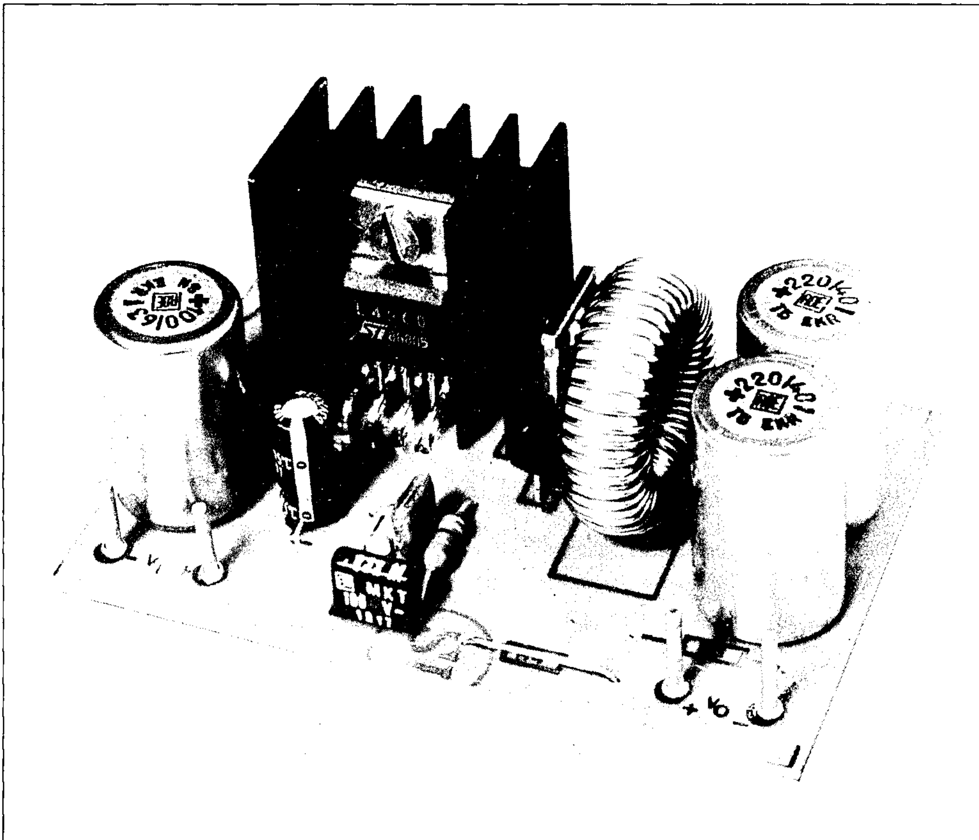
SGS-THOMSON MICROELECTRONICS

APPLICATION NOTE

DESIGNING MULTIPLE-OUTPUT POWER SUPPLIES WITH THE L296 AND L4960

Multiple output supplies can be realized simply and economically using the SGS THOMSON Microelectronics L296 and L4960 high power switching regulators. This note describes several practical circuits of this type.



Most of the switching regulators produced today have multiple outputs. The output voltages most frequently used - at least for powers up to 50W - are + 5V – 5V, + 12V and – 12V. In these supplies the 5 V output is normally the output which delivers the highest current and requires the highest precision. For the other voltages - particularly the negative outputs - less precision (± 5 % ± 7 %) is usually sufficient. Often, however, for high current 12V outputs better stabilization and greater precision (typically ± 4 % - the output tolerance of an L7800 series linear regulator) are required.

Multiple output supplies which satisfy these requirements can be realized using the SGS THOMSON L296 and L4960 high power switching regulator ICs, Several practical supply designs are described below to illustrate how these components are used to build compact and inexpensive multi-output supplies.

DUAL OUTPUT 15W SUPPLY

V_{o1} = 5V/3A, V_{o2} = 12V/150mA

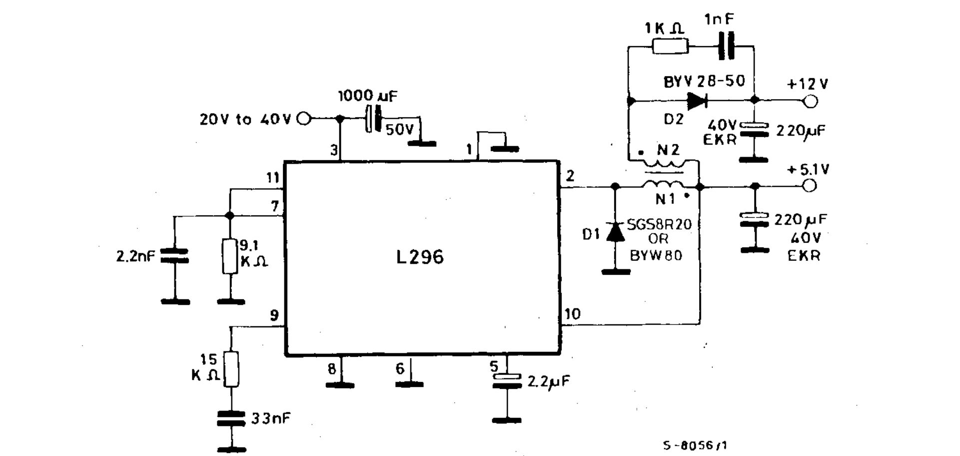
A single L296 is used in this application to produce two outputs. The application circuit, figure 1, illustrates how the second output (12V) is obtained by adding a second winding to the output inductor. Energy is transferred to the secondary during the recirculation period when the internal power device of the L296 is OFF.

Since the 12V output is not separated from the 5V output fewer turns are necessary for the second winding, therefore less copper is needed and load regulation is improved.

In applications of this type it is a good rule to ensure that the power drain on the auxiliary output is no more than 20-25% of the power delivered by the main output.

Table 1 shows the performance obtained with this dual output supply. This circuit operates at a switching frequency of 50KHz.

Figure 1 : Dual Output DC-DC Converter (5V/3A, 12V/150mA).



Transformer : magnetics 58930, N1 = 30 turns, N2 = 40 turns.

Table 1.

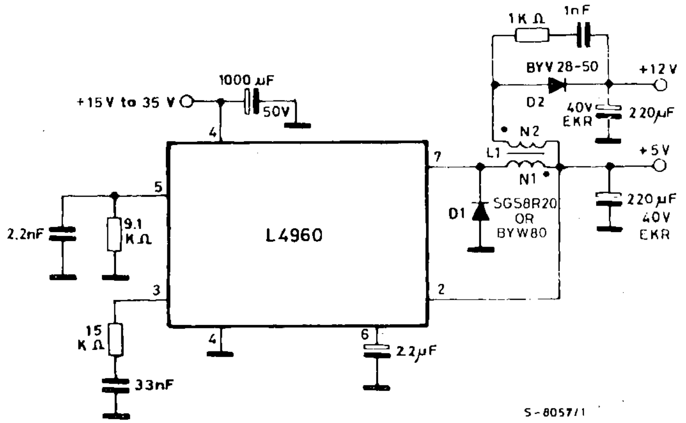
Parameter		V_{O1}	V_{O2}	Unit
Output Voltage I_{O1} = 3A	V_i = 30V I_{O2} = 150mA	5.120	12.089	V
Output Ripple		70	40	mV
Line Regulation I_{O1} = 3A	$20V \le V_i \le 40V$ I_{O2} = 150mA	15	30	mV
Line Regulation I_{O1} = 700mA	$20V \le V_i \le 40V$ I_{O2} = 100mA	15	10	mV
Load Regulation I_{O1} = 700mA → 3A	V_i = 30V I_{O2} = 150mA	10	130	mV
Load Regulation I_{O1} = 700mA	V_i = 30V I_{O2} = 100 → 150mA	0	40	mV
Load Regulation I_{O1} = 3A	V_i = 30V I_{O2} = 100 → 150mA	0	40	mV
Efficiency	V_i = 30V V_{O1} = 5.120V I_{O1} = 3A V_{O2} = 12.089V I_{O2} = 150mA	75		%

DUAL OUTPUT 7.5W SUPPLY

V_{o1} = 5V/1.5A, V_{o2} = 12V/100mA

The same technique - adding a secondary winding - can also be used to produce an economical and simple dual output supply with the L4960, a device containing the same control loop blocks as the L296 and a 2A output stage (fig. 2). Though this circuit costs very little the performance obtained (see table 2) is more than satisfactory. The switching frequency is 50kHz.

Figure 2 : Dual Output DC-DC Converter (5V/1.5A, 12V/100mA).



Transformer : magnetics 58206, N1 = 30 turns, N2 = 40 turns.

Table 2.

Parameter		V_{O1}	V_{O2}	Unit
Output Voltage I_{O1} = 1.5A	V_i = 25V I_{O2} = 100mA	5.050	12.010	V
Output Ripple		50	30	mV
Line Regulation I_{O1} = 1.5A	15V ≤ V_i ≤ 35V I_{O2} = 100mA	7	75	mV
Line Regulation I_{O1} = 500mA	15V ≤ V_i ≤ 35V I_{O2} = 50mA	7	60	mV
Load Regulation I_{O1} = 0.5A → 1.5A	V_i = 25V I_{O2} = 100mA	3	100	mV
Load Regulation I_{O1} = 500mA	V_i = 25V I_{O2} = 50mA → 100mA	0	55	mV
Load Regulation I_{O1} = 1.5A	V_i = 25V I_{O2} = 50mA → 100mA	0	50	mV
Efficiency	V_i = 25V V_{O1} = 1.5V V_{O2} = 100mA	78		%

TRIPLE OUTPUT 15W SUPPLY

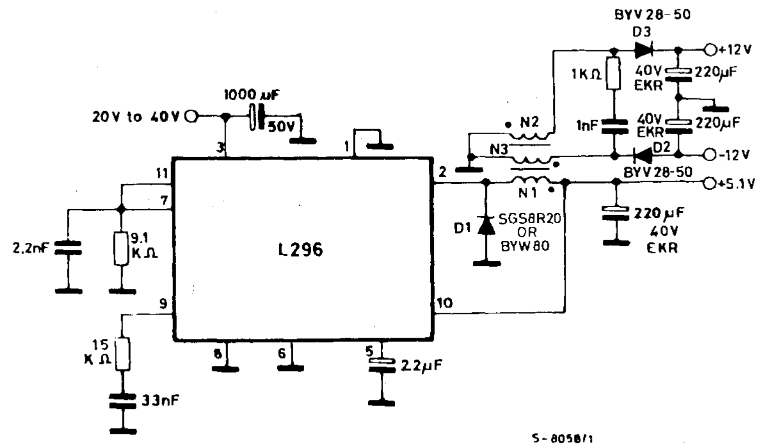
V_{o1} = 5V/3A, V_{o2} = 12V/100mA, V_{o3} = -12V/100mA

Figure 3 shows how to obtain two auxiliary outputs (± 12V) which are isolated from the 5V output. For this output power range an L296 is used.

To ensure good tracking of the 12V and - 12V outputs the secondary outputs in this application should be bifilar wound.

This circuit operates at 50KHz and gives the performance indicated in table 3.

Figure 3 : Triple Output DC-DC Converter (5V/3A, 12V/100mA).



Transformer : magnetics 58206, N1 = 30 turns, N2 = 40 turns.

Table 3.

Parameter		V_{O1}	V_{O2}	V_{O3}	Unit
Output Voltage I_{O1} = 3A	V_i = 30V I_{O2} = I_{O3} = 100mA	5.057	12.300	– 12.300	V
Output Ripple		80	30	30	mV
Line Regulation I_{O1} = 700 mA	20V ≤ V_i ≤ 40V I_{O2} = I_{O3} = 100mA	15	60	60	mV
Line Regulation I_{O1} = 3A	20V ≤ V_i ≤ 40V I_{O2} = I_{O3} = 100mA	18	100	100	mV
Load Regulation I_{O1} = 0.7A → 3A	V_i = 30V I_{O2} = I_{O3} =100mA	4	150	150	mV
Load Regulation I_{O1} = 3A	V_i = 30V I_{O2} = 100mA I_{O3} = 50 → 100mA	0	125	52	mV
Load Regulation I_{O1} = 3A I_{O2} = 50 → 100mA	V_i = 30V I_{O3} = 100mA	0	50	120	mV
Efficiency			76		%

TRIPLE OUTPUT 7.5W SUPPLY

V_{o1} = 5V/1.5A, V_{o2} = 12V/50mA, V_{o3} = – 12/50mA

For lower output powers, the L296 in the previous application may be replaced by an L4960 as shown in figure 4. The performance of this circuit is indicated in table 4.

Figure 4 : Triple Output DC-DC Converter (5V/1.5A, 12V/50mA, – 12V/50mA).

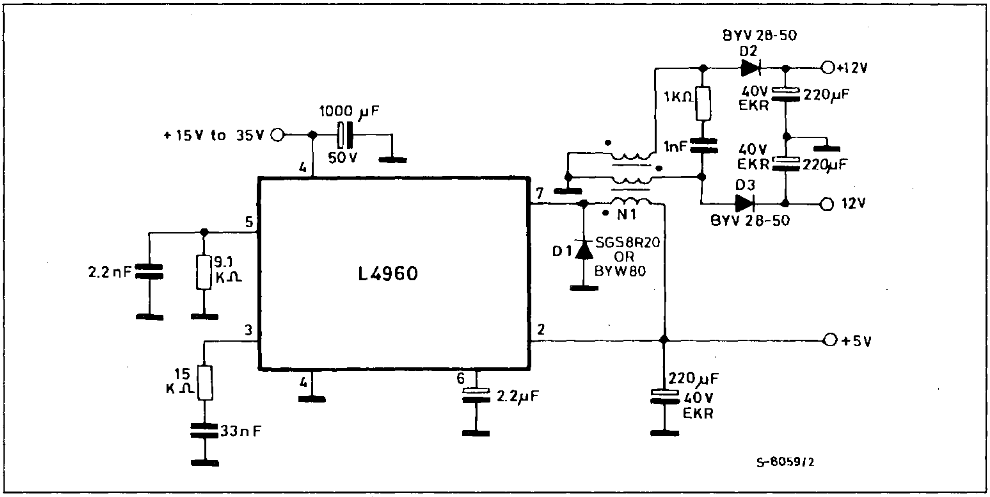


Table 4.

Parameter		V_{O1}	V_{O2}	V_{O3}	Unit
Output Voltage I_{O1} = 1.5A	V_i = 25V I_{O2} = I_{O3} = 50mA	5.040	12.020	– 12.020	V
Output Ripple		60	30	30	mV
Line Regulation I_{O1} = 500mA	15V ≤ V_i ≤ 35V I_{O2} = I_{O3} = 50mA	5	80	80	mV
Line Regulation I_{O1} = 1.5A	15V ≤ V_i ≤ 35V I_{O2} = I_{O3} = 50mA	4	60	60	mV
Load Regulation I_{O1} = 0.5A → 1.5A	V_i = 25V I_{O2} = I_{O3} = 50mA	5	120	120	mV
Load Regulation I_{O1} = 1.5A I_{O3} = 20 → 50mA	V_i = 25V I_{O2} = 50mA	0	15	50	mV
Load Regulation I_{O1} = 1.5A I_{O2} = 20 → 50mA	V_i = 25V I_{O3} = 100mA	0	50	15	mV
Efficiency			70		%

THE L296 AND L4960 HIGH POWER SWITCHING REGULATORS

The SGS THOMSON L296 is a monolithic stepdown switching regulator assembled in the 15-pin Multiwatt package. Operating with supply input voltages up to 46V it provides a regulated 4A output variable from 5.1V to 40V.

Internally the device is equipped with current limiter, soft start and reset (or power fail) functions, making it particularly suitable for supplying microprocessors and logic.

The precision of the L296's internal reference (± 2%) eliminates the need for external dividers or trinning to obtain a 5V output.

The synchronization pin allows synchronous operation of several devices at the same frequency to avoid generating undesirable beat frequencies.

The L4960 is a similar device assembled in the 7-lead Heptawatt package. Like the L296 it has a maximum input voltage of 46V and it provides a regulated output voltage variable from 5V to 40V with a maximum load current of 2.5A. Current limiting, soft start and thermal protection functions are included.

The thermal protection circuit in both the L296 and L4960 has a hysteresis of 30°C to allow soft restarting after a fault condition.

THE STEP DOWN CONFIGURATION

Figure 5 shows the basic structure of a step down switching regulator. The transistor Q is used as a switch and the ON and OFF times are determined by the control circuit.

When Q is saturated current flows from the supply, Vi, to the load through the inductor L. Neglecting the saturation voltage of Q, $V_e \cong V_i$.

When Q is OFF, current continues to flow in the inductor L, in the same direction, forcing the diode into conduction immediately therefore Ve is negative. In these conditions the load current flows through L and D.

The average value of the current in the inductor is equal to the load current. In the inductor a triangular current ripple equal to . ΔI_L is added to this average current.

During the time when Q is ON this ripple is :

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

and when Q is off it is :

$$\Delta I_L = \frac{V_o \cdot T_{OFF}}{L}$$

Equating these expression and assuming that the transistor and diode are ideal we obtain :

$$V_o = V_i \cdot \frac{T_{ON}}{T}$$

T_{ON} is the conduction time of the transistor

T is the oscillator period

The absolute average current in the supply is therefore :

$$I_{ioc} = I_o \cdot \frac{T_{ON}}{T}$$

Once the working frequency and desired ripple current have been fixed the value of the inductor L is given by :

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

and the value of the capacitor C required to give the desired output voltage ripple (Δ V) is :

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

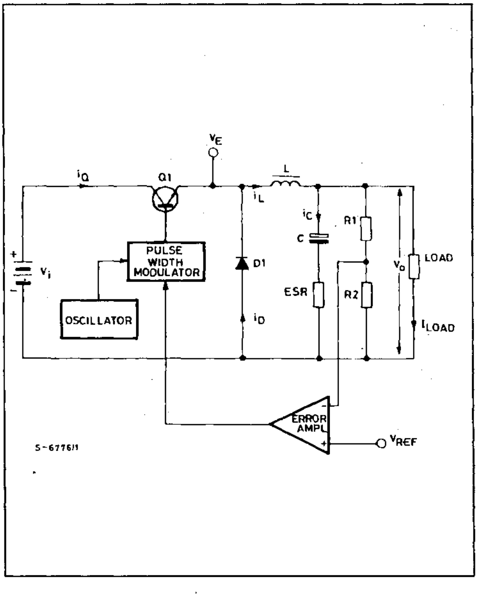
This capacitor must have a maximum ESR given by :

$$ESR_{MAX} = \frac{\Delta V_o}{\Delta I_L}$$

And, finally, the minimum load current, I_{OMIN}, must be :

$$I_{OMIN} = \frac{\Delta I_L}{2} = \frac{(V_i - V_o)\, V_o}{2\, V_i\, f_L}$$

Figure 5 : Basic STEP-DOWN Configuration.



30W DC-DC CONVERTER

Designing power supplies in the 30-40W range is becoming increasingly difficult because it is here that there is the greatest need to maintain performance levels and reduce costs. The application proposed here is very competitive because it exploits new ICs to reduce size, number of components and assembly costs.

This solution, the DC-DC converter, compares very favourable with off-line switching supplies in terms of cost. DC-DC converters can, in fact, be realized even by designers with little experience and allows the convenience of working with low voltages, Off-line switching supplies are only preferable when the weight and size of the mains transformer in a DC-DC converter would be excessive.

In this circuit, figure 6 two devices are used, an L296 and an L4960. The L296 is used, to supply a 5V output with a current of 3A and the auxiliary – 5V/100mA output and the L4960 is used to provide the 12V/1.5A output and the auxiliary – 12V/100mA output.

Figure 6 : Multioutput DC-DC Converter with L296 and L4960 (5V / 3A, 12V / 1.5A, –12V/100mA, –5V/100mA).

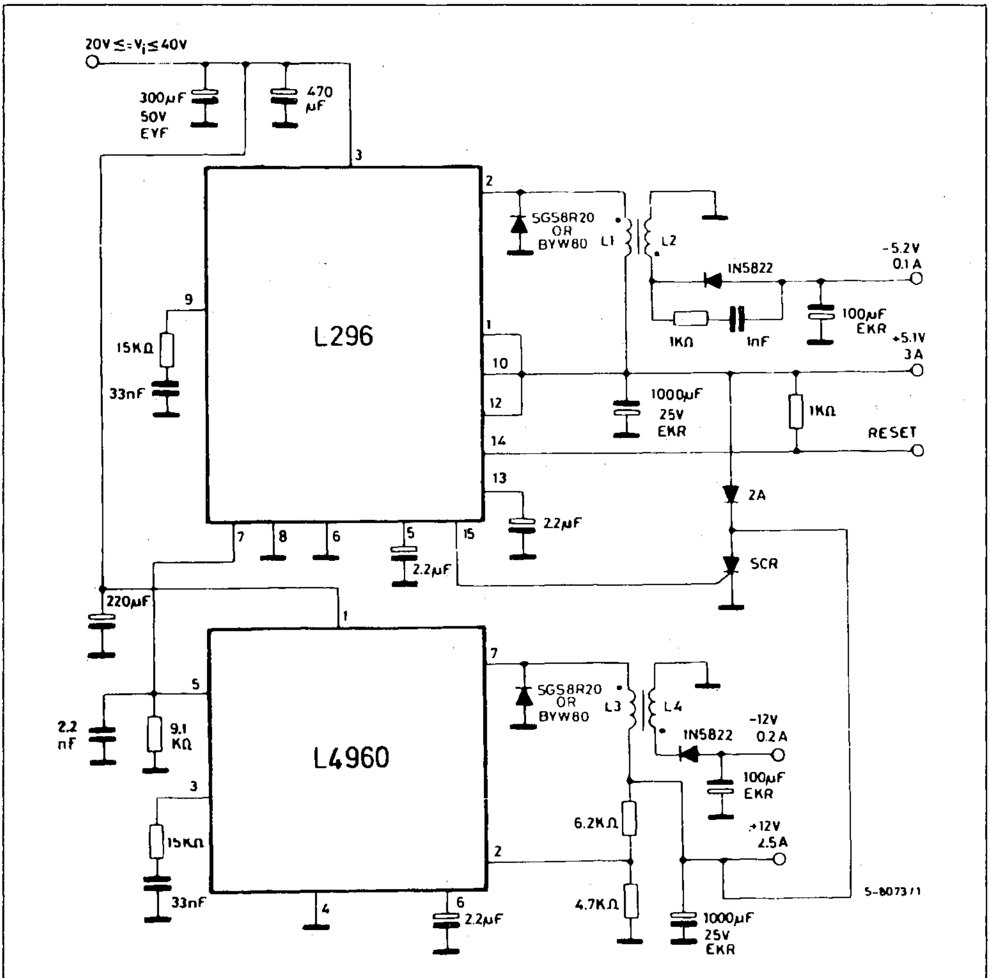


Table 5 shows the performance obtained with this power supply.

Table 5.

Parameter		V_{O1}	V_{O2}	V_{O3}	V_{O4}	Unit
Output Voltage I_{O1} = 3A I_{O2} = 100mA	V_i = 30V I_{O3} = 1.5A I_{O4} = 100mA	5.080	– 5010	11.96	12.00	V
Output Ripple		50	30	50	40	mV
Line Regulation I_{O1} = 1A I_{O3} = 0.5A	$20V \leq V_i \leq 40V$ I_{O2} = 100mA I_{O4} = 100mA	13	15	10	20	mV
Load Regulation I_{O1} = 1A to 3A	V_i = 30V I_{O2} = 100mA	8	90			mV
I_{O3} = 0.5 to 1.5A	I_{O4} = 100mA			3	80	mV
Load Regulation I_{O1} = 3A	V_i = 30V I_{O2} = 50 → 100mA	0	100			mV
I_{O3} = 1.5A	I_{O4} = 50 → 100mA			0	100	mV
Load Regulation I_{O1} = 1A	V_i = 30V I_{O2} = 50 → 100mA	0	35			mV
I_{O3} = 0.5A	I_{O4} = 50 → 100mA			0	90	mV
Line Regulation I_{O1} = 3A	$20 \leq V_i \leq 40V$ I_{O2} = 100mA	15	45			mV
I_{O3} = 1.5A	I_{O4} = 100mA			15	40	mV

This application illustrates how two devices may be synchronized. Note also that the reset circuit is used in this case to monitor the output voltage (see figure 7).

If a power fail function is required in place of the reset function the figure 6 circuit should be modified as shown in figure 8.

Figure 7 : Reset Output Waveforms.

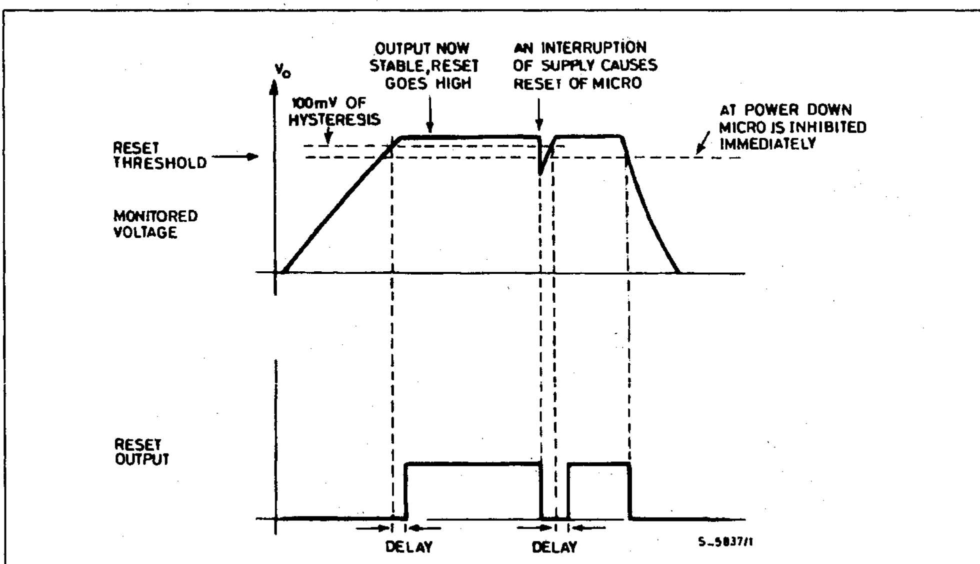
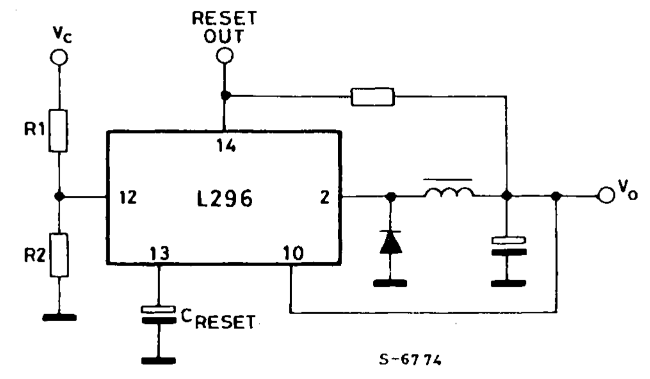


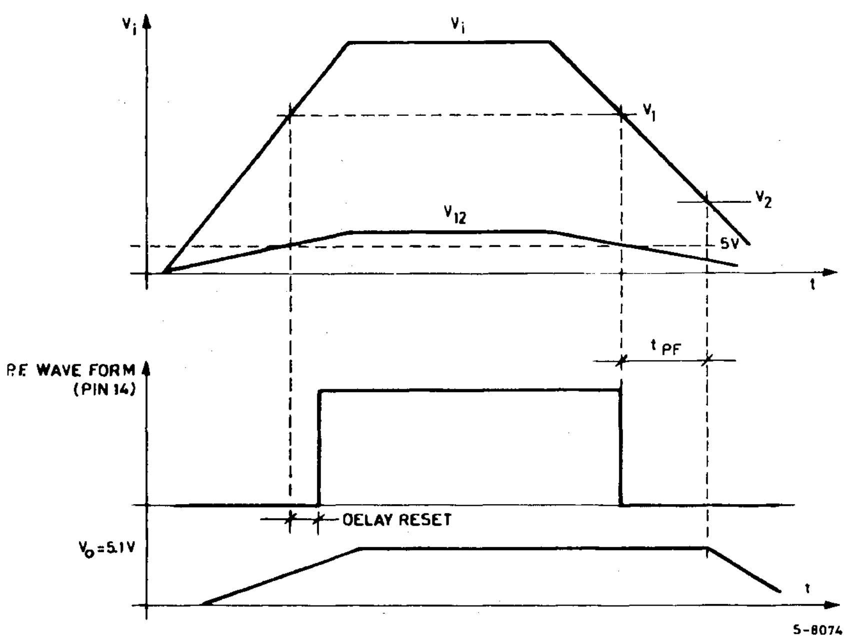
Figure 8.



CALCULATING THE POWER FAIL TIME

The 'power fail time' is defined as the time from when the power fail output (pin 14) goes low to the time when the input voltage falls to the minimum level required to maintain the regulated output (see figure 9). From this definition we can evaluate the energy balance.

Figure 9.



The energy which the filter capacitor C supplies to the operating device while it discharges is :

$$E = 1/2\, C\, (V_1^2 - V_2^2) \qquad (1)$$

The load drains a power of $P_o = V_o\, I_o$. Taking into consideration the average efficiency η (derived with the input between V_1 and V_2), the power to be supplied at the input of the device is :

$$P_{o2} = \frac{P_o}{\eta} \qquad (2)$$

Equating the expressions (1) and (2) gives :

$$1/2\, C\, (V_1^2 - V_2^2) = \frac{P_o}{\eta} \cdot t_{PF}$$

where V_i is the input voltage at which the voltage on pin 12 reaches 5V (through the divider R_1/R_2) ; V_2 is the maximum input voltage below which the device no longer regulates.

Rearranging this expression to obtain C :

$$C = \frac{2\, P_o\, t_{PF}}{\eta\, (V_1^2 - V_2^2)}$$

EXAMPLE - Suppose that V_o = 5V, I_o = 3A, T_{pf} = 10ms and V_i = 35V. Fixing V_1 = 25V and V_2 = 10V we obtain :

$$C = \frac{2\, P_o\, t_{PF}}{\eta\, (V_1^2 - V_2^2)} = \frac{2 \times 15 \times 10 \,.\, 10^{-3}}{0.75\, (25^2 - 10^2)} = 760\mu F$$

We obtain choose a capacitor of 1000µF.

CROWBAR

The L296 includes an internal crowbar function ; the only external component needed is an SCR. The intervention threshold of this block is fixed internally at 20% of the nominal value of the internal reference.

In the figure 6 circuit the SCR is triggered by an overvoltage on the 5V output (usually the most important output to monitor) and shortcircuits to ground the 5V output and, through the diode which connects the two outputs, the 12V output.

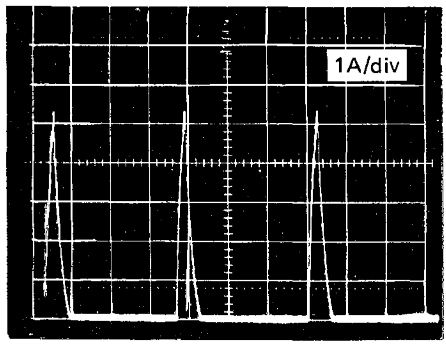
Since the internal current limiter in the device is designed to function as shown in figure 10 (that is, with pulsed output current) the SCR turns off in the gap between pulses and is re-activated gain if, when the device restarts softly, the fault condition has not been eliminated. But if the fault no longer exists the SCR remains OFF and the output voltage returns to the normal value.

If the designer prefers the supply to remain off after the SCR has been activated the circuit can be modified as shown in figure 11. In this modification, when the SCR is triggered a very high current flows in the fuse, blowing it.

Since the filter capacitor can have a high value and be charged to high voltages the choice of SCR is important. The type used in this circuit - the TYP512 - is a plastic packaged SCR able to handle 12 Arms and 300A for 10ms. The maximum forward and reverse voltages are about 50V.

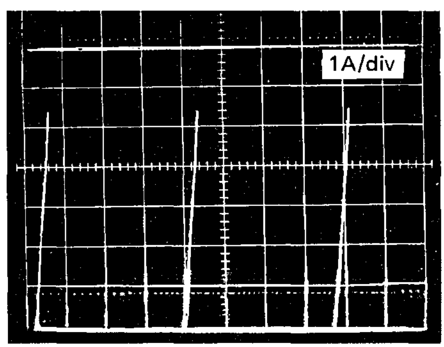
If the crowbar circuit is not used it is advisable to connect pin 1 to ground or pin 10.

Figure 10 : Load Current in Short Circuit Conditions (V_i = 40V, L = 300µH, f = 100KHz).



t: 5ms/div

Current at Pin 2 when the Output is Short Circuited.



t: 5ms/div

Figure 11.