

# RC4194 Dual Tracking Voltage Regulators

## Features

- Simultaneously adjustable outputs with one resistor to  $\pm 42V$
- Load current —  $\pm 200$  mA with 0.04% load regulation
- Internal thermal shutdown at  $T_j = +175^\circ C$
- External balance for  $\pm V_o$  unbalancing
- 3W power dissipations

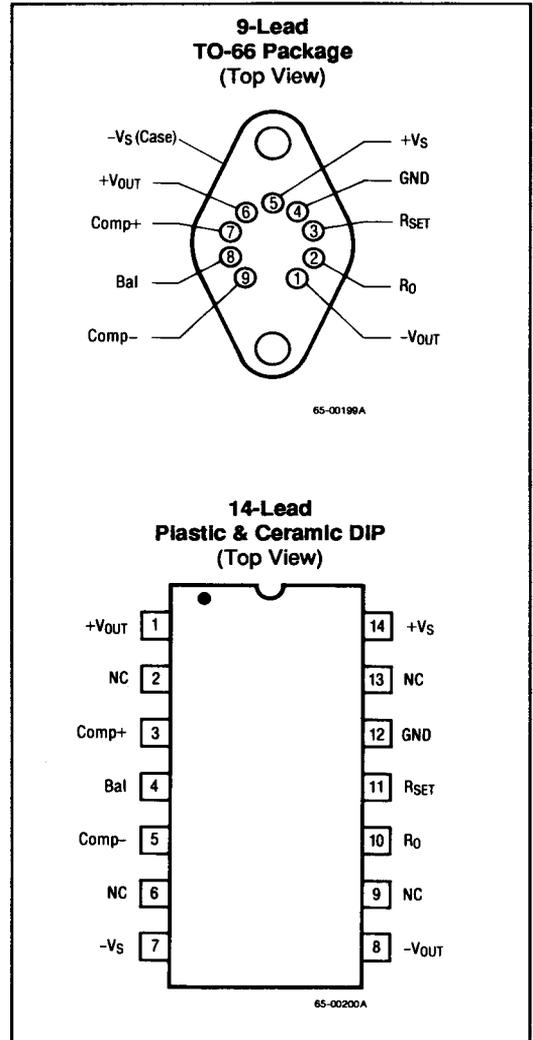
## Description

The RM4194 and RC4194 are dual polarity tracking regulators designed to provide balanced or unbalanced positive and negative output voltages at currents to 200 mA. A single external resistor adjustment can be used to change both outputs between the limits of  $\pm 50$  mV and  $\pm 42V$ .

These devices are designed for local "on-card" regulation, eliminating distribution problems associated with single-point regulation. To simplify application the regulators require a minimum number of external parts.

The device is available in three package types to accommodate various power requirements. The K (TO-66) power package can dissipate up to 3W at  $T_A = +25^\circ C$ . The D 14-pin dual in-line will dissipate up to 1W and the N 14-pin dual in-line will dissipate up to 625 mW.

## Connection Information

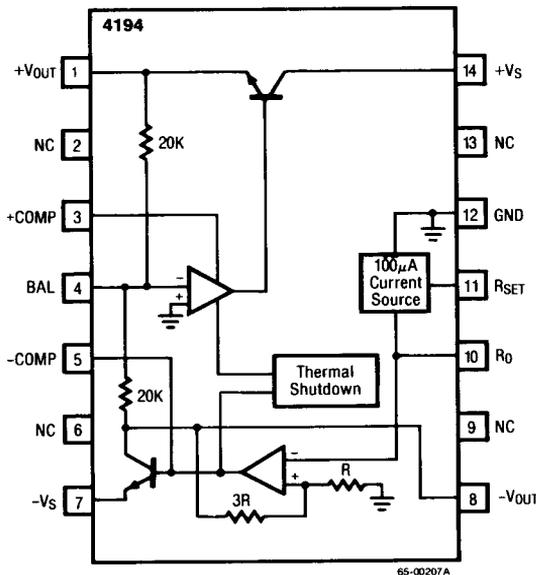


### Ordering Information

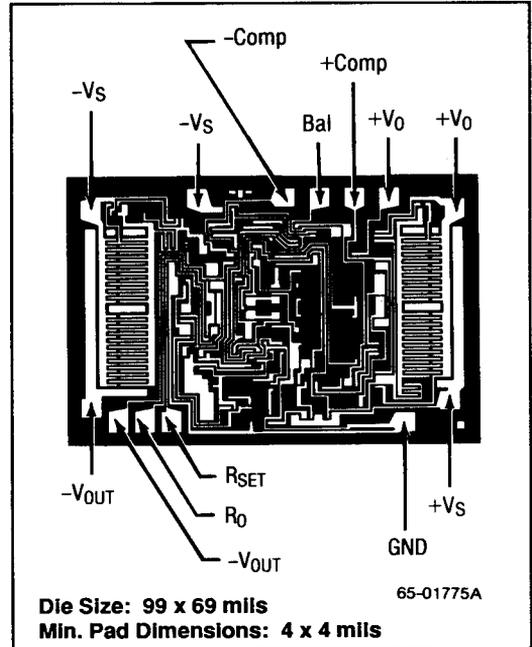
Part Number	Package	Operating Temperature Range
RC4194N	N	0°C to +70°C
RC4194D	D	0°C to +70°C
RC4194K	K	0°C to +70°C
RM4194D	D	-55°C to +125°C
RM4194D/883B	D	-55°C to +125°C
RM4194K	K	-55°C to +125°C

Notes:  
 /883B suffix denotes Mil-Std-883, Level B processing  
 N = 14-lead plastic DIP  
 D = 14-lead ceramic DIP  
 K = 9-lead TO-66  
 Contact a Raytheon sales office or representative for ordering information on special package/temperature range combinations.

### Functional Block Diagram



### Mask Pattern



### Absolute Maximum Ratings

- Supply Voltage
  - RC4194 .....±35V
  - RM4194 .....±45V
- Supply Input to Output Voltage Differential
  - RC4194 .....±35V
  - RM4194 .....±45V
- Load Current
  - N Package ..... 100 mA
  - D Package ..... 150 mA
  - K Package ..... 250 mA
- Operating Junction Temperature Range
  - RC4194 .....0°C to +125°C
  - RM4194 .....-55°C to +150°C
- Storage Temperature Range .....-65°C to +150°C
- Lead Soldering Temperature ( 60 sec) .....+300°C

## Thermal Characteristics

	14-Lead Plastic DIP	14-Lead Ceramic DIP	9-Lead TO-66 Metal Can
Max. Junction Temp.	125°C	175°C	150°C
Max. $P_D$ $T_A < 50^\circ\text{C}$	468mW	1042mW	2381mW
Therm. Res $\theta_{JC}$	—	60°C/W	7°C/W
Therm. Res. $\theta_{JA}$	160°C/W	120°C/W	42°C/W
For $T_A > 50^\circ\text{C}$ Derate at	6.25 mW/°C	8.38 mW/°C	23.81 mW/°C

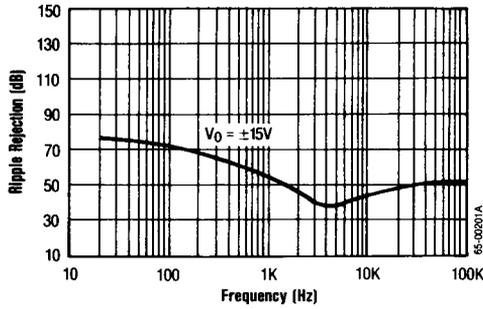
**Electrical Characteristics** ( $\pm 5 \leq V_{OUT} \leq V_{MAX}$ ;  $-V_{IN} \leq -8\text{V}$ ;  $I_L = \pm 1\text{mA}$ ; RM4194:  $-55^\circ\text{C} \leq T_J \leq +125^\circ\text{C}$ ; RC4194:  $0^\circ\text{C} \leq T_J \leq +70^\circ\text{C}$  unless otherwise specified)

Parameters	Test Conditions	Min	Typ	Max	Units
Line Regulation	$\Delta V_S = 0.1 V_{IN}$		0.04	0.1	% $V_{OUT}$
Load Regulation	4194K: $I_L < 200\text{ mA}$ 4194D: $I_L < 100\text{ mA}$ $\pm V_S = \pm(V_O + 5)\text{V}$		0.002	0.004	% $V_O \times I_L$ (mA)
Output Voltage Drift With Temperature <sup>3</sup>					
Positive Output	$V_{OUT} = \pm 5\text{V}$		0.002	0.015	%/°C
Negative Output	$V_{OUT} = \pm 5\text{V}$		0.003	0.015	%/°C
Supply Current <sup>1</sup> (Positive)	$V_S = \pm V_{MAX}$ ; $V_O = 0\text{V}$ , $I_L = 0\text{ mA}$		+0.8	+2.5	mA
Supply Current <sup>2</sup> (Negative)	$V_S = \pm V_{MAX}$ ; $V_O = 0\text{V}$ , $I_L = 0\text{ mA}$		-1.8	-4.0	mA
Supply Voltage	RM4194	$\pm 9.5$		$\pm 45$	V
	RC4194	$\pm 9.5$		$\pm 35$	V
Output Voltage Scale Factor	$R_{SET} = 71.5\text{ k}\Omega$ , $T_J = +25^\circ\text{C}$ $V_S = \pm V_{MAX}$	2.38	2.5	2.62	k $\Omega$ /V
Output Voltage Range	RM4194: $R_{SET} = 71.5\text{ k}\Omega$ , $I_L = 25\text{ mA}$	0.05		$\pm 42$	V
	RC4194: $R_{SET} = 71.5\text{ k}\Omega$ , $I_L = 25\text{ mA}$	0.05		$\pm 42$	V
Output Voltage Tracking			$\pm 0.4$	$\pm 2.0$	%
Ripple Rejection	$F = 120\text{ Hz}$ , $T_J = +25^\circ\text{C}$		70		dB
Input-Output Voltage Differential	$I_L = 50\text{ mA}$ , $T_J = +25^\circ\text{C}$	3.0			V
Short Circuit Current	$V_S = \pm 30\text{V}$ , $T_J = +25^\circ\text{C}$		300		mA
Output Noise Voltage	$C_L = 4.7\text{ }\mu\text{F}$ , $V_O = \pm 15\text{V}$ $F = 10\text{ Hz to } 100\text{ kHz}$		250		$\mu\text{V}_{RMS}$
Internal Thermal Shutdown			175		°C

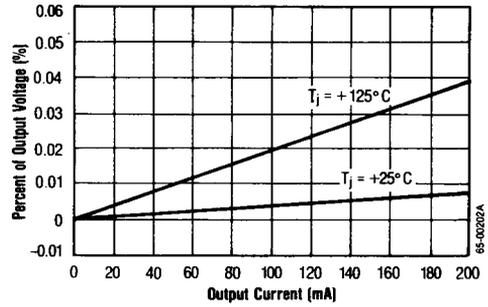
- Notes: 1. The current drain will increase by  $50\mu\text{A}/V_{OUT}$  on positive side and  $100\mu\text{A}/V_{OUT}$  on negative side.  
2. The specifications above apply for the given junction temperatures since pulse test conditions are used.  
3. Output voltage temperature drift guaranteed by design.

# Typical Performance Characteristics

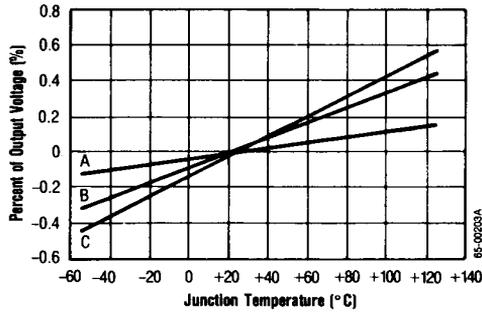
**Ripple Rejection**



**Load Regulation vs. Output Current**



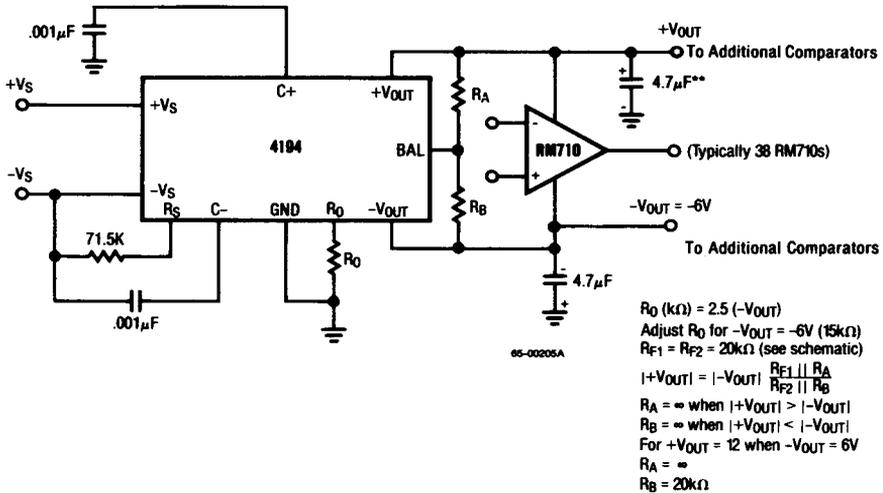
**Output Voltage Tracking vs. Temperature**



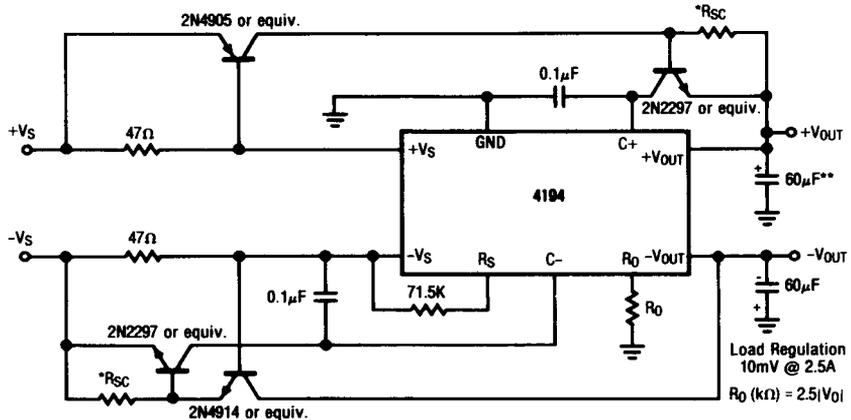
A = % Tracking of Output Voltage  
 B = T.C. for Positive Regulator  
 C = T.C. for Negative Regulator

# Typical Applications

## Unbalanced Output Voltage — Comparator Application



## High Output Application



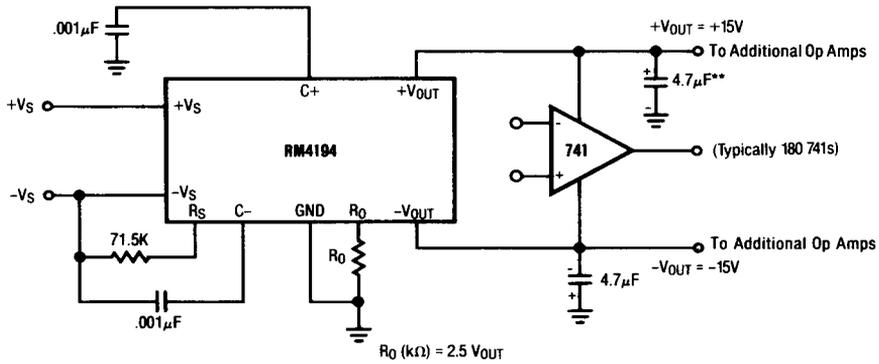
$$*R_{sc} = \frac{0.7}{I_{sc}}$$

Note: Compensation and bypass capacitor connections should be close as possible to the 4194.

\*\*Optional usage — not as critical as -V<sub>O</sub> bypass capacitors.

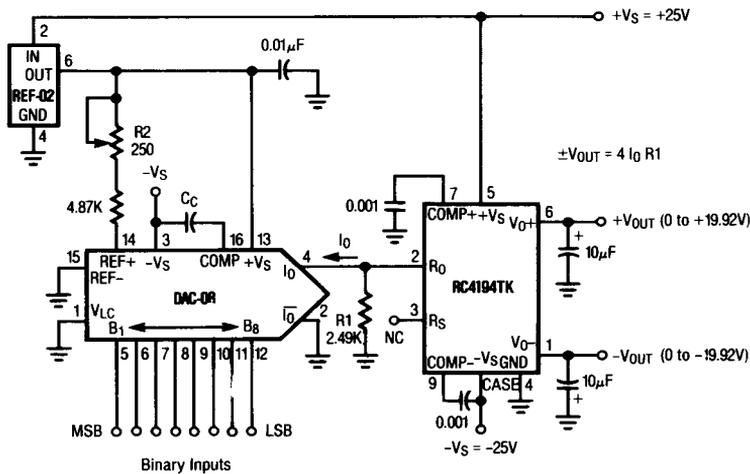
Typical Applications (Continued)

Balanced Output Voltage — Op Amp Application

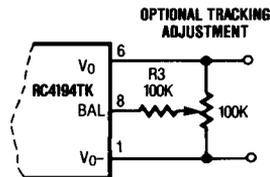


65-00204A

Digitally Controlled Dual 200mA Voltage Regulator



Adjust R2 for -19.92V at  $-V_{OUT}$  with all "1s" at binary inputs, then optionally adjust R3 for +19.92V at  $+V_{OUT}$



65-01725A

## 4194 Switchable Power Supply

The outputs of the 4194 can be simultaneously switched on or off under logic control as shown in Figure 1. In the "off" state, the outputs will be forced to a minimum voltage, or about  $\pm 20$  mV, rather than becoming open-circuit. The turn-on time, with the outputs programmed to  $\pm 12$ V, is approximately 200  $\mu$ S. This circuit works by forcing the  $R_o$  pin to ground with an analog switch. Refer to the 4194 internal schematic diagram. A reference voltage that regulates with respect to  $-V_s$  is generated at the  $R_s$  pin by the zener diode Q12 and the buffer circuit of Q11 and Q13. When the external 71.5k  $R_s$  resistor is connected between the  $R_s$  pin and

$-V_s$ , a precision current of 100  $\mu$ A is generated which then flows into Q13's collector. Since Q13's collector is tied to the  $R_o$  pin, the 100  $\mu$ A current will develop a ground-referenced voltage drop proportional to the value of  $R_o$ , which is then amplified by the internal error amplifier. When the analog switch in Figure 1 turns on, it effectively shorts out  $R_o$  and causes 0V to be applied to the error amplifier. The output voltage in the off state will be approximately  $\pm 20$  mV. If a higher value (50 to 100 mV) is acceptable, then the DG201 FET switch can be replaced with a low-cost small signal transistor, as shown in the alternate switch configuration.

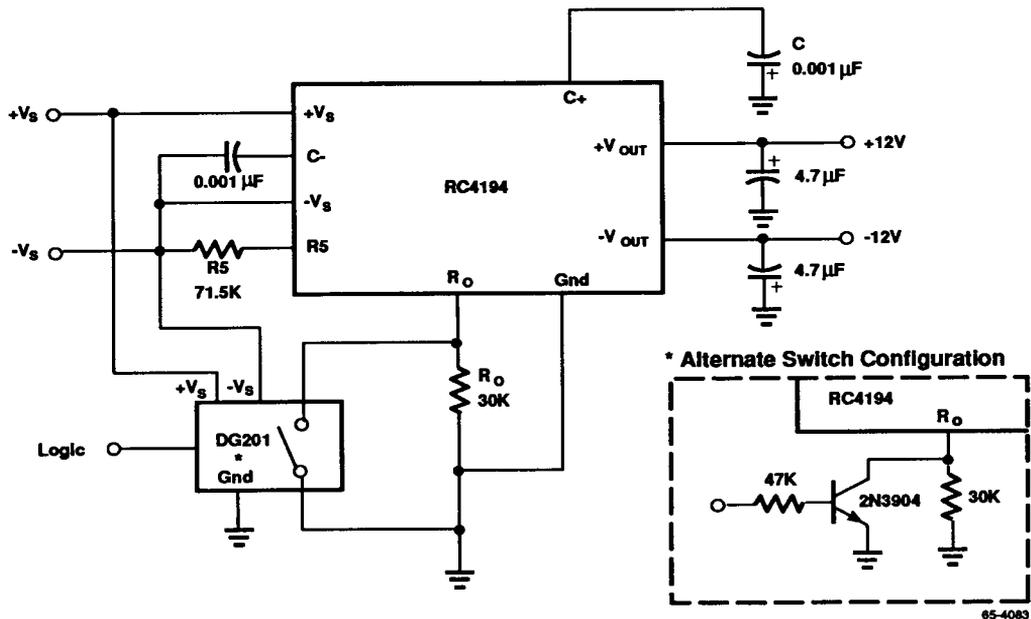


Figure 1.  $\pm 12$ V Switchable Power Supply

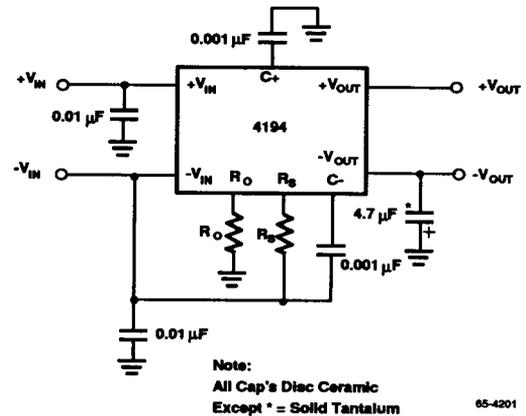
## Compensation

For most applications, the compensation technique shown in the data sheet is sufficient. The positive regulator section of the 4194 is compensated by a  $0.001\ \mu\text{F}$  ceramic disc capacitor from the C+ terminal to ground. The negative regulator requires compensation at two points. The first is the C- pin, which should have  $0.001\ \mu\text{F}$  to the  $-V_{\text{IN}}$  pin, or case. A ceramic disc is best here also. The second compensation point for the negative side is the  $-V_{\text{OUT}}$  terminal, which ideally should be a  $4.7\ \mu\text{F}$  solid tantalum capacitor with enough reserve voltage capacity to avoid the momentary shorting and reforming which can occur with tantalum caps. For systems where the cost of a solid tantalum capacitor cannot be justified, it is usually sufficient to use an aluminum capacitor with a  $0.03\ \mu\text{F}$  ceramic disc in parallel to bypass high frequencies. In addition, if the rectifier filter capacitors have poor high frequency characteristics (like aluminum electrolytics) or if any impedance is in series with the  $+V_{\text{IN}}$  and  $-V_{\text{IN}}$  terminals, it is necessary to bypass these two points with  $0.01\ \mu\text{F}$  ceramic disc capacitors. Just as with monolithic op amps, some applications may not require these bypass caps, but if in doubt, be sure to include them.

All compensation and bypass caps should have short leads, solid grounds, and be located as close to the RM/RC4194 as possible. Refer to Figure 2 for recommended compensation circuitry.

## Protection

In systems using monolithic voltage regulators, a number of conditions can exist which, left uncorrected, will destroy the regulator. Fortunately, regulators can easily be protected against these potentially destructive conditions. Monolithic regulators can be destroyed by any reversal of input or output voltage polarity, or if the input voltage drops below the output voltage in magnitude. These conditions can be



**Figure 2. 4194 Recommended Compensation**

caused by inductive loads at the inputs or outputs of the regulator. Other problems are caused by heavy loads at the unregulated inputs to the regulator, which might cause the input voltage to drop below the output voltage at turn-off. If any of the preceding problem conditions are present in your system, it is recommended that you protect the regulator using diodes. These diodes should be high speed types capable of handling large current surges. Figure 3 shows all six of the possible protection diodes. The diodes at the inputs and outputs prevent voltages at those points from becoming reversed. Diodes from outputs to inputs prevent the output voltage from exceeding the input voltage. Chances are that the system under consideration will not require all six diodes, but if in doubt, be sure to include them.

## Brownout Protection

The 4194/4195 is one of the most easily applied and trouble-free monolithic ICs available. When used within the data sheet ratings (package power dissipation, maximum output cur-



$$T_J = T_A + P_D \theta_{J-A} \quad (1)$$

where

- $T_J$  = junction temperature (°C)
- $T_A$  = ambient air temperature (°C)
- $P_D$  = power dissipated by device (W)
- $\theta_{J-A}$  = thermal resistance from junction to ambient air (°C/W)

The power dissipated by the voltage regulator can be detailed as follows:

$$P_D = (V_{IN} - V_{OUT}) \times I_O + V_{IN} \times I_Q \quad (2)$$

where

- $V_{IN}$  = input voltage
- $V_{OUT}$  = regulated output voltage
- $I_O$  = load current
- $I_Q$  = quiescent current drain

Let's look at an application where a user is trying to determine whether the RM4194 in a high temperature environment will need a heatsink.

Given:

- $T_J$  at thermal shutdown = 150°C
- $T_A$  = 125°C
- $\theta_{J-A}$  = 41.6°C/W, K (TO-66) pkg.
- $V_{IN}$  = 40V
- $V_{OUT}$  = 30V
- $I_Q$  = 1 mA + 75  $\mu$ A/ $V_{OUT}$  x 30V = 3.25 mA \*

$$\theta_{J-A} = \frac{T_J - T_A}{P_D}$$

$$P_D = \frac{T_J - T_A}{\theta_{J-A}} = (V_{IN} - V_{OUT}) \times I_O + V_{IN} \times I_Q$$

Solve for  $I_O$ ,

$$I_O = \frac{T_J - T_A}{\theta_{J-A} (V_{IN} - V_{OUT})} - \frac{V_{IN} \times I_Q}{(V_{IN} - V_{OUT})}$$

$$I_O = \frac{50^\circ\text{C} - 125^\circ\text{C}}{41.6^\circ\text{C/W} \times 10\text{V}} - \frac{40 \times 3.25 \times 10^{-3}}{10}$$

$$= 50 \text{ mA} - 13 \text{ mA} \approx 47 \text{ mA}$$

If this supply current does not provide at least a 10% margin under worst case load conditions, heatsinking should be employed. If reliability is of prime importance, the multiple regulator approach should be considered.

In equation 1,  $\theta_{J-A}$  can be broken into the following components:

$$\theta_{J-A} = \theta_{J-C} + \theta_{C-S} + \theta_{S-A}$$

where

- $\theta_{J-C}$  = junction-to-case thermal resistance
- $\theta_{C-S}$  = case-to-heatsink thermal resistance
- $\theta_{S-A}$  = heatsink-to-ambient thermal resistance

In the above example, let's say that the user's load current is 200 mA and he wants to calculate the combined  $\theta_{C-S}$  and  $\theta_{S-A}$  he needs:

Given:  $I_O = 200 \text{ mA}$ ,

$$\theta_{J-A} = \frac{T_J - T_A}{(V_{IN} - V_{OUT}) \times I_O + V_{IN} \times I_Q}$$

$$= \frac{50^\circ\text{C} - 125^\circ\text{C}}{10\text{V} \times 200 \text{ mA} + 40 \times 3.25 \times 10^{-3}}$$

$$= 11.75^\circ\text{C/W}$$

\* The current drain will increase by 50 $\mu$ A/ $V_{OUT}$  on positive side and 100 $\mu$ A/ $V_{OUT}$  on negative side.

Given  $\theta_{J-C} = 7.15^{\circ}\text{C/W}$  for the 4194 in the K package,

$$\begin{aligned}\theta_{C-S} + \theta_{S-A} &= 11.75^{\circ}\text{C/W} - 7.15^{\circ}\text{C/W} \\ &= 4.6^{\circ}\text{C/W}\end{aligned}$$

When using heatsink compound with a metal-to-metal interface, a typical  $\theta_{C-S} = 0.5^{\circ}\text{C/W}$  for the K package. The remaining  $\theta_{S-A}$  of approximately  $4^{\circ}\text{C/W}$  is a large enough thermal resistance to be easily provided by a number of heatsinks currently available. Table 1 is a brief selection guide to heatsink manufacturers.

**Table 1. Commercial Heatsink Selection Guide**

No attempt has been made to provide a complete list of all heatsink manufacturers. This list is only representative.

$\theta_{S-A}^*$ ( $^{\circ}\text{C/W}$ )	Manufacturer/Series or Part Number
<b>TO-66 Package</b>	
0.31-1.0	Thermalloy — 6441, 6443, 6450, 6470, 6560, 6590, 6660, 6690
1.0 - 3.0	Wakefield — 641 Thermalloy — 6123, 6135, 6169, 6306, 6401, 6403, 6421, 6423, 6427, 6442, 6463, 6500
3.0 - 5.0	Wakefield — 621, 623 Thermalloy — 6606, 6129, 6141, 6303 IERC — HP Staver — V3-3-2
5.0 - 7.0	Wakefield — 690 Thermalloy — 6002, 6003, 6004, 6005, 6052, 6053, 6054, 6176, 6301 IERC — LB Staver — V3-5-2
7.0 - 10.0	Wakefield — 672 Thermalloy — 6001, 6016, 6051, 6105, 6601 IERC — LA, uP Staver — V1-3, V1-5, V3-3, V3-5, V3-7
10.0-25.0	Thermalloy — 6-13, 6014, 6015, 6103, 6104, 6105, 6117
<b>TO-99 Package</b>	
12.0 - 20.0	Wakefield — 260 Thermalloy — 1101, 1103 Staver — V3A-5
20.0 - 30.0	Wakefield — 209 Thermalloy — 1116, 1121, 1123, 1130, 1131, 1132, 2227, 3005 IERC — LP Staver — F5-5

\* All values are typical as given by manufacturer or as determined from characteristic curves supplied by manufacturer.

**Table 1. Commercial Heatsink Selection Guide — Continued**

$\theta_{S-A}$ *(°C/W)	Manufacturer/Series or Part Number
30.0 - 50.0	Wakefield — 207 Thermalloy — 2212, 2215, 225, 2228, 2259, 2263, 2264 Staver — F5-5, F6-5
	<b>Dual-Inline Package</b>
20	Thermalloy — 6007
30	Thermalloy — 6010
32	Thermalloy — 6011
34	Thermalloy — 6012
45	IERC — LIC
60	Wakefield — 650, 651

\* All values are typical as given by manufacturer or as determined from characteristic curves supplied by manufacturer.

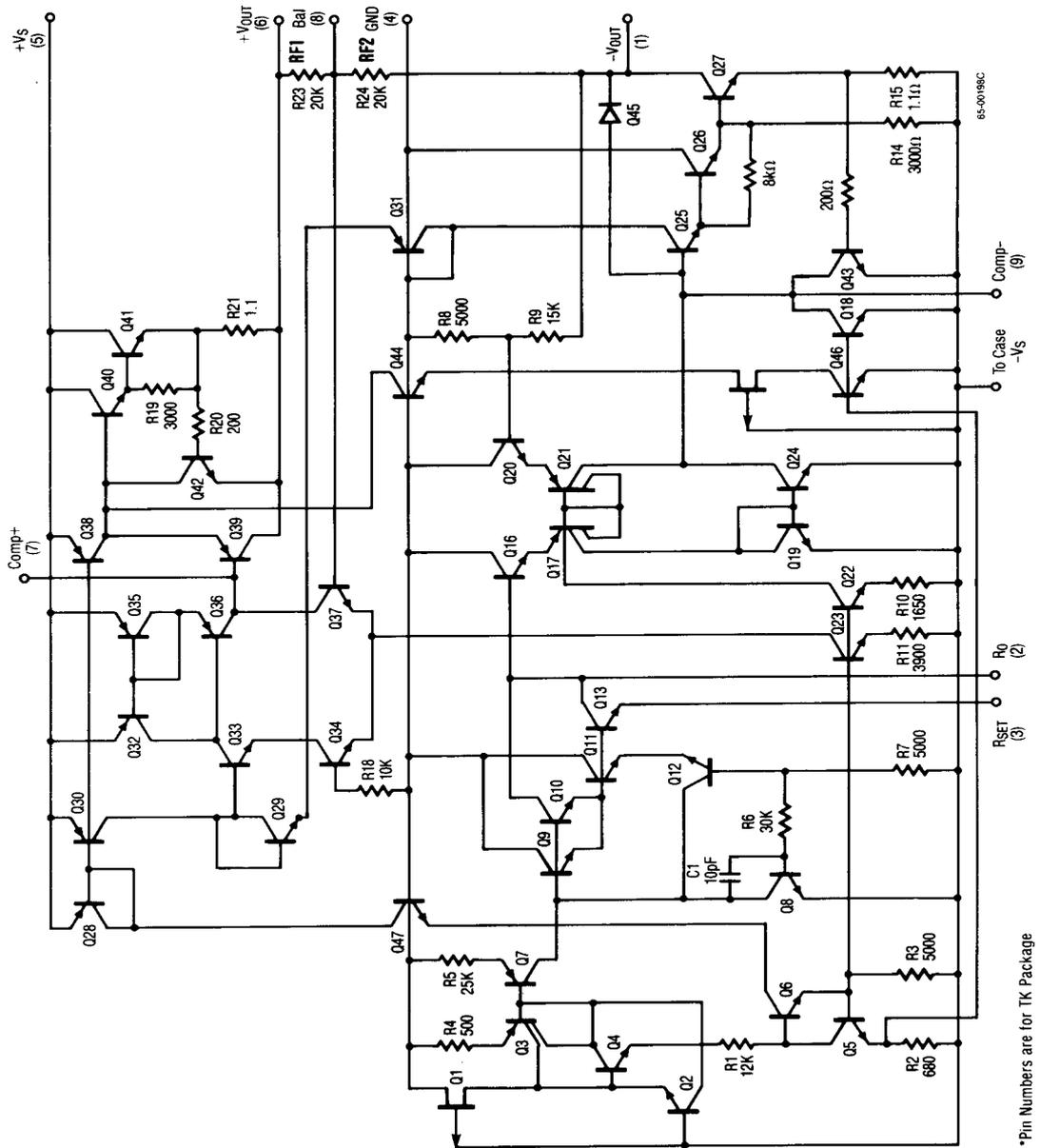
Staver Co., Inc.: 41-51 N Saxon Ave., Bay Shore, NY 11706

IERC: 135 W Magnolia Blvd., Burbank, CA 91502

Thermalloy: P.O. Box 34829, 2021 W Valley View Ln., Dallas, TX

Wakefield Engin Ind: Wakefield, MA 01880

# Schematic Diagram



\*Pin Numbers are for TK Package