

# HIGH CURRENT SWITCHING REGULATOR

- 4 A OUTPUT CURRENT
- 5.1 V TO 28 V OUTPUT VOLTAGE RANGE
- 0 TO 100 % DUTY CYCLE RANGE
- PRECISE (± 3 %) ON-CHIP REFERENCE
- SWITCHING FREQUENCY UP TO 120 KHz
- VERY HIGH EFFICIENCY (UP TO 90 %)
- VERY FEW EXTERNAL COMPONENTS
- SOFT START
- RESET OUTPUT
- CURRENT LIMITING
- INPUT FOR REMOTE INHIBIT AND SYN-CHRONUS PWM
- THERMAL SHUTDOWN

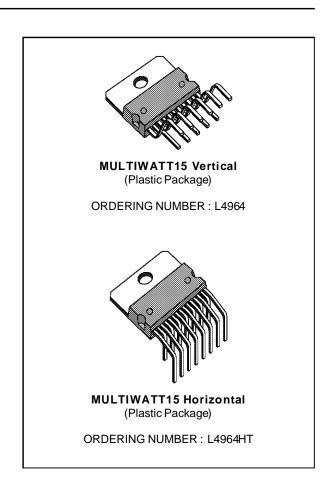
#### **DESCRIPTION**

The L4964 is a stepdown power switching regulator delivering 4A at a voltage variable from 5.1V to 28V.

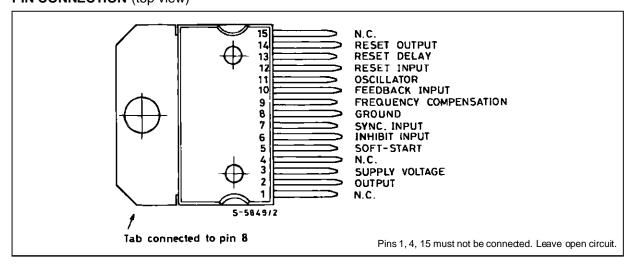
Features of the device include overload protection, soft start, remote inhibit, thermal protection, a reset output for microprocessors and a PWM comparator input for synchronization in multichip configurations.

The L4964 is mounted in a 15-lead Multiwatt® plastic power package and requires very few external components.

Efficient operation at switching frequencies up to 120kHz allows a reduction in the size and cost of external filter components.



## PIN CONNECTION (top view)

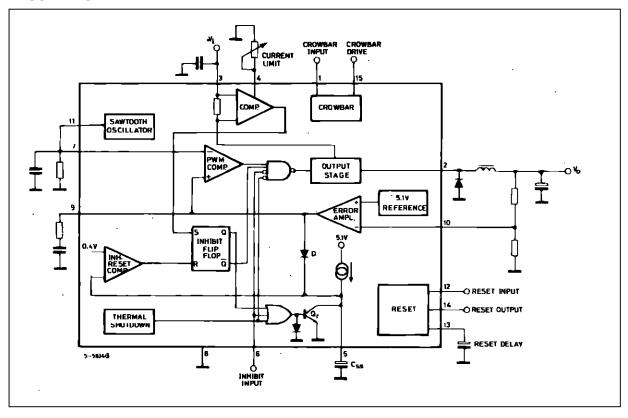


April 1993 1/13

# **PIN FUNCTIONS**

N°	Name	Function
1	N.C.	Must not be connected. Leave open circuit.
2	Output	Regulator Output.
3	Supply Voltage	Unregulated Voltage Input. An internal regulator powers the L4964's internal logic.
4	N.C.	Must not be connected. Leave open circuit.
5	Soft Start	Soft Start Time Constant. A capacitor is connected between this terminal and ground to define the soft start time constant. This capacitor also determines the average short circuit output current.
6	Inhibit Input	TTL - Level Remote Inhibit. A logic high level on this input disables the L4964.
7	Sync Input	Multiple L4964's are synchronized by connecting the pin 7 inputs together and omitting the oscillator RC network on all but one device.
8	Ground	Common Ground Terminal.
9	Frequency Compensation	A series RC network connected between this terminal and ground determines the regulation loop gain characteristics.
10	Feedback Input	The Feedback Terminal of the Regulation Loop. The output is connected directly to this terminal for 5.1 V operation; it is connected via a divider for higher voltages.
11	Oscillator	A parallel RC network connected to this terminal determines the switching frequency. The pin must be connected to pin 7 input when the internal oscillator is used.
12	Reset Input	Input of the Reset Circuit. The threshold is roughly 5 V. It may be connected to the beedback point or via a divider to the input.
13	Reset Delay	A capacitor connected between this terminal and ground determines the reset signal delay time.
14	Reset Output	Open Collector Reset Signal Output. This output is high when the supply is safe.
15	N.C.	Must not be connected. Leave open circuit.

## **BLOCK DIAGRAM**



#### **CIRCUIT OPERATION** (refer to the block diagram)

The L4964 is a monolithic stepdown switching regulator providing output voltages from 5.1 V to 28 V and delivering 4A.

The regulation loop consists of a sawtooth oscillator, error amplifier, comparator and the output stage. An error signal is produced by comparing the output voltage with a precise 5.1 V on-chip reference (zener zap trimmed to  $\pm$  3 %). This error signal is then compared with the sawtooth signal to generate the fixed frequency pulse width modulated pulses which drive the output stage. The gain and frequency stability of the loop can be ajusted by an external RC network connected to pin 9. Closing the loop directly gives an output voltage of 5.1 V. Higher voltages are obtained by inserting a voltage divider.

Output overcurrents at switch on are prevented by the soft start function. The error amplifier output is initially clamped by the external capacitor  $C_{ss}$  and allowed to rise, linearly, as this capacitor is charged by a constant current source.

Output overload protection is provided in the form of a current limiter. The load current is sensed by an internal metal resistor connected to a comparator. When the load current exceeds a preset threshold this comparator sets a flip flop which disables the output stage and discharges the soft start capacitor. A second comparator resets the flip flop when the voltage across the soft start capacitor has fallen to 0.4 V. The output stage is thus re-enable and the output voltage rises under contro of the soft start network. If the overload condition is still present the limiter will trigger again when the thershold current is reached. The average short circuit current is limited to a safe value by the dead time introduced by the soft start network.

The reset circuit generates an output signal when the supply voltage exceeds a threshold programmed by an external divider. The reset signal is generated with a delay time programmed by an external capacitor. When the supply falls below the threshold the reset output goes low immediately. The reset output is an open collector.

A TTL - level input is provided for applications such as remote on/off control. This input is activated by high level and disables circuit operation. After an inhibit the L4964 restarts under control of the soft start network.

The thermal overload circuit disables circuit operation when the junction temperature reaches about 150 and has hysteresis to prevent unstable conditions.



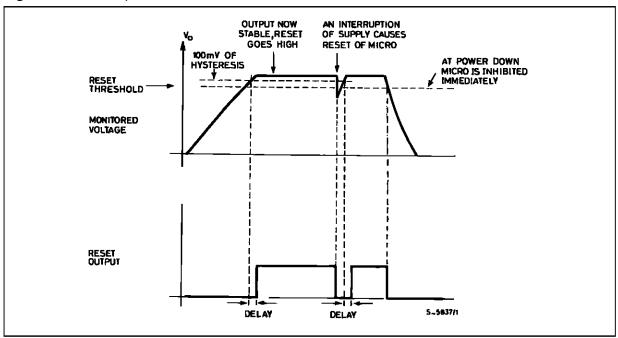


Figure 2: Soft Start Waveforms

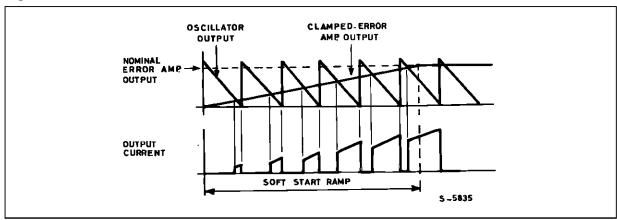
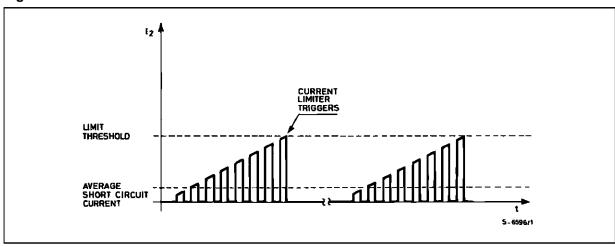


Figure 3: Current Limiter Waveforms



## **ABSOLUTE MAXIMUM RATINGS**

Symbol	Parameter	Value	Unit
Vi	Input Voltage (pin 3)	36	V
$V_i - V_2$	Input to Output Voltage Difference	38	V
V <sub>2</sub>	Output DC Voltage Output Peak Voltage at t = 0.1 μsec f = 100 kHz	-1 -7	V
V <sub>12</sub>	Voltage at Pin 12	10	V
V <sub>5</sub> , V <sub>7</sub> , V <sub>9</sub>	Voltage at Pins 5, 7 and 9	5.5	V
V <sub>10</sub> , V <sub>6</sub> , V <sub>13</sub>	Voltage at Pins 10, 6 and 13	7	V
V <sub>14</sub>	Voltage at Pin 14 (I <sub>14</sub> ≤ 1 mA)	Vi	
l <sub>9</sub>	Pin 9 Sink Current	1	mA
I <sub>11</sub>	Pin 11 Source Current	20	mA
I <sub>14</sub>	Pin 14 Sink Current (V <sub>14</sub> < 5 V)	50	mA
P <sub>tot</sub>	Power Dissipation at T <sub>case</sub> ≤ 90 °C	20	W
T <sub>j</sub> , T <sub>stg</sub>	Junction and Storage Temperature	- 40 to 150	°C

## THERMAL DATA

Symbol	Parameter	Parameter		Unit
R <sub>th j-case</sub>	Thermal Resistance Junction-case	Max.	3	°C/W
R <sub>th j-amb</sub>	Thermal Resistance Junction-ambient	Max.	35	°C/W

# **ELECTRICAL CHARACTERISTICS**

(refer to the test circuits  $T_j = 25^{\circ}C$ ,  $V_i = 25V$ , unless otherwise specified)

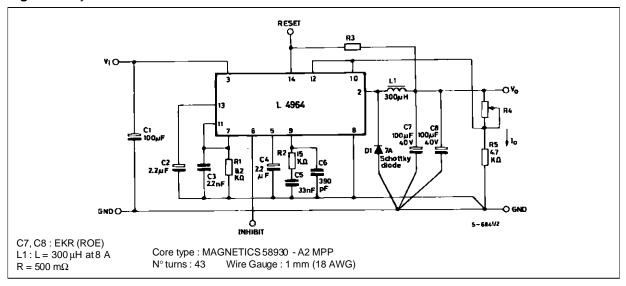
DYNAMIC CHARACTERISTICS (pin 6 to GND unless otherwise specified)         V <sub>o</sub> Output Voltage Range         V <sub>I</sub> = 36V, I <sub>0</sub> = 1A         V <sub>ref</sub> 28         V         4           V <sub>I</sub> Input Voltage Range         V <sub>I</sub> = 36V, I <sub>0</sub> = 1A         V <sub>I</sub> = 10V to 28V, I <sub>0</sub> = 3A         9         36         V         4           ΔV <sub>O</sub> Line Regulation         V <sub>I</sub> = 10V to 30V, V <sub>0</sub> = V <sub>Nef</sub> , I <sub>0</sub> = 2A         15         70         mV         4           ΔV <sub>ort</sub> Internal Reference Voltage (Pin 10)         V <sub>I</sub> = 9V to 36V, V <sub>0</sub> = V <sub>Nef</sub> , I <sub>0</sub> = 2A         10         30         mV         4           V <sub>ref</sub> Internal Reference Voltage (Pin 10)         V <sub>I</sub> = 9V to 36V, I <sub>0</sub> = 2A         4.95         5.1         5.25         V         4           Avrage Temperature Coefficient of Reference Voltage         T <sub>I</sub> = 0°C to 125°C, I <sub>0</sub> = 2A         4.95         5.1         5.25         V         4           V <sub>d</sub> Dropout Voltage between Pin 2 and Pin 3         I <sub>0</sub> = 3A         1,5         2.4         V         4           1 <sub>2</sub> Current Imiting Threshold (Pin 2)         I <sub>0</sub> = 9V to 36V, V <sub>0</sub> = V <sub>ref</sub> to 28V         4.5         8         A         4           1 <sub>2</sub> Au         V <sub>1</sub> = 36V, V <sub>1</sub> V <sub>1</sub> = 36V, V <sub>1</sub> 80         140<	Symbol	Parameter	Test Conditions	Min.	Тур.	Max.	Unit	Fig.
V <sub>0</sub>   Output Voltage Range   V <sub>1</sub> = 36V, I <sub>0</sub> = 1A					. , p.	max.	Oilit	1
V <sub>1</sub>   Input Voltage Range				\/ .		20	\/	1
ΔV <sub>o</sub>   Line Regulation   V <sub>i</sub> = 10V to 30V, V <sub>o</sub> = V <sub>ref.</sub> I <sub>o</sub> = 2A   15   70   mV   4     ΔV <sub>o</sub>   Load Regulation   I <sub>o</sub> = 1A to 2A   I <sub>o</sub> = 0.5A   I <sub>o</sub> = 0.5A     V <sub>rst</sub>   Internal Reference Voltage (Pin 10)   V <sub>i</sub> = 9V to 36V, V <sub>o</sub> = V <sub>ref</sub>   I <sub>o</sub> = 0.5A     ΔV <sub>ref</sub>   ΔV <sub>ref</sub>   Average Temperature Coefficient of Reference Voltage (Pin 10)   V <sub>i</sub> = 9V to 36V, I <sub>o</sub> = 2A   4.95   5.1   5.25   V   4     ΔV <sub>ref</sub>   ΔV <sub>ref</sub>   ΔV <sub>ref</sub>   Average Temperature Coefficient of Reference Voltage   T <sub>i</sub> = 0°C to 125°C, I <sub>o</sub> = 2A   0.4   mV/°C     ΔV <sub>ref</sub>   Δ								
$ \begin{array}{ c c c c c } \hline \Delta V_{ver} & \text{Internal Reference Voltage (Pin 10)} & I_{ver} & 1.5 h to 3A, V_{vo} = V_{ref} \\ \hline \Delta V_{verf} & \text{Internal Reference Voltage (Pin 10)} & V_{i} = 9V to 36V, I_{vo} = 2A \\ \hline \Delta V_{verf} & \text{Reference Voltage (Pin 10)} & V_{i} = 9V to 36V, I_{vo} = 2A \\ \hline \Delta V_{verf} & \text{Reference Voltage} & 0.4 \\ \hline \Delta V_{verf} & \text{Reference Voltage} & 0.4 \\ \hline V_{o} & \text{Dropout Voltage between Pin 2} & I_{vo} = 3A \\ I_{low} & \text{Maximum Operating Load Current} \\ I_{2L} & \text{Current Limiting Threshold (Pin 2)} & V_{i} = 9V to 36V, V_{o} = V_{ref} \text{ to } 28V \\ I_{SH} & \text{Input Average Current} \\ \hline V_{i} & = 9V to 36V, V_{o} = V_{ref} \text{ to } 28V \\ I_{SH} & \text{Input Average Current} \\ \hline V_{i} & = 3A \\ V_{o} & = 12V \\ \hline \end{array} & V_{o} = 12V \\ \hline \end{array} & 0.4 \\ \hline \begin{array}{c} \text{Efficiency} & V_{i} & = 3A \\ V_{o} & = V_{ref} \\ V_{o} & = 12V \\ \hline \end{array} & 0.5 \\ \hline \end{array} & 0.4 \\ \hline \begin{array}{c} \text{SVR} & \text{Supply Voltage Ripple Rejection} \\ \hline \begin{array}{c} \Delta V_{i} & = 9V \text{ to } 36V, V_{o} & V_{ref} \text{ to } 28V \\ V_{o} & = 12V \\ \hline \end{array} & 0.5 \\ \hline \begin{array}{c} A V_{o} & = 12V \\ \hline \end{array} & 0.5 \\ \hline \begin{array}{c} \text{SWitching Frequency} \\ \hline \end{array} & 0.5 \\ \hline \begin{array}{c} \Delta V_{i} & = 9V \text{ to } 36V \\ V_{o} & = V_{ref} \\ \hline \end{array} & 0.5 \\ \hline \begin{array}{c} A V_{o} & = 12V \\ \hline \end{array} & 0.5 \\ \hline \begin{array}{c} A V_{o} & = 12V \\ \hline \end{array} & 0.5 \\ \hline \begin{array}{c} A V_{o} & = 12V \\ \hline \end{array} & 0.5 \\ \hline \begin{array}{c} A V_{o} & = 12V \\ \hline \end{array} & 0.5 \\ \hline \begin{array}{c} A V_{o} & = 12V \\ \hline \end{array} & 0.5 \\ \hline \begin{array}{c} A V_{o} & = 12V \\ \hline \end{array} & 0.5 \\ \hline \begin{array}{c} A V_{o} & = 12V \\ \hline \end{array} & 0.5 \\ \hline \begin{array}{c} A V_{o} & = 12V \\ \hline \end{array} & 0.5 \\ \hline \begin{array}{c} A V_{o} & = 12V \\ \hline \end{array} & 0.5 \\ \hline \begin{array}{c} A V_{o} & = 12V \\ \hline \end{array} & 0.5 \\ \hline \begin{array}{c} A V_{o} & = 12V \\ \hline \end{array} & 0.5 \\ \hline \begin{array}{c} A V_{o} & = 12V \\ \hline \end{array} & 0.5 \\ \hline \begin{array}{c} A V_{o} & = 12V \\ \hline \end{array} & 0.5 \\ \hline \begin{array}{c} A V_{o} & = 12V \\ \hline \end{array} & 0.5 \\ \hline \begin{array}{c} A V_{o} & = 12V \\ \hline \end{array} & 0.5 \\ \hline \begin{array}{c} A V_{o} & = 12V \\ \hline \end{array} & 0.5 \\ \hline \begin{array}{c} A V_{o} & = 12V \\ \hline \end{array} & 0.5 \\ \hline \begin{array}{c} A V_{o} & = 12V \\ \hline \end{array} & 0.5 \\ \hline \begin{array}{c} A V_{o} & = 12V \\ \hline \end{array} & 0.5 \\ \hline \begin{array}{c} A V_{o} & = 12V \\ \hline \end{array} & 0.5 \\ \hline \begin{array}{c} A V_{o} & = 12V \\ \hline \end{array} & 0.5 \\ \hline \begin{array}{c} A V_{o} & = 12V \\ \hline \end{array} & 0.5 \\ \hline \begin{array}{c} A V_{o} & = 12V \\ \hline \end{array} & 0.5 \\ \hline \begin{array}{c} A V_{o} & = 12V \\ \hline \end{array} & 0$				9	15		-	_
$ \begin{array}{ c c c c c c c } \hline & V_{ref} & Internal Reference Voltage (Pin 10) & V_i = 9V to 36V, I_0 = 2A & 4.95 & 5.1 & 5.25 & V & 4 \\ \hline \Delta V_{ref} & Average Temperature Coefficient of Reference Voltage & I_0 = 9V to 125°C, I_0 = 2A & 4.95 & 5.1 & 5.25 & V & 4 \\ \hline \Delta V_{ref} & Average Temperature Coefficient of Reference Voltage between Pin 2 of Reference Voltage & I_0 = 3A & I_0 & $					_			-
$ \begin{array}{ c c c c c } \hline \Delta V_{ref} \\ \overline{\Delta T} \\ \hline \begin{tabular}{ c c c c c c c } \hline \Delta V_{ref} \\ \overline{\Delta T} \\ \hline \begin{tabular}{ c c c c c c c c c c } \hline A_{ref} \\ \hline \begin{tabular}{ c c c c c c c c c c c c c c c c c c c$	Δν0	Load Regulation						
$ \begin{array}{ c c c c c } \hline \Delta T & of Reference Voltage \\ \hline V_d & Dropout Voltage between Pin 2 & l_o = 3A & 2 & 3.2 & V & 4 \\ \hline lom & Maximum Operating Load Current & V_1 = 9V to 36V, V_o = V_{ref} to 28V & 4 & A & 4 \\ \hline lom & Maximum Operating Load Current & V_1 = 9V to 36V, V_o = V_{ref} to 28V & 4.5 & 8 & A & 4 \\ \hline lom & Maximum Operating Load Current & V_1 = 9V to 36V, V_o = V_{ref} to 28V & 4.5 & 8 & A & 4 \\ \hline lom & Load Current Limiting Threshold (Pin 2) & V_1 = 9V to 36V, V_0 = V_{ref} to 28V & 4.5 & 8 & A & 4 \\ \hline lom & Load Current & V_1 = 36V, Output Short-circuited & 80 & 1400 & mA & 4 \\ \hline lom & Efficiency & I_o = 3A & V_o = V_{ref} to 28V & 4.5 & 85 & A & 4 \\ \hline lom & Load Current & V_1 = 36V, Output Short-circuited & 80 & 1400 & mA & 4 \\ \hline lom & Load Current & V_1 = 3AV & V_0 = V_{ref} to 28V & 4.5 & 8 & A & 4 \\ \hline lom & Load Current & V_1 = 3AV & V_0 = V_{ref} to 28V & 4.5 & 8 & A & 4 \\ \hline lom & Load Current & V_1 = 3AV & V_0 = V_{ref} to 28V & 4.5 & 8 & A & 4 \\ \hline lom & Load Current & V_1 = 3AV & V_0 = V_{ref} to 28V & 4.5 & 8 & A & 4 \\ \hline lom & Load Current & V_1 = 3AV & V_0 = V_{ref} to 28V & 4.5 & 8 & A & 4 \\ \hline lom & Load Current & V_1 = 3AV & V_0 = V_{ref} to 28V & 4.5 & 8 & A & 4 \\ \hline lom & Load Current & V_1 = 3AV & V_2 = V_1 & A & A & A & A & A & A & A & A & A & $				4.95		5.25		4
$ \begin{array}{ c c c c c } & \text{and Pin 3} & l_0 = 2A & l_1 & l_2 & l_2 & l_3 & l_4 \\ l_{2L} & \text{Current Limiting Threshold (Pin 2)} & V_1 = 9V \text{ to } 36V, V_0 = V_{\text{ref}} \text{ to } 28V & l_4 & l_5 & l_4 & l_4 \\ l_{2H} & \text{Input Average Current} & V_1 = 36V, \text{Output Short-circuited} & l_6 & l_6 & l_6 & l_6 \\ \hline \eta & \text{Efficiency} & l_0 = 3A & V_0 = V_{\text{ref}} & 75 & \% & 4 \\ \hline SVR & \text{Supply Voltage Ripple Rejection} & \Delta V_1 = 2V_{\text{Ins., fingle}} = 100\text{Hz} & 46 & 56 & - & dB & 4 \\ \hline f & \text{Switching Frequency} & \Delta V_1 = 2V_{\text{Ins., fingle}} = 100\text{Hz} & 46 & 56 & - & dB & 4 \\ \hline f & \text{Switching Frequency} & V_1 = 9V \text{ to } 36V & V_2 = V_{\text{ref. lo}} & 2A & 4 & 4 & 4 \\ \hline \frac{\Delta f}{\Delta V_1} & \text{Voltage Stability of Switching} & V_2 = 9V \text{ to } 36V & 0.5 & 60 & \text{kHz} & 4 \\ \hline \frac{\Delta f}{\Delta V_1} & \text{Temperature Stability of Switching} & V_2 = 9V \text{ to } 36V & 125^{\circ}C & 1 & \% & 4 \\ \hline \frac{\Delta f}{\Delta V_1} & \text{Temperature Stability of Switching} & V_2 = V_{\text{ref. lo}} = 1A & 120 & \text{kHz} & - \\ \hline T_{\text{red}} & \text{Thermal Shutdown Junction} & 135 & 145 & °C & - \\ \hline DC CHARACTERISTICS & & & & 66 & 100 \\ \hline 13Q & Quiescent Drain Current & V_2 = 36V, V_7 = 0V, S1 : B, S2 : B & 66 & 100 \\ V_2 = 3V & & & & & & 66 & 100 \\ V_3 = 3V & & & & & & & & 66 \\ \hline 15_{\text{S0}} & \text{Source Current} & V_3 = 36V, V_5 = 3V & 80 & 130 & 180 & \muA & 60 \\ \hline 15_{\text{S0}} & \text{Source Current} & V_6 = 0V, V_5 = 3V & 80 & 130 & 180 & \muA & 60 \\ \hline 15_{\text{S1}} & \text{Sink Current} & V_6 = 3V, V_5 = 3V & 80 & 130 & 180 & \muA & 60 \\ \hline 10_{\text{H}} & \text{High Input Voltage} & V_1 = 9V \text{ to } 36V, V_7 = 0V & 0.3 & 0.8 & V & 6a \\ \hline V_{\text{CH}} & \text{High Input Voltage} & V_1 = 9V \text{ to } 36V, V_7 = 0V & 0.3 & 0.8 & V & 6a \\ \hline V_{\text{S1}} & \text{High Level} & V_{\text{C0}} = 2V \text{ to } 36V, V_7 = 0V \\ \hline S1 : B, S2 : B & 2 & 5.5 & V & 6a \\ \hline V_{\text{S1}} & \text{High Level} & V_{\text{C0}} = 5.3V, V_{\text{C0}} = 100\mu\text{A}, S1 : A, \\ \hline V_{\text{S1}} & \text{High Level} & V_{\text{C0}} = 5.3V, V_{\text{C0}} = 100\mu\text{A}, S1 : A, \\ \hline V_{\text{S2}} & \text{Sink Output Voltage} & V_{\text{C0}} = 5.3V, V_{\text{C0}} = 100\mu\text{A}, S1 : A, \\ \hline V_{\text{C0}} & Sink Output Cu$			$T_j = 0^{\circ}C$ to 125°C, $I_0 = 2A$		0.4		mV/°C	
$ \begin{array}{ c c c c } \hline I_{2L} & Current Limiting Threshold (Pin 2) & V_i = 9V to 36V, V_o = V_{ref} to 28V & 4.5 & 8 & A & 4 \\ \hline I_{SH} & Input Average Current & V_i = 36V, Output Short-circuited & 80 & 140 & mA & 4 \\ \hline \eta & Efficiency & I_o = 3A & V_o = V_{ref} & 7.5 & 9.4 & 4 \\ \hline SVR & Supply Voltage Ripple Rejection & V_0 = 2V_{ref}, I_o = 12V & 85 & 9.4 & 4 \\ \hline SVR & Supply Voltage Ripple Rejection & V_o = V_{ref}, I_o = 2A & 40 & 50 & 60 & kHz & 4 \\ \hline f & Switching Frequency & 40 & 50 & 60 & kHz & 4 \\ \hline \frac{\Delta f}{\Delta V_i} & Voltage Stability of Switching & V_i = 9V to 36V & 0.5 & 9.5 & 9.4 \\ \hline \frac{\Delta f}{\Delta V_i} & Temperature Stability of Switching & V_i = 9V to 36V & 0.5 & 9.5 & 9.4 \\ \hline f_{max} & Maximum Operating Switching & V_o = V_{ref}, I_o = 1A & 120 & kHz & - \\ \hline T_{sd} & Thermal Shutdown Junction & 135 & 145 & °C & - \\ \hline DC CHARACTERISTICS & V_i = 36V, V_7 = 0V, S1 : B, S2 : B & 66 & 100 \\ \hline I_{3Q} & Quiescent Drain Current & V_i = 36V, V_7 = 0V, S1 : B, S2 : B \\ \hline V_0 = 0V & V_0 = 3V & 9.0 & 66 & 100 \\ \hline V_0 = 3V & 9.0 & 9.0 & 9.0 & 9.0 & 9.0 \\ \hline I_{5so} & Source Current & V_i = 36V, V_5 = 3V & 80 & 130 & 180 & \muA & 6b \\ \hline I_{5so} & Source Current & V_6 = 0V, V_5 = 3V & 80 & 130 & 180 & \muA & 6b \\ \hline I_{5so} & Source Current & V_6 = 0V, V_5 = 3V & 80 & 130 & 180 & \muA & 6b \\ \hline V_{6H} & High Input Voltage & V_1 = 9V to 36V, V_7 = 0V & 1.5 & 5.5 & V & 6a \\ \hline V_{6H} & High Input Voltage & V_1 = 9V to 36V, V_7 = 0V & 1.5 & 5.5 & V & 6a \\ \hline I_{10H} & Love Level & V_0 = 2V to 36V, V_7 = 0V & 1.5 & 5.5 & V & 6a \\ \hline V_{9H} & High Level & V_0 = 4.7V, I_0 = 100\mu A, S1 : A, & 3.4 & V & 6c \\ \hline V_{9H} & High Level Output Voltage & V_{10} = 4.7V, I_0 = 100\mu A, S1 : A, & 3.4 & V & 6c \\ \hline V_{9L} & Low Level Output Voltage & V_{10} = 5.3V, V_5 = 100\mu A, S1 : A, & 0.6 & V & 6c \\ \hline V_{9L} & Low Level Output Voltage & V_{10} = 5.3V, S1 : A, S2 : B & 100 & 150 & \muA & 6c \\ \hline V_{9L} & Low Level Output Voltage & V_{10} = 5.3V, S1 : A, S2 : B & 100 & 150 & \muA & 6c \\ \hline V_{9L} & Low Level Output Voltage & V_{10} = 5.3V, S1 : A, S2 : B & 100 &$	V <sub>d</sub>		I <sub>o</sub> = 2A					
$ \begin{array}{ c c c c c } \hline I_{SH} & Input Average Current & V_i = 36V, Output Short-circuited \\ \hline \eta & Efficiency & I_0 = 3A & V_0 = V_{ret} \\ \hline V_0 = 12V & 85 & 96 & 4 \\ \hline SVR & Supply Voltage Ripple Rejection & \Delta V_1 = 2V_{rms}, fripple = 100Hz & 46 & 56 & - & dB & 4 \\ \hline SVR & Supply Voltage Ripple Rejection & \Delta V_1 = 2V_{rms}, fripple = 100Hz & 46 & 56 & - & dB & 4 \\ \hline f & Switching Frequency & 40 & 50 & 60 & kHz & 4 \\ \hline \frac{\Delta f}{\Delta V_1} & Voltage Stability of Switching & V_1 = 9V to 36V & 0.5 & 96 & 4 \\ \hline \frac{\Delta f}{\Delta T_1} & Temperature Stability of Switching & T_1 = 0^{\circ}C to 125^{\circ}C & 1 & 96 & 4 \\ \hline f_{max} & Maximum Operating Switching & V_0 = V_{ret}, I_0 = 1A & 120 & kHz & - \\ \hline T_{requency} & T_{sd} & Thermal Shutdown Junction & 135 & 145 & ^{\circ}C & - \\ \hline DC CHARACTERISTICS & & & 66 & 100 & mA & 6a \\ \hline I_{2Q} & Quiescent Drain Current & V_1 = 36V, V_7 = 0V, S1 : B, S2 : B & 66 & 100 & 30 & 50 \\ \hline I_{2Q} & Quiescent Drain Current & V_1 = 36V, V_6 = 3 V, V_7 = 0V & 2 & mA & 6a \\ \hline SOFT START & & & & & & & & & & & & & & & & & & &$	lom	-					Α	
$\begin{array}{ c c c c }\hline \eta & Efficiency & I_0 = 3A & V_0 = V_{ref} \\ \hline SVR & Supply Voltage Ripple Rejection \\ \hline SVR & Supply Voltage Ripple Rejection \\ \hline AV_1 = 2V_{rms}, f_{ripple} = 100Hz \\ \hline V_0 = V_{ref}, I_0 = 2A \\ \hline F & Switching Frequency \\ \hline AV_1 & Voltage Stability of Switching \\ \hline Frequency \\ \hline AV_2 & Voltage Stability of Switching \\ \hline AV_3 & Voltage Stability of Switching \\ \hline AV_4 & Voltage Stability of Switching \\ \hline AV_5 & Voltage Stability of Switching \\ \hline AV_6 & Voltage Stability of Switching \\ \hline AV_7 & Voltage Stability of Switching Avoltage Stability of Switching Avolta$				4.5		8		
$ \begin{array}{ c c c c c c } \hline & V_0 = 12V & 85 & 96 & 4 \\ \hline SVR & Supply Voltage Ripple Rejection & \Delta V_1 = 2V_{rms}, f_{ripple} = 100Hz & 46 & 56 & - & dB & 4 \\ \hline f & Switching Frequency & 40 & 50 & 60 & kHz & 4 \\ \hline \Delta f & Voltage Stability of Switching & V_1 = 9V to 36V & 0.5 & 96 & 4 \\ \hline \Delta f & Voltage Stability of Switching & V_1 = 9V to 36V & 0.5 & 96 & 4 \\ \hline \Delta f & Temperature Stability of Switching & T_2 = 0^{\circ}C to 125^{\circ}C & 1 & 96 & 4 \\ \hline A f & Temperature Stability of Switching & V_2 = V_{ref}, I_2 = 1A & 120 & kHz & - \\ \hline f_{max} & Maximum Operating Switching & V_2 = V_{ref}, I_2 = 1A & 120 & kHz & - \\ \hline T_{sd} & Thermal Shutdown Junction & 135 & 145 & 9^{\circ}C & - \\ \hline DC CHARACTERISTICS & & & & & & & & & & & & & & & & & & &$	I <sub>SH</sub>					140		-
$ \begin{array}{ c c c c c } \hline SVR & Supply Voltage Ripple Rejection & \Delta V_1 = 2V_{rms}, f_{ripple} = 100Hz & 46 & 56 & - & dB & 4 \\ \hline f & Switching Frequency & V_0 = V_{ref}, I_0 = 2A & 40 & 50 & 60 & kHz & 4 \\ \hline \Delta f & Voltage Stability of Switching & V_1 = 9V to 36V & 0.5 & 0.5 & 0.5 & 0.5 \\ \hline \Delta f & Temperature Stability of Switching & T_1 = 0^{\circ}C to 125^{\circ}C & 1 & 0.5 & 0.5 & 0.5 \\ \hline \Delta f & Temperature Stability of Switching & T_1 = 0^{\circ}C to 125^{\circ}C & 1 & 0.5 & 0.5 & 0.5 \\ \hline f_{max} & Maximum Operating Switching & V_0 = V_{ref}, I_0 = 1A & 120 & 0.5 & 0.5 & 0.5 \\ \hline f_{max} & Thermal Shutdown Junction & 135 & 145 & 0.6 & 0.5 & 0.5 & 0.5 \\ \hline T_{sd} & Thermal Shutdown Junction & 135 & 145 & 0.6 & 0.5 & 0.5 & 0.5 \\ \hline DC CHARACTERISTICS & & & & & & & & & & & & & & & & & & &$	η	Efficiency						
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	SVR	Supply Voltage Ripple Rejection	$\Delta V_I = 2V_{rms}$ , $f_{ripple} = 100Hz$	46		_		<del>                                     </del>
$\begin{array}{ c c c c c }\hline \Delta V_i & Frequency \\ \Delta f_{\overline{\Delta T_j}} & Temperature Stability of Switching Frequency \\ \hline f_{max} & Maximum Operating Switching Frequency \\ \hline T_{sd} & Thermal Shutdown Junction Temperature \\ \hline DC CHARACTERISTICS \\ \hline I_{3Q} & Quiescent Drain Current & V_i = 36V, V_7 = 0V, S1 : B, S2 : B & 66 & 100 & MA & 6a \\ \hline V_6 = 0V & V_6 = 3V & 0.30 & 50 & 0.50 & 0.50 \\ \hline I_{12L} & Output Leakage Current & V_i = 36V, V_7 = 0V & 1.8, S2 : B & 66 & 100 & MA & 6a \\ \hline SOFT START & & & & & & & & & & & & & & & & & & &$	f	Switching Frequency	307	40	50	60	kHz	4
$\begin{array}{ c c c c c } \hline \Delta f \\ \overline{\Delta T_{j}} & \text{Temperature Stability of Switching} \\ \hline Frequency & frequency & V_{0} = V_{ref}, I_{0} = 1A & 120 & kHz \\ \hline f_{max} & \text{Maximum Operating Switching} \\ \hline Frequency & V_{0} = V_{ref}, I_{0} = 1A & 120 & kHz \\ \hline T_{sd} & \text{Thermal Shutdown Junction} \\ \hline T_{emperature} & V_{0} = V_{ref}, I_{0} = 1A & 120 & kHz \\ \hline T_{sd} & \text{Thermal Shutdown Junction} \\ \hline DC CHARACTERISTICS & & 66 & 100 \\ \hline I_{3Q} & \text{Quiescent Drain Current} & V_{i} = 36V, V_{7} = 0V, S1 : B, S2 : B \\ \hline V_{6} = 0V \\ \hline V_{6} = 3V & 2 & mA & 6a \\ \hline S1 : B, S2 : A & & 2 & mA & 6a \\ \hline SOFT START & & & & & & & & & & & & & & & & & & &$			$V_i = 9V \text{ to } 36V$		0.5		%	4
$ \begin{array}{ c c c c c } \hline Frequency \\ \hline T_{sd} & Thermal Shutdown Junction \\ \hline Temperature \\ \hline \\ DC CHARACTERISTICS \\ \hline \\ I_{3Q} & Quiescent Drain Current \\ \hline \\ & V_6 = 0V \\ & V_6 = 3V \\ & V_6 = 3V \\ & V_7 = 0V, S1:B, S2:B \\ & V_6 = 0V \\ & V_6 = 3V, V_7 = 0V \\ \hline \\ S1:B, S2:A \\ \hline \\ SOFT START \\ \hline \\ \hline \\ & I_{5S0} & Source Current \\ \hline \\ & I_{5S0} & Source Current \\ \hline \\ & V_6 = 3V, V_5 = 3V \\ \hline \\ & V_6 = 3V, V_5 = 3V \\ \hline \\ & V_6 = 3V, V_7 = 0V \\ \hline \\ & I_{5S0} & Source Current \\ \hline \\ & I_{5S0} & Source Current \\ \hline \\ & V_6 = 3V, V_5 = 3V \\ \hline \\ & V_6 = 3V, V_5 = 3V \\ \hline \\ & V_6 = 3V, V_7 = 0V \\ \hline \\ & I_{5S1} & Sink Current \\ \hline \\ & V_{6} = 3V, V_5 = 3V \\ \hline \\ & V_{6} = 3V, V_7 = 0V \\ \hline \\ & I_{10} & I_{10} & I_{10} & I_{10} \\ \hline \\ & I_{10} & I_{10} & I_{10} & I_{10} \\ \hline \\ & I_{10} & I_{10} & I_{10} & I_{10} \\ \hline \\ & I_{10} & I_{10} & I_{10} & I_{10} \\ \hline \\ & I_{10} & I_{10} & I_{10} \\ \hline \\ & I_{10} & I_{10} & I_{10} \\ \hline \\ & I_{10} & I_{10} & I_{10} \\ \hline \\ & I_{10} & I_{10} & I_{10} \\ \hline \\ & I_{10} & I_{10} & I_{10} \\ \hline \\ & I_{10} & I_{10} & I_{10} \\ \hline \\ & I_{10} & I_{10} & I_{10} \\ \hline \\ & I_{10$			$T_j = 0$ °C to 125°C		1		%	4
	f <sub>max</sub>	Maximum Operating Switching Frequency	$V_0 = V_{ref}$ , $I_0 = 1A$	120			kHz	-
$ \begin{array}{ c c c c c } \hline I_{3Q} & Quiescent Drain Current & V_{i} = 36V, V_{7} = 0V, S1:B, S2:B & 66 & 100 & mA & 6a \\ \hline V_{6} = 0V & V_{6} = 3V & V_{7} = 0V & 2 & mA & 6a \\ \hline I_{2L} & Output Leakage Current & V_{i} = 36V, V_{6} = 3 & V, V_{7} = 0V & 2 & mA & 6a \\ \hline SOFT START & & & & & & & & & & & & & & & & & & &$	T <sub>sd</sub>			135	145		°C	_
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	DC CHAR	ACTERISTICS						
$ \begin{array}{ c c c c c c } \hline -I_{2L} & Output \ Leakage \ Current & V_i = 36V, \ V_6 = 3 \ V, \ V_7 = 0V \\ S1: B, S2: A & & & & & & & & & & & & & & & & & & $	I <sub>3Q</sub>	Quiescent Drain Current	$V_6 = 0V$				mA	6a
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	-I <sub>2L</sub>	Output Leakage Current	$V_i = 36V, V_6 = 3 V, V_7 = 0V$		- 00		mA	6a
$ \begin{array}{ c c c c c } \hline I_{5si} & Sink Current & V_6 = 3V,  V_5 = 3V & 40 & 70 & 140 & \mu A & 6b \\ \hline \hline & INHIBIT & & & & & & & & & & & & & & & & & & &$	SOFT STA	ART						
$ \begin{array}{ c c c c c } \hline I_{5si} & Sink Current & V_6 = 3V,  V_5 = 3V & 40 & 70 & 140 & \mu A & 6b \\ \hline \hline & INHIBIT & & & & & & & & & & & & & & & & & & &$	I <sub>5so</sub>	Source Current	$V_6 = 0V, V_5 = 3V$	80	130	180	μA	6b
$ \begin{array}{ c c c c c c } \hline V_{6L} & Low \ Input \ Voltage \\ \hline V_{6H} & High \ Input \ Voltage \\ \hline V_{6H} & High \ Input \ Voltage \\ \hline -I_{6H} & Input \ Current \ with \ Input \ Voltage \\ \hline -I_{6H} & Low \ Level \\ \hline -I_{6H} & High \ Level \\ \hline \end{array} \begin{array}{ c c c c } \hline V_{9H} & High \ Level \ Output \ Voltage \\ \hline \hline V_{9L} & Low \ Level \ Output \ Voltage \\ \hline \hline V_{9L} & Low \ Level \ Output \ Voltage \\ \hline \hline V_{9L} & Low \ Level \ Output \ Voltage \\ \hline \hline V_{10} = 5.3V, \ I_{9} = 100\mu A, \ S1:A, \ S2:B \\ \hline \hline V_{10} = 5.3V, \ S1:A, \ S2:B \\ \hline \hline V_{10} = 5.3V, \ S1:A, \ S2:B \\ \hline \hline \end{array} \begin{array}{ c c c c c c c c c c c c c c c c c c c$		Sink Current		40	70	140	<u>μ</u> Α	6b
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	INHIBIT							
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$	V <sub>6</sub> L	Low Input Voltage	$V_i = 9V \text{ to } 36V, V_7 = 0V$	- 0.3		0.8	V	6a
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$		' '		2		5.5	V	<b>.</b>
							μΑ	6a
ERROR AMPLIFIER			$V_6 = 0.8V$					
$ \begin{array}{ c c c c c c c c c c c c c c c c c c c$								
V <sub>9</sub> L         Low Level Output Voltage         V <sub>10</sub> = 5.3V, I <sub>9</sub> = 100μA, S1 : A, S2 : E         0.6         V         6c           I <sub>9 si</sub> Sink Output Current         V <sub>10</sub> = 5.3V, S1 : A, S2 : B         100         150         μA         6c				3.4			V	6c
$I_{9 si}$ Sink Output Current $V_{10} = 5.3V$ , S1 : A, S2 : B 100 150 μA 6c	V <sub>9</sub> L	Low Level Output Voltage	$V_{10} = 5.3V$ , $I_9 = 100\mu A$ , $S1:A$ ,			0.6	V	6c
	I <sub>9 si</sub>	Sink Output Current		100	150		μА	6c
in the property of the control of th	-l <sub>9 so</sub>	Source Output Current	V <sub>10</sub> = 4.7V, S1 : A, S2 : D	100	150		<u>.</u> μΑ	6c

# **ELECTRICAL CHARACTERISTICS** (continued)

(refer to the test circuits  $T_j = 25^{\circ}C$ ,  $V_i = 25V$ , unless otherwise specified)

Symbol	Parameter	Test Conditions	Min.	Тур.	Max.	Unit	Fig.
ERROR A	MPLIFIER (continued)						
I <sub>10</sub>	Input Bias Current	V <sub>10</sub> = 5.2V, S1 : B		2	20	μΑ	6c
Gv	DC Open Loop Gain	$V_9 = 1V \text{ to } 3V, S1 : A, S2 : C$	40	55		dB	6c
OSCILLAT	OR AND PWM COMPARA	TOR					
-l <sub>7</sub>	Input Bias Current of PWM Comparator	$V_7 = 0.5V$ to 3.5V			10	μΑ	6a
-l <sub>11</sub>	Oscillator Source Current	V <sub>11</sub> = 2V, S1 : A, S2 : B	4		-	mΑ	6a
RESET							
V <sub>12R</sub>	Rising Threshold Voltage	V <sub>i</sub> = 9 V to 36 V, S1 : B, S2 : B	V <sub>ref</sub> - 150mV	V <sub>ref</sub> - 100mV	V <sub>ref</sub> - 50mV	V	6d
V <sub>12F</sub>	Falling Threshold Voltage	V <sub>1</sub> = 9 V 10 30 V, 31 . B, 32 . B	4.75	V <sub>ref</sub> - 150mV	V <sub>ref</sub> - 100mV	V	6d
V <sub>13D</sub>	Delay Threshold Voltage		4.3	4.5	4.7	V	6d
V <sub>13H</sub>	Delay Threshold Voltage Hysteresis	V <sub>12</sub> = 5.3 V, S1 : A, S2 : B		100		mV	6d
V <sub>14S</sub>	Output Saturation Volt.	$I_{14} = 5mA, V_{12} = 4.7V - S1, S2 : B$			0.4	V	6d
I <sub>12</sub>	Input Bias Current	$V_{12} = 0V \text{ to } V_{ref}, \text{ S1} : B, \text{ S2} : B$		1	10	μΑ	6d
-I <sub>13 so</sub>	Delay Source Current Delay Sink Current	$V_{13} = 3V$ , S1 : A, S2 : B $V_{12} = 5.3V$ $V_{12} = 4.7V$	60 8	110	150	μA mA	6d
I <sub>14</sub>	Output Leakage Current	$V_i = 36V, V_{12} = 5.3V, S1 : B, S2 : A$		100		μΑ	6d

Figure 4: Dynamic Test Circuit



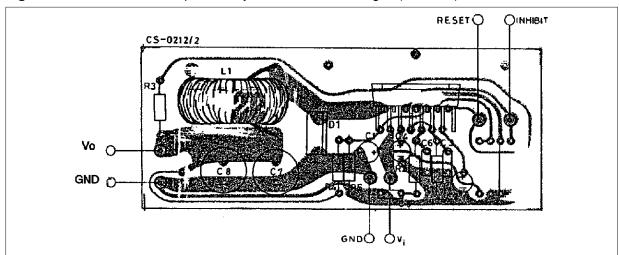


Figure 5: PC. Board and Component Layout of the Circuit of Fig. 4 (1:1 scale)

Figure 6 : DC Test Circuits.

Figure 6a.

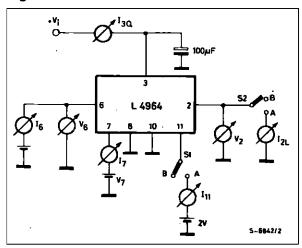


Figure 6b.

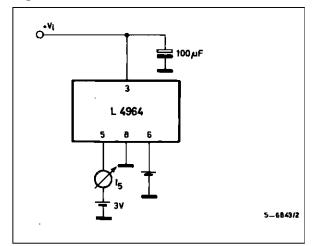


Figure 6c.

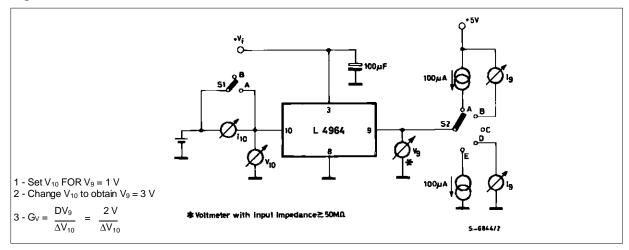


Figure 6d.

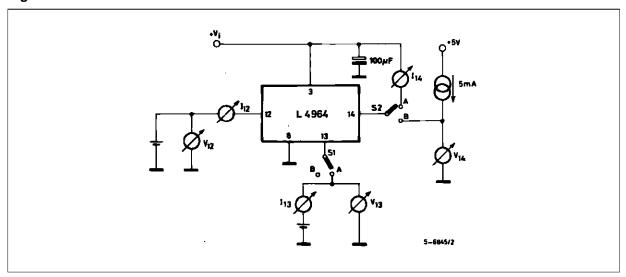


Figure 7: Switching Frequency vs. R1 (see fig. 4).

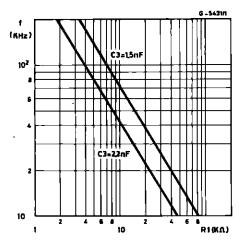


Figure 9: Reference Voltage (pin 10) vs. Junction Temperature (see fig. 4).

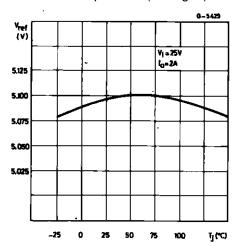
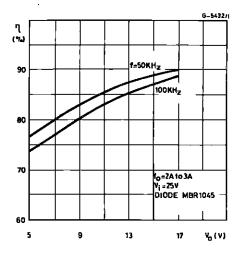
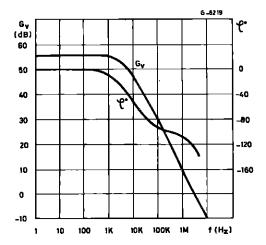


Figure 11: Efficiency vs. Output Voltage.



**Figure 8 :** Open Loop Frequency and Phase Response of Error Amplifier (see fig. 6c).



**Figure 10 :** Power Dissipation (L4964 only) vs. Input Voltage.

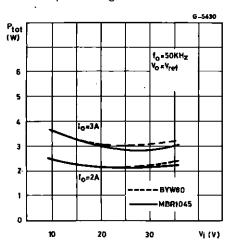
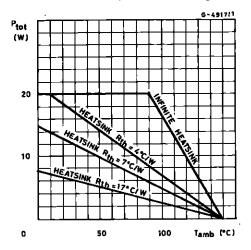


Figure 12: Power Dissipation Derrating Curve.



#### **APPLICATION INFORMATION**

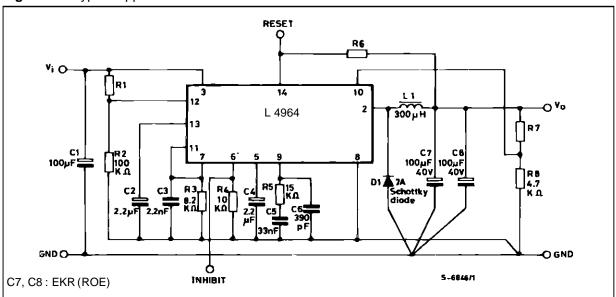
CHOOSING THE INDUCTOR AND CAPACITOR The input and output capacitors of the L4964 must have a low ESR and low inductance at high current ripple.

Preferably, the inductor should be a toroidal type or wound on a Moly-Permalloy nucleus. Saturation must not occur at current levels below 1.5 times the current limiter level. MPP nuclei have very soft saturation characteristics.

$$L = \frac{(V_i - V_o) \ V_0}{V_i \ f \ \Delta I_L}, \ C = \frac{(V_i - V_o) \ V_0}{8L \ f^2 \ \Delta V_o}$$

 $\Delta I_L$  = Inductance current ripple  $\Delta V_0$  = Output ripple voltage

Figure 13: Typical Application Circuit.

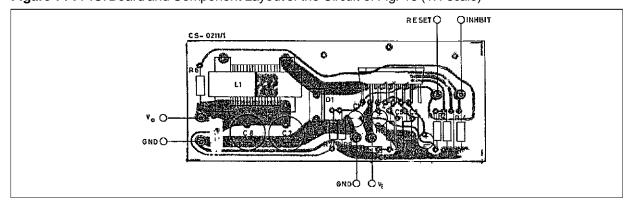


# **SUGGESTED INDUCTOR (L1)**

Core Type	No Turns	Wire Gauge (mmm)	Air Gap (mm)		
Magnetics 58930 - A2MPP	43	1.0	_		
Thomson GUP 20 x 16 x 7	50	0.8	0.7		
Siemens EC 35/17/10 (B6633& - G0500 - X127)	40	2 x 0.8	_		
VOGT 250 μH Toroidal Coil, Part Number 5730501800					

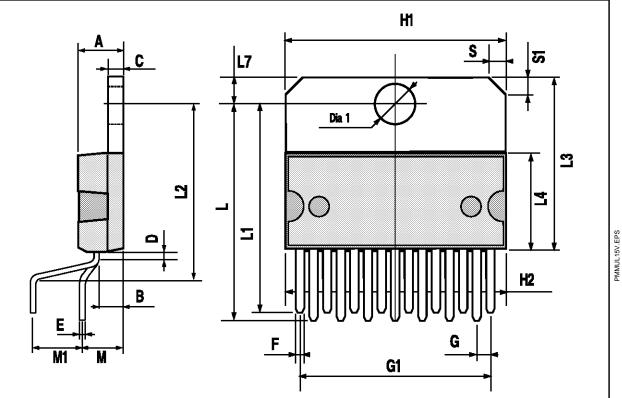
Resistor Values for Standard Output Voltages						
V <sub>0</sub>	R8	R7				
12 V 15 V 18 V	4.7 kΩ 4.7 kΩ 4.7 kΩ	6.2 kΩ 9.1 kΩ 12 kΩ				

Figure 14: P.C. Board and Component Layout of the Circuit of Fig. 13 (1:1 scale)



# **MULTIWATT15 (Vertical) PACKAGE MECHANICAL DATA**

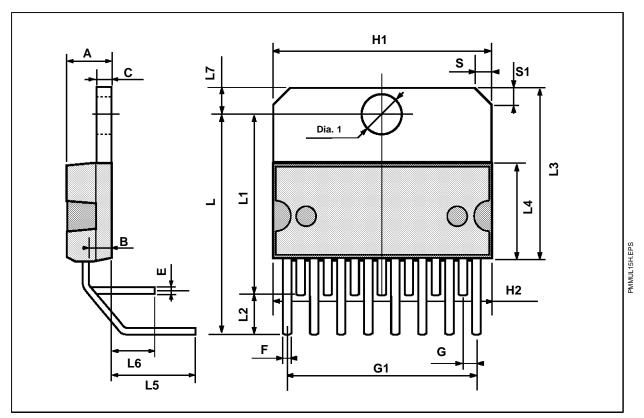
Dimensions	Millimeters			Inches			
mensions	Min.	Тур.	Max.	Min.	Тур.	Max.	
Α			5			0.197	
В			2.65			0.104	
С			1.6			0.063	
D		1			0.039		
E	0.49		0.55	0.019		0.022	
F	0.66		0.75	0.026		0.030	
G	1.14	1.27	1.4	0.045	0.050	0.055	
G1	17.57	17.78	17.91	0.692	0.700	0.705	
H1	19.6			0.772			
H2			20.2			0.795	
L	22.1		22.6	0.870		0.890	
L1	22		22.5	0.866		0.886	
L2	17.65		18.1	0.695		0.713	
L3	17.25	17.5	17.75	0.679	0.689	0.699	
L4	10.3	10.7	10.9	0.406	0.421	0.429	
L7	2.65		2.9	0.104		0.114	
М	4.2	4.3	4.6	0.165	0.169	0.181	
M1	4.5	5.08	5.3	0.177	0.200	0.209	
S	1.9		2.6	0.075		0.102	
S1	1.9		2.6	0.075		0.102	
Dia. 1	3.65		3.85	0.144		0.152	



11/13

# **MULTIWATT15 (Horizontal) PACKAGE MECHANICAL DATA**

Dimensions		Millimeters Inches			Inches		
Dimensions	Min.	Тур.	Max.	Min.	Тур.	Max.	
Α			5			0.197	
В			2.65			0.104	
С			1.6			0.063	
E	0.49		0.55	0.019		0.022	
F	0.66		0.75	0.026		0.030	
G	1.14	1.27	1.4	0.045	0.050	0.055	
G1	17.57	17.78	17.91	0.692	0.700	0.705	
H1	19.6			0.772			
H2			20.2			0.795	
L		20.57			0.810		
L1		18.03			0.710		
L2		2.54			0.100		
L3	17.25	17.5	17.75	0.679	0.689	0.699	
L4	10.3	10.7	10.9	0.406	0.421	0.429	
L5		5.28			0.208		
L6		2.38			0.094		
L7	2.65		2.9	0.104		0.114	
S	1.9		2.6	0.075		0.102	
S1	1.9		2.6	0.075		0.102	
Dia. 1	3.65		3.85	0.144		0.152	



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