LINEAR INTEGRATED CIRCUITS

HIGH CURRENT SWITCHING REGULATOR

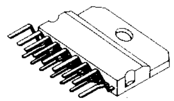
- 4A OUTPUT CURRENT
- 5.1V TO 40V OUTPUT VOLTAGE RANGE
- 0 TO 100% DUTY CYCLE RANGE
- PRECISE (± 2%) ON-CHIP REFERENCE
- SWITCHING FREQUENCY UP TO 200 KHz
- VERY HIGH EFFICIENCY (UP TO 90%)
- VERY FEW EXTERNAL COMPONENTS
- SOFT START
- RESET OUTPUT
- CONTROL CIRCUIT FOR CROWBAR SCR
- INPUT FOR REMOTE INHIBIT AND SYNCHRONUS PWM
- THERMAL SHUTDOWN

The L296 is a stepdown power switching regulator delivering 4A at a voltage variable from 5.1V to 40V.

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

The L296 is mounted in a 15-lead Multiwatt® plastic power package and requires very few external components.

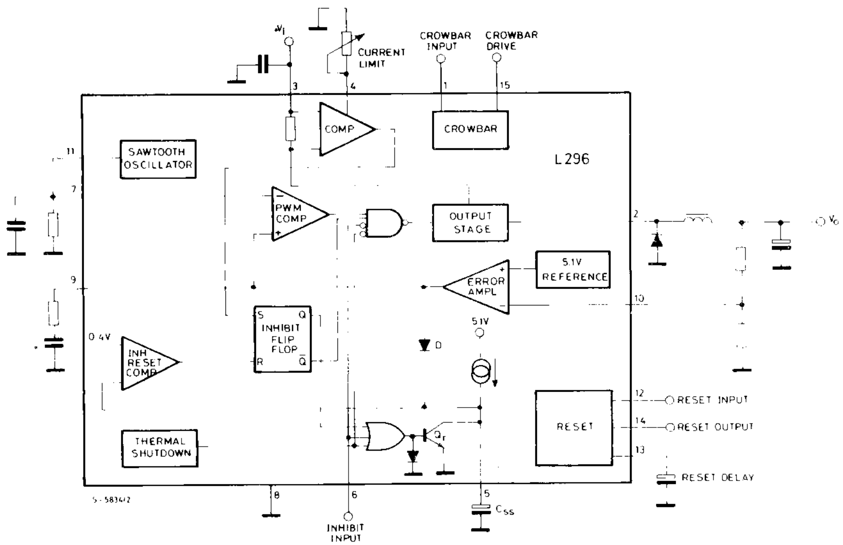
Efficient operation at switching frequencies up to 200kHz allows a reduction in the size and cost of external filter components. A voltage sense input and SCR drive output are provided for optional crowbar overvoltage protection with an external SCR.



Multiwatt®
(15-lead)

ORDERING NUMBER: L296

BLOCK DIAGRAM



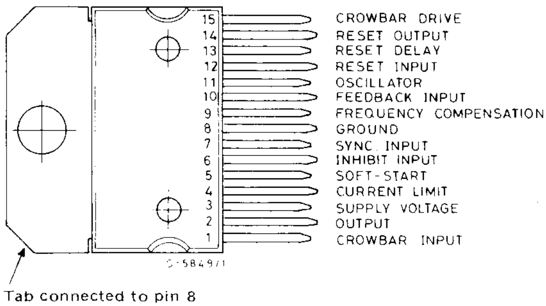
ABSOLUTE MAXIMUM RATINGS

V_i	Input voltage (pin 3)	50	V
$V_i - V_2$	Input to output voltage difference	50	V
V_2	Output DC voltage	-1	V
	Output peak voltage at t = 0.1 µsec f = 200 kHz	-7	V
V_1, V_{12}	Voltage at pins 1, 12	10	V
V_6, V_{15}	Voltage at pins 6, and 15	15	V
V_4, V_5, V_7, V_9	Voltage at pins 4, 5, 7 and 9	5.5	V
V_{10}, V_6	Voltage at pins 10 and 6	7	V
V_{14}	Voltage at pin 14 ($I_{14} \leq 1$ mA)	V_i	
I_9	Pin 9 sink current	1	mA
I_{11}	Pin 11 source current	20	mA
I_{14}	Pin 14 sink current ($V_{14} < 5V$)	50	mA
P_{tot}	Power dissipation at $T_{case} \leq 90\ °C$	20	W
T_j, T_{stg}	Junction and storage temperature	-40 to 150	°C

THERMAL DATA

$R_{th\ j\text{-}case}$	Thermal resistance junction-case	max	3	°C/W
$R_{th\ j\text{-}amb}$	Thermal resistance junction-ambient	max	35	°C/W

CONNECTION DIAGRAM
(top view)



PIN FUNCTIONS

N°	NAME	FUNCTION
1	CROWBAR INPUT	Voltage sense input for crowbar overvoltage protection. Normally connected to the feedback input thus triggering the SCR when V_{out} exceeds nominal by 20%. May also monitor the input and a voltage divider can be added to increase the threshold. Connected to ground when SCR not used.
2	OUTPUT	Regulator output.
3	SUPPLY VOLTAGE	Unregulated voltage input. An internal regulator powers the L296's internal logic.
4	CURRENT LIMIT	A resistor connected between this terminal and ground sets the current limiter threshold. If this terminal is left unconnected the threshold is internally set (see electrical charateristics).
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 L296.
7	SYNC INPUT	Multiple L296s 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 5.1V operation; it is connected via a divider for higher voltages.
11	OSCILLATOR	A parallel RC network connected to this terminal determines the switching frequency. This pin must be connected to pin 7 input when the internal oscillator is used.

PIN FUNCTIONS (continued)

N°	NAME	FUNCTION
12	RESET INPUT	Input of the reset circuit. The threshold is roughly 5V. It may be connected to the feedback 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	CROWBAR OUTPUT	SCR gate drive output of the crowbar circuit.

CIRCUIT OPERATION (refer to the block diagram)

The L296 is a monolithic stepdown switching regulator providing output voltages from 5.1V to 40V 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 5.1V on-chip reference (zener zap trimmed to ± 2%). 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 adjusted by an external RC network connected to pin 9. Closing the loop directly gives an output voltage of 5.1V. 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 0.4V. The output stage is thus re-enabled and the output voltage rises under control of the soft start network. If the overload condition is still present the limiter will trigger again when the threshold 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.

The crowbar circuit senses the output voltage and the crowbar output can provide a current of 100 mA to switch on an external SCR. This SCR is triggered when the output voltage exceeds the nominal by 20%. There is no internal connection between the output and crowbar sense input therefore the crowbar can monitor either the input or the output.

A TTL - level inhibit input is provided for applications such as remote on/off control. This input is activated by high logic level and disables circuit operation. After an inhibit the L296 restarts under control of the soft start network.

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

CIRCUIT OPERATION (continued)

Fig. 1 - Reset output waveforms

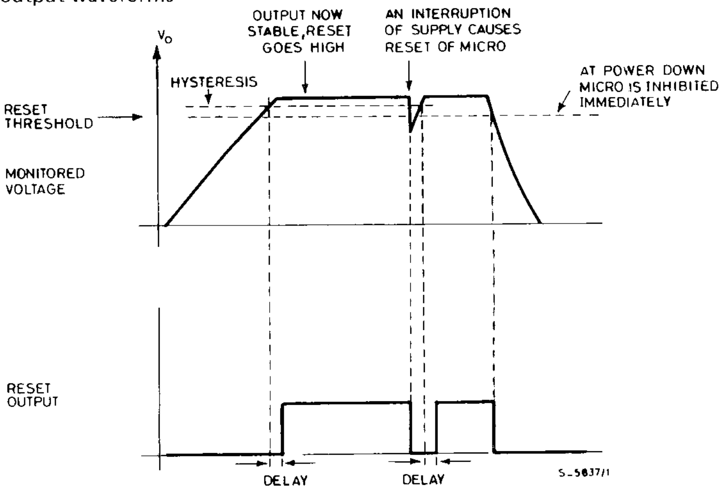


Fig. 2 - Soft start waveforms

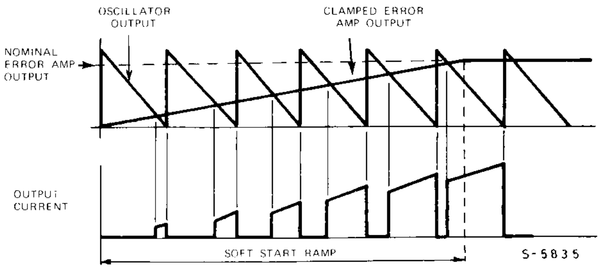
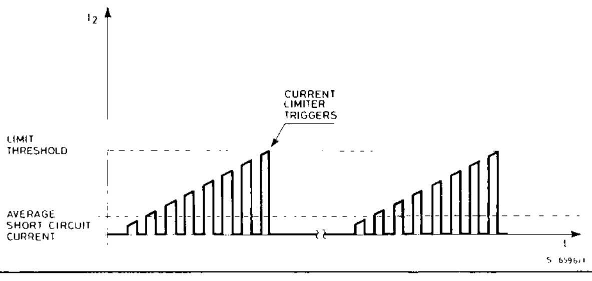


Fig. 3 - Current limiter waveforms



ELECTRICAL CHARACTERISTICS (Refer to the test circuits T_j = 25°C, V_i = 35V, unless otherwise specified)

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit	Fig.
DYNAMIC CHARACTERISTICS (pin 6 to GND unless otherwise specified)								
V_o	Output voltage range	V_i = 46V	I_o = 1A	V_{ref}		40	V	4
V_i	Input voltage range	$V_o = V_{ref}$ to 36V	I_o = 4A	9		46	V	4
ΔV_o	Line regulation	V_i=10V to 40V, $V_o = V_{ref}$, Io = 2A			15	50	mV	4
ΔV_o	Load regulation	$V_o = V_{ref}$	I_o = 2A to 4A		10	30	mV	4
			I_o=0,5A to 4A		15	45	mV	4
V_{ref}	Internal reference voltage (pin 10)	V_i = 9V to 46V I_o = 2A		5	5.1	5.2	V	4
$\frac{\Delta V_{ref}}{\Delta T}$	Average temperature coefficient of reference voltage	T_j = 0°C to 125°C	I_o = 2A		0.4		mV/°C	
V_d	Dropout voltage between pin 2 and pin 3	I_o = 4A			2	3.2	V	4
		I_o = 2A			1.3	2.1	V	4
Io_m	Maximum operating load current	V_i = 9V to 46V,	$V_o = V_{ref}$ to 36 V	4			A	4
I_{2L}	Current limiting threshold (pin 2)	V_i = 9V to 46V $V_o = V_{ref}$ to 40V	Pin 4 open			8	A	4
			R_{lim} = 33 kΩ		2.5		A	4
I_{SH}	Input average current	V_i = 46V; Output short-circuited			60	100	mA	4
η	Efficiency	I_o = 3A	$V_o = V_{ref}$		75		%	4
			V_o = 12V		85		%	4
SVR	Supply voltage ripple rejection	$\Delta V_I = 2\ V_{rms}$ $V_o = V_{ref}$	f_{ripple} = 100 Hz I_o = 2A	50	56		dB	4
f	Switching frequency			85	100	115	kHz	4
$\frac{\Delta f}{\Delta V_i}$	Voltage stability of switching frequency	V_i = 9V to 46V			0.5		%	4
$\frac{\Delta f}{\Delta T_j}$	Temperature stability of switching frequency	T_j = 0°C to 125°C			1		%	4
f_{max}	Maximum operating switching frequency	$V_o = V_{ref}$ I_o = 1A		200			kHz	–
T_{sd}	Thermal shutdown junction temperature			135	145		°C	–
DC CHARACTERISTICS								
I_{3Q}	Quiescent drain current	V_i = 46V V_7= 0V S1:B S2:B	V_6 = 0V		66	85	mA	6a
			V_6 = 3V		30	40	mA	6a
$-I_{2L}$	Output leakage current	V_i = 46V,V6=3V,S1:B,S2:A,V7=0V				2	mA	6a

Fig. 6 – DC test circuits

Fig. 6a

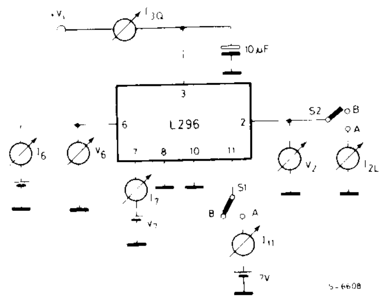


Fig. 6b

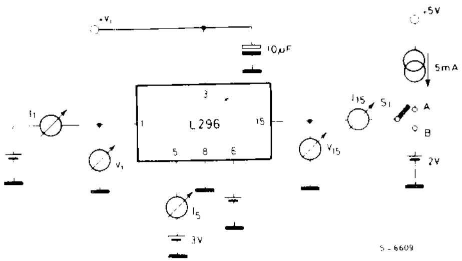
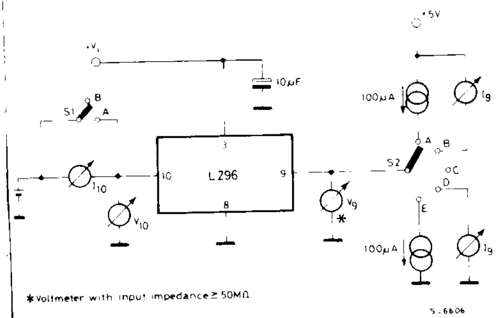


Fig. 6c



*Voltmeter with input impedance ≥ 50MΩ

1 - Set V_{10} for V_9 = 1V

2 - Change V_{10} to obtain V_9 = 3V

3 - $G_v = \frac{\Delta V_9}{\Delta V_{10}} = \frac{2V}{\Delta V_{10}}$

Fig. 6d

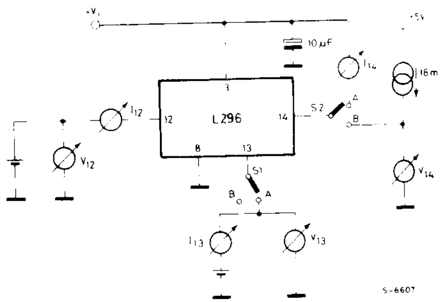


Fig. 7 - Quiescent drain current vs. supply voltage (0% duty cycle - see fig. 6a)

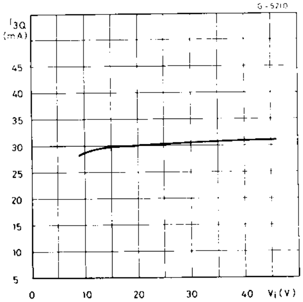


Fig. 8 - Quiescent drain current vs. supply voltage (100% duty cycle see fig. 6a)

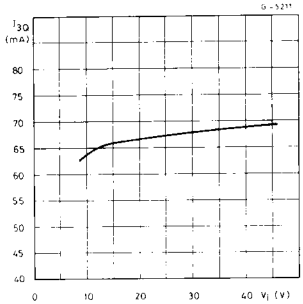


Fig. 9 - Quiescent drain current vs. junction temperature (0% duty cycle - see fig. 6a)

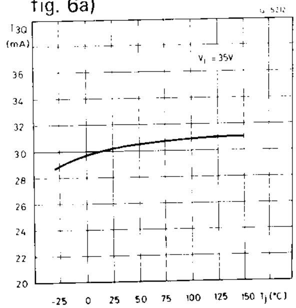


Fig. 10 - Quiescent drain current vs. junction temperature (100% duty cycle - see fig. 6a)

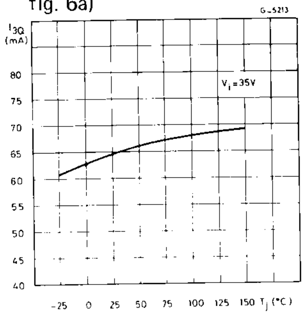


Fig. 11 - Reference voltage (pin 10) vs. V_i (see fig. 4)

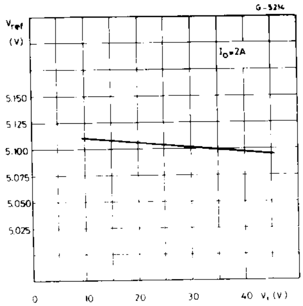


Fig. 12 - Reference voltage (pin 10) vs. junction temperature (see fig. 4)

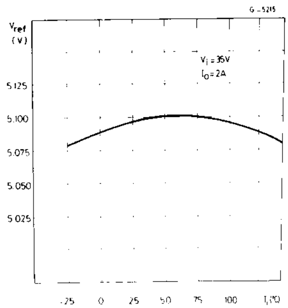


Fig. 13 - Open loop frequency and phase response of error amplifier (see fig. 6c)

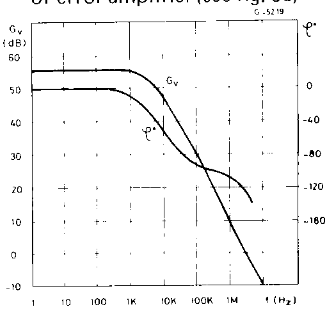


Fig. 14 - Switching frequency vs. input voltage (see fig. 4)

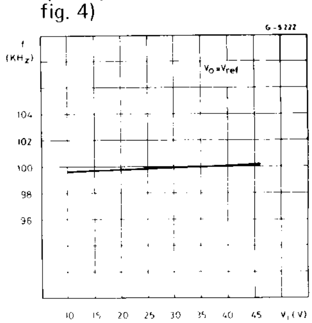


Fig. 15 - Switching frequency vs. junction temperature (see fig. 4)

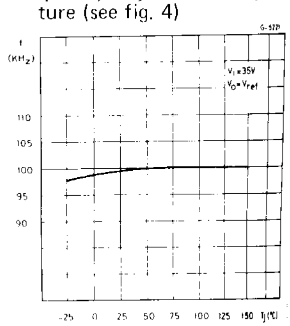


Fig. 16 - Switching frequency vs. R1 (see fig. 4)

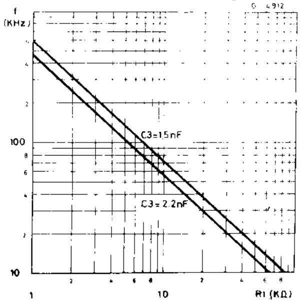


Fig. 17 - Line transient response (see fig. 4)

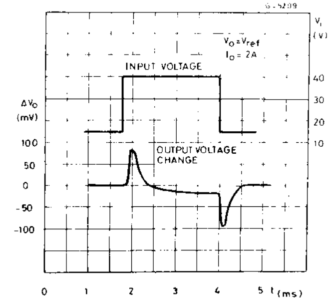


Fig. 18 - Load transient response (see fig. 4)

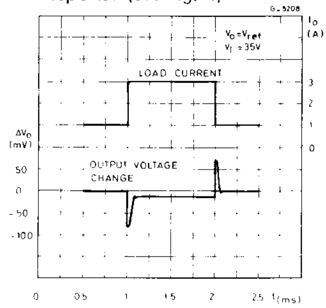


Fig. 19 - Supply voltage ripple rejection vs. frequency (see fig. 4)

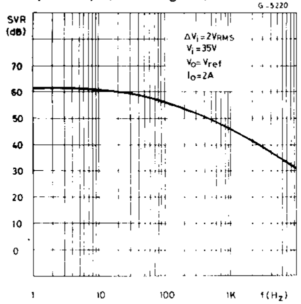


Fig. 20 - Dropout voltage between pin 3 and pin 2 vs. current at pin 2

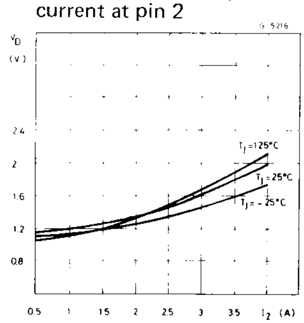


Fig. 21 - Dropout voltage between pin 3 and pin 2 vs. junction temperature

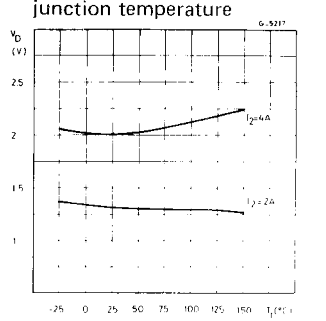


Fig. 22 - Power dissipation derating curve

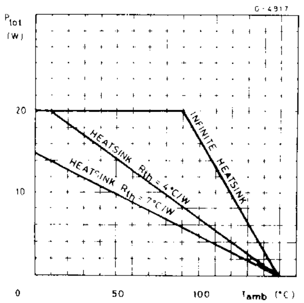


Fig. 23 - Power dissipation (L296 only) vs. input voltage

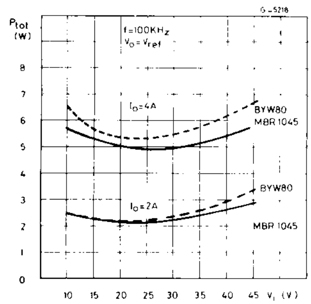


Fig. 24 - Power dissipation (L296 only) vs. input voltage

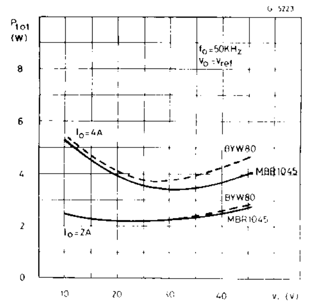


Fig. 25 - Power dissipation (L296 only) vs. output voltage (see fig. 4)

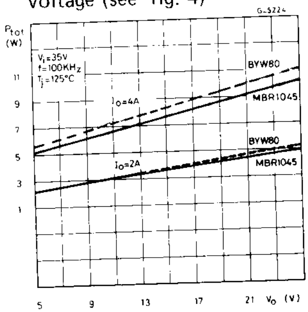


Fig. 26 - Power dissipation (L296 only) vs. output voltage (see fig. 4)

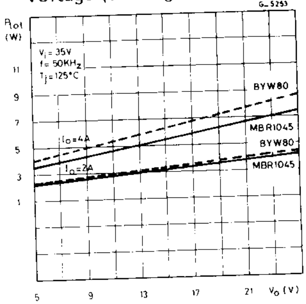


Fig. 27 - Voltage and current waveforms at pin 2 (see fig. 4)

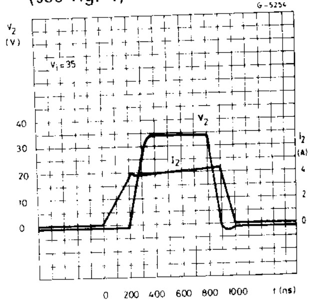


Fig. 28 - Efficiency vs. output current

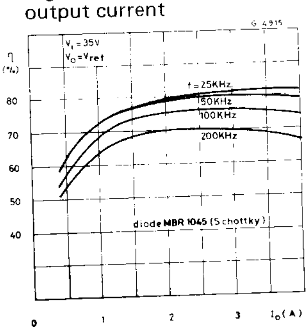


Fig. 29 - Efficiency vs. output current

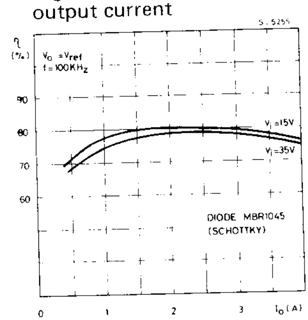
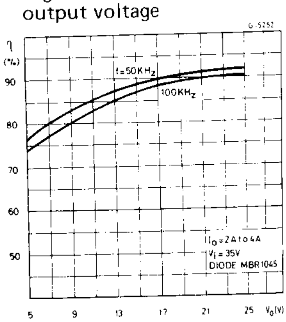


Fig. 30 - Efficiency vs. output voltage



APPLICATION INFORMATION

CHOOSING THE INDUCTOR AND CAPACITOR

The input and output capacitors of the L296 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.

$$L = \frac{(V_i - V_o)\, V_o}{V_i\, f\, \Delta I_L}$$

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

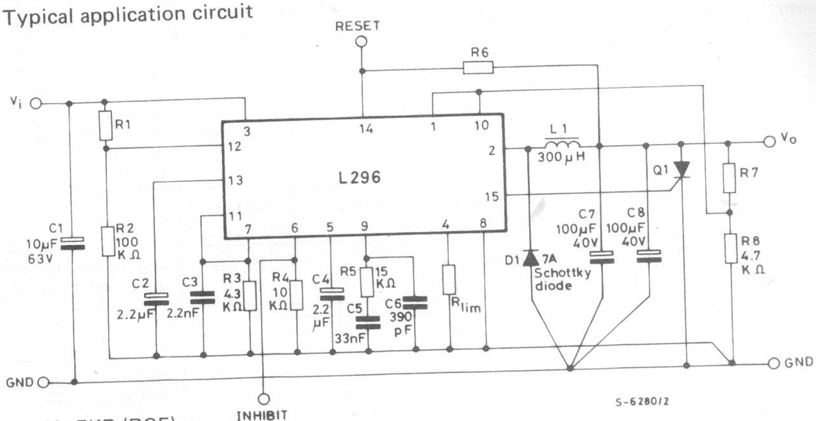
f = frequency

ΔI_L = Inductance current ripple

ΔV_O = Output ripple voltage

APPLICATION INFORMATION

Fig. 31 – Typical application circuit



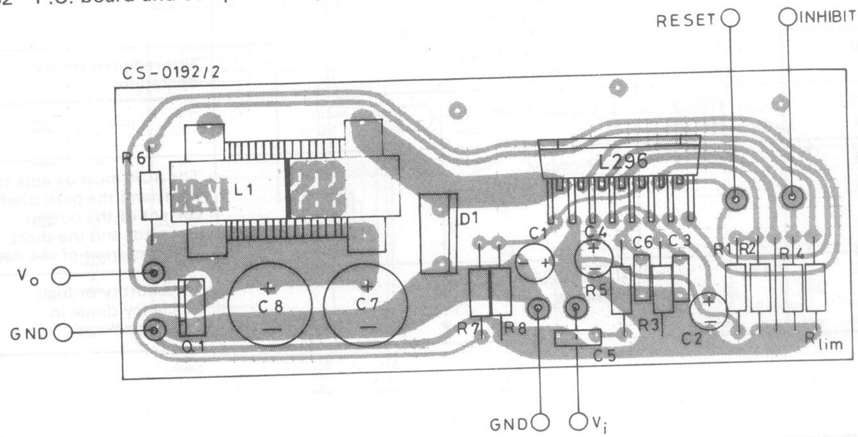
C7, C8: EKR (ROE)

SUGGESTED INDUCTOR (L1)

Core Type	No Turns	Wire Gauge	Air Gap
Magnetics 58930 – A2MPP	43	1.0 mm.	–
Thomson GUP 20x16x7	50	0.8 mm.	0.7 mm.
Siemens EC 35/17/10 (B6633& – G0500 – X127)	40	2 x 0.8 mm.	–
VOGT 250 µH Toroidal coil, part number 5730501800			

Resistor values for standard output voltages		
V_o	R8	R7
12V	4.7 kΩ	6.2 kΩ
15V	4.7 kΩ	9.1 kΩ
18V	4.7 kΩ	12 kΩ
24V	4.7 kΩ	18 kΩ

Fig. 32 – P.C. board and component layout of the circuit of fig. 31 (1 : 1 scale)



SELECTION OF COMPONENT VALUES (See fig. 31)

Component	Recommended Value	Purpose	Allowed rage Min	Allowed rage Max	NOTES
R1 R2	– 100 kΩ	Set input voltage threshold for reset.	–	220 kΩ	$R1/R2 = \frac{V_{i\,min}}{5} - 1$ If output voltage is sensed R1 and R2 may be limited and pin 12 connected to pin 10.
R3	4.3 kΩ	Sets switching frequency	1 kΩ	100 kΩ	
R4	10 kΩ	Pull-down resistor		22 kΩ	May be omitted and pin 6 grounded if inhibit not used.
R5	15 kΩ	Frequency compensation	10 kΩ		
R6		Collector load for reset output	$\frac{V_o}{0.05A}$		Omitted if reset function not used.
R7 R8	– 4.7 kΩ	Divider to set output voltage	– –	– 10 kΩ	$R7/R8 = \frac{V_o - V_{ref}}{V_{ref}}$
R_{lim}	–	Sets current limit level			If R_{lim} is omitted and pin 4 left open the current limit is internally fixed.
C1	10 µF	Stability	1 µF		
C2	2.2 µF	Sets reset delay	–	–	Omitted if reset function not used.
C3	2.2 nF	Sets switching frequency	1 nF	3.3 nF	
C4	2.2 µF	Soft start	1 µF	–	Also determines average short circuit current.
C5	33 nF	Frequency compensation			
C6	390 pF	High frequency compensation	–	–	Not required for 5V operation
C7,C8 L1	100 µF 300 µH	Output filter			
Q1		Crowbar protection			The SCR must be able to withstand the peak discharge current of the output capacitor and the short circuit current of the device.
D1		Recirculation diode			7A schottky or high efficiency diode in D0220 package

APPLICATION INFORMATION (continued)

Fig. 33 - A minimal 5.1V fixed regulator. Very few components are required.

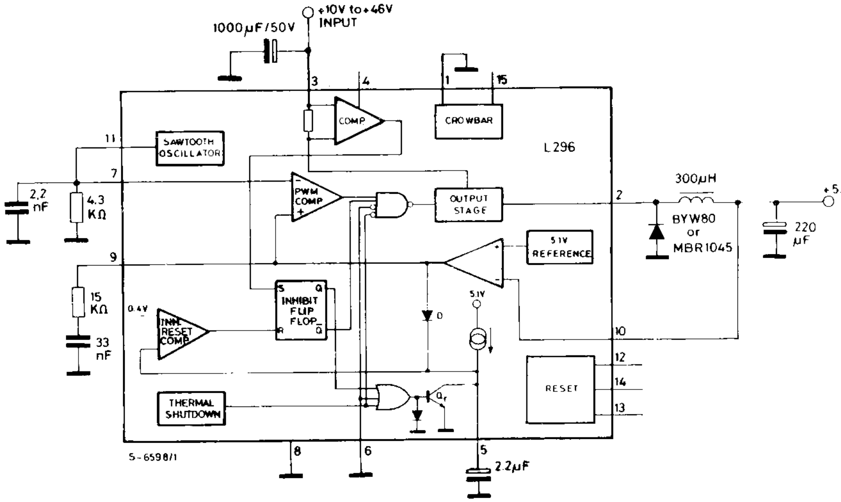
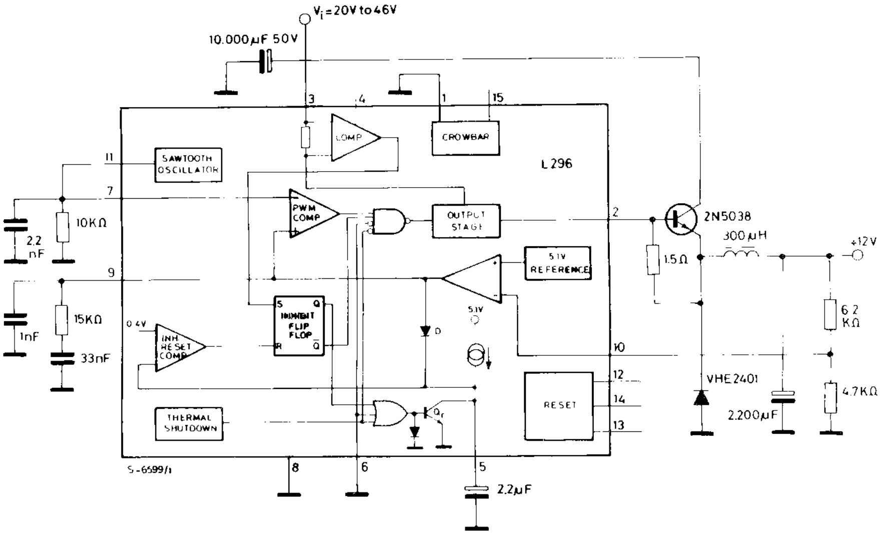
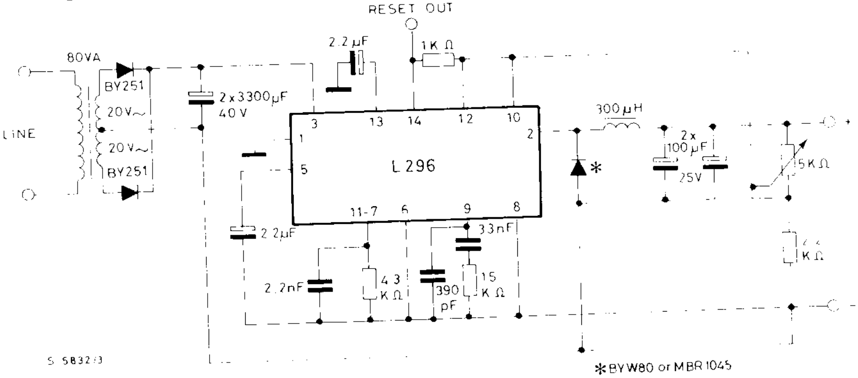


Fig. 34 - 12V/10A Power supply



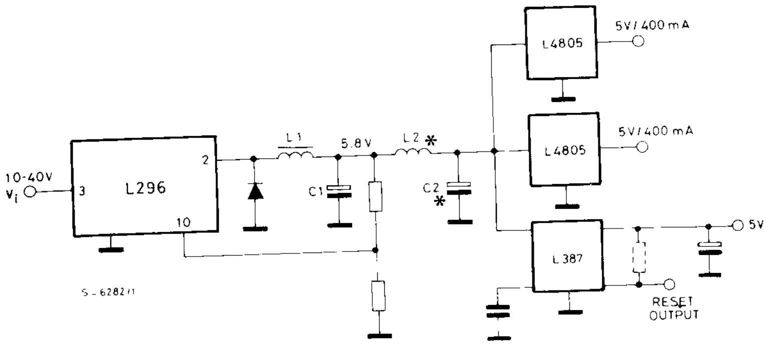
APPLICATION INFORMATION (continued)

Fig. 35 - Programmable power supply



V_o = 5.1 to 15V
I_o = 4A max. (min. load current = 100 mA)
ripple ≤ 20 mV
load regulation (1A to 4A) = 10 mV (V_o = 5.1V)
line regulation (220V ± 15% and to I_o = 3A) = 15 mV (V_o = 5.1V)

Fig. 36 - Preregulator for distributed supplies.



(*) L2 and C2 are necessary to reduce the switching frequency spikes.

APPLICATION INFORMATION (continued)

Fig. 37 – In multiple supplies several L296s can be synchronized as shown.

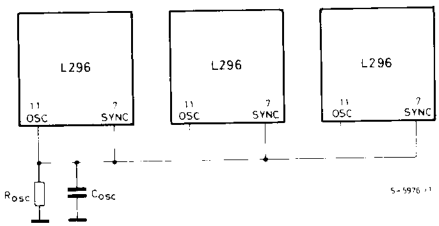


Fig. 38 – Voltage sensing for remote load

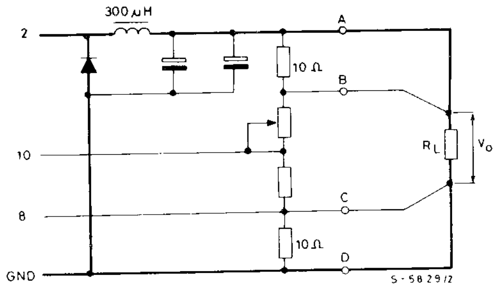
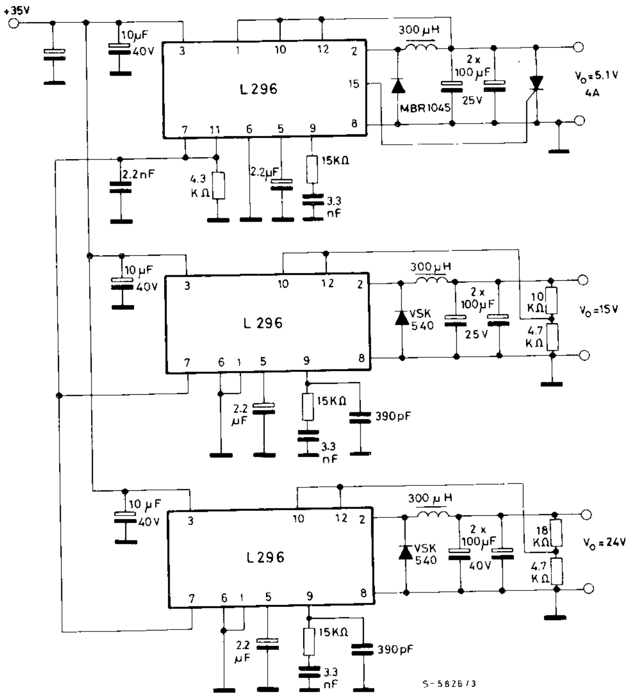


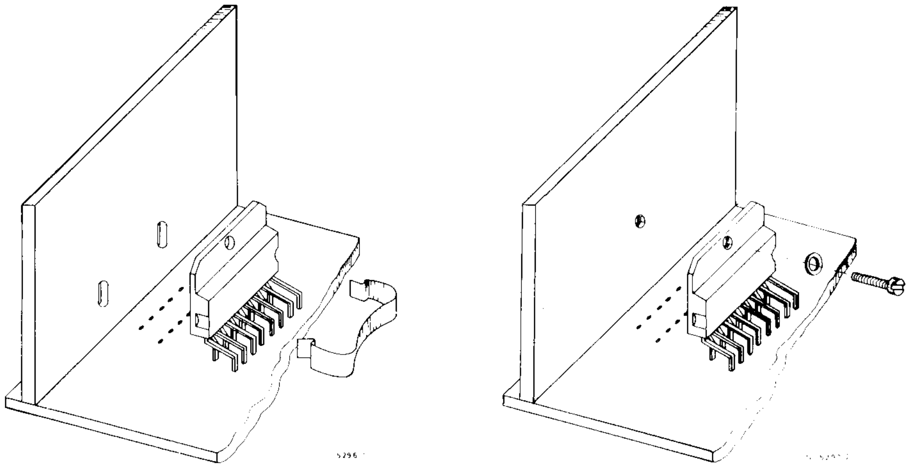
Fig. 39 – A 5.1V/15V/24V multiple supply. Note the synchronization of the three L296s.



MOUNTING INSTRUCTIONS

The power dissipated in the circuit must be removed by adding an external heatsink.
Thanks to the Multiwatt® package attaching the heatsink is very simple, a screw or a compression spring (clip) being sufficient. Between the heatsink and the package it is better to insert a layer of silicon grease, to optimize the thermal contact; no electrical isolation is needed between the two surfaces.

Fig. 40 - Mounting example



MECHANICAL DATA (Dimensions in mm)