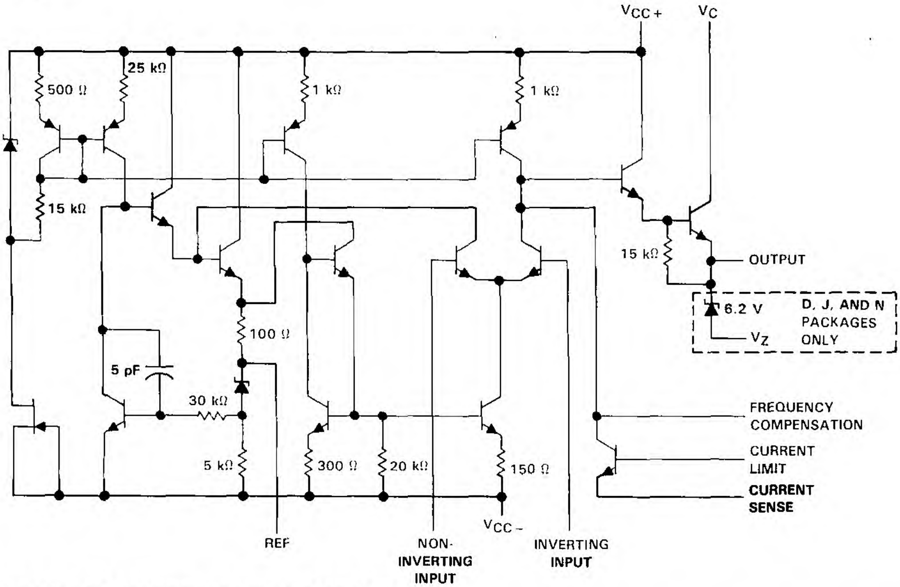
PARAMETER	TEST CONDITIONS†		uA723M MIN	uA723M TYP	uA723M MAX	uA723C MIN	uA723C TYP	uA723C MAX	UNIT
Input regulation	V_I = 12 V to V_I = 15 V	25°C		0.01%	0.1%		0.01%	0.1%	
	V_I = 12 V to V_I = 40 V	25°C		0.02%	0.2%		0.1%	0.5%	
	V_I = 12 V to V_I = 15 V	Full range			0.3%			0.3%	
Ripple rejection	f = 50 Hz to 10 kHz, $C_{(ref)}$ = 0	25°C		74			74		dB
	f = 50 Hz to 10 kHz, $C_{(ref)}$ = 5 μF	25°C		86			86		
Output regulation	I_O = 1 mA to I_O = 50 mA	25°C		−0.03%	−0.15%		−0.03%	−0.2%	
		Full range			−0.6%			−0.6%	
Reference voltage, $V_{(ref)}$		25°C	6.95	7.15	7.35	6.8	7.15	7.5	V
Standby current	V_I = 30 V, I_O = 0	25°C		2.3	3.5		2.3	4	mA
Temperature coefficient of output voltage		Full range		0.002	0.015		0.003	0.015	%/°C
Short-circuit output current	R_{SC} = 10 Ω, V_O = 0	25°C		65			65		mA
Output noise voltage	BW = 100 Hz to 10 kHz, $C_{(ref)}$ = 0	25°C		20			20		μV
	BW = 100 Hz to 10 kHz, $C_{(ref)}$ = 5 μF	25°C		2.5			2.5		

†Full range for uA723M is −55°C to 125°C and for uA723C is 0°C to 70°C.

NOTES: 2. For all values in this table, the device is connected as shown in Figure 1 with the divider resistance as seen by the error amplifier ≤ 10 kΩ. Unless otherwise specified, $V_I = V_{CC+} = V_C$ = 12 V, V_{CC-} = 0, V_O = 5 V, I_O = 1 mA, R_{SC} = 0, and $C_{(ref)}$ = 0.

3. Pulse testing techniques must be used that will maintain the junction temperature as close to the ambient temperature as possible.

schematic



RESISTOR AND CAPACITOR VALUES SHOWN ARE NOMINAL.

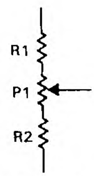
TYPICAL APPLICATION DATA

TABLE 1. RESISTOR VALUES (kΩ) FOR STANDARD OUTPUT VOLTAGES

OUTPUT VOLTAGE (V)	APPLICABLE FIGURES (SEE NOTE 3)	FIXED OUTPUT ±5%		OUTPUT ADJUSTABLE ±10% (SEE NOTE 4)			OUTPUT VOLTAGE (V)	APPLICABLE FIGURES (SEE NOTE 3)	FIXED OUTPUT ±5%		OUTPUT ADJUSTABLE ±10% (SEE NOTE 4)		
		R1 (kΩ)	R2 (kΩ)	R1 (kΩ)	P1 (kΩ)	P2 (kΩ)			R1 (kΩ)	R2 (kΩ)	R1 (kΩ)	P1 (kΩ)	P2 (kΩ)
+3.0	1,5,6,9,11, 12 (4)	4.12	3.01	1.8	0.5	1.2	+100	7	3.57	105	2.2	10	91
+3.6	1,5,6,9,11, 12 (4)	3.57	3.65	1.5	0.5	1.5	+250	7	3.57	255	2.2	10	240
+5.0	1,5,6,9,11, 12 (4)	2.15	4.99	0.75	0.5	2.2	−6 (Note 5)	3, (10)	3.57	2.43	1.2	0.5	0.75
+6.0	1,5,6,9,11, 12 (4)	1.15	6.04	0.5	0.5	2.7	−9	3, 10	3.48	5.36	1.2	0.5	2.0
+9.0	2,4, (5,6, 9, 12)	1.87	7.15	0.75	1.0	2.7	−12	3, 10	3.57	8.45	1.2	0.5	3.3
+12	2,4, (5,6, 9, 12)	4.87	7.15	2.0	1.0	3.0	−15	3, 10	3.57	11.5	1.2	0.5	4.3
+15	2,4, (5, 6, 9, 12)	7.87	7.15	3.3	1.0	3.0	−28	3, 10	3.57	24.3	1.2	0.5	10
+28	2,4, (5, 6, 9, 12)	21.0	7.15	5.6	1.0	2.0	−45	8	3.57	41.2	2.2	10	33
+45	7	3.57	48.7	2.2	10	39	−100	8	3.57	95.3	2.2	10	91
+75	7	3.57	78.7	2.2	10	68	−250	8	3.57	249	2.2	10	240

NOTES: 3. The R1/R2 divider may be across either V_O or $V_{(ref)}$. If the divider is across $V_{(ref)}$, use the figure numbers without parentheses. If the divider is across V_O, use the figure numbers in parentheses.

4. To make the voltage adjustable, the R1/R2 divider shown in the figures must be replaced by the divider shown below.



ADJUSTABLE OUTPUT CIRCUIT

5. The device requires a minimum of 9 V between V_{CC+} and V_{CC-} when V_O is equal to or more positive than −9 V.

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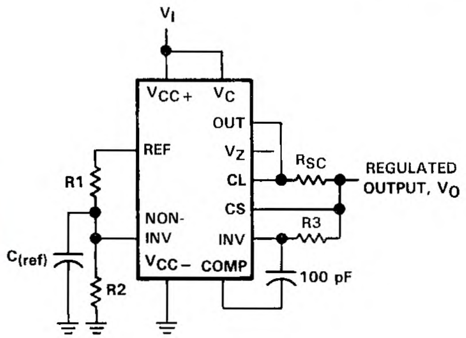
TYPICAL APPLICATION DATA

TABLE 2. FORMULAS FOR INTERMEDIATE OUTPUT VOLTAGES

Outputs from +2 to +7 V [Figures 1,5,6,9, 11, 12, (4)]	Outputs from +4 to +250 V (Figure 7)	Current Limiting
$V_O = V_{(ref)} \times \frac{R2}{R1 + R2}$	$V_O = \frac{V_{(ref)}}{2} \times \frac{R2 - R1}{R1}$; $R3 = R4$	$I_{(limit)} \approx \frac{0.65\ V}{R_{SC}}$
Outputs from +7 to +37 V [Figures 2,4,(5,6,9, 11, 12)]	**Outputs from −6 to −250 V [Figures 3,8, 10]**	**Foldback Current Limiting [Figure 6]**
$V_O = V_{(ref)} \times \frac{R1 + R2}{R2}$	$V_O = -\frac{V_{(ref)}}{2} \times \frac{R1 + R2}{R1}$, $R3 = R4$	$I_{(knee)} \approx \frac{V_O R3 + (R3 + R4)\,0.65\ V}{R_{SC} R4}$; $I_{OS} \approx \frac{0.65\ V}{R_{SC}} \times \frac{R3 + R4}{R4}$

NOTES: 3. The R1/R2 divider may be across either V_O or $V_{(ref)}$. If the divider is across $V_{(ref)}$ and uses figures without parentheses, use figures with parentheses when the divider is across V_O.
4. To make the voltage adjustable, the R1/R2 divider shown in the figures must be replaced by the divider shown at the right.
5. The device requires a minimum of 9 V between V_{CC+} and V_{CC-} when V_O is equal to or more positive than −9 V.

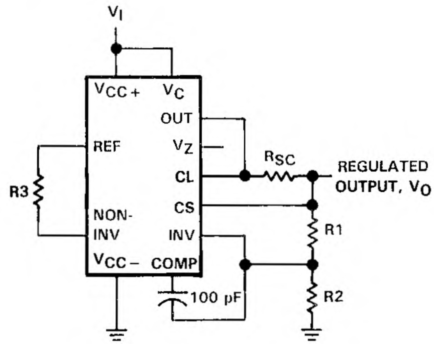
TYPICAL APPLICATION DATA



NOTES: A. $R3 = \frac{R1 \cdot R2}{R1 + R2}$ for minimum α_{VO}.

B. R3 may be eliminated for minimum component count. Use direct connection (i.e., $R_3 = 0$).

FIGURE 1. BASIC LOW-VOLTAGE REGULATOR (V_O = 2 TO 7 VOLTS)



NOTES: A. $R3 = \frac{R1 \cdot R2}{R1 + R2}$ for minimum α_{VO}.

B. R3 may be eliminated for minimum component count. Use direct connection (i.e., $R_3 = 0$).

FIGURE 2. BASIC HIGH-VOLTAGE REGULATOR (V_O = 7 TO 37 VOLTS)

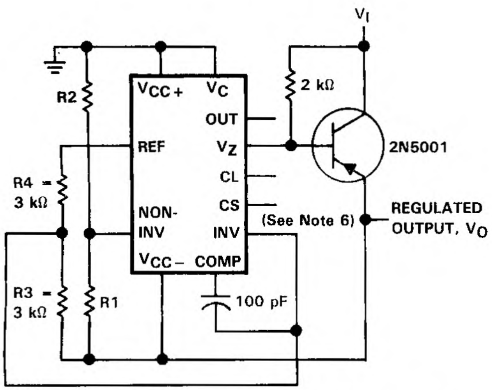


FIGURE 3. NEGATIVE-VOLTAGE REGULATOR

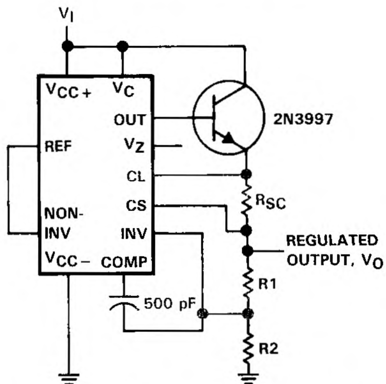


FIGURE 4. POSITIVE-VOLTAGE REGULATOR (EXTERNAL N-P-N PASS TRANSISTOR)

NOTE 6: When 10-lead uA723U devices are used in applications requiring V_Z, an external 6.2-V regulator diode must be connected in series with the OUT terminal.

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TYPICAL APPLICATION DATA

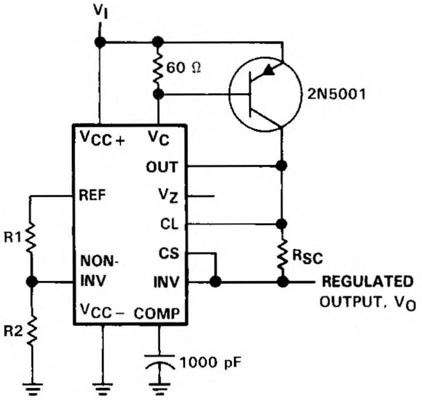

FIGURE 5. POSITIVE-VOLTAGE REGULATOR (EXTERNAL P-N-P PASS TRANSISTOR)

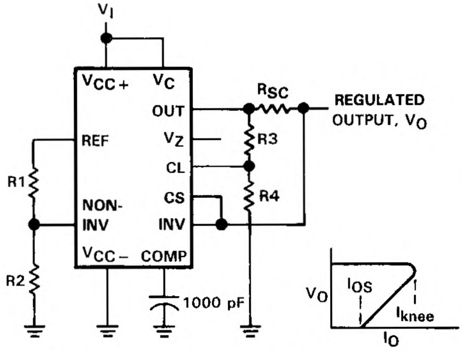

FIGURE 6. FOLDBACK CURRENT LIMITING

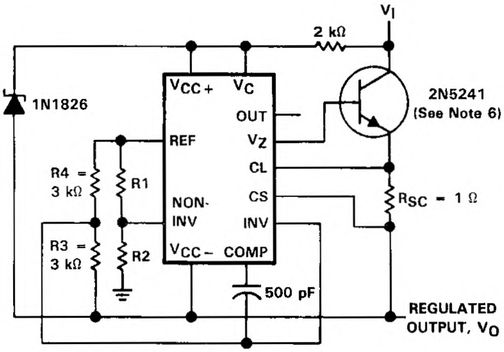

FIGURE 7. POSITIVE FLOATING REGULATOR

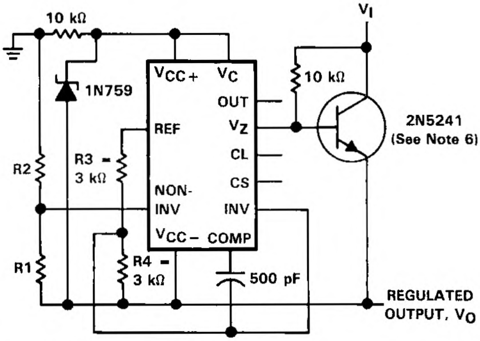

FIGURE 8. NEGATIVE FLOATING REGULATOR

NOTE 6: When 10-lead uA723U devices are used in applications requiring V_Z, an external 6.2-V regulator diode must be connected in series with the OUT terminal.

TYPICAL APPLICATION DATA

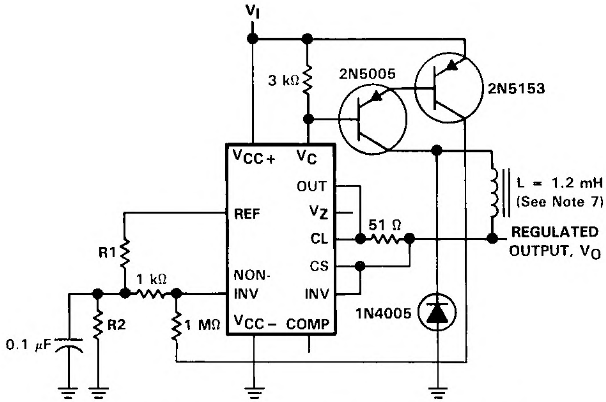

FIGURE 9. POSITIVE SWITCHING REGULATOR

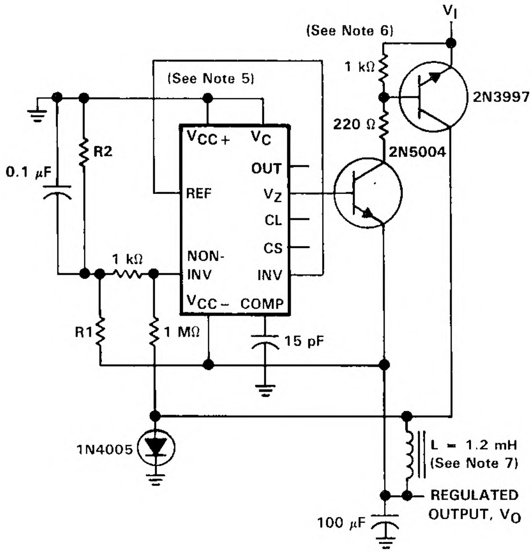

FIGURE 10. NEGATIVE SWITCHING REGULATOR

NOTES: 5. The device requires a minimum of 9 V between V_{CC+} and V_{CC-} when V_O is equal to or more positive than −9 V.

6. When 10-lead uA723U devices are used in applications requiring V_Z, an external 6.2-V regulator diode must be connected in series with the OUT terminal.

7. L is 40 turns of No. 20 enameled copper wire wound on Ferroxcube P36/22-3B7 potted core, or equivalent, with an 0.009-inch air gap.

TEXAS INSTRUMENTS
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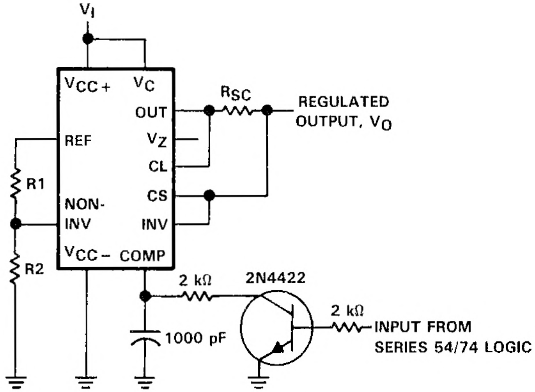
TYPICAL APPLICATION DATA



NOTE A: Current limit transistor may be used for shutdown if current limiting is not required.

FIGURE 11. REMOTE SHUTDOWN REGULATOR WITH CURRENT LIMITING

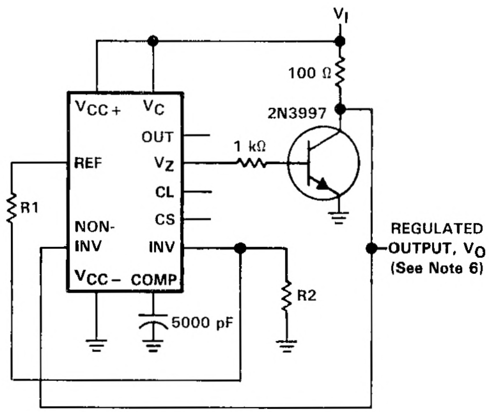


FIGURE 12. SHUNT REGULATOR

NOTE 6: When 10-lead uA723U devices are used in applications requiring V_Z, an external 6.2-V regulator diode must be connected in series with the OUT terminal.

D2154, MAY 1976—REVISED APRIL 1988

- 3-Terminal Regulators
- Output Current Up to 1.5 A
- No External Components
- Internal Thermal Overload Protection
- High Power Dissipation Capability
- Internal Short-Circuit Current Limiting
- Output Transistor Safe-Area Compensation
- Direct Replacements for Fairchild μA7800 Series

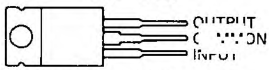
NOMINAL OUTPUT VOLTAGE	REGULATOR
5 V	uA7805C
6 V	uA7806C
8 V	uA7808C
8.5 V	uA7885C
10 V	uA7810C
12 V	uA7812C
15 V	uA7815C
18 V	uA7818C
24 V	uA7824C

description

This series of fixed-voltage monolithic integrated-circuit voltage regulators is designed for a wide range of applications. These applications include on-card regulation for elimination of noise and distribution problems associated with single-point regulation. Each of these regulators can deliver up to 1.5 amperes of output current. The internal current limiting and thermal shutdown features of these regulators make them essentially immune to overload. In addition to use as fixed-voltage regulators, these devices can be used with external components to obtain adjustable output voltages and currents and also as the power-pass element in precision regulators.

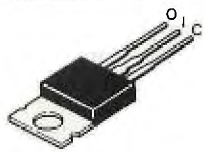
KC PACKAGE

(TOP VIEW)



THE COMMON TERMINAL IS IN ELECTRICAL CONTACT WITH THE MOUNTING BASE

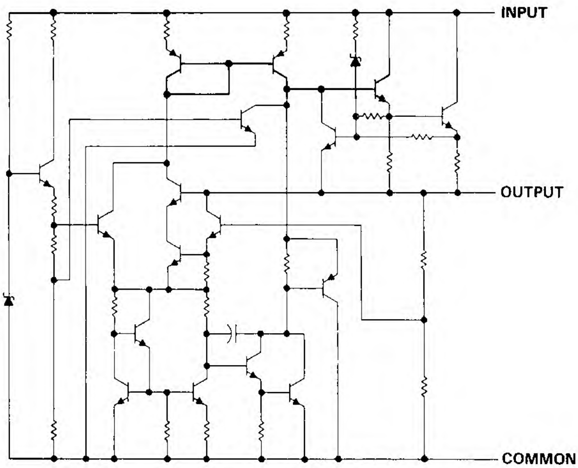
TO-220AB



2

Data Sheets

schematic



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absolute maximum ratings over operating temperature range (unless otherwise noted)

		uA78__ __C	UNIT
Input voltage	uA7824C	40	V
	All others	35	
Continuous total dissipation at 25°C free-air temperature (see Note 1)		2	W
Continuous total dissipation at (or below) 25°C case temperature (see Note 1)		15	W
Operating free-air, case, or virtual junction temperature range		0 to 150	°C
Storage temperature range		−65 to 150	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds		[illegible]	°C

NOTE 1: For operation above 25°C free-air or case temperature, refer to Figures 1 and 2. To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variations in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVE

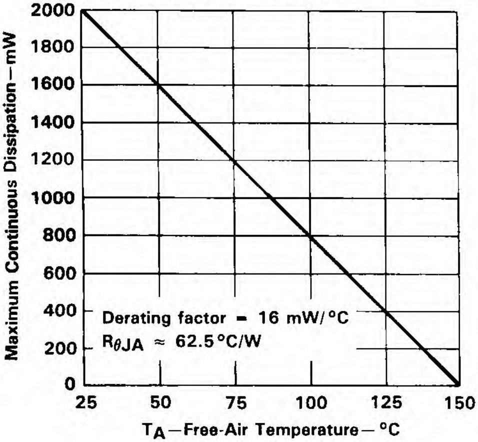

FIGURE 1

CASE TEMPERATURE
DISSIPATION DERATING CURVE

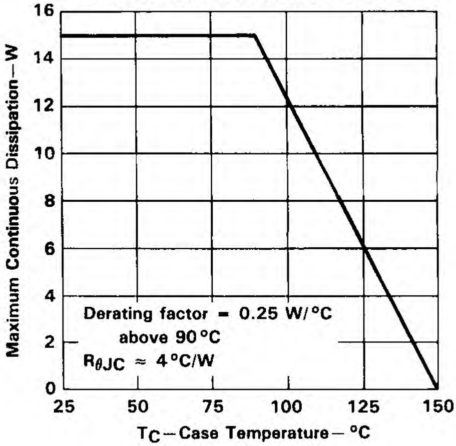

FIGURE 2

recommended operating conditions

		MI[illegible]	MAX	UNIT
Input voltage, V_I	uA7805C	[illegible]	25	V
	uA7806C	8	25	
	[illegible]	10.5	25	
	[illegible]	10.5	25	
	uA7810C	12.5	28	
	uA7812C	14.5	30	
	uA7815C	17.5	30	
	[illegible]	21	33	
	uA7824C	27	38	
Output current, I_O			1.5	A
Operating virtual junction temperature, T_J		0	125	°C

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uA7805C electrical characteristics at specified virtual junction temperature, V_I = 10 V, I_O = 500 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		uA7805C			UNIT
			MIN	TYP	MAX	
Output voltage‡		25°C	4.8	5	5.2	V
	I_O = 5 mA to 1 A, V_I = 7 V to 20 V, P ≤ 15 W	0°C to 125°C	4.75		5.25	
Input regulation	V_I = 7 V to 25 V	25°C		3	100	mV
	V_I = 8 V to 12 V			1	50	
Ripple rejection	V_I = 8 V to 18 V, f = 120 Hz	0°C to [illegible] C	62	78		dB
Output regulation	I_O = 5 mA to 1.5 A	25°C		15	100	mV
	I_O = 250 mA to 750 mA			5	50	
Output resistance	f = 1 kHz	0°C to 125°C		0.017		Ω
Temperature coefficient of output voltage	I_O = 5 mA	0°C to 125°C		−1.1		mV/°C
Output noise voltage	f = 10 Hz to 100 kHz	25°C		40		μV
Dropout voltage	I_O = 1 A	25°C		2.0		V
Bias current		25°C		4.2	8	mA
Bias current change	V_I = 7 V to 25 V	0°C to 125°C			1.3	mA
	I_O = 5 mA to 1 A				0.5	
Short-circuit output current		25°C		750		mA
Peak output current		25°C		[illegible]		A

uA7806C electrical characteristics at specified virtual junction temperature, V_I = 11 V, I_O = 500 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		uA7806C			UNIT
			MIN	TYP	MAX	
Output voltage‡		25°C	5.75	6	6.25	V
	I_O = 5 mA to 1 A, V_I = 8 V to 21 V, P ≤ 15 W	0°C to 125°C	5.7		6.3	
Input regulation	V_I = 8 V to 25 V	25°C		5	120	mV
	V_I = 9 V to 13 V			1.5	60	
Ripple rejection	V_I = 9 V to 19 V, f = 120 Hz	0°C to 125°C	59	75		dB
Output regulation	I_O = 5 mA to 1.5 A	25°C		14	120	mV
	I_O = 250 mA to 750 mA			4	60	
Output resistance	f = 1 kHz	0°C to 125°C		0.019		Ω
Temperature coefficient of output voltage	I_O = 5 mA	0°C to 125°C		−0.8		mV/°C
Output noise voltage	f = 10 Hz to 100 kHz	25°C		45		μV
Dropout voltage	I_O = 1 A	25°C		2.0		V
Bias current		25°C		4.3	8	mA
Bias current change	V_I = 8 V to 25 V	0°C to 125°C			1.3	mA
	I_O = 5 mA to 1 A				0.5	
Short-circuit output current		25°C		550		mA
Peak output current		25°C		2.2		A

†Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.
‡This specification applies only for dc power dissipation permitted by absolute maximum ratings.

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uA7808C electrical characteristics at specified virtual junction temperature, V_I = 14 V, I_O = 500 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		uA7808C MIN	uA7808C TYP	uA7808C MAX	UNIT
Output voltage‡		25°C	7.7	8	8.3	V
	I_O = 5 mA to 1 A, V_I = 10.5 V to 23 V, P ≤ 15 W	0°C to 125°C	7.6		8.4	
Input regulation	V_I = 10.5 V to 25 V	25°C		6	160	mV
	V_I = 11 V to 17 V			2	80	
Ripple rejection	V_I = 11.5 V to 21.5 V, f = 120 Hz	0°C to 125°C	55	72		dB
Output regulation	I_O = 5 mA to 1.5 A	25°C		12	[illegible]	mV
	I_O = 250 mA to 750 mA			4	80	
Output resistance	f = 1 kHz	0°C to 125°C		0.016		Ω
Temperature coefficient of output voltage	I_O = 5 mA	0°C to 125°C		−0.8		mV/°C
Output noise voltage	f = 10 Hz to 100 kHz	25°C		52		μV
Dropout voltage	I_O = 1 A	25°C		2.0		V
Bias current		25°C		4.3	8	mA
Bias current change	V_I = 10.5 V to 25 V	0°C to 125°C			1	mA
	I_O = 5 mA to 1 A				0.5	
Short-circuit output current		25°C		450		mA
Peak output current		25°C		2.2		A

uA7885C electrical characteristics at specified virtual junction temperature, V_I = 15 V, I_O = 500 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		uA7885C MIN	uA7885C TYP	uA7885C MAX	UNIT
Output voltage‡		25°C	8.15	8.5	8.85	V
	I_O = 5 mA to 1 A, V_I = 11 V to 23.5 V, P ≤ 15 W	0°C to 125°C	8.1		8.9	
Input regulation	V_I = 10.5 V to 25 V	25°C		6	170	mV
	V_I = 11 V to 17 V			2	85	
Ripple rejection	V_I = 11.5 V to 21.5 V, f = 120 Hz	0°C to 125°C	54	70		dB
Output regulation	I_O = 5 mA to 1.5 A	25°C		12	170	mV
	I_O = 250 mA to 750 mA			4	85	
Output resistance	f = 1 kHz	0°C to 125°C		0.016		Ω
Temperature coefficient of output voltage	I_O = 5 mA	0°C to 125°C		−0.8		mV/°C
Output noise voltage	f = 10 Hz to 100 kHz	25°C		55		μV
Dropout voltage	I_O = 1 A	25°C		2.0		V
Bias current		25°C		4.3	8	mA
Bias current change	V_I = 10.5 V to 25 V	0°C to 125°C			1	mA
	I_O = 5 mA to 1 A				0.5	
Short-circuit output current		25°C		[illegible]		mA
Peak output current		25°C		2.2		A

†Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.
‡This specification applies only for dc power dissipation permitted by absolute maximum ratings.

uA7810C electrical characteristics at specified virtual junction temperature, V_I = 17 V, I_O = 500 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		uA7810C MIN	TYP	MAX	UNIT
Output voltage‡		25°C	9.6	10	10.4	V
	I_O = 5 mA to 1 A, V_I = 12.5 V to 25 V, P ≤ 15 W	0°C to 125°C	9.5	10	10.5	
Input regulation	V_I = 12.5 V to 28 V	25°C		7	200	mV
	V_I = 14 V to 20 V			2	100	
Ripple rejection	V_I = 13 V to 23 V, f = 120 Hz	0°C to [illegible] C	55	71		dB
Output regulation	I_O = 5 mA to 1.5 A	25°C		12	200	mV
	I_O = [illegible] mA to 750 mA			4	100	
Output resistance	f = [illegible]	0°C to [illegible] C		[illegible]		Ω
Temperature coefficient of output voltage	I_O = 5 mA	0°C to 125°C		−1.0		mV/°C
Output noise voltage	f = 10 Hz to 100 kHz	25°C		70		μV
Dropout voltage	I_O = 1 A	25°C		2.0		V
Bias current		25°C		4.3	8	mA
Bias current change	V_I = 12.5 V to 28 V	0°C to 125°C			1	mA
	I_O = 5 mA to 1 A				0.5	
Short-circuit output current		25°C		400		mA
Peak output current		25°C		2.2		A

uA7812C electrical characteristics at specified virtual junction temperature, V_I = 19 V, I_O = 500 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		uA7812C MIN	TYP	MAX	UNIT
Output voltage‡		25°C	11.5	12	12.5	V
	I_O = 5 mA to 1 A, V_I = 14.5 V to 27 V, P ≤ 15 W	0°C to 125°C	11.4		12.6	
Input regulation	V_I = 14.5 V to 30 V	25°C		10	240	mV
	V_I = 16 V to 22 V			3	120	
Ripple rejection	V_I = 15 V to 25 V, f = 120 Hz	0°C to 125°C	55	71		dB
Output regulation	I_O = 5 mA to 1.5 A	25°C		12	240	mV
	I_O = 250 mA to 750 mA			4	120	
Output resistance	f = 1 kHz	0°C to 125°C		0.018		Ω
Temperature coefficient of output voltage	I_O = 5 mA	0°C to 125°C		−1.0		mV/°C
Output noise voltage	f = 10 Hz to 100 kHz	25°C		75		μV
Dropout voltage	I_O = 1 A	25°C		2.0		V
Bias current		25°C		4.3	8	mA
Bias current change	V_I = 14.5 V to 30 V	0°C to 125°C			1	mA
	I_O = 5 mA to 1 A				0.5	
Short-circuit output current		25°C		350		mA
Peak output current		25°C		2.2		A

†Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.
‡This specification applies only for dc power dissipation permitted by absolute maximum ratings.

uA7815C electrical characteristics at specified virtual junction temperature, V_I = 23 V, I_O = 500 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		uA7[illegible]C MIN	TYP	MAX	UNIT
Output voltage‡		25°C	14.4	15	15.6	V
	I_O = 5 mA to 1 A, V_I = 17.5 V to 30 V, P ≤ 15 W	0°C to 125°C	14.25		15.75	
Input regulation	V_I = 17.5 V to 30 V	25°C		11	300	mV
	V_I = 20 V to 26 V			3	150	
Ripple rejection	V_I = 18.5 V to 28.5 V, f = 120 Hz	0°C to 125°C	54	70		dB
Output regulation	I_O = 5 mA to 1.5 A	25°C		12	300	mV
	I_O = 250 mA to 750 mA			4	150	
Output resistance	f = 1 kHz	0°C to [illegible]C		0.019		Ω
Temperature coefficient of output voltage	I_O = 5 mA	0°C to 125°C		−1.0		mV/°C
Output noise voltage	f = 10 Hz to 100 kHz	25°C		90		μV
Dropout voltage	I_O = 1 A	25°C		2.0		V
Bias current		25°C		4.4	8	mA
Bias current change	V_I = 17.5 V to 30 V	0°C to 125°C			1	mA
	I_O = 5 mA to 1 A				0.5	
Short-circuit output current		25°C		230		mA
Peak output current		25°C		2.1		A

uA7818C electrical characteristics at specified virtual junction temperature, V_I = 27 V, I_O = 500 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		uA7818C MIN	TYP	MAX	UNIT
Output voltage‡		25°C	[illegible]	18	[illegible]	V
	I_O = 5 mA to 1 A, V_I = 21 V to 33 V, P ≤ 15 W	0°C to 125°C	17.1		18.9	
Input regulation	V_I = 21 V to 33 V	25°C		15	[illegible]	mV
	V_I = 24 V to 30 V			5	[illegible]	
Ripple rejection	V_I = 22 V to 32 V, f = [illegible]Hz	0°C to 125°C	53	69		dB
Output regulation	I_O = 5 mA to 1.5 A	25°C		12	[illegible]	mV
	I_O = 250 mA to 750 mA			4	[illegible]	
Output resistance	f = 1 kHz	0°C to 125°C		0.022		Ω
Temperature coefficient of output voltage	I_O = 5 mA	0°C to 125°C		−1.0		mV/°C
Output noise voltage	f = 10 Hz to 100 kHz	25°C		110		μV
Dropout voltage	I_O = 1 A	25°C		2.0		V
Bias current		25°C		4.5	8	mA
Bias current change	V_I = 21 V to 33 V	0°C to 125°C			1	mA
	I_O = 5 mA to 1 A				0.5	
Short-circuit output current		25°C		200		mA
Peak output current		25°C		2.1		A

†Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.
‡This specification applies only for dc power dissipation permitted by absolute maximum ratings.

uA7824C electrical characteristics at specified virtual junction temperature, V_I = 33 V, I_O = 500 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		uA7824C MIN	uA7824C TYP	uA7824C MAX	UNIT
Output voltage‡		25°C	23	24	25	V
	I_O = 5 mA to 1 A, V_I = 27 V to 38 V, P ≤ 15 W	0°C to 125°C	22.8		25.2	
Input regulation	V_I = 27 V to 38 V	25°C		18	480	mV
	V_I = 30 V to 36 V			6	240	
Ripple rejection	V_I = 28 V to 38 V, f = 120 Hz	0°C to 125°C	50	66		dB
Output regulation	I_O = 5 mA to 1.5 A	25°C		12	480	mV
	I_O = 250 mA to 750 mA			4	240	
Output resistance	f = 1 kHz	0°C to 125°C		0.028		Ω
Temperature coefficient of output voltage	I_O = 5 mA	0°C to 125°C		−1.5		mV/°C
Output noise voltage	f = 10 Hz to 100 kHz	25°C		170		μV
Dropout voltage	I_O = 1 A	25°C		2.0		V
Bias current		25°C		4.6	8	mA
Bias current change	V_I = 27 V to 38 V	0°C to 125°C			1	mA
	I_O = 5 mA to 1 A				0.5	
Short-circuit output current		25°C		150		mA
Peak output current		25°C		2.1		A

†Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.
‡This specification applies only for dc power dissipation permitted by absolute maximum ratings.

- 3-Terminal Regulators
- Output Current Up to 100 mA
- No External Components
- Internal Thermal Overload Protection
- Internal Short-Circuit Limiting
- Direct Replacement for Fairchild μA78L00 Series

NOMINAL OUTPUT VOLTAGE	5% OUTPUT VOLTAGE TOLERANCE	10% OUTPUT VOLTAGE TOLERANCE
2.6 V	uA78L02AC	uA78L02C
5 V	uA78L05AC	uA78L05C
6.2 V	UA78L06AC	uA78L06C
8 V	uA78L08AC	uA78L08C
9 V	uA78L09AC	uA78L09C
10 V	uA78L10AC	uA78L10C
12 V	uA78L12AC	uA78L12C
15 V	uA78L15AC	uA78L15C

2

Data Sheets

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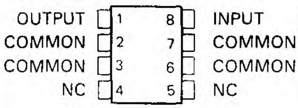

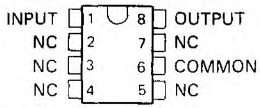

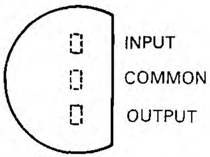

T0-226AA

OCI

NC – No internal connection

description

This series of fixed-voltage monolithic integrated-circuit voltage regulators is designed for a wide range of applications. These applications include on-card regulation for elimination of noise and distribution problems associated with single-point regulation. In addition, they can be used with power-pass elements to make high-current voltage regulators. One of these regulators can deliver up to 100 mA of output current. The internal limiting and thermal shutdown features of these regulators make them essentially immune to overload. When used as a replacement for a Zener diode-resistor combination, an effective improvement in output impedance can be obtained together with lower-bias current.

TEXAS INSTRUMENTS

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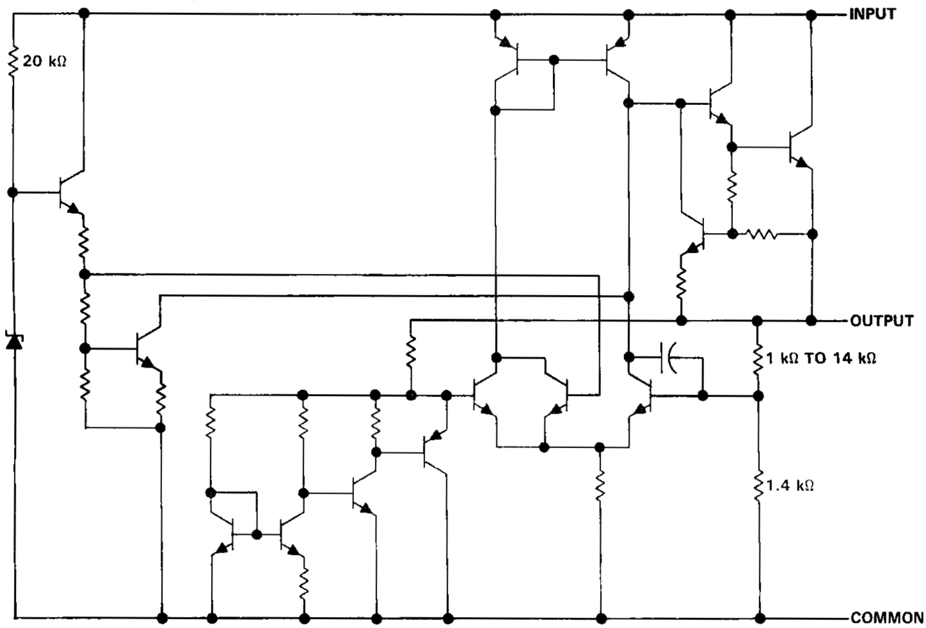
schematic



Resistor values shown are nominal.

absolute maximum ratings over operating temperature range (unless otherwise noted)

	uA78L02AC, uA78L02C THRU uA78L10AC, uA78L10C	uA78L12AC, uA78L12C uA78L15AC, uA78L15C	UNIT
Input voltage	30	35	V
Continuous total dissipation (see Note 1)	See Dissipation Rating Tables 1 and 2		
Operating free-air, case, or virtual junction temperature range	0 to 150	0 to 150	°C
Storage temperature range	−65 to 150	−65 to 150	°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	260	260	°C

NOTE 1: To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variations in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

DISSIPATION RATING TABLE 1 — FREE-AIR TEMPERATURE

PACKAGE	$T_A \leq 25°C$ POWER RATING	DERATING FA[illegible]	DERATE ABOVE T_A	$T_A = 70°C$ POWER RATING
D	825 mW	5.8 [illegible]	25°C	464 mW
JG	825 mW	6.6 mW/°C	25°C	528 mW
LP†	775 mW	6.2 mW/°C	25°C	496 mW

†The LP package dissipation rating is based on thermal resistance $R_{\theta JA}$ measured in still air with the device mounted in an Augat socket. The bottom of the package was 10 mm (0.375 in) above the socket.

DISSIPATION RATING TABLE 2 — CASE TEMPERATURE

PACKAGE	$T_C \leq 25°C$ PO[illegible]RATING	DERATING FACTOR	DERATE ABOVE T_C	$T_C = 125°C$ PO[illegible]RATING
D	[illegible] mW	19.6 mW/°C	65°C	[illegible] mW
JG	1600 mW	17.2 mW/°C	57°C	430 mW
LP	1600 mW	28.6 mW/°C	94°C	715 mW

recommended operating conditions

		MIN	MAX	UNIT
Input voltage, V_I	uA78L02C, uA78L02AC	4.75	20	V
	uA78L05C, uA78L05AC	7	20	
	uA78L06C, uA78L06AC	8.5	20	
	uA78[illegible] uA78L08AC	10.5	23	
	uA78[illegible] uA78L09AC	11.5	24	
	uA78L10C, uA78L10AC	12.5	25	
	uA78L[illegible] uA78L12AC	14.5	27	
	uA78L[illegible], uA78L15AC	17.5	30	
Output current, I_O			100	mA
Operating virtual junction temperature, T_J		0	125	°C

uA78L02AC, uA78L02C electrical characteristics at specified virtual junction temperature, V_I = 9 V, I_O = 40 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		uA78L02AC MIN	uA78L02AC TYP	uA78L02AC MAX	uA78L02C MIN	uA78L02C TYP	uA78L02C MAX	UNIT
Output voltage‡		25°C	2.5	2.6	2.7	2.4	2.6	2.8	V
	V_I = 4.75 V to 20 V, I_O = 1 mA to 40 mA	0°C to 125°C	2.45		2.75	2.35		2.85	
	I_O = 1 mA to 70 mA		2.45		2.75	2.35		[illegible]	
Input regulation	V_I = 4.75 V to 20 V	25°C		20	[illegible]		20	[illegible]	mV
	V_I = 5 V to 20 V			16	[illegible]		16	[illegible]	
Ripple rejection	V_I = 6 V to 16 V, f = 120 Hz	25°C	43	51		42	51		dB
Output regulation	I_O = 1 mA to [illegible] mA	25°C		12	50		12	50	mV
	I_O = 1 mA to 40 mA			6	25		6	25	
Output noise voltage	f = 10 Hz to 100 kHz	25°C		30			30		μV
Dropout voltage		25°C		1.7			1.7		V
Bias current		25°C		3.6	6		3.6	6	mA
		125°C			5.5			5.5	
Bias current change	V_I = 5 V to 20 V	0°C to 125°C			2.5			2.5	mA
	I_O = 1 mA to 40 mA				0.1			0.2	

uA78L05AC, uA78L05C electrical characteristics at specified virtual junction temperature, V_I = 10 V, I_O = 40 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		uA78L05AC MIN	uA78L05AC TYP	uA78L05AC MAX	uA78L05C MIN	uA78L05C TYP	uA78L05C MAX	UNIT
Output voltage‡		25°C	4.8	5	5.2	4.6	5	5.4	V
	V_I = 7 V to 20 V, I_O = 1 mA to 40 mA	0°C to 125°C	4.75		5.25	4.5		5.5	
	I_O = 1 mA to 70 mA		4.75		[illegible]	4.5		5.5	
Input regulation	V_I = 7 V to 20 V	25°C		32	[illegible]		32	[illegible]	mV
	V_I = 8 V to 20 V			26	[illegible]		26	[illegible]	
Ripple rejection	V_I = 8 V to 18 V, f = 120 Hz	25°C	41	49		40	49		dB
Output regulation	I_O = 1 mA to 100 mA	25°C		15	60		15	60	mV
	I_O = 1 mA to 40 mA			8	30		8	30	
Output noise voltage	f = 10 Hz to 100 kHz	25°C		42			42		μV
Dropout voltage		25°C		1.7			1.7		V
Bias current		25°C		3.8	6		3.8	6	mA
		125°C			5.5			5.5	
Bias current change	V_I = 8 V to 20 V	0°C to 125°C			1.5			1.5	mA
	I_O = 1 mA to 40 mA				0.1			0.2	

†Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.33-μF capacitor across the input and a 0.1-μF capacitor across the output.
‡This specification applies only for dc power dissipation permitted by absolute maximum ratings.

2 Data Sheets

uA78L06AC, uA78L06C electrical characteristics at specified virtual junction temperature, V_I = 12 V, I_O = 40 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		uA78L06AC			uA78L06C			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
Output voltage‡		25°C	5.95	6.2	6.45	5.7	6.2	6.7	V
	V_I = 8.5 V to 20 V, I_O = 1 mA to 40 mA	0°C to	5.9		6.5	5.6		6.8	
	I_O = 1 mA to 70 mA	125°C	5.9		6.5	5.6		6.8	
Input regulation	V_I = 8.5 V to 20 V	25°C		35	175		35	200	mV
	V_I = 9 V to 20 V			29	125		29	150	
Ripple rejection	V_I = 10 V to 20 V, f = 120 Hz	25°C	40	48		39	48		dB
Output regulation	I_O = 1 mA to [illegible] mA	25°C		16	80		16	80	mV
	I_O = 1 mA to 40 mA			9	40		9	40	
Output noise voltage	f = 10 Hz to 100 kHz	25°C		46			46		μV
Dropout voltage		25°C		1.7			1.7		V
Bias current		25°C		3.9	6		3.9	6	mA
		125°C			5.5			5.5	
Bias current change	V_I = 9 V to 20 V	0°C to			1.5			1.5	mA
	I_O = 1 mA to 40 mA	125°C			0.1			0.2	

uA78L08AC, uA78L08C electrical characteristics at specified virtual junction temperature, V_I = 14 V, I_O = 40 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		uA78L08AC			uA78L08C			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
Output voltage‡		25°C	[illegible]	8	8.3	7.36	8	8.64	V
	V_I = 10.5 V to 23 V, I_O = 1 mA to 40 mA	0°C to	7.6		8.4	7.2		8.8	
	I_O = 1 mA to 70 mA	125°C	7.6		8.4	7.2		8.8	
Input regulation	V_I = 10.5 V to 23 V	25°C		42	175		42	[illegible]	mV
	V_I = 11 V to 23 V			36	125		36	[illegible]	
Ripple rejection	V_I = 13 V to 23 V, f = 120 Hz	25°C	37	46		36	46		dB
Output regulation	I_O = 1 mA to 100 mA	25°C		18	80		18	80	mV
	I_O = 1 mA to 40 mA			10	40		10	40	
Output noise voltage	f = 10 Hz to 100 kHz	25°C		54			54		μV
Dropout voltage		25°C		1.7			1.7		V
Bias current		25°C		4	6		4	6	mA
		[illegible]C			5.5			5.5	
Bias current change	V_I = 11 V to 23 V	[illegible] to			1.5			1.5	mA
	I_O = 1 mA to 40 mA	125°C			0.1			0.2	

†Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.33-μF capacitor across the input and a 0.1-μF capacitor across the output.

‡This specification applies only for dc power dissipation permitted by absolute maximum ratings.

uA78L09AC, uA78L09C electrical characteristics at specified virtual junction temperature, V_I = 16 V, I_O = 40 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		uA78L09AC			uA78L09C			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
Output voltage‡		25°C	8.6	9	[illegible]	8.3	9	9.7	V
	V_I = 12 V to 24 V, I_O = 1 mA to 40 mA	0°C to	8.55		9.45	8.1		9.9	
	I_O = 1 mA to 70 mA	125°C	8.55		9.45	8.1		[illegible]	
Input regulation	V_I = 12 V to 24 V	25°C		45	175		45	[illegible]	mV
	V_I = 13 V to 24 V			40	125		40	[illegible]	
Ripple rejection	V_I = 15 V to 25 V, f = 120 Hz	25°C	38	45		36	45		dB
Output regulation	I_O = 1 mA to 100 mA	25°C		19	90		19	90	mV
	I_O = 1 mA to 40 mA			11	40		11	40	
Output noise voltage	f = 10 Hz to 100 kHz	25°C		58			58		μV
Dropout voltage		25°C		1.7			1.7		V
Bias current		25°C		4.1	6		4.1	6	mA
		125°C			5.5			5.5	
Bias current change	V_I = 13 V to 24 V	0°C to			1.5			1.5	mA
	I_O = 1 mA to 40 mA	125°C			0.1			0.2	

uA78L10AC, uA78L10C electrical characteristics at specified virtual junction temperature, V_I = 17 V, I_O = 40 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		uA78L10AC			uA78L10C			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
Output voltage‡		25°C	9.6	10	10.4	9.2	10	10.8	V
	V_I = 13 V to 25 V, I_O = 1 mA to 40 mA	0°C to	9.5		10.5	9		11	
	I_O = 1 mA to 70 mA	125°C	9.5		10.5	9		11	
Input regulation	V_I = 13 V to 25 V	25°C		51	175		51	[illegible]	mV
	V_I = 14 V to 25 V			42	125		42	[illegible]	
Ripple rejection	V_I = 15 V to 25 V, f = 120 Hz	25°C	37	44		36	44		dB
Output regulation	I_O = 1 mA to [illegible] mA	25°C		20	90		20	90	mV
	I_O = 1 mA to 40 mA			11	40		11	40	
Output noise voltage	f = 10 Hz to 100 kHz	25°C		62			62		μV
Dropout voltage		25°C		1.7			1.7		V
Bias current		25°C		4.2	6		4.2	6	mA
		125°C			5.5			5.5	
Bias current change	V_I = 14 V to 25 V	0°C to			1.5			1.5	mA
	I_O = 1 mA to 40 mA	125°C			0.1			0.2	

†Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.33-μF capacitor across the input and a 0.1-μF capacitor across the output.

‡This specification applies only for dc power dissipation permitted by absolute maximum ratings.

uA78L12AC, uA78L12C electrical characteristics at specified virtual junction temperature, V_I = 19 V, I_O = 40 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		uA78L12AC			uA78L12C			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
Output voltage‡		25°C	11.5	12	12.5	11.1	12	12.9	V
	V_I = 14 V to 27 V, I_O = 1 mA to 40 mA	0°C to	11.4		12.6	10.8		13.2	
	I_O = 1 mA to 70 mA	125°C	11.4		12.6	10.8		13.2	
Input regulation	V_I = 14.5 V to 27 V	25°C		55	250		55	.	mV
	V_I = 16 V to 27 V			49	200		49	.	
Ripple rejection	V_I = 15 V to 25 V, f = 120 Hz	25°C	37	42		36	42		dB
Output regulation	I_O = 1 mA to 100 mA	25°C		22	100		22	100	mV
	I_O = 1 mA to 40 mA			13	50		13	50	
Output noise voltage	f = 10 Hz to 100 kHz	25°C		70			70		μV
Dropout voltage		25°C		1.7			1.7		V
Bias current		25°C		4.3	6.5		4.3	6.5	mA
		125°C			6			6	
Bias current change	V_I = 16 V to 27 V	0°C to			1.5			1.5	mA
	I_O = 1 mA to 40 mA	125°C			0.1			0.2	

uA78L15AC, uA78L15C electrical characteristics at specified virtual junction temperature, V_I = 23 V, I_O = 40 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		uA78L15AC			uA78L15C			UNIT
			[illegible]	TYP	MAX	MIN	TYP	MAX	
Output voltage‡		25°C	[illegible]	15	15.6	13.8	15	16.2	V
	V_I = 17.5 V to 30 V, I_O = 1 mA to 40 mA	0°C to	14.25		15.75	13.5		16.5	
	I_O = 1 mA to 70 mA	125°C	14.25		15.75	13.5		16.5	
Input regulation	V_I = 17.5 V to 30 V	25°C		65	300		65	300	mV
	V_I = 20 V to 30 V			58	250		58	250	
Ripple rejection	V_I = 18.5 V to 28.5 V, f = 120 Hz	25°C	34	39		33	39		dB
Output regulation	I_O = 1 mA to 100 mA	25°C		25	150		25	150	mV
	I_O = 1 mA to 40 mA			15	75		15	75	
Output noise voltage	f = 10 Hz to [illegible] kHz	25°C		82			82		μV
Dropout voltage		25°C		1.7			1.7		V
Bias current		25°C		4.6	6.5		4.6	6.5	mA
		[illegible] C			6			6	
Bias current change	V_I = 10 V to 30 V	[illegible]			1.5			1.5	mA
	I_O = 1 mA to 40 mA	125°C			0.1			0.2	

†Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately. All characteristics are measured with a 0.33-μF capacitor across the input and a 0.1-μF capacitor across the output.

‡This specification applies only for dc power dissipation permitted by absolute maximum ratings.

D2214, JUNE 1976—REVISED APRIL 1988

- 3-Terminal Regulators
- Output Current Up to 500 mA
- No External Components
- Internal Thermal Overload Protection
- High Power Dissipation Capability
- Internal Short-Circuit Current Limiting
- Output Transistor Safe-Area Compensation
- Direct Replacements for Fairchild μA78M00 Series

NOMINAL OUTPUT VOLTAGE	−55°C TO 150°C OPERATING TEMPERATURE RANGE	0°C TO 125°C OPERATING TEMPERATURE RANGE
5 V	uA78M05M	uA78M05C
6 V		uA78M06C
8 V		uA78M08C
9 V		uA78M09C
10 V		uA78M10C
12 V	uA78M12M	uA78M12C
15 V	uA78M15M	uA78M15C
20 V		uA78M20C
24 V		uA78M24C
PACKAGES	JG	KC

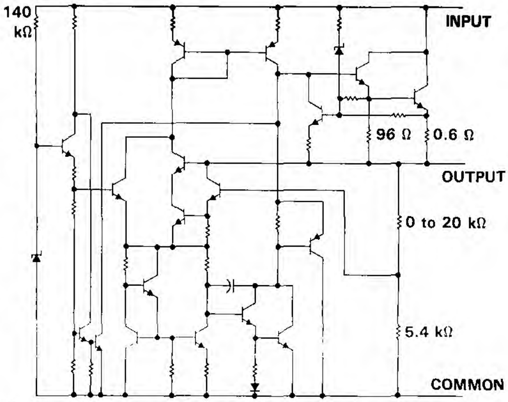
2

Data Sheets

description

This series of fixed-voltage monolithic integrated-circuit voltage regulators is designed for a wide range of applications. These applications include on-card regulation for elimination of noise and distribution problems associated with single-point regulation. Each of these regulators can deliver up to 500 mA of output current. The internal current limiting and thermal shutdown features of these regulators make them essentially immune to overload. In addition to use as fixed-voltage regulators, these devices can be used with external components to obtain adjustable output voltages and currents and also as the power pass element in precision regulators.

schematic

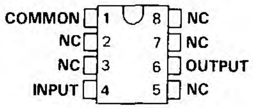


Resistor values shown are nominal.

terminal assignments

uA78M_M . . . JG PACKAGE

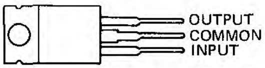
(TOP VIEW)



NC No internal connection.

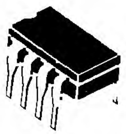
uA78M_C . . . KC PACKAGE

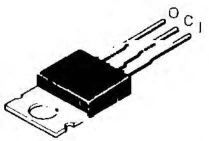
(TOP VIEW)



THE COMMON TERMINAL IS IN ELECTRICAL CONTACT WITH THE MOUNTING BASE

TO-220AB





TEXAS INSTRUMENTS

POST OFFICE BOX 655012 • DALLAS, TEXAS 75265

absolute maximum ratings over operating temperature range (unless otherwise noted)

		uA78M05M uA78M12M uA78M15M	uA78M05C THRU uA78M24C	UNIT
Input voltage	uA78M20, uA[illegible]		−40	V
	All others	35	35	
Continuous total dissipation (see Note 1)		See D[illegible]ion Rating [illegible] 1 and 2		
Operating free-air, case or virtual junction temperature range		−55 to [illegible]	0 to [illegible]	°C
Storage temperature range		−65 to [illegible]	−65 to [illegible]	°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	JG package	300		°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	KC package		[illegible]	°C

NOTE 1: To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variations in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

DISSIPATION RATING TABLE 1—FREE-AIR TEMPERATURE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25°C$	$T_A = 70°C$ POWER RATING
JG	1050 mW	8.4 mW/°C	672 mW
KC	2000 mW	16 mW/°C	1280 mW

DISSIPATION RATING TABLE 2—CASE TEMPERATURE

PACKAGE	$T_C \le 50°C$ POWER RATING	DERATING FACTOR ABOVE $T_C = 50°C$	$T_C = 125°C$ POWER RATING
KC	20 W	200 mW/°C	5 W

recommended operating conditions

		MIN	MAX	UNIT
Input voltage, V_I	uA78[illegible], uA[illegible]	[illegible]	25	V
	uA[illegible]	8	25	
	uA78M08C	10.5	25	
	uA[illegible]	11.5	26	
	u[illegible]	12.5	28	
	uA78M12M, u[illegible]	14.5	30	
	uA78M15M, uA78M15C	17.5	30	
	uA78M20C	23	35	
	uA78M24C	27	38	
Output current, I_O	All [illegible]		[illegible]	mA
Operating virtual junction temperature, T_J	uA[illegible] thru uA78M[illegible]	−55		°C
	uA[illegible] thru uA[illegible]	0		

uA78M05M, uA78M05C electrical characteristics at specified virtual junction temperature, V_I = 10 V, I_O = 350 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†			uA7[illegible]M MIN	[illegible]	[illegible]	uA78M05C MIN	TYP	MAX	UNIT
Output voltage‡			25°[illegible]	4.8	5	[illegible]	4.8	5	5.2	V
	I_O = 5 mA to 350 mA	V_I = 8 V to 20 V	−55°C to [illegible]°C	4.7		5.3				
		V_I = 7 V to 20 V	0°C to [illegible]				4.75		5.25	
Input regulation	I_O = 200 mA	V_I = 7 V to 25 V	25°C		3	50		3	100	mV
		V_I = 8 V to 20 V			1	25				
		V_I = 8 V to 25 V						1	50	
Ripple rejection	V_I = 8 V to 18 V, f = 120 Hz	I_O = 100 mA	−55°C to 150°C	62						dB
			0°C to 125°C				62			
		I_O = 300 mA	25°C	62	80		62	80		
Output regulation	I_O = 5 mA to 500 mA		25°C		20	50		20	100	mV
	I_O = 5 mA to 200 mA				10	25		10	50	
Temperature coefficient of output voltage	I_O = 5 mA		−55°C to 25°C			−2				mV/°C
			25°C to 150°C			−1.5				
			0°C to 125°C					−1		
Output noise voltage	f = 10 Hz to 100 kHz		25°C		40	200		40	200	µV
Dropout voltage			25°C		2	2.5		2	2.5	V
Bias current			25°C		4.5	7		4.5	6	mA
Bias current change	I_O = 200 mA, V_I = 8 V to 25 V		−55°C to 150°C			0.8				mA
			0°C to 125°C						0.8	
	I_O = 5 mA to 350 mA		−55°C to 150°C			0.5				
			0°C to 125°C						0.5	
Short-circuit output current	V_I = 35 V		25°C		300	600		300		mA
Peak output current			25°C	0.5	0.7	1.4		0.7		A

†Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible Thermal effects must be taken into account separately.
‡This specification applies only for dc power dissipation permitted by absolute maximum ratings.

uA78M06C electrical characteristics at specified virtual junction temperature, V_I = 11 V, I_O = 350 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†			MIN	TYP	MAX	UNIT
Output voltage‡			25°C	5.75	6	6.25	V
	I_O = 5 mA to 350 mA	V_I = 8 V to 21 V	0°C to 125°C	5.7		6.3	
Input regulation	I_O = 200 mA	V_I = 8 V to 25 V	25°C		5	100	mV
		V_I = 9 V to 25 V			1.5	50	
Ripple rejection	V_I = 9 V to 19 V,	I_O = 100 mA	0°C to 125°C	59			dB
	f = 120 Hz	I_O = 300 mA	25°C	59	80		
Output regulation	I_O = 5 mA to 500 mA		25°C		20	120	mV
	I_O = 5 mA to 200 mA				10	60	
Temperature coefficient of output voltage	I_O = 5 mA		0°C to 125°C		−1		mV/°C
Output noise voltage	f = 10 Hz to 100 kHz		25°C		45		μV
Dropout voltage			25°C		2		V
Bias current			25°C		4.5	6	mA
Bias current change	I_O = 200 mA,	V_I = 9 V to 25 V	0°C to 125°C			0.8	mA
	I_O = 5 mA to 350 mA		0°C to 125°C			0.5	
Short-circuit output current	V_I = 35 V		25°C		270		mA
Peak output current			25°C		0.7		A

uA78M08C electrical characteristics at specified virtual junction temperature, V_I = 14 V, I_O = 350 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†			MIN	TYP	MAX	UNIT
Output voltage‡			25°C	7.7	8	8.3	V
	I_O = 5 mA to [illegible] mA	V_I = 10.5 V to 23 V	0°C to 125°C	7.6		8.4	
Input regulation	I_O = 200 mA	V_I = 10.5 V to 25 V	25°C		6	100	mV
		V_I = 11 V to 25 V			2	50	
Ripple rejection	V_I = 11.5 V to 21.5 V,	I_O = 100 mA	0°C to 125°C	56			dB
	f = 120 Hz	I_O = [illegible] mA	25°C	56	80		
Output regulation	I_O = 5 mA to 500 mA		25°C		25	160	mV
	I_O = 5 mA to 200 mA				10	80	
Temperature coefficient of output voltage	I_O = 5 mA		0°C to 125°C		−1		mV/°C
Output noise voltage	f = 10 Hz to 100 kHz		25°C		52		μV
Dropout voltage			25°C		2		V
Bias current			25°C		4.6	6	mA
Bias current change	I_O = 200 mA	V_I = 10.5 V to 25 V	0°C to 125°C			0.8	mA
	I_O = 5 mA to [illegible] mA		0°C to 125°C			0.5	
Short-circuit output current	V_I = 35 V		25°C		250		mA
Peak output current			25°C		0.7		A

†Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.
‡This specification applies only for dc power dissipation permitted by absolute maximum ratings.

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uA78M09C electrical characteristics at specified virtual junction temperature, V_I = 16 V, I_O = 350 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†			MIN	TYP	MAX	UNIT
Output voltage ‡			25°C	8.6	9	9.4	V
	I_O = 5 mA to [illegible] mA	V_I = 11.5 V to 24 V	0°C to 125°C	8.5		9.5	
Input regulation	I_O = 200 mA	V_I = 11.5 V to 26 V	25°C		6	100	mV
		V_I = 12 V to 26 V			2	50	
Ripple rejection	V_I = 13 V to 23 V,	I_O = [illegible] mA	0°C to 125°C	56			dB
	f = 120 Hz	I_O = 300 mA	25°C	56	80		
Output regulation	I_O = 5 mA to 500 mA		25°C		25	[illegible]	mV
	I_O = 5 mA to [illegible] mA				10	[illegible]	
Temperature coefficient of output voltage	I_O = 5 mA		0°C to 125°C		−1		mV/°C
Output noise voltage	f = 10 Hz to 100 kHz		25°C		58		μV
Dropout voltage			25°C		2		V
Bias current			25°C		4.6	6	mA
Bias current change	I_O = 200 mA	V_I = 11.5 V to 26 V	0°C to 125°C			0.8	mA
	I_O = 5 mA to [illegible] mA					0.5	
Short-circuit output current	V_I = 35 V		25°C		250		mA
Peak output current			25°C		0.7		A

uA78M10C electrical characteristics at specified virtual junction temperature, V_I = 17 V, I_O = 350 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†			MIN	TYP	MAX	UNIT
Output voltage‡			25°C	9.6	10	10.4	V
	I_O = 5 mA to 350 mA	V_I = 12.5 V to 25 V	0°C to 125°C	9.5		[illegible]	
Input regulation	I_O = 200 mA	V_I = 12.5 V to 28 V	25°C		7	[illegible]	mV
		V_I = 14 V to 28 V			2	50	
Ripple rejection	V_I = 15 V to 25 V,	I_O = 100 mA	0°C to 125°C	59			dB
	f = 120 Hz	I_O = [illegible] mA	25°C	55	80		
Output regulation	I_O = 5 mA to 500 mA		25°C		25	200	mV
	I_O = 5 mA to 200 mA				10	100	
Temperature coefficient of output voltage	I_O = 5 mA		0°C to 125°C		−1		mV/°C
Output noise voltage	f = 10 Hz to 100 kHz		25°C		64		μV
Dropout voltage			25°C		2		V
Bias current			25°C		4.7	6	mA
Bias current change	I_O = 200 mA	V_I = 13.5 V to 28 V	0°C to 125°C			0.8	mA
		V_I = 12.5 V to 28 V					
	I_O = 5 mA to 350 mA		0°C to 125°C			0.5	
Short-circuit output current	V_I = 35 V		25°C		245		mA
Peak output current			25°C		0.7		A

†Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.
‡This specification applies only for dc power dissipation permitted by absolute maximum ratings.

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Data Sheets

uA78M12M, uA78M12C electrical characteristics at specified virtual junction temperature, $V_I = 19$ V, $I_O = 350$ mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†			uA78M12M MIN	uA78M12M TYP	uA78M12M MAX	uA78M12C MIN	uA78M12C TYP	uA78M12C MAX	UNIT
Output voltage‡			25°C	11.5	12	12.5	11.5	12	12.5	V
	I_O = 5 mA to 350 mA	V_I = 15.5 V to 27 V	−55°C to [illegible]°C	11.4		12.6				
		V_I = 14.5 V to 27 V	0°C to [illegible]				11.4		[illegible]	
Input regulation	I_O = 200 mA	V_I = 14.5 V to 30 V	25°C		8	60		8		mV
		V_I = 16 V to 25 V			2	30				
		V_I = 16 V to 30 V						2	50	
Ripple rejection	V_I = 15 V to 25 V, f = 120 Hz	I_O = 100 mA	−55°C to 150°C	55						dB
			0°C to [illegible]°C				55			
		I_O = 300 mA	25[illegible]	55	80		55	80		
Output regulation	I_O = 5 mA to 500 mA		25°C		25	[illegible]		25	240	mV
	I_O = 5 mA to 200 mA				10	[illegible]		10	120	
Temperature coefficient of output voltage	I_O = 5 mA		−55°C to 25°C			−4.8				mV/°C
			25°C to [illegible]°C			−3.6				
			0°C to [illegible]C					−1		
Output noise voltage	f = 10 Hz to 100 kHz		25°C		75	480		75		μV
Dropout voltage			25°C		2	2.5		2		V
Bias current			25°C		4.8	7		4.8	6	mA
Bias current change	I_O = 200 mA	V_I = 15 V to 30 V	−55°C to 150°C			0.8				mA
		V_I = 14.5 V to 30 V	0°C to 125°C						0.8	
	I_O = 5 mA to 350 mA		−55°C to 150°C			0.5				
			0°C to 125°C						0.5	
Short-circuit output current	V_I = 35 V		25°C		240	600		240		mA
Peak output current			25°C	0.5	0.7	1.4		0.7		A

†Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.
‡This specification applies only for dc power dissipation permitted by absolute maximum ratings.

uA78M15M, uA78M15C electrical characteristics at specified virtual junction temperature, V_I = 23 V, I_O = 350 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†			uA78M15M			uA78M15C			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
Output voltage‡			25 °C	14.4	15	15.6	14.4	15	15.6	V
	I_O = 5 mA to 350 mA	V_I = 18.5 V to 30 V	−55 °C to 150 °C	14.25		15.75				
		V_I = 17.5 V to 30 V	0 °C to 125 °C				14.25		15.75	
Input regulation	I_O = 200 mA	V_I = 17.5 V to 30 V	25 °C		10	60		10	100	mV
		V_I = 20 V to 30 V			3	30		3	50	
Ripple rejection	V_I = 18.5 V to 28.5 V, f = 120 Hz	I_O = 100 mA	−55 °C to 150 °C	54						dB
			0 °C to 125 °C				54			
		I_O = 300 mA	25 °C	54	70		54	70		
Output regulation	I_O = 5 mA to 500 mA		25 °C		25	150		25	300	mV
	I_O = 5 mA to 200 mA				10	75		10	150	
Temperature coefficient of output voltage	I_O = 5 mA		−55 °C to 25 °C			−6				mV/°C
			25 °C to 150 °C			−4.5				
			0 °C to 125 °C					−1		
Output noise voltage	f = 10 Hz to 100 kHz		25 °C		90	600		90		μV
Dropout voltage			25 °C		2	2.5		2		V
Bias current			25 °C		4.8	7		4.8	6	mA
Bias current change	I_O = 200 mA	V_I = 18.5 V to 30 V	−55 °C to 150 °C			0.8				mA
		V_I = 17.5 V to 30 V	0 °C to 125 °C						0.8	
	I_O = 5 mA to 350 mA		−55 °C to 150 °C			0.5				
			0 °C to 125 °C						0.5	
Short-circuit output current	V_I = 35 V		25 °C		240	600		240		mA
Peak output current			25 °C	0.5	0.7	1.4		0.7		A

†Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.
‡This specification applies only for dc power dissipation permitted by absolute maximum ratings.

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uA78M20C electrical characteristics at specified virtual junction temperature, V_I = 29 V, I_O = 350 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†			MIN	TYP	MAX	UNIT
Output voltage ‡			25°C	19.2	20	20.8	V
	I_O = 5 mA to 350 mA	V_I = 23 V to 35 V	0°C to 125°C	19		21	
Input regulation	I_O = 200 mA	V_I = 23 V to 35 V	25°C		10	100	mV
		V_I = 24 V to 35 V			5	50	
Ripple rejection	V_I = 24 V to 34 V,	I_O = 100 mA	0°C to 125°C	53			dB
	f = 120 Hz	I_O = [illegible] mA	25°C	53	70		
Output regulation	I_O = 5 mA to 500 mA		25°C		30	400	mV
	I_O = 5 mA to 200 mA				10	200	
Temperature coefficient of output voltage	I_O = 5 mA		0°C to 125°C		−1.1		mV/°C
Output noise voltage	f = 10 Hz to 100 kHz		25°C		110		μV
Dropout voltage			25°C		2		V
Bias current			25°C		4.9	6	mA
Bias current change	I_O = 200 mA,	V_I = 23 V to 35 V	0°C to 125°C			0.8	mA
	I_O = 5 mA to 350 mA					0.5	
Short-circuit output current	V_I = 35 V		25°C		240		mA
Peak output current			25°C		0.7		A

†Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.
‡This specification applies only for dc power dissipation permitted by absolute maximum ratings.

uA78M24C electrical characteristics at specified virtual junction temperature, V_I = 33 V, I_O = 350 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†			MIN	TYP	MAX	UNIT
Output voltage‡			25°C	23	24	25	V
	I_O = 5 mA to 350 mA	V_I = 27 V to 38 V	0°C to 125°C	22.8		25.2	
Input regulation	I_O = 200 mA	V_I = 27 V to 38 V	25°C		10	100	mV
		V_I = 28 V to 38 V			5	50	
Ripple rejection	V_I = 28 V to 38 V, f = 120 Hz	I_O = 100 mA	−55°C to 150°C				dB
			0°C to 125°C	50			
		I_O = 300 mA	25°C	50	70		
Output regulation	I_O = 5 mA to [illegible] mA		25°C		30	480	mV
	I_O = 5 mA to [illegible] mA				10	240	
Temperature coefficient of output voltage	I_O = 5 mA		0°C to 125°C		−1.2		mV/°C
Output noise voltage	f = 10 Hz to 100 kHz		25°C		170		μV
Dropout voltage			25°C		2		V
Bias current			25°C		5	6	mA
Bias current change	I_O = 200 mA,	V_I = 27 V to 38 V	0°C to 125°C			0.8	mA
	I_O = 5 mA to 350 mA		0°C to 125°C			0.5	
Short-circuit output current	V_I = 35 V		25°C		240		mA
Peak output current			25°C		0.7		A

†Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.

‡This specification applies only for dc power dissipation permitted by absolute maximum ratings.

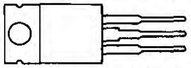
D2215, JUNE 1976—REVISED AUGUST 1983

- 3-Terminal Regulators
- Output Current Up to 1.5 A
- No External Components
- Internal Thermal Overload Protection
- High Power Dissipation Capability
- Internal Short-Circuit Current Limiting
- Output Transistor Safe-Area Compensation
- Essentially Equivalent to National LM320 Series

NOMINAL OUTPUT VOLTAGE	REGULATOR
−5 V	uA7905C
−5.2 V	uA7952C
−6 V	uA7906C
−8 V	uA7908C
−12 V	uA7912C
−15 V	uA7915C
−18 V	uA7918C
−24 V	uA7924C

KC PACKAGE

(TOP VIEW)



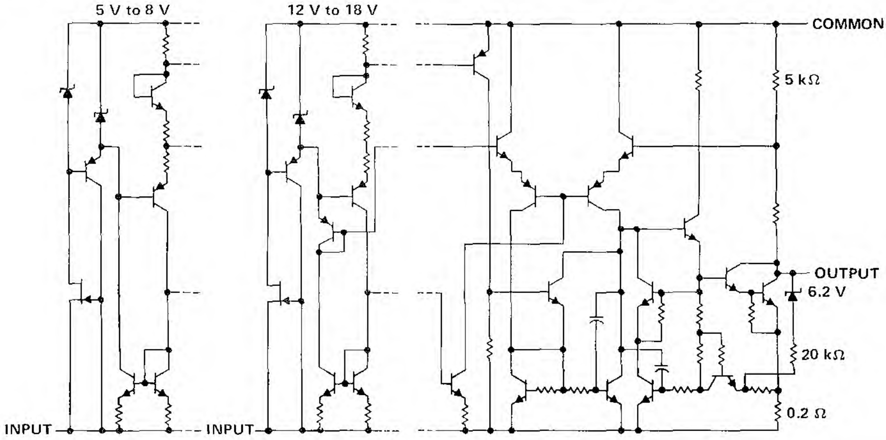
THE INPUT TERMINAL IS IN ELECTRICAL CONTACT WITH THE MOUNTING BASE

TO-220AB

description

This series of fixed-negative-voltage monolithic integrated-circuit voltage regulators is designed to complement Series uA7800 in a wide range of applications. These applications include on-card regulation for elimination of noise and distribution problems associated with single-point regulation. Each of these regulators can deliver up to 1.5 amperes of output current. The internal current limiting and thermal shutdown features of these regulators make them essentially immune to overload. In addition to use as fixed-voltage regulators, these devices can be used with external components to obtain adjustable output voltages and currents and also as the power pass element in precision regulators.

schematic



All component values are nominal.

absolute maximum ratings over operating temperature range (unless otherwise noted)

		uA7905C THRU uA7924C	UNIT
Input voltage	uA7924C	−40	V
	All others	−35	
Continuous total dissipation at 25°C free-air temperature (see Note 1)		2	W
Continuous total dissipation at (or below) 25°C case temperature (see Note 1)		15	W
Operating free-air, case, or virtual junction temperature range		0 to [illegible]	°C
Storage temperature range		−65 to 150	°C
Lead temperature 3.2 mm (1/8 inch) from case for 10 seconds		260	°C

NOTE 1: For operation above 25°C free-air or case temperature, refer to Figures 1 and 2. To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variations in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

2

Data Sheets

FREE-AIR TEMPERATURE
DISSIPATION DERATING CURVE

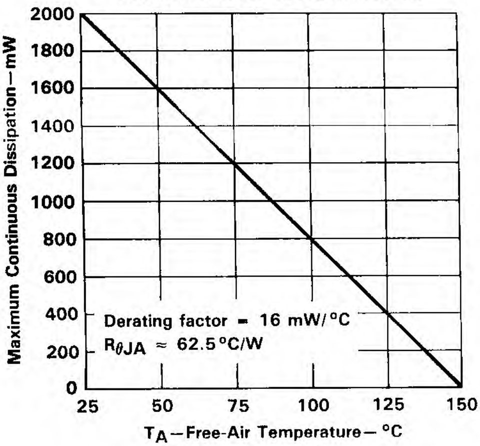


FIGURE 1

CASE TEMPERATURE
DISSIPATION DERATING CURVE

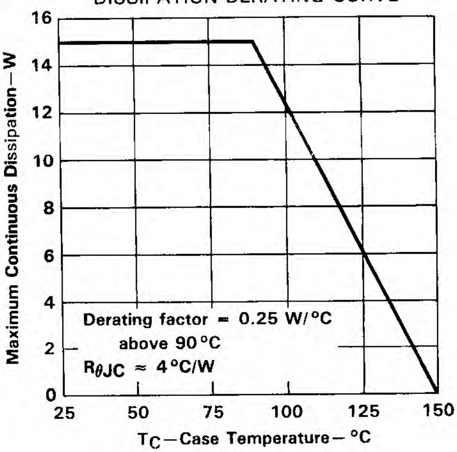


FIGURE 2

recommended operating conditions

		MIN	MAX	UNIT
Input voltage, V_I	[illegible]	−7	−25	V
	[illegible]	−7.2	−25	
	[illegible]	−8	−25	
	uA7908C	−10.5	−25	
	[illegible]	−14.5	−30	
	[illegible]	−17.5	−30	
	[illegible]	−21	−33	
	[illegible]	−27	−38	
Output current, I_O			1.5	A
Operating virtual junction temperature, T_J		0	125	°C

uA7905C electrical characteristics at specified virtual junction temperature, $V_I = -10$ V, $I_O = 500$ mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		uA7905C MIN	uA7905C TYP	uA7905C MAX	UNIT
Output voltage‡		25°C	−4.8	−5	−5.2	V
	I_O = 5 mA to 1 A, V_I = −7 V to −20 V, P ≤ 15 W	0°C to 125°C	−4.75		−5.25	
Input regulation	V_I = −7 V to −25 V	25°C		12.5	50	mV
	V_I = −8 V to −12 V			4	15	
Ripple rejection	V_I = −8 V to −18 V, f = 120 Hz	0°C to 125°C	54	60		dB
Output regulation	I_O = 5 mA to 1.5 A	25°C		15	100	mV
	I_O = 250 mA to 750 mA			5	50	
Temperature coefficient of output voltage	I_O = 5 mA	0°C to 125°C		−0.4		mV/°C
Output noise voltage	f = 10 Hz to 100 kHz	25°C		[illegible]		μV
Dropout voltage	I_O = 1 A	25°C		1.1		V
Bias current		25°C		1.5	2	mA
Bias current change	V_I = −7 V to −25 V	0°C to 125°C		0.15	0.5	mA
	I_O = 5 mA to 1 A			0.08	0.5	
Peak output current		25°C		2.1		A

uA7952C electrical characteristics at specified virtual junction temperature, $V_I = -10$ V, $I_O = 500$ mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		uA7952C MIN	uA7952C TYP	uA7952C MAX	UNIT
Output voltage‡		25°C	−5	−5.2	−5.4	V
	I_O = 5 mA to 1 A, V_I = −7.2 V to −20 V, P ≤ 15 W	0°C to 125°C	−4.95		−5.45	
Input regulation	V_I = −7.2 V to −25 V	25°C		12.5	100	mV
	V_I = −8.2 V to −12 V			4	50	
Ripple rejection	V_I = −8.2 V to −18 V, f = 120 Hz	0°C to 125°C	54	60		dB
Output regulation	I_O = 5 mA to 1.5 A	25°C		15	100	mV
	I_O = 250 mA to 750 mA			5	50	
Temperature coefficient of output voltage	I_O = 5 mA	0°C to 125°C		−0.4		mV/°C
Output noise voltage	f = 10 Hz to 100 kHz	25°C		125		μV
Dropout voltage	I_O = 1 A	25°C		1.1		V
Bias current		25°C		1.5	2	mA
Bias current change	V_I = −7.2 V to −25 V	0°C to 125°C		0.15	1.3	mA
	I_O = 5 mA to 1 A				0.5	
Peak output current		25°C		2.1		A

†Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.
‡This specification applies only for dc power dissipation permitted by absolute maximum ratings.

uA7906C electrical characteristics at specified virtual junction temperature, V_I = −11 V, I_O = 500 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		uA7906C			UNIT
			MIN	TYP	MAX	
Output voltage‡		25°C	−5.75	−6	−6.25	V
	I_O = 5 mA to 1 A, V_I = −8 V to −21 V, P ≤ 15 W	0°C to 125°C	−5.7		−6.3	
Input regulation	V_I = −8 V to −25 V	25°C		12.5	120	mV
	V_I = −9 V to −13 V			4	60	
Ripple rejection	V_I = −9 V to −19 V, f = 120 Hz	0°C to 125°C	54	60		dB
Output regulation	I_O = 5 mA to 1.5 A	25°C		15	120	mV
	I_O = 250 mA to 750 mA			5	60	
Temperature coefficient of output voltage	I_O = 5 mA	0°C to 125°C		−0.4		mV/°C
Output noise voltage	f = 10 Hz to 100 kHz	25°C		150		μV
Dropout voltage	I_O = 1 A	25°C		1.1		V
Bias current		25°C		1.5	2	mA
Bias current change	V_I = −8 V to −25 V	0°C to 125°C		0.15	1.3	mA
	I_O = 5 mA to 1 A			0.08	0.5	
Peak output current		25°C		2.1		A

uA7908C electrical characteristics at specified virtual junction temperature, V_I = −14 V, I_O = 500 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		[illegible]			UNIT
			[illegible]	[illegible]	MAX	
Output voltage ‡		25°C	[illegible]	−8	−8.3	V
	I_O = 5 mA to 1 A, V_I = −10.5 V to −23 V, P ≤ 15 W	0°C to 125°C	−7.6		−8.4	
Input regulation	V_I = −10.5 V to −25 V	25°C		12.5	160	mV
	V_I = −11 V to −17 V			4	80	
Ripple rejection	V_I = −11.5 V to −21.5 V, f = 120 Hz	0°C to 125°C	54	60		dB
Output regulation	I_O = 5 mA to 1.5 A	25°C		15	[illegible]	mV
	I_O = 250 mA to 750 mA			5	[illegible]	
Temperature coefficient of output voltage	I_O = 5 mA	0°C to 125°C		−0.6		mV/°C
Output noise voltage	f = 10 Hz to 100 kHz	25°C		[illegible]		μV
Dropout voltage	I_O = 1 A	25°C		[illegible]		V
Bias current		25°C		1.5	2	mA
Bias current change	V_I = −10.5 V to −25 V	0°C to 125°C		0.15	1	mA
	I_O = 5 mA to 1 A			0.08	0.5	
Peak output current		25°C		2.1		A

†Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.
‡This specification applies only for dc power dissipation permitted by absolute maximum ratings.

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uA7912C electrical characteristics at specified virtual junction temperature, V_I = −19 V, I_O = 500 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		uA7912C MIN	TYP	MAX	UNIT
Output voltage‡		25°C	−11.5	−12	−12.5	V
	I_O = 5 mA to 1 A, V_I = −14.5 V to −27 V, P ≤ 15 W	0°C to 125°C	−11.4		−12.6	
Input regulation	V_I = −14.5 V to −30 V	25°C		5	80	mV
	V_I = −16 V to −22 V			3	30	
Ripple rejection	V_I = −15 V to −25 V, f = 120 Hz	0°C to [illegible] C	54	60		dB
Output regulation	I_O = 5 mA to 1.5 A	25°C		15	200	mV
	I_O = 250 mA to 750 mA			5	75	
Temperature coefficient of output voltage	I_O = 5 mA	0°C to 125°C		−0.8		mV/°C
Output noise voltage	f = 10 Hz to 100 kHz	25°C		300		μV
Dropout voltage	I_O = 1 A	25°C		1.1		V
Bias current		25°C		2	3	mA
Bias current change	V_I = −14.5 V to −30 V	0°C to 125°C		0.04	0.5	mA
	I_O = 5 mA to 1 A			0.06	0.5	
Peak output current		25°C		2.1		A

uA7915C electrical characteristics at specified virtual junction temperature, V_I = −23 V, I_O = 500 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		uA7915C MIN	TYP	MAX	UNIT
Output voltage‡		25°C	−14.4	−15	−15.6	V
	I_O = 5 mA to 1 A, V_I = −17.5 V to −30 V, P ≤ 15 W	0°C to 125°C	−14.25		−15.75	
Input regulation	V_I = −17.5 V to −30 V	25°C		5	100	mV
	V_I = −20 V to −26 V			3	50	
Ripple rejection	V_I = −18.5 V to −28.5 V, f = 120 Hz	0°C to 125°C	54	60		dB
Output regulation	I_O = 5 mA to 1.5 A	25°C		15	[illegible]	mV
	I_O = [illegible] mA to 750 mA			5	[illegible]	
Temperature coefficient of output voltage	I_O = 5 mA	0°C to 125°C		−1		mV/°C
Output noise voltage	f = 10 Hz to 100 kHz	25°C		375		μV
Dropout voltage	I_O = 1 A	25°C		1.1		V
Bias current		25°C		2	3	mA
Bias current change	V_I = −17.5 V to −30 V	0°C to 125°C		0.04	0.5	mA
	I_O = 5 mA to 1 A			0.06	0.5	
Peak output current		25°C		2.1		A

†Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.
‡This specification applies only for dc power dissipation permitted by absolute maximum ratings.

uA7918C electrical characteristics at specified virtual junction temperature, V_I = −27 V, I_O = 500 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		uA7918C MIN	TYP	MAX	UNIT
Output voltage‡		25°C	−17.3	−18	−18.7	V
	I_O = 5 mA to 1 A, V_I = −21 V to −33 V, P ≤ 15 W	0°C to 125°C	−17.1		−18.9	
Input regulation	V_I = −21 V to −33 V	25°C		5	[illegible]	mV
	V_I = −24 V to −30 V			3	[illegible]	
Ripple rejection	V_I = −22 V to −32 V, f = 120 Hz	0°C to 125°C	54	60		dB
Output regulation	I_O = 5 mA to 1.5 A	25°C		30	360	mV
	I_O = 250 mA to 750 mA			10	180	
Temperature coefficient of output voltage	I_O = 5 mA	0°C to 125°C		−1		mV/°C
Output noise voltage	f = 10 Hz to 100 kHz	25°C		450		μV
Dropout voltage	I_O = 1 A	25°C		1.1		V
Bias current		25°C		2	3	mA
Bias current change	V_I = −21 V to −33 V	0°C to 125°C		0.04	1	mA
	I_O = 5 mA to 1 A			0.06	0.5	
Peak output current		25°C		2.1		A

uA7924C electrical characteristics at specified virtual junction temperature, V_I = −33 V, I_O = 500 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		uA7924C MIN	TYP	MAX	UNIT
Output voltage‡		25°C	−23	−24	−25	V
	I_O = 5 mA to 1 A, V_I = −27 V to −38 V, P ≤ 15 W	0°C to 125°C	−22.8		−25.2	
Input regulation	V_I = −27 V to −38 V	25°C		5	480	mV
	V_I = −30 V to −36 V			3	240	
Ripple rejection	V_I = −28 V to −38 V, f = 120 Hz	0°C to 125°C	54	60		dB
Output regulation	I_O = 5 mA to 1.5 A	25°C		85	[illegible]	mV
	I_O = 250 mA to 750 mA			25	240	
Temperature coefficient of output voltage	I_O = 5 mA	0°C to 125°C		−1		mV/°C
Output noise voltage	f = 10 Hz to [illegible] kHz	25°C		[illegible]		μV
Dropout voltage	I_O = 1 A	25°C		[illegible]		V
Bias current		25°C		2	3	mA
Bias current change	V_I = −27 V to −38 V	0°C to 125°C		0.04	1	mA
	I_O = 5 mA to 1 A			0.06	0.5	
Peak output current		25°C		2.1		A

†Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.

‡This specification applies only for dc power dissipation permitted by absolute maximum ratings.

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. 6, '. 1976- APRIL

- 3-Terminal Regulators
- Output Current Up to 500 mA
- No External Components
- High Power Dissipation Capability
- Internal Short-Circuit Current Limiting
- Output Transistor Safe-Area Compensation
- Direct Replacements for Fairchild µA79M00 Series

NOMINAL OUTPUT VOLTAGE	−55°C TO 150°C OPERATING TEMPERATURE RANGE	0°C TO 125°C OPERATING TEMPERATURE RANGE
−5 V	uA79M05M	uA79M05C
−6 V	uA79M06M	uA79M06C
−8 V	uA79M08M	uA79M08C
−12 V	uA79M12M	uA79M12C
−15 V	uA79M15M	uA79M15C
−20 V		uA79M20C
−24 V		uA79M24C
PACKAGE	JG	KC

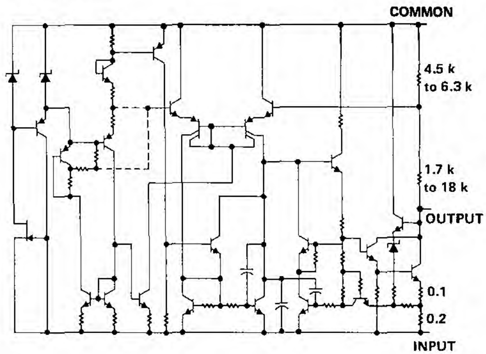
2

Data Sheets

description

This series of fixed-negative-voltage monolithic integrated-circuit voltage regulators is designed to complement Series uA78M00 in a wide range of applications. These applications include on-card regulation for elimination of noise and distribution problems associated with single-point regulation. Each of these regulators can deliver up to 500 mA of output current. The internal current limiting and thermal shutdown features of these regulators make them essentially immune to overload. In addition to use as fixed-voltage regulators, these devices can be used with external components to obtain adjustable output voltages and currents and also as the power pass element in precision regulators.

schematic

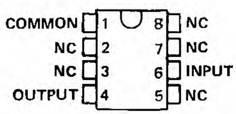


Resistor values shown are nominal and in ohms.

terminal assignments

uA79M_M. . .JG PACKAGE

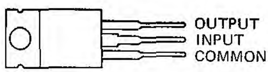
(TOP VIEW)



NC—No internal connection

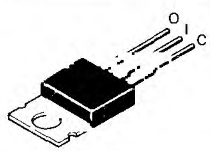
uA79M_C. . .KC PACKAGE

(TOP VIEW)



THE INPUT TERMINAL IS IN ELECTRICAL CONTACT WITH THE MOUNTING BASE

TO-220AB



TEXAS INSTRUMENTS
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absolute maximum ratings over operating temperature range (unless otherwise noted)

		uA79M05M THRU uA79M15M	uA79M05C THRU uA79M24C	UNIT
Input voltage	uA79M20, uA79M24		−40	V
	All others	−35	−35	
Continuous total dissipation (see Note 1)		See Dissipation Rating Tables 1 and 2		
Operating free-air, case or virtual junction temperature range		−55 to 150	0 to 150	°C
Storage temperature range		−65 to [illegible]	−65 to 150	°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds	JG package	300		°C
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds	KC package		260	°C

NOTE 1: To avoid exceeding the design maximum virtual junction temperature, these ratings should not be exceeded. Due to variations in individual device electrical characteristics and thermal resistance, the built-in thermal overload protection may be activated at power levels slightly above or below the rated dissipation.

DISSIPATION RATING TABLE 1—FREE-AIR TEMPERATURE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR ABOVE $T_A = 25°C$	$T_A = 70°C$ POWER RATING
JG	1050 mW	8.4 mW/°C	[illegible] mW
KC	2000 mW	16 mW/°C	1280 mW

DISSIPATION RATING TABLE 2—CASE TEMPERATURE

PACKAGE	$T_C \le 50°C$ POWER RATING	DERATING FACTOR ABOVE $T_C = 50°C$	$T_C = 125°C$ POWER RATING
KC	20 W	[illegible] mW/°C	5 W

recommended operating conditions

			MIN	MAX	UNIT
Input voltage, V_I	uA[illegible]	uA[illegible]	−7	[illegible]	V
	uA[illegible]	uA[illegible]	−8	−25	
	uA[illegible]	uA[illegible]	−10.5	−25	
	uA79M[illegible]	uA79M12C	−14.5	30	
	uA79M[illegible]	uA79M15C	−17.5	−30	
		uA79M20C	−23	−35	
		uA[illegible]C	−27	−38	
Output current, I_O				500	mA
Operating virtual junction temperature, T_J	uA79M05M thru uA79M15M		−55	150	°C
	uA79M05C thru uA79M24C		0	125	

uA79M05M, uA79M05C electrical characteristics at specified virtual junction temperature, V_I = −10 V, I_O = 350 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†			uA79M05M			uA79M05C			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
Output voltage‡			25°C	−4.8	−5	−5.2	−4.8	−5	−5.2	V
	I_O = 5 mA to 350 mA, V_I = −7 V to −25 V		−55°C to 150°C	−4.75		−5.25				
			0°C to 125°C				−4.75		−5.25	
Input regulation	V_I = −7 V to −25 V		25°C		7	50		7	50	mV
	V_I = −8 V to −18 V				3	30		3	30	
Ripple rejection	V_I = −8 V to −18 V, f = 120 Hz	I_O = 100 mA	−55°C to 150°C	50						dB
			0°C to 125°C				50			
		I_O = 300 mA	25°C	54	60		54	60		
Output regulation	I_O = 5 mA to 500 mA		25°C		75	100		75	100	mV
	I_O = 5 mA to 350 mA				50			50		
Temperature coefficient of output voltage	I_O = 5 mA		−55°C to 150°C			−1.5				mV/°C
			0°C to 125°C					−0.4		
Output noise voltage	f = 10 Hz to 100 kHz		25°C		125	400		125		μV
Dropout voltage			25°C		1.1	2.3		1.1		V
Bias current			25°C		1	2		1	2	mA
Bias current change	V_I = −8 V to −25 V		−55°C to 150°C			0.4				mA
			0°C to 125°C						0.4	
	I_O = 5 mA to 350 mA		−55°C to 150°C			0.4				
			0°C to 125°C						0.4	
Short-circuit output current	V_I = −30 V		25°C			600		140		mA
Peak output current			25°C	0.5	0.65	1.4		0.65		A

†Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.
‡This specification applies only for dc power dissipation permitted by absolute maximum ratings.

2 Data Sheets

uA79M06M, uA79M06C electrical characteristics at specified virtual junction temperature, $V_I = -11$ V, $I_O = 350$ mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†			uA79M06M			uA79M06C			UNIT
				MIN	TYP	MAX	MIN	TYP	MAX	
Output voltage‡			25°C	−5.75	−6	[illegible]	[illegible]	−6	[illegible]	V
	I_O = 5 mA to 350 mA, V_I = −8 V to −25 V		−55°C to 150°C	−5.7		−6.3				
			[illegible]				−5.7		−6.3	
Input regulation	V_I = −8 V to −25 V		25°C		7	60		7	60	mV
	V_I = −9 V to −19 V				3	40		3	40	
Ripple rejection	V_I = −9 V to −19 V, f = 120 Hz	I_O = 100 mA	−55°C to 150°C	50						dB
			0°C to 125°C				50			
		I_O = 300 mA	25°C	54	60		54	60		
Output regulation	I_O = 5 mA to 500 mA		25°C		80	120		80	120	mV
	I_O = 5 mA to 350 mA				55			55		
Temperature coefficient of output voltage	I_O = 5 mA		−55°C to 150°C			−1.5				mV/°C
			0°C to 125°C					−0.4		
Output noise voltage	f = 10 Hz to 100 kHz		25°C		150	480		150		μV
Dropout voltage			25°C		1.1	2.3		1.1		V
Bias current			25°C		1	2		1	2	mA
Bias current change	V_I = −9 V to −25 V		−55°C to 150°C			0.4				mA
			0°C to 125°C						0.4	
	I_O = 5 mA to 350 mA		−55°C to 150°C			0.4				
			0°C to 125°C						0.4	
Short-circuit output current	V_I = −30 V		25°C			600		140		mA
Peak output current			25°C	0.5	0.65	1.4		0.65		A

†Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.
‡This specification applies only for dc power dissipation permitted by absolute maximum ratings.

2 Data Sheets

uA79M08M, uA79M08C electrical characteristics at specified virtual junction temperature, V_I = −19 V, I_O = 350 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†			uA79M08M			uA[illegible]C			UNIT
				MIN	TYP	MAX	[illegible]		MAX	
Output voltage‡			25°C	−7.7	−8	−8.3	[illegible]	−8	−8.3	V
	I_O = 5 mA to 350 mA,		−55°C to 150°C	−7.6		−8.4				
	V_I = −10.5 V to −25 V		0°C to 125°C				−7.6		−8.4	
Input regulation	V_I = −10.5 V to −25 V		25°C		8	80		8	80	mV
	V_I = −11 V to −21 V				4	50		4	50	
Ripple rejection	V_I = −11.5 V to −21.5 V, f = 120 Hz	V = 100 mA	−55°C to 150°C	50						dB
			0°C to 125°C				50			
		I_O = 300 mA	25°C	54	59		54	59		
Output regulation	I_O = 5 mA to 500 mA		25°C		90	160		90	160	mV
	I_O = 5 mA to 350 mA				60			60		
Temperature coefficient of output voltage	I_O = 5 mA		−55°C to 150°C			−2.4				mV/°C
			0°C to [illegible]					−0.6		
Output noise voltage	f = 10 Hz to 100 kHz		25°C		200	640		200		μV
Dropout voltage			25°C		1.1	2.3		1.1		V
Bias current			25°C		1	2		1	2	mA
Bias current change	V_I = −10.5 V to −25 V		−55°C to 150°C			0.4				mA
			0°C to 125°C						0.4	
	I_O = 5 mA to 350 mA		−55°C to 150°C			0.4				
			0°C to [illegible]C						0.4	
Short-circuit output current	V_I = −30 V		25°C			600		140		mA
Peak output current			25°C	0.5	0.65	1.4		0.65		A

†Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.
‡This specification applies only for dc power dissipation permitted by absolute maximum ratings.

uA79M12M, uA79M12C electrical characteristics at specified virtual junction temperature, $V_I = -19$ V, $I_O = 350$ mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†			uA79M12M MIN	uA79M12M TYP	uA79M12M MAX	uA79M12C MIN	uA79M12C TYP	uA79M12C MAX	UNIT
Output voltage‡			25°C	−11.5	−12	−12.5	−11.5	−12	−12.5	V
	I_O = 5 mA to 350 mA, V_I = −14.5 V to −30 V		−55°C to 150°C	−11.4		−12.6				
			0°C to 125°C				−11.4		−12.6	
Input regulation	V_I = −14.5 V to −30 V		25°C		9	80		9	80	mV
	V_I = −15 V to −25 V				5	50		5	50	
Ripple rejection	V_I = −15 V to −25 V, f = 120 Hz	I_O = 100 mA	−55°C to 150°C	50						dB
			0°C to 125°C				50			
		I_O = 300 mA	25°C	54	60		54	60		
Output regulation	I_O = 5 mA to 500 mA		25°C		65	240		65	240	mV
	I_O = 5 mA to 350 mA				45			45		
Temperature coefficient of output voltage	I_O = 5 mA		−55°C to 150°C			−3.6				mV/°C
			0°C to 125°C					−0.8		
Output noise voltage	f = 10 Hz to 100 kHz		25°C		300	960		300		μV
Dropout voltage			25°C		1.1	2.3		1.1		V
Bias current			25°C		1.5	3		1.5	3	mA
Bias current change	V_I = −14.5 V to −30 V		−55°C to 150°C			0.4				mA
			0°C to 125°C						0.4	
	I_O = 5 mA to 350 mA		−55°C to 150°C			0.4				
			0 [illegible]						0.4	
Short-circuit output current	V_I = −30 V		25°C			600		140		mA
Peak output current			25°C	0.5	0.65	1.4		0.65		A

†Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.

‡This specification applies only for dc power dissipation permitted by absolute maximum ratings.

uA79M15M, uA79M15C electrical characteristics at specified virtual junction temperature, V_I = −23 V, I_O = 350 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†			uA79M15M MIN	uA79M15M TYP	uA79M15M MAX	uA79M15C MIN	uA79M15C TYP	uA79M15C MAX	UNIT
Output voltage‡			25°C	−14.4	−15	−15.6	−14.4	−15	−15.6	V
	I_O = 5 mA to 350 mA, V_I = −17.5 V to −30 V		−55°C to 150°C	−14.25		−15.75				
			0°C to 125°C				−14.25		−15.75	
Input regulation	V_I = −17.5 V to −30 V		25°C		9	80		9	80	mV
	V_I = −18 V to −28 V				7	50		7	50	
Ripple rejection	V_I = −18.5 V to −28.5 V, f = 120 Hz	I_O = 100 mA	−55°C to 150°C	50						dB
			0°C to 125°C				50			
		I_O = 300 mA	25°C	54	59		54	59		
Output regulation	I_O = 5 mA to 500 mA		25°C		65	240		65	240	mV
	I_O = 5 mA to 350 mA				45			45		
Temperature coefficient of output voltage	I_O = 5 mA		−55°C to 150°C			−4.5				mV/°C
			0°C to 125°C					−1		
Output noise voltage	f = 10 Hz to 100 kHz		25°C		375	1200		375		μV
Dropout voltage			25°C		1.1	2.3		1.1		V
Bias current			25°C		1.5	3		1.5	3	mA
Bias current change	V_I = −17.5 V to −30 V		−55°C to 150°C			0.4				mA
			0°C to 125°C						0.4	
	I_O = 5 mA to 350 mA		−55°C to 150°C			0.4				
			0°C to 125°C						0.4	
Short-circuit output current	V_I = −30 V		25°C			600		140		mA
Peak output current			25°C	0.5	0.65			0.65		A

†Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.
‡This specification applies only for dc power dissipation permitted by absolute maximum ratings.

uA79M20C electrical characteristics at specified virtual junction temperature, V_I = −29 V, I_O = 350 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†		uA79M20C MIN	uA79M20C TYP	uA79M20C MAX	UNIT
Output voltage‡	I_O = 5 mA to 350 mA, V_I = −23 V to −35 V	25°C	−19.2	−20	−20.8	V
		0 to 125°C	−19		−21	
Input regulation	V_I = −23 V to −35 V	25°C		12	80	mV
	V_I = −24 V to −34 V			10	70	
Ripple rejection	V_I = −24 V to −34 V, f = 120 Hz, I_O = 100 mA	0°C to [illegible] C	50			dB
	V_I = −24 V to −34 V, f = 120 Hz, I_O = 300 mA	25 [illegible]	54	58		
Output regulation	I_O = 5 mA to [illegible] mA	25°C		75	300	mV
	I_O = 5 mA to [illegible] mA			50		
Temperature coefficient of output voltage	I_O = 5 mA	0°C to 125°C		−1		mV/°C
Output noise voltage	f = 10 Hz to [illegible] kHz	25°C		[illegible]		μV
Dropout voltage		25°C		[illegible]		V
Bias current		25°C		1.5	3.5	mA
Bias current change	V_I = −23 V to −35 V	0°C to 125°C			0.4	mA
	I_O = 5 mA to 350 mA				0.4	
Short-circuit output current	V_I = −30 V	25°C		140		mA
Peak output current		25°C		0.65		A

†Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.
‡This specification applies only for dc power dissipation permitted by absolute maximum ratings.

uA79M24C electrical characteristics at specified virtual junction temperature, V_I = −33 V, I_O = 350 mA (unless otherwise noted)

PARAMETER	TEST CONDITIONS†			uA79M24C MIN	uA79M24C TYP	uA79M24C MAX	UNIT
Output voltage‡	I_O = 5 mA to 350 mA, V_I = −27 V to −38 V		25°C	−23	−24	−25	V
			0 to 125°C	−22.8		−25.2	
Input regulation	V_I = −27 V to −38 V		25°C		12	80	mV
	V_I = −28 V to −38 V				12	70	
Ripple rejection	V_I = −28 V to −38 V, f = 120 Hz	I_O = 100 mA	0°C to 125°C	50			dB
		I_O = 300 mA	25°C	54	58		
Output regulation	I_O = 5 mA to 500 mA		25°C		75	300	mV
	I_O = 5 mA to 350 mA				50		
Temperature coefficient of output voltage	I_O = 5 mA		0°C to 125°C		−1		mV/°C
Output noise voltage	f = 10 Hz to 100 kHz		25°C		600		μV
Dropout voltage			25°C		1.1		V
Bias current			25°C		1.5	3.5	mA
Bias current change	V_I = −27 V to −38 V		0°C to 125°C			0.4	mA
	I_O = 5 mA to 350 mA					0.4	
Short-circuit output current	V_I = −30 V		25°C		140		mA
Peak output current			25°C		0.65		A

†Pulse testing techniques are used to maintain the junction temperature as close to the ambient temperature as possible. Thermal effects must be taken into account separately.
‡This specification applies only for dc power dissipation permitted by absolute maximum ratings.

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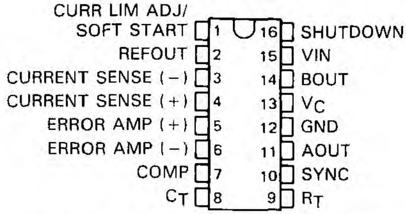
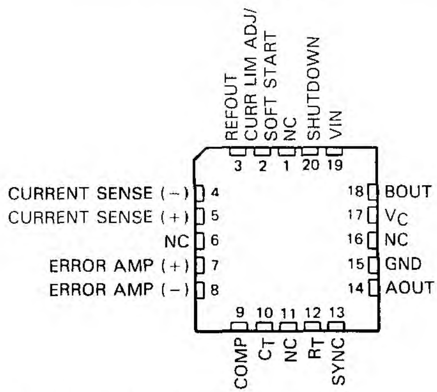
- Automatic Feed-Forward Compensation
- Programmable Pulse-by-Pulse Current Limiting
- Automatic Symmetry Correction in Push-Pull Configuration
- Enhanced Load Response Characteristics
- Parallel Operation Capability for Modular Power Systems
- Differential Current-Sense Amplifier with Wide Common-Mode Range
- Double-Pulse Suppression
- 200-mA Totem-Pole Outputs
- ±1% Bandgap Reference
- Under-Voltage Lockout
- Soft-Start Capability
- Shutdown Terminal
- 500-kHz Operation

UC1846, UC1847 . . . J PACKAGE
UC2846, UC2847, UC3846, UC3847 . . . N PACKAGE
(TOP VIEW)



UC2846, UC2847, UC3846, UC3847 . . . FN PACKAGE
(TOP VIEW)



NC – No internal connection

description

This family of control ICs provides all of the necessary features to implement fixed frequency, current-mode control schemes while maintaining a minimum external parts count. The superior performance of this technique can be measured in improved line regulation, enhanced load response characteristics, and a simpler, easier-to-design control loop. Topological advantages include inherent pulse-by-pulse current-limiting capability, automatic symmetry correction for push-pull converters, and the ability to parallel "power modules" while maintaining equal current sharing.

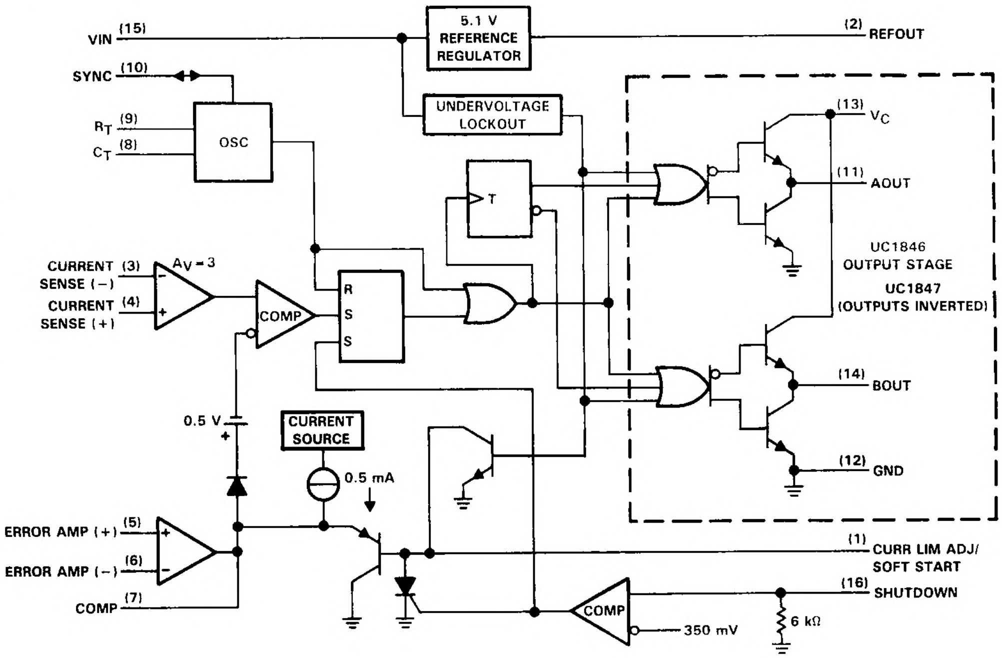
Protection circuitry includes built-in under-voltage lockout and programmable current limiting in addition to soft-start capability. A shutdown function is also available that can initiate either a complete shutdown *with* automatic restart, or latch the supply off.

Other features include fully-latched operation, double-pulse suppression, deadtime adjustment capability, and a ±1% trimmed bandgap reference.

In the off state, the UC1846 outputs are low and the UC1847 outputs are high.

The UC1846 and UC1847 are characterized for operation over the full military temperature range of −55°C to 125°C, the UC2846 and UC2847 are characterized for operation from −25°C to 85°C, and the UC3846 and UC3847 are characterized for operation from 0°C to 70°C.

functional block diagram



absolute maximum ratings over operating free-air temperature range (unless otherwise *noted)*

Supply voltage, V_{IN} (see Note 1) .... 40 V
Collector supply voltage, V_C .... 40 V
Output current, source or sink, I_O .... 500 mA
Analog input voltage (CURRENT SENSE (−), CURRENT SENSE (+), ERROR AMP (+), ERROR AMP (−), or SHUTDOWN) .... −0.3 V to V_{IN}
Reference output current .... −30 mA
SYNC output current .... −5 mA
Error amplifier output current .... −5 mA
Soft-start sink current .... 50 mA
Oscillator charging current .... 5 mA
Continuous total dissipation .... See Dissipation Rating Table
Operating free-air temperature range: UC1846, UC1847 .... −55°C to 125°C
UC2846, UC2847 .... −25°C to 85°C
UC3846, UC3847 .... 0°C to 70°C
Storage temperature range .... −65°C to 150°C
Case temperature for 10 seconds: FN package .... 260°C
Lead temperature 1,6 mm (1/16 inch) from case for 60 seconds: J package .... *300°C*
Lead temperature 1,6 mm (1/16 inch) from case for 10 seconds: N package .... 260°C

NOTE 1: All voltage values are with respect to network ground terminal.

DISSIPATION RATING TABLE

PACKAGE	$T_A \le 25°C$ POWER RATING	DERATING FACTOR ABOVE T_A = 25°C	T_A = 70°C POWER RATING	T_A = 85°C POWER RATING	T_A = 125°C POWER RATING
FN	1400 mW	11.2 mW/°C	896 mW	728 mW	280 mW
J	1375 mW	11.0 mW/°C	880 mW	715 mW	275 mW
N	1150 mW	9.2 mW/°C	736 mW	598 mW	

recommended operating conditions

	UC1846, UC1847		UC2846, UC2847		UC3846, UC3847		UNIT
	MIN	MAX	MIN	MAX	MIN	MAX	
High-level input [illegible]ge, V_{IH} ([illegible]r Section)	3.9		3.9		3.9		V
Low-level input voltage, V_{IL} (Oscillator Section)		2.5		2.5		2.5	V
Supply voltage operating range, V_{IN}	8	40	8	40	8	40	V
Operating free-air temperature, T_A	−55	125	−25	85	0	70	°C

electrical characteristics over operating free-air temperature range, V_{IN} = 15 V, R_T = 10 kΩ, C_T = 4.7 nF (unless otherwise noted)

reference section

PARAMETER		TEST CONDITIONS	UC1846, UC1847 UC2846, UC2847			UC3846, UC3847			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
V_O	Output voltage	I_O = 1 mA, T_A = 25°C	5.05	5.1	5.1	5	5.1	5.2	V
	Line regulation	V_{IN}(pin 15) = 8 V to 40 V		5	20		5	20	mV
	Load regulation	I_{IL} = 1 mA to 10 mA		3	15		3	15	mV
α_{VO}	Temperature coefficient of output voltage			0.4			0.4		mV/°C
	[illegible] output [illegible]n		5		5.2	4.95		5.25	V
	Output noise voltage	f = 1 kHz to 10 kHz, T_A = 25°C			100			100	µV
	Output voltage long-term drift	t = 1000 hours, T_A = 25°C		5			5		mV
I_{OS}	Short-circuit output current (REFOUT)	V_{REF} = 0	−10	−45		−10	−45		mA

oscillator section

PARAMETER		TEST CONDITIONS	UC1846, UC1847 UC2846, UC2847			UC3846, UC3847			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
	Initial accuracy	T_A = 25°C	39	43	47	39	43	47	kHz
	Frequency change with voltage	V_{IN}(pin 15) = 8 V to 40 V		−1%	±2%		−1%	±2%	
	Frequency change with temperature			−1%			−1%		
V_T	Threshold voltage (SYNC)		2.5		3.9	2.5		3.9	V
V_{OH}	High-level output voltage (SYNC)		3.9			3.9			V
V_{OL}	Low-level output voltage (SYNC)				2.5			2.5	V
I_I	Input current (SYNC)	Sync voltage = 5.25 V, C_T at 0 V		1.3	1.5		1.3	1.5	mA

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electrical characteristics over operating free-air temperature range, V_{IN} = 15 V, R_T = 10 kΩ, C_T = 4.7 nF (unless otherwise noted) (continued)

error amplifier section

PARAMETER		TEST CONDITIONS	UC1846, UC1847 UC2846, UC2847			UC3846, UC3847			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage			0.5	5		0.5	5	mV
I_{IO}	Input offset current			40			40	250	nA
I_{IB}	Input bias current			−0.6			−0.6	−1	µA
V_{OH}	High-level output voltage	$R_{L(COMP)}$ = 15 kΩ	4.3	4.6		4.3	4.6		V
I_{OH}	High-level output current	V_{ID} = 15 mV to 5 V, COMP at 2.5 V	−0.4	−0.5		−0.4	−0.5		mA
V_{OL}	Low-level output voltage	$R_{L(COMP)}$ = 15 kΩ		0.7	1		0.7	1	V
I_{OL}	Low-level output current	V_{ID} = −15 mV to −5 V, COMP at 1.2 V	2	6		2	6		mA
V_{ICR}	Common-mode input voltage range	V_{IN} = 8 V to 40 V	0 to $V_{IN}-2$			0 to $V_{IN}-2$			V
A_{VD}	Open-loop voltage amplification	ΔV_O = 1.2 V to 3 V, V_{IC} = 2 V	80	105		80	105		dB
CMRR	Common-mode rejection ratio	V_{IC} = 0 to 38 V, V_{IN} = 40 V	75	100		75	100		dB
k_{SVR}	Supply-voltage rejection ratio	V_{IN} = 8 V to 40 V	80	105		80	105		dB

current-sense amplifier section

PARAMETER		TEST CONDITIONS	UC1846, UC1847 UC2846, UC2847			UC3846, UC3847			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage	CURR LIM ADJ/SOFT START at 0.5 V, COMP open, See Note 3		5	25		5	25	mV
I_{IO}	Input offset current			0.08	1		0.08	1	µA
I_{IB}	Input bias current			−2.5	−10		−2.5	−10	µA
A_V	Voltage amplification	CURRENT SENSE (−) at 0 V, CURR LIM ADJ/SOFT START open, See Notes 2 and 3	2.5	2.75	3	2.5	2.75	3	V
V_{ICR}	Common-mode input voltage range		0 to $V_{IN}-3$			0 to $V_{IN}-3$			V
	Maximum usable differential input signal	CURR LIM ADJ/SOFT START open, $R_{L(COMP)}$ = 15 kΩ, See Note 2	1.1	1.3		1.1	1.2		V
CMRR	Common-mode rejection ratio	V_{IC} = 1 V to 12 V	60	83		60	83		dB
k_{SVR}	Supply-voltage rejection ratio	V_{IN} = 8 V to 40 V	60	84		60	84		dB
t_d	Input-to-output delay time	T_A = 25°C		200	600		200	600	ns

NOTES: 2. This parameter is measured at the trip point of the latch with ERROR AMP (+) at V_{REF}, ERROR AMP (−) at 0 V.
3. Amplifier gain is defined as:

$$AV = \frac{\Delta V_{PIN\ 7}}{\Delta V_{PIN\ 4}}$$

Where:

$\Delta V_{PIN\ 4}$ = 0 V to 1.0 V

electrical characteristics over operating free-air temperature range, V_{IN} = 15 V, R_T = 10 kΩ, C_T = 4.7 nF (unless otherwise noted) (continued)

current limit adjustment section

PARAMETER		TEST CONDITIONS	UC1846, UC1847 UC2846, UC2847			UC3846, UC3847			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
V_{IO}	Input offset voltage	CURRENT SENSE (−) at 0 V, CURRENT SENSE (+) at 0 V, COMP [illegible] See Note 3	0.45	0.5	0.55	0.45	0.5	0.55	V
I_{IB}	Input bias current	ERROR [illegible] (+) at V_{REF}, ERROR AMP (−) at 0 V		−10	−30		−10	−30	μA

shutdown terminal section

PARAMETER		TEST CONDITIONS	UC1846, UC1847 UC2846, UC2847			UC3846, UC3847			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
V_T	Differential-input threshold voltage		250	350	400	250	350	400	mV
V_I	Input voltage range		0 to V_{IN}			0 to V_{IN}			V
	Minimum latching current (CURR LIM ADJ/SOFT START)	See Note 4	0.8	1.5	3	0.8	1.5	3	mA
	Output delay	T_A = 25°C		300	600		300	600	ns

output section

PARAMETER		TEST CONDITIONS	UC1846, UC1847 UC2846, UC2847			UC3846, UC3847			UNIT
			MIN	TYP	MAX	MIN	TYP	MAX	
$V_{(BR)CE}$	Collector-emitter breakdown voltage		40			40			V
I_{CEX}	Collector-emitter off-state current	V_{CE} = 40 V, See Note 5			200			200	μA
V_{OH}	High-level output voltage (AOUT and BOUT)	I_{OH} = −20 mA	13	13.5		13	13.5		V
		I_{OH} = −100 mA	12	13.5		12	13.5		
V_{OL}	Low-level output voltage (AOUT and BOUT)	I_{OL} = 20 mA		0.1	0.4		0.1	0.4	V
		I_{OL} = 100 mA		0.4	2.1		0.4	2.1	
t_r	Rise time (AOUT and BOUT)	C_L = 1 nF, T_A = 25°C		50	300		50	300	ns
t_f	Fall time (AOUT and BOUT)			50	300		50	300	ns

under-voltage lockout section

PARAMETER	TEST CONDITIONS	UC1846, UC1847 UC2846, UC2847			UC3846, UC3847			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
Startup threshold			7.7	8		7.7	8	V
Thr[illegible]			0.75			0.75		V

NOTES: 3. This parameter is measured at the trip point of the latch with ERROR AMP (+) at V_{REF} and ERROR AMP (−) at 0 V.
4. This is the lowest current into Pin 1 that will latch the circuit in the shutdown state.
5. This applies for UC1846, UC2846, and UC3846 only (due to polarity of outputs).

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electrical characteristics over operating free-air temperature range, V_{IN} = 15 V, R_T = 10 kΩ, C_T = 4.7 nF (unless otherwise noted) (continued)

total device

PARAMETER	TEST CONDITIONS	UC1846, UC1847 UC2846, UC2847			UC3846, UC3847			UNIT
		MIN	TYP	MAX	MIN	TYP	MAX	
Supply current			17	21		17	21	mA

TYPICAL CHARACTERISTICS

ERROR AMPLIFIER AMPLIFICATION AND PHASE
vs
FREQUENCY

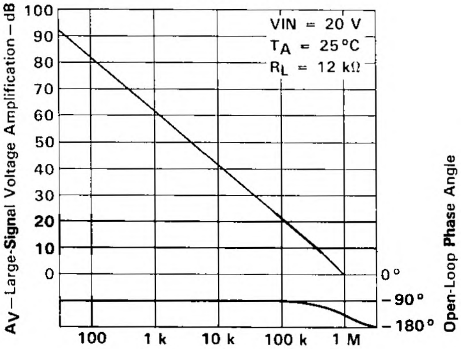


FIGURE 1

ERROR AMPLIFIER LARGE-SIGNAL DC AMPLIFICATION
vs
LOAD RESISTANCE

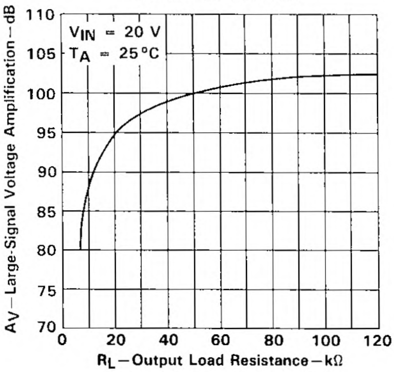
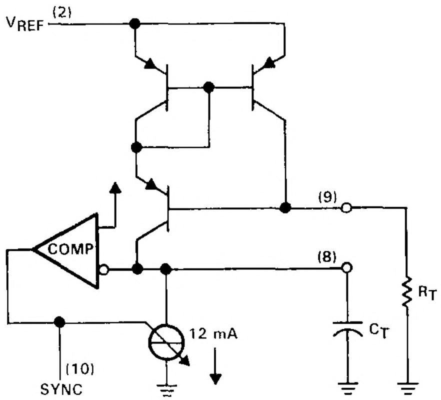
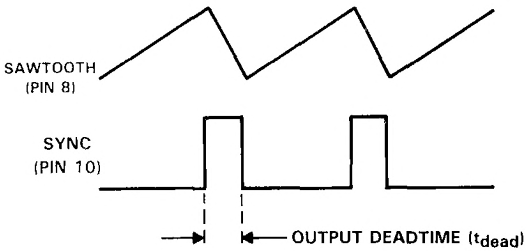


FIGURE 2

TYPICAL APPLICATION DATA



OSCILLATOR CIRCUIT



OSCILLATOR WAVEFORMS

NOTE: Oscillator frequency is approximated by the formula: $f_T \approx \frac{2.2}{R_T C_T}$

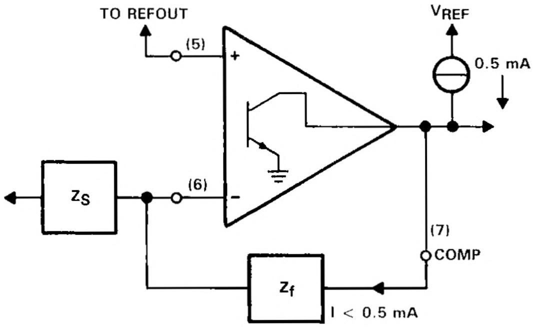
Output deadtime is determined by the size of the external capacitor, C_T, according to the following formula:

$$t_{dead} = 145\,C_T \left(\frac{12}{12 - \frac{3.6}{R_T\ (k\Omega)}} \right)$$

For large values of R_T, $t_{dead} \approx 145\,C_T$

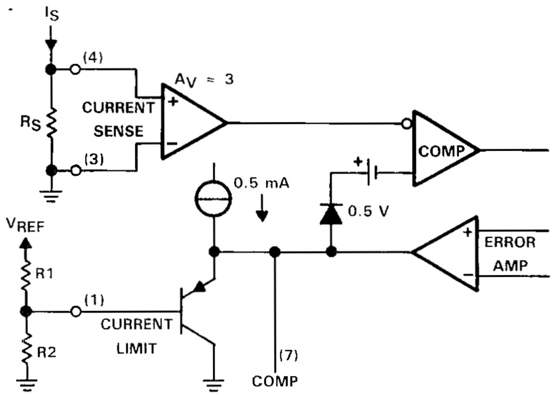
FIGURE 3. OSCILLATOR CIRCUIT

TYPICAL APPLICATION DATA



NOTE. Error Amplifier can source up to 0.5 mA.

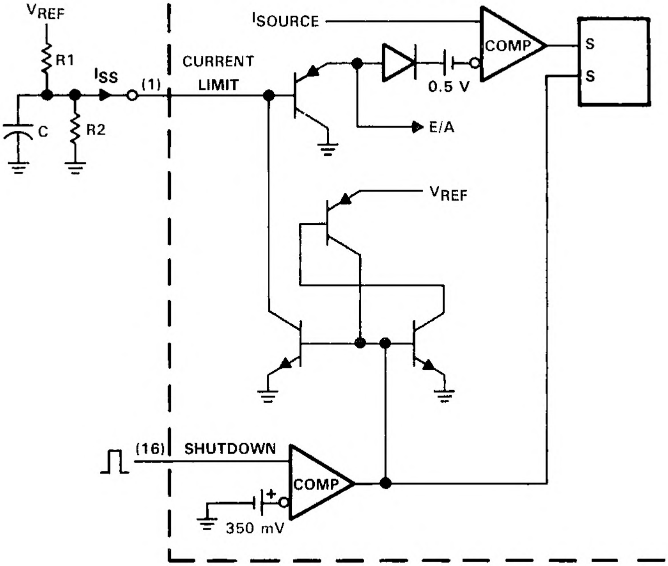
FIGURE 4. ERROR AMPLIFIER OUTPUT CONFIGURATION



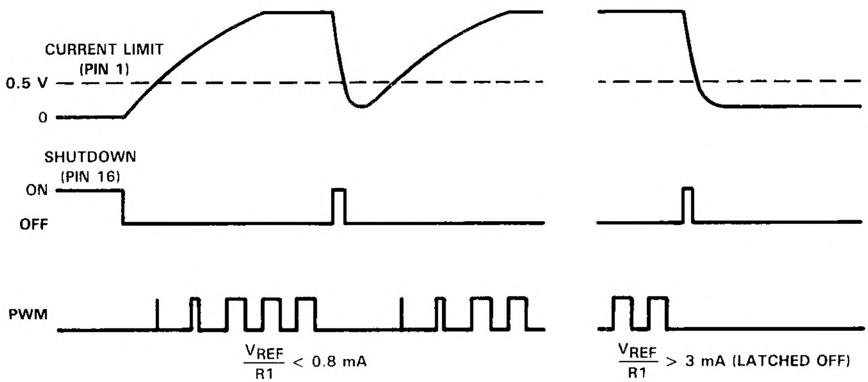
NOTE: Peak Current (I_S) is determined by the formula: $I_S = \dfrac{\dfrac{R2\ V_{REF}}{R1 + R2} - 0.5\ V}{3R_S}$

FIGURE 5. PULSE-BY-PULSE CURRENT LIMITING

TYPICAL APPLICATION DATA



SOFT START AND SHUTDOWN/RESTART CIRCUIT



NOTE: If $\frac{V_{REF}}{R1} < 0.8$ mA, the shutdown latch will commutate when $I_{SS} = 0.8$ mA and a restart cycle will be initiated.

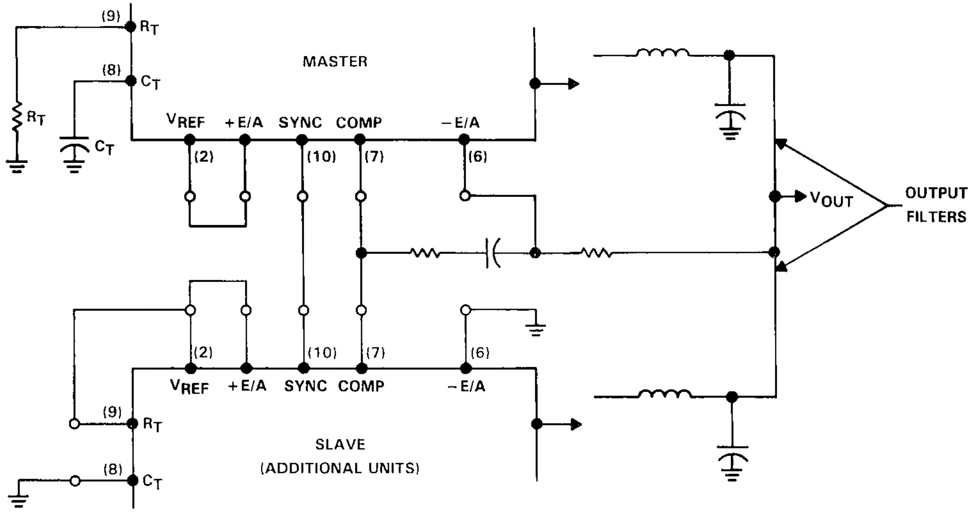
NOTE. If $\frac{V_{REF}}{R1} > 3$ mA, the device will latch off until power is cycled.

SHUTDOWN WITH AUTO-RESTART

SHUTDOWN WITHOUT AUTO-RESTART (LATCHED)

FIGURE 6. SOFT START AND SHUTDOWN/RESTART FUNCTIONS

TYPICAL APPLICATION DATA



NOTE: Slaving allows parallel operation of two or more units with equal current sharing.

FIGURE 7. PARALLEL OPERATION