

HIGH CURRENT SWITCHING REGULATORS

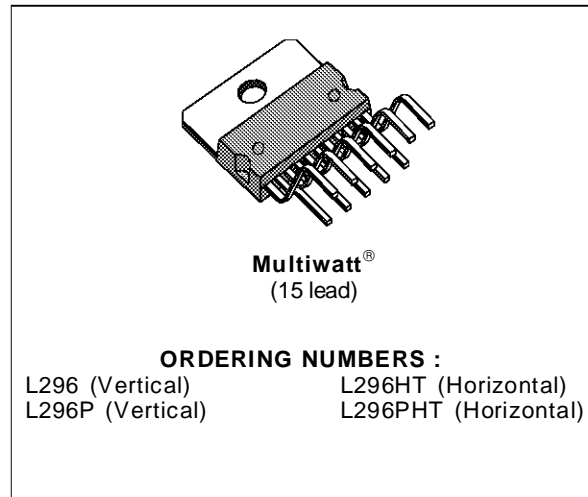
- 4 A OUTPUT CURRENT
- 5.1 V TO 40 V OUTPUT VOLTAGE RANGE
- 0 TO 100 % DUTY CYCLE RANGE
- PRECISE (± 2 %) ON-CHIP REFERENCE
- SWITCHING FREQUENCY UP TO 200 KHz
- VERY HIGH EFFICIENCY (UP TO 90 %)
- VERY FEW EXTERNAL COMPONENTS
- SOFT START
- RESET OUTPUT
- EXTERNAL PROGRAMMABLE LIMITING CURRENT (L296P)
- CONTROL CIRCUIT FOR CROWBAR SCR
- INPUT FOR REMOTE INHIBIT AND SYNCHRONOUS PWM
- THERMAL SHUTDOWN

DESCRIPTION

The L296 and L296P are stepdown power switching regulators delivering 4 A at a voltage variable from 5.1 V to 40 V.

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

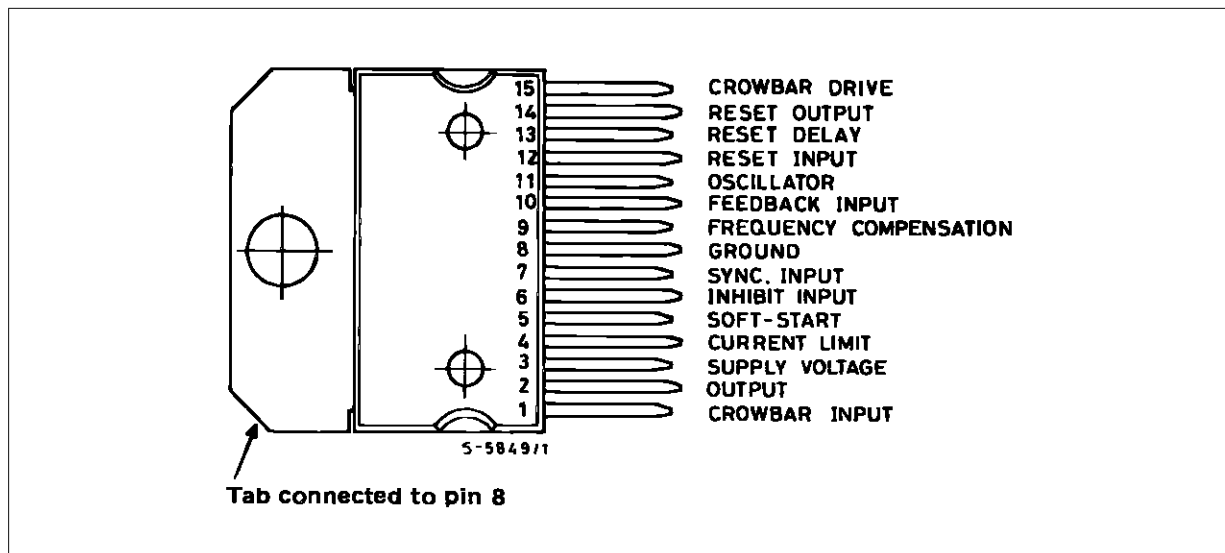
The L296P includes external programmable limiting current.



The L296 and L296P are mounted in a 15-lead Multiwatt® plastic power package and requires very few external components.

Efficient operation at switching frequencies up to 200 KHz 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.

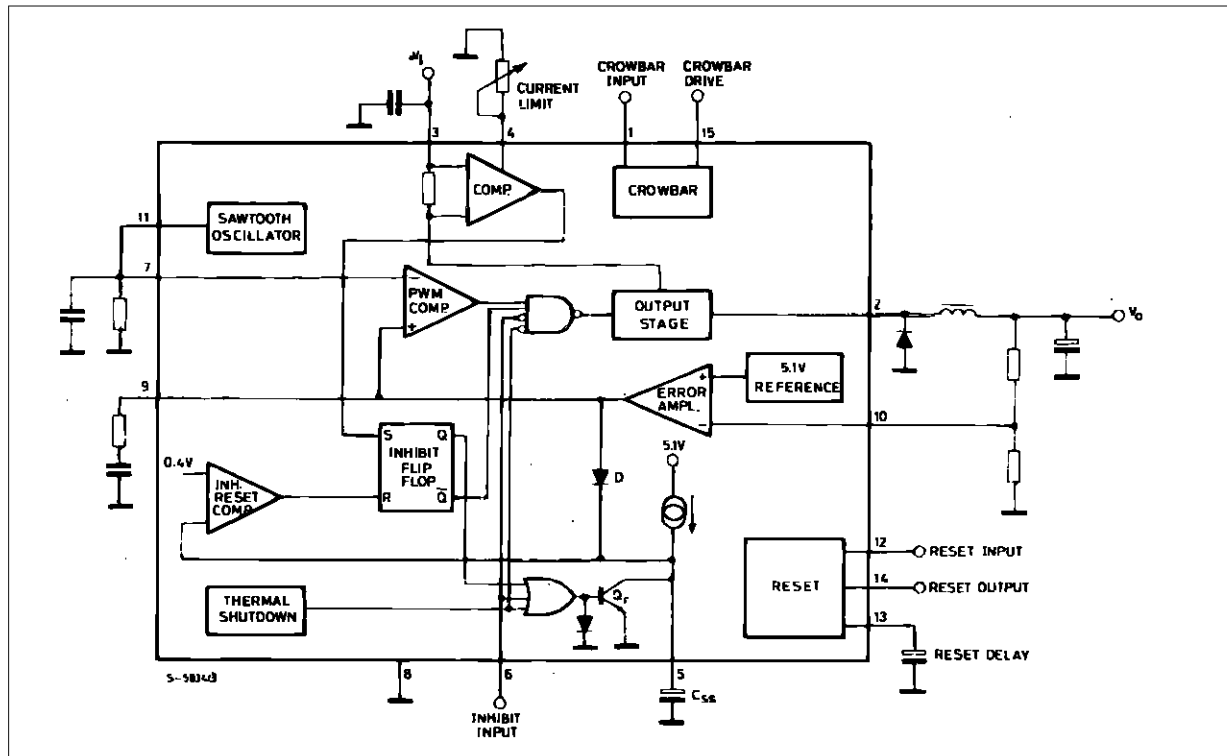
PIN CONNECTION (top view)



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 L296s 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 characteristics). |
| 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 device. |
| 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 on 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. |
| 12 | RESET INPUT | Input of the Reset Circuit. The threshold is roughly 5 V. 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. |

BLOCK DIAGRAM



CIRCUIT OPERATION

(refer to the block diagram)

The L296 and L296P are monolithic stepdown switching regulators 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 $\pm 2\%$). 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 scrowbar circuit senses the output voltage and the crowbar output can provide a current of 100mA 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 $150\text{ }^{\circ}\text{C}$ and has hysteresis to prevent unstable conditions.

Figure 1 : Reset Output Waveforms

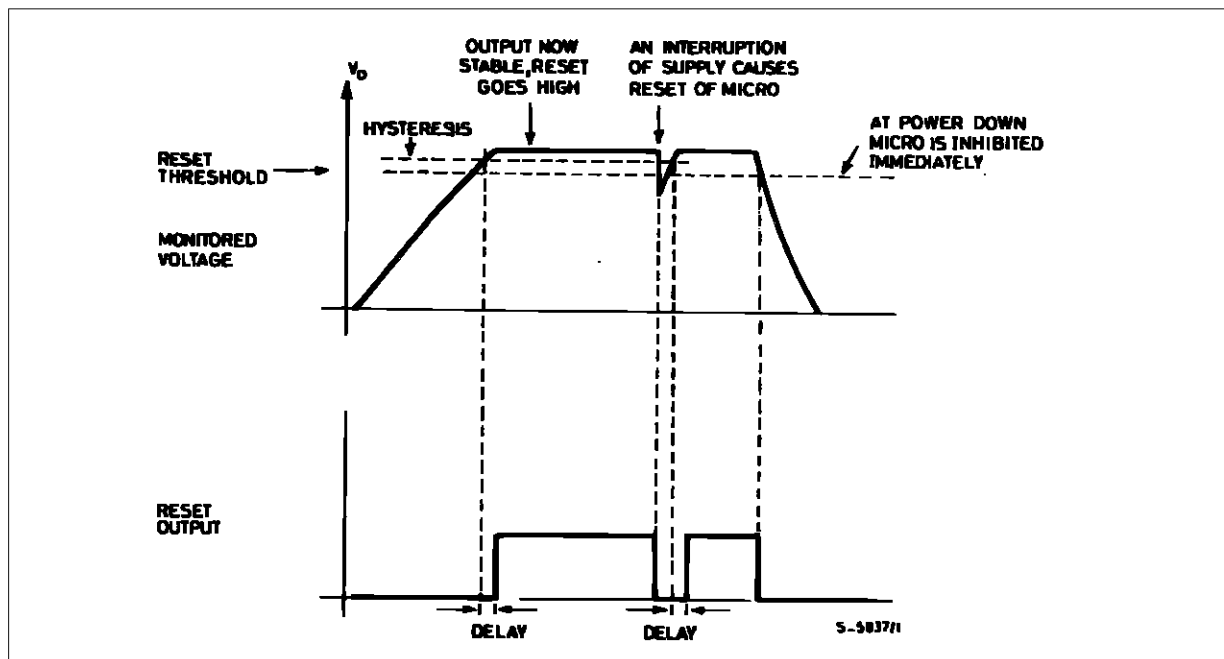


Figure 2 : Soft Start Waveforms

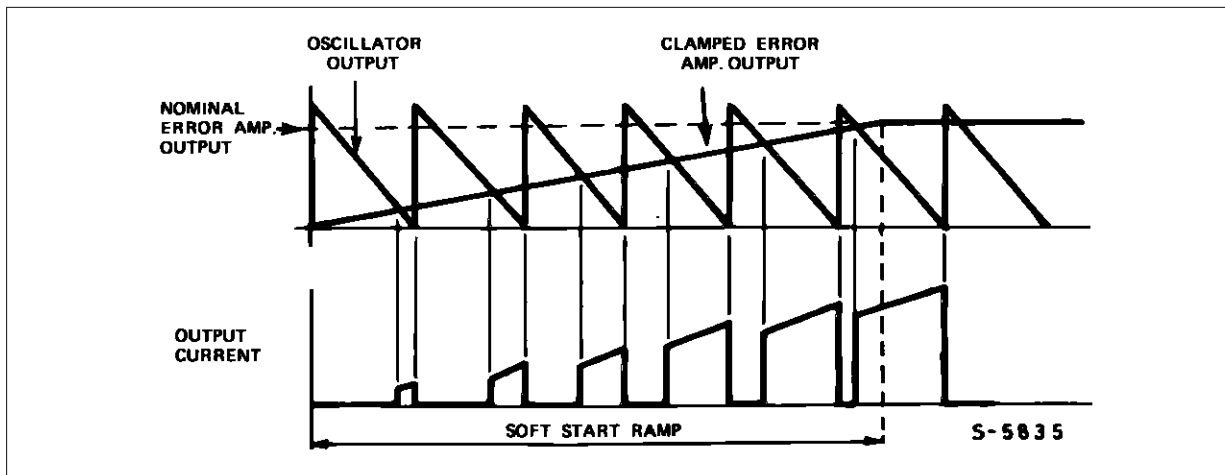
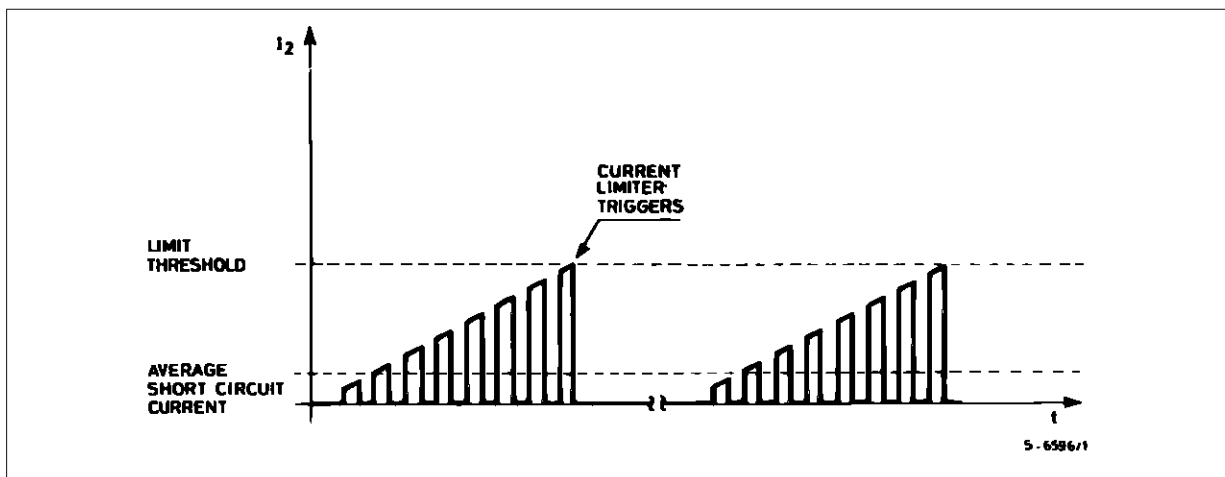


Figure 3 : Current Limiter Waveforms



ABSOLUTE MAXIMUM RATINGS

| Symbol | Parameter | Value | Unit |
|------------------------------|---|------------|------------------|
| V_i | Input Voltage (pin 3) | 50 | V |
| $V_i - V_2$ | Input to Output Voltage Difference | 50 | V |
| V_2 | Output DC Voltage Output Peak Voltage at $t = 0.1 \mu\text{sec}$ $f = 200\text{KHz}$ | -1 -7 | V V |
| V_1, V_{12} | Voltage at Pins 1, 12 | 10 | V |
| V_{15} | Voltage at Pin 15 | 15 | V |
| $V_4, V_5, V_7, V_9, V_{13}$ | Voltage at Pins 4, 5, 7, 9 and 13 | 5.5 | V |
| V_{10}, V_6 | Voltage at Pins 10 and 6 | 7 | V |
| V_{14} | Voltage at Pin 14 ($I_{14} \leq 1 \text{ mA}$) | V_i | |
| I_9 | Pin 9 Sink Current | 1 | mA |
| I_{11} | Pin 11 Source Current | 20 | mA |
| I_{14} | Pin 14 Sink Current ($V_{14} < 5 \text{ V}$) | 50 | mA |
| P_{tot} | Power Dissipation at $T_{\text{case}} \leq 90 \text{ }^\circ\text{C}$ | 20 | W |
| T_j, T_{stg} | Junction and Storage Temperature | -40 to 150 | $^\circ\text{C}$ |

THERMAL DATA

| Symbol | Parameter | Value | Unit |
|------------------|-------------------------------------|---------|------|
| $R_{th\ j-case}$ | Thermal Resistance Junction-case | Max. 3 | °C/W |
| $R_{th\ j-amb}$ | Thermal Resistance Junction-ambient | Max. 35 | °C/W |

ELECTRICAL CHARACTERISTICS

(refer to the test circuits $T_j = 25^\circ\text{C}$, $V_i = 35\text{V}$, 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 | $V_i = 46\text{V}$, $I_o = 1\text{A}$ | V_{ref} | | 40 | V | 4 |
| V_i | Input Voltage Range | $V_o = V_{ref}$ to 36V, $I_o \leq 3\text{A}$ | 9 | | 46 | V | 4 |
| V_i | Input Voltage Range | Note (1), $V_o = V_{REF}$ to 36V, $I_o = 4\text{A}$ | | | 46 | V | 4 |
| ΔV_o | Line Regulation | $V_i = 10\text{V}$ to 40V, $V_o = V_{ref}$, $I_o = 2\text{A}$ | | 15 | 50 | mV | 4 |
| ΔV_o | Load Regulation | $V_o = V_{ref}$ $I_o = 2\text{A}$ to 4A $I_o = 0.5\text{A}$ to 4A | | 10 15 | 30 45 | mV | 4 |
| V_{ref} | Internal Reference Voltage (pin 10) | $V_i = 9\text{V}$ to 46V, $I_o = 2\text{A}$ | 5 | 5.1 | 5.2 | V | 4 |
| $\frac{\Delta V_{ref}}{\Delta T}$ | Average Temperature Coefficient of Reference Voltage | $T_j = 0^\circ\text{C}$ to 125°C, $I_o = 2\text{A}$ | | 0.4 | | mV/°C | |
| V_d | Dropout Voltage Between Pin 2 and Pin 3 | $I_o = 4\text{A}$ $I_o = 2\text{A}$ | | 2 1.3 | 3.2 2.1 | V V | 4 4 |
| I_{2L} | Current Limiting Threshold (pin 2) | L296 - Pin 4 Open, $V_i = 9\text{V}$ to 40V, $V_o = V_{ref}$ to 36V | 4.5 | | 7.5 | A | 4 |
| | | L296P - $V_i = 9\text{V}$ to 40V, $V_o = V_{ref}$ Pin 4 Open $R_{lim} = 22\text{k}\Omega$ | 5 2.5 | | 7 4.5 | A | 4 |
| I_{SH} | Input Average Current | $V_i = 46\text{V}$, Output Short-circuited | | 60 | 100 | mA | 4 |
| η | Efficiency | $I_o = 3\text{A}$ $V_o = V_{ref}$ $V_o = 12\text{V}$ | | 75 85 | | % | 4 |
| SVR | Supply Voltage Ripple Rejection | $\Delta V_i = 2 V_{rms}$, $f_{ripple} = 100\text{Hz}$ $V_o = V_{ref}$, $I_o = 2\text{A}$ | 50 | 56 | | dB | 4 |
| f | Switching Frequency | | 85 | 100 | 115 | kHz | 4 |
| $\frac{\Delta f}{\Delta V_i}$ | Voltage Stability of Switching Frequency | $V_i = 9\text{V}$ to 46V | | 0.5 | | % | 4 |
| $\frac{\Delta f}{\Delta T_j}$ | Temperature Stability of Switching Frequency | $T_j = 0^\circ\text{C}$ to 125°C | | 1 | | % | 4 |
| f_{max} | Maximum Operating Switching Frequency | $V_o = V_{ref}$, $I_o = 1\text{A}$ | 200 | | | kHz | – |
| T_{sd} | Thermal Shutdown Junction Temperature | Note (2) | 135 | 145 | | °C | – |

DC CHARACTERISTICS

| | | | | | | | |
|-----------|-------------------------|---|--|--|----------|----------|----|
| I_{3Q} | Quiescent Drain Current | $V_i = 46\text{V}$, $V_7 = 0\text{V}$, S1 : B, S2 : B $V_6 = 0\text{V}$ $V_6 = 3\text{V}$ | | | 66 30 | 85 40 | mA |
| $-I_{2L}$ | Output Leakage Current | $V_i = 46\text{V}$, $V_6 = 3\text{V}$, S1 : B, S2 : A, $V_7 = 0\text{V}$ | | | | 2 | mA |

Note (1) : Using min. 7 A schottky diode.
(2) : Guaranteed by design, not 100 % tested in production.

L296 - L296P

ELECTRICAL CHARACTERISTICS (continued)

| Symbol | Parameter | Test Conditions | Min. | Typ. | Max. | Unit | Fig. |
|--------|-----------|-----------------|------|------|------|------|------|
|--------|-----------|-----------------|------|------|------|------|------|

SOFT START

| | | | | | | | |
|-------------|----------------|----------------------|----|-----|-----|---------|----|
| $I_{5\ so}$ | Source Current | $V_6 = 0V, V_5 = 3V$ | 80 | 130 | 150 | μA | 6b |
| $I_{5\ si}$ | Sink Current | $V_6 = 3V, V_5 = 3V$ | 50 | 70 | 120 | μA | 6b |

INHIBIT

| | | | | | | | |
|--------------------------|--|---|-----------|--|------------|---------|----|
| V_{6L} V_{6H} | Input Voltage Low Level High Level | $V_i = 9V$ to 46V, $V_7 = 0V$, $S1 : B, S2 : B$ | -0.3 2 | | 0.8 5.5 | V | 6a |
| - I_{6L} - I_{6H} | Input Current with Input Voltage Low Level High Level | $V_i = 9V$ to 46V, $V_7 = 0V$, $S1 : B, S2 : B$ $V_6 = 0.8V$ $V_6 = 2V$ | | | 10 3 | μA | 6a |

ERROR AMPLIFIER

| | | | | | | | |
|---------------|---------------------------|---|-----|--------|----------|--------------------|----------|
| V_{9H} | High Level Output Voltage | $V_{10} = 4.7V, I_9 = 100\mu A$, $S1 : A, S2 : A$ | 3.5 | | | V | 6c |
| V_{9L} | Low Level Output Voltage | $V_{10} = 5.3V, I_9 = 100\mu A$, $S1 : A, S2 : E$ | | | 0.5 | V | 6c |
| $I_{9\ si}$ | Sink Output Current | $V_{10} = 5.3V, S1 : A, S2 : B$ | 100 | 150 | | μA | 6c |
| - $I_{9\ so}$ | Source Output Current | $V_{10} = 4.7V, S1 : A, S2 : D$ | 100 | 150 | | μA | 6c |
| I_{10} | Input Bias Current | $V_{10} = 5.2V, S1 : B$ $V_{10} = 6.4V, S1 : B, L296P$ | | 2 2 | 10 10 | μA μA | 6c 6c |
| G_v | DC Open Loop Gain | $V_9 = 1V$ to 3V, $S1 : A, S2 : C$ | 46 | 55 | | dB | 6c |

OSCILLATOR AND PWM COMPARATOR

| | | | | | | | |
|------------|---|-------------------------------|---|--|---|---------|----|
| - I_7 | Input Bias Current of PWM Comparator | $V_7 = 0.5V$ to 3.5V | | | 5 | μA | 6a |
| - I_{11} | Oscillator Source Current | $V_{11} = 2V, S1 : A, S2 : B$ | 5 | | | mA | |

RESET

| | | | | | | | |
|--------------------------------|--|---|---------------------|---------------------|---------------------|---------------|----|
| $V_{12\ R}$ | Rising Threshold Voltage | $V_i = 9V$ to 46V, $S1 : B, S2 : B$ | V_{ref} -150mV | V_{ref} -100mV | V_{ref} -50mV | V | 6d |
| $V_{12\ F}$ | Falling Threshold Voltage | | 4.75 | V_{ref} -150mV | V_{ref} -100mV | V | 6d |
| $V_{13\ D}$ | Delay Thershold Voltage | $V_{12} = 5.3V, S1 : A, S2 : B$ | 4.3 | 4.5 | 4.7 | V | 6d |
| $V_{13\ H}$ | Delay Threshold Voltage Hysteresis | | | 100 | | mV | 6d |
| $V_{14\ S}$ | Output Saturation Voltage | $I_{14} = 16mA, V_{12} = 4.7V, S1, S2 : B$ | | | 0.4 | V | 6d |
| I_{12} | Input Bias Current | $V_{12} = 0V$ to $V_{ref}, S1 : B, S2 : B$ | | 1 | 3 | μA | 6d |
| - $I_{13\ so}$ $I_{13\ si}$ | Delay Source Current Delay Sink Current | $V_{13} = 3V, S1 : A, S2 : B$ $V_{12} = 5.3V$ $V_{12} = 4.7V$ | 70 10 | 110 | 140 | μA mA | 6d |
| I_{14} | Output Leakage Current | $V_i = 46V, V_{12} = 5.3V, S1 : B, S2 : A$ | | | 100 | μA | 6d |

CROWBAR

| | | | | | | | |
|------------|---------------------------|---|-----|-----|-----|---------|----|
| V_1 | Input Threshold Voltage | $S1 : B$ | 5.5 | 6 | 6.4 | V | 6b |
| V_{15} | Output Saturation Voltage | $V_i = 9V$ to 46V, $V_i = 5.4V$, $I_{15} = 5mA, S1 : A$ | | 0.2 | 0.4 | V | 6b |
| I_1 | Input Bias Current | $V_1 = 6V, S1 : B$ | | | 10 | μA | 6b |
| - I_{15} | Output Source Current | $V_i = 9V$ to 46V, $V_1 = 6.5V$, $V_{15} = 2V, S1 : B$ | 70 | 100 | | mA | 6b |

Figure 4 : Dynamic Test Circuit

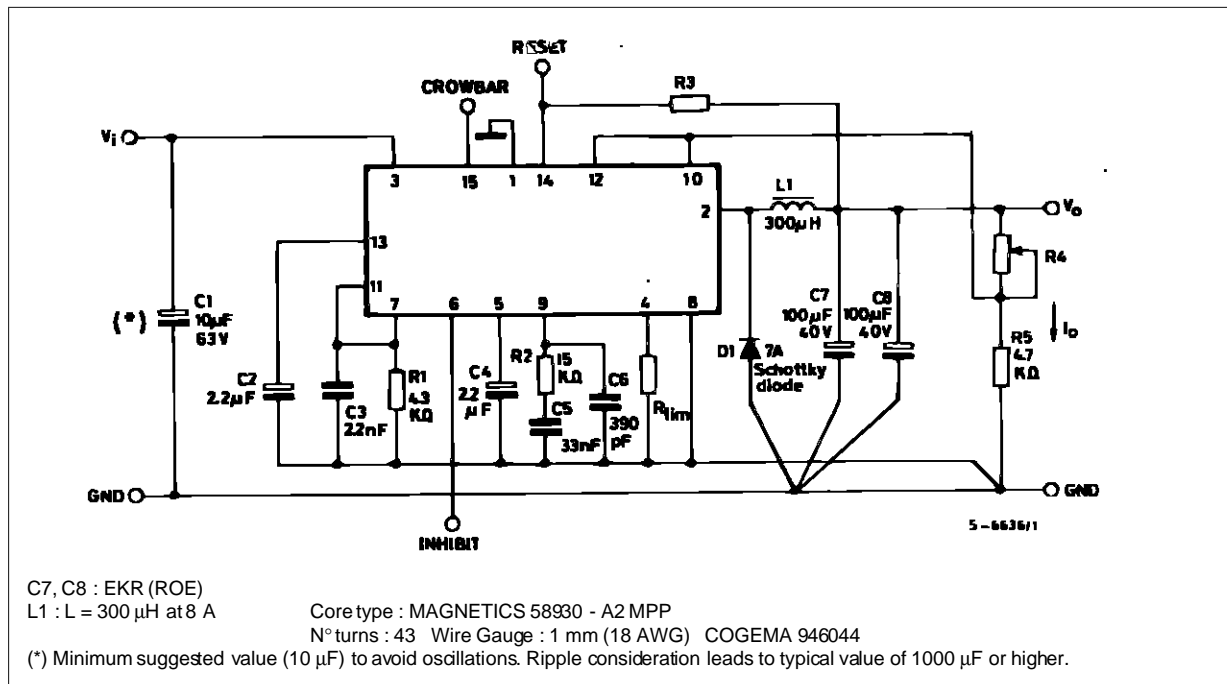


Figure 5 : PC. Board and Component Layout of the Circuit of Figure 4 (1:1 scale)

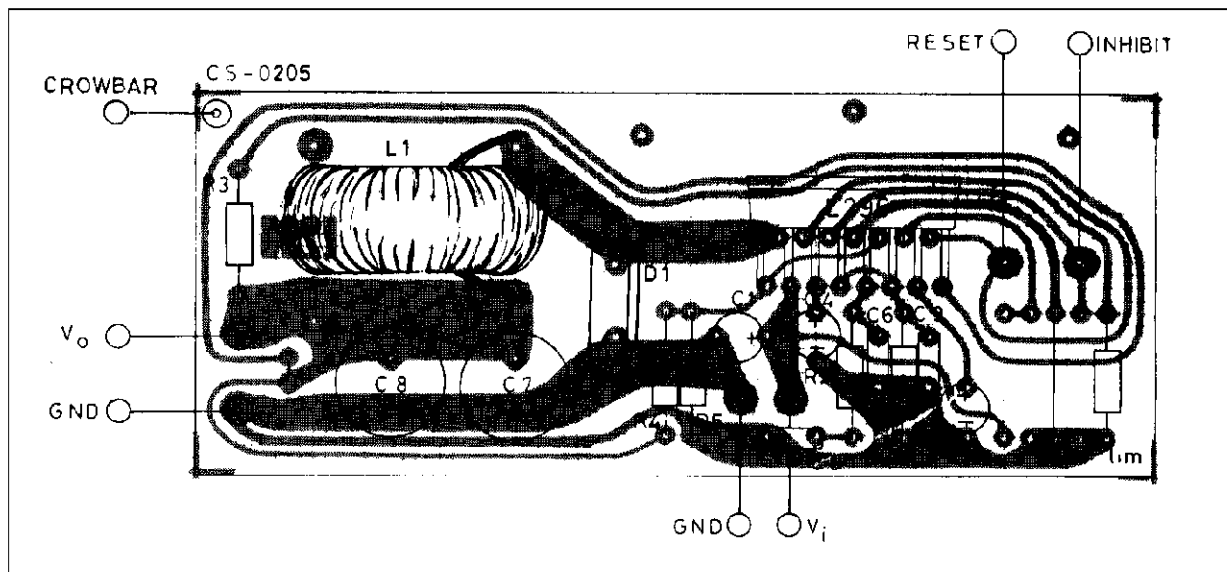


Figure 6 : DC Test Circuits.

Figure 6a.

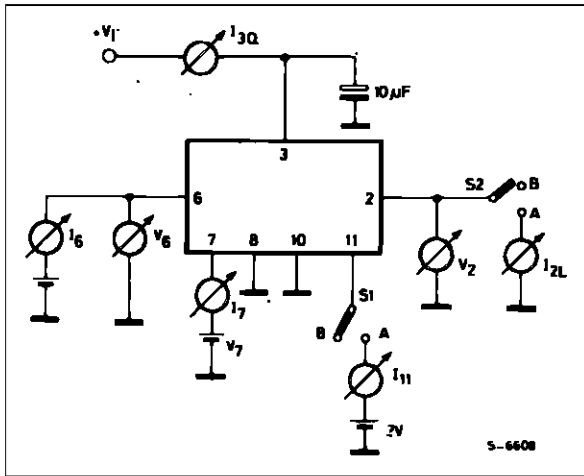


Figure 6b.

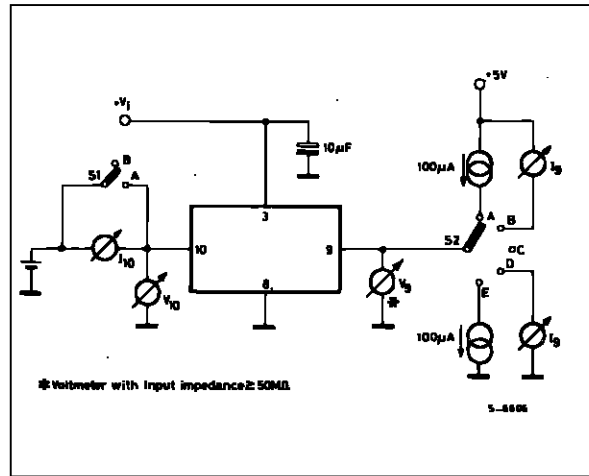


Figure 6c.

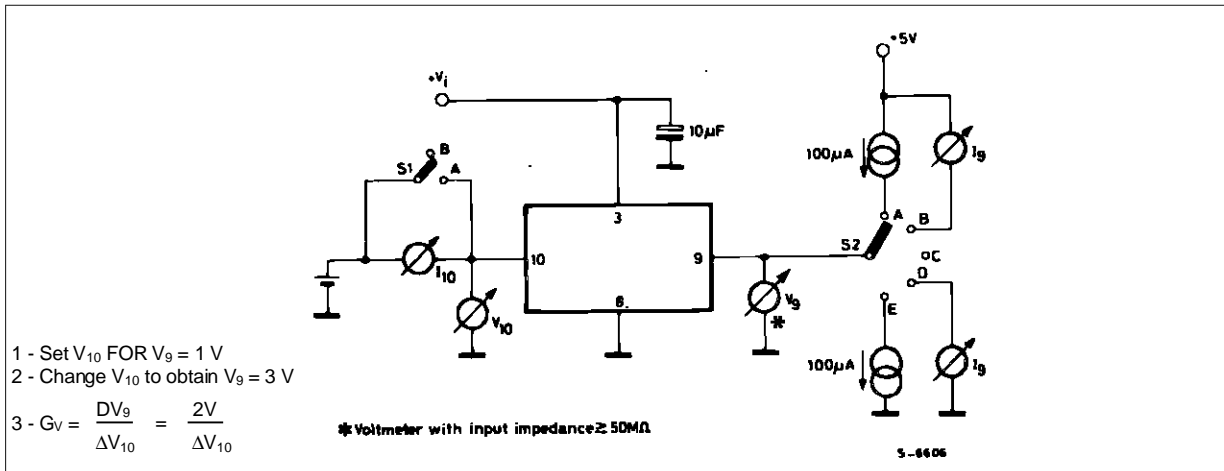


Figure 6d.

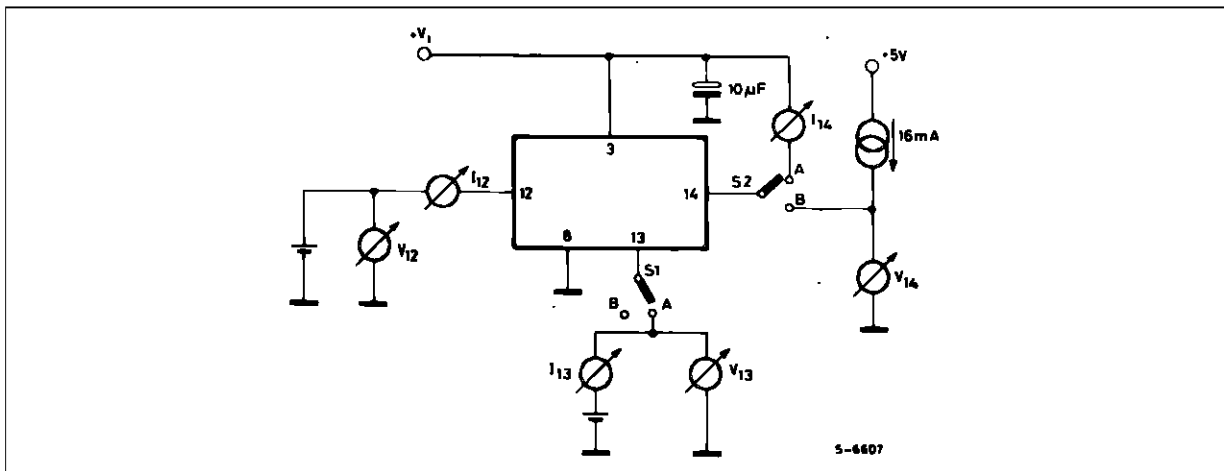


Figure 7 : Quiescent Drain Current vs. Supply Voltage (0 % Duty Cycle - see fig. 6a).

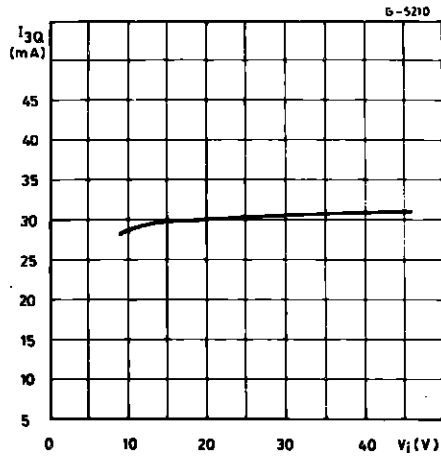


Figure 8 : Quiescent Drain Current vs. Supply Voltage (100 % Duty Cycle see fig. 6a).

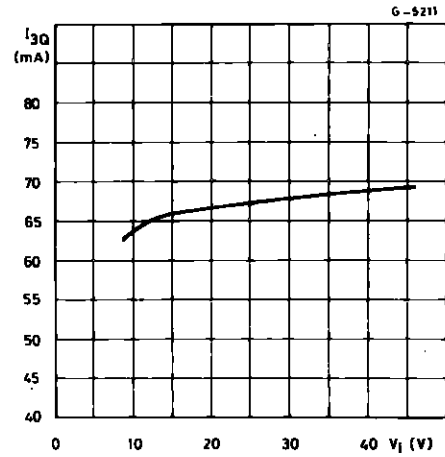


Figure 9 : Quiescent Drain Current vs. Junction Temperature (0 % Duty Cycle - see fig. 6a).

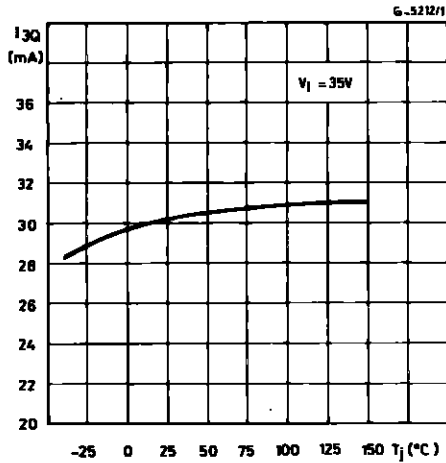


Figure 10 : Quiescent Drain Current vs. Junction Temperature (100 % Duty Cycle - see fig. 6a).

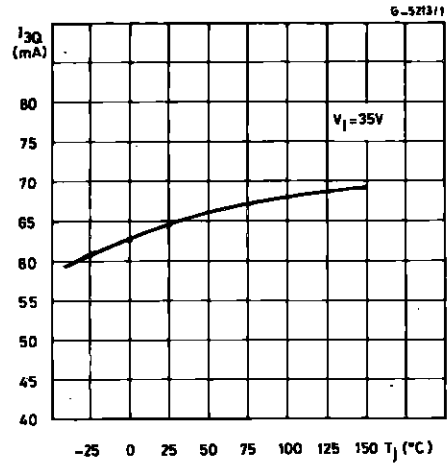


Figure 11 : Reference Voltage (pin 10) vs. V_I (see fig. 4).

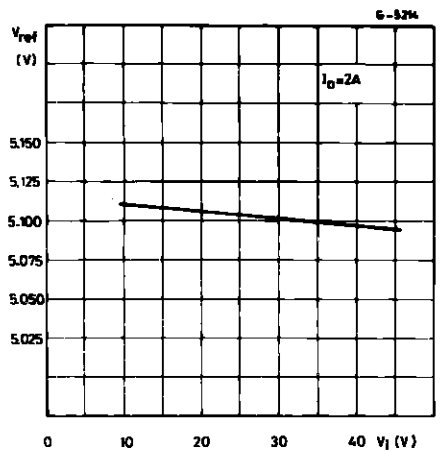


Figure 12 : Reference Voltage (pin 10) vs. Junction Temperature (see fig. 4).

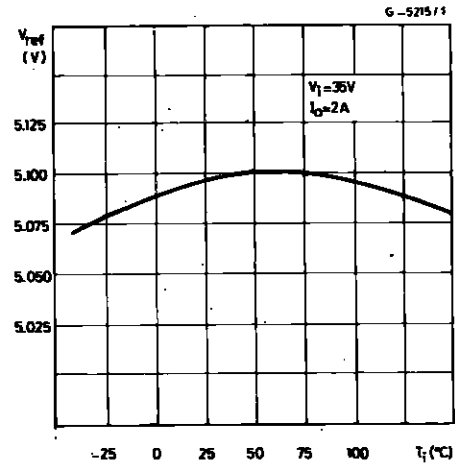


Figure 13 : Open Loop Frequency and Phase Response of Error Amplifier (see fig. 6c).

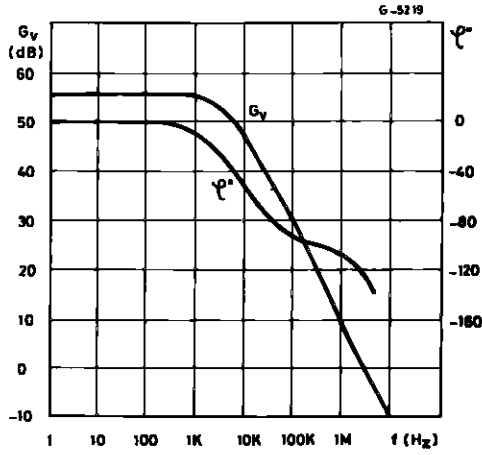


Figure 14 : Switching Frequency vs. Input Voltage (see fig. 4).

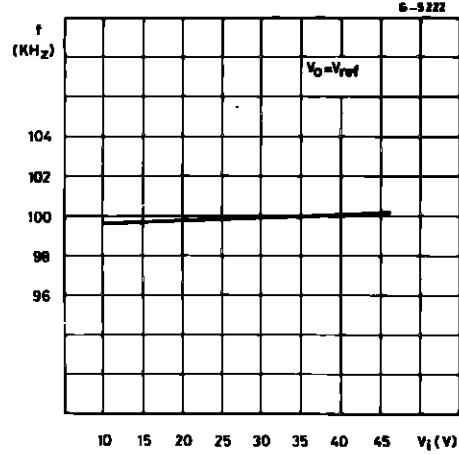


Figure 15 : Switching Frequency vs. Junction Temperature (see fig. 4).

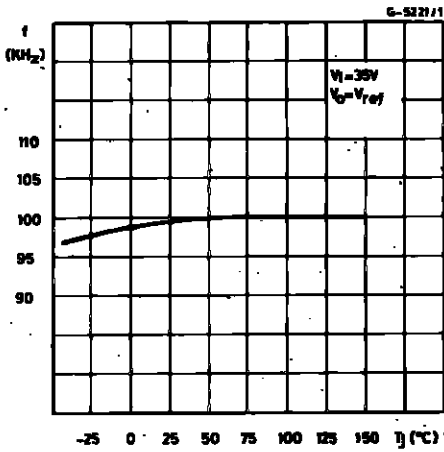


Figure 16 : Switching Frequency vs. R1 (see fig. 4).

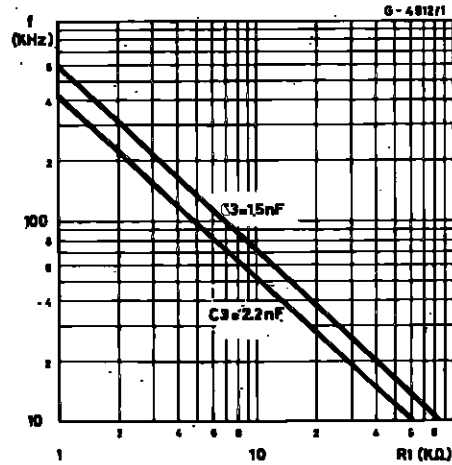


Figure 17 : Line Transient Response (see fig. 4).

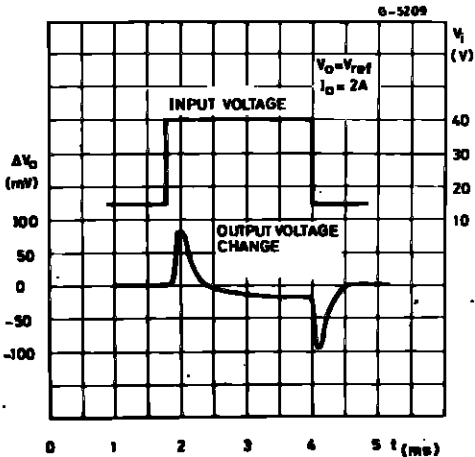


Figure 18 : Load Transient Response (see fig. 4).

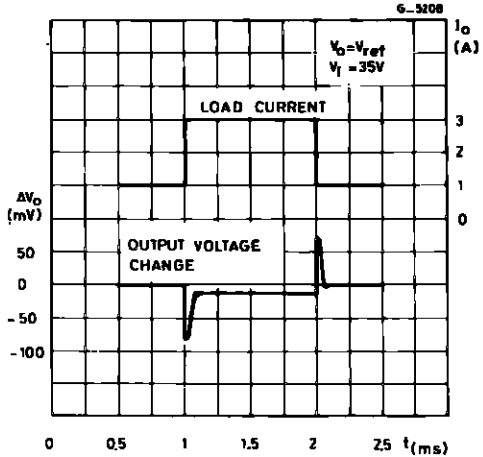


Figure 19 : Supply Voltage Ripple Rejection vs. Frequency (see fig. 4).

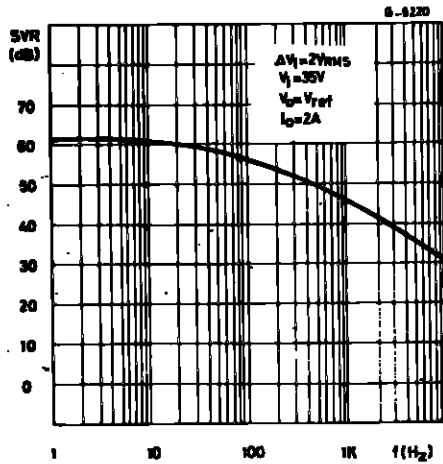


Figure 20 : Dropout Voltage Between Pin 3 and Pin 2 vs. Current at Pin 2.

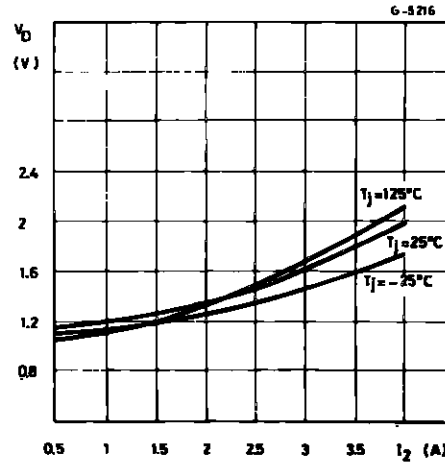


Figure 21 : Dropout Voltage Between Pin 3 and Pin 2 vs. Junction Temperature.

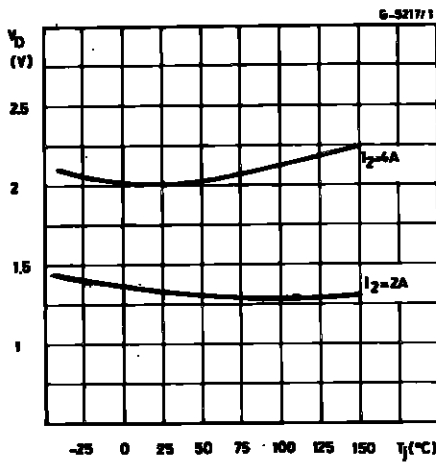


Figure 22 : Power Dissipation Derating Curve.

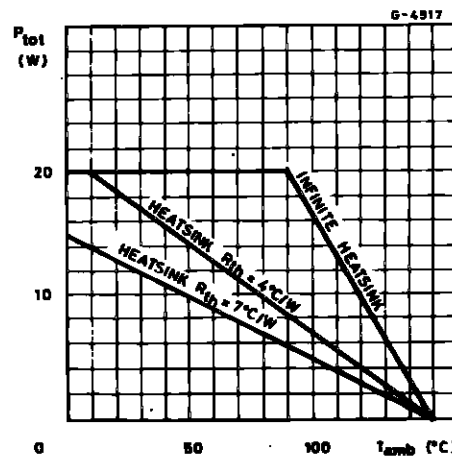


Figure 23 : Power Dissipation (device only) vs. Input Voltage.

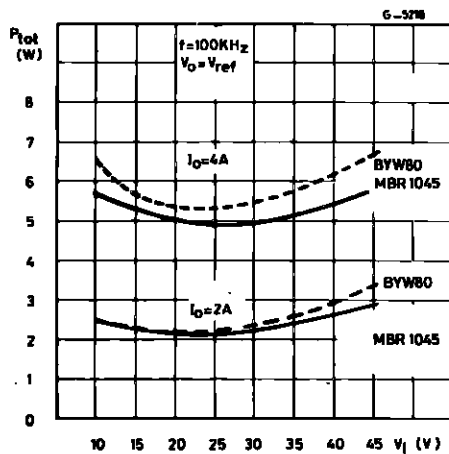


Figure 24 : Power Dissipation (device only) vs. Input voltage.

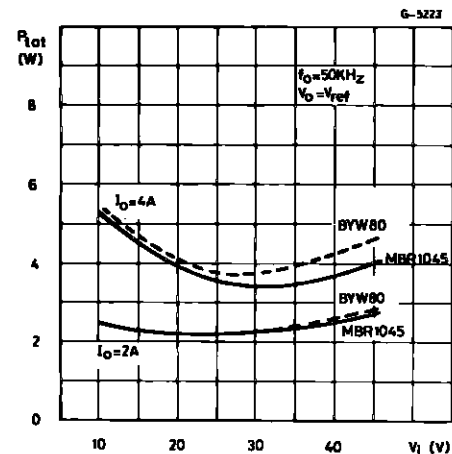


Figure 25 : Power Dissipation (device only) vs. Output Voltage (see fig. 4).

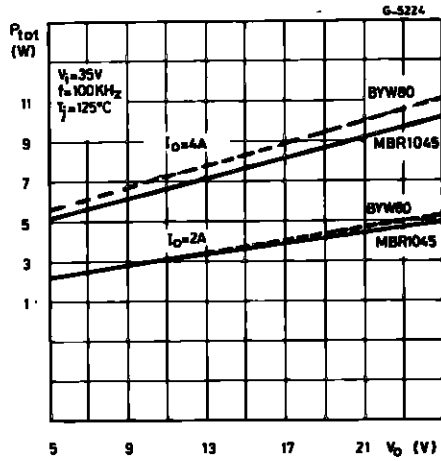


Figure 26 : Power Dissipation (device only) vs. Output Voltage (see fig. 4).

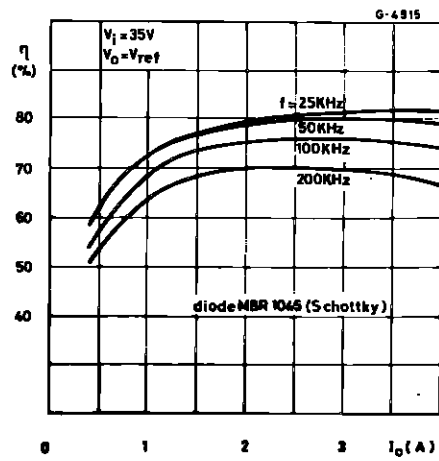


Figure 27 : Voltage and Current Waveforms at Pin 2 (see fig. 4).

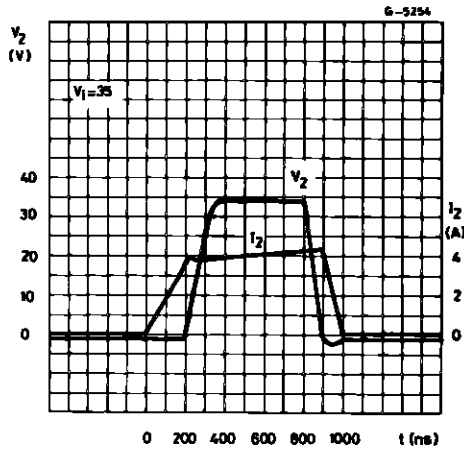


Figure 28 : Efficiency vs. Output Current.

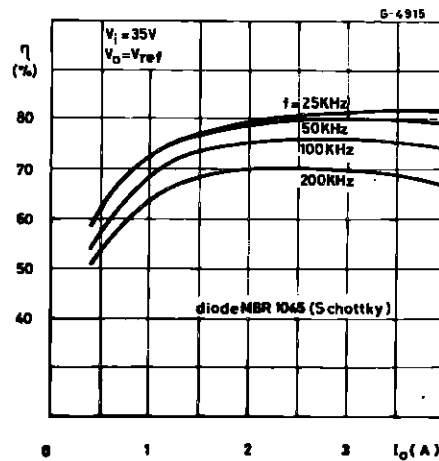


Figure 29 : Efficiency vs. Output Voltage.

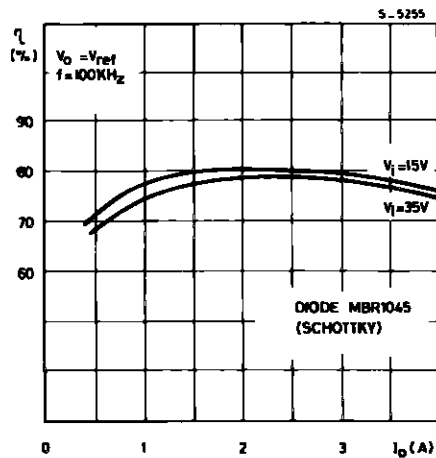


Figure 30 : Efficiency vs. Output Voltage.

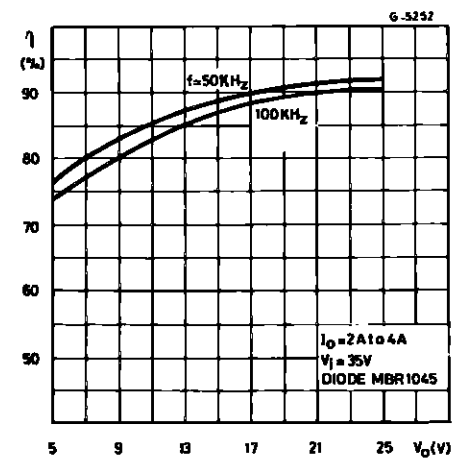


Figure 31 : Current Limiting Threshold vs. $R_{pin\ 4}$ (L296P only).

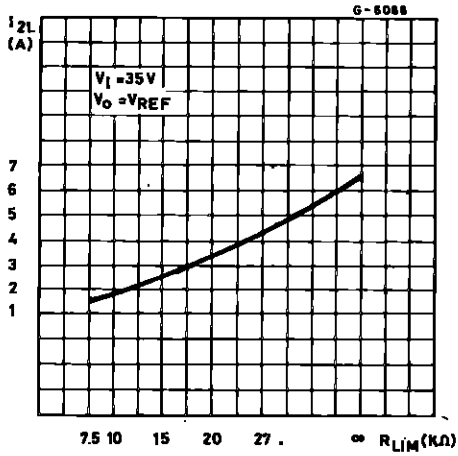


Figure 32 : Current Limiting Threshold vs. Junction Temperature.

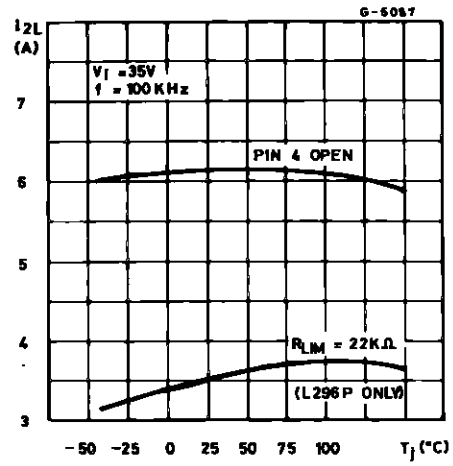
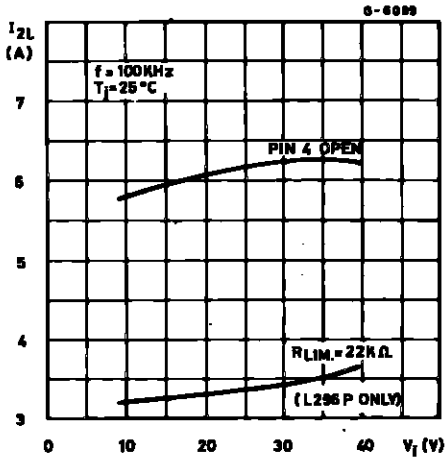
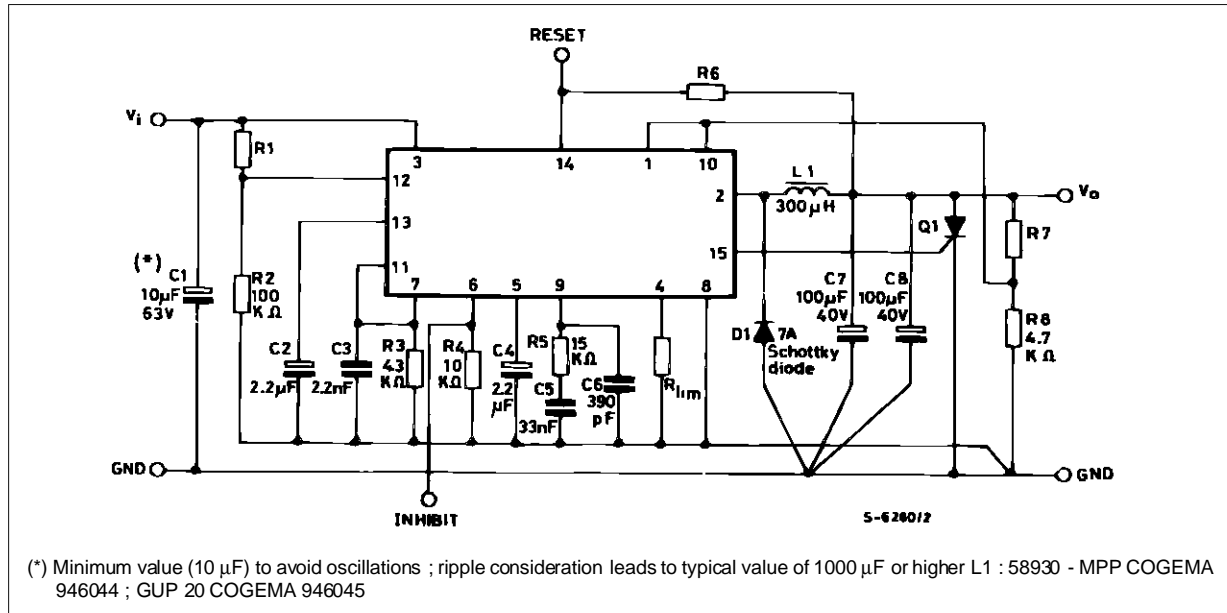


Figure 33 : Current Limiting Threshold vs. Supply Voltage.



APPLICATION INFORMATION

Figure 34 : Typical Application Circuit.

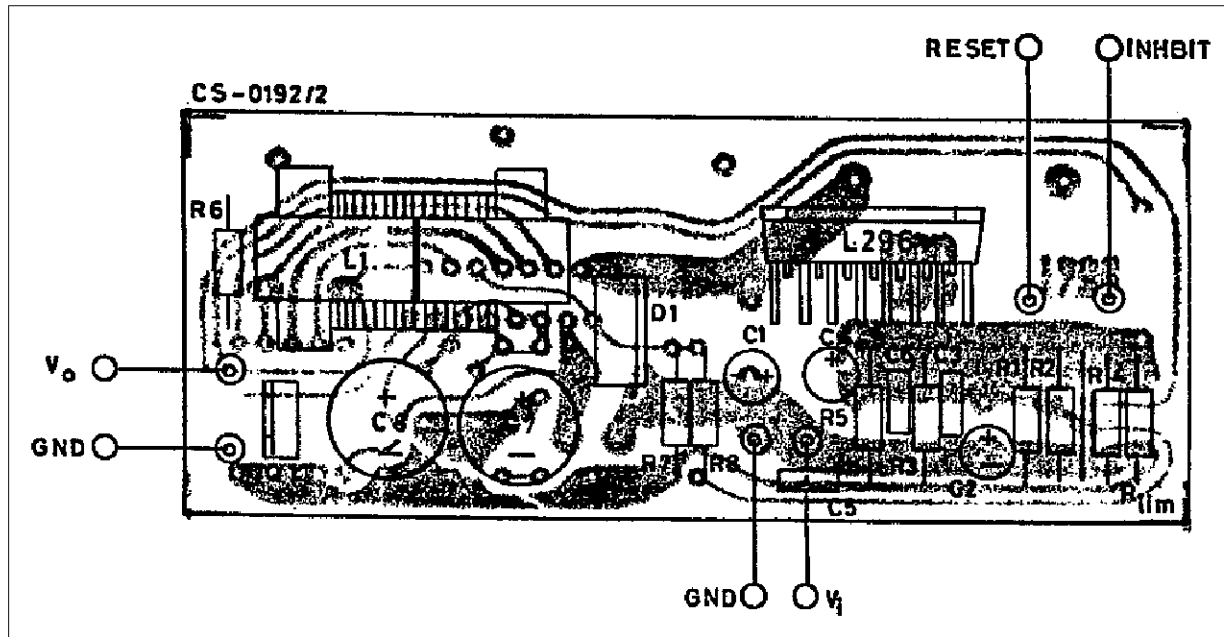


SUGGESTED INDUCTOR (L1)

| Core Type | No Turns | Wire Gauge | Air Gap |
|---|----------|------------|---------|
| Magnetics 58930 – A2MPP | 43 | 1.0 mm | – |
| Thomson GUP 20 x 16 x 7 | 65 | 0.8 mm | 1 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 ₀ | R8 | R7 |
| 12 V | 4.7 KΩ | 6.2 KΩ |
| 15 V | 4.7 KΩ | 9.1 KΩ |
| 18 V | 4.7 KΩ | 12 KΩ |
| 24 V | 4.7 KΩ | 18 KΩ |

Figure 35 : P.C. Board and Component Layout of the Circuit of fig. 34 (1:1 scale)



SELECTION OF COMPONENT VALUES (see fig. 34)

| Component | Recommended Value | Purpose | Allowed Range | | Notes |
|------------------|----------------------------|--|---------------------|------------------|---|
| | | | Min. | Max. | |
| R1 R2 | – 100 k Ω | Set Input Voltage Threshold for Reset. | – | 220k Ω | $R1/R2 = \frac{V_{i\ min}}{5} - 1$ If output voltage is sensed R1 and R2 may be limited and pin 12 connected to pin 10. |
| R3 | 4.3 k Ω | Sets Switching Frequency | 1 k Ω | 100k Ω | |
| R4 | 10 k Ω | Pull-down Resistor | | 22k Ω | May be omitted and pin 6 grounded if inhibit not used. |
| R5 | 15 k Ω | Frequency Compensation | 10k Ω | | |
| R6 | | Collector Load For Reset Output | $\frac{V_o}{0.05A}$ | | Omitted if reset function not used. |
| R7 R8 | – 4.7 k Ω | Divider to Set Output Voltage | – | – 1k Ω | $R7/R8 = \frac{V_o - V_{REF}}{V_{REF}}$ |
| R _{lim} | – | Sets Current Limit Level | 7.5k Ω | | If R _{lim} is omitted and pin 4 left open the current limit is internally fixed. |
| C1 | 10 μ F | Stability | 2.2 μ F | | |
| C2 | 2.2 μ F | Sets Reset Delay | – | – | Omitted if reset function not used. |
| C3 | 2.2 nF | Sets Switching Frequency | 1 nF | 3.3nF | |
| C4 | 2.2 μ F | Soft Start | 1 μ F | – | Also determines average short circuit current. |
| C5 | 33 nF | Frequency Compensation | | | |
| C6 | 390 pF | High Frequency Compensation | – | – | Not required for 5 V operation. |
| C7, C8 L1 | 100 μ F 300 μ H | Output Filter | – 100 μ H | – | |
| 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 35 ns t_{rr} Diode. |

L296 - L296P

Figure 36 : A Minimal 5.1 V Fixed Regulator. Very Few Components are Required.

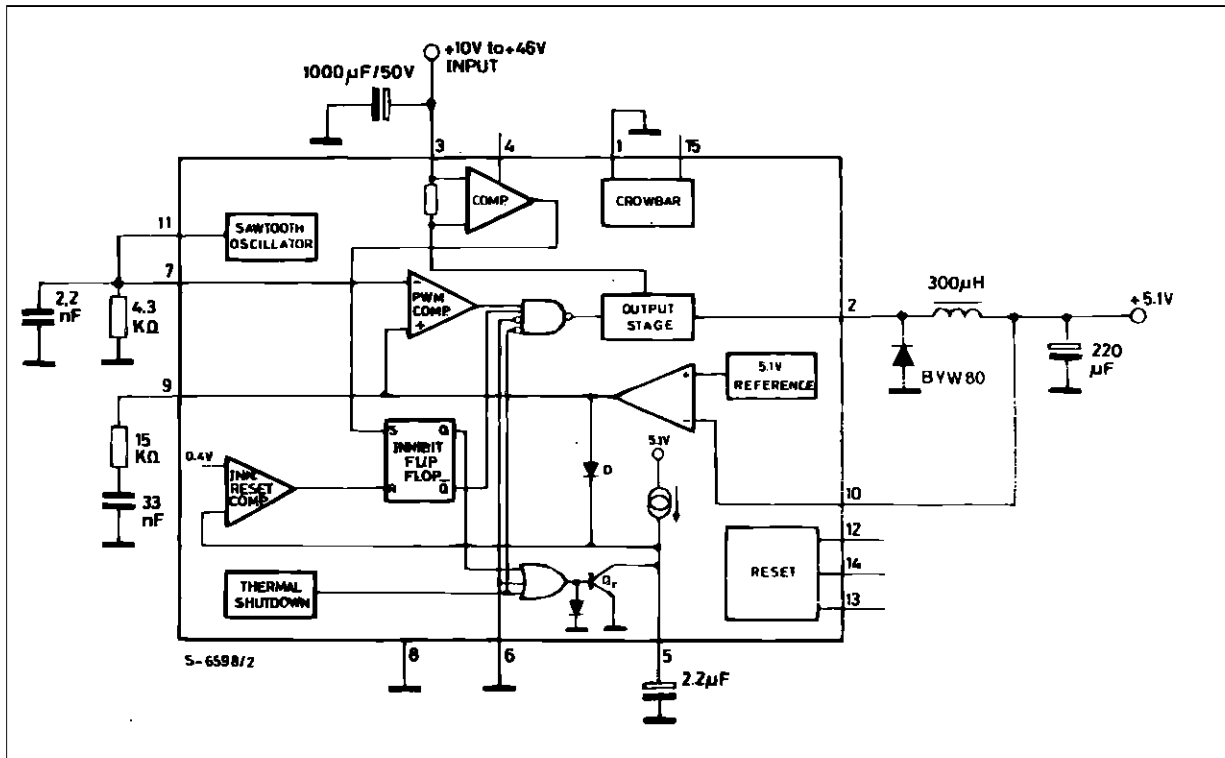


Figure 37 : 12 V/10 A Power Supply.

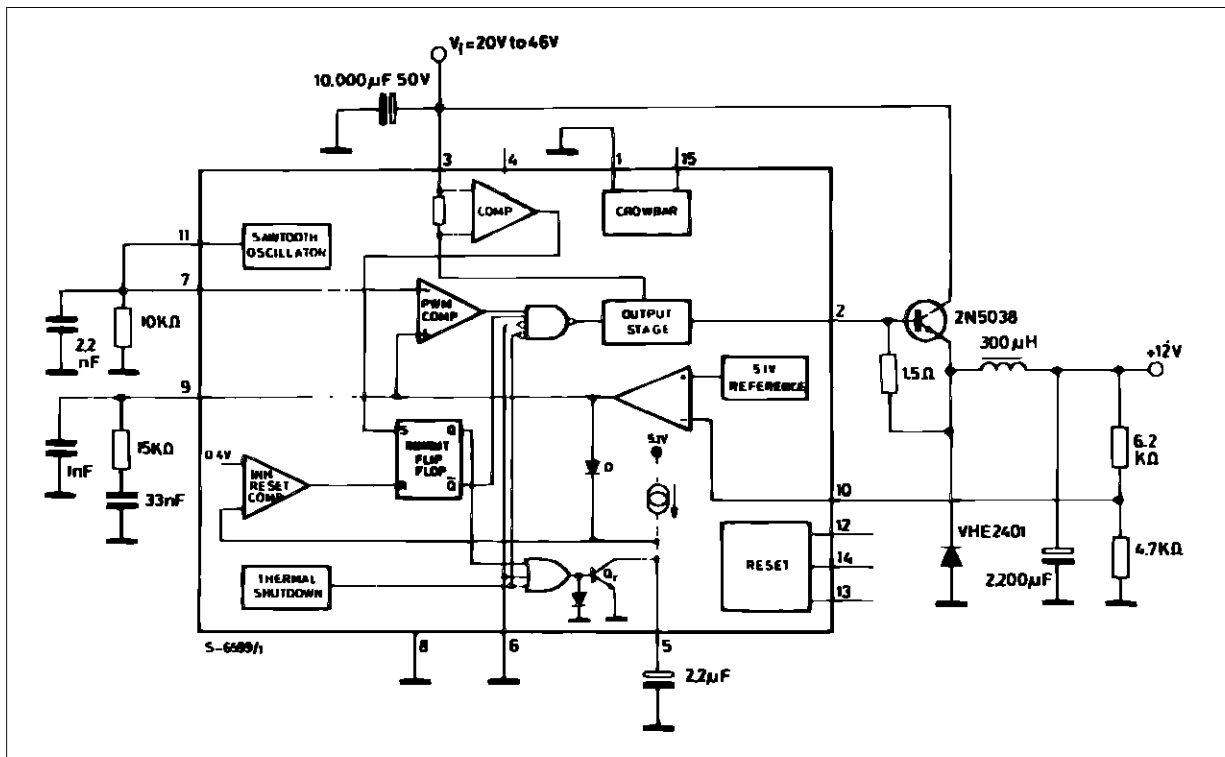


Figure 38 : Programmable Power Supply.

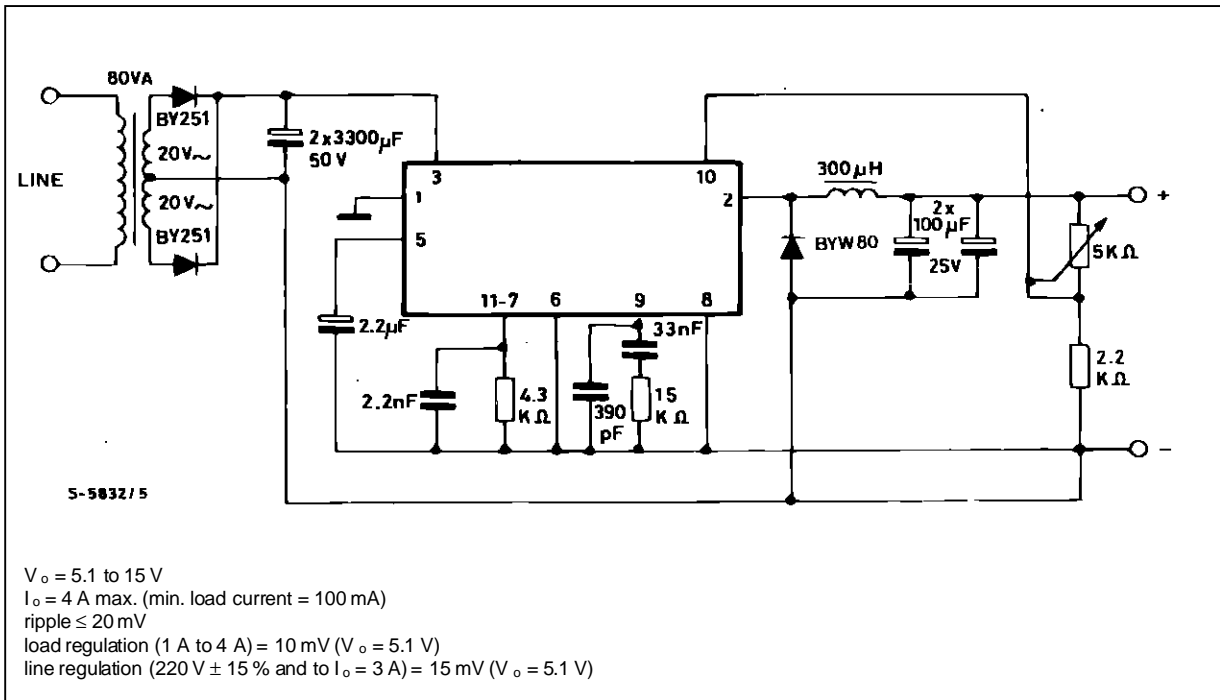
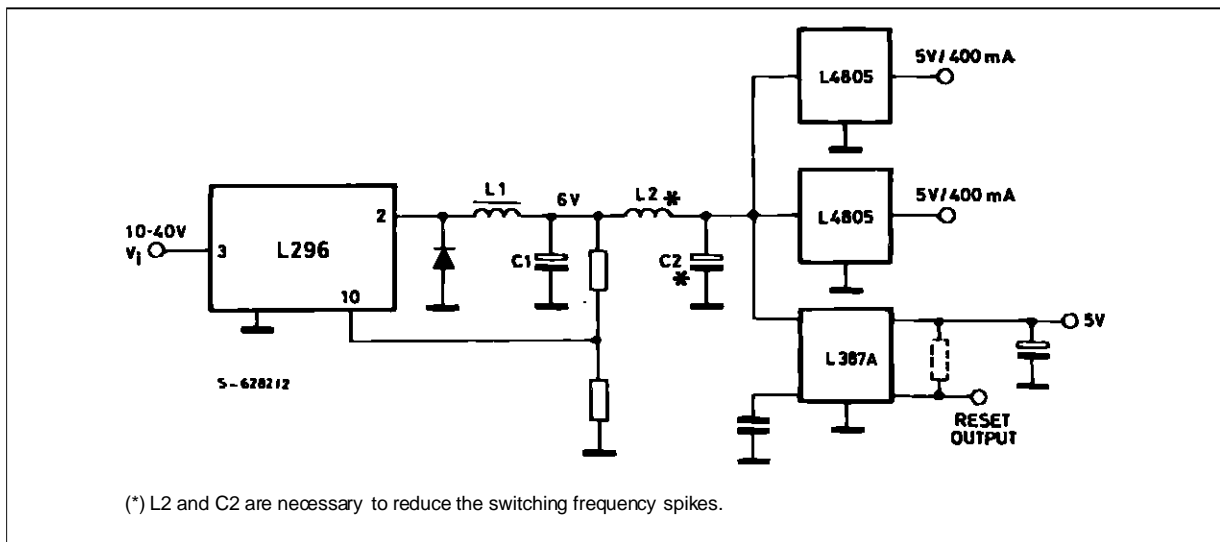


Figure 39 : Preregulator for Distributed Supplies.



L296 - L296P

Figure 40 : In Multiple Supplies Several L296s can be Synchronized As Shown.

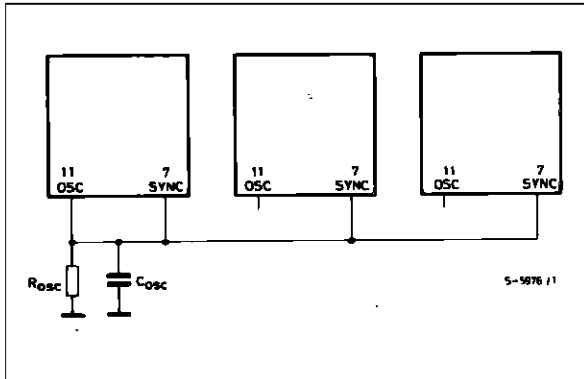


Figure 41 : Voltage Sensing for Remote Load.

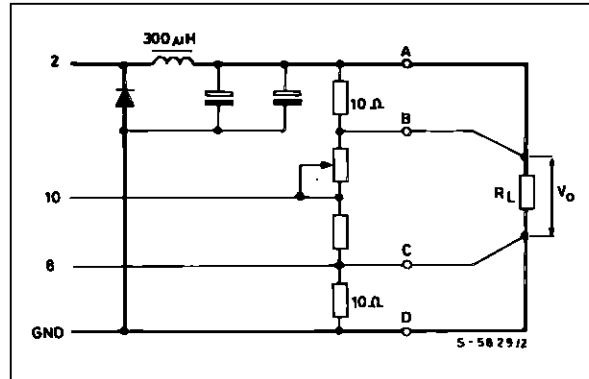


Figure 42 : A 5.1 V/15 V/24 V Multiple Supply. Note the Synchronization of the Three L296s.

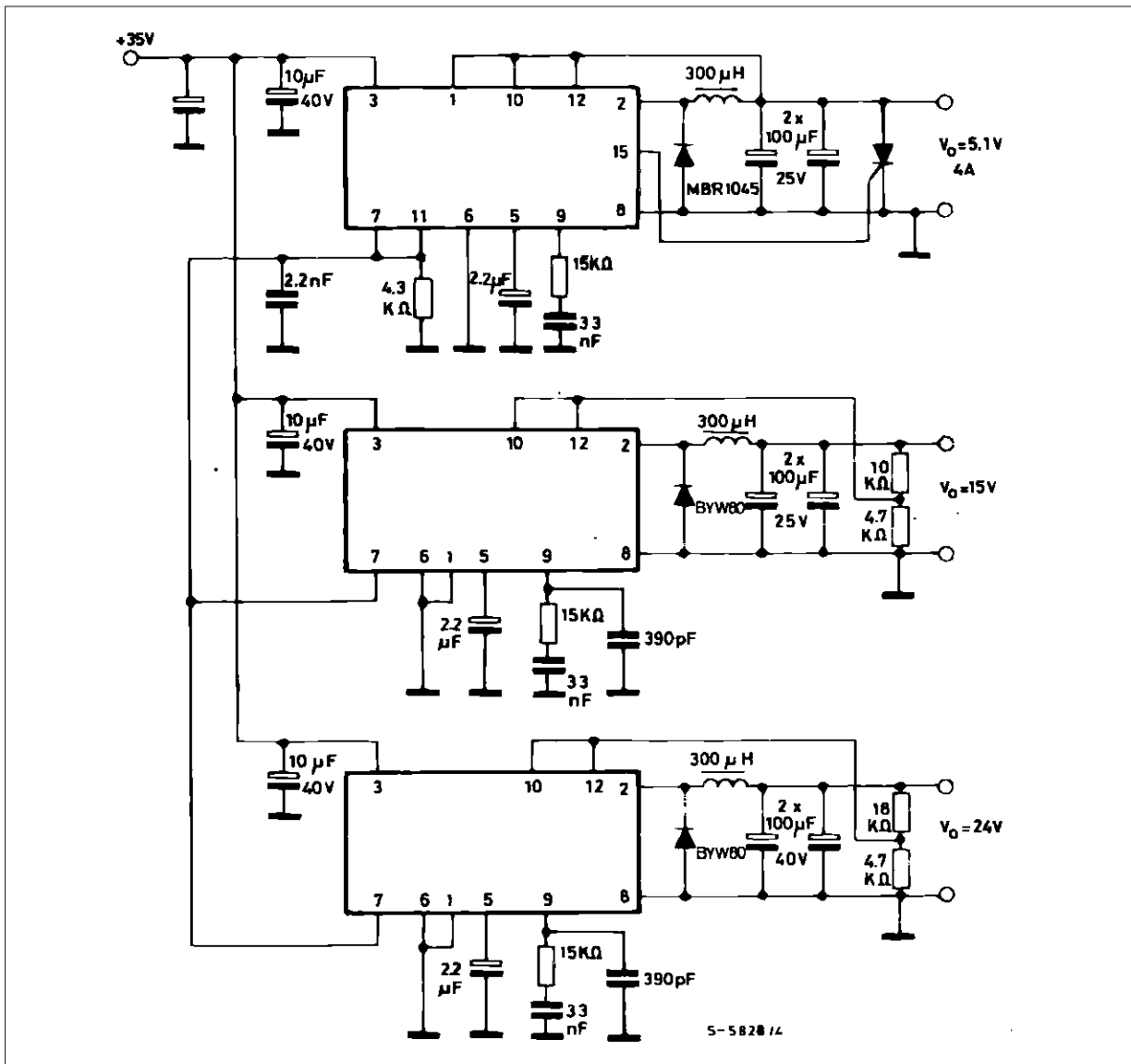
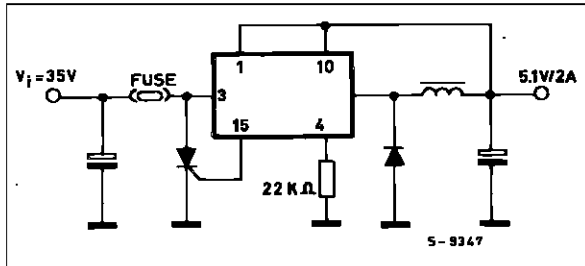


Figure 43 : 5.1V/2A Power Supply using External Limiting Current Resistor and Crowbar Protection on the Supply Voltage (L296P only)

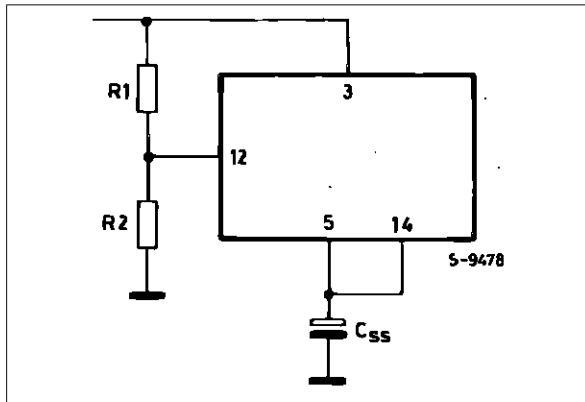


SOFT-START AND REPETITIVE POWER-ON

When the device is repetitively powered-on, the soft-start capacitor, C_{SS} , must be discharged rapidly to ensure that each start is "soft". This can be achieved economically using the reset circuit, as shown in Figure 44.

In this circuit the divider R1, R2 connected to pin 12 determines the minimum supply voltage, below which the open collector transistor at the pin 14 output discharges C_{SS} .

Figure 44

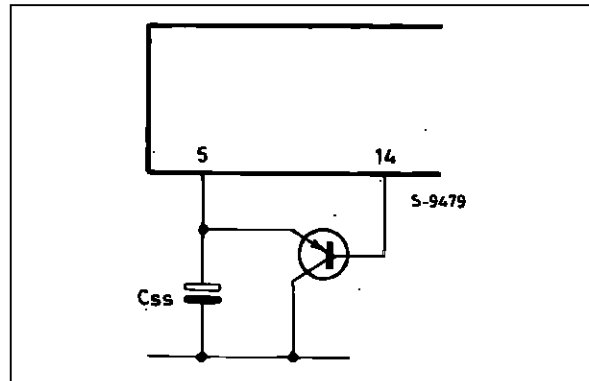


The approximate discharge times obtained with this circuit are :

| C_{SS} (μF) | t_{DIS} (μs) |
|----------------------|-----------------------|
| 2.2 | 200 |
| 4.7 | 300 |
| 10 | 600 |

If these times are still too long, an external PNP transistor may be added, as shown in Figure 45 ; with this circuit discharge times of a few microseconds may be obtained.

Figure 45



HOW TO OBTAIN BOTH RESET AND POWER FAIL

Figure 46 illustrates how it is possible to obtain at the same time both the power fail and reset functions simply by adding one diode (D) and one resistor (R).

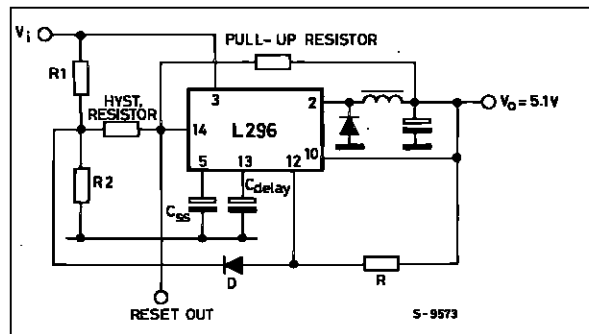
In this case the Reset delay time (pin 13) can only start when the output voltage is $V_O \geq V_{REF} - 100mV$ and the voltage across R2 is higher than 4.5V.

With the hysteresis resistor it is possible to fix the input pin 12 hysteresis in order to increase immunity to the 100Hz ripple present on the supply voltage.

Moreover, the power fail and reset delay time are automatically locked to the soft-start. Soft-start and delayed reset are thus two sequential functions.

The hysteresis resistor should be in the range of about 100kΩ and the pull-up resistor of 1 to 2.2kΩ.

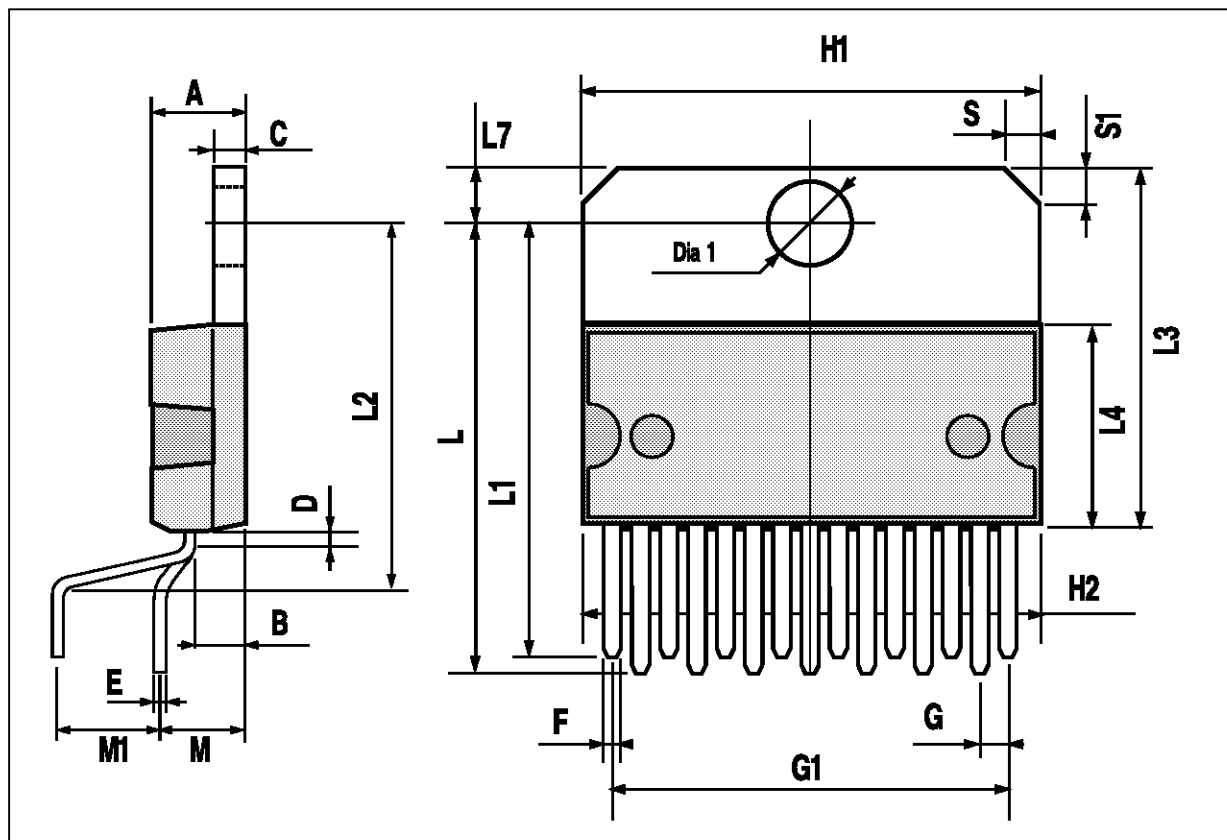
Figure 46



MULTIWATT15 VERTICAL PACKAGE MECHANICAL DATA

| Dimensions | Millimeters | | | Inches | | |
|------------|-------------|-------|-------|--------|-------|-------|
| | Min. | Typ. | Max. | Min. | Typ. | Max. |
| A | | | 5 | | | 0.197 |
| B | | | 2.65 | | | 0.104 |
| C | | | 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 |
| M | 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 |

MUL15V.TBL



PMUL15V.EPS

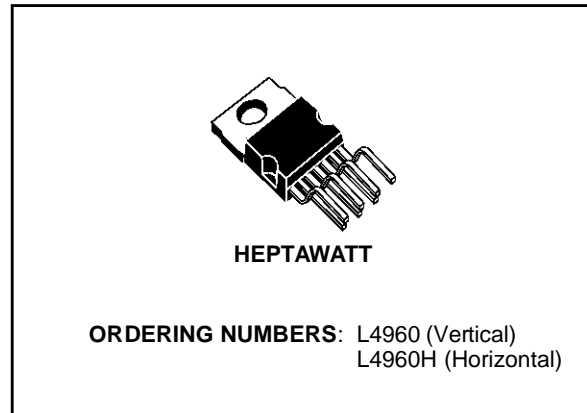
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2.5A POWER SWITCHING REGULATOR

- 2.5A OUTPUT CURRENT
- 5.1V TO 40V OPUTUT VOLTAGE RANGE
- PRECISE ($\pm 2\%$) ON-CHIP REFERENCE
- HIGH SWITCHING FREQUENCY
- VERY HIGH EFFICIENCY (UP TO 90%)
- VERY FEW EXTERNAL COMPONENTS
- SOFT START
- INTERNAL LIMITING CURRENT
- THERMAL SHUTDOWN

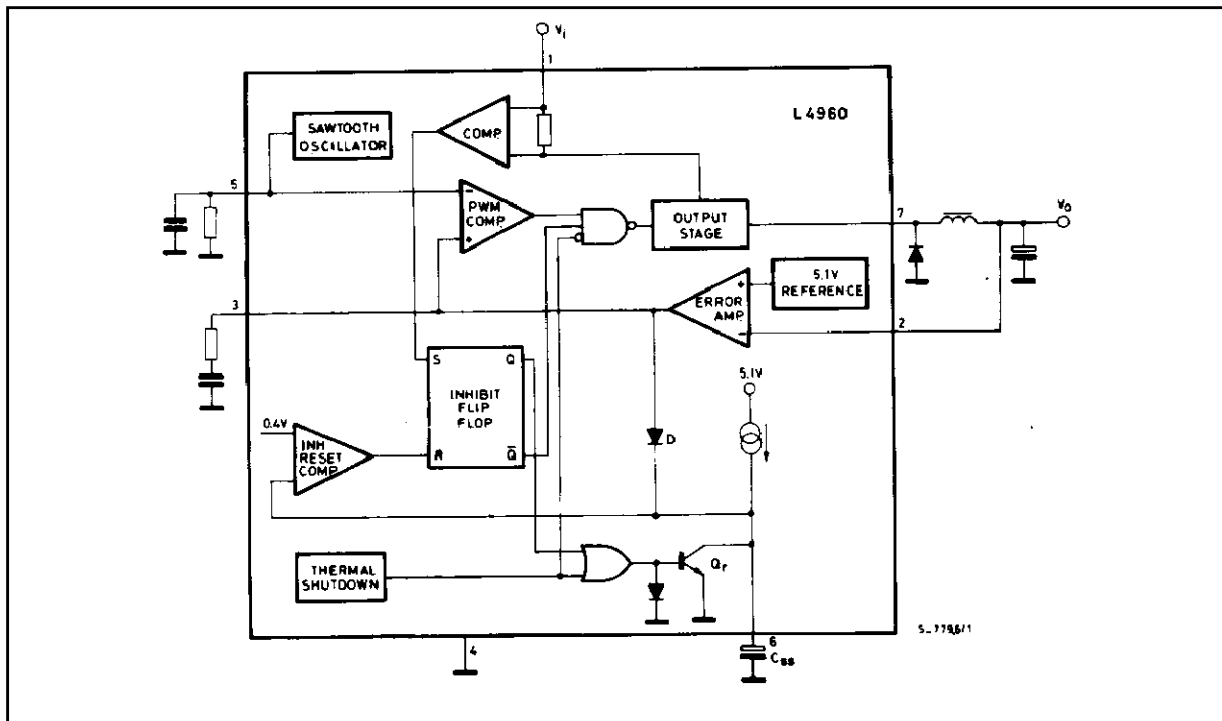


DESCRIPTION

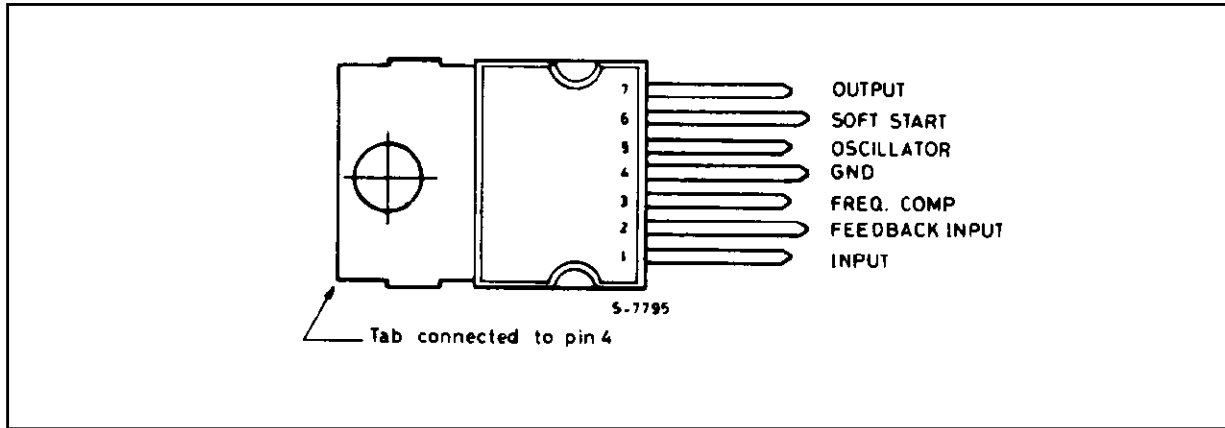
The L4960 is a monolithic power switching regulator delivering 2.5A at a voltage variable from 5V to 40V in step down configuration. Features of the device include current limiting, soft start, thermal protection and 0 to 100% duty cycle for continuous operation mode.

The L4960 is mounted in a Heptawatt plastic power package and requires very few external components. Efficient operation at switching frequencies up to 150KHz allows a reduction in the size and cost of external filter components.

BLOCK DIAGRAM



PIN CONNECTION (Top view)



ABSOLUTE MAXIMUM RATINGS

| Symbol | Parameter | Value | Unit |
|----------------|---|------------|------------|
| V_1 | Input voltage | 50 | V |
| $V_1 - V_7$ | Input to output voltage difference | 50 | V |
| V_7 | Negative output DC voltage | -1 | V |
| | Negative output peak voltage at $t = 0.1\mu s$; $f = 100KHz$ | -5 | V |
| V_3, V_6 | Voltage at pin 3 and 6 | 5.5 | V |
| V_2 | Voltage at pin 2 | 7 | V |
| I_3 | Pin 3 sink current | 1 | mA |
| I_5 | Pin 5 source current | 20 | mA |
| P_{tot} | Power dissipation at $T_{case} \leq 90^\circ C$ | 15 | W |
| T_j, T_{stg} | Junction and storage temperature | -40 to 150 | $^\circ C$ |

PIN FUNCTIONS

| N° | NAME | FUNCTION |
|----|------------------------|--|
| 1 | SUPPLY VOLTAGE | Unregulated voltage input. An internal regulator powers the internal logic. |
| 2 | 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. |
| 3 | FREQUENCY COMPENSATION | A series RC network connected between this terminal and ground determines the regulation loop gain characteristics. |
| 4 | GROUND | Common ground terminal. |
| 5 | OSCILLATOR | A parallel RC network connected to this terminal determines the switching frequency. |
| 6 | 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. |
| 7 | OUTPUT | Regulator output. |

THERMAL DATA

| Symbol | Parameter | Value | Unit |
|------------------|-------------------------------------|--------|------|
| $R_{th\ j-case}$ | Thermal resistance junction-case | max 4 | °C/W |
| $R_{th\ j-amb}$ | Thermal resistance junction-ambient | max 50 | °C/W |

ELECTRICAL CHARACTERISTICS (Refer to the test circuit, $T_j = 25\text{ °C}$, $V_i = 35V$, unless otherwise specified)

| Symbol | Parameter | Test Conditions | Min. | Typ. | Max. | Unit |
|--------|-----------|-----------------|------|------|------|------|
|--------|-----------|-----------------|------|------|------|------|

DYNAMIC CHARACTERISTICS

| | | | | | | |
|-----------------------------------|--|--|-----------------|-----|-----|-------|
| V_o | Output voltage range | $V_i = 46V$ $I_o = 1A$ | V_{ref} | | 40 | V |
| V_i | Input voltage range | $V_o = V_{ref}$ to 36V $I_o = 2.5A$ | 9 | | 46 | V |
| ΔV_o | Line regulation | $V_i = 10V$ to 40V $V_o = V_{ref}$ $I_o = 1A$ | | 15 | 50 | mV |
| ΔV_o | Load regulation | $V_o = V_{ref}$ $I_o = 0.5A$ to 2A | | 10 | 30 | mV |
| V_{ref} | Internal reference voltage (pin 2) | $V_i = 9V$ to 46V $I_o = 1A$ | 5 | 5.1 | 5.2 | V |
| $\frac{\Delta V_{ref}}{\Delta T}$ | Average temperature coefficient of refer voltage | $T_j = 0\text{°C}$ to 125°C $I_o = 1A$ | | 0.4 | | mV/°C |
| V_d | Dropout voltage | $I_o = 2A$ | | 1.4 | 3 | V |
| I_{om} | Maximum operating load current | $V_i = 9V$ to 46V $V_o = V_{ref}$ to 36V | 2.5 | | | A |
| I_{7L} | Current limiting threshold (pin 7) | $V_i = 9V$ to 46V $V_o = V_{ref}$ to 36V | 3 | | 4.5 | A |
| I_{SH} | Input average current | $V_i = 46V$; output short-circuit | | 30 | 60 | mA |
| η | Efficiency | $f = 100KHz$ | $V_o = V_{ref}$ | | 75 | % |
| | | $I_o = 2A$ | $V_o = 12V$ | | 85 | % |
| SVR | Supply voltage ripple rejection | $\Delta V_i = 2V_{rms}$ fripple = 100Hz $V_o = V_{ref}$ $I_o = 1A$ | 50 | 56 | | dB |
| f | Switching frequency | | 85 | 100 | 115 | KHz |
| $\frac{\Delta f}{\Delta V_i}$ | Voltage stability of switching frequency | $V_i = 9V$ to 46V | | 0.5 | | % |
| $\frac{\Delta f}{\Delta T_j}$ | Temperature stability of switching frequency | $T_j = 0\text{°C}$ to 125°C | | 1 | | % |
| f_{max} | Maximum operating switching frequency | $V_o = V_{ref}$ $I_o = 2A$ | 120 | 150 | | KHz |
| T_{sd} | Thermal shutdown junction temperature | | | 150 | | °C |

ELECTRICAL CHARACTERISTICS (continued)

| Symbol | Parameter | Test Conditions | Min. | Typ. | Max. | Unit |
|--------|-----------|-----------------|------|------|------|------|
|--------|-----------|-----------------|------|------|------|------|

DC CHARACTERISTICS

| | | | | | | | |
|------------------|-------------------------|--------------------------------------|----------------------|--|----|----|----|
| I _{IQ} | Quiescent drain current | 100% duty cycle pins 5 and 7 open | V _i = 46V | | 30 | 40 | mA |
| | | 0% duty cycle | | | 15 | 20 | mA |
| -I _{7L} | Output leakage current | 0% duty cycle | | | | 1 | mA |

SOFT START

| | | | | | | |
|------------------|----------------|--|-----|-----|-----|----|
| I _{6SO} | Source current | | 100 | 140 | 180 | μA |
| I _{6SI} | Sink current | | 50 | 70 | 120 | μA |

ERROR AMPLIFIER

| | | | | | | | |
|-------------------|---------------------------|---------------------------|------------------------|-----|-----|-----|----|
| V _{3H} | High level output voltage | V ₂ = 4.7V | I ₃ = 100μA | 3.5 | | | V |
| V _{3L} | Low level output voltage | V ₂ = 5.3V | I ₃ = 100μA | | | 0.5 | V |
| I _{3SI} | Sink output current | V ₂ = 5.3V | | 100 | 150 | | μA |
| -I _{3SO} | Source output current | V ₂ = 4.7V | | 100 | 150 | | μA |
| I ₂ | Input bias current | V ₂ = 5.2V | | | 2 | 10 | μA |
| G _v | DC open loop gain | V ₃ = 1V to 3V | | 46 | 55 | | dB |

OSCILLATOR

| | | | | | | |
|-----------------|---------------------------|--|---|--|--|----|
| -I ₅ | Oscillator source current | | 5 | | | mA |
|-----------------|---------------------------|--|---|--|--|----|

CIRCUIT OPERATION (refer to the block diagram)

The L4960 is a monolithic stepdown switching regulator providing output voltages from 5.1V to 40V and delivering 2.5A.

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 $\pm 2\%$).

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

Figure 1. Soft start waveforms

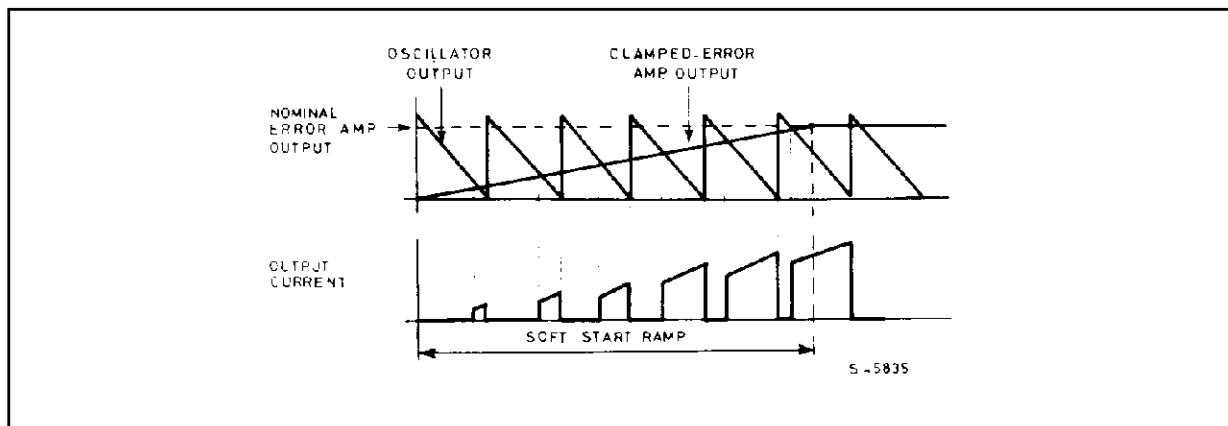


Figure 2. Current limiter waveforms

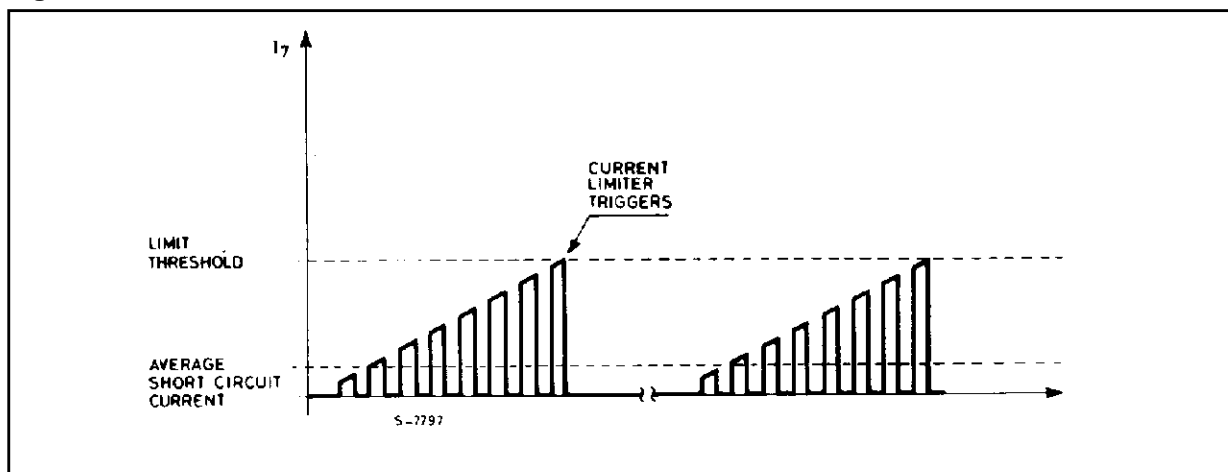


Figure 3. Test and application circuit

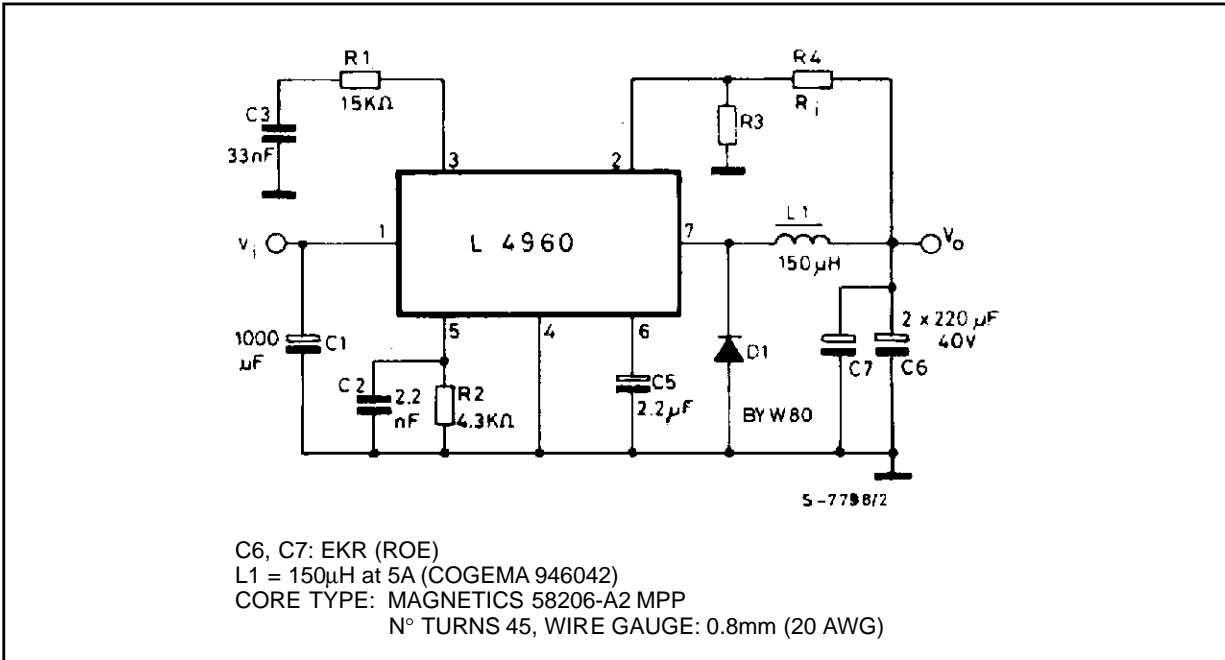


Figure 4. Quiescent drain current vs. supply voltage (0% duty cycle)

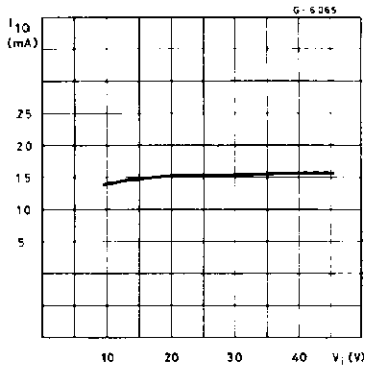


Figure 5. Quiescent drain current vs. supply voltage (100% duty cycle)

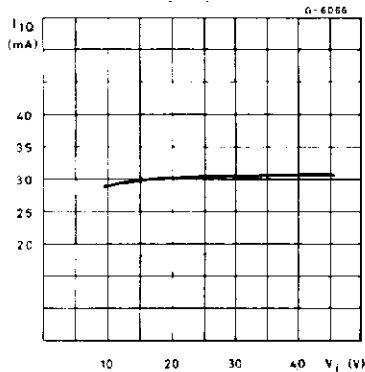


Figure 6. Quiescent drain current vs. junction temperature (0% duty cycle)

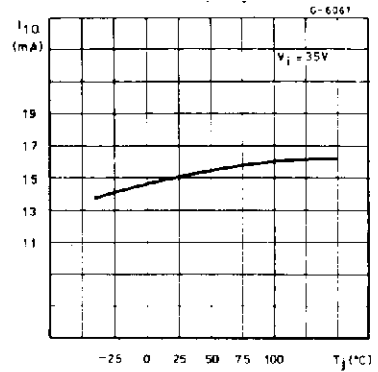


Figure 7. Quiescent drain current vs. junction temperature (100% duty cycle)

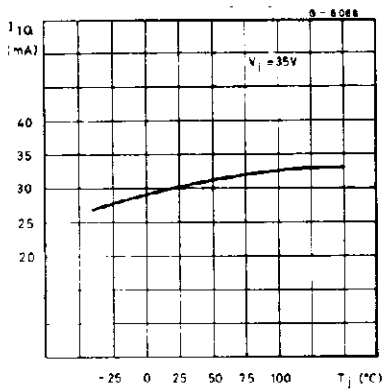


Figure 8. Reference voltage (pin 2) vs. V_i

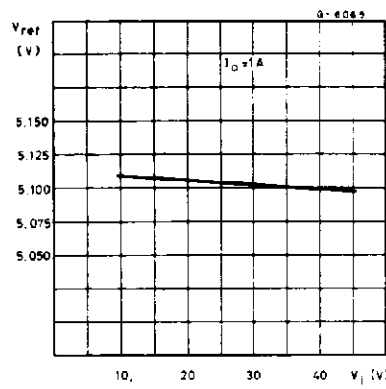


Figure 9. Reference voltage versus junction temperature (pin 2)

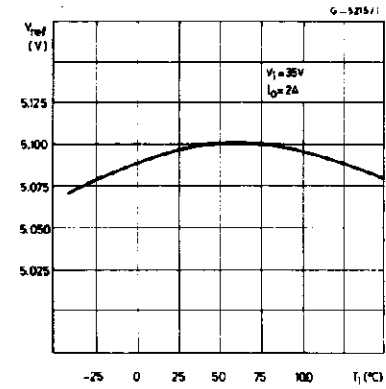


Figure 10. Open loop frequency and phase response of error amplifier

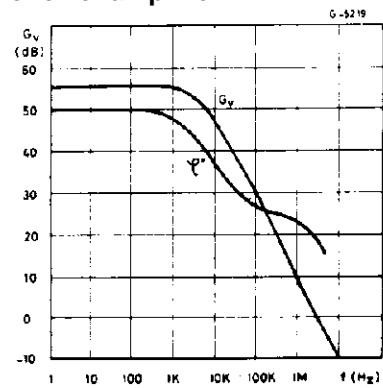


Figure 11. Switching frequency vs. input voltage

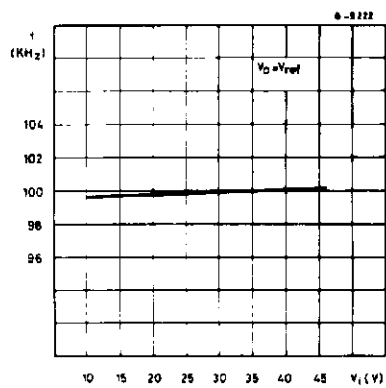


Figure 12. Switching frequency vs. junction temperature

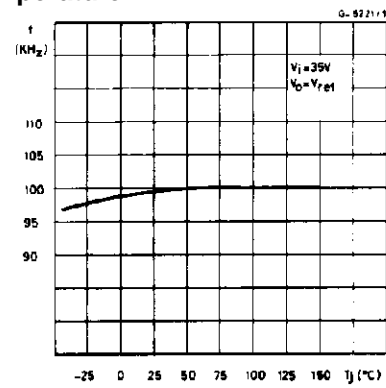


Figure 13. Switching frequency vs. R2 (see test circuit)

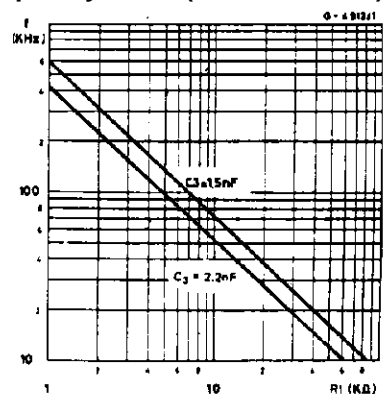


Figure 14. Line transient response

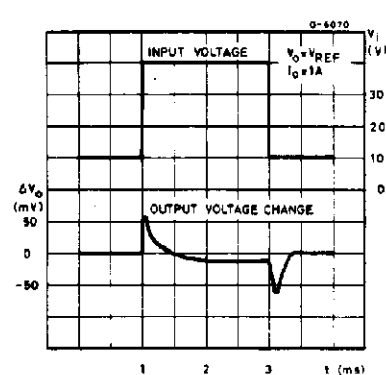


Figure 15. Load transient response

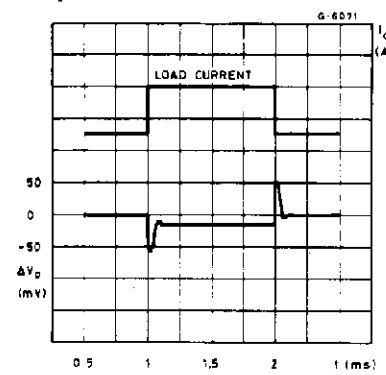


Figure 16. Supply voltage ripple rejection vs. frequency

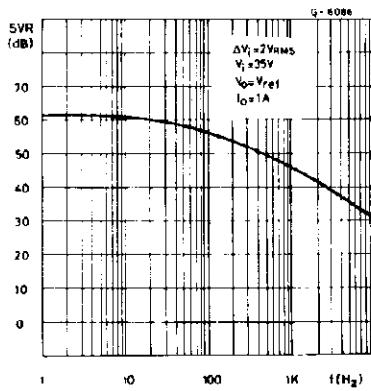


Figure 17. Dropout voltage between pin 1 and pin 7 vs. current at pin 7

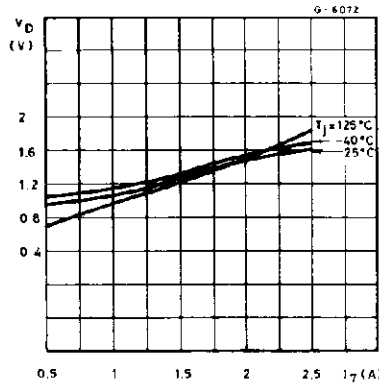


Figure 18. Dropout voltage between pin 1 and 7 vs. junction temperature

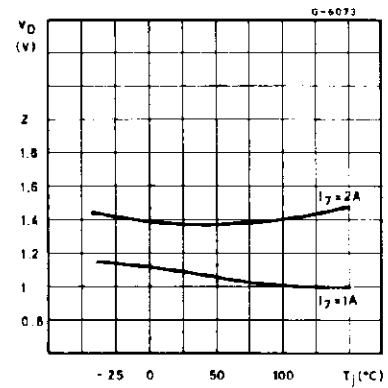


Figure 19. Power dissipation derating curve

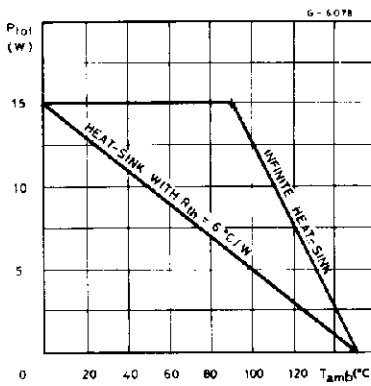


Figure 20. Efficiency vs. output current

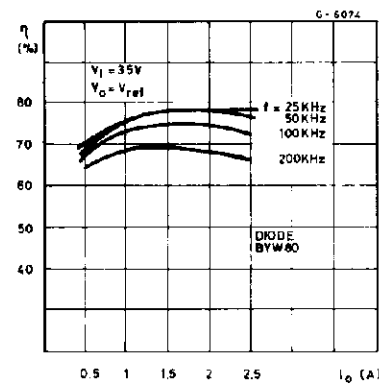


Figure 21. Efficiency vs. output current

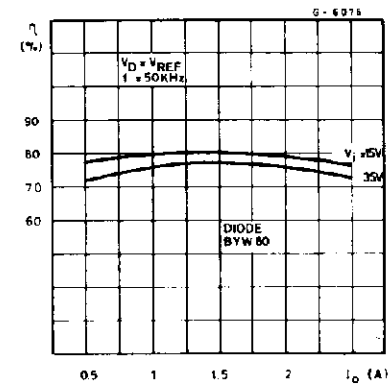


Figure 22. Efficiency vs. output current

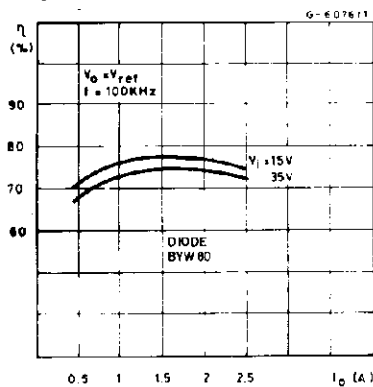
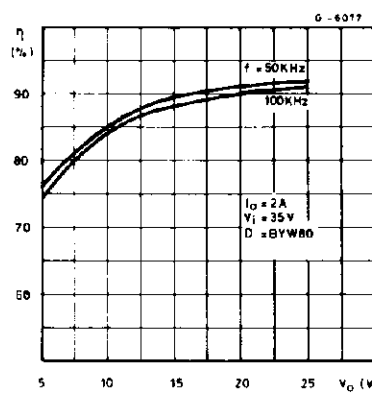


Figure 23. Efficiency vs. output voltage



APPLICATION INFORMATION

Figure 24. Typical application circuit

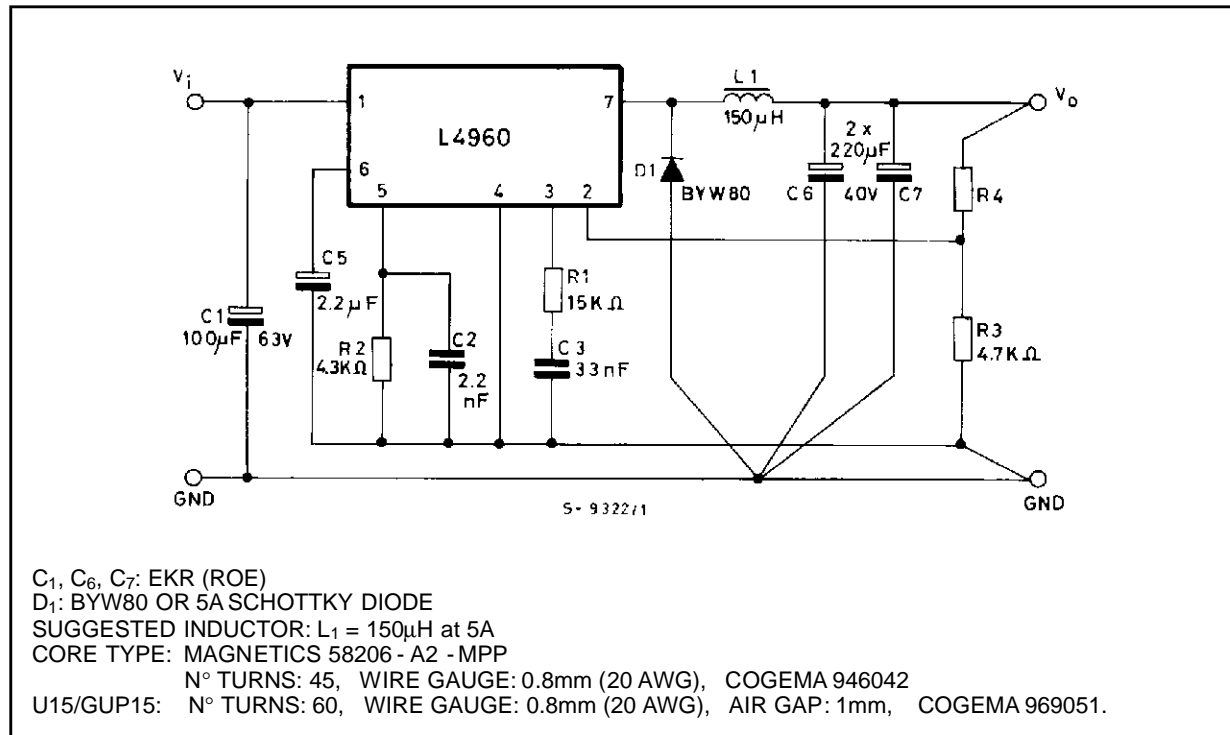
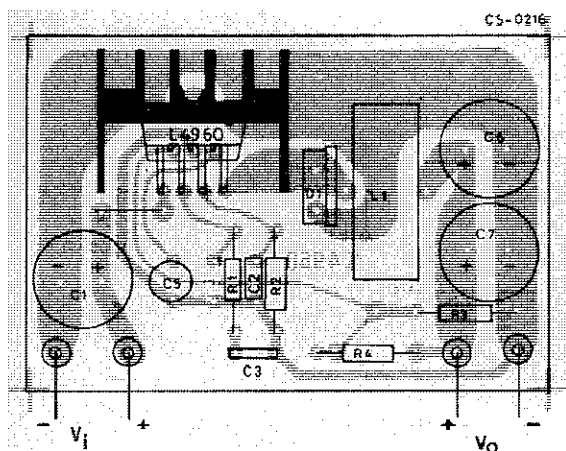


Figure 25. P.C. board and component layout of the Fig. 24 (1 : 1 scale)



| Resistor values for standard output voltages | | |
|--|-------|-------|
| V _o | R3 | R4 |
| 12V | 4.7KΩ | 6.2KΩ |
| 15V | 4.7KΩ | 9.1KΩ |
| 18V | 4.7KΩ | 12KΩ |
| 24V | 4.7KΩ | 18KΩ |

APPLICATION INFORMATION

Figure 26. A minimal 5.1V fixed regulator; Very few component are required

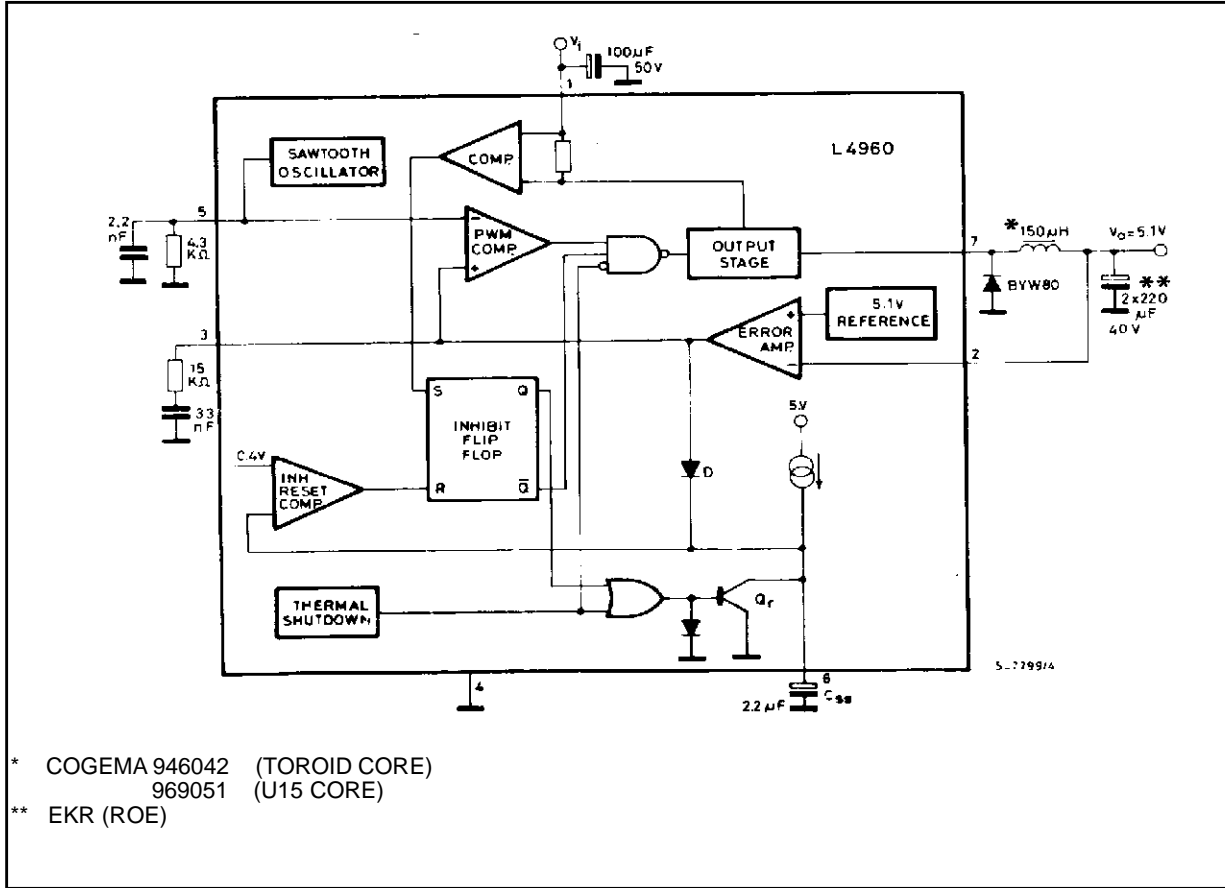
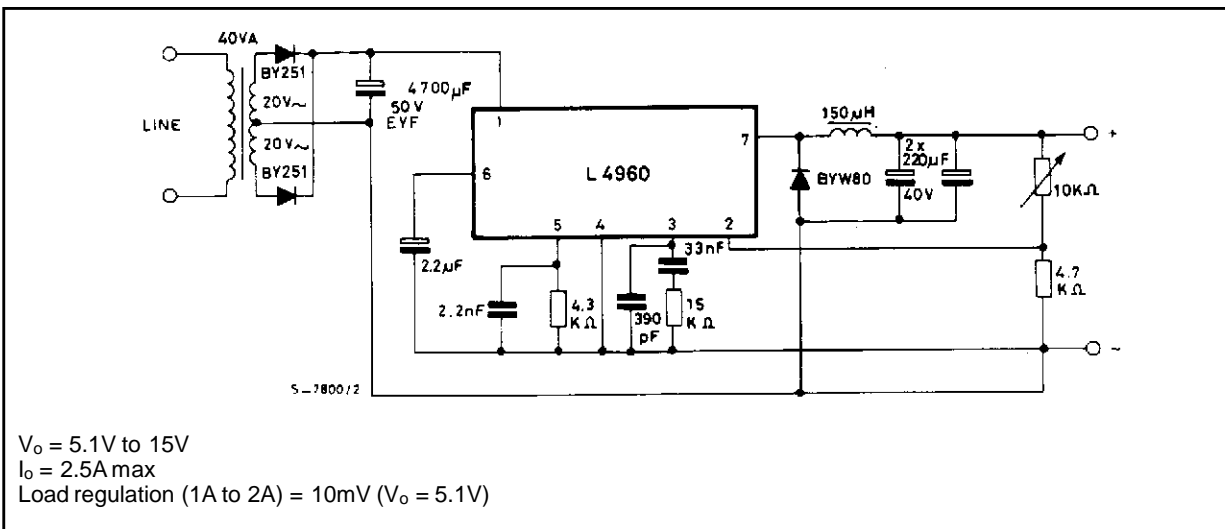
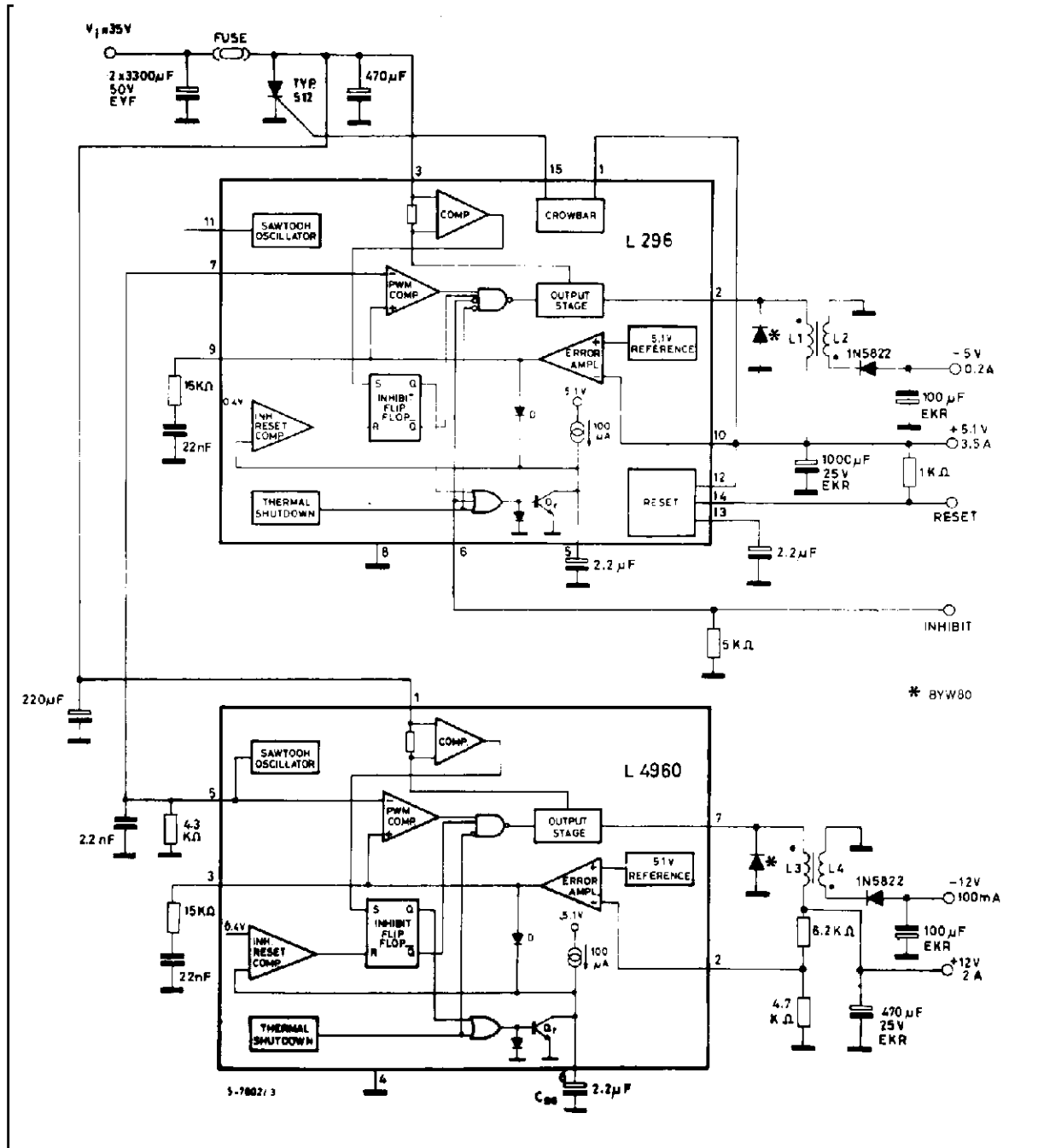


Figure 27. Programmable power supply



APPLICATION INFORMATION (continued)

Figure 28. Microcomputer supply with + 5.1V, -5V, +12V and -12V outputs



APPLICATION INFORMATION (continued)

Figure 29. DC-DC converter 5.1V/4A, ± 12V/2.5A; a suggestion how to synchronize a negative output

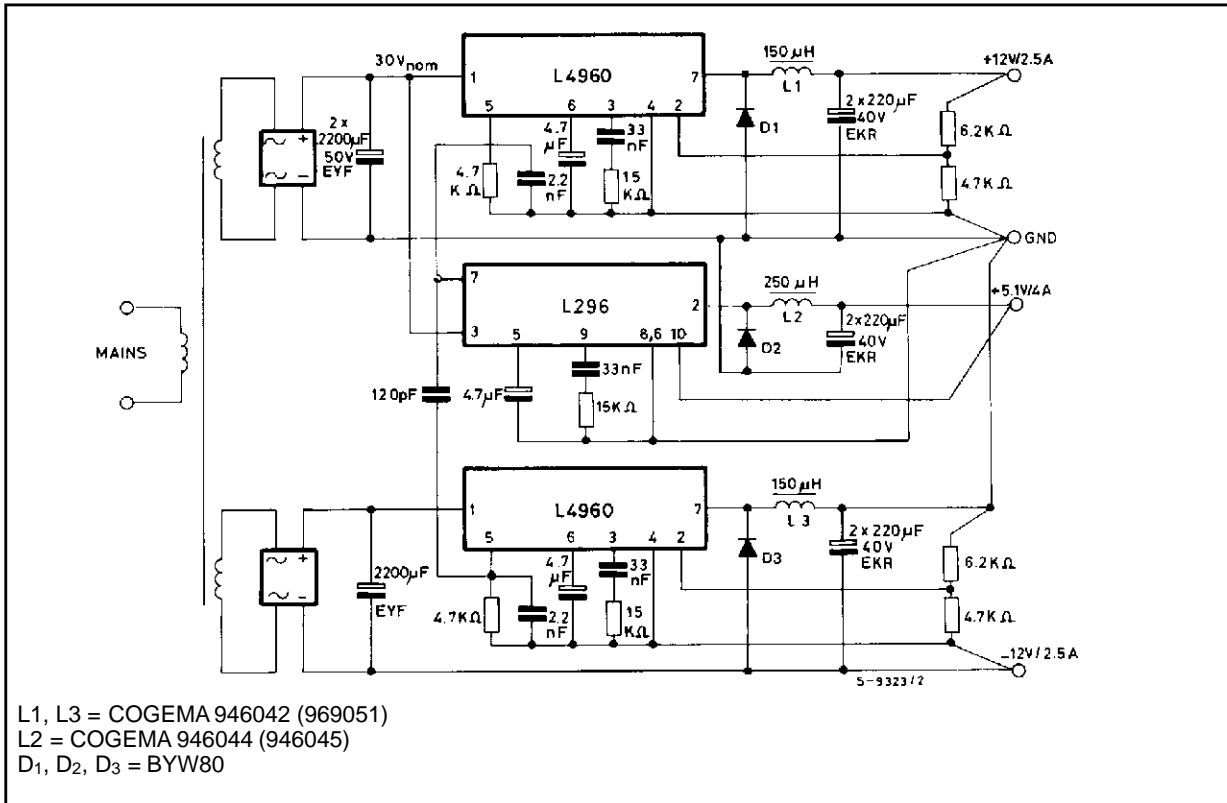
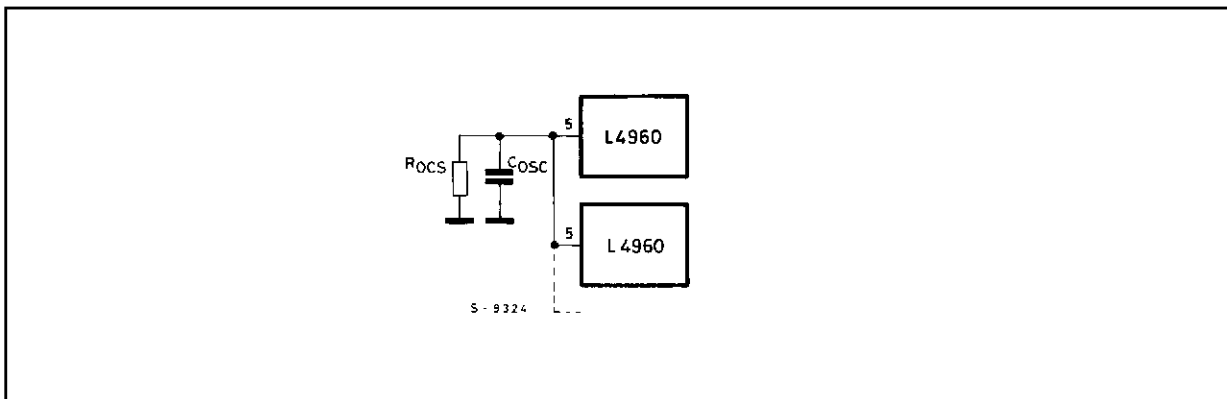
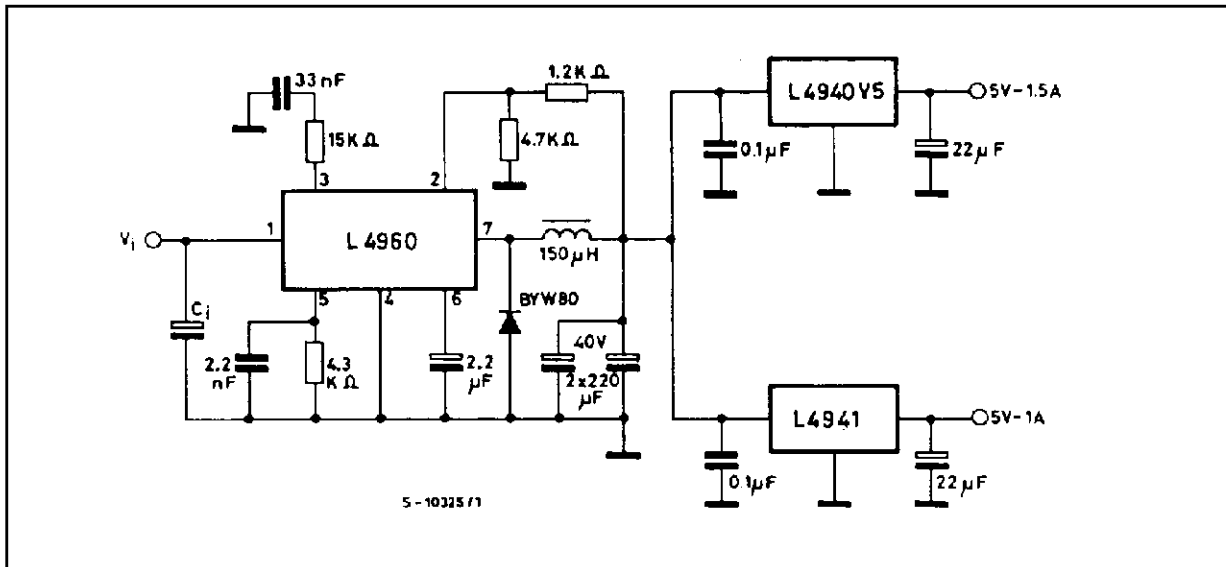


Figure 30. - In multiple supplies several L4960s can be synchronized as shown



APPLICATION INFORMATION (continued)

Figure 31. Regulator for distributed supplies

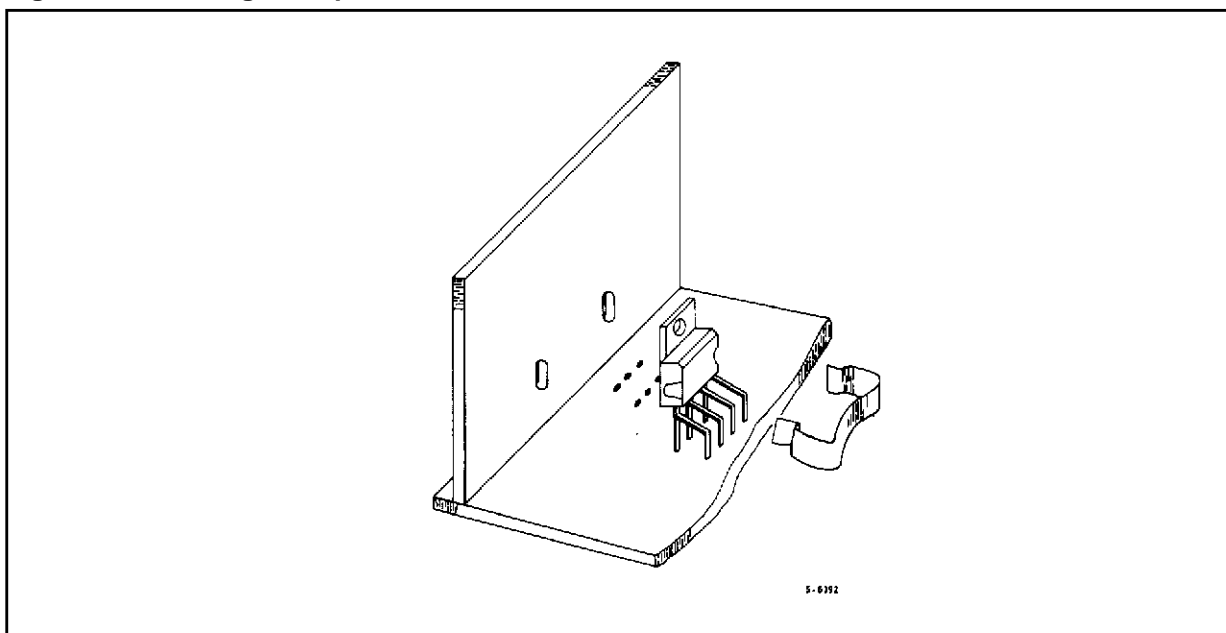


MOUNTING INSTRUCTION

The power dissipated in the circuit must be removed by adding an external heatsink. Thanks to the Heptawatt package attaching the heatsink is very simple, a screw or a compression spring (clip) being sufficient. Between the heatsink

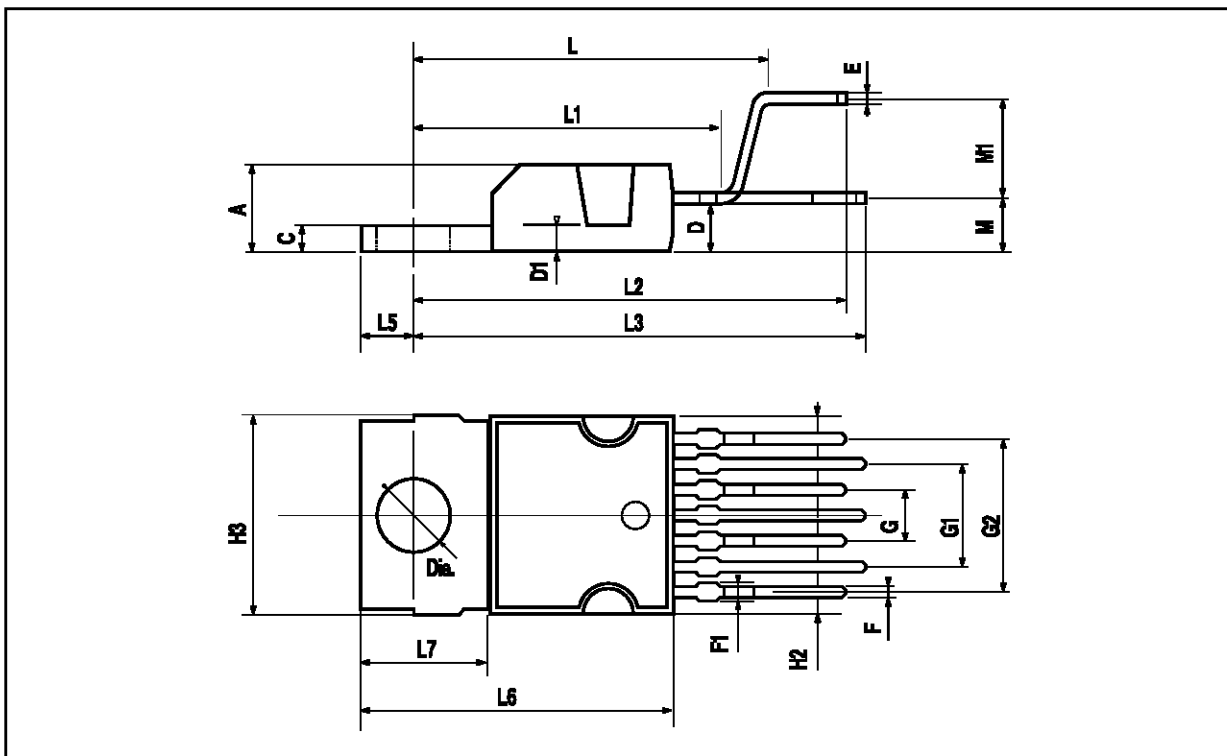
and the package it is better to insert a layer of silicon grease, to optimize the thermal contact, no electrical isolation is needed between the two surfaces.

Figure 32. Mounting example



HEPTAWATT PACKAGE MECHANICAL DATA

| DIM. | mm | | | inch | | |
|------|-------|-------|------|-------|-------|-------|
| | MIN. | TYP. | MAX. | MIN. | TYP. | MAX. |
| A | | | 4.8 | | | 0.189 |
| C | | | 1.37 | | | 0.054 |
| D | 2.4 | | 2.8 | 0.094 | | 0.110 |
| D1 | 1.2 | | 1.35 | 0.047 | | 0.053 |
| E | 0.35 | | 0.55 | 0.014 | | 0.022 |
| F | 0.6 | | 0.8 | 0.024 | | 0.031 |
| F1 | | | 0.9 | | | 0.035 |
| G | 2.41 | 2.54 | 2.67 | 0.095 | 0.100 | 0.105 |
| G1 | 4.91 | 5.08 | 5.21 | 0.193 | 0.200 | 0.205 |
| G2 | 7.49 | 7.62 | 7.8 | 0.295 | 0.300 | 0.307 |
| H2 | | | 10.4 | | | 0.409 |
| H3 | 10.05 | | 10.4 | 0.396 | | 0.409 |
| L | | 16.97 | | | 0.668 | |
| L1 | | 14.92 | | | 0.587 | |
| L2 | | 21.54 | | | 0.848 | |
| L3 | | 22.62 | | | 0.891 | |
| L5 | 2.6 | | 3 | 0.102 | | 0.118 |
| L6 | 15.1 | | 15.8 | 0.594 | | 0.622 |
| L7 | 6 | | 6.6 | 0.236 | | 0.260 |
| M | | 2.8 | | | 0.110 | |
| M1 | | 5.08 | | | 0.200 | |
| Dia | 3.65 | | 3.85 | 0.144 | | 0.152 |



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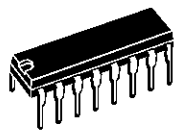
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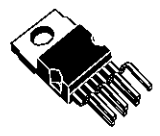
Australia - Brazil - France - Germany - Hong Kong - Italy - Japan - Korea - Malaysia - Malta - Morocco - The Netherlands - Singapore - Spain - Sweden - Switzerland - Taiwan - Thailand - United Kingdom - U.S.A.

1.5A POWER SWITCHING REGULATOR

- 1.5A OUTPUT CURRENT
- 5.1V TO 40V OUTPUT VOLTAGE RANGE
- PRECISE ($\pm 2\%$) ON-CHIP REFERENCE
- HIGH SWITCHING FREQUENCY
- VERY HIGH EFFICIENCY (UP TO 90%)
- VERY FEW EXTERNAL COMPONENTS
- SOFT START
- INTERNAL LIMITING CURRENT
- THERMAL SHUTDOWN



POWERDIP
(12 + 2 + 2)



HEPTAWATT

ORDERING NUMBERS : L4962/A (12 + 2 + 2 Powerdip)
L4962E/A (Heptawatt)
L4962EH/A (Horizontal Heptawatt)

DESCRIPTION

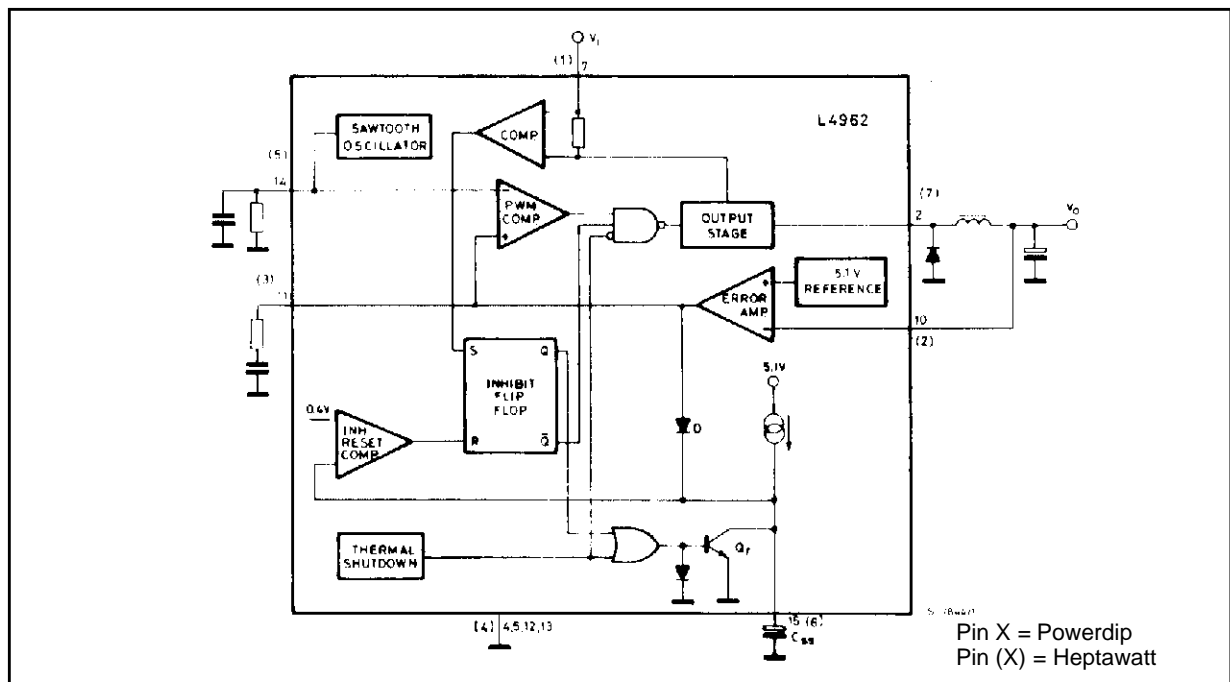
The L4962 is a monolithic power switching regulator delivering 1.5A at a voltage variable from 5V to 40V in step down configuration.

Features of the device include current limiting, soft start, thermal protection and 0 to 100% duty cycle for continuous operating mode.

The L4962 is mounted in a 16-lead Powerdip plastic package and Heptawatt package and requires very few external components.

Efficient operation at switching frequencies up to 150KHz allows a reduction in the size and cost of external filter components.

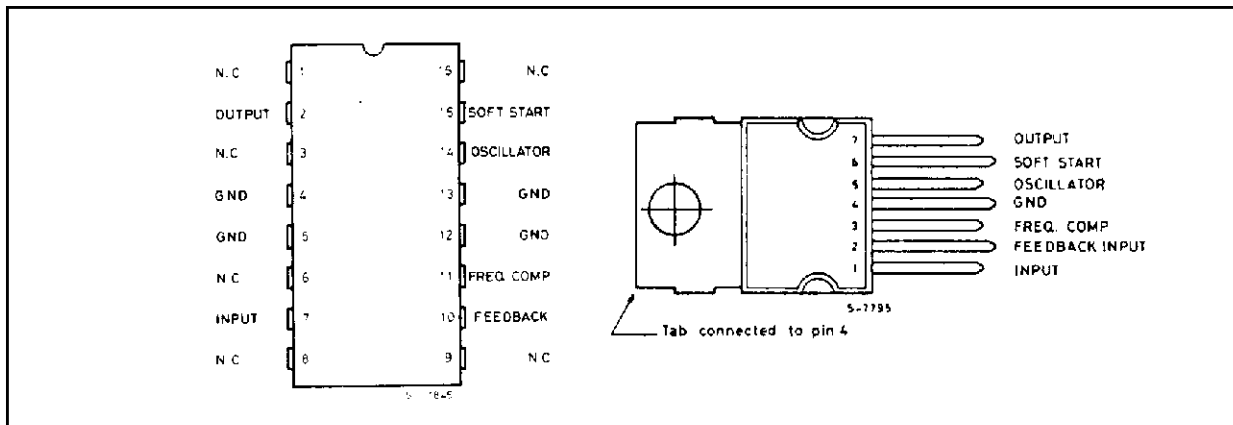
BLOCK DIAGRAM



ABSOLUTE MAXIMUM RATINGS

| Symbol | Parameter | Value | Unit |
|-----------------------------------|--|------------|------|
| V ₇ | Input voltage | 50 | V |
| V ₇ - V ₂ | Input to output voltage difference | 50 | V |
| V ₂ | Negative output DC voltage | -1 | V |
| | Output peak voltage at t = 0.1μs; f = 100KHz | -5 | V |
| V ₁₁ , V ₁₅ | Voltage at pin 11, 15 | 5.5 | V |
| V ₁₀ | Voltage at pin 10 | 7 | V |
| I ₁₁ | Pin 11 sink current | 1 | mA |
| I ₁₄ | Pin 14 source current | 20 | mA |
| P _{tot} | Power dissipation at T _{pins} ≤ 90°C (Powerdip) | 4.3 | W |
| | T _{case} ≤ 90°C (Heptawatt) | 15 | W |
| T _j , T _{stg} | Junction and storage temperature | -40 to 150 | °C |

PIN CONNECTION (Top view)



THERMAL DATA

| Symbol | Parameter | | Heptawatt | Powerdip |
|------------------------|-------------------------------------|-----|-----------|----------|
| R _{th j-case} | Thermal resistance junction-case | max | 4°C/W | - |
| R _{th j-pins} | Thermal resistance junction-pins | max | - | 14°C/W |
| R _{th j-amb} | Thermal resistance junction-ambient | max | 50°C/W | 80°C/W* |

* Obtained with the GND pins soldered to printed circuit with minimized copper area.

PIN FUNCTIONS

| HEPTAWATT | POWERDIP | NAME | FUNCTION |
|-----------|----------|------------------------|--|
| 1 | 7 | SUPPLY VOLTAGE | Unregulated voltage input. An internal regulator powers the internal logic. |
| 2 | 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. |
| 3 | 11 | FREQUENCY COMPENSATION | A series RC network connected between this terminal and ground determines the regulation loop gain characteristics. |

PIN FUNCTIONS (cont'd)

| HEPTAWATT | POWERDIP | NAME | FUNCTION |
|-----------|----------------------|------------|--|
| 4 | 4, 5, 12, 13 | GROUND | Common ground terminal. |
| 5 | 14 | 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. |
| 6 | 15 | 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. |
| 7 | 2 | OUTPUT | Regulator output. |
| | 1, 3, 6, 8, 9, 16 | | N.C. |

ELECTRICAL CHARACTERISTICS (Refer to the test circuit, $T_j = 25\text{ }^\circ\text{C}$, $V_i = 35\text{V}$, unless otherwise specified)

| Symbol | Parameter | Test Condition s | Min. | Typ. | Max. | Unit |
|--------|-----------|------------------|------|------|------|------|
|--------|-----------|------------------|------|------|------|------|

DYNAMIC CHARACTERISTICS

| | | | | | | | |
|-----------------------------------|---|---|-----------------------------------|-----------|-----|-----|----------------------|
| V_o | Output voltage range | $V_i = 46\text{V}$ | $I_o = 1\text{A}$ | V_{ref} | | 40 | V |
| V_i | Input voltage range | $V_o = V_{ref}$ to 36V | $I_o = 1.5\text{A}$ | 9 | | 46 | V |
| ΔV_o | Line regulation | $V_i = 10\text{V}$ to 40V | $V_o = V_{ref}$ $I_o = 1\text{A}$ | | 15 | 50 | mV |
| ΔV_o | Load regulation | $V_o = V_{ref}$ | $I_o = 0.5\text{A}$ to 1.5A | | 8 | 20 | mV |
| V_{ref} | Internal reference voltage (pin 10) | $V_i = 9\text{V}$ to 46V | $I_o = 1\text{A}$ | 5 | 5.1 | 5.2 | V |
| $\frac{\Delta V_{ref}}{\Delta T}$ | Average temperature coefficient of refer. voltage | $T_j = 0^\circ\text{C}$ to 125°C | $I_o = 1\text{A}$ | | 0.4 | | mV/ $^\circ\text{C}$ |
| V_d | Dropout voltage | $I_o = 1.5\text{A}$ | | | 1.5 | 2 | V |
| I_{om} | Maximum operating load current | $V_i = 9\text{V}$ to 46V $V_o = V_{ref}$ to 36V | | 1.5 | | | A |
| I_{2L} | Current limiting threshold (pin 2) | $V_i = 9\text{V}$ to 46V $V_o = V_{ref}$ to 36V | | 2 | | 3.3 | A |
| I_{SH} | Input average current | $V_i = 46\text{V}$; output short-circuit | | | 15 | 30 | mA |
| η | Efficiency | $f = 100\text{KHz}$ | $V_o = V_{ref}$ | | 70 | | % |
| | | $I_o = 1\text{A}$ | $V_o = 12\text{V}$ | | 80 | | % |
| SVR | Supply voltage ripple rejection | $\Delta V_i = 2V_{rms}$ fripple = 100Hz $V_o = V_{ref}$ | $I_o = 1\text{A}$ | 50 | 56 | | dB |

ELECTRICAL CHARACTERISTICS (continued)

| Symbol | Parameter | Test Conditions | Min. | Typ. | Max. | Unit |
|--------|-----------|-----------------|------|------|------|------|
|--------|-----------|-----------------|------|------|------|------|

DYNAMIC CHARACTERISTICS (cont'd)

| | | | | | | |
|-------------------------------|--|----------------------------------|-----|-----|-----|-----|
| f | Switching frequency | | 85 | 100 | 115 | KHz |
| $\frac{\Delta f}{\Delta V_i}$ | Voltage stability of switching frequency | $V_i = 9V$ to 46V | | 0.5 | | % |
| $\frac{\Delta f}{\Delta T_j}$ | Temperature stability of switching frequency | $T_j = 0^\circ\text{C}$ to 125°C | | 1 | | % |
| f _{max} | Maximum operating switching frequency | $V_o = V_{ref}$ $I_o = 1A$ | 120 | 150 | | KHz |
| T _{sd} | Thermal shutdown junction temperature | | | 150 | | °C |

DC CHARACTERISTICS

| | | | | | | | |
|------------------|-------------------------|---------------------------------------|-------------|--|----|----|----|
| I _{7Q} | Quiescent drain current | 100% duty cycle pins 2 and 14 open | $V_i = 46V$ | | 30 | 40 | mA |
| | | 0% duty cycle | | | 15 | 20 | mA |
| -I _{2L} | Output leakage current | 0% duty cycle | | | | 1 | mA |

SOFT START

| | | | | | | |
|-------------------|----------------|--|-----|-----|-----|----|
| I _{15SO} | Source current | | 100 | 140 | 180 | μA |
| I _{15SI} | Sink current | | 50 | 70 | 120 | μA |

ERROR AMPLIFIER

| | | | | | | |
|--------------------|---------------------------|-------------------------------------|-----|-----|-----|----|
| V _{11H} | High level output voltage | $V_{10} = 4.7V$ $I_{11} = 100\mu A$ | 3.5 | | | V |
| V _{11L} | Low level output voltage | $V_{10} = 5.3V$ $I_{11} = 100\mu A$ | | | 0.5 | V |
| I _{11SI} | Sink output current | $V_{10} = 5.3V$ | 100 | 150 | | μA |
| -I _{11SO} | Source output current | $V_{10} = 4.7V$ | 100 | 150 | | μA |
| I ₁₀ | Input bias current | $V_{10} = 5.2V$ | | 2 | 10 | μA |
| G _v | DC open loop gain | $V_{11} = 1V$ to 3V | 46 | 55 | | dB |

OSCILLATOR

| | | | | | | |
|------------------|---------------------------|--|---|--|--|----|
| -I ₁₄ | Oscillator source current | | 5 | | | mA |
|------------------|---------------------------|--|---|--|--|----|

CIRCUIT OPERATION (refer to the block diagram)

The L4962 is a monolithic stepdown switching regulator providing output voltages from 5.1V to 40V and delivering 1.5A.

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 $\pm 2\%$).

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

Figure 1. Soft start waveforms

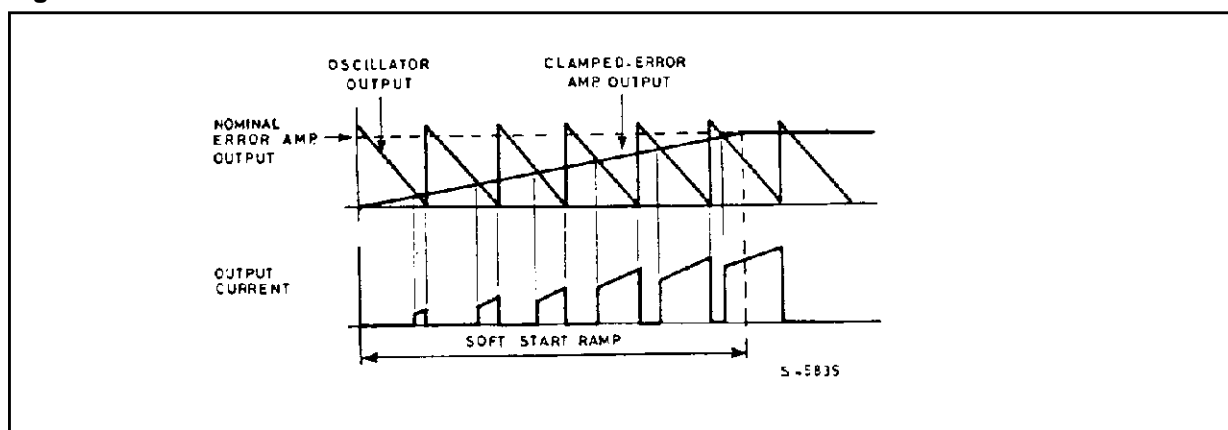


Figure 2. Current limiter waveforms

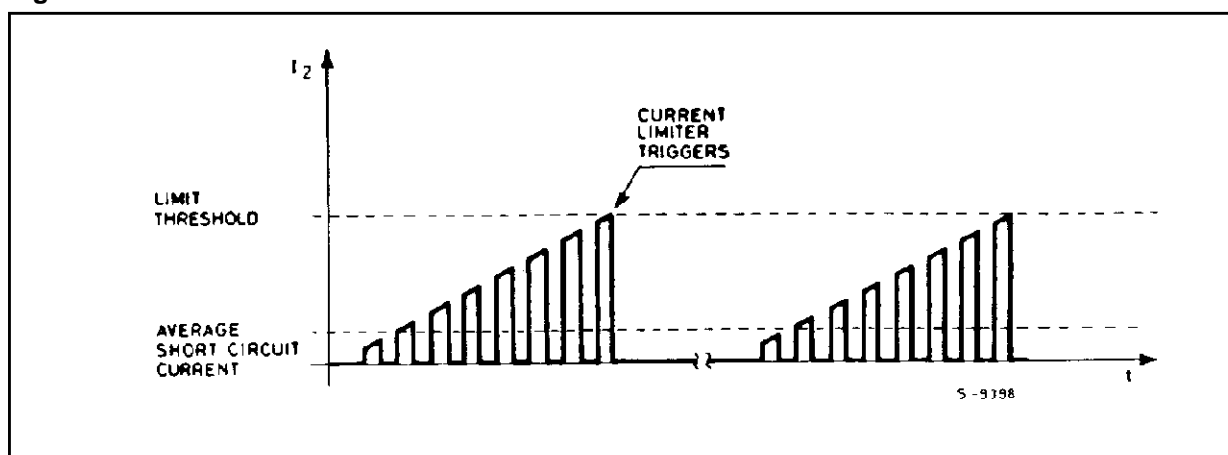


Figure 3. Test and application circuit (Powerdip)

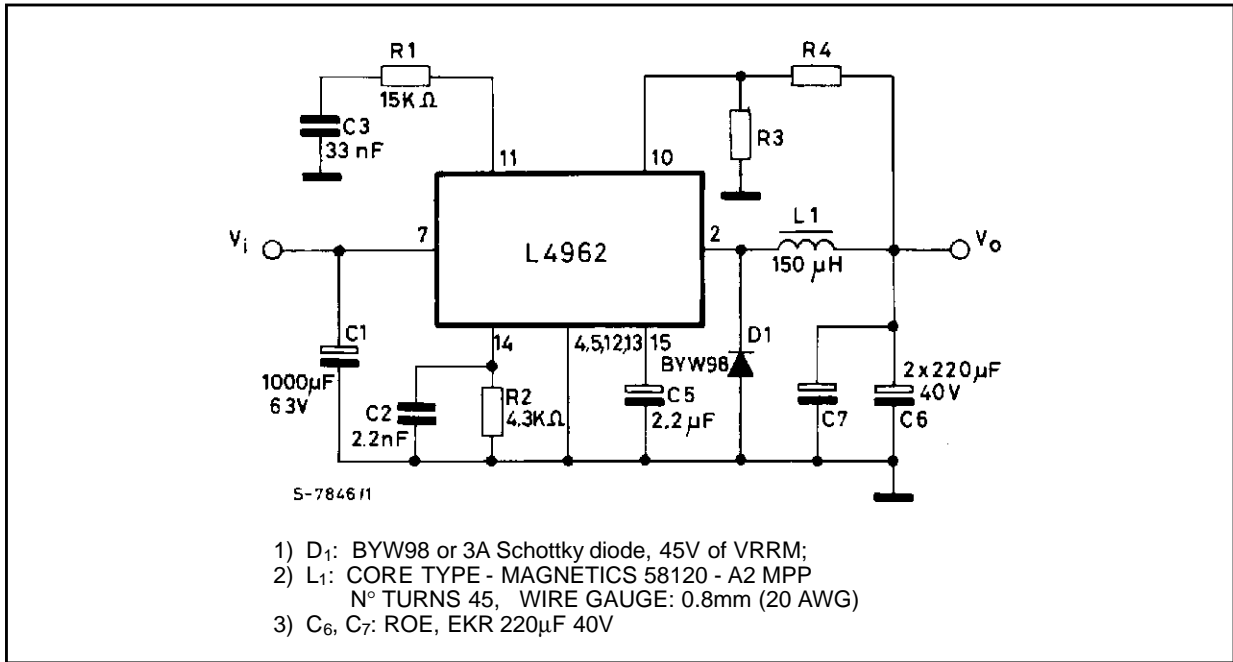


Figure 4. Quiescent drain current vs. supply voltage (0% duty cycle)

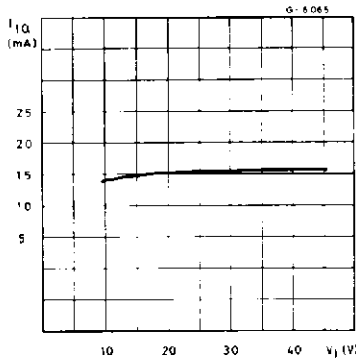


Figure 5. Quiescent drain current vs. supply voltage (100% duty cycle)

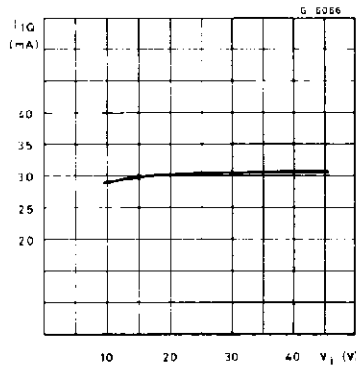


Figure 6. Quiescent drain current vs. junction temperature (0% duty cycle)

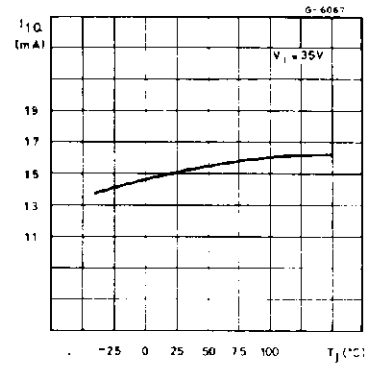


Figure 7. Quiescent drain current vs. junction temperature (100% duty cycle)

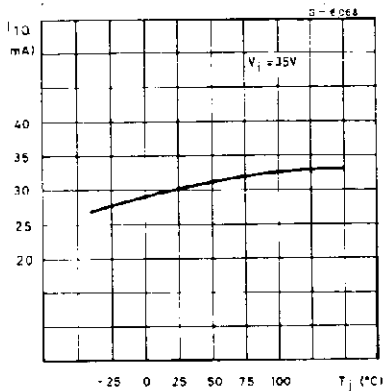


Figure 8. Reference voltage (pin 10) vs. V_i (rdip) vs. V_i

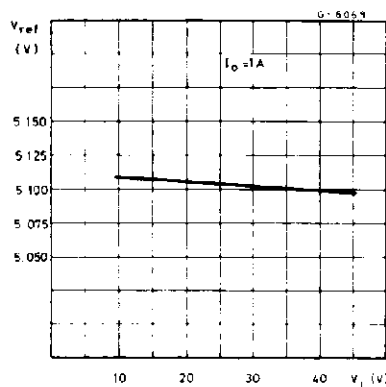


Figure 9. Reference voltage (pin 10) vs. junction temperature

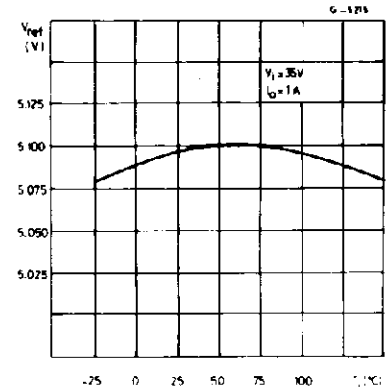


Figure 10. Open loop frequency and phase response of error amplifier

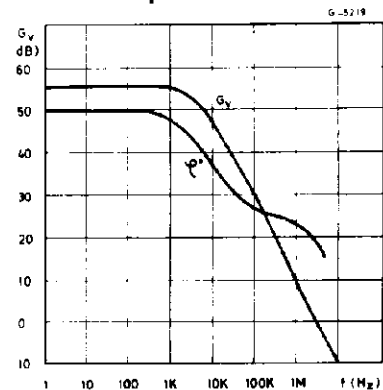


Figure 11. Switching frequency vs. input voltage

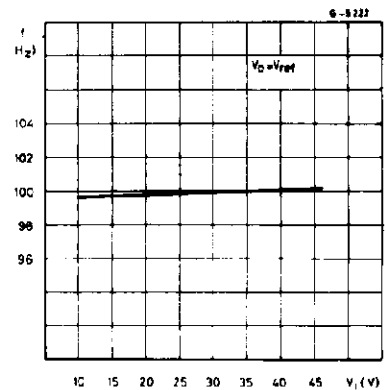


Figure 12. Switching frequency vs. junction temperature

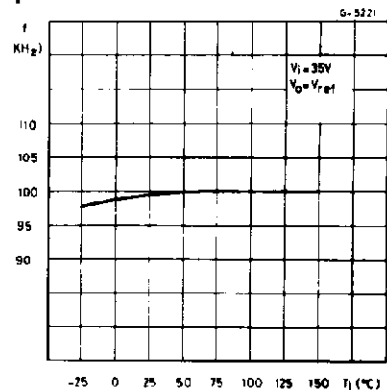


Figure 13. Switching frequency vs. R2 (see test circuit)

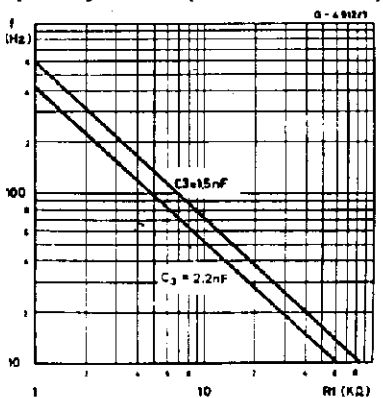


Figure 14. Line transient response

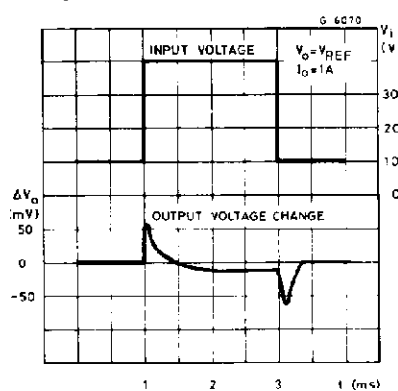


Figure 15. Load transient response

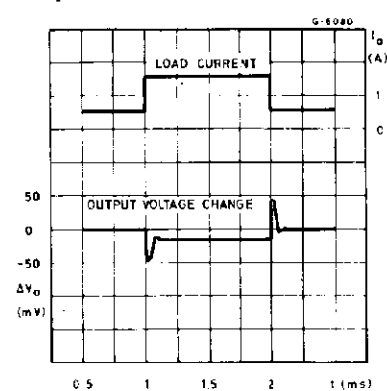


Figure 16. Supply voltage ripple rejection vs. frequency

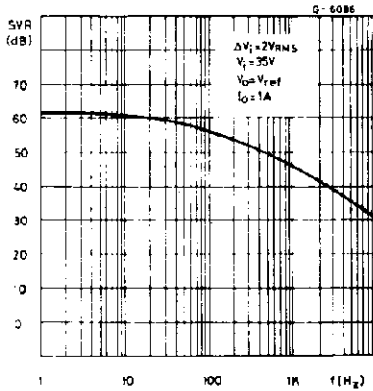


Figure 17. Dropout voltage between pin 7 and pin 2 vs. current at pin 2

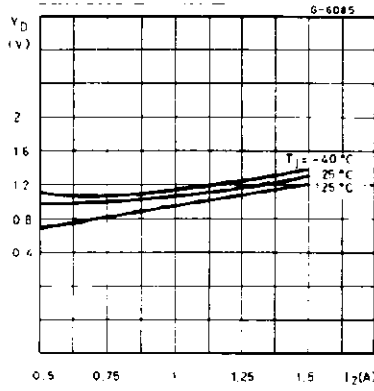


Figure 18. Dropout voltage between pin 7 and 2 vs. junction temperature

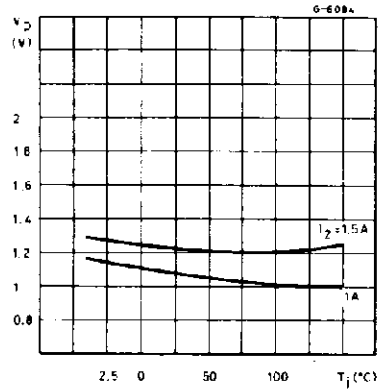


Figure 19. Efficiency vs. output current

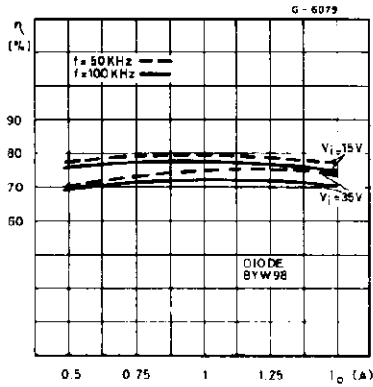


Figure 20. Efficiency vs. output current

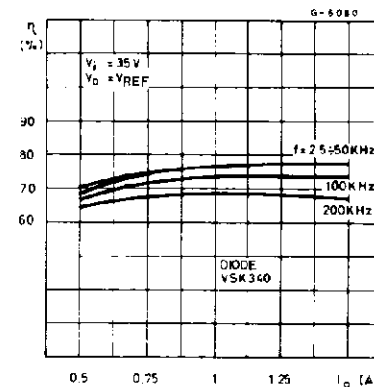


Figure 21. Efficiency vs. output current

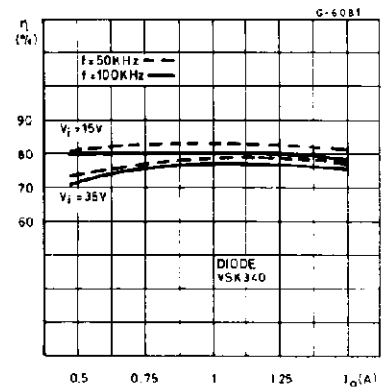


Figure 22. Efficiency vs. output voltage

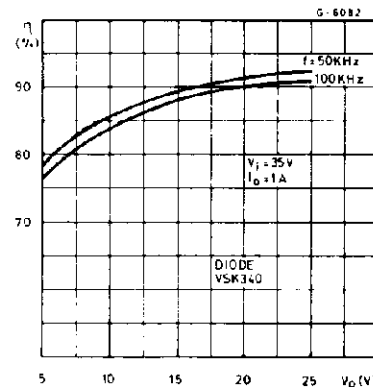


Figure 23. Efficiency vs. output voltage

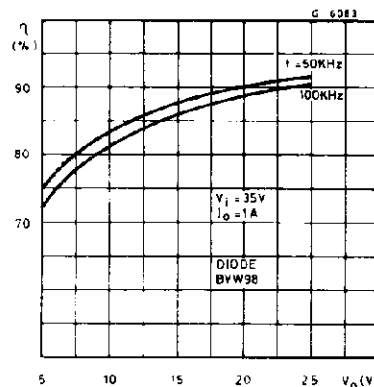
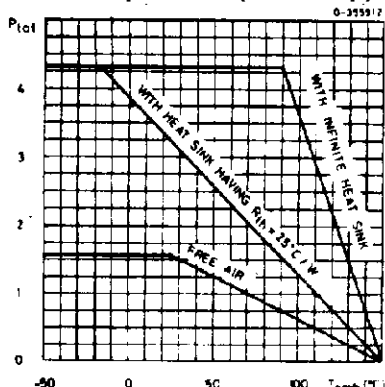


Figure 24. Maximum allowable power dissipation vs. ambient temperature (Powerdip)



APPLICATION INFORMATION

Figure 25. Typical application circuit

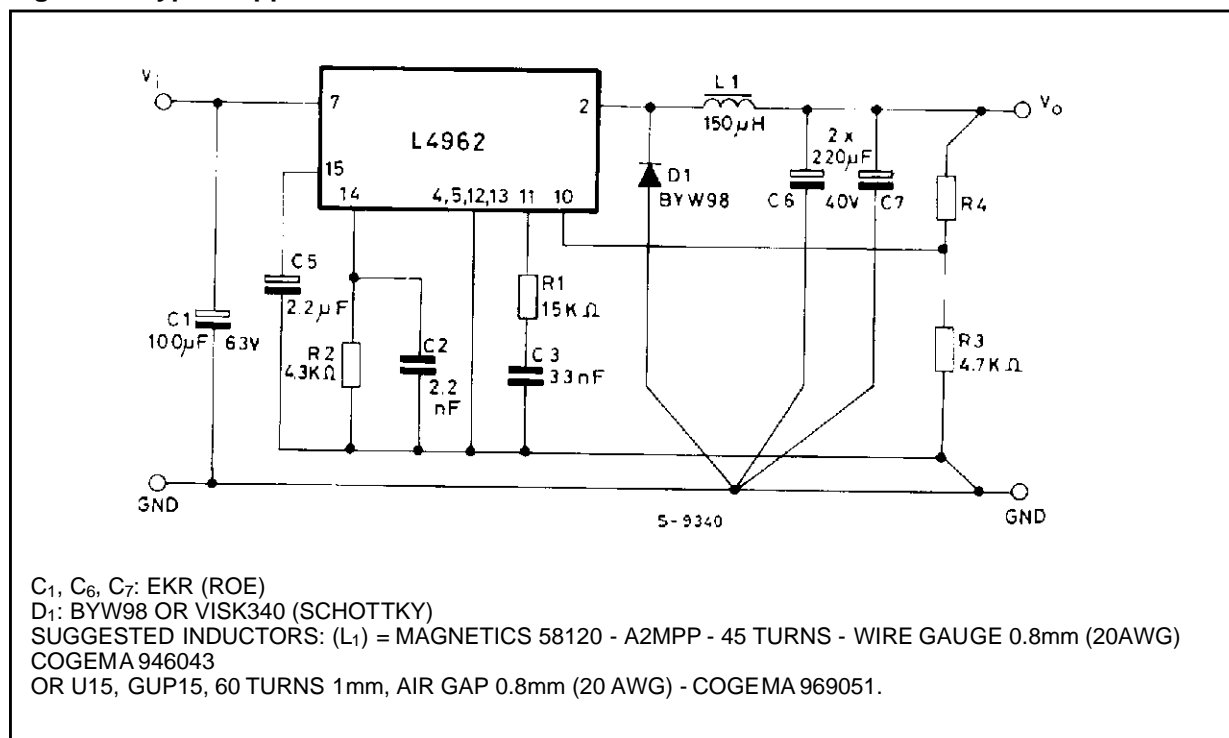
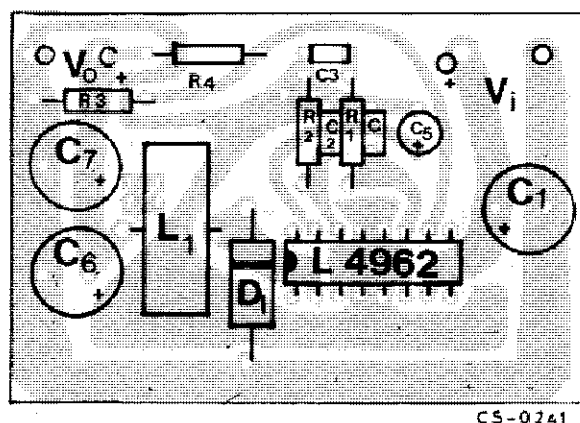


Figure 26. P.C. board and component layout of the circuit of Fig. 25 (1 : 1 scale)



| Resistor values for standard output 7 voltages | | |
|--|-------|-------|
| V _o | R3 | R4 |
| 12V | 4.7KΩ | 6.2KΩ |
| 15V | 4.7KΩ | 9.1KΩ |
| 18V | 4.7KΩ | 12KΩ |
| 24V | 4.7KΩ | 18KΩ |

APPLICATION INFORMATION (continued)

Figure 27. - A minimal 5.1V fixed regulator; Very few component are required

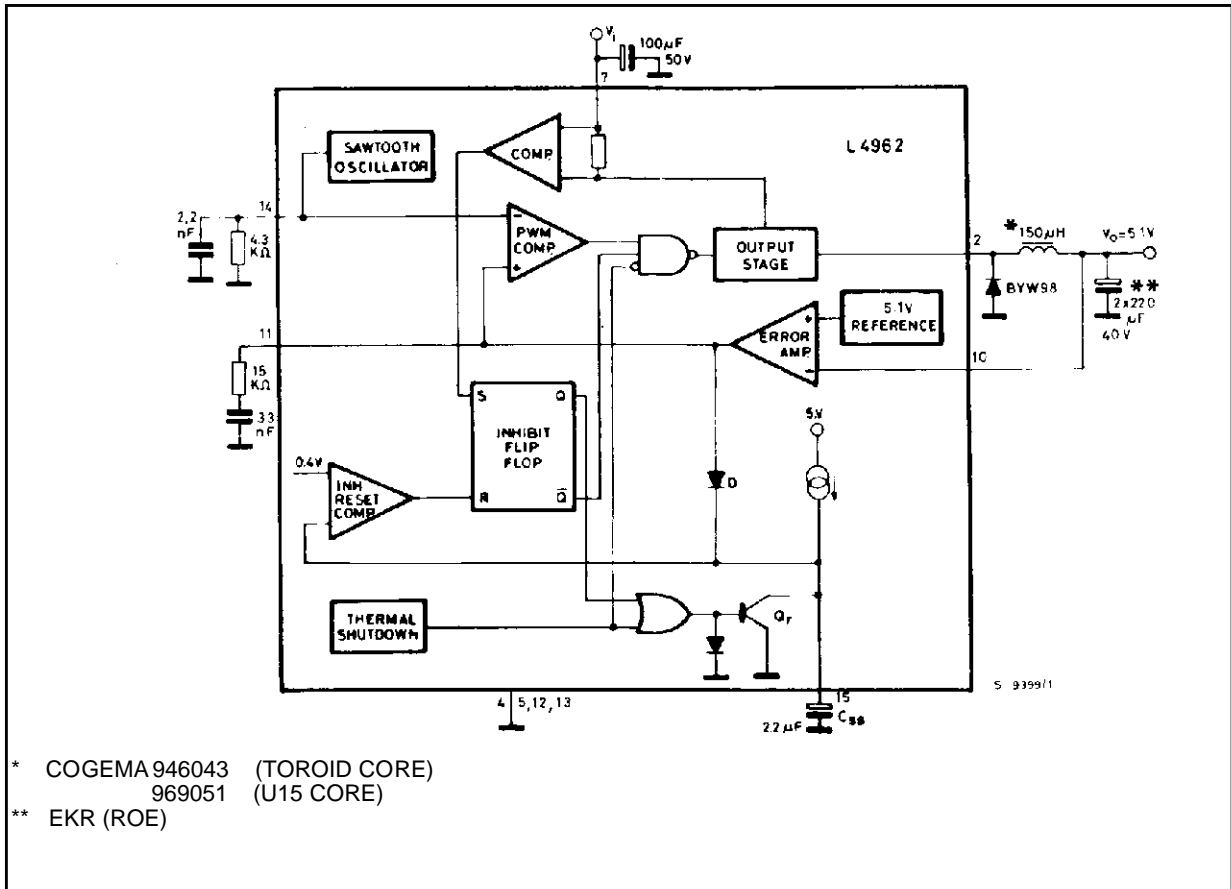
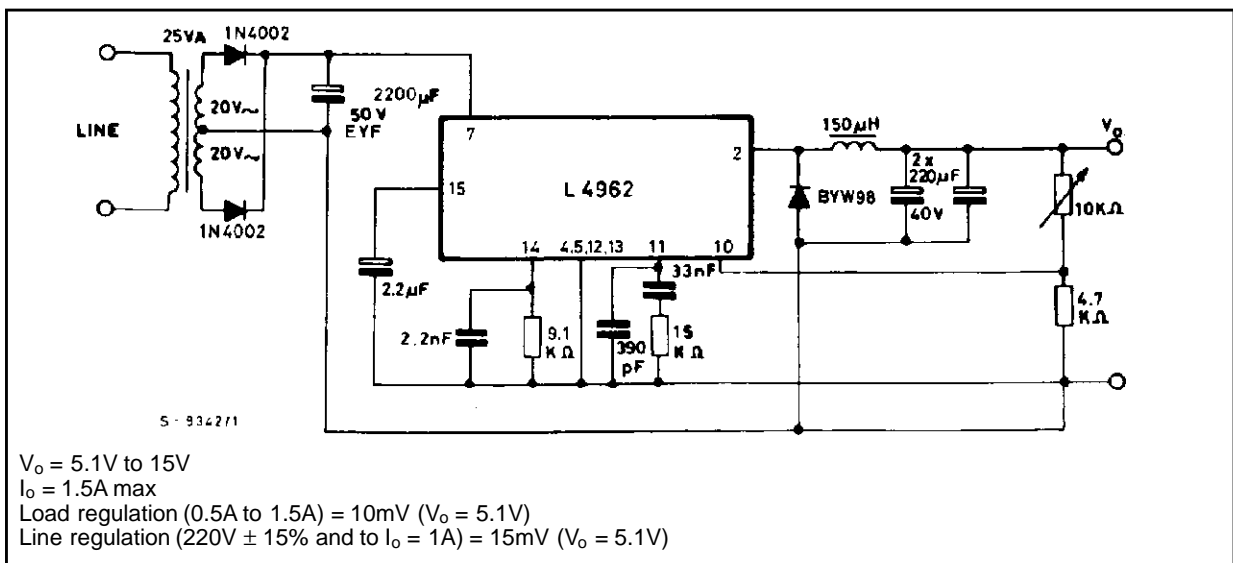


Figure 28. Programmable power supply



APPLICATION INFORMATION (continued)

Figure 29. DC-DC converter 5.1V/4A, ± 12V/1A. A suggestion how to synchronize a negative output

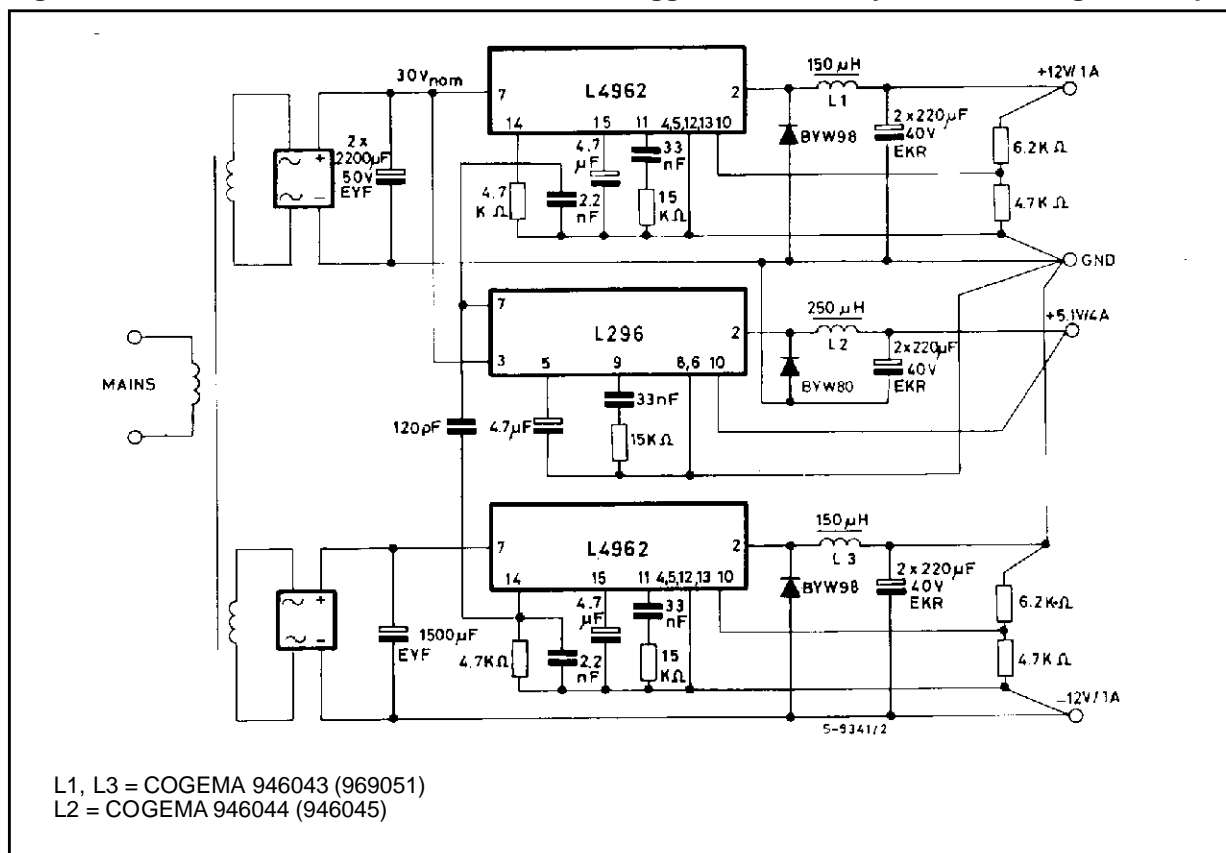


Figure 30. In multiple supplies several L4962s can be synchronized as shown

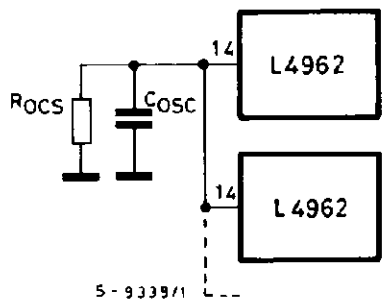
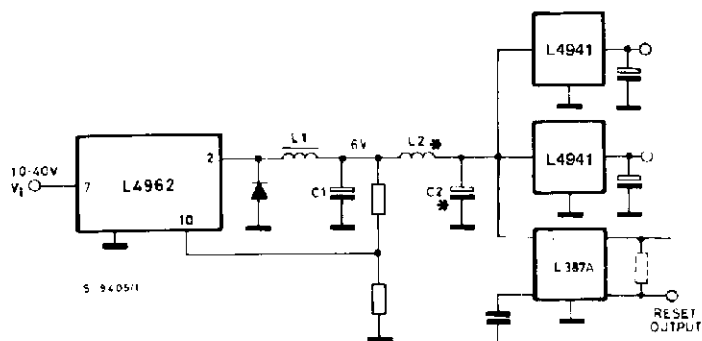


Figure 31. Preregulator for distributed supplies



* L2 and C2 are necessary to reduce the switching frequency spikes when linear regulators are remote from L4962

MOUNTING INSTRUCTION

The $R_{th-j-amb}$ of the L4962 can be reduced by soldering the GND pins to a suitable copper area of the printed circuit board (Fig. 32).

The diagram of figure 33 shows the $R_{th-j-amb}$ as a function of the side "l" of two equal square copper areas having the thickness of 35μ (1.4 mils). During

soldering the pins temperature must not exceed 260°C and the soldering time must not be longer than 12 seconds.

The external heatsink or printed circuit copper are must be connected to electrical ground.

Figure 32. Example of P.C. board copper area which is used as heatsink

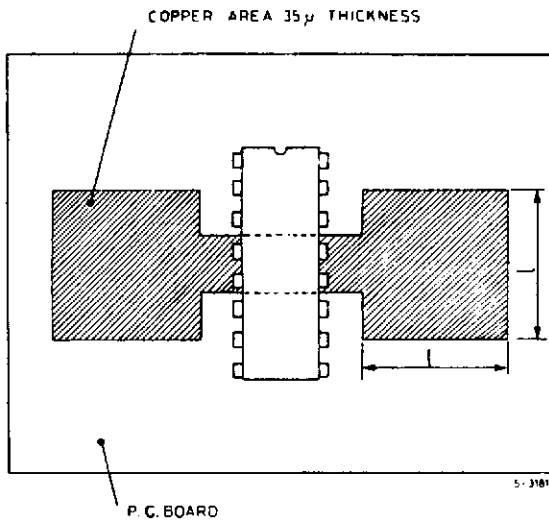
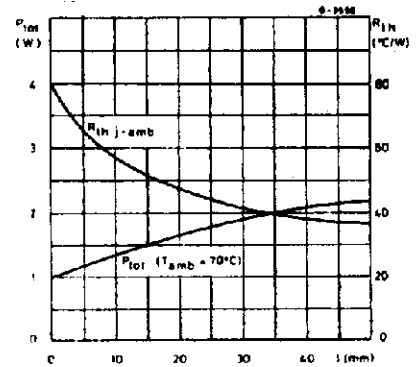
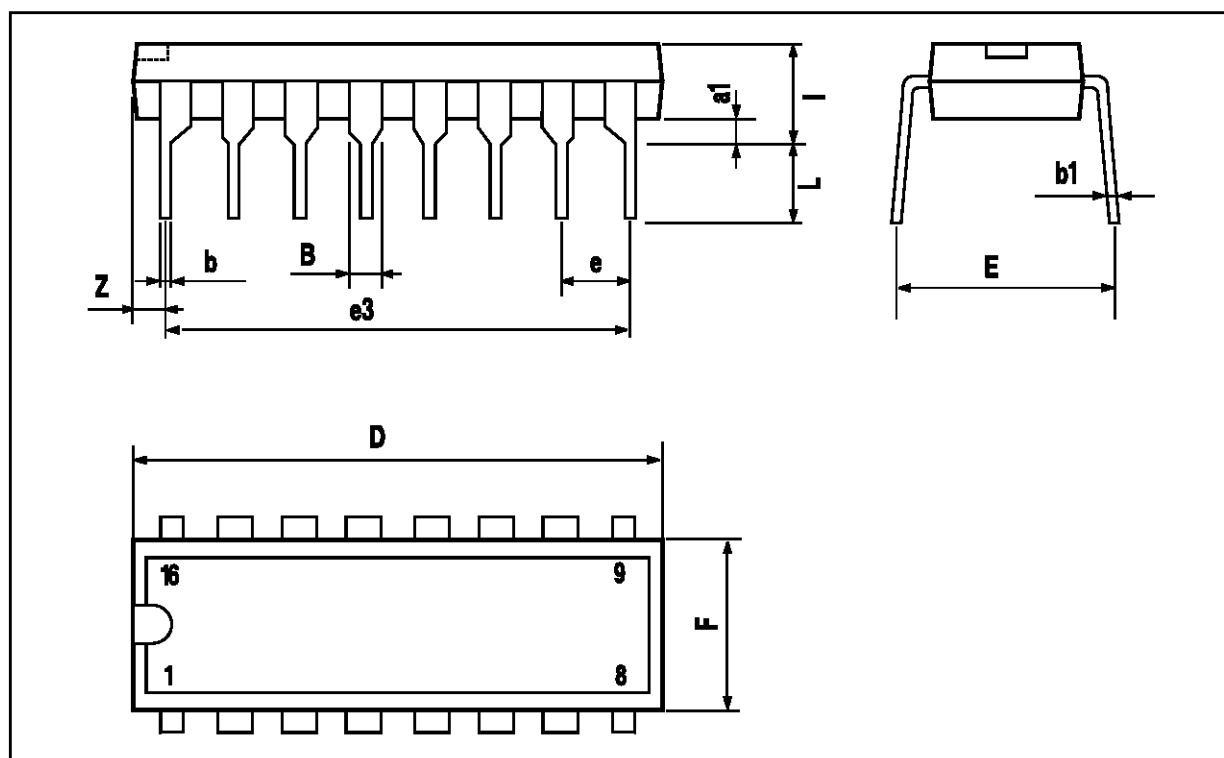


Figure 33. Maximum dissippable power and junction to ambient thermal resistance vs. side "l"



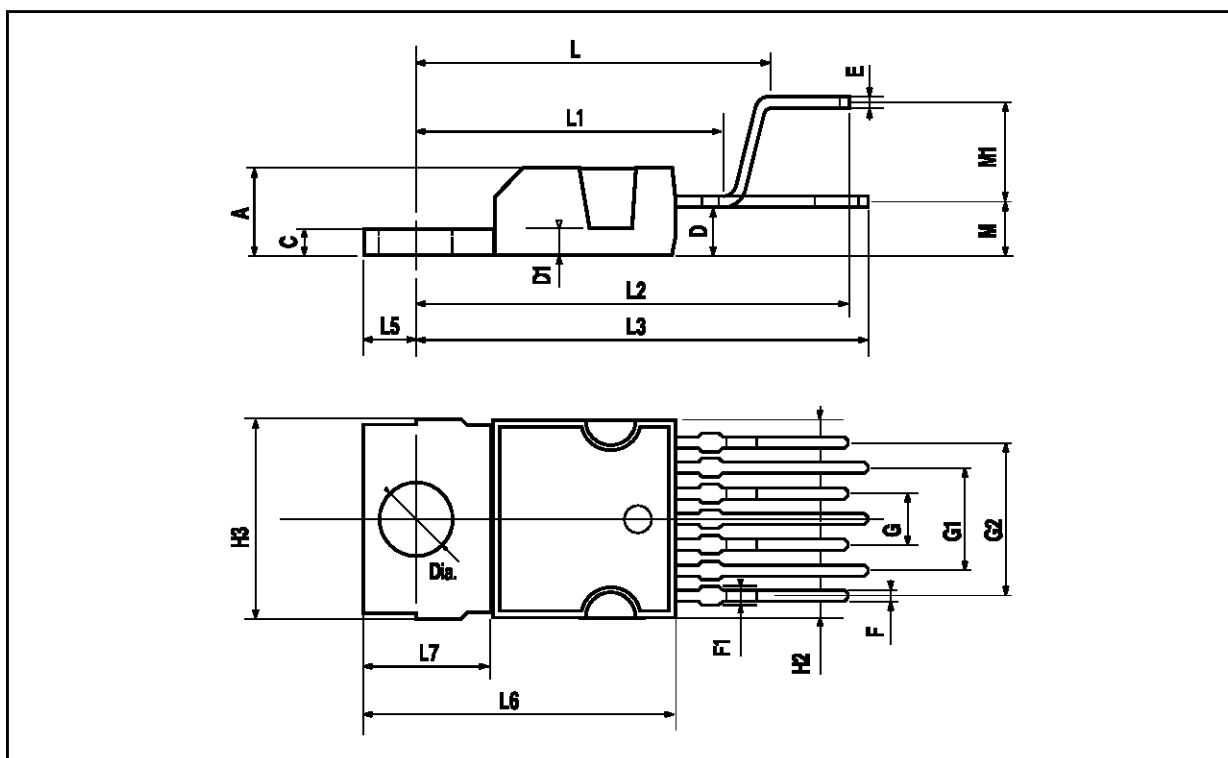
POWERDIP PACKAGE MECHANICAL DATA

| DIM. | mm | | | inch | | |
|------|------|-------|------|-------|-------|-------|
| | MIN. | TYP. | MAX. | MIN. | TYP. | MAX. |
| a1 | 0.51 | | | 0.020 | | |
| B | 0.85 | | 1.40 | 0.033 | | 0.055 |
| b | | 0.50 | | | 0.020 | |
| b1 | 0.38 | | 0.50 | 0.015 | | 0.020 |
| D | | | 20.0 | | | 0.787 |
| E | | 8.80 | | | 0.346 | |
| e | | 2.54 | | | 0.100 | |
| e3 | | 17.78 | | | 0.700 | |
| F | | | 7.10 | | | 0.280 |
| I | | | 5.10 | | | 0.201 |
| L | | 3.30 | | | 0.130 | |
| Z | | | 1.27 | | | 0.050 |



HEPTAWATT PACKAGE MECHANICAL DATA

| DIM. | mm | | | inch | | |
|------|-------|-------|------|-------|-------|-------|
| | MIN. | TYP. | MAX. | MIN. | TYP. | MAX. |
| A | | | 4.8 | | | 0.189 |
| C | | | 1.37 | | | 0.054 |
| D | 2.4 | | 2.8 | 0.094 | | 0.110 |
| D1 | 1.2 | | 1.35 | 0.047 | | 0.053 |
| E | 0.35 | | 0.55 | 0.014 | | 0.022 |
| F | 0.6 | | 0.8 | 0.024 | | 0.031 |
| F1 | | | 0.9 | | | 0.035 |
| G | 2.41 | 2.54 | 2.67 | 0.095 | 0.100 | 0.105 |
| G1 | 4.91 | 5.08 | 5.21 | 0.193 | 0.200 | 0.205 |
| G2 | 7.49 | 7.62 | 7.8 | 0.295 | 0.300 | 0.307 |
| H2 | | | 10.4 | | | 0.409 |
| H3 | 10.05 | | 10.4 | 0.396 | | 0.409 |
| L | | 16.97 | | | 0.668 | |
| L1 | | 14.92 | | | 0.587 | |
| L2 | | 21.54 | | | 0.848 | |
| L3 | | 22.62 | | | 0.891 | |
| L5 | 2.6 | | 3 | 0.102 | | 0.118 |
| L6 | 15.1 | | 15.8 | 0.594 | | 0.622 |
| L7 | 6 | | 6.6 | 0.236 | | 0.260 |
| M | | 2.8 | | | 0.110 | |
| M1 | | 5.08 | | | 0.200 | |
| Dia | 3.65 | | 3.85 | 0.144 | | 0.152 |



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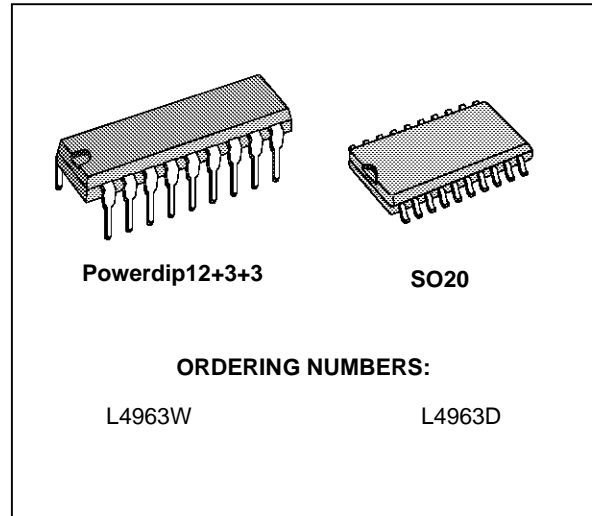
Australia - Brazil - France - Germany - Hong Kong - Italy - Japan - Korea - Malaysia - Malta - Morocco - The Netherlands - Singapore - Spain - Sweden - Switzerland - Taiwan - Thailand - United Kingdom - U.S.A.

1.5A SWITCHING REGULATOR

- 1.5A OUTPUT LOAD CURRENT
- 5.1 TO 36V OUTPUT VOLTAGE RANGE
- DISCONTINUOUS VARIABLE FREQUENCY MODE
- PRECISE (+/-2%) ON CHIP REFERENCE
- VERY HIGH EFFICIENCY
- VERY FEW EXTERNAL COMPONENTS
- NO FREQ. COMPENSATION REQUIRED
- RESET AND POWER FAIL OUTPUT FOR MICROPROCESSOR
- INTERNAL CURRENT LIMITING
- THERMAL SHUTDOWN

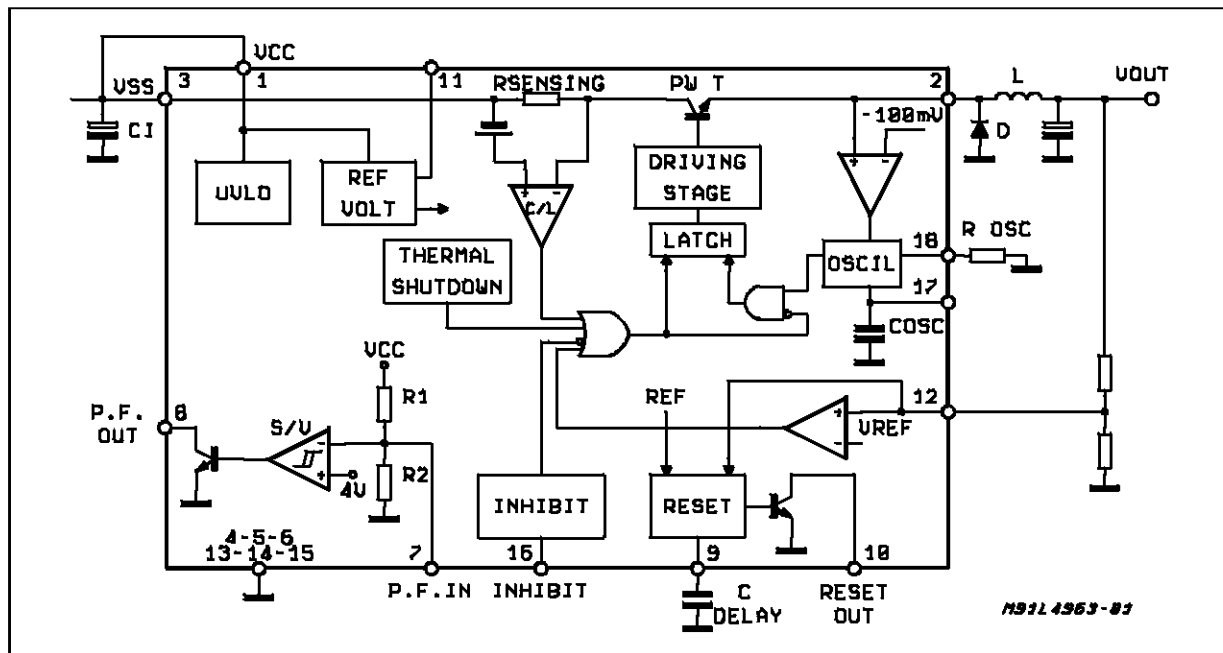
DESCRIPTION

The L4963 is a monolithic power switching regulator delivering 1.5A at 5.1V. The output voltage is adjustable from 5.1V to 36V, working in discontinuous variable frequency mode. Features of the device include remote inhibit, internal current limiting and thermal protection, reset and power fail outputs for microprocessor.



The L4963 is mounted in a 12+3+3 lead Powerdip (L4963) and SO20 large (L4963D) plastic packages and requires very few external components.

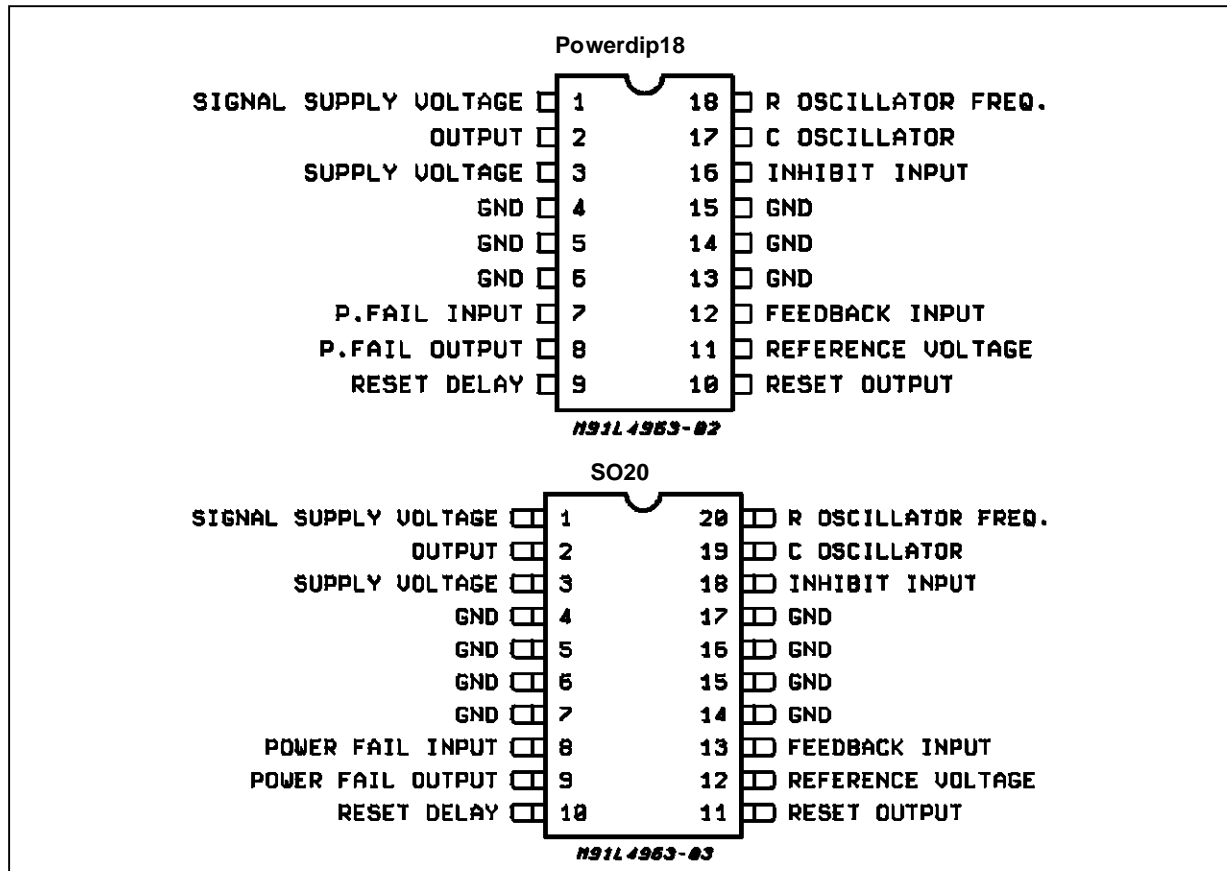
BLOCK DIAGRAM



ABSOLUTE MAXIMUM RATINGS

| Symbol | | Parameter | Value | Unit |
|-----------------------------------|-----------------------------------|---|--------------------|-------------|
| SO20 | Powerdip | | | |
| V _i | | Input Voltage (pin 1 and pin 3 connected together) | 47 | V |
| V ₃ -V ₂ | | Input to Output Voltage Difference | 47 | V |
| V ₂ | | Negative Output DC Voltage | -1 | V |
| V ₂ | | Negative Output Peak Voltage at t=0.2 μs, f=50kHz | -5 | V |
| V ₈ | V ₇ | Power Fail Input | 25 | V |
| V ₉ , V ₁₁ | V ₈ , V ₁₀ | Reset and Power Fail Output | V _i | |
| V ₁₀ | V ₉ | Reset Delay Input | 5.5 | V |
| V ₁₃ , V ₁₈ | V ₁₂ , V ₁₆ | Feedback and Inhibit Inputs | 7 | V |
| V ₁₉ , V ₂₀ | V ₁₇ , V ₁₈ | Oscillator Inputs | 5.5 | V |
| P _{tot} | | Total Power Dissipation Tpins ≤ 90°C (Power DIP) (T _{amb} = 70°C no copper area on PCB) (T _{amb} = 70°C, 4cm ² copper area on PCB) | 5 1.3 2 | W W W |
| T _{stg} , T _j | | Storage & Junction Temperature (T _{amb} = 70°C 6cm ² copper area on PCB) | -40 to 150 1.45 | °C W |
| P _{tot} | | Total Power Dissipation Tpins ≤90°C (SO20L) | 4 | W |

PIN CONNECTION (top view)



PIN FUNCTIONS

| SO20L | Power DIP | Name | Description |
|------------------------------|-----------------------|-----------------------|--|
| 1 | 1 | SIGNAL SUPPLY VOLTAGE | Must be Connected to pin 3 |
| 2 | 2 | OUTPUT | Regulator output |
| 3 | 3 | SUPPLY VOLTAGE | Unregulated voltage input. An internal regulator powers the internal logic. |
| 4, 5, 6, 7 14, 15, 16, 17 | 4, 5, 6 13, 14, 15 | GROUND | Common ground terminal |
| 8 | 7 | POWER FAIL INPUT | Input of the power fail circuit. The threshold can be modified introducing an external voltage divider between the Supply Voltage and GND. |
| 9 | 8 | POWER FAIL OUTPUT | Open collector power fail signal output. This output is high when the supply voltage is safe. |
| 10 | 9 | RESET DELAY | A capacitor connected between this terminal and ground determines the reset signal delay time. |
| 11 | 10 | RESET OUTPUT | Open collector reset signal output. This output is high when the output voltage value is correct. |
| 12 | 11 | REFERENCE VOLTAGE | Reference voltage output. |
| 13 | 12 | FEEDBACK INPUT | 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. |
| 18 | 16 | INHIBIT INPUT | TTL level remote inhibit. A logic low level on this input disables the device. |
| 19 | 17 | C OSCILLATOR | Oscillator waveform. A capacitor connected between this terminal and ground modifies the maximum oscillator frequency. |
| 20 | 18 | R OSCILLATOR FREQ. | A resistor connected between this terminal and ground defines the maximum switching frequency. |

THERMAL DATA

| Symbol | Parameter | | SO20 | Powerdip | Unit |
|------------------------|--|------|------|----------|------|
| R _{th j-pins} | Thermal Resistance Junction to Pins | max. | 15 | 12 | °C/W |
| R _{th j-amb} | Thermal Resistance Junction to Ambient (*) | max. | 85 | 80 | °C/W |

(*) See Fig. 28

CIRCUIT DESCRIPTION (Refer to Block Diagram)

The L4963 is a monolithic stepdown regulator providing 1.5A at 5.1V working in discontinuous variable frequency mode. In normal operation the device resonates at a frequency depending primarily on the inductance value, the input and output voltage and the load current. The maximum switching however can be limited by an internal oscillator, which can be programmed by only one external resistor.

The fundamental regulation loop consists of two comparators, a precision 5.1V on-chip reference and a drive latch. Briefly the operation is as follows: when the choke ends its discharge the catch free-wheeling recirculation filter diode begins to come out of forward conduction so the output voltage of the device approaches ground. When the output voltage reaches $-0.1V$ the internal comparator sets the latch and the power stage is turned on. Then the inductor current rises linearly until the voltage sensed at the feedback input reaches the 5.1V reference.

The second comparator then resets the latch and the output stage is turned off. The current in the choke falls linearly until it is fully discharged, then the cycle repeats. Closing the loop directly gives an output voltage of 5.1V. Higher output voltages are

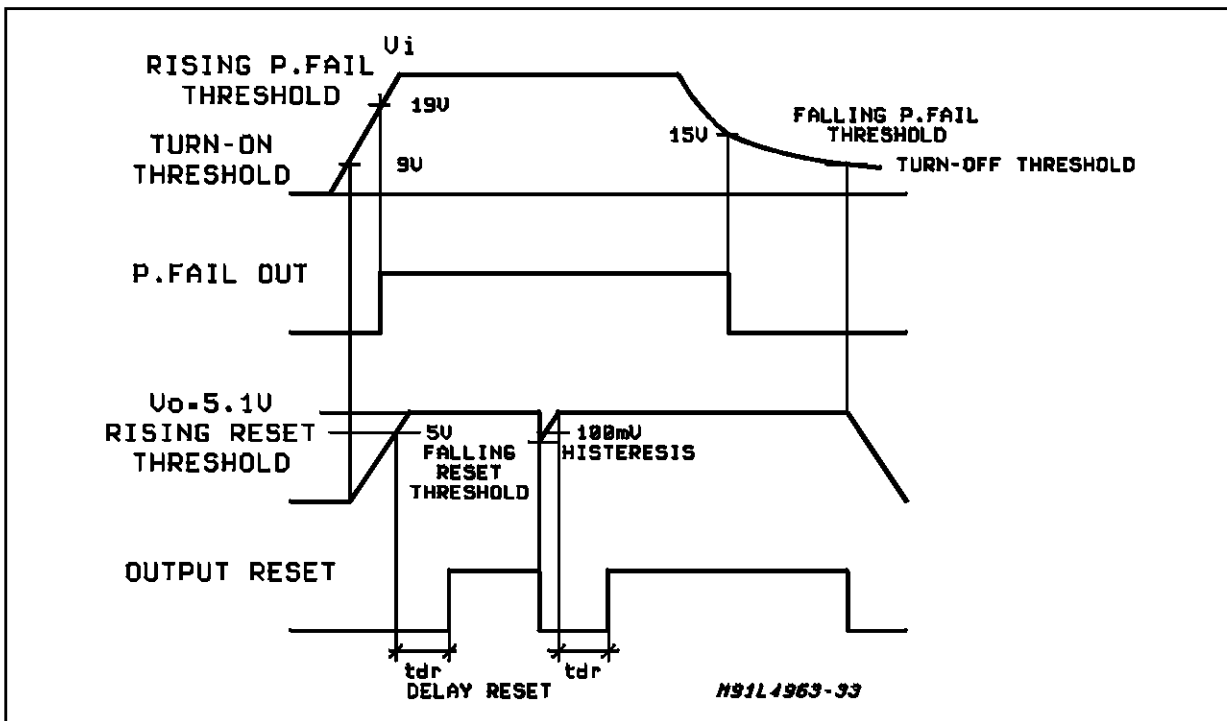
obtained by inserting a voltage divider and this method of control requires no frequency compensation network. At output voltages greater than 5.1V the available output current must be derated due to the increased power dissipation of the device.

Output overload protection is provided by an internal current limiter. The load current is sensed by a on-chip metal resistor connected to a comparator which resets the latch and turns off the power stage in overload condition. The reset circuits (see fig. 1) generates an output high signal when the output voltage value is correct. It has an open collector output and the output signal delay time can be programmed with an external capacitor. A power-fail circuit is also available and is used to monitor the supply voltage. Its output goes high when the supply voltage reaches a pre-programmed threshold set by a voltage divider to its input from the supply to ground. With the input left open the threshold is approximately equal to 5.1V. The output of the power fail is an open collector.

A TTL level inhibit is provided for applications such as remote on/off control. This input is activated by a low logic level and disables circuits operation.

The thermal overload circuit disables the device when the junction temperature is about $150^{\circ}C$ and has hysteresis to prevent unstable conditions.

Figure 1: Reset and Power Fail Function



ELECTRICAL CHARACTERISTIC (Refer to the test circuit $V_i = 30V$ $T_j = 25^\circ\text{C}$ unless otherwise specified)

| Symbol | Parameter | Test Conditions | Min. | Typ. | Max. | Unit | Fig. |
|--------|-----------|-----------------|------|------|------|------|------|
|--------|-----------|-----------------|------|------|------|------|------|

DYNAMIC CHARACTERISTICS

| | | | | | | | |
|-----------------|---|--|-----------|-----|-----|---------------|----|
| V_o | Output Voltage Range | $V_i = 46V$ $I_o = 0.5A$ | V_{ref} | | 36 | V | 2 |
| V_i | Input Voltage Range | $V_o = V_{ref}$ to 36V $I_o = 0.5A$ | 9 | | 46 | V | 2 |
| V_{12} | Feedback Voltage | $V_i = 9$ to 46V $I_o = 0.5A$ | 5 | 5.1 | 5.2 | V | 2 |
| I_{12} | Input Bias Current | $V_i = 15V$ $V_{12} = 6V$ $V_{17f} = 5V$ | | 5 | 20 | μA | 3a |
| V_{OS12} | Input Offset Voltage | | | 5 | 10 | mV | 3a |
| ΔV_o | Line Regulation | $V_i = 9$ to 46V $V_o = V_{ref}$ $I_o = 0.5A$ | | 15 | 50 | mV | 2 |
| ΔV_o | Load Regulation | $V_o = V_{ref}$ $I_o = 0.5$ to 1.5A | | 15 | 45 | mV | 2 |
| V_d | Dropout Voltage Between pin 3 and pin 2 | $I_2 = 3A$ $V_i = 20V$ | | 1.5 | 2 | V | 2 |
| I_{2L} | Current Limiting | $V_i = 9$ to 46V $V_o = V_{ref}$ to 28V | 3.5 | | 6.5 | A | 2 |
| I_o | Maximum Operating Load Current | $V_i = 9$ to 46V $V_o = V_{ref}$ | 1.5 | | | A | 2 |
| SVR | Supply Voltage Ripple Rejection | $V_i = 2V_{rms}$ $V_o = V_{ref}$ fripple = 100Hz $I_o = 1.5A$ | 50 | 56 | | dB | 2 |
| V_{11} | Reference Voltage | $V_i = 9$ to 46V $0 < I_{11} < 5mA$ | 5 | 5.1 | 5.2 | V | 3a |
| | Average Temperature Coefficient of Ref. Volt. | $T_j = 0$ to 125 °C | | 0.4 | | mV/°C | – |
| ΔV_{11} | V_{ref} Line Regulation | $V_i = 9$ to 46V | | 10 | 20 | mV | 3a |
| ΔV_{11} | V_{ref} Line Regulation | $I_{ref} = 0$ to 5mA $V_i = 46V$ $R_{osc} = 51K\Omega$ | 65 69 | 7 | 15 | mV | 3a |
| η | Efficiency | $I_o = 1.5A$ $V_o = V_{ref}$ | 65 | 75 | | % | 2 |
| T_{sd} | Thermal Shutdown Junction Temperature | | 145 | 150 | | °C | – |
| | Hysteresis | | | 30 | | °C | – |

DC CHARACTERISTICS

| | | | | | | | | |
|-------|-------------------------|----------------------------|---------------------------------------|--|----|----|----|----|
| I_q | Quiescent Drain Current | $V_i = 46V$ $I_o = 0mA$ | $V_{16} = V_{12} = 0$ | | 14 | 20 | mA | 3a |
| | | | $V_{16} = V_{ref}$ $V_{12} = 5.3V$ | | 11 | 16 | mA | 3a |

INHIBIT

| | | | | | | | |
|-----------|---------------------------------------|------------------|-----|----|-----|---------------|---|
| V_{16L} | Low Input Voltage | $V_i = 9$ to 46V | 0.3 | | 0.8 | V | 2 |
| V_{16H} | High Input Voltage | $V_i = 9$ to 46V | 2 | | 5.5 | V | 2 |
| I_{16L} | Input Current with Low Input Voltage | $V_{16} = 0.8V$ | | 50 | 100 | μA | 2 |
| I_{16L} | Input Current with High Input Voltage | $V_{16} = 2V$ | | 10 | 20 | μA | 2 |

L4963 - L4963D

ELECTRICAL CHARACTERISTIC (Continued)

| Symbol | Parameter | Test Condition s | Min. | Typ. | Max. | Unit | Fig. |
|--------|-----------|------------------|------|------|------|------|------|
|--------|-----------|------------------|------|------|------|------|------|

RESET

| | | | | | | | |
|------------|---------------------------------|------------------------------------|-------------------|-------------------|-------------------|---------|----|
| V_{12} | Rising Threshold Voltage | $V_i = 9$ to 46V | V_{ref} -150 | V_{ref} -100 | V_{ref} -50 | mV | 3b |
| V_{12} | Falling Threshold Voltage | $V_i = 9$ to 46V | V_{ref} -150 | V_{ref} -200 | V_{ref} -250 | mV | 3b |
| V_{9D} | Delay Rising Thershold Voltage | $V_7 = OPEN$ | 4.3 | 4.5 | 4.7 | V | 3b |
| V_{9F} | Delay Falling Thershold Voltage | | 1 | 1.5 | 2 | V | 3b |
| $-I_{9SO}$ | Delay Source Current | $V_9 = 4.7V$ $V_{12} = 5.3V$ | 70 | 110 | 140 | μA | 3b |
| I_{9SI} | Delay Sink Current | $V_9 = 4.7V$ $V_{12} = 4.7V$ | 10 | | | mA | 3b |
| I_{10} | Output Leakage Current | $V_i = 46V$ $V_7 = 8.5V$ | 50 | | | μA | 3b |
| V_{10} | Output Saturation Volt. | $I_{10} = 15mA$; $V_i = 3$ to 46V | | | 0.4 | V | 3b |

POWER FAIL

| | | | | | | | |
|-------|---------------------------|-------------|-------|-----|-------|---------|----|
| V_R | Rising Threshold Voltage | Pin7 = open | 17.5 | 19 | 20.5 | V | 3C |
| V_F | Falling Threshold Voltage | Pin7 = open | 14.25 | 15 | 15.75 | V | 3c |
| V_7 | Rising Threshold Voltage | $V_i = 20V$ | 4.14 | 4.5 | 4.86 | V | - |
| V_7 | Falling Threshold Voltage | $V_i = 20V$ | 3.325 | 3.5 | 3.675 | V | - |
| V_s | Output Saturation Volt. | $I_a = 5mA$ | | | 0.4 | V | 3c |
| I_s | Output Leakage Current | $V_i = 46V$ | | | 50 | μA | 3c |

OSCILLATOR

| | | | | | | | |
|---|----------------------|---|----|----|----|-----|---|
| f | Oscillator Frequency | $R_T = 51K\Omega$ | 46 | 60 | 79 | kHz | - |
| f | Oscillator Frequency | $V_i = 9$ to 46V $T_j = 0$ to 125°C $R_T = 51K\Omega$ | 42 | | 83 | kHz | - |

Figure 2: Test Circuit

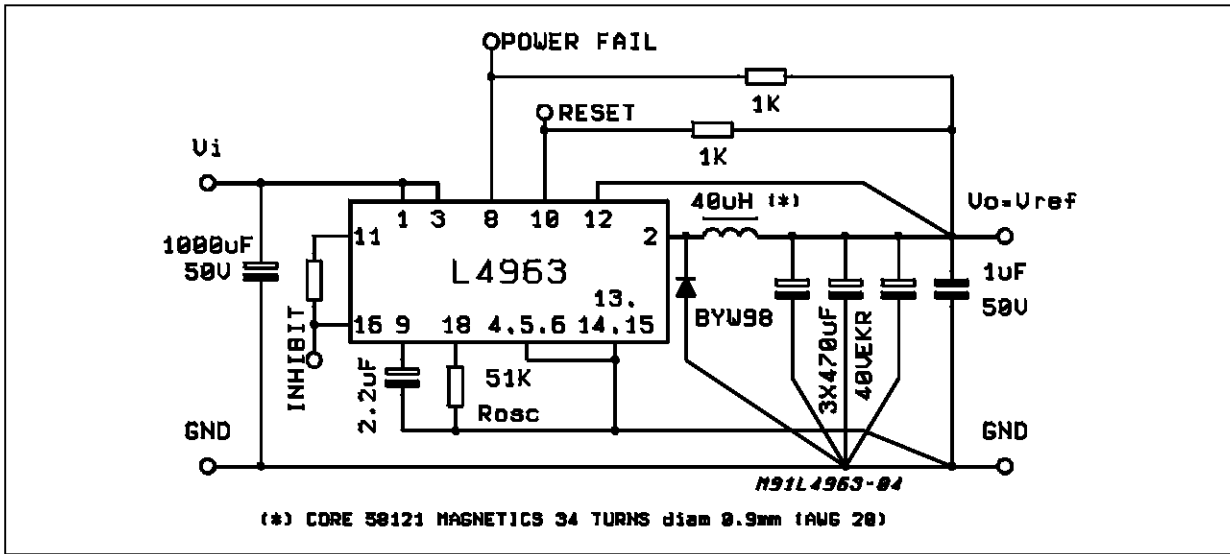


Figure 3: DC Test Circuit

Figure 3a

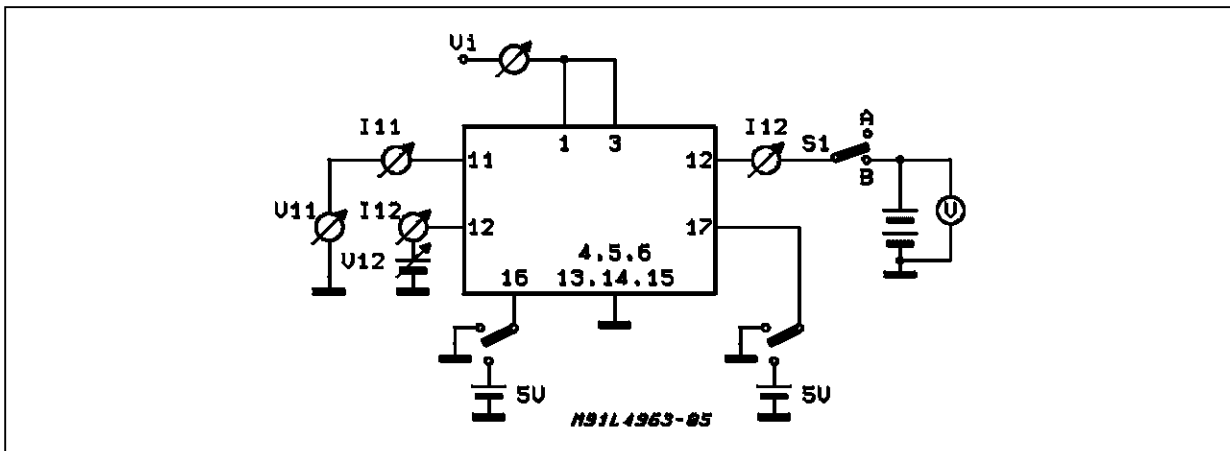


Figure 3b

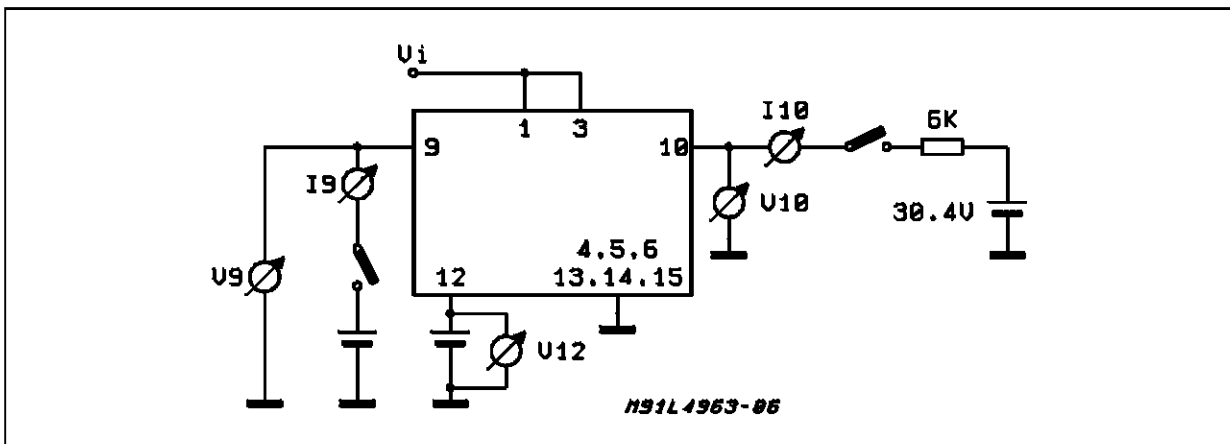


Figure 3c

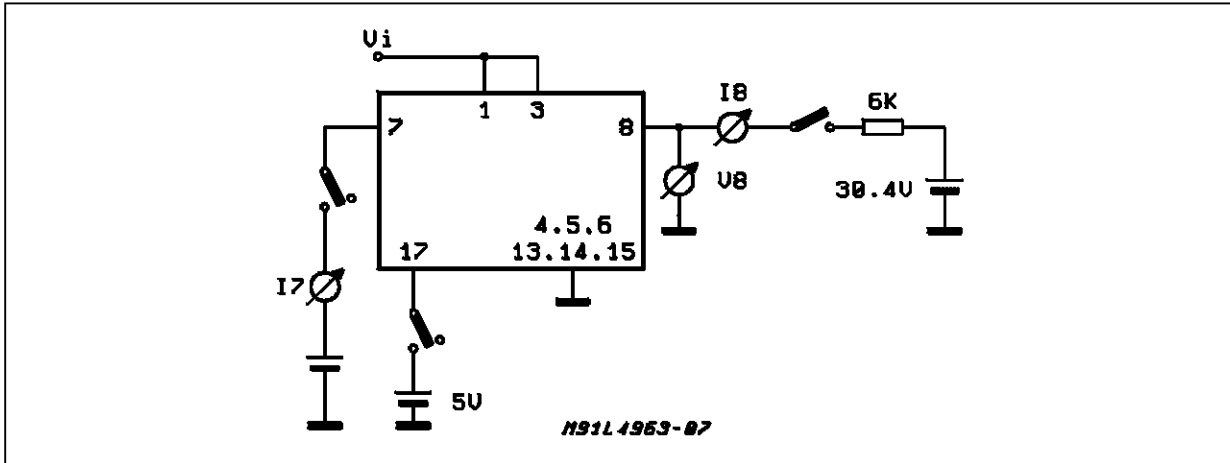


Figure 4: Quiescent Drain Current vs. Supply Voltage (0% Duty Cycle)

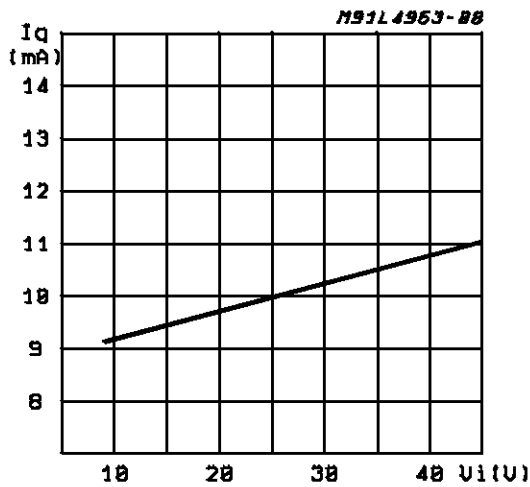


Figure 5: Quiescent Drain Current vs. Supply Voltage (100% Duty Cycle)

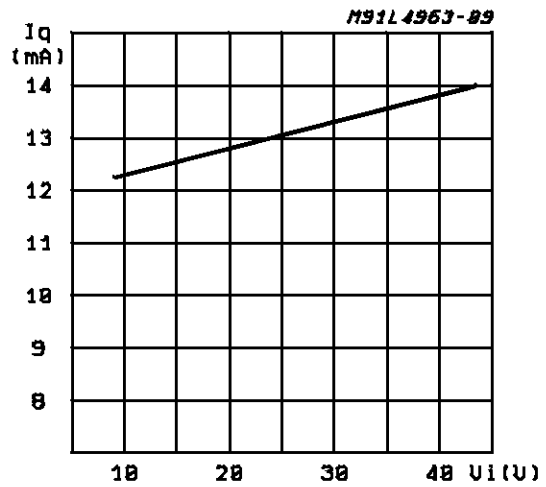


Figure 6: Quiescent Drain Current vs. Junction Temperature (0% Duty Cycle)

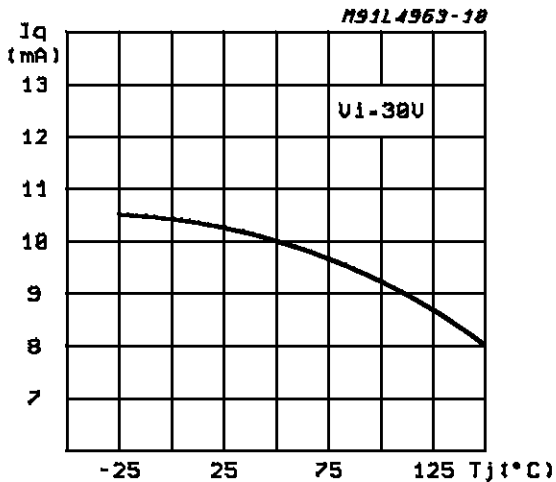


Figure 7: Quiescent Drain Current vs. Junction Temperature (100% Duty Cycle)

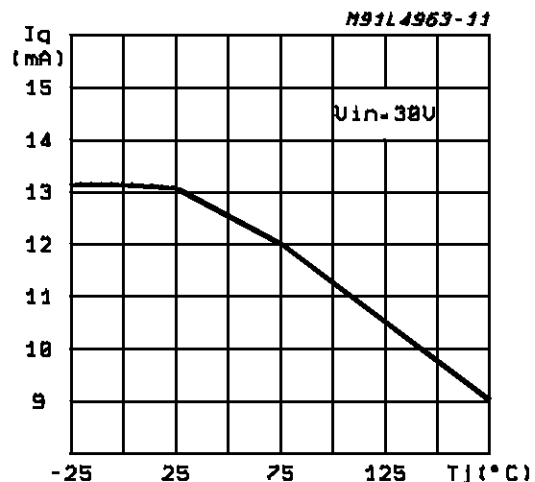


Figure 8: Reference Voltage vs. V_i

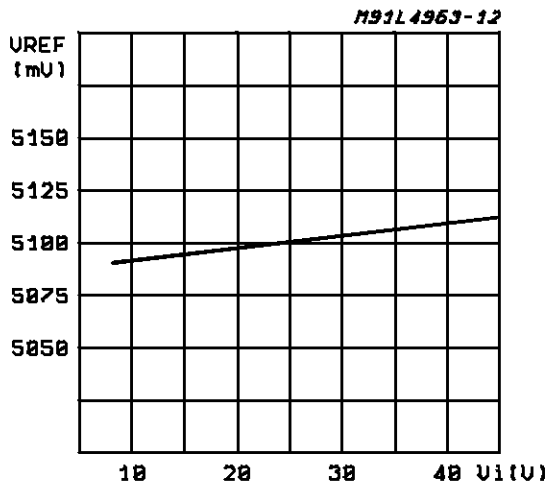


Figure 9: Reference Voltage vs. T_j

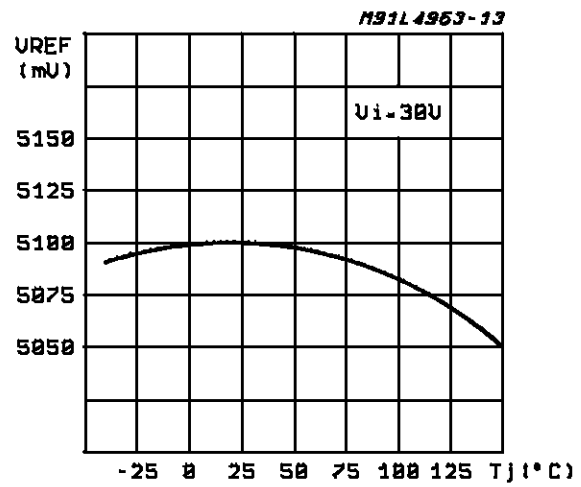


Figure 10: Line Transient Response

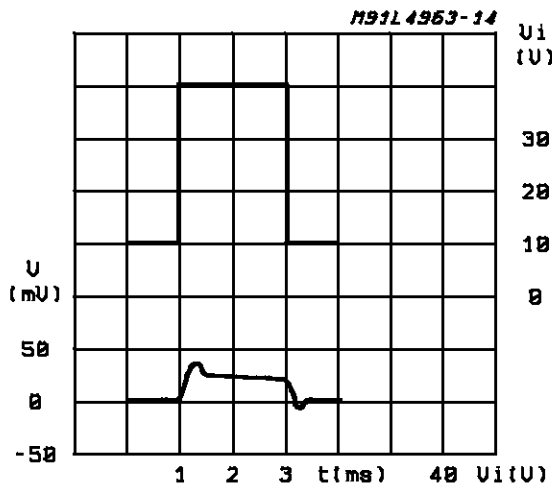


Figure 11: Load Transient

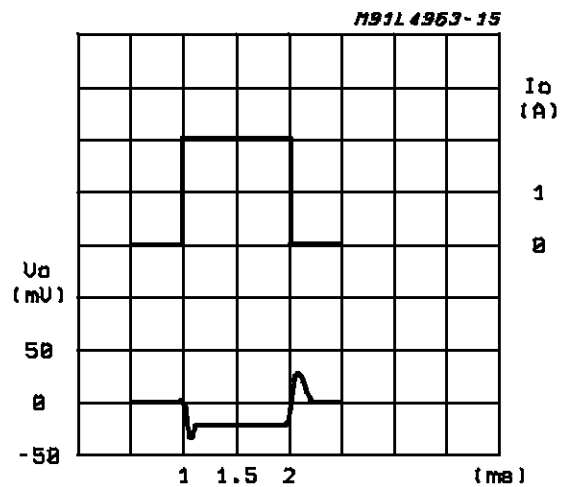


Figure 12: Supply Voltage Ripple Rejection vs. Frequency

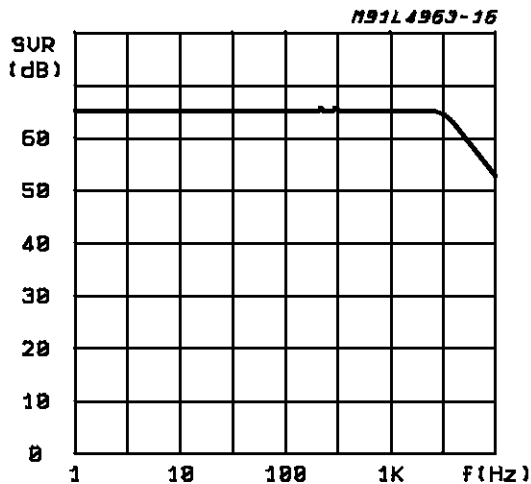


Figure 13: Dropout Voltage Between $pin3$ and 2 vs. Current at $pin2$

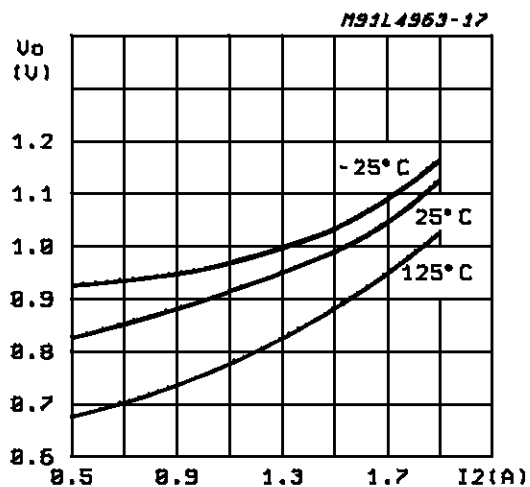


Figure 14: Dropout Voltage Between pin3 and 2 vs. Junction Temperature

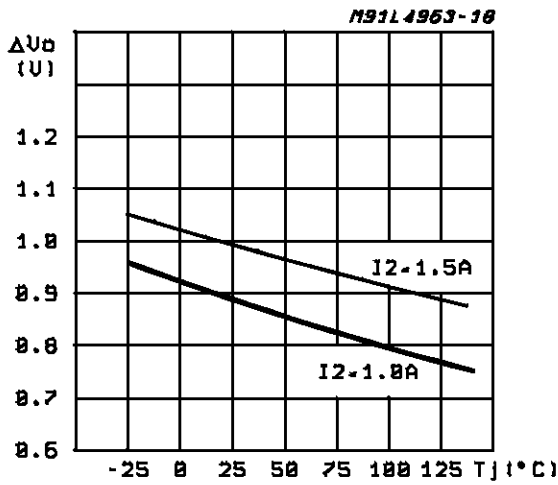


Figure 15: Maximum Allowable Power Dissipation vs. Ambient Temperature (Powerdip Package Only)

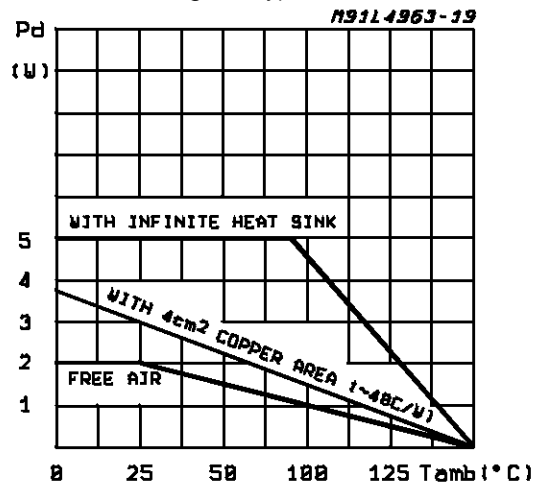


Figure 16: Power Dissipation (device only) vs. Input Voltage (Powerdip Package Only)

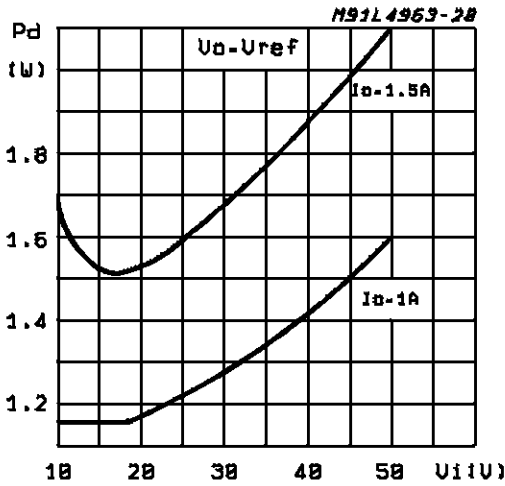


Figure 17: Power Dissipation (device only) vs. Output Voltage (Powerdip Package Only)

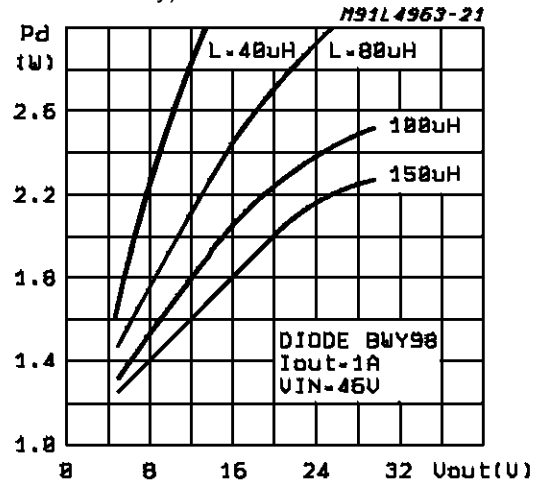


Figure 18: Voltage and Current Waveform at pin2

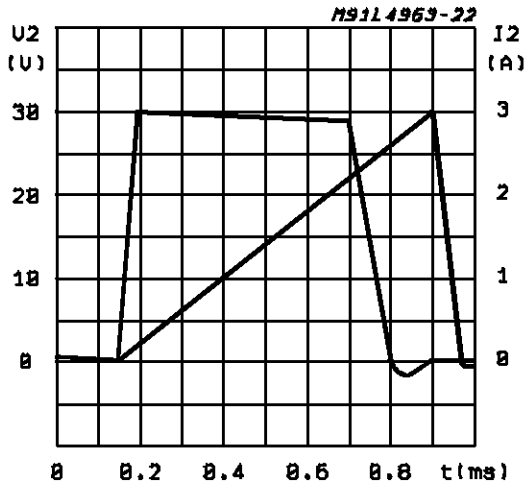


Figure 19: Efficiency vs. Output Current (Powerdip Package Only)

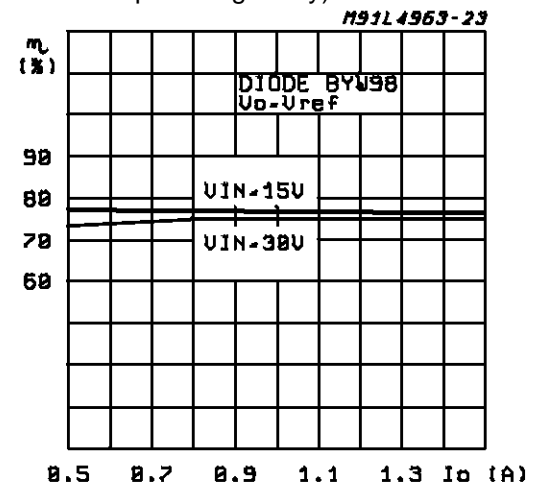


Figure 20: Efficiency vs. Output Voltage (Power-dip Package Only)

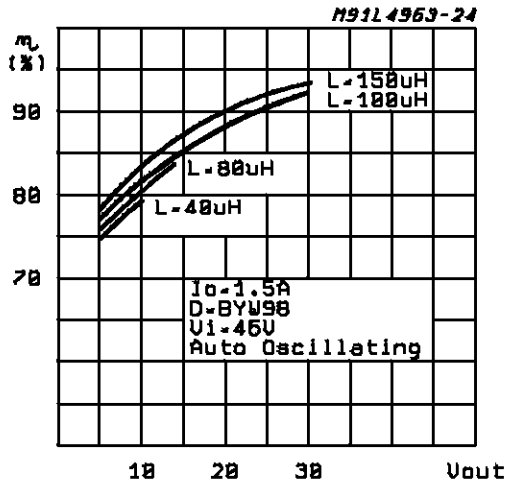


Figure 21: Current Limit vs. Junction Temperature $V_i = 30V$

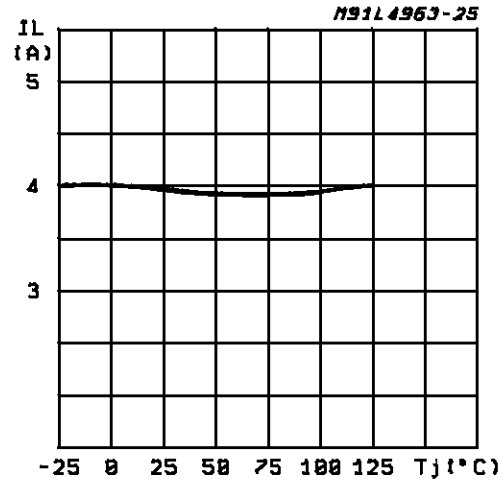


Figure 22: Current Limit vs. Input Voltage

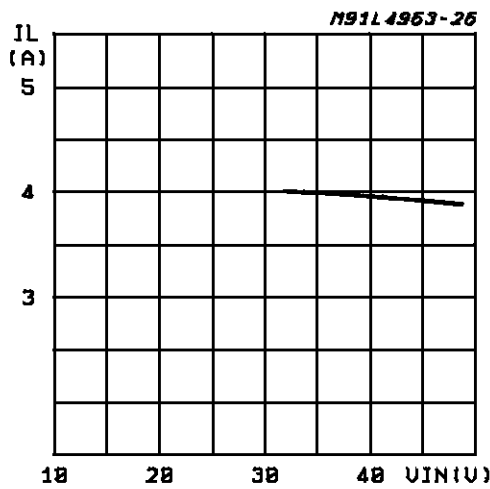


Figure 23: Oscillator Frequency vs. R2 (see fig. 26)

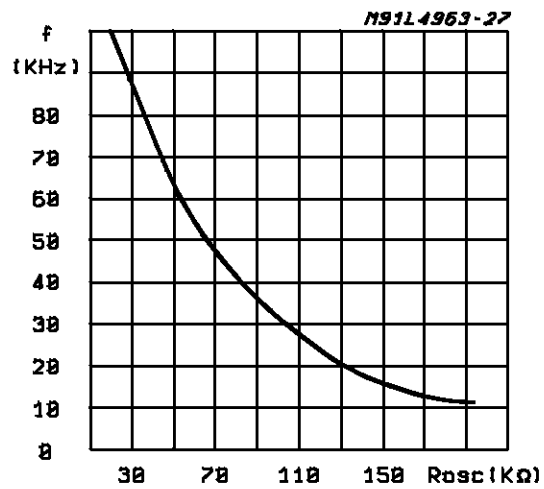


Figure 24: Oscillator Frequency vs. Junction Temperature

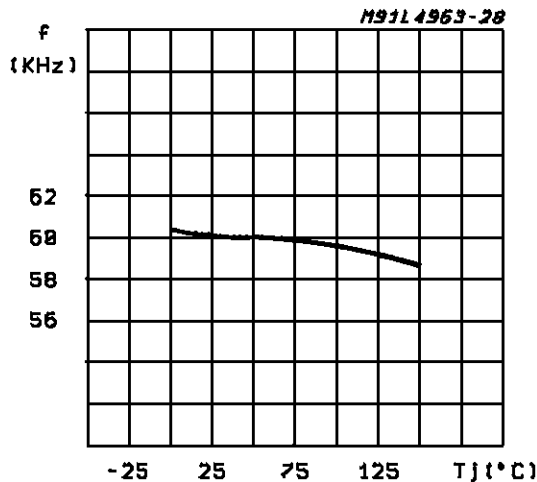


Figure 25: Oscillator Frequency vs. Input Voltage

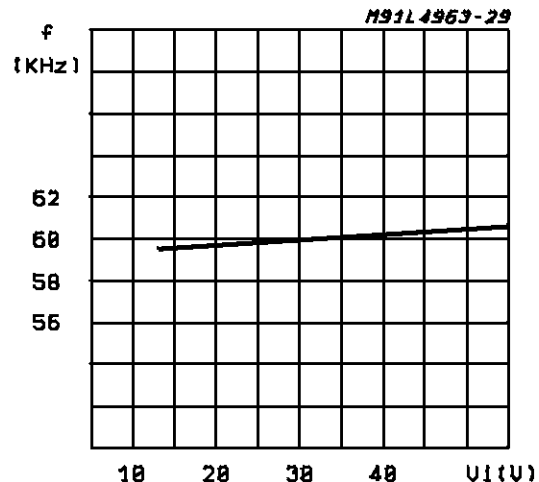
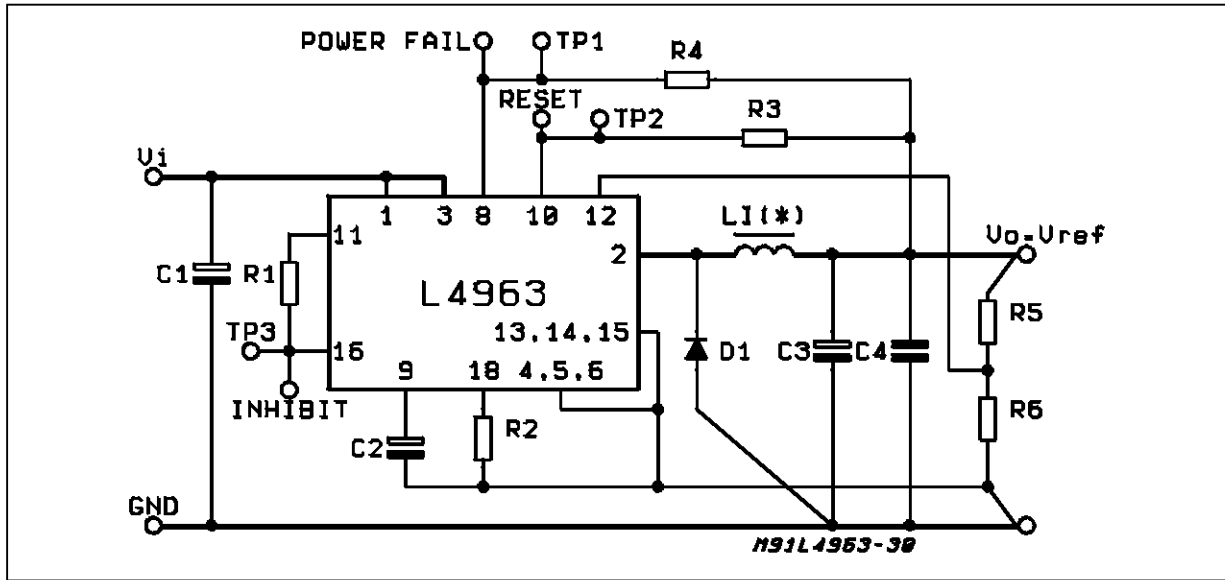


Figure 26: Evaluation Board Circuit



PART LIST

| CAPACITOR | |
|-----------|-------------------------------|
| C1 | 1000 μ F 50V EKR (*) |
| C2 | 2.2mF 16V |
| C3 | 1000 μ F 40V with low ESR |
| C4 | 1 μ F 50V film |
| RESISTOR | |
| R1 | 1K Ω |
| R2 | 51K Ω |
| R3 | 1K Ω |
| R4 | 1K Ω |
| R5, R6 | see table |

| Resistor Values for Standard Output Voltages | | |
|--|---------------|---------------|
| V _o | R6 | R5 |
| 12 | 4.7K Ω | 6.2K Ω |
| 15 | 4.7K Ω | 9.1K Ω |
| 18 | 4.7K Ω | 12K Ω |
| 24 | 4.7K Ω | 18K Ω |

Diode: BYW98
 Core: L = 40 μ H Magnetics58121-A2MPP34 Turns
 0.9mm (20AWG)

(*) Minimum 100 μ F if V_i is a preregulated offline SMPS output or 1000 μ F if a 50Hz transformer plus rectifiers is used.

Figure 27: P.C. Board and Component Layout of the Circuit of fig. 26 (Powerdip Package) (1:1 scale).

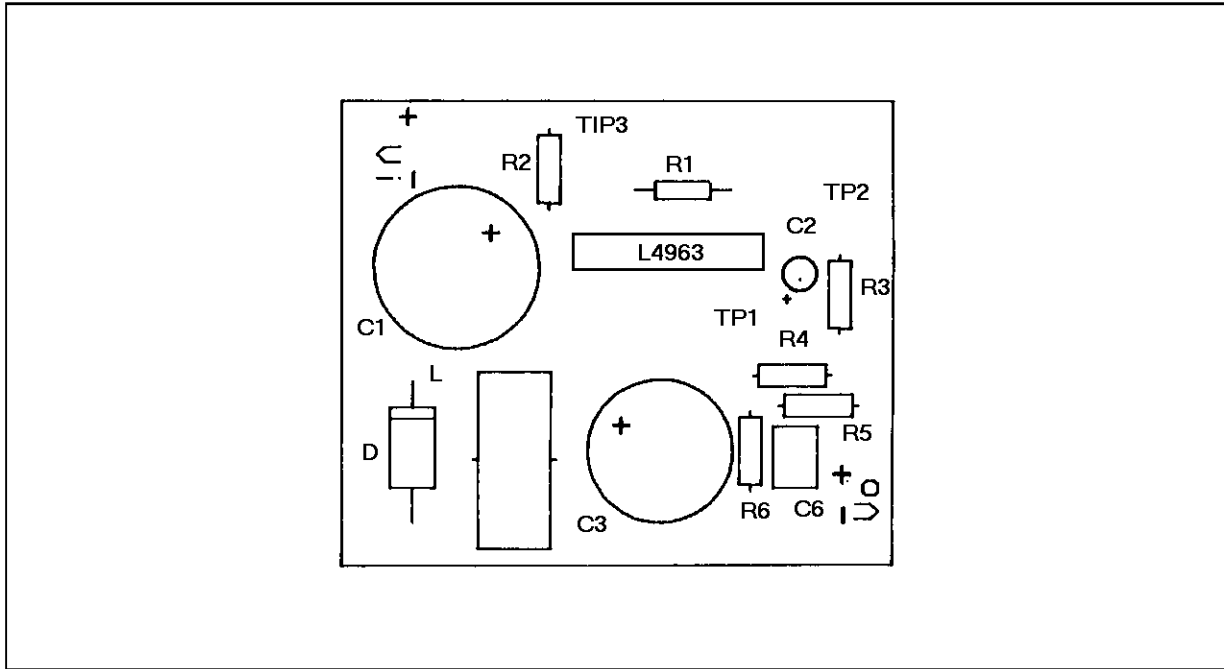


Figure 28: Thermal Characteristics

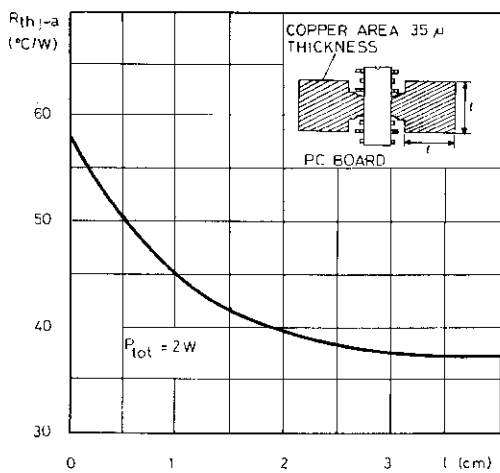
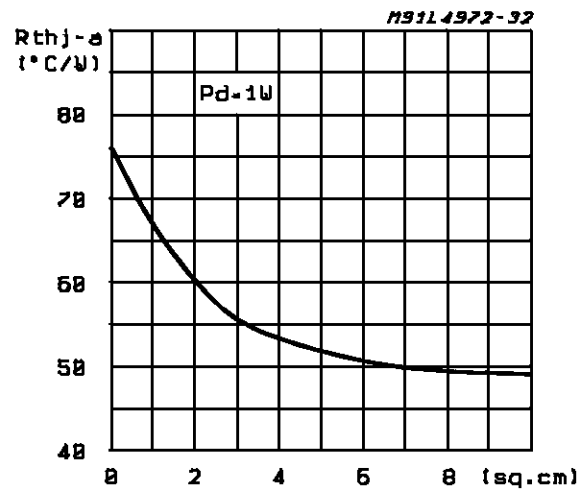


Figure 29: Junction to Ambient Thermal Resistance vs. Area on Board Heatsink (SO20)



L4963 - L4963D

Figure 30: A Minimal 5.1 Fixed Regulator — Very Few Components are Required

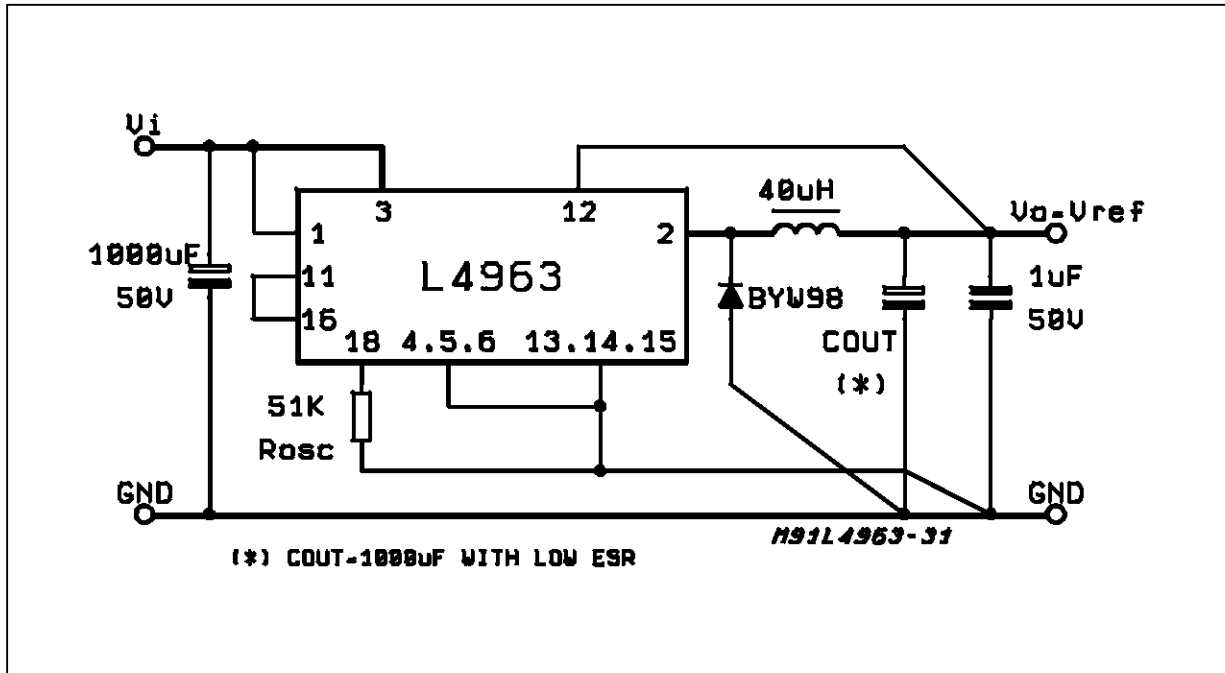
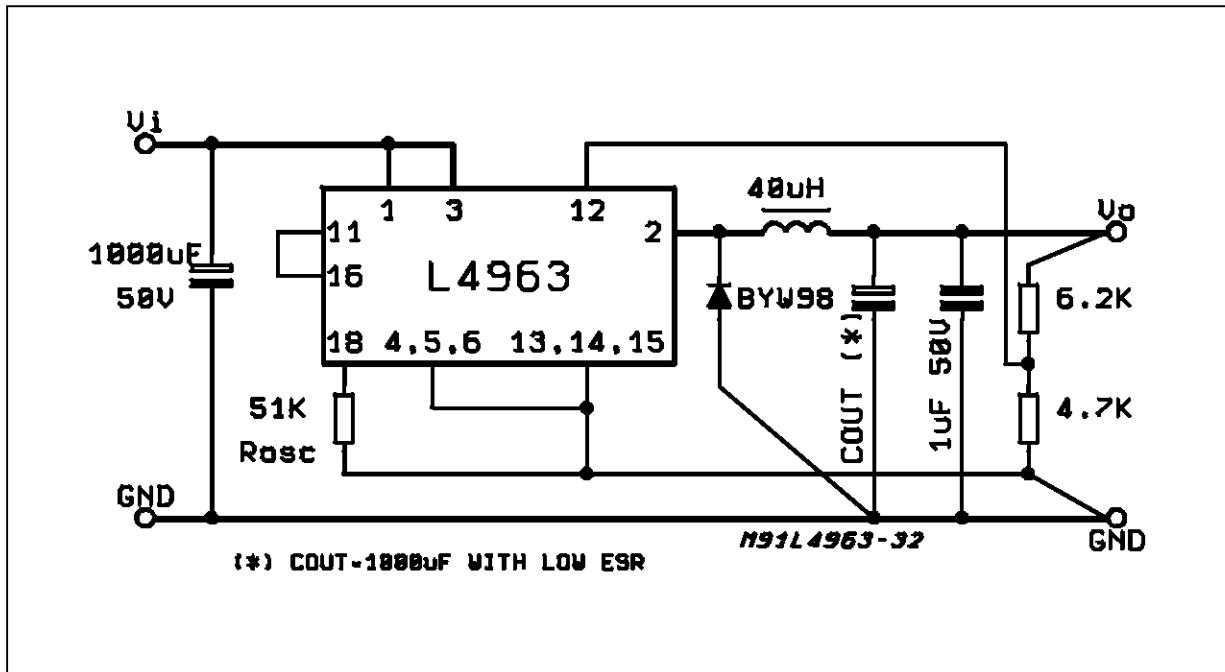
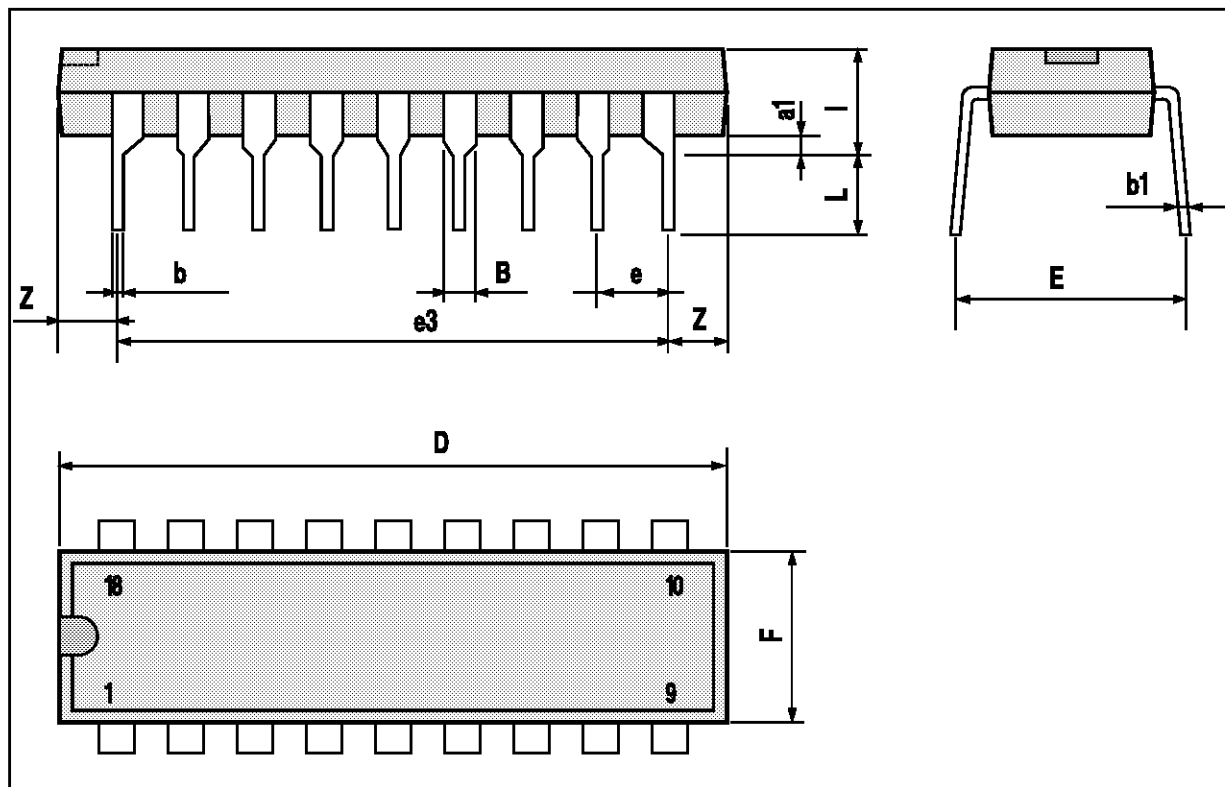


Figure 31: A Minimal Components count for $V_O = 12V$



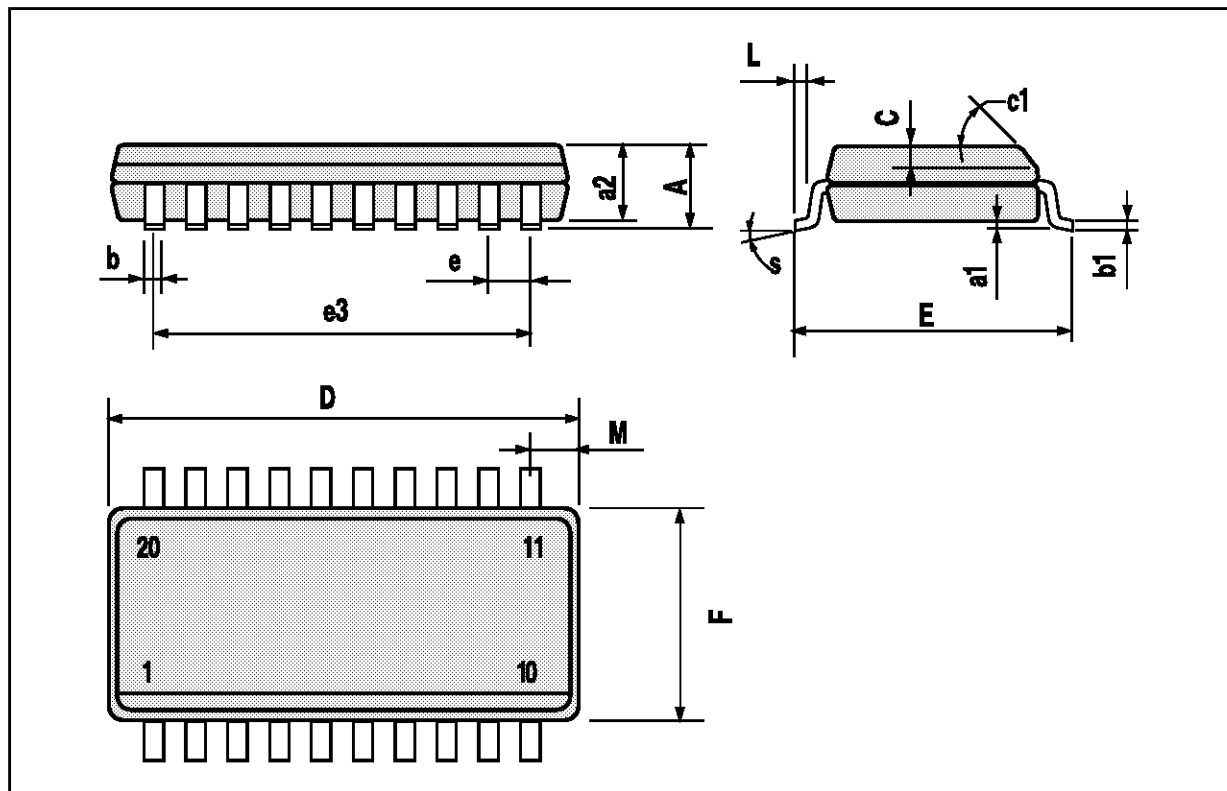
POWERDIP18 PACKAGE MECHANICAL DATA

| DIM. | mm | | | inch | | |
|------|------|-------|-------|-------|-------|-------|
| | MIN. | TYP. | MAX. | MIN. | TYP. | MAX. |
| a1 | 0.51 | | | 0.020 | | |
| B | 0.85 | | 1.40 | 0.033 | | 0.055 |
| b | | 0.50 | | | 0.020 | |
| b1 | 0.38 | | 0.50 | 0.015 | | 0.020 |
| D | | | 24.80 | | | 0.976 |
| E | | 8.80 | | | 0.346 | |
| e | | 2.54 | | | 0.100 | |
| e3 | | 20.32 | | | 0.800 | |
| F | | | 7.10 | | | 0.280 |
| I | | | 5.10 | | | 0.201 |
| L | | 3.30 | | | 0.130 | |
| Z | | | 2.54 | | | 0.100 |



SO20 PACKAGE MECHANICAL DATA

| DIM. | mm | | | inch | | |
|------|-----------|-------|-------|-------|-------|-------|
| | MIN. | TYP. | MAX. | MIN. | TYP. | MAX. |
| A | | | 2.65 | | | 0.104 |
| a1 | 0.1 | | 0.3 | 0.004 | | 0.012 |
| a2 | | | 2.45 | | | 0.096 |
| b | 0.35 | | 0.49 | 0.014 | | 0.019 |
| b1 | 0.23 | | 0.32 | 0.009 | | 0.013 |
| C | | 0.5 | | | 0.020 | |
| c1 | 45 (typ.) | | | | | |
| D | 12.6 | | 13.0 | 0.496 | | 0.512 |
| E | 10 | | 10.65 | 0.394 | | 0.419 |
| e | | 1.27 | | | 0.050 | |
| e3 | | 11.43 | | | 0.450 | |
| F | 7.4 | | 7.6 | 0.291 | | 0.299 |
| L | 0.5 | | 1.27 | 0.020 | | 0.050 |
| M | | | 0.75 | | | 0.030 |
| S | 8 (max.) | | | | | |



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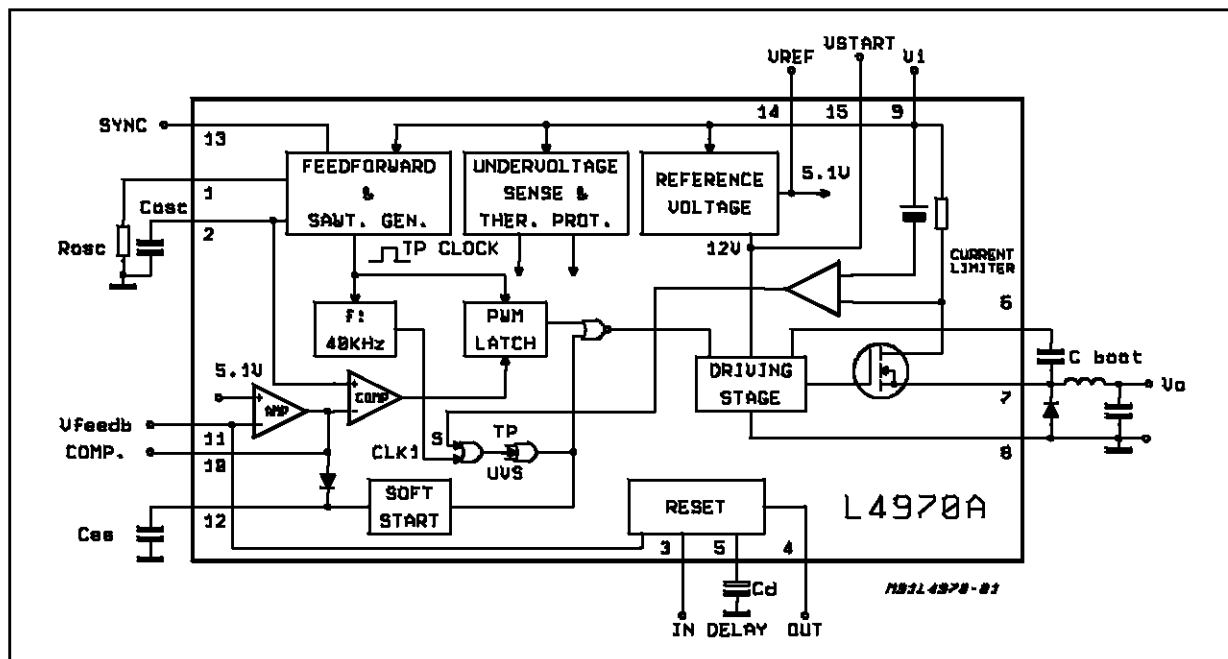
10A SWITCHING REGULATOR

- 10A OUTPUT CURRENT
- 5.1V TO 40V OUTPUT VOLTAGE RANGE
- 0 TO 90% DUTY CYCLE RANGE
- INTERNAL FEED-FORWARD LINE REGULATION
- INTERNAL CURRENT LIMITING
- PRECISE $5.1V \pm 2\%$ ON CHIP REFERENCE
- RESET AND POWER FAIL FUNCTIONS
- SOFT START
- INPUT/OUTPUT SYNC PIN
- UNDER VOLTAGE LOCK OUT WITH HYSTERETIC TURN-ON
- PWM LATCH FOR SINGLE PULSE PER PERIOD
- VERY HIGH EFFICIENCY
- SWITCHING FREQUENCY UP TO 500KHZ
- THERMAL SHUTDOWN
- CONTINUOUS MODE OPERATION

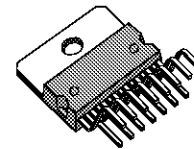
DESCRIPTION

The L4970A is a stepdown monolithic power switching regulator delivering 10A at a voltage variable from 5.1 to 40V.

BLOCK DIAGRAM



MULTIPOWER BCD TECHNOLOGY



Multiwatt15V
ORDERING NUMBER: L4970A

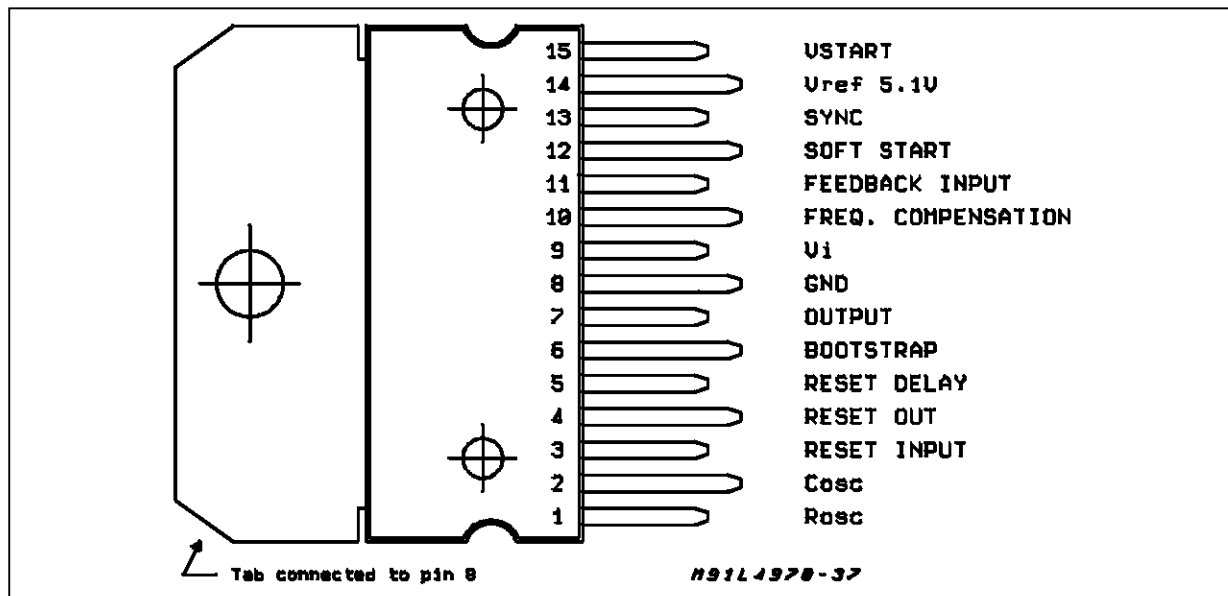
Realized with BCD mixed technology, the device uses a DMOS output transistor to obtain very high efficiency and very fast switching times. Features of the L4970A include reset and power fail for microprocessors, feed forward line regulation, soft start, limiting current and thermal protection. The device is mounted in a 15-lead multiwatt plastic power package and requires few external components. Efficient operation at switching frequencies up to 500KHz allows reduction in the size and cost of external filter components.

L4970A

ABSOLUTE MAXIMUM RATINGS

| Symbol | Parameter | Value | Unit |
|--|--|---------------------|------|
| V ₉ | Input Voltage | 55 | V |
| V ₉ | Input Operating Voltage | 50 | V |
| V ₇ | Output DC Voltage | -1 | V |
| | Output Peak Voltage at t = 0.1μs f = 200KHz | -7 | V |
| I ₇ | Maximum Output Current | Internally Limited | |
| V ₆ | Bootstrap Voltage | 65 | V |
| | Bootstrap Operating Voltage | V ₉ + 15 | V |
| V ₃ , V ₁₂ | Input Voltage at Pins 3, 12 | 12 | V |
| V ₄ | Reset Output Voltage | 50 | V |
| I ₄ | Reset Output Sink Current | 50 | mA |
| V ₅ , V ₁₀ , V ₁₁ , V ₁₃ | Input Voltage at Pin 5, 10, 11, 13 | 7 | V |
| I ₅ | Reset Delay Sink Current | 30 | mA |
| I ₁₀ | Error Amplifier Output Sink Current | 1 | A |
| I ₁₂ | Soft Start Sink Current | 30 | mA |
| P _{tot} | Total Power Dissipation at T _{case} < 120°C | 30 | W |
| T _j , T _{stg} | Junction and Storage Temperature | -40 to 150 | °C |

PIN CONNECTION (Top view)



THERMAL DATA

| Symbol | Parameter | Value | Unit |
|------------------------|-------------------------------------|-------|------|
| R _{th j-case} | Thermal Resistance Junction-case | 1 | °C/W |
| R _{th j-amb} | Thermal Resistance Junction-ambient | 35 | °C/W |

PIN FUNCTIONS

| N° | Name | Function |
|----|------------------------|---|
| 1 | OSCILLATOR | R_{osc} . External resistor connected to ground determines the constant charging current of C_{osc} . |
| 2 | OSCILLATOR | C_{osc} . External capacitor connected to ground determines (with R_{osc}) the switching frequency. |
| 3 | RESET INPUT | Input of Power Fail Circuit. The threshold is 5.1V. It may be connected via a divider to the input for power fail function. It must be connected to the pin 14 an external 30K Ω resistor when power fail signal not required. |
| 4 | RESET OUT | Open Collector Reset/power Fail Signal Output. This output is high when the supply and the output voltages are safe. |
| 5 | RESET DELAY | A C_d capacitor connected between this terminal and ground determines the reset signal delay time. |
| 6 | BOOTSTRAP | A C_{boot} capacitor connected between this terminal and the output allows to drive properly the internal D-MOS transistor. |
| 7 | OUTPUT | Regulator Output. |
| 8 | GROUND | Common Ground Terminal |
| 9 | SUPPLY VOLTAGE | Unregulated Input Voltage. |
| 10 | FREQUENCY COMPENSATION | A series RC network connected between this terminal and ground determines the regulation loop gain characteristics. |
| 11 | 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. |
| 12 | SOFT START | Soft Start Time Constant. A capacitor is connected between this terminal and ground to define the soft start time constant. |
| 13 | SYNC INPUT | Multiple L4970A are synchronized by connecting pin 13 inputs together or via an external syncr. pulse. |
| 14 | V_{ref} | 5.1V V_{ref} Device Reference Voltage. |
| 15 | V_{start} | Internal Start-up Circuit to Drive the Power Stage. |

CIRCUIT OPERATION (refer to the block diagram)

The L4970A is a 10A monolithic stepdown switching regulator working in continuous mode realized in the new BCD Technology. This technology allows the integration of isolated vertical DMOS power transistors plus mixed CMOS/Bipolar transistors.

The device can deliver 10A at an output voltage adjustable from 5.1V to 40V, and contains diagnostic and control functions that make it particularly suitable for microprocessor based systems.

BLOCK DIAGRAM

The block diagram shows the DMOS power transistor and the PWM control loop. Integrated functions include a reference voltage trimmed to $5.1V \pm 2\%$, soft start, undervoltage lockout, oscillator with feedforward control, pulse by pulse current limit, thermal shutdown and finally the reset and power fail circuit. The reset and power fail circuit provides an output signal for a microprocessor indicating the status of the system.

Device turn on is around 11V with a typical 1V hysteresis, this threshold provides a correct voltage for the driving stage of the DMOS gate and the hysteresis prevents instabilities.

An external bootstrap capacitor charged to 12V by an internal voltage reference is needed to provide correct gate drive to the power DMOS. The driving circuit is able to source and sink peak currents of around 0.5A to the gate of the DMOS transistor. A typical switching time of the current in the DMOS transistor is 50ns. Due to the fast commutation switching frequencies up to 500kHz are possible.

The PWM control loop consists of a sawtooth oscillator, error amplifier, comparator, latch and the output stage. An error signal is produced by comparing the output voltage with the precise $5.1V \pm 2\%$ on chip reference. This error signal is then compared with the sawtooth oscillator, in order to generate a fixed frequency pulse width modulated drive for the output stage. A PWM latch is included to eliminate multiple pulsing within a period even in noisy environments. The gain and

Figure 1: Feedforward Waveform

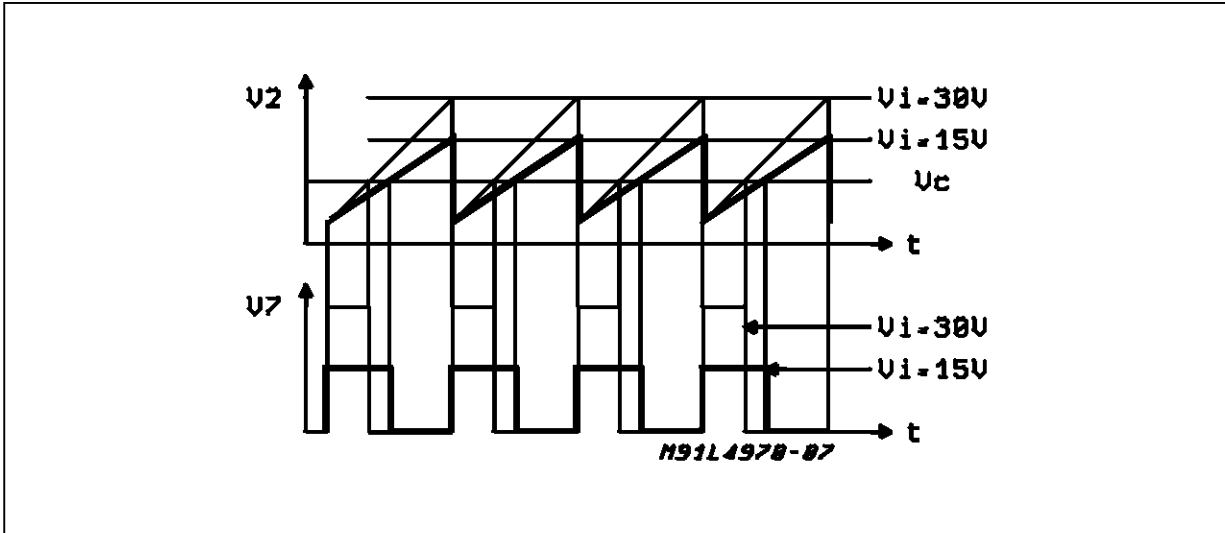


Figure 2: Soft Start Function

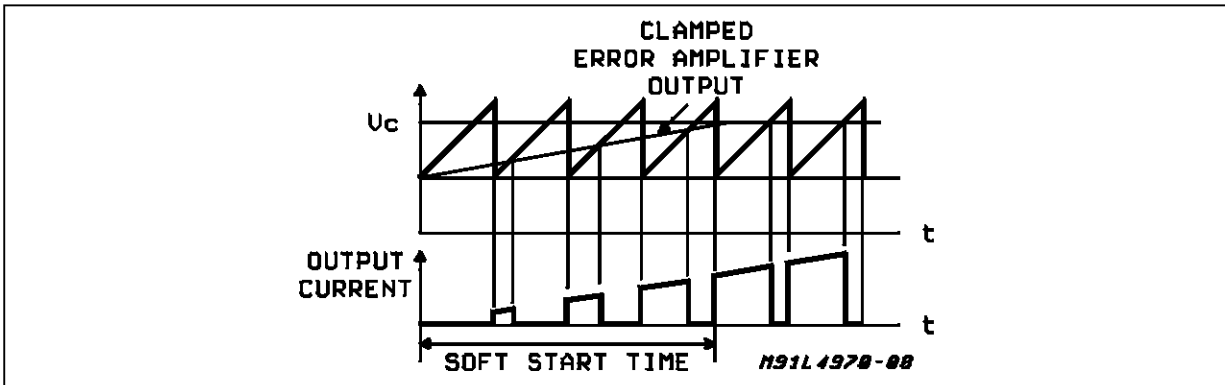
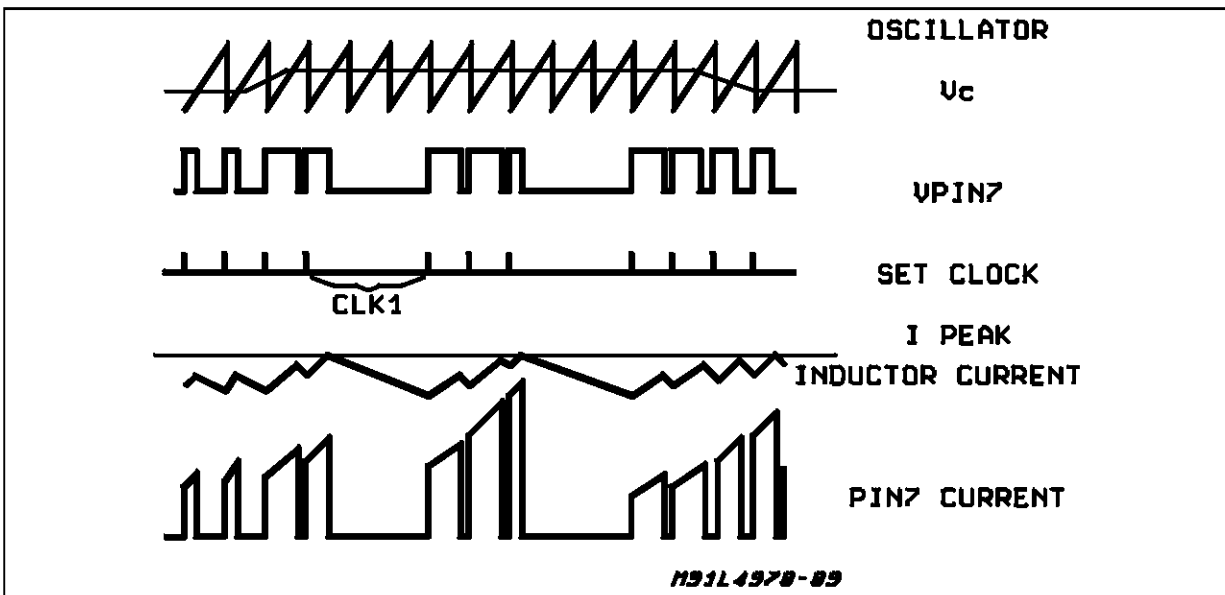


Figure 3: Limiting Current Function



stability of the loop can be adjusted by an external RC network connected to the output of the error amplifier. A voltage feedforward control has been added to the oscillator, this maintains superior line regulation over a wide input voltage range. Closing the loop directly gives an output voltage of 5.1V, higher voltages are obtained by inserting a voltage divider.

At turn on output overcurrents are prevented by the soft start function (fig. 2). The error amplifier is initially clamped by an external capacitor C_{ss} and allowed to rise linearly under the charge of an internal constant current source.

Output overload protection is provided by a current limit circuit (fig. 3). The load current is sensed by an internal metal resistor connected to a comparator. When the load current exceeds a preset threshold the output of the comparator sets a flip flop which turns off the power DMOS. The next clock pulse, from an internal 40kHz oscillator will reset the flip flop and the power DMOS will again conduct. This current protection method, ensures

a constant current output when the system is overloaded or short circuited and limits the switching frequency, in this condition, to 40kHz.

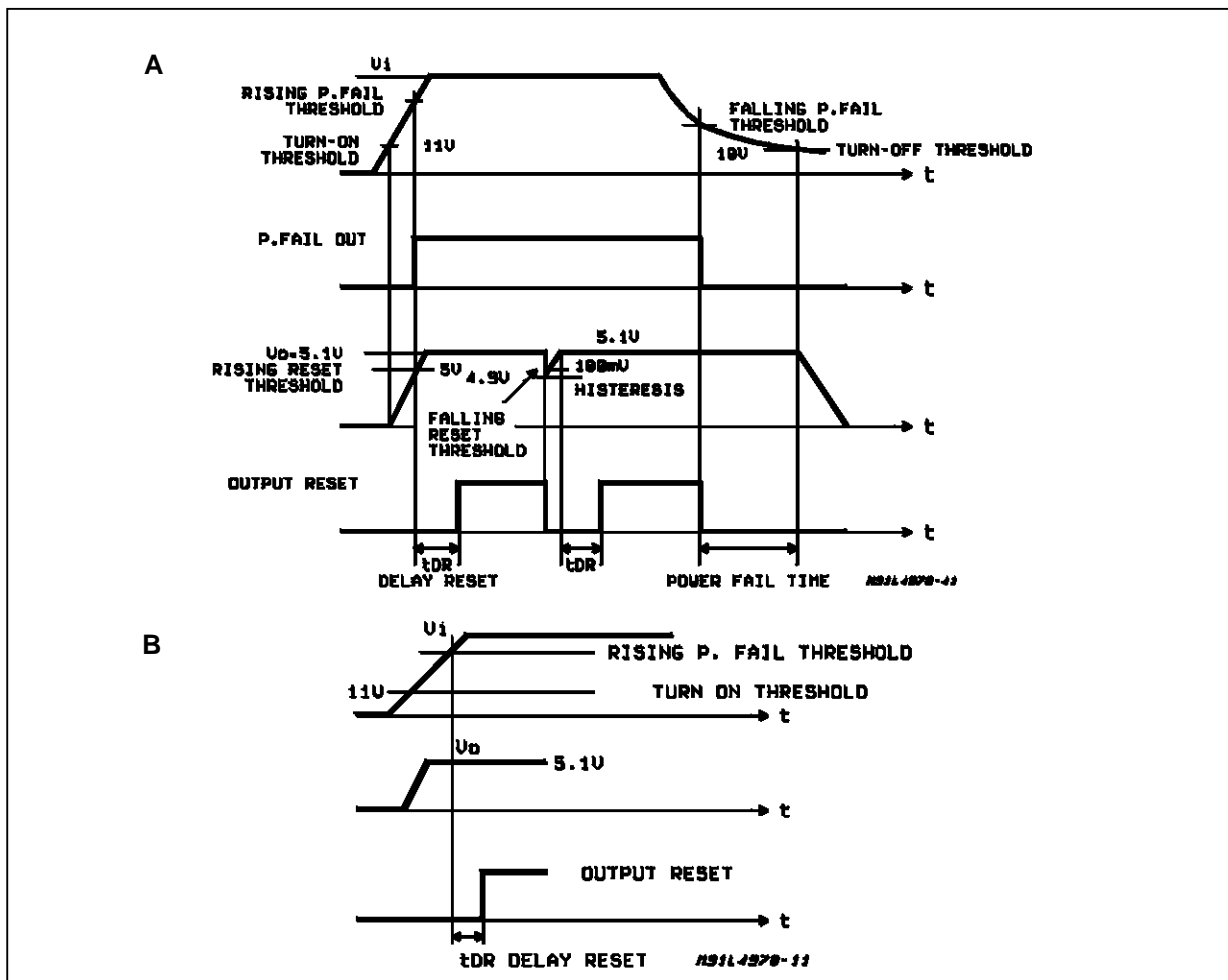
The Reset and Power fail circuitry (fig 4) generates an output signal when the supply voltage exceeds a threshold programmed by an external voltage divider. The reset signal, is generated with a delay time programmed by an external capacitor on the delay pin. When the supply voltage falls below the threshold or the output voltage goes below 5V the reset output goes low immediately. The reset output is an open collector-drain.

Fig 4A shows the case when the supply voltage is higher than the threshold, but the output voltage is not yet 5V.

Fig 4B shows the case when the output is 5.1V but the supply voltage is not yet higher than the fixed threshold.

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

Figure 4: Reset and Power Fail Functions.



L4970A

ELECTRICAL CHARACTERISTICS (Refer to the test circuit, $T_j = 25^\circ\text{C}$, $V_i = 35\text{V}$, $R_4 = 16\text{K}\Omega$, $C_9 = 2.2\text{nF}$, $f_{\text{SW}} = 200\text{KHz}$ typ, unless otherwise specified)

DYNAMIC CHARACTERISTICS

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|-------------------------------|--|--|------|-------------|------------|----------|------|
| V_i | input Voltage Range (pin 9) | $V_o = V_{\text{ref}}$ to 40V $I_o = 10\text{A}$ | 15 | | 50 | V | 5 |
| V_o | Output Voltage | $V_i = 15\text{V}$ to 50V $I_o = 5\text{A}$; $V_o = V_{\text{ref}}$ | 5 | 5.1 | 5.2 | V | 5 |
| ΔV_o | Line Regulation | $V_i = 15\text{V}$ to 50V $I_o = 5\text{A}$; $V_o = V_{\text{ref}}$ | | 12 | 30 | mV | 5 |
| ΔV_o | Load Regulation | $V_o = V_{\text{ref}}$ $I_o = 3\text{A}$ to 6A $I_o = 2\text{A}$ to 10A | | 10 20 | 30 50 | mV mV | 5 |
| V_d | Dropout Voltage Between Pin 9 and 7 | $I_o = 5\text{A}$ $I_o = 10\text{A}$ | | 0.55 1.1 | 0.8 1.6 | V V | 5 |
| I_{7L} | Max. Limiting Current | $V_i = 15$ to 50V | 11 | 13 | 15 | A | 5 |
| η | Efficiency | $I_o = 5\text{A}$ $V_o = V_{\text{ref}}$ $V_o = 12\text{V}$ | 80 | 85 92 | | % % | 5 |
| | | $I_o = 10\text{A}$ $V_o = V_{\text{ref}}$ $V_o = 12\text{V}$ | 75 | 80 87 | | % % | 5 |
| SVR | Supply Voltage Ripple Reject. | $V_i = 2\text{VRMS}$; $I_o = 5\text{A}$ $f = 100\text{Hz}$; $V_o = V_{\text{ref}}$ | 56 | 60 | | dB | 5 |
| f | Switching Frequency | | 180 | 200 | 220 | KHz | 5 |
| $\frac{\Delta f}{\Delta V_i}$ | Voltage Stability of Switching Frequency | $V_i = 15\text{V}$ to 45V | | 2 | 6 | % | 5 |
| $\frac{\Delta f}{T_j}$ | Temperature Stability of Switching Frequency | $T_j = 0$ to 125°C | | 1 | | % | 5 |
| f_{max} | Maximum Operating Switching Frequency | $V_o = V_{\text{ref}}$; $R_4 = 10\text{K}\Omega$ $I_o = 10\text{A}$; $C_9 = 1\text{nF}$ | 500 | | | KHz | 5 |

V_{ref} SECTION (pin 14)

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|----------------------------------|---|--|------|------|------|----------------------|------|
| V_{14} | Reference Voltage | | 5 | 5.1 | 5.2 | V | 7 |
| ΔV_{14} | Line Regulation | $V_i = 15\text{V}$ to 50V | | 10 | 25 | mV | 7 |
| ΔV_{14} | Load Regulation | $I_{14} = 0$ to 1mA | | 20 | 40 | mV | 7 |
| $\frac{\Delta V_{14}}{\Delta T}$ | Average Temperature Coefficient Reference Voltage | $T_j = 0^\circ\text{C}$ to 125°C | | 0.4 | | mV/ $^\circ\text{C}$ | 7 |
| $I_{14 \text{ short}}$ | Short Circuit Current Limit | $V_{14} = 0$ | | 70 | | mA | 7 |

V_{START} SECTION (pin 15)

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|------------------------|-----------------------------|----------------------|------|------|------|------|------|
| V_{15} | Reference Voltage | | 11.4 | 12 | 12.6 | V | 7 |
| ΔV_{15} | Line Regulation | $V_i = 15$ to 50V | | 0.6 | 1.4 | V | 7 |
| ΔV_{15} | Load Regulation | $I_{15} = 0$ to 1mA | | 50 | 200 | mV | 7 |
| $I_{15 \text{ short}}$ | Short Circuit Current Limit | $V_{15} = 0\text{V}$ | | 80 | | mA | 7 |

ELECTRICAL CHARACTERISTICS (continued)**DC CHARACTERISTICS**

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|-------------|--------------------------|---------------------------------------|------|------|------|------|------|
| V_{9on} | Turn-on Threshold | | 10 | 11 | 12 | V | 7A |
| V_{9Hyst} | Turn-off Hysteresys | | | 1 | | V | 7A |
| I_{9Q} | Quiescent Current | $V_{12} = 0$; $S1 = D$ | | 13 | 19 | mA | 7A |
| I_{9OQ} | Operating Supply Current | $V_{12} = 0$; $S1 = C$; $S2 = B$ | | 16 | 23 | mA | 7A |
| I_{7L} | Out Leak Current | $V_i = 55V$; $S3 = A$; $V_{12} = 0$ | | | 2 | mA | 7A |

SOFT START

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|----------|---------------------------|-----------------------------------|------|------|------|---------|------|
| I_{12} | Soft Start Source Current | $V_{12} = 3V$; $V_{11} = 0V$ | 70 | 100 | 130 | μA | 7B |
| V_{12} | Output Saturation Voltage | $I_{12} = 20mA$; $V_9 = 10V$ | | | 1 | V | 7B |
| | | $I_{12} = 200\mu A$; $V_9 = 10V$ | | | 0.7 | V | 7B |

ERROR AMPLIFIER

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|-----------|--------------------------|--|------|------|------|---------|------|
| V_{10H} | High Level Out Voltage | $I_{10} = -100\mu A$; $S1 = C$ $V_{11} = 4.7V$ | 6 | | | V | 7C |
| V_{10L} | Low Level Out Voltage | $I_{10} = +100\mu A$; $S1 = C$ $V_{11} = 5.3V$; | | | 1.2 | V | 7C |
| I_{10H} | Source Output Current | $V_{10} = 1V$; $S1 = E$ $V_{11} = 4.7V$ | 100 | 150 | | μA | 7C |
| I_{10L} | Sink Output Current | $V_{10} = 6V$; $S1 = D$ $V_{11} = 5.3V$ | 100 | 150 | | μA | 7C |
| I_{11} | Input Bias Current | $R_S = 10K\Omega$ | | 0.4 | 3 | μA | – |
| G_V | DC Open Loop Gain | $V_{VCM} = 4V$; $R_S = 10\Omega$ | 60 | | | dB | – |
| SVR | Supply Voltage Rejection | $15 < V_i < 50V$; $R_S = 10\Omega$ | 60 | 80 | | dB | – |
| V_{OS} | Input Offset Voltage | $R_S = 50\Omega$ | | 2 | 10 | mV | – |

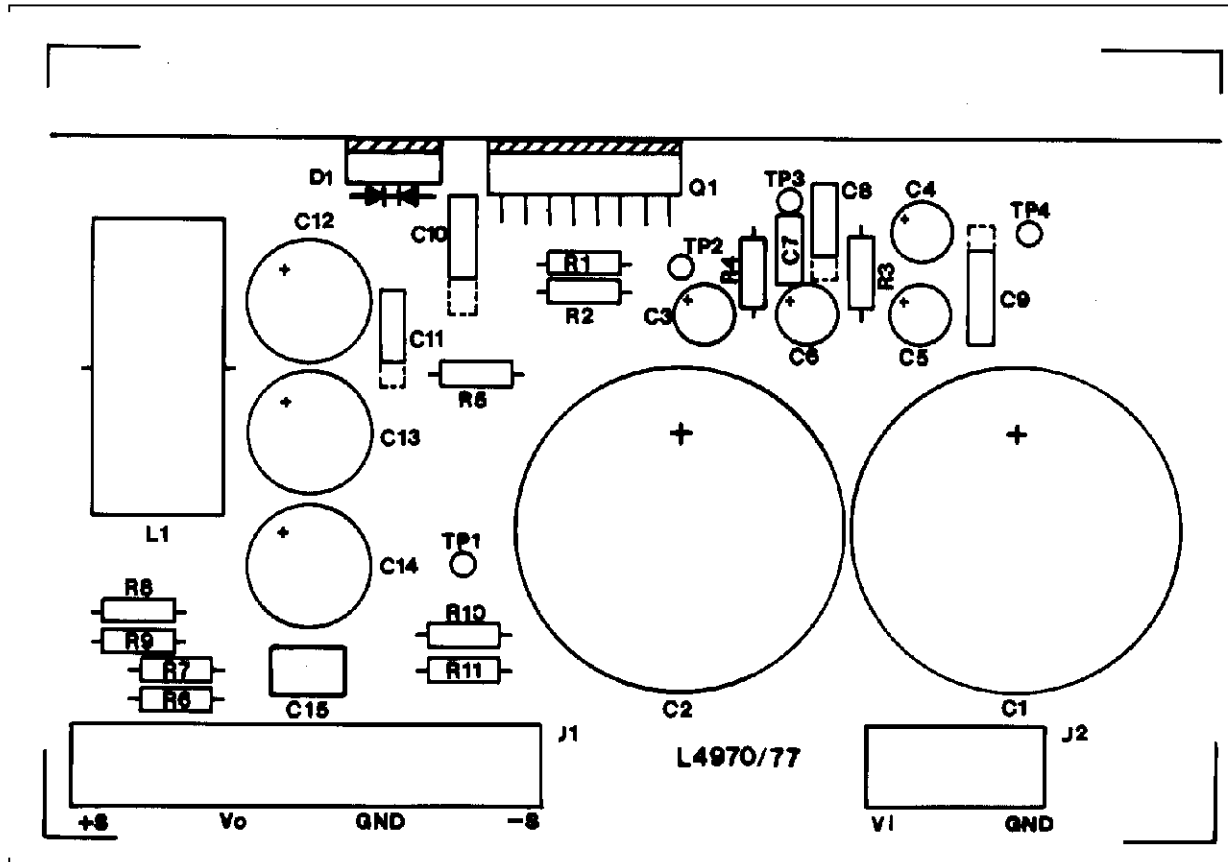
RAMP GENERATOR (pin 2)

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|--------|-------------------|-----------------------------|-------------|------|------|---------|------|
| V_2 | Ramp Valley | $S1 = C$; $S2 = B$ | 1.2 | 1.5 | | V | 7A |
| V_2 | Ramp Peak | $S1 = C$; $S2 = B$; | $V_i = 15V$ | | 2.5 | V | 7A |
| | | | $V_i = 45V$ | | 5.5 | V | 7A |
| I_2 | Min. Ramp Current | $S1 = A$; $I_1 = 100\mu A$ | | 270 | 300 | μA | 7A |
| I_2 | Max. Ramp Current | $S1 = A$; $I_1 = 1mA$ | 2.4 | 2.7 | | mA | 7A |

SYNC FUNCTION (pin 13)

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|-----------|---|---|------|------|------|---------|------|
| V_{13} | Low Input Voltage | $V_i = 15V$ to $50V$; $V_{12} = 0$; $S1 = C$; $S2 = B$; $S4 = B$ | -0.3 | | 0.9 | V | 7A |
| V_{13} | High Input voltage | $V_{12} = 0$; $S1 = C$; $S2 = B$; $S4 = B$ | 3.5 | | 5.5 | V | 7A |
| I_{13L} | Sync Input Current with Low Input Voltage | $V_{13} = V_2 = 0.9V$; $S4 = A$; $S1 = C$; $S2 = B$ | | | 0.4 | mA | 7A |
| I_{13H} | Input Current with High Input Voltage | $V_{13} = 3.5V$; $S4 = A$; $S1 = C$; $S2 = B$ | | | 1.5 | mA | 7A |
| V_{13} | Output Amplitude | | 4 | 5 | | V | – |
| t_W | Output Pulse Width | $V_{thr} = 2.5V$ | 0.3 | 0.5 | 0.8 | μs | – |

Figure 6a: P.C. Board (components side) and Components Layout of Figure 5 (1:1 scale).



PARTS LIST

| | |
|--|--|
| R ₁ = 30K Ω | C ₁ , C ₂ = 3300 μ F 63V _L EYF (ROE) |
| R ₂ = 10K Ω | C ₃ , C ₄ , C ₅ , C ₆ = 2.2 μ F |
| R ₃ = 15K Ω | C ₇ = 390pF Film |
| R ₄ = 16K Ω | C ₈ = 22nF MKT 1817 (ERO) |
| R ₅ = 22 Ω 0,5W | |
| R ₆ = 4K7 | C ₉ = 2.2nF KP1830 |
| R ₇ = 10 Ω | C ₁₀ = 220nF MKT |
| R ₈ = see tab. A | C ₁₁ = 2.2nF MP1830 |
| R ₉ = OPTION | **C ₁₂ , C ₁₃ , C ₁₄ = 220 μ F 40V _L EKR |
| R ₁₀ = 4K7 | C ₁₅ = 1 μ F Film |
| R ₁₁ = 10 Ω | |
| D1 = MBR 1560CT (or 16A/60V or equivalent) | |
| L1 = 40 μ H | core 58071 MAGNETICS 27 TURNS \varnothing 1,3mm (AWG 16) COGEMA 949178 |

* 2 capacitors in parallel to increase input RMS current capability
 ** 3 capacitors in parallel to reduce total output ESR

Table A

| V ₀ | R ₉ | R ₇ |
|----------------|----------------|----------------|
| 12V | 4.7k Ω | 6.2k Ω |
| 15V | 4.7k Ω | 9.1k Ω |
| 18V | 4.7k Ω | 12k Ω |
| 24V | 4.7k Ω | 18k Ω |

Table B
SUGGESTED BOOTSTRAP CAPACITORS

| Operating Frequency | Bootstrap Cap.c10 |
|---------------------|-------------------|
| f = 20KHz | \geq 680nF |
| f = 50KHz | \geq 470nF |
| f = 100KHz | \geq 330nF |
| f = 200KHz | \geq 220nF |
| f = 500KHz | \geq 100nF |

Figure 6b: P.C. Board (Back side) and Components Layout of the Circuit of Fig. 5. (1:1 scale)

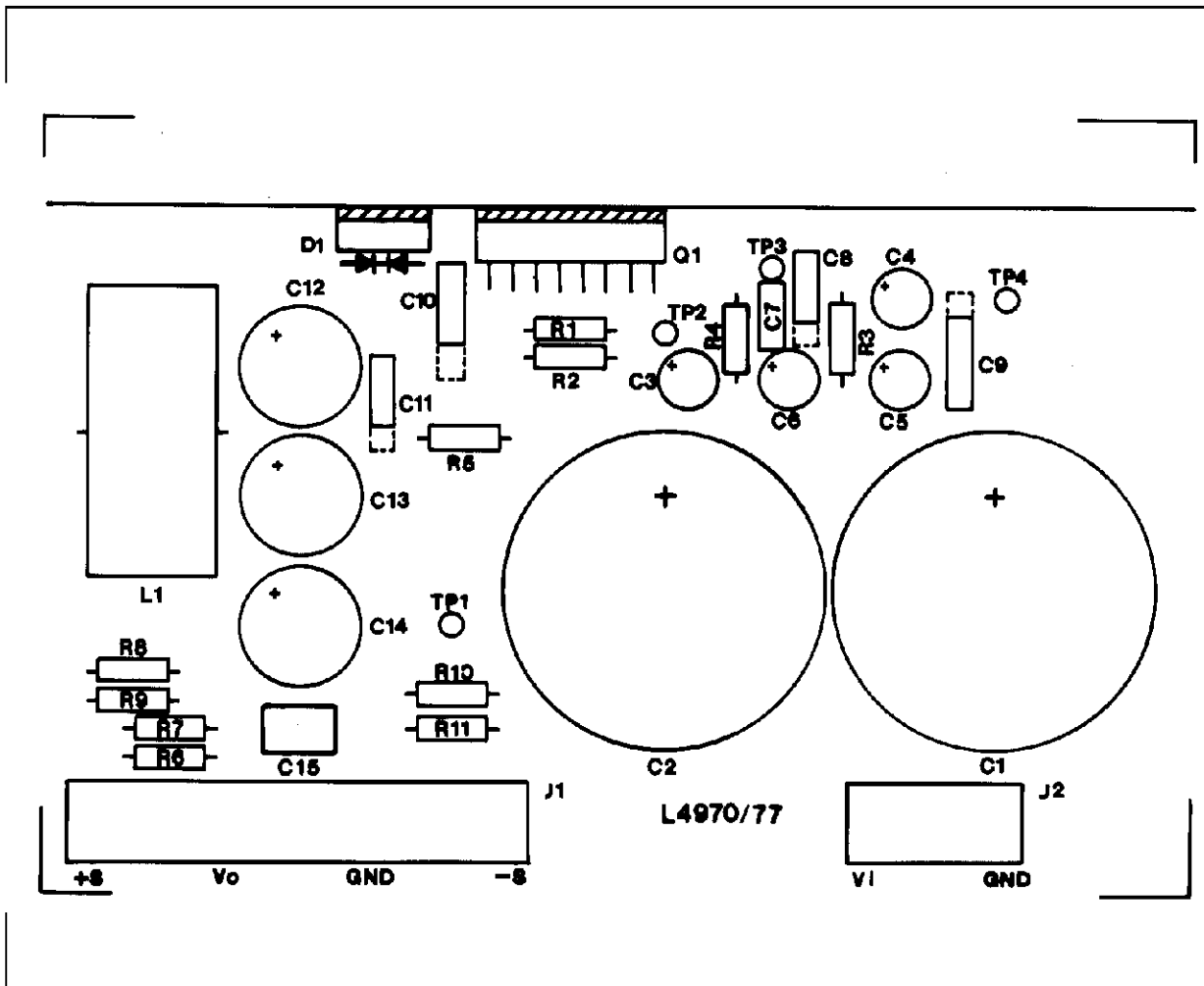


Figure 7: DC Test Circuits

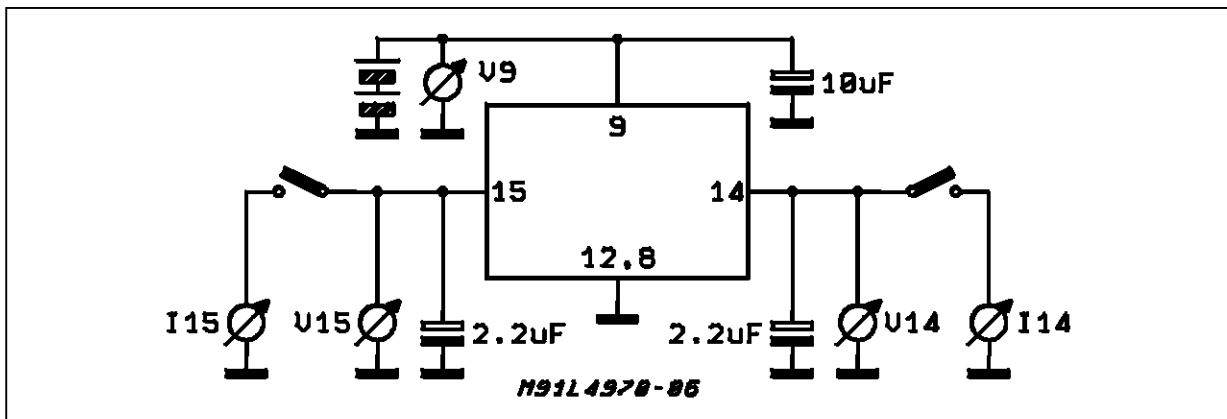


Figure 7A

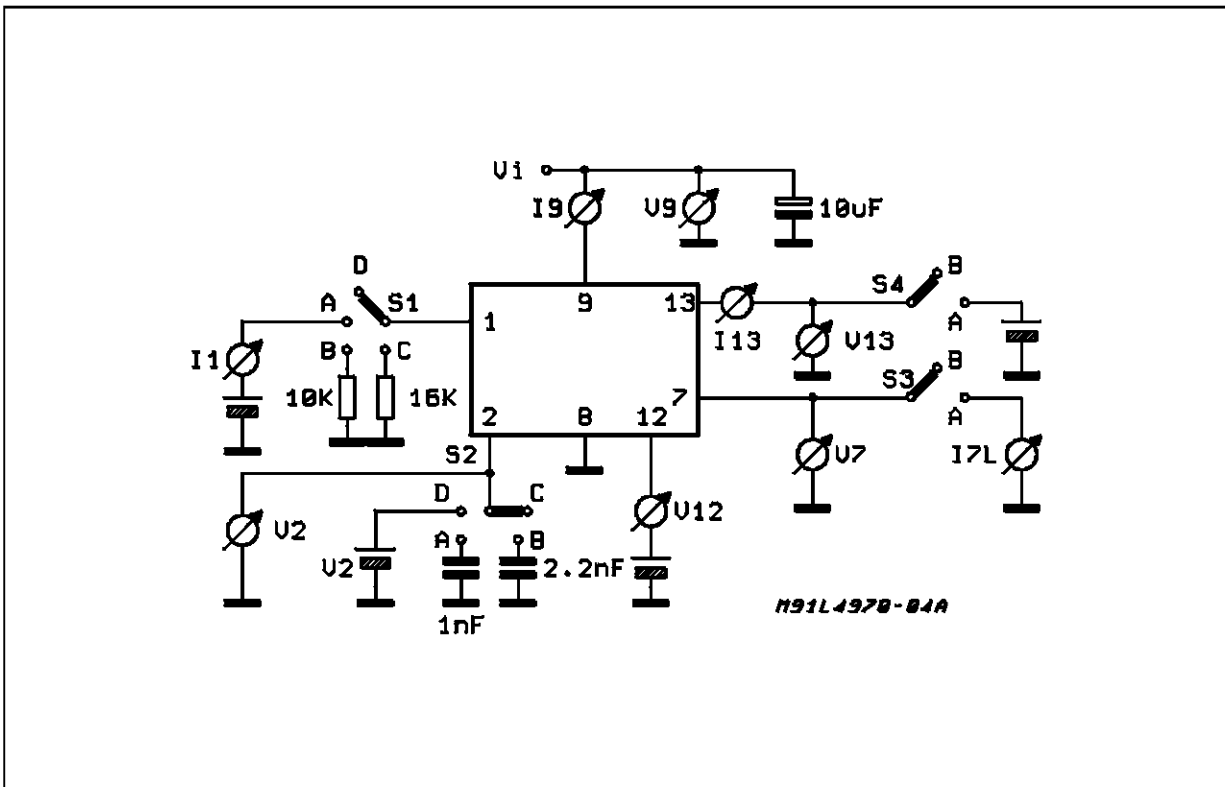


Figure 7B

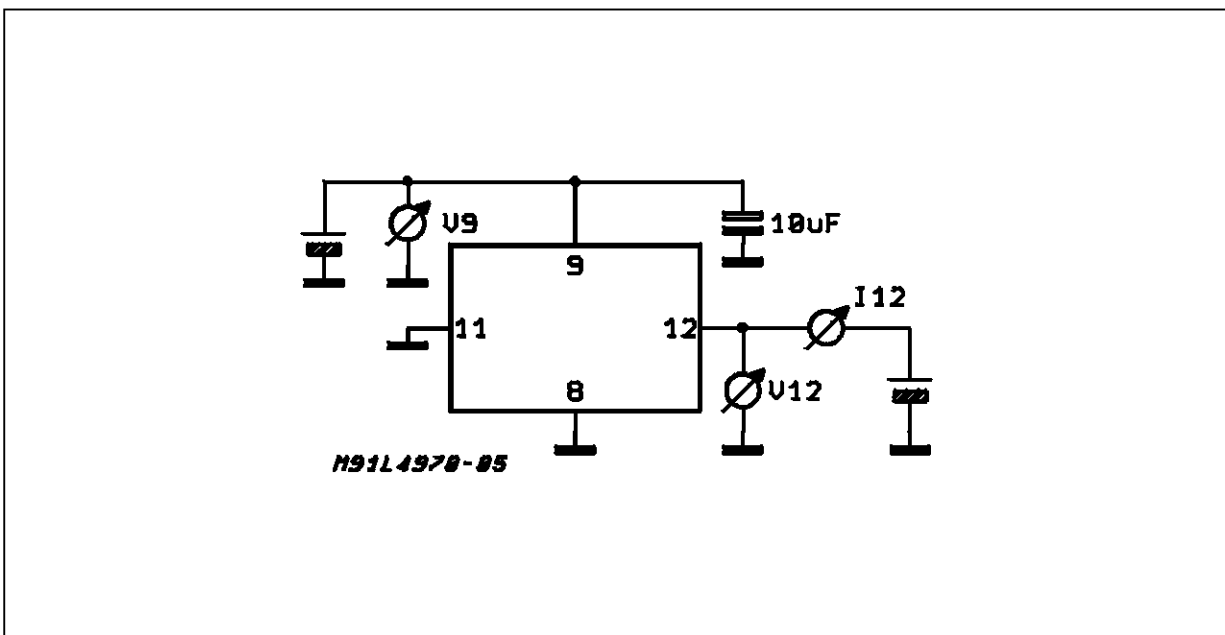


Figure 7D

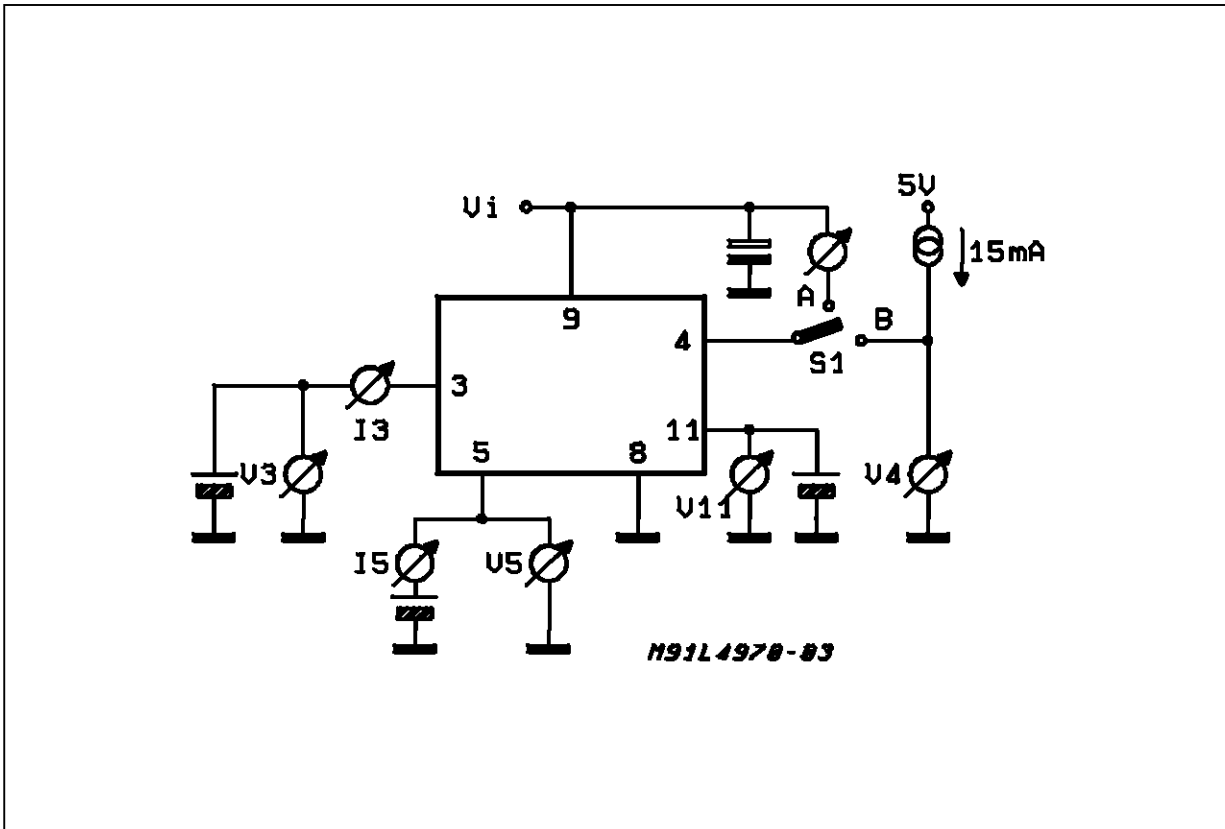


Figure 7C

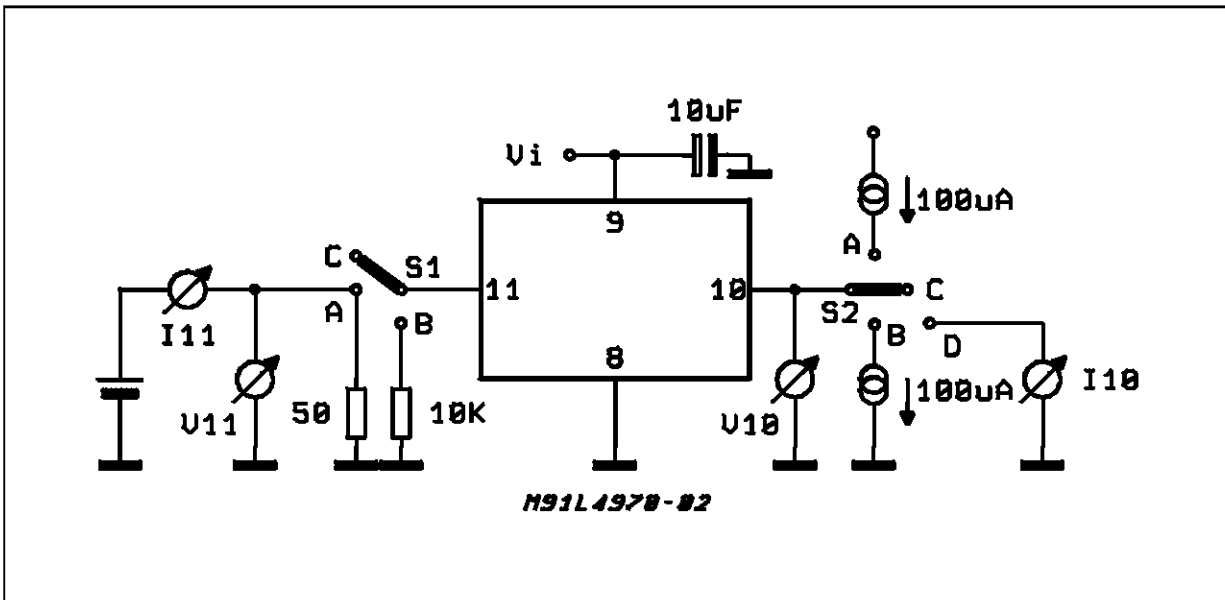


Figure 8: Quiescent Drain Current vs. Supply Voltage (0% duty cycle - see fig. 7A).

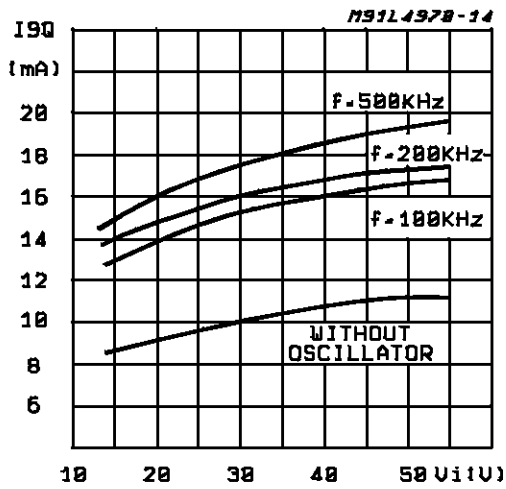


Figure 9: Quiescent Drain Current vs. Junction Temperature (0% duty cycle).

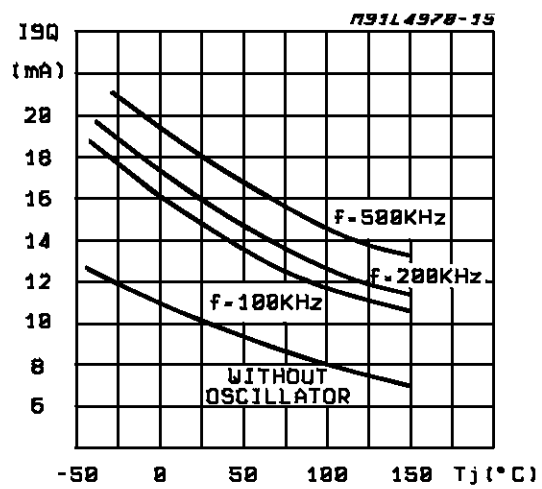


Figure 10: Quiescent Drain Current vs. Duty Cycle

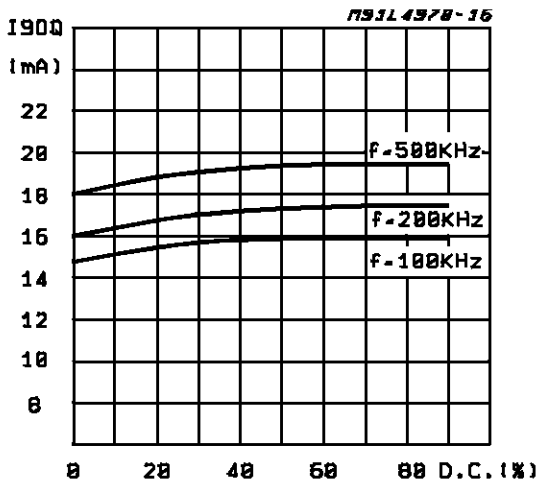


Figure 11: Reference Voltage (pin14) vs. V_i (see fig. 7)

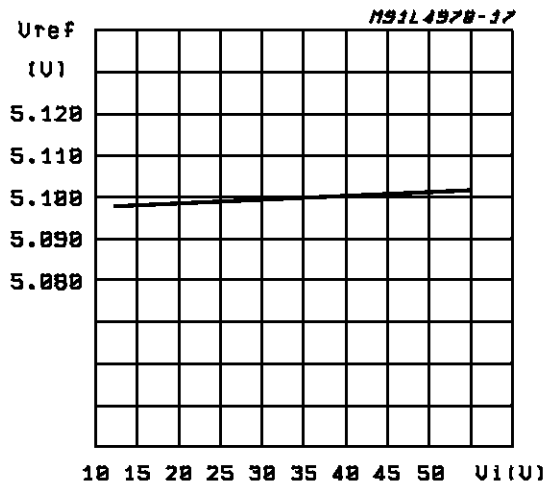


Figure 12: Reference Voltage (pin 14) vs. Junction Temperature (see fig. 7)

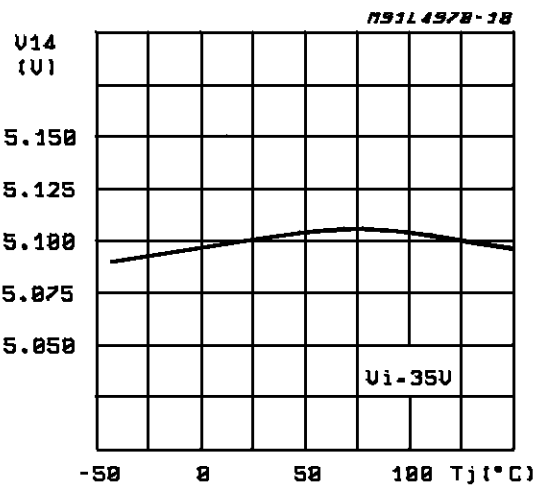


Figure 13: Reference Voltage (pin15) vs. V_i (see fig. 7)

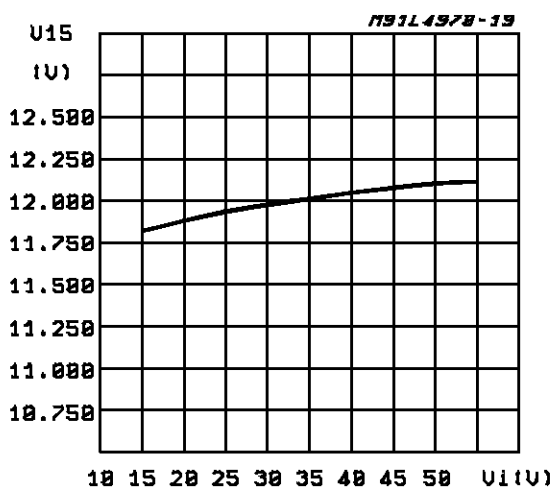


Figure 14: Reference Voltage (pin 15) vs. Junction Temperature (see fig. 7)

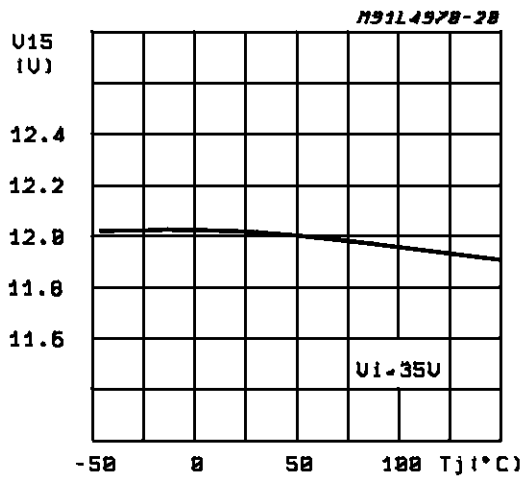


Figure 15: Reference Voltage 5.1V (pin 14) Supply Voltage Ripple Rejection vs. Frequency

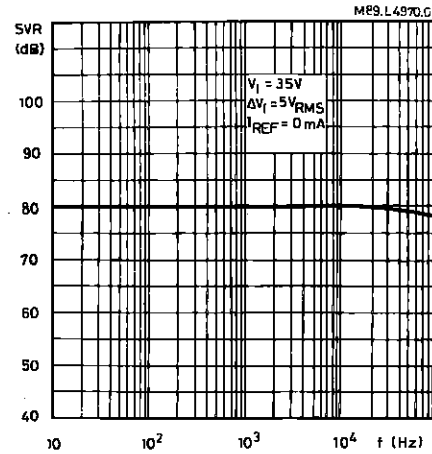


Figure 16: Switching Frequency vs. Input Voltage (see fig. 5)

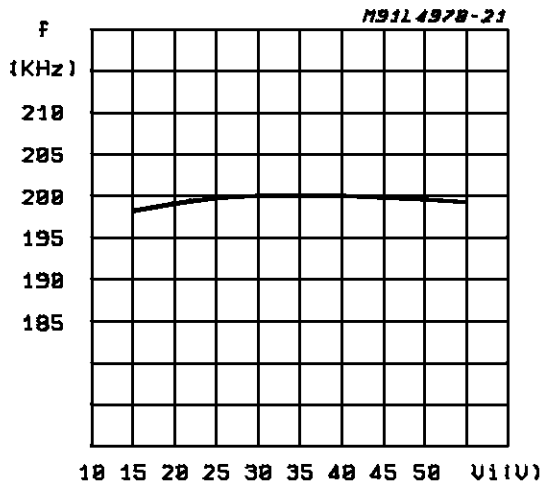


Figure 17: Switching Frequency vs. Junction Temperature (see fig. 5)

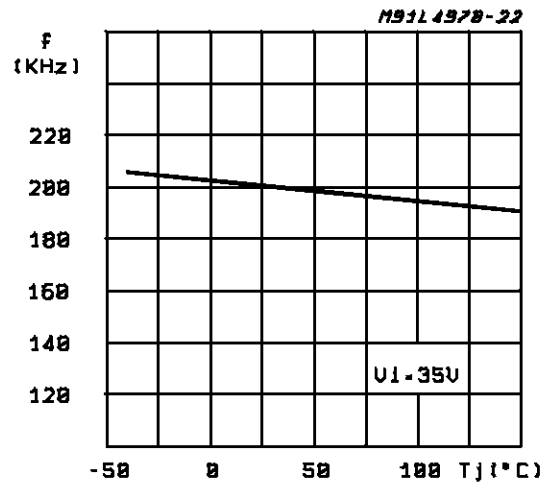


Figure 18: Switching Frequency vs. R4 (see fig. 5)

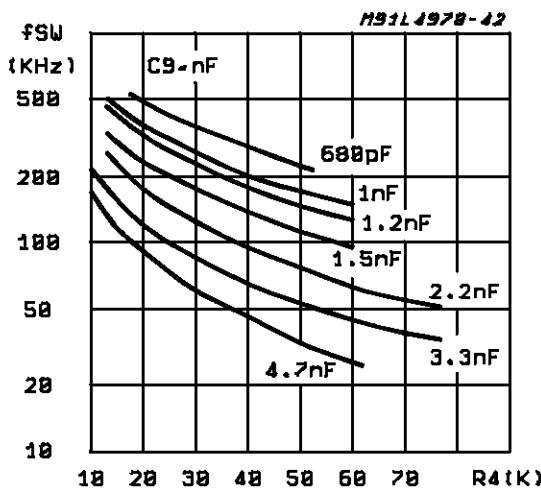


Figure 19: Max. Duty Cycle vs. Frequency

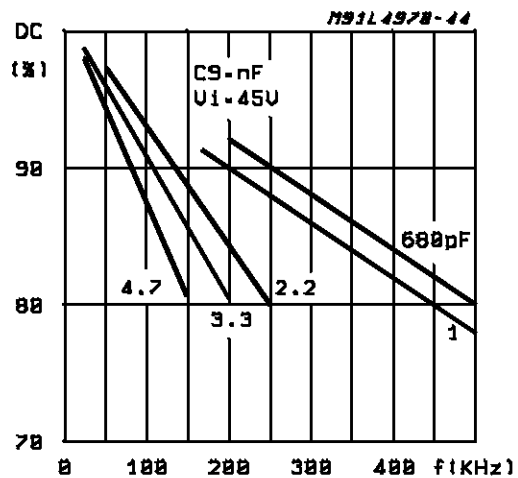


Figure 20: Supply Voltage Ripple Rejection vs. Frequency (see fig. 5)

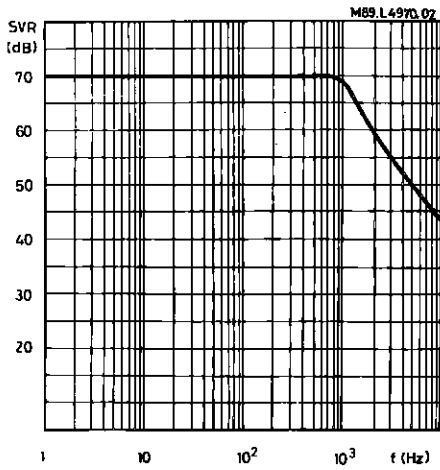


Figure 21: Line Transient Response (see fig. 5)

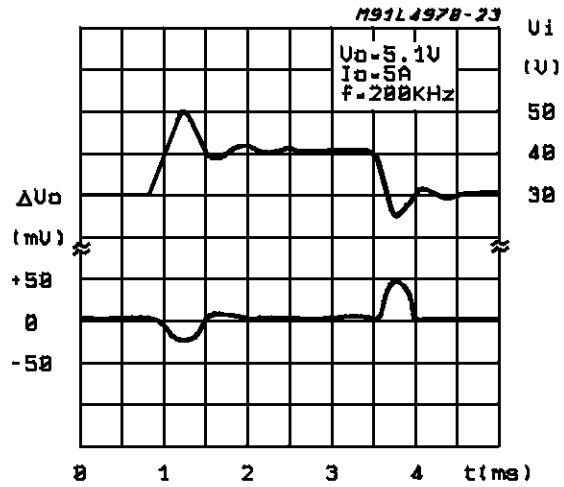


Figure 22: Load Transient Response (see fig. 5)

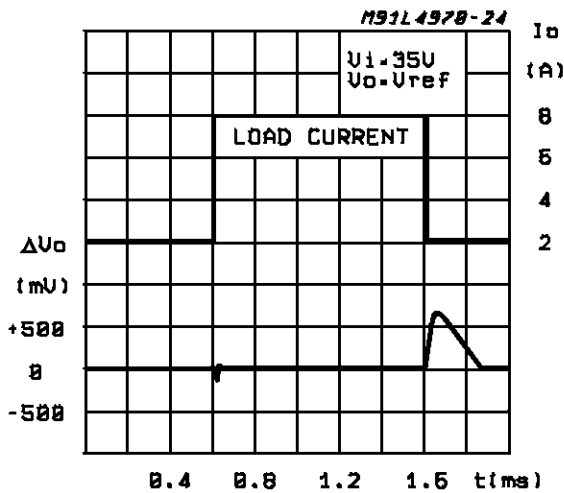


Figure 23: Dropout Voltage Between Pin 9 and Pin 7 vs. Current at Pin 7

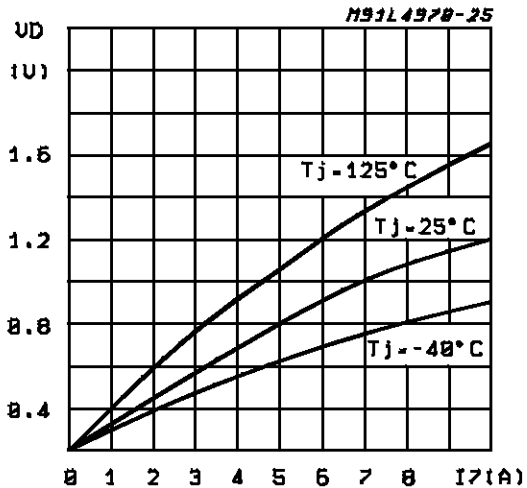


Figure 24: Dropout Voltage Between Pin 9 and Pin 7 vs. Junction Temperature

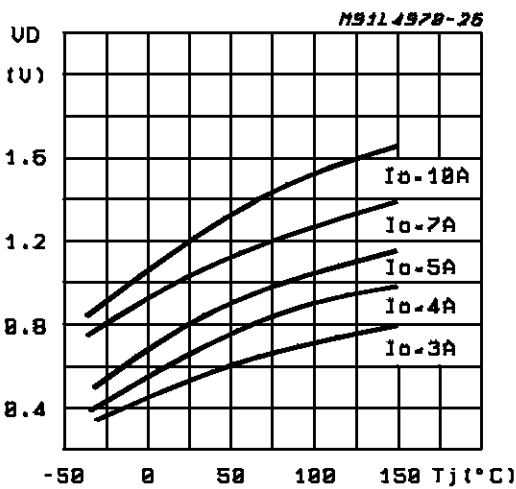


Figure 25: Power Dissipation (device only) vs. Input Voltage

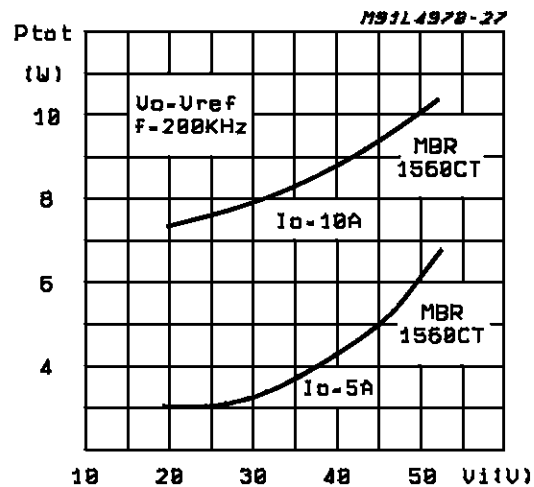


Figure 26: Power Dissipation (device only) vs. Output Voltage

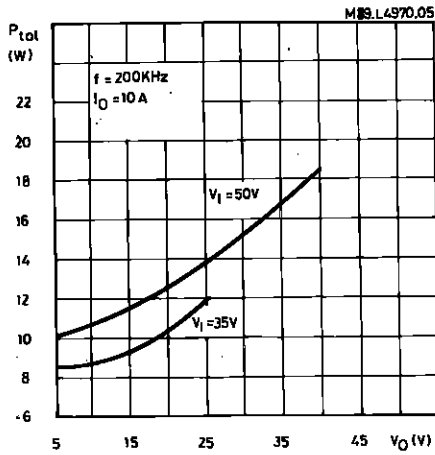


Figure 28: Efficiency vs. Output Current

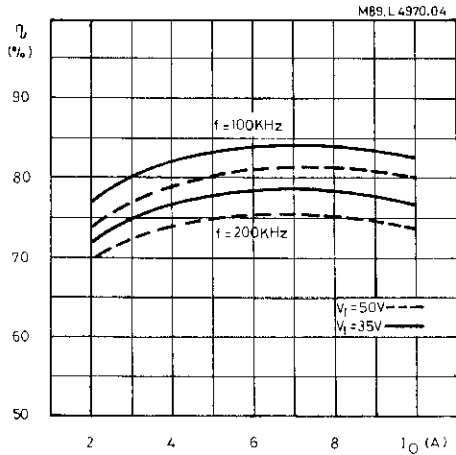


Figure 30: Efficiency vs. Output Voltage

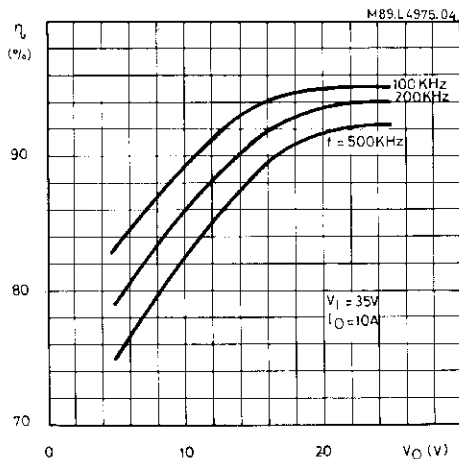


Figure 27: Heatsink Used to Derive the Device's Power Dissipation

$$R_{th} - \text{Heatsink} = \frac{T_{case} - T_{amb}}{P_d}$$

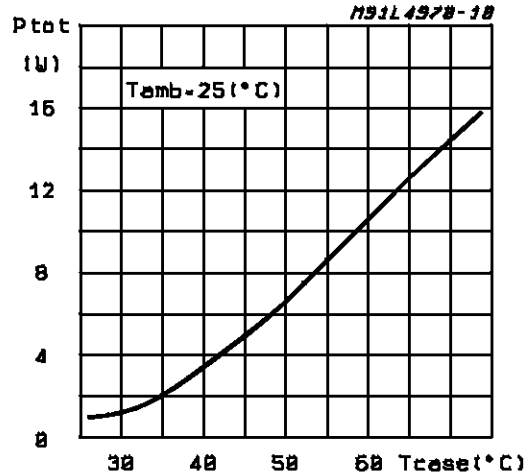


Figure 29: Efficiency vs. Output Voltage

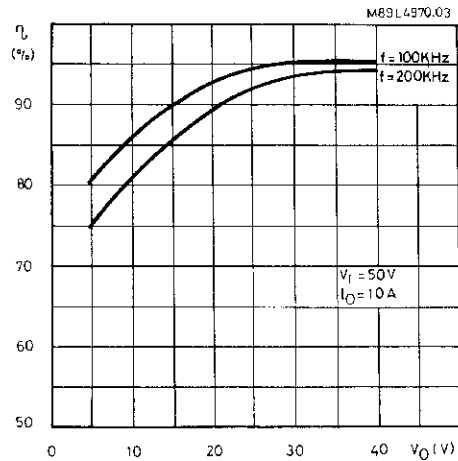


Figure 31: Open Loop Frequency and Phase Response of Error Amplifier (see fig.7C)

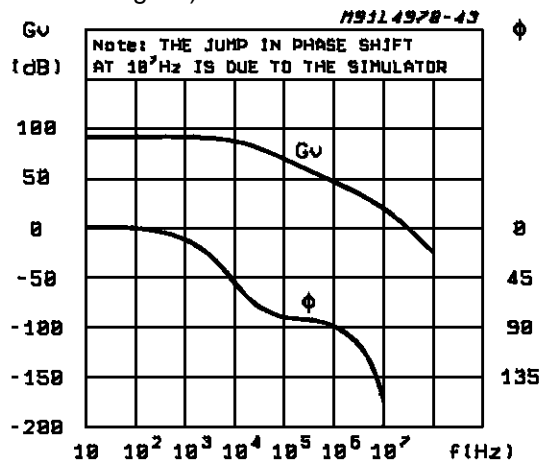


Figure 32: Power Dissipation Derating Curve

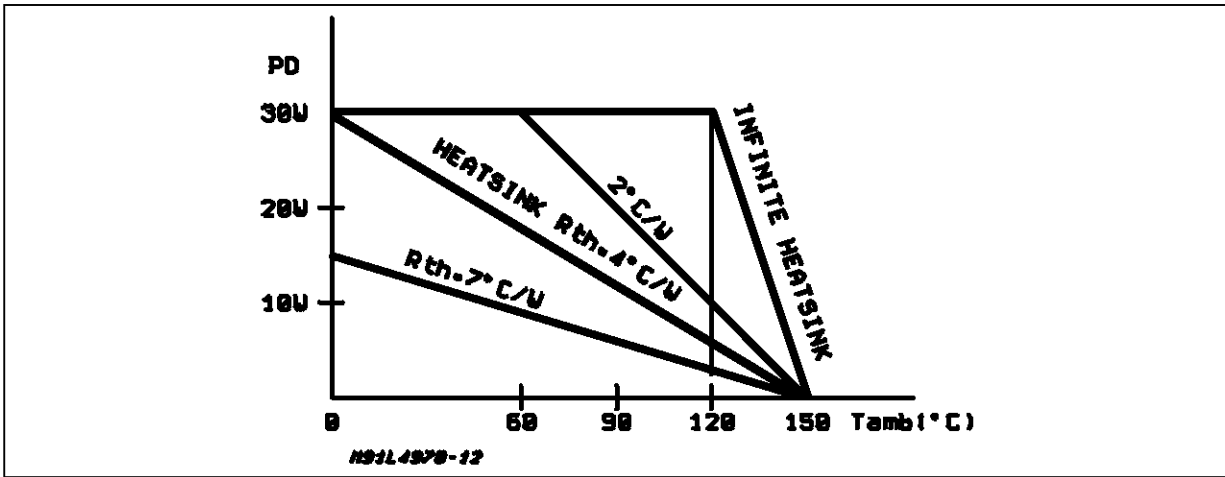
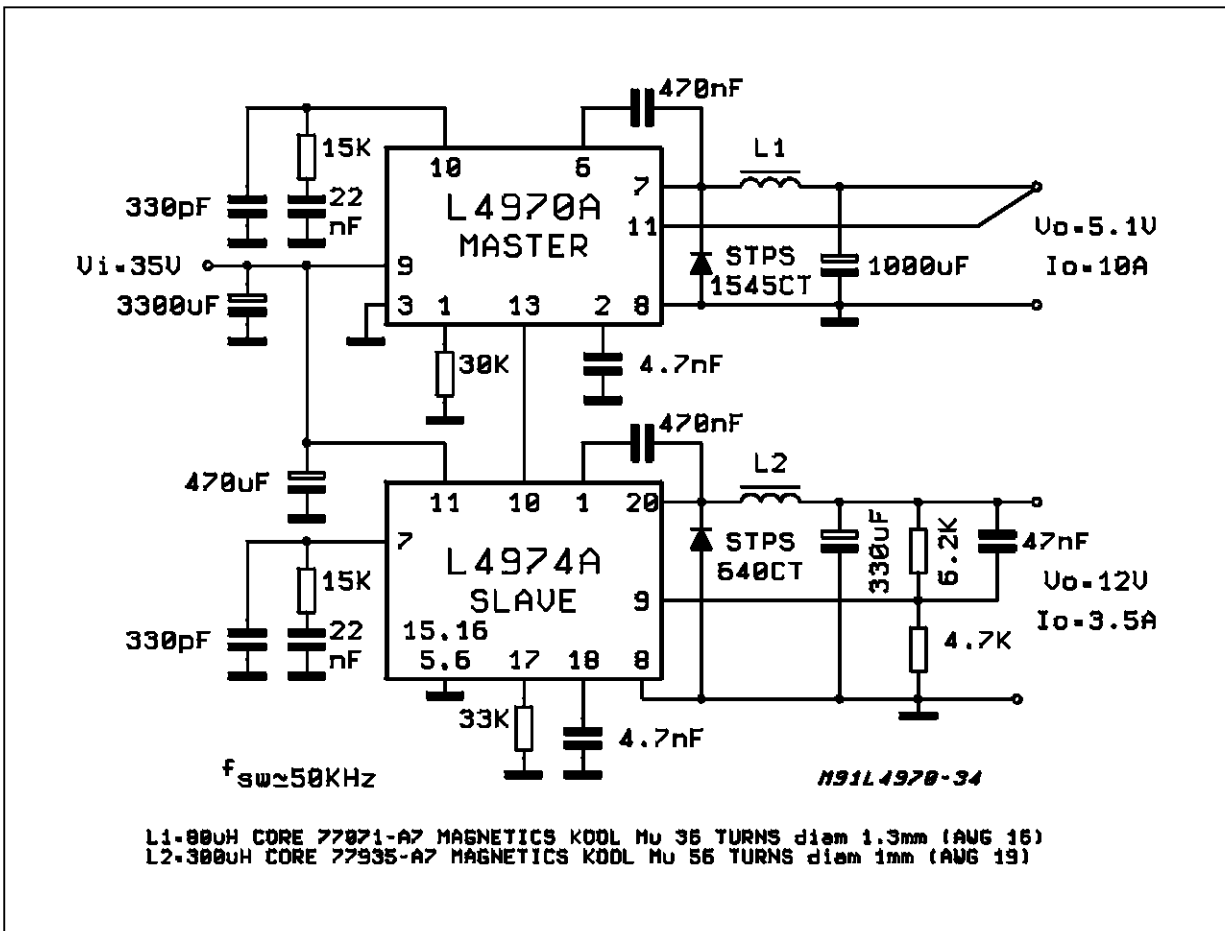


Figure 33: A5.1V/12V Multiple Supply. Note the Synchronization between the L4970A and the L4974A



L4970A

Figure 34: 5.1V / 10A Low Cost Application

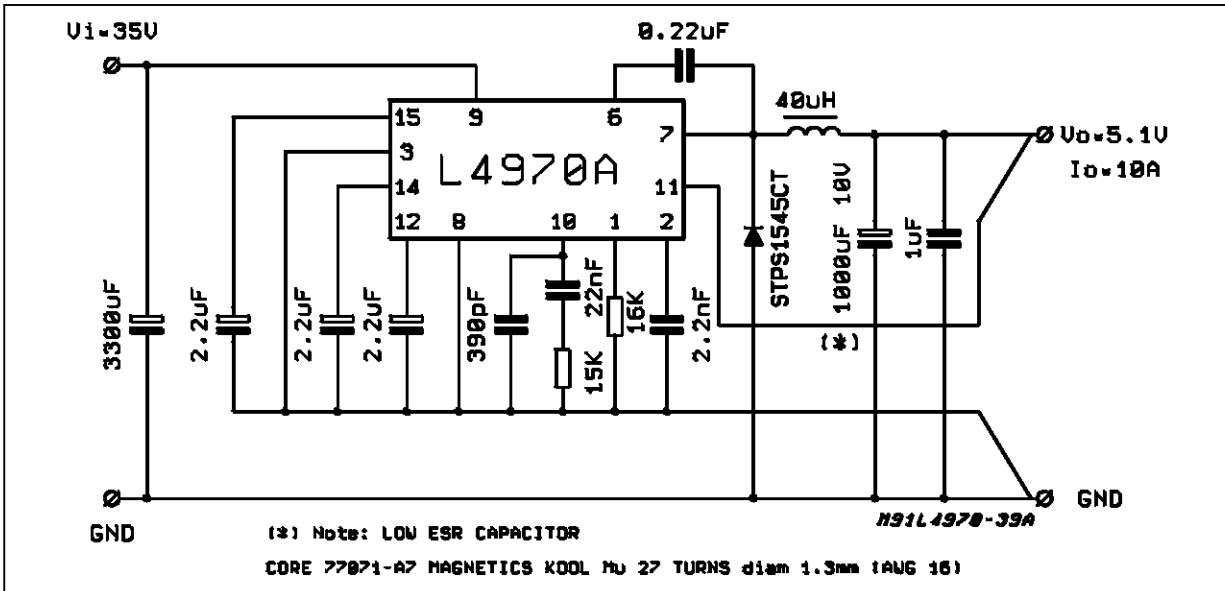


Figure 35: 10A Switching Regulator, Adjustable from 0V to 25V.

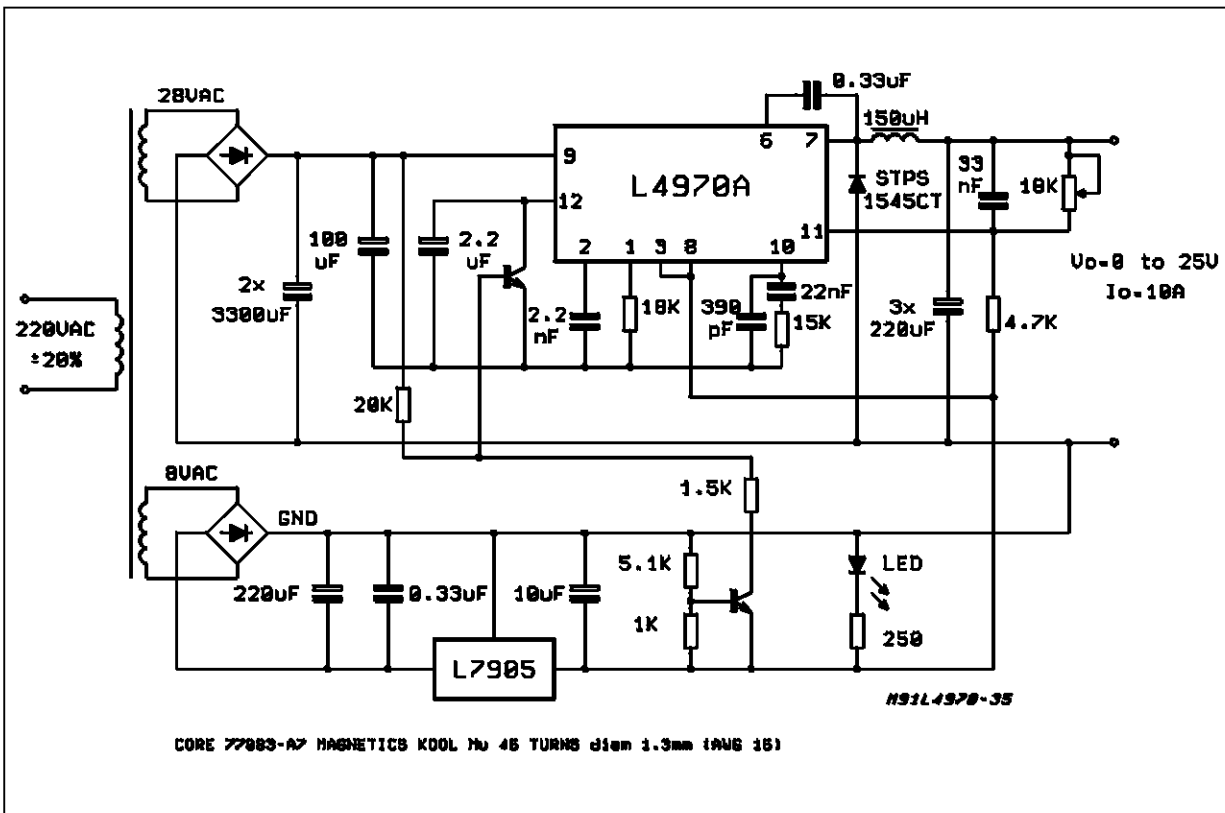
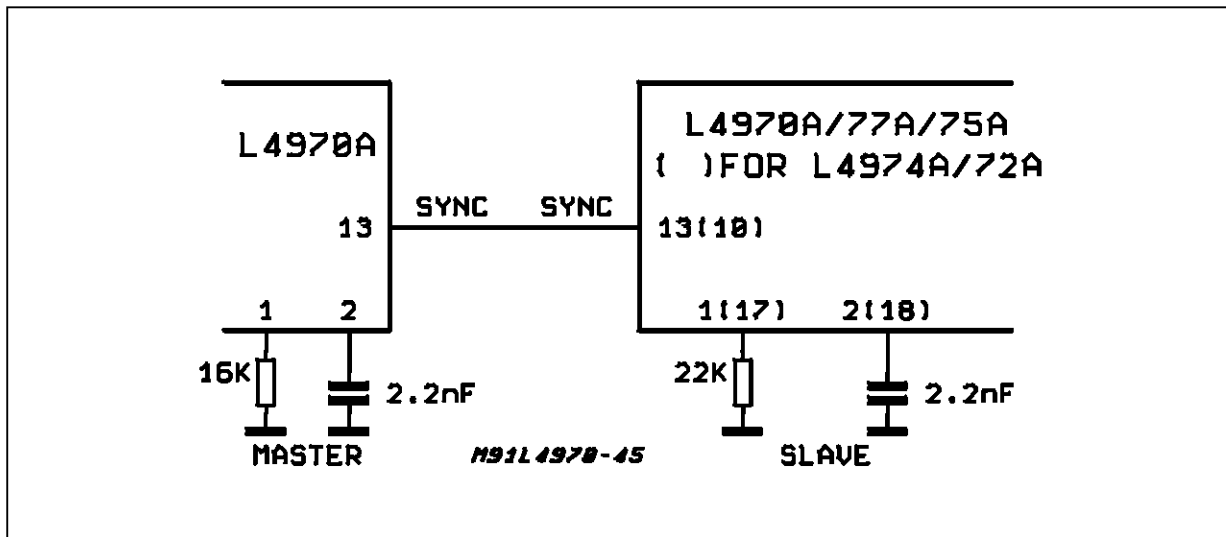
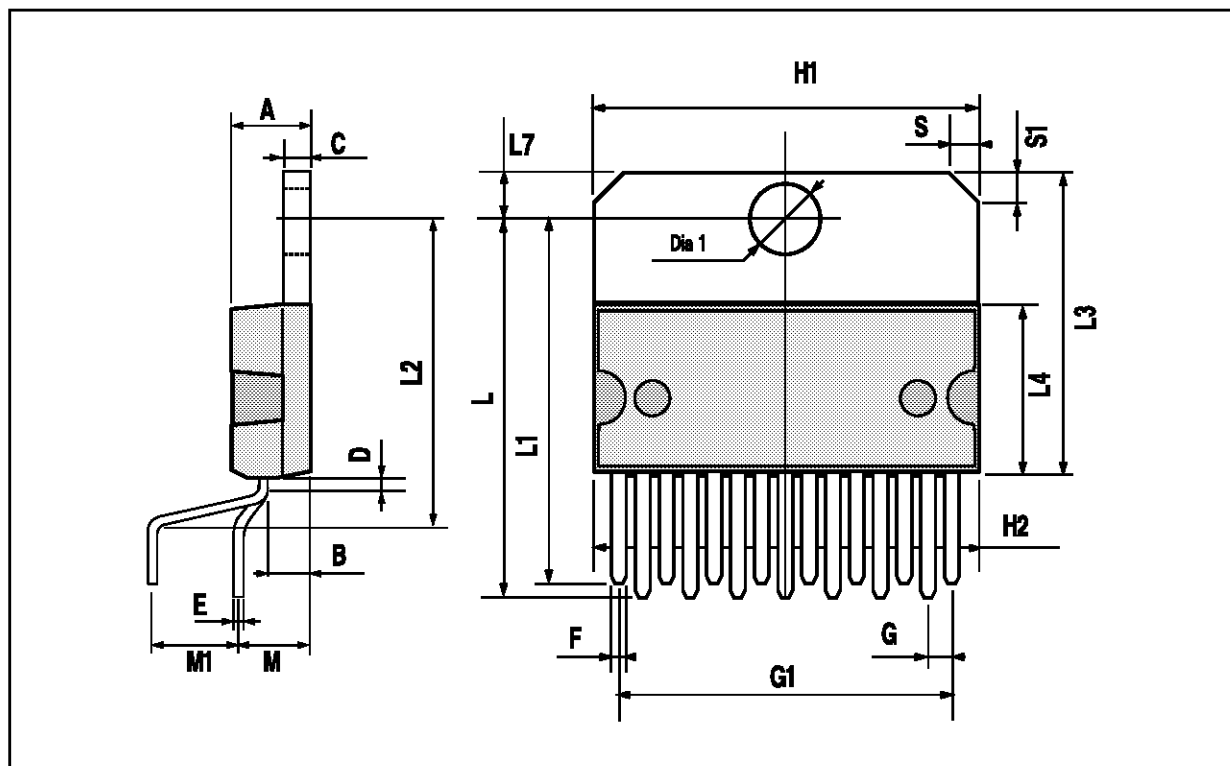


Figure 36: L4970A's Sync. Example



MULTIWATT15 PACKAGE MECHANICAL DATA

| DIM. | mm | | | inch | | |
|------|-------|-------|-------|-------|-------|-------|
| | MIN. | TYP. | MAX. | MIN. | TYP. | MAX. |
| A | | | 5 | | | 0.197 |
| B | | | 2.65 | | | 0.104 |
| C | | | 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 |
| M | 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 |
| Dia1 | 3.65 | | 3.85 | 0.144 | | 0.152 |



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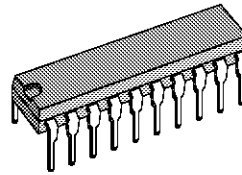
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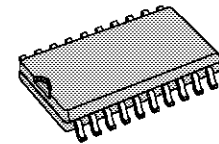
2A SWITCHING REGULATOR

- 2A OUTPUT CURRENT
- 5.1V TO 40V OUTPUT VOLTAGE RANGE
- 0 TO 90% DUTY CYCLE RANGE
- INTERNAL FEED-FORWARD LINE REG.
- INTERNAL CURRENT LIMITING
- PRECISE 5.1V ± 2% ON CHIP REFERENCE
- RESET AND POWER FAIL FUNCTIONS
- INPUT/OUTPUT SYNC PIN
- UNDER VOLTAGE LOCK OUT WITH HYS-TERETIC TURN-ON
- PWM LATCH FOR SINGLE PULSE PER PE-RIOD
- VERY HIGH EFFICIENCY
- SWITCHING FREQUENCY UP TO 200KHz
- THERMAL SHUTDOWN
- CONTINUOUS MODE OPERATION

MULTIPOWER BCD TECHNOLOGY



POWERDIP
(16 + 2 + 2)



SO20

ORDERING NUMBERS : L4972A (Powerdip)
L4972AD (SO20)

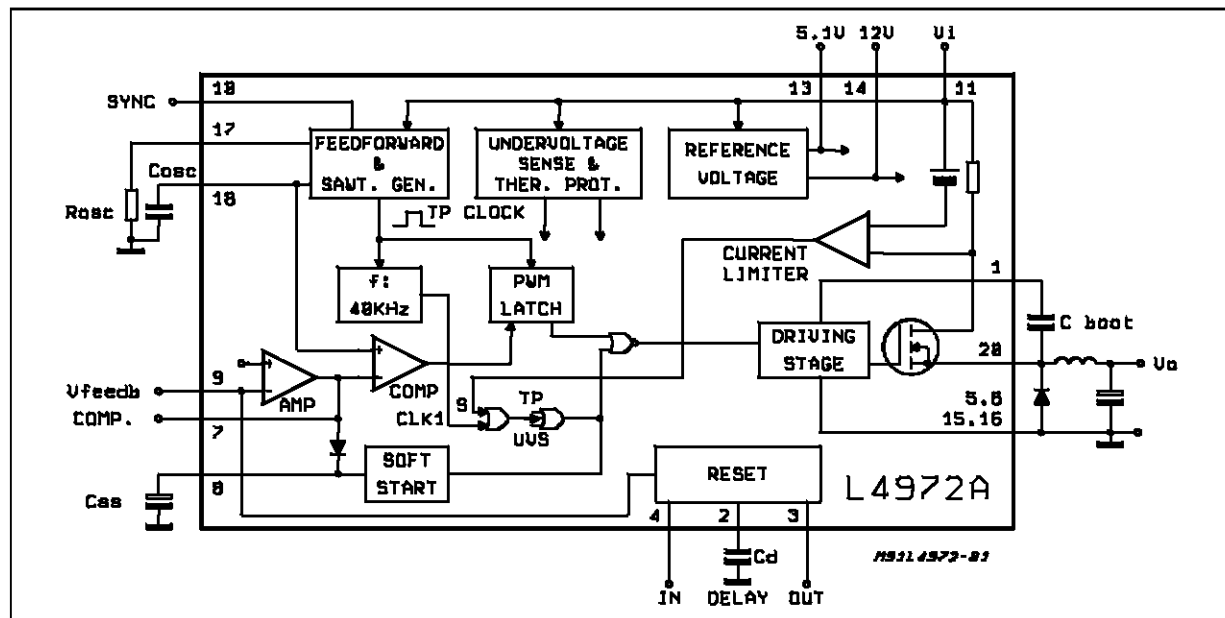
DESCRIPTION

The L4972A is a stepdown monolithic power switching regulator delivering 2A at a voltage variable from 5.1 to 40V.

Realized with BCD mixed technology, the device uses a DMOS output transistor to obtain very high efficiency and very fast switching times. Features of

the L4972A include reset and power fail for micro-processors, feed forward line regulation, soft start, limiting current and thermal protection. The device is mounted in a Powerdip 16 + 2 + 2 and SO20 large plastic packages and requires few external components. Efficient operation at switching frequencies up to 200KHz allows reduction in the size and cost of external filter component.

BLOCK DIAGRAM



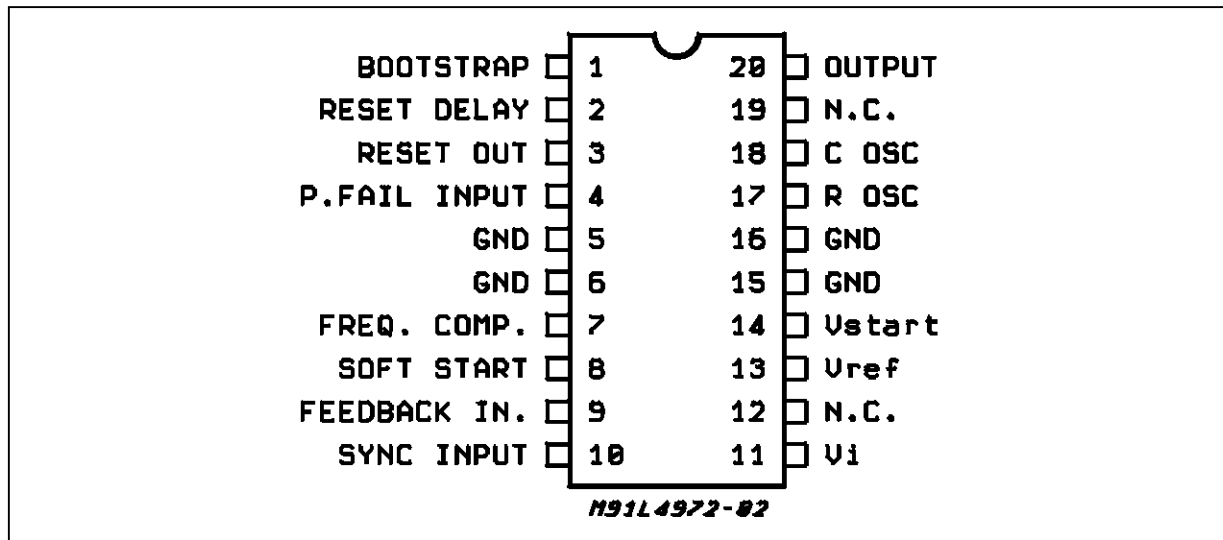
L4972A-L4972AD

ABSOLUTE MAXIMUM RATINGS

| Symbol | Parameter | Value | Unit |
|--|---|--------------------------|--------|
| V ₁₁ | Input Voltage | 55 | V |
| V ₁₁ | Input Operating Voltage | 50 | V |
| V ₂₀ | Output DC Voltage | -1 | V |
| | Output Peak Voltage at t = 0.1μs f = 200khz | -5 | V |
| I ₂₀ | Maximum Output Current | Internally Limited | |
| V ₁ | Bootstrap Voltage | 65 | V |
| | Bootstrap Operating Voltage | V ₁₁ + 15 | V |
| V ₄ , V ₈ | Input Voltage at Pins 4, 12 | 12 | V |
| V ₃ | Reset Output Voltage | 50 | V |
| I ₃ | Reset Output Sink Current | 50 | mA |
| V ₂ , V ₇ , V ₉ , V ₁₀ | Input Voltage at Pin 2, 7, 9, 10 | 7 | V |
| I ₂ | Reset Delay Sink Current | 30 | mA |
| I ₇ | Error Amplifier Output Sink Current | 1 | A |
| I ₈ | Soft Start Sink Current | 30 | mA |
| P _{tot} | Total Power Dissipation at T _{PINS} ≤ 90°C at T _{amb} = 70°C (No copper area on PCB) | 5 / 3.75(*) 1.3/1 (*) | W W |
| T _J , T _{stg} | Junction and Storage Temperature | -40 to 150 | °C |

(*) SO-20

PIN CONNECTION (top view)



THERMAL DATA

| Symbol | Parameter | Powerdip | SO-20 |
|------------------------|-------------------------------------|------------|--------|
| R _{th j-pins} | Thermal Resistance Junction-Pins | max 12°C/W | 16°C/W |
| R _{th j-amb} | Thermal Resistance Junction-ambient | max 60°C/W | 80°C/W |

PIN FUNCTIONS

| N° | Name | Function |
|----------------|------------------------|---|
| 1 | BOOTSTRAP | A C_{boot} capacitor connected between this terminal and the output allows to drive properly the internal D-MOS transistor. |
| 2 | RESET DELAY | A C_d capacitor connected between this terminal and ground determines the reset signal delay time. |
| 3 | RESET OUT | Open Collector Reset/power Fail Signal Output. This output is high when the supply and the output voltages are safe. |
| 4 | RESET INPUT | Input of Power Fail Circuit. The threshold is 5.1V. It may be connected via a divider to the input for power fail function. It must be connected to the pin 14 an external 30K Ω resistor when power fail signal not required. |
| 5, 6 15, 16 | GROUND | Common Ground Terminal |
| 7 | FREQUENCY COMPENSATION | A series RC network connected between this terminal and ground determines the regulation loop gain characteristics. |
| 8 | SOFT START | Soft Start Time Constant. A capacitor is connected between this terminal and ground to define the soft start time constant. |
| 9 | 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. |
| 10 | SYNC INPUT | Multiple L4972A's are synchronized by connecting pin 10 inputs together or via an external syncr. pulse. |
| 11 | SUPPLY VOLTAGE | Unregulated Input Voltage. |
| 12, 19 | N.C. | Not Connected. |
| 13 | V_{ref} | 5.1V V_{ref} Device Reference Voltage. |
| 14 | V_{start} | Internal Start-up Circuit to Drive the Power Stage. |
| 17 | OSCILLATOR | R_{osc} . External resistor connected to ground determines the constant charging current of C_{osc} . |
| 18 | OSCILLATOR | C_{osc} . External capacitor connected to ground determines (with R_{osc}) the switching frequency. |
| 20 | OUTPUT | Regulator Output. |

CIRCUIT OPERATION

The L4972A is a 2A monolithic stepdown switching regulator working in continuous mode realized in the new BCD Technology. This technology allows the integration of isolated vertical DMOS power transistors plus mixed CMOS/Bipolar transistors.

The device can deliver 2A at an output voltage adjustable from 5.1V to 40V and contains diagnostic and control functions that make it particularly suitable for microprocessor based systems.

BLOCK DIAGRAM

The block diagram shows the DMOS power transistors and the PWM control loop. Integrated functions include a reference voltage trimmed to $5.1V \pm 2\%$, soft start, undervoltage lockout, oscillator with feedforward control, pulse by pulse current limit, thermal shutdown and finally the reset and power fail circuit. The reset and power fail circuit provides an output signal for a microprocessor indicating the status of the system.

Device turn on is around 11V with a typical 1V hysteresis, this threshold provides a correct voltage for the driving stage of the DMOS gate and the hysteresis prevents instabilities.

An external bootstrap capacitor charge to 12V by an internal voltage reference is needed to provide correct gate drive to the power DMOS. The driving circuit is able to source and sink peak currents of around 0.5A to the gate of the DMOS transistor. A typical switching time of the current in the DMOS transistor is 50ns. Due to the fast commutation switching frequencies up to 200kHz are possible.

The PWM control loop consists of a sawtooth oscillator, error amplifier, comparator, latch and the output stage. An error signal is produced by comparing the output voltage with the precise $5.1V \pm 2\%$ on chip reference. This error signal is then compared with the sawtooth oscillator in order to generate fixed frequency pulse width modulated drive for the output stage. A PWM latch is included to eliminate multiple pulsing within a period even in noisy environments.

The gain and stability of the loop can be adjusted by

an external RC network connected to the output of the error amplifier. A voltage feedforward control has been added to the oscillator, this maintains superior line regulation over a wide input voltage range. Closing the loop directly gives an output voltage of 5.1V, higher voltages are obtained by inserting a voltage divider.

At turn on, output overcurrents are prevented by the soft start function (fig. 2). The error amplifier is initially clamped by an external capacitor, C_{ss} , and allowed to rise linearly under the charge of an internal constant current source.

Output overload protection is provided by a current limit circuit. The load current is sensed by a internal metal resistor connected to a comparator. When the load current exceeds a preset threshold, the output of the comparator sets a flip flop which turns off the power DMOS. The next clock pulse, from an internal 40kHz oscillator, will reset the flip flop and the power DMOS will again conduct. This current protection method, ensures a constant current output when the system is overloaded or short circuited and limits the switching frequency, in this condition, to 40kHz. The Reset and Power fail circuit (fig. 4), generates an output signal when the supply voltage exceeds a threshold programmed by an external voltage divider. The reset signal, is generated with a delay time programmed by a external capacitor on the delay pin. When the supply voltage falls below the threshold or the output voltage goes below 5V, the reset output goes low immediately. The reset output is an open drain.

Fig. 4A shows the case when the supply voltage is higher than the threshold, but the output voltage is not yet 5V.

Fig. 4B shows the case when the output is 5.1V, but the supply voltage is not yet higher than the fixed threshold.

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

Figure 1 : Feedforward Waveform.

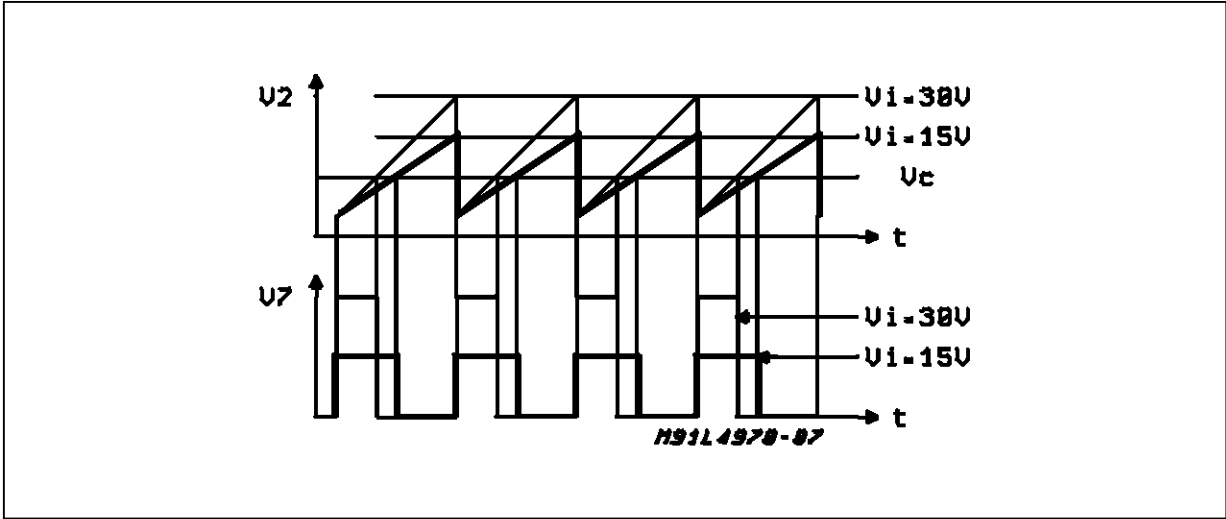


Figure 2 : Soft Start Function.

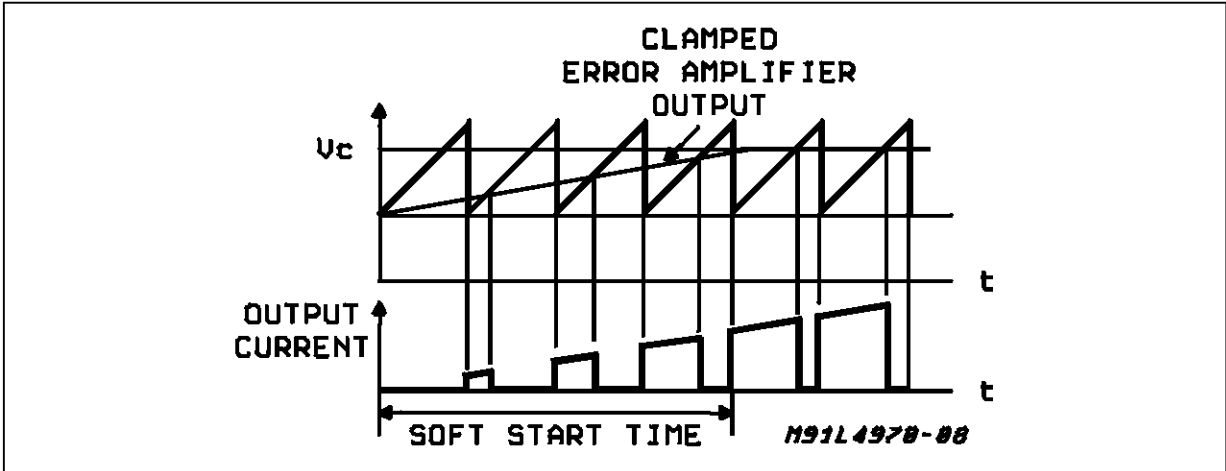


Figure 3 : Limiting Current Function.

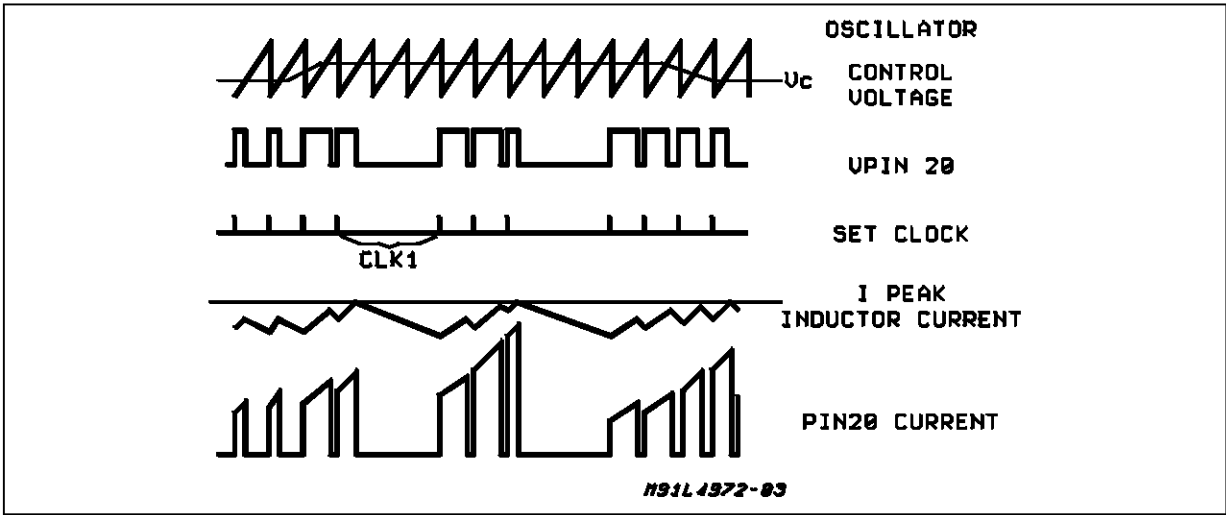
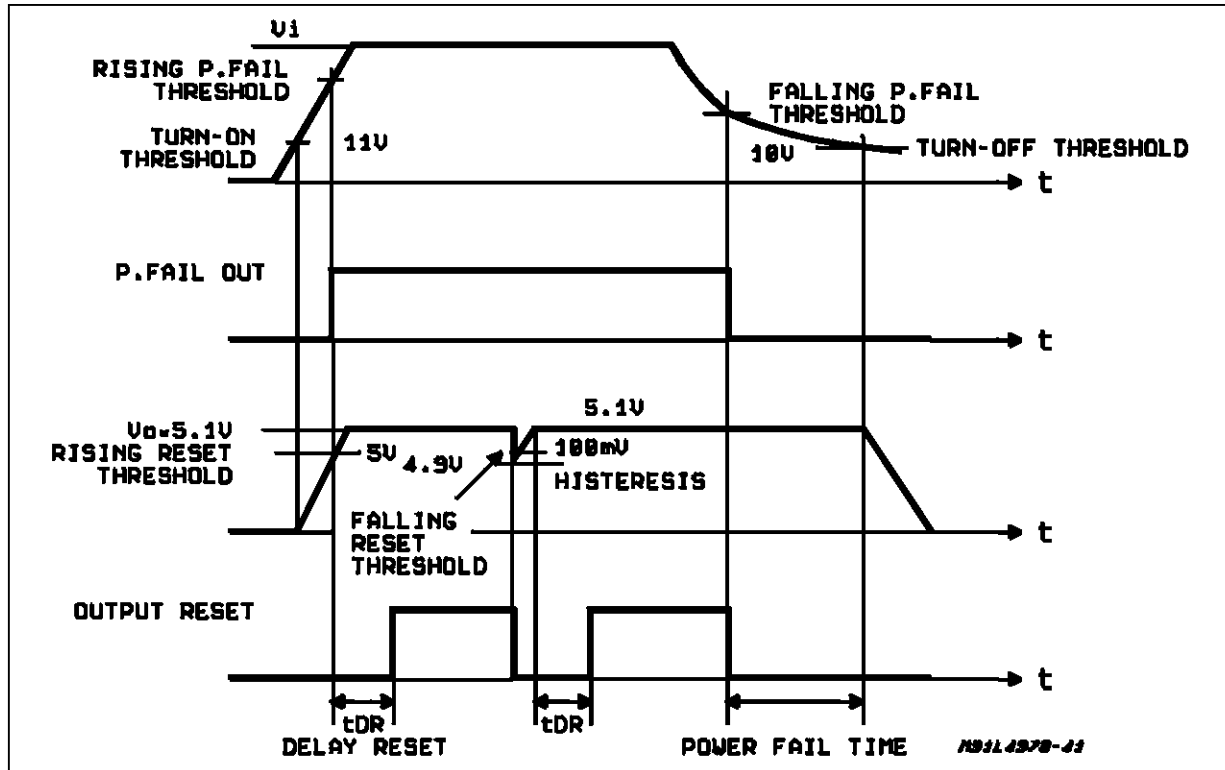
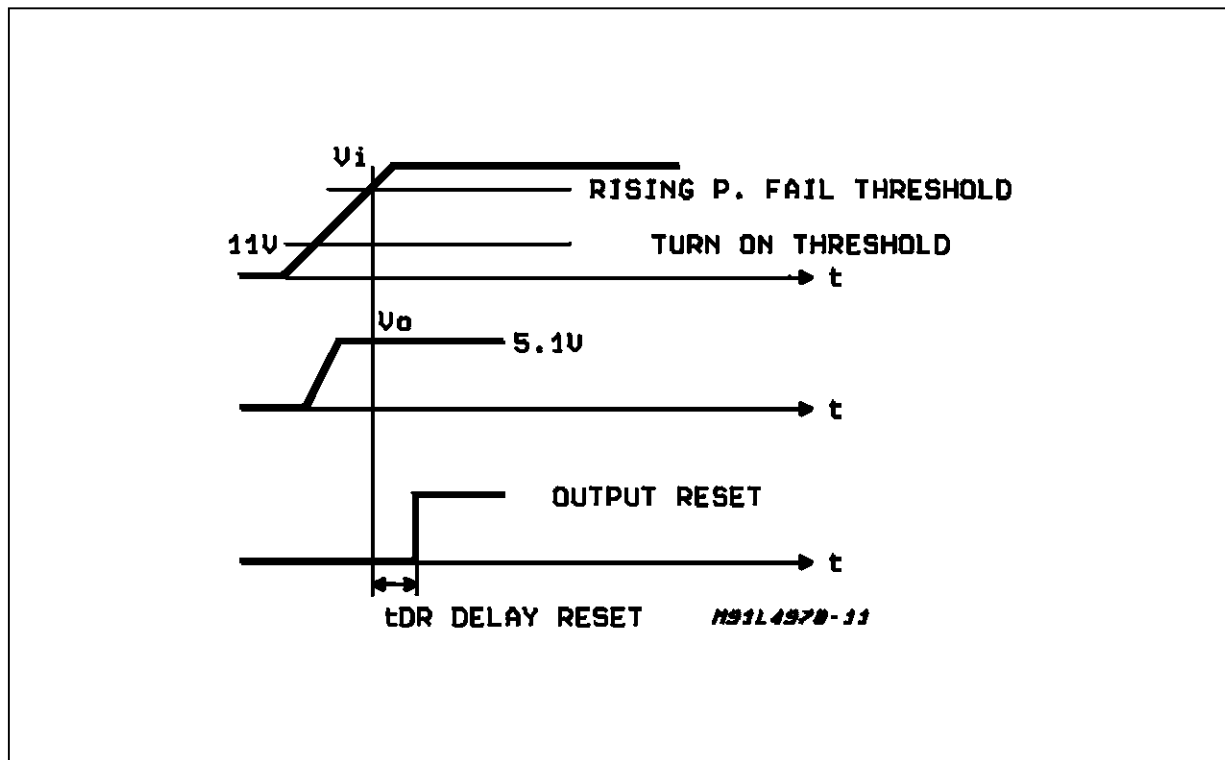


Figure 4 : Reset and Power Fail Functions.

A



B



ELECTRICAL CHARACTERISTICS (refer to the test circuit, $T_J = 25^\circ\text{C}$, $V_i = 35\text{V}$, $R_4 = 30\text{K}\Omega$, $C_9 = 2.7\text{nF}$, $f_{\text{SW}} = 100\text{KHz}$ typ, unless otherwise specified)

DYNAMIC CHARACTERISTICS

| Symbol | Parameter | Test Conditions | Min. | Typ. | Max. | Unit | Fig. |
|-----------------------|--|---|------|----------|------|--------|------|
| V_i | Input Volt. Range (pin 11) | $V_o = V_{\text{ref}}$ to 40V $I_o = 2\text{A}$ (**) | 15 | | 50 | V | 5 |
| V_o | Output Voltage | $V_i = 15\text{V}$ to 50V $I_o = 1\text{A}$; $V_o = V_{\text{ref}}$ | 5 | 5.1 | 5.2 | V | 5 |
| ΔV_o | Line Regulation | $V_i = 15\text{V}$ to 50V $I_o = 0.5\text{A}$; $V_o = V_{\text{ref}}$ | | 12 | 30 | mV | |
| ΔV_o | Load Regulation | $V_o = V_{\text{ref}}$ $I_o = 0.5\text{A}$ to 2A | | 7 | 20 | mV | |
| V_d | Dropout Voltage between Pin 11 and 20 | $I_o = 2\text{A}$ | | 0.25 | 0.4 | V | |
| I_{20L} | Max Limiting Current | $V_i = 15\text{V}$ to 50V $V_o = V_{\text{ref}}$ to 40V | 2.5 | 2.8 | 3.5 | A | |
| η | Efficiency (*) | $I_o = 2\text{A}$, $f = 100\text{KHz}$ $V_o = V_{\text{ref}}$ $V_o = 12\text{V}$ | 75 | 85 90 | | % % | |
| SVR | Supply Voltage Ripple Rejection | $V_i = 2\text{VRMS}$; $I_o = 1\text{A}$ $f = 100\text{Hz}$; $V_o = V_{\text{ref}}$ | 56 | 60 | | dB | 5 |
| f | Switching Frequency | | 90 | 100 | 110 | KHz | 5 |
| $\Delta f/\Delta V_i$ | Voltage Stability of Switching Frequency | $V_i = 15\text{V}$ to 45V | | 2 | 6 | % | 5 |
| $\Delta f/T_j$ | Temperature Stability of Switching Frequency | $T_j = 0$ to 125°C | | 1 | | % | 5 |
| f_{max} | Maximum Operating Switching Frequency | $V_o = V_{\text{ref}}$ $R_4 = 15\text{K}\Omega$ $I_o = 2\text{A}$ $C_9 = 2.2\text{nF}$ | 200 | | | KHz | 5 |

(*) Only for DIP version (**) Pulse testing with a low duty cycle

V_{ref} SECTION (pin 13)

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|----------------------------------|---|--|------|------|------|----------------------|------|
| V_{13} | Reference Voltage | | 5 | 5.1 | 5.2 | V | 7 |
| ΔV_{13} | Line Regulation | $V_i = 15\text{V}$ to 50V | | 10 | 25 | mV | 7 |
| ΔV_{13} | Load Regulation | $I_{13} = 0$ to 1mA | | 20 | 40 | mV | 7 |
| $\frac{\Delta V_{13}}{\Delta T}$ | Average Temperature Coefficient Reference Voltage | $T_j = 0^\circ\text{C}$ to 125°C | | 0.4 | | mV/ $^\circ\text{C}$ | 7 |
| $I_{13\text{short}}$ | Short Circuit Current Limit | $V_{13} = 0$ | | 70 | | mA | 7 |

V_{START} SECTION (pin 15)

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|----------------------|-----------------------------|----------------------|------|------|------|------|------|
| V_{14} | Reference Voltage | | 11.4 | 12 | 12.6 | V | 7 |
| ΔV_{14} | Line Regulation | $V_i = 15$ to 50V | | 0.6 | 1.4 | V | 7 |
| ΔV_{14} | Load Regulation | $I_{14} = 0$ to 1mA | | 50 | 200 | mV | 7 |
| $I_{14\text{short}}$ | Short Circuit Current Limit | $V_{15} = 0\text{V}$ | | 80 | | mA | 7 |

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ELECTRICAL CHARACTERISTICS (continued)

DC CHARACTERISTICS

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|----------------------|--------------------------|--|------|------|------|------|------|
| V _{11on} | Turn-on Threshold | | 10 | 11 | 12 | V | 7A |
| V _{11 Hyst} | Turn-off Hysteresys | | | 1 | | V | 7A |
| I _{11Q} | Quiescent Current | V ₈ = 0; S1 = D | | 13 | 19 | mA | 7A |
| I _{11OQ} | Operating Supply Current | V ₈ = 0; S1 = B; S2 = B | | 16 | 23 | mA | 7A |
| I _{20L} | Out Leak Current | V _i = 55V; S3 = A; V ₈ = 0 | | | 2 | mA | 7A |

SOFT START (pin 8)

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|----------------|---------------------------|---|------|------|------|------|------|
| I ₈ | Soft Start Source Current | V ₈ = 3V; V ₉ = 0V | 80 | 115 | 150 | μA | 7B |
| V ₈ | Output Saturation Voltage | I ₈ = 20mA; V ₁₁ = 10V I ₈ = 200μA; V ₁₁ = 10V | | | 1 | V | 7B |
| | | | | | 0.7 | V | 7B |

ERROR AMPLIFIER

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|------------------|--------------------------|--|------|------|------|------|------|
| V _{7H} | High Level Out Voltage | I ₇ = 100μA; S1 = C V ₉ = 4.7V | 6 | | | V | 7C |
| V _{7L} | Low Level Out Voltage | I ₇ = 100μA; S1 = C V ₉ = 5.3V; | | | 1.2 | V | 7C |
| I _{7H} | Source Output Current | V ₇ = 1V; V ₇ = 4.7V | 100 | 150 | | μA | 7C |
| -I _{7L} | Sink Output Current | V ₇ = 6V; V ₉ = 5.3V | 100 | 150 | | μA | 7C |
| I ₉ | Input Bias Current | S1 = B; R _S = 10KΩ | | 0.4 | 3 | μA | 7C |
| G _V | DC Open Loop Gain | S1 = A; R _S = 10Ω | 60 | | | dB | 7C |
| SVR | Supply Voltage Rejection | 15 < V _i < 50V | 60 | 80 | | dB | 7C |
| V _{OS} | Input Offset Voltage | R _S = 50Ω S1 = A | | 2 | 10 | mV | 7C |

RAMP GENERATOR (pin 18)

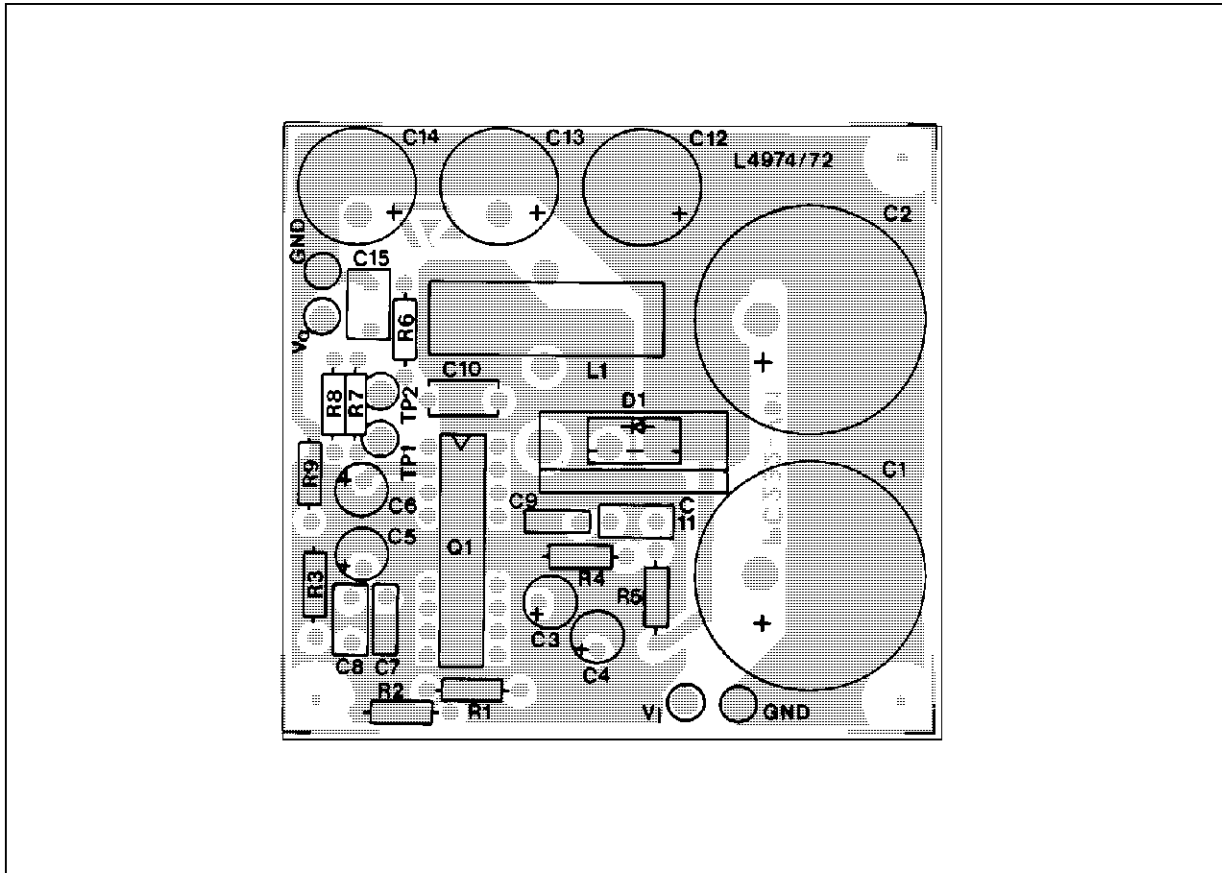
| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|-----------------|-------------------|---------------------------------|------|----------------------|------|------|------|
| V ₁₈ | Ramp Valley | S1 = B; S2 = B | 1.2 | 1.5 | | V | 7A |
| V ₁₈ | Ramp Peak | S1 = B S2 = B | | V _i = 15V | 2.5 | V | 7A |
| | | | | V _i = 45V | 5.5 | V | 7A |
| I ₁₈ | Min. Ramp Current | S1 = A; I ₁₇ = 100μA | | 270 | 300 | μA | 7A |
| I ₁₈ | Max. Ramp Current | S1 = A; I ₁₇ = 1mA | 2.4 | 2.7 | | mA | 7A |

SYNC FUNCTION (pin 10)

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|------------------|---|--|------|------|------|------|------|
| V ₁₀ | Low Input Voltage | V _i = 15V to 50V; V ₈ = 0; S1 = B; S2 = B; S4 = B | -0.3 | | 0.9 | V | 7A |
| V ₁₀ | High Input voltage | V ₈ = 0; S1 = B; S2 = B; S4 = B | 2.5 | | 5.5 | V | 7A |
| I _{10L} | Sync Input Current with Low Input Voltage | V ₁₀ = V ₁₈ = 0.9V; S4 = B; S1 = B; S2 = B | | | 0.4 | mA | 7A |
| I _{10H} | Input Current with High Input Voltage | V ₁₀ = 2.5V | | | 1.5 | mA | 7A |
| V ₁₀ | Output Amplitude | | 4 | 5 | | V | - |
| t _w | Output Pulse Width | V _{thr} = 2.5V | 0.3 | 0.5 | 0.8 | μs | - |

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Figure 6a : Component Layout of fig.5 (1 : 1 scale). Evaluation Board Available (only for DIP version)



PART LIST

- R₁ = 30K Ω
- R₂ = 10K Ω
- R₃ = 15K Ω
- R₄ = 30K Ω
- R₅ = 22 Ω
- R₆ = 4.7K Ω
- R₇ = see table A
- R₈ = OPTION
- R₉ = 4.7K Ω

- * C₁ = C₂ = 1000 μ F 63V EYF (ROE)
- C₃ = C₄ = C₅ = C₆ = 2,2 μ F 50V
- C₇ = 390pF Film
- C₈ = 22nF MKT 1837 (ERO)
- C₉ = 2.7nF KP 1830 (ERO)
- C₁₀ = 0.33 μ F Film
- C₁₁ = 1nF
- ** C₁₂ = C₁₃ = C₁₄ = 100 μ F 40V EKR (ROE)
- C₁₅ = 1 μ F Film

D1 = SB 560 (OR EQUIVALENT)

L1 = 150 μ H
 core 58310 MAGNETICS
 45 TURNS 0.91mm (AWG 19)
 COGEMA 949181

* 2 capacitors in parallel to increase input RMS current capability.
 ** 3 capacitors in parallel to reduce total output ESR.

Table A

| V ₀ | R ₉ | R ₇ |
|----------------|----------------|----------------|
| 12V | 4.7k Ω | 6.2kW |
| 15V | 4.7k Ω | 9.1k Ω |
| 18V | 4.7k Ω | 12 Ω |
| 24V | 4.7k Ω | 18 Ω |

Note:
 In the Test and Application Circuit for L4972D are not mounted C2, C14 and R8.

Table B
 SUGGESTED BOOSTRAP CAPACITORS

| Operating Frequency | Bootstrap Cap.c10 |
|---------------------|-------------------|
| f = 20KHz | \geq 680nF |
| f = 50KHz | \geq 470nF |
| f = 100KHz | \geq 330nF |
| f = 200KHz | \geq 220nF |
| f = 500KHz | \geq 100nF |

Figure 6b: P.C. Board and Component Layout of the Circuit of Fig. 5. (1:1 scale)

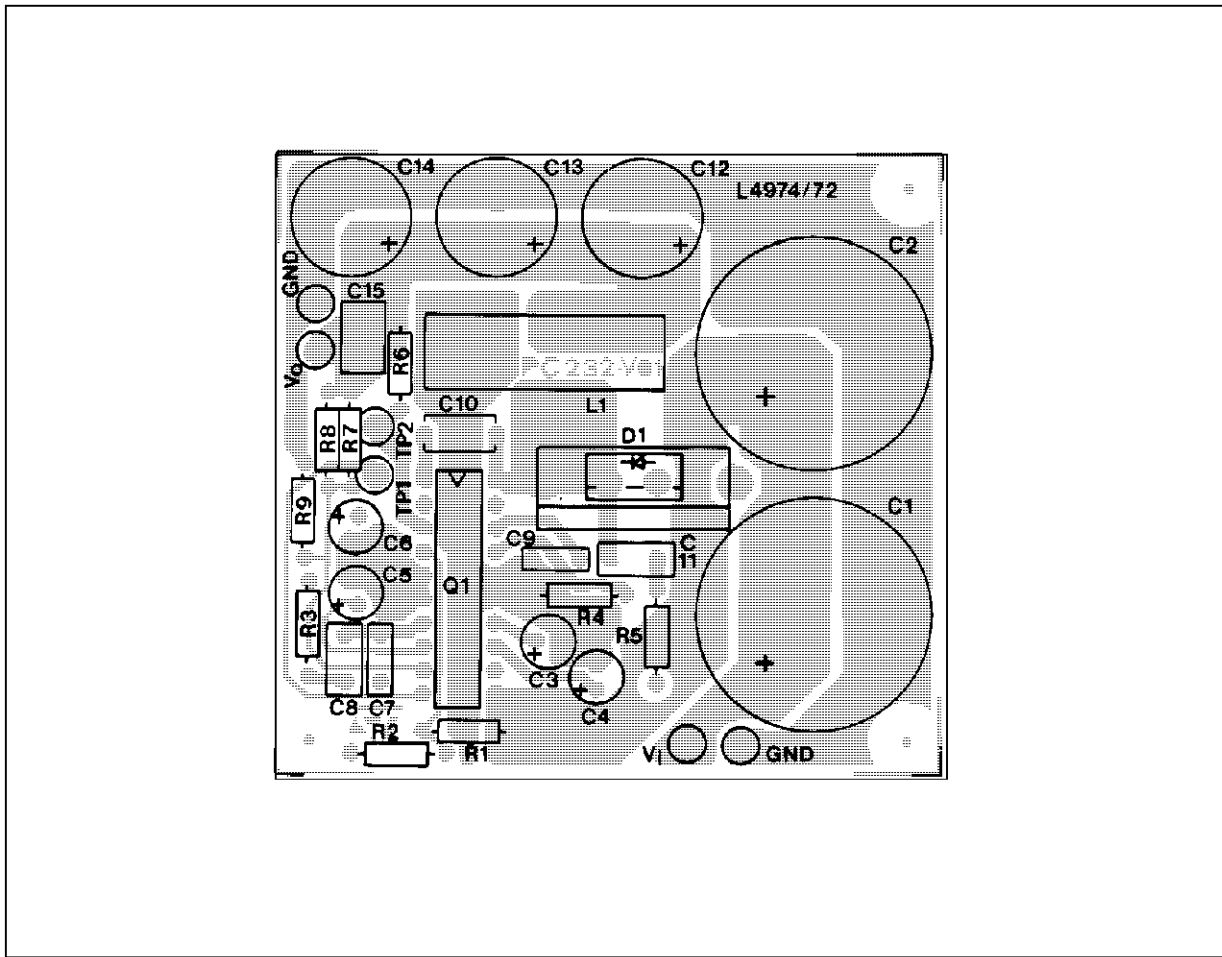
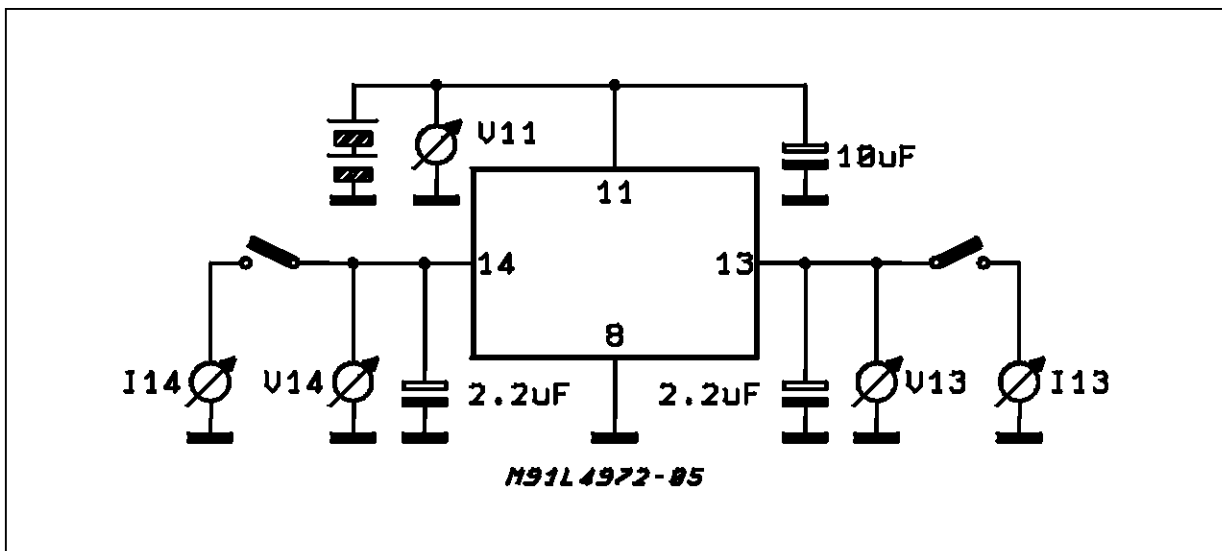


Figure 7 : DC Test Circuits.



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Figure 7A.

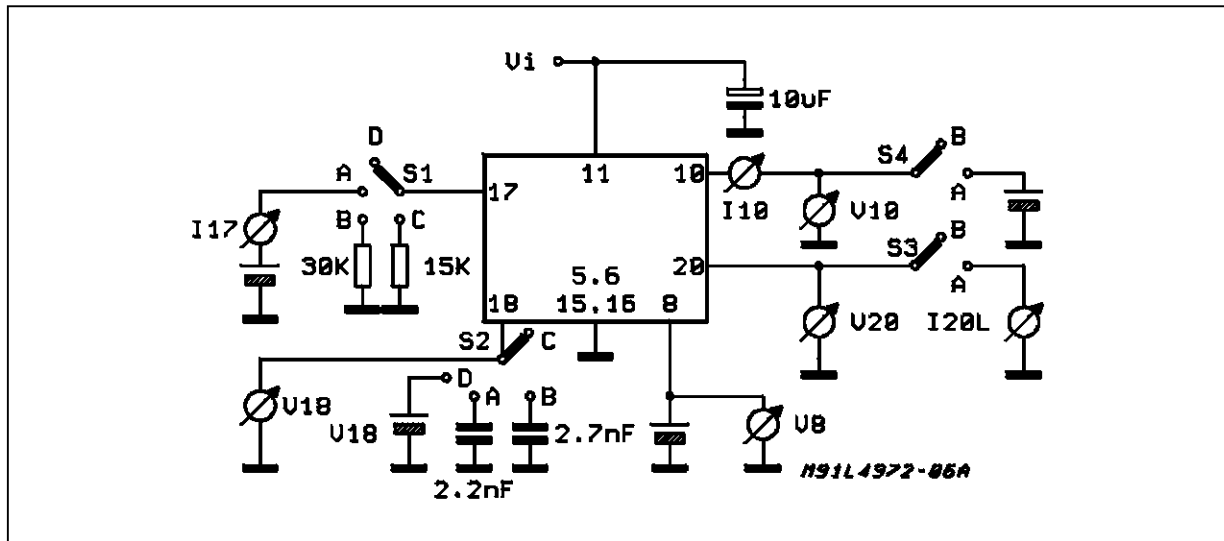


Figure 7B.

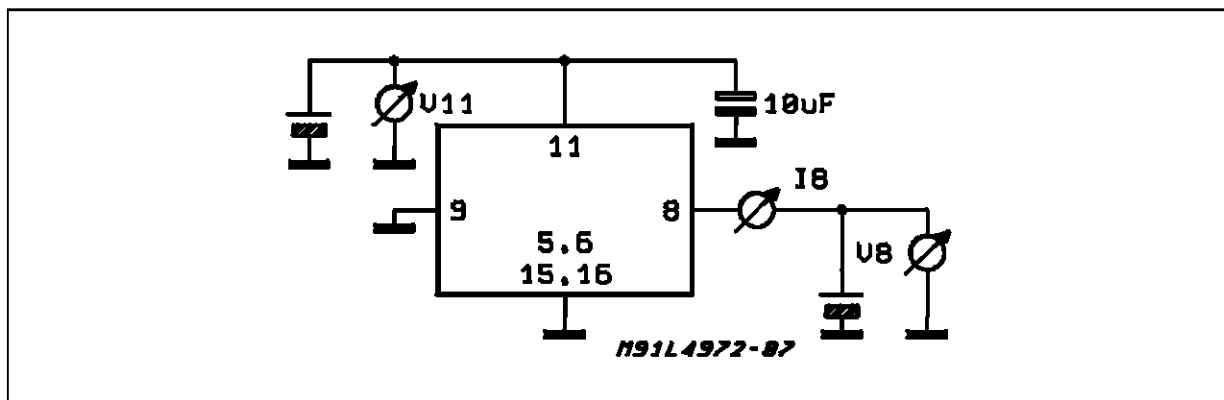


Figure 7C.

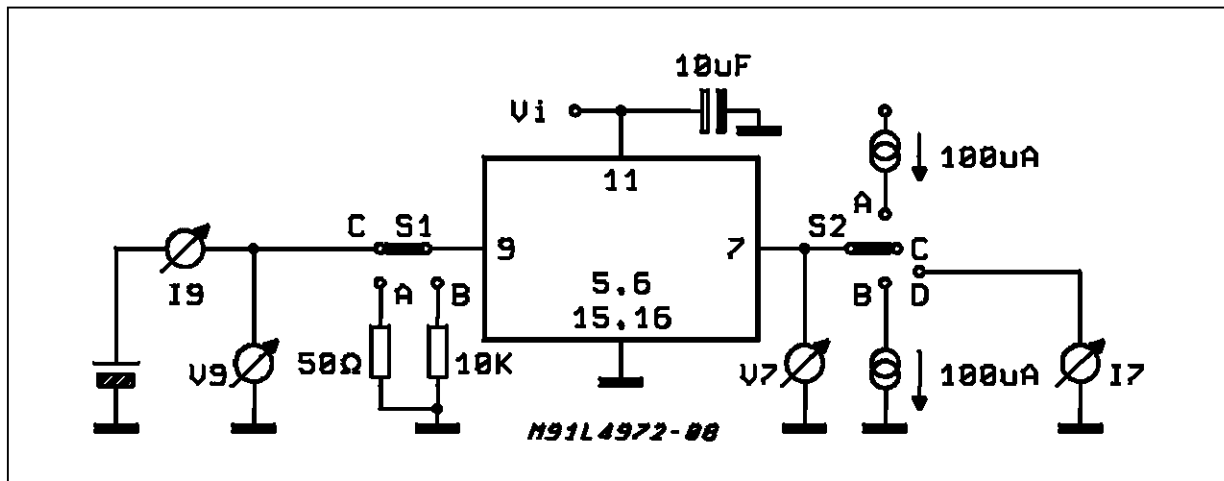


Figure 7D.

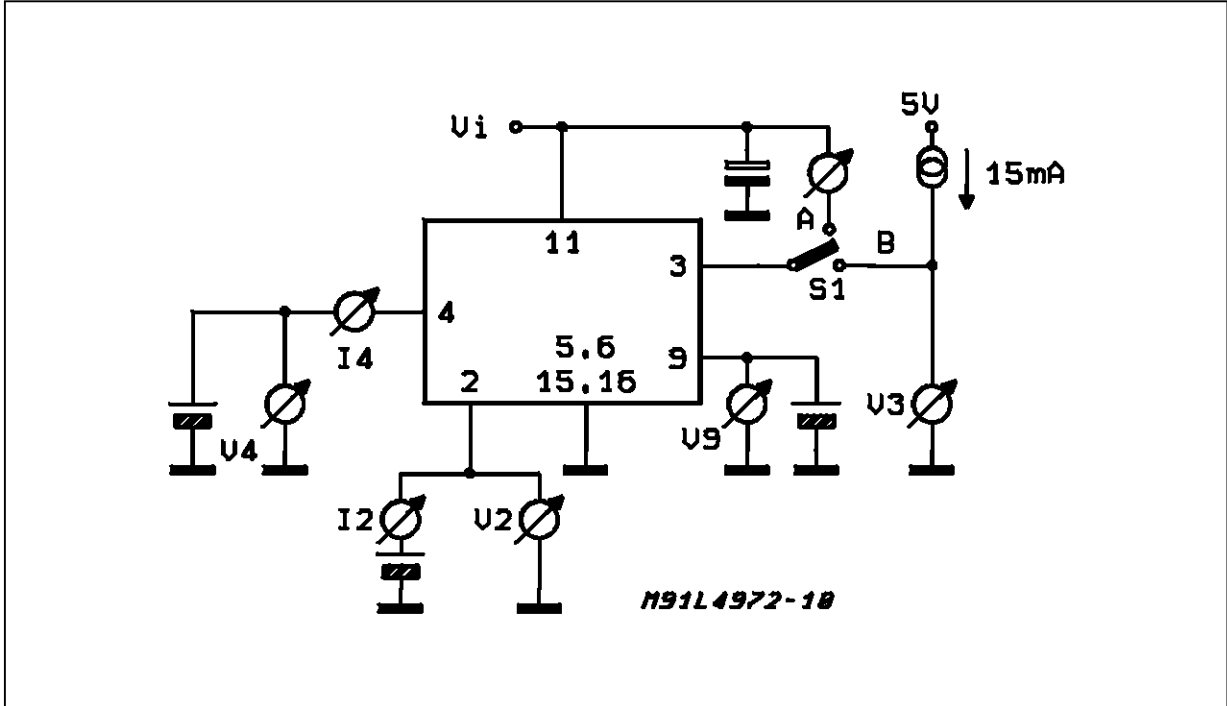


Figure 8 : Quiescent Drain Current vs. Supply Voltage (0% duty cycle - see fig. 7A).

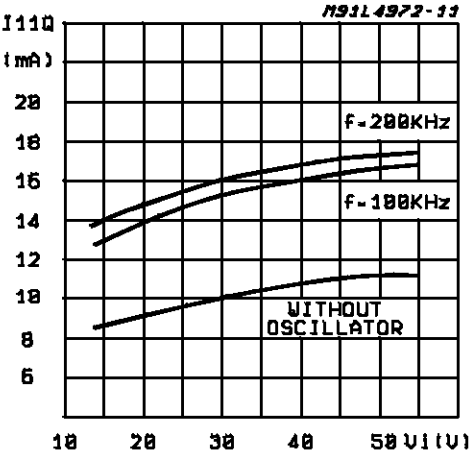
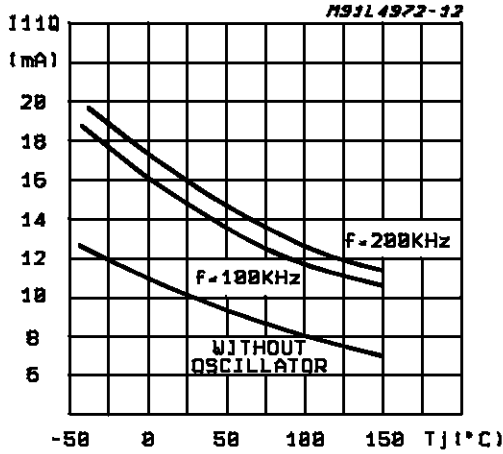


Figure 9 : Quiescent Drain Current vs. Junction Temperature (0% duty cycle).



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Figure 10 : Quiescent Drain Current vs. Duty Cycle.

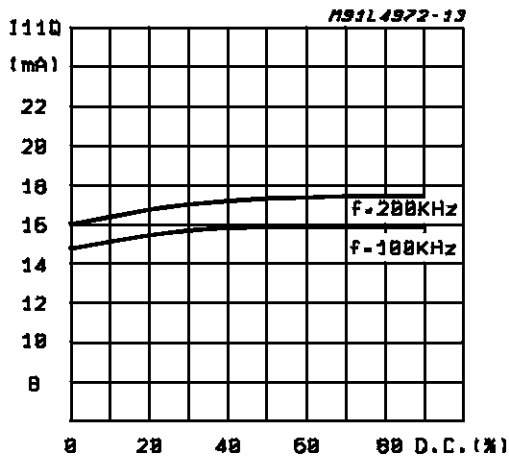


Figure 11 : Reference Voltage (pin 13) vs. V_i (see fig. 7).

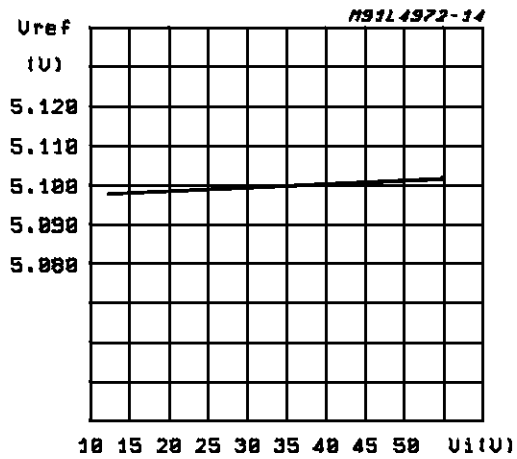


Figure 12 : Reference Voltage (pin 13) vs. Junction Temperature (see fig. 7).

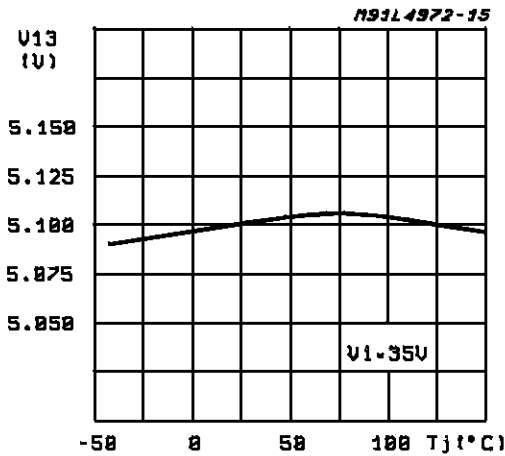


Figure 13 : Reference Voltage (pin 14) vs. V_i (see fig. 7).

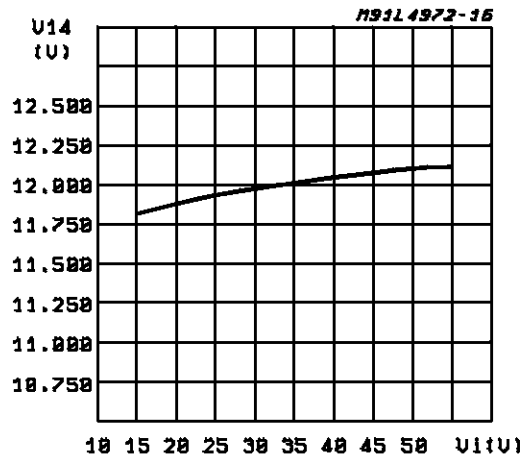


Figure 14 : Reference Voltage (pin 14) vs. Junction Temperature (see fig. 7).

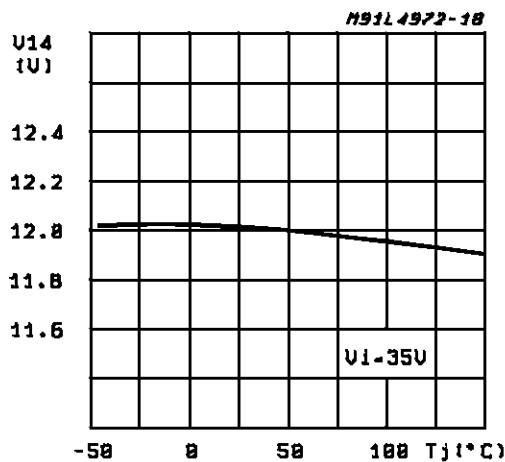


Figure 15 : Reference Voltage 5.1V (pin 13) Supply Voltage Ripple Rejection vs. Fre-

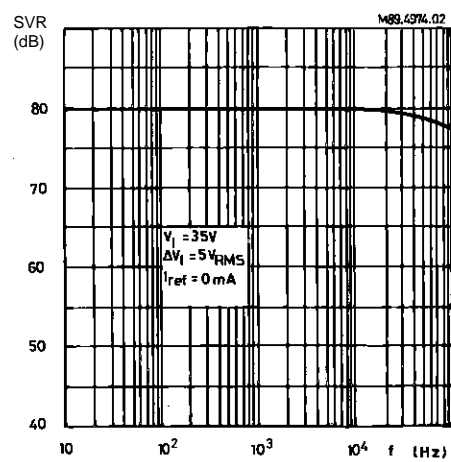


Figure 16 : Switching Frequency vs. Input Voltage (see fig. 5).

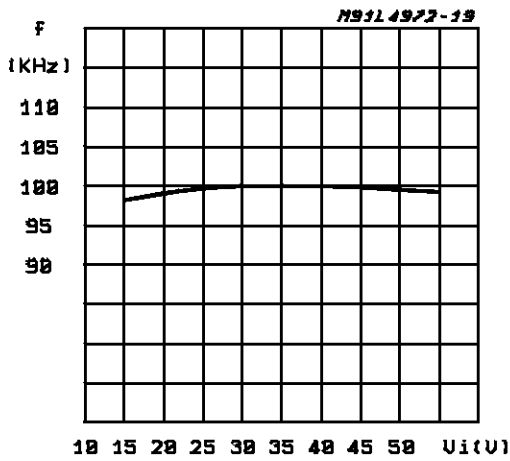


Figure 17 : Switching Frequency vs. Junction Temperature (see fig. 5).

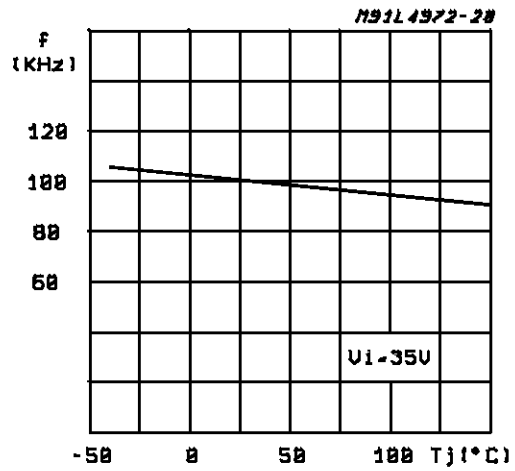


Figure 18 : Switching Frequency vs. R4 (see fig.5).

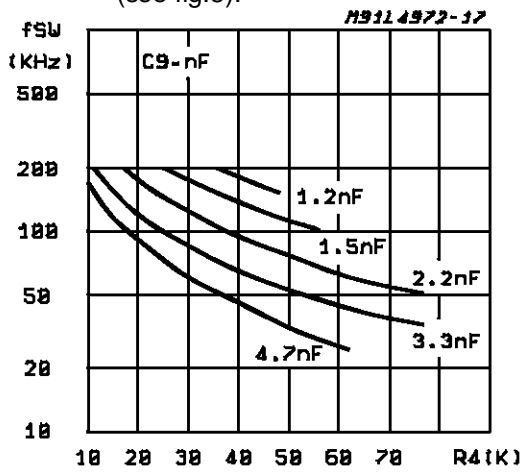


Figure 19 : Maximum Duty Cycle vs. Frequency.

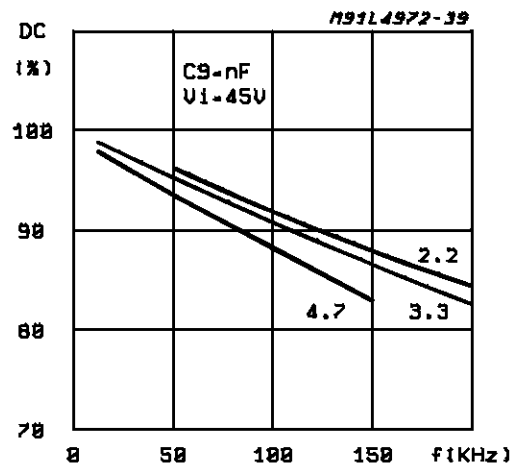


Figure 20 : Supply Voltage Ripple Rejection vs. Frequency (see fig. 5).

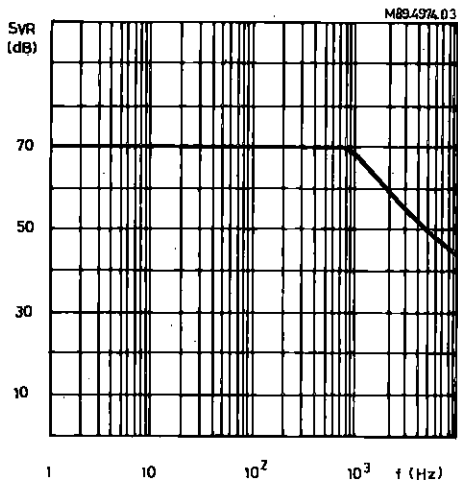
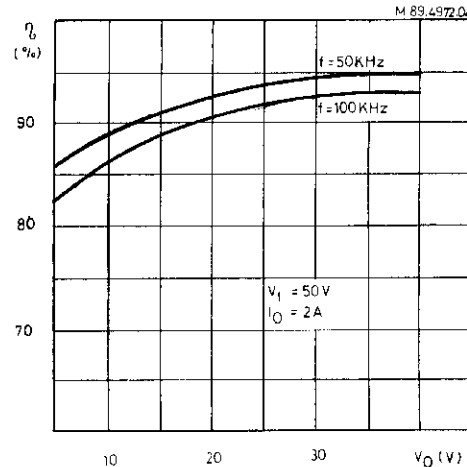


Figure 21 : Efficiency vs. Output Voltage.



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Figure 22 : Line Transient Response (see fig. 5).

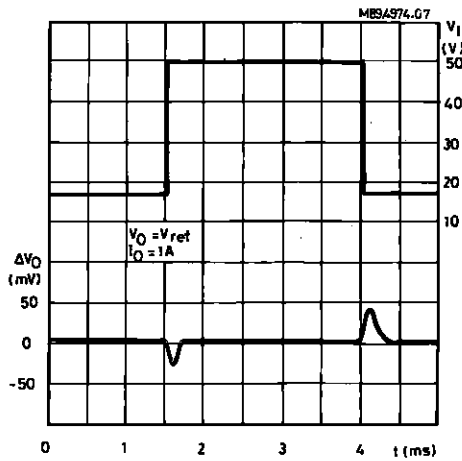


Figure 23 : Load Transient Response (see fig. 5).

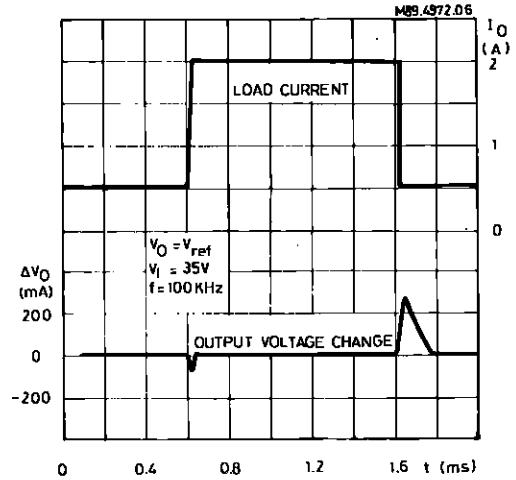


Figure 24 : Dropout Voltage between Pin 11 and Pin 20 vs. Current at Pin 20.

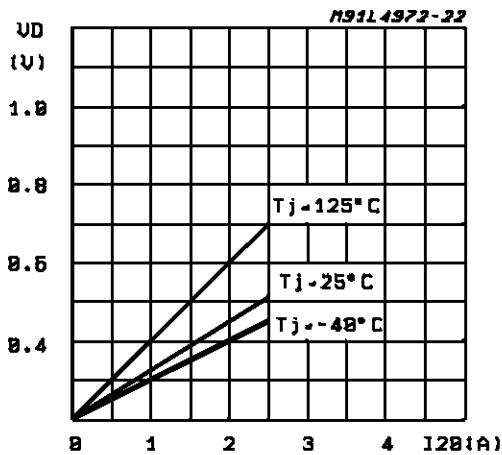


Figure 25 : Dropout Voltage between Pin 11 and Pin 20 vs. Junction Temperature.

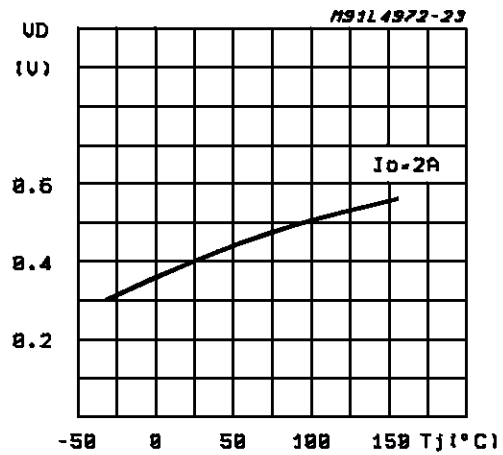


Figure 26 : Power Dissipation (device only) vs. Input Voltage.

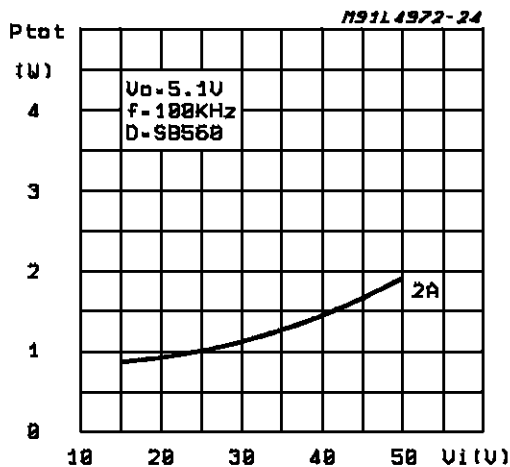


Figure 27 : Power Dissipation (device only) vs. Input Voltage.

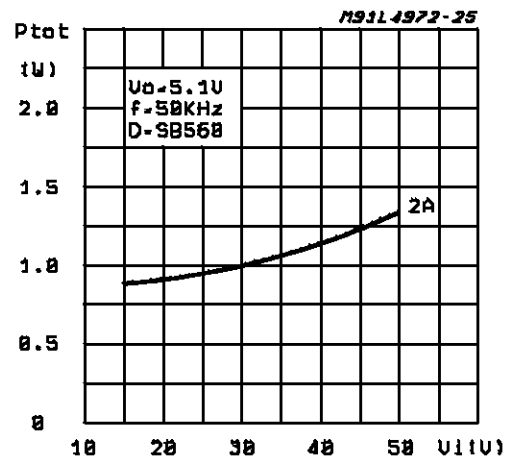


Figure 28 : Power Dissipation (device only) vs. Output Voltage.

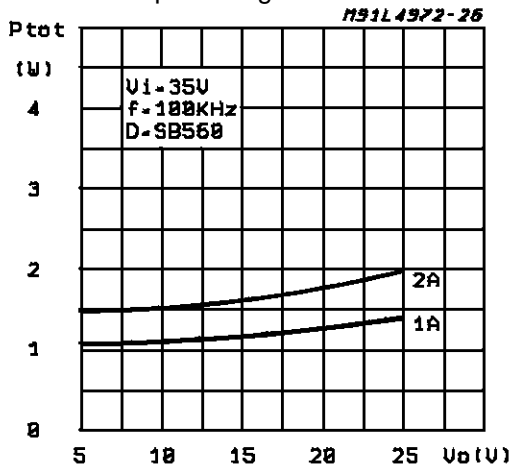


Figure 29 : Power Dissipation (device only) vs. Output Voltage.

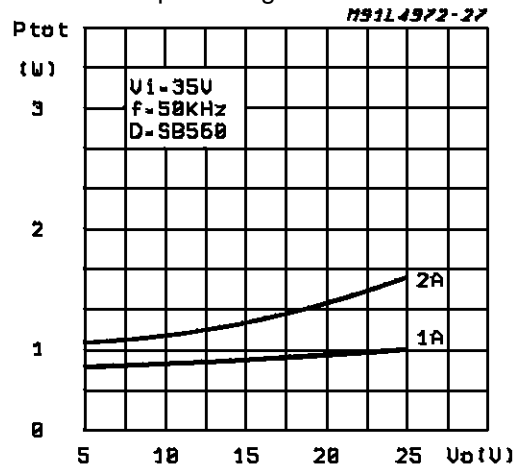


Figure 30 : Power Dissipation (device only) vs. Output Current.

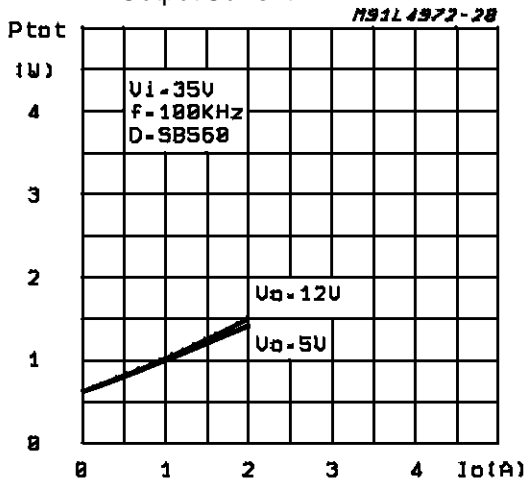


Figure 31 : Power Dissipation (device only) vs. Output Current.

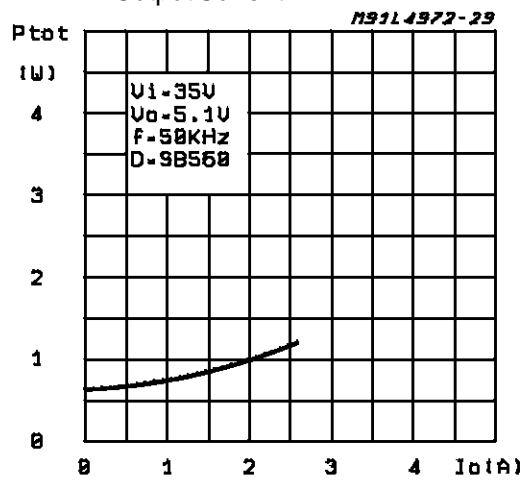


Figure 32 : Efficiency vs. Output Current.

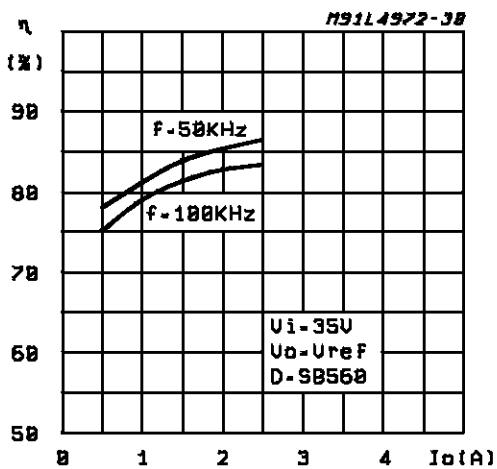
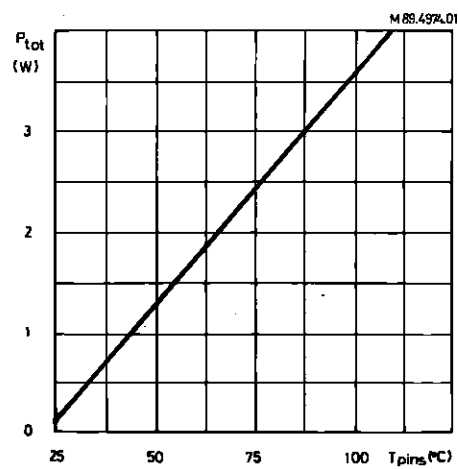


Figure 33 : Test PCB Thermal Characteristic.



L4972A-L4972AD

Figure 34 : Junction to Ambient Thermal Resistance vs. Area on Board Heatsink (DIP 16+2+2)

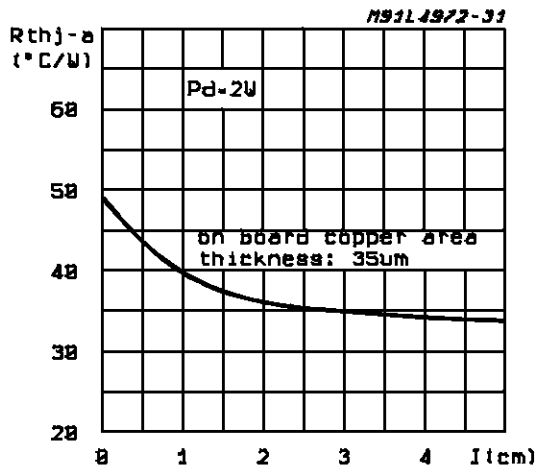


Figure 35: Junction to Ambient Thermal Resistance vs. Area on Board Heatsink (SO20)

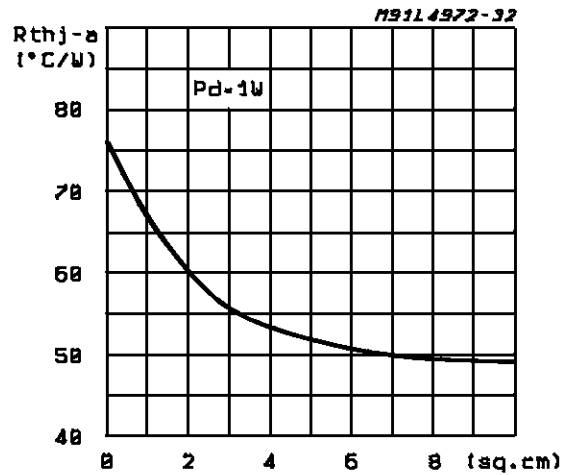


Figure 36: Maximum Allowable Power Dissipation vs. Ambient Temperature (Powerdip)

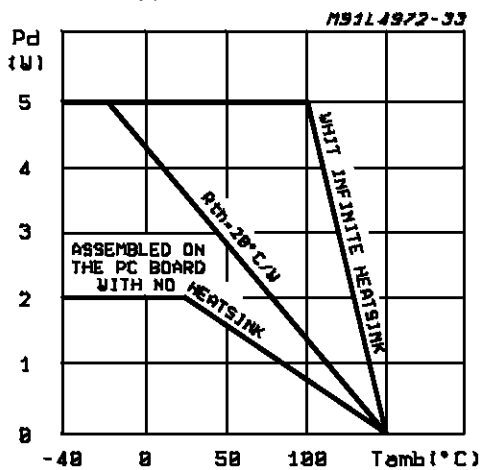


Figure 37: Maximum Allowable Power Dissipation vs. Ambient Temperature (SO20)

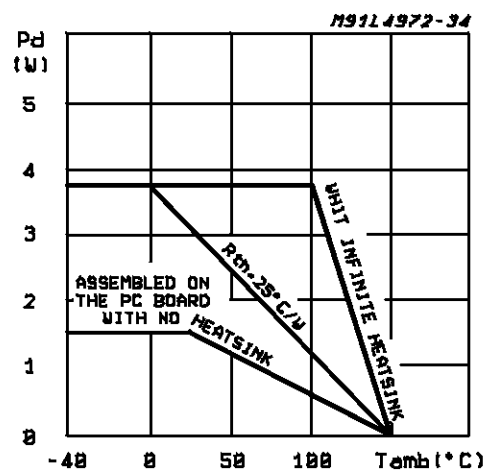


Figure 38: Open Loop Frequency and Phase of Error Amplifier (see fig. 7C).

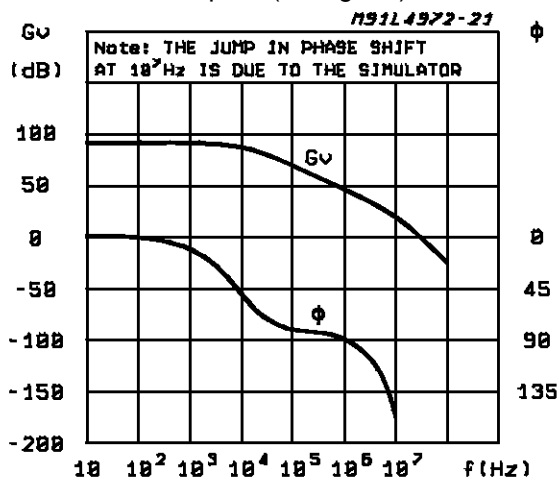


Figure 39 : 2A – 5.1V Low Cost Application Circuit.

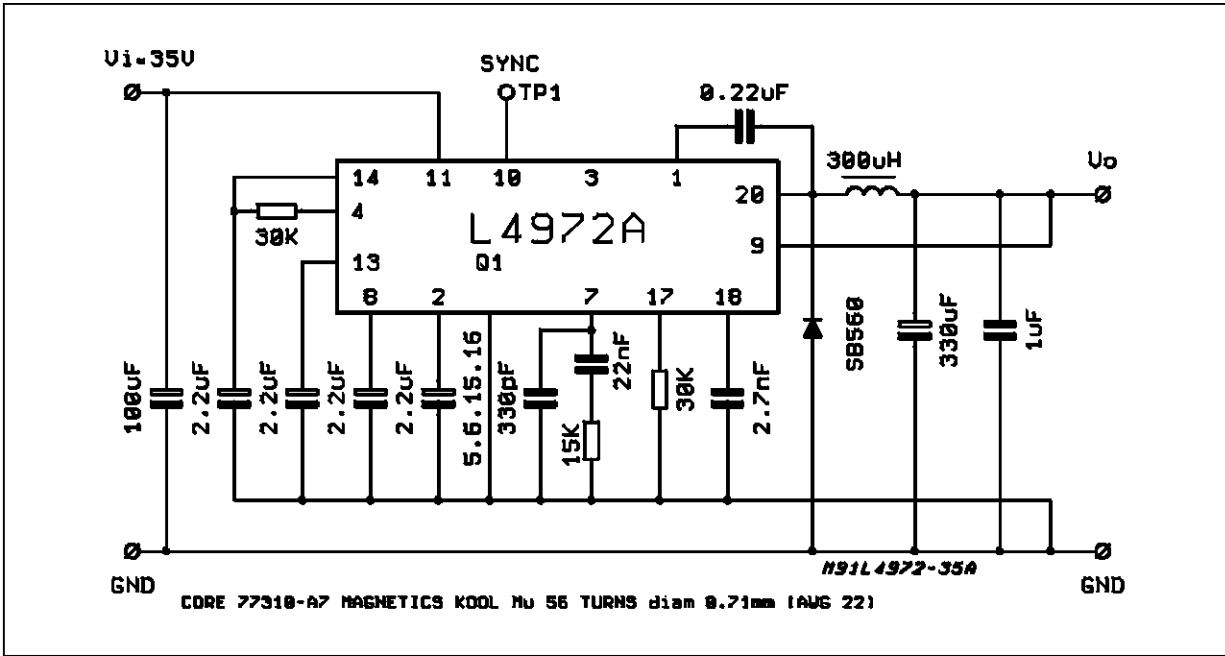
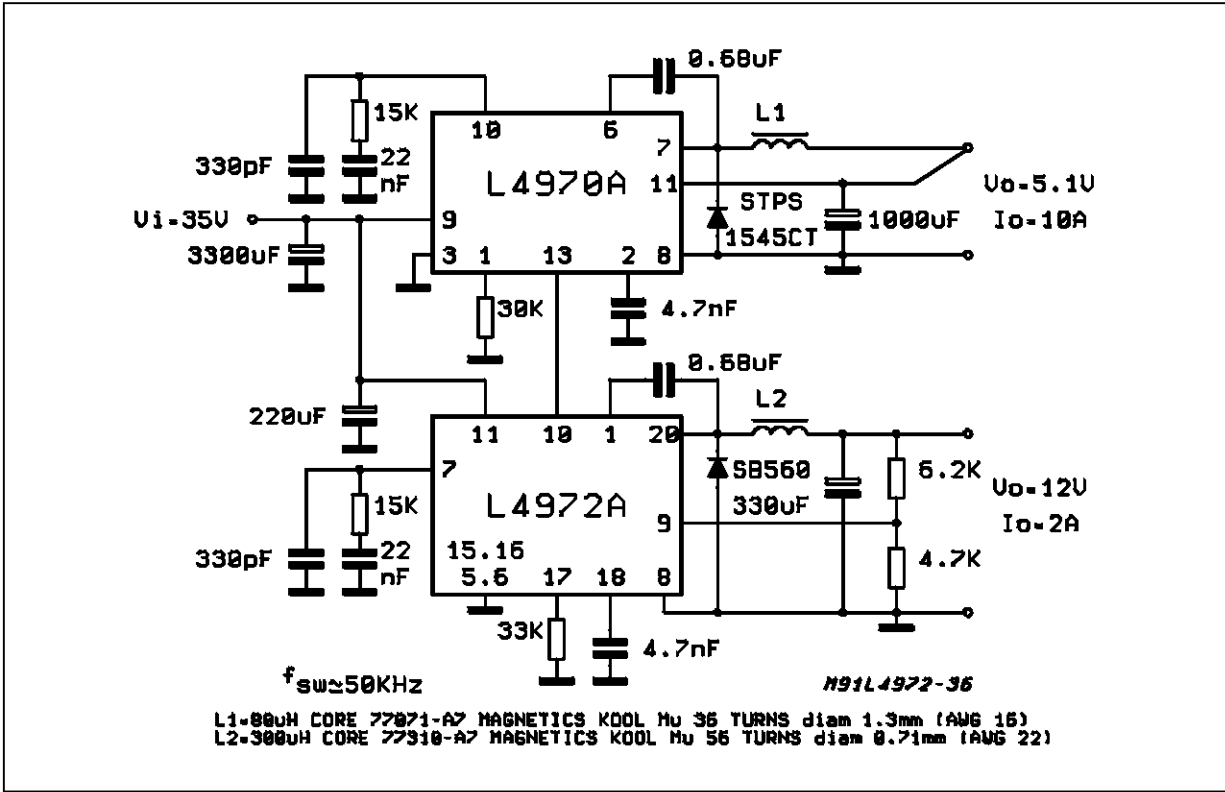


Figure 40 : A 5.1V/12V Multiple Supply. Note the Synchronization between the L4972A and L4970A.



L4972A-L4972AD

Figure 41 : L4972A's Sync. Example.

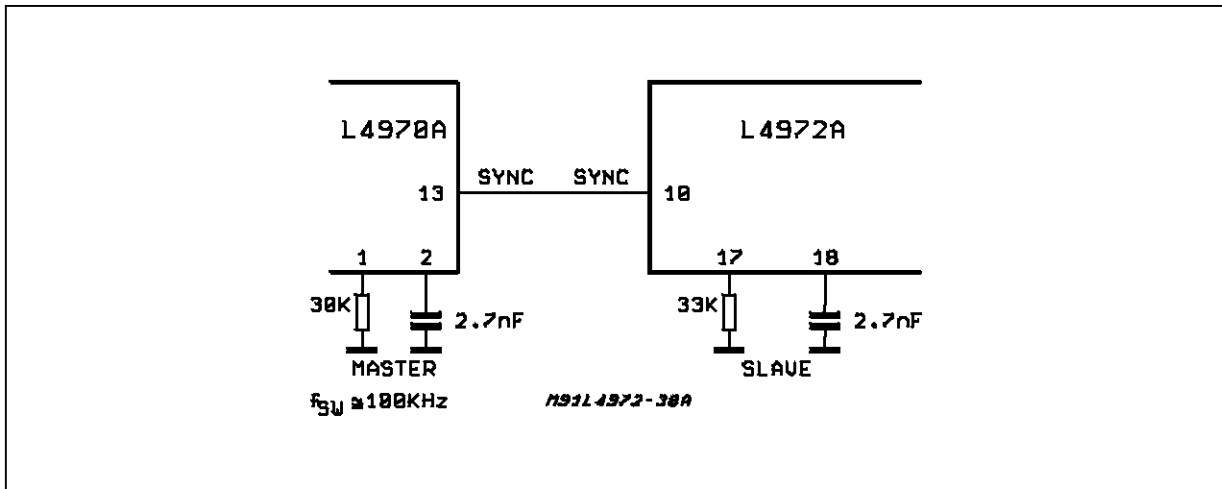
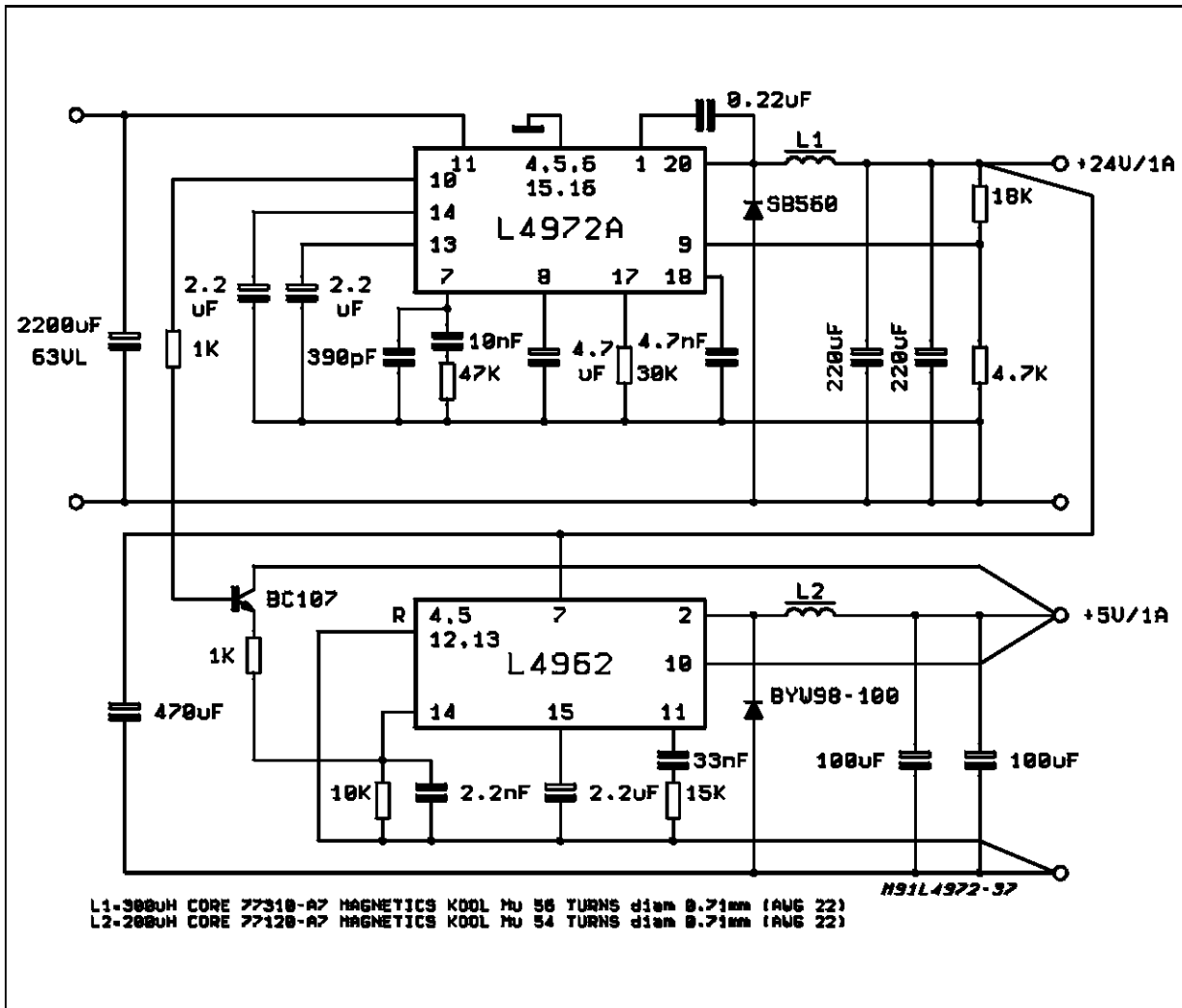
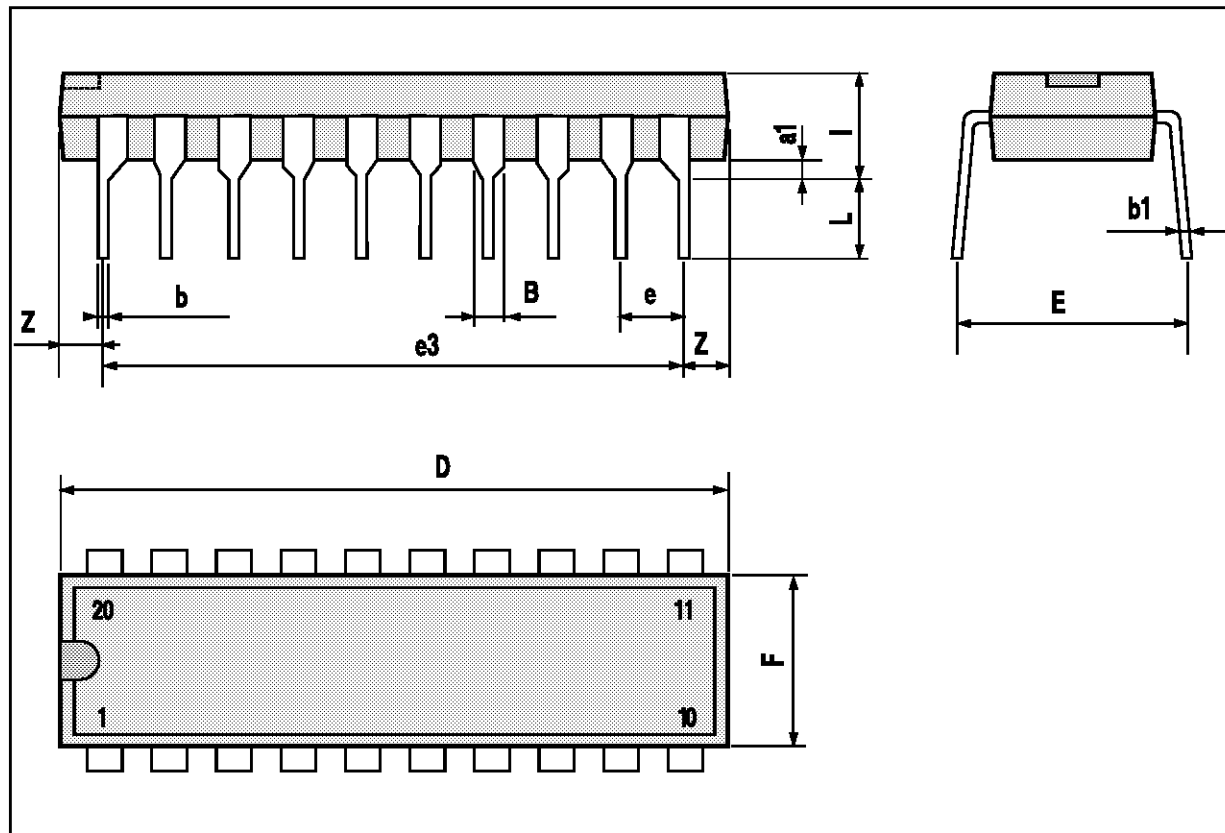


Figure 42: 1A/24V Multiple Supply. Note the synchronization between the L4972A and L4962



POWERDIP20 PACKAGE MECHANICAL DATA

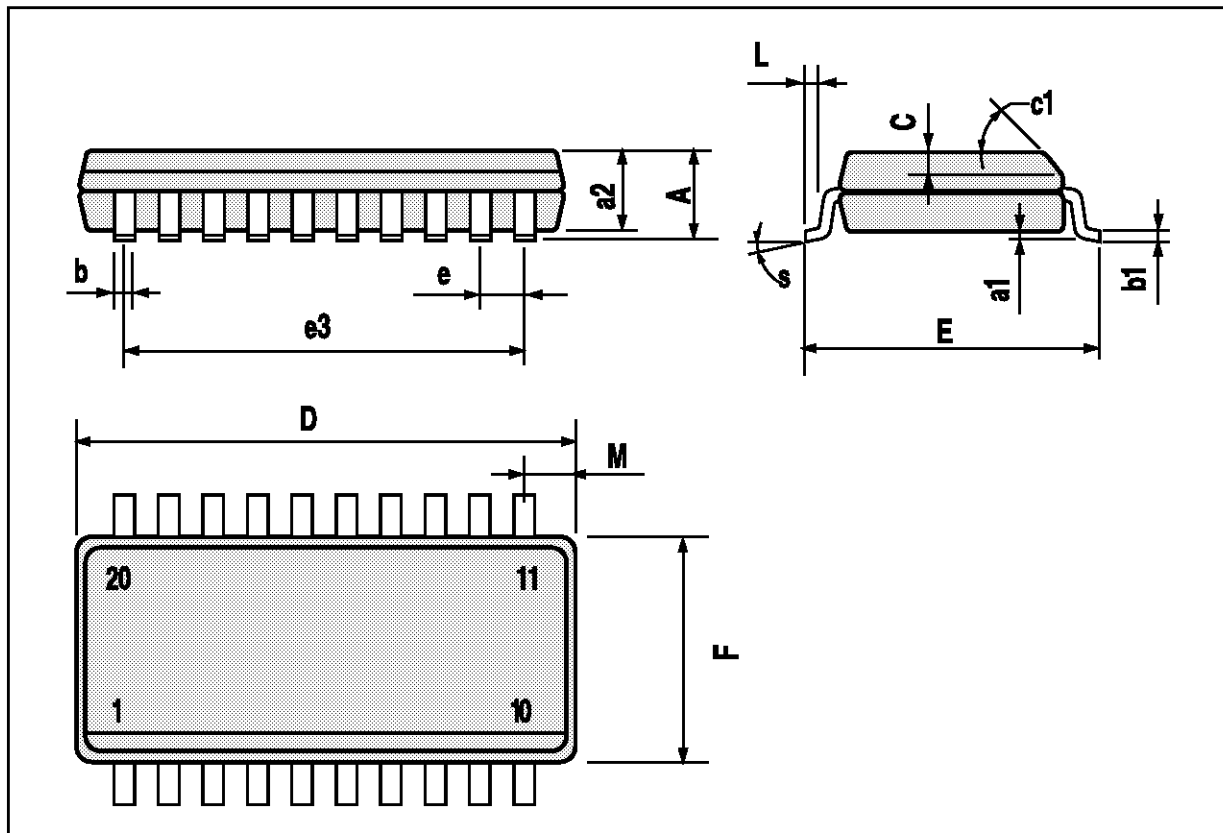
| DIM. | mm | | | inch | | |
|------|------|-------|-------|-------|-------|-------|
| | MIN. | TYP. | MAX. | MIN. | TYP. | MAX. |
| a1 | 0.51 | | | 0.020 | | |
| B | 0.85 | | 1.40 | 0.033 | | 0.055 |
| b | | 0.50 | | | 0.020 | |
| b1 | 0.38 | | 0.50 | 0.015 | | 0.020 |
| D | | | 24.80 | | | 0.976 |
| E | | 8.80 | | | 0.346 | |
| e | | 2.54 | | | 0.100 | |
| e3 | | 22.86 | | | 0.900 | |
| F | | | 7.10 | | | 0.280 |
| l | | | 5.10 | | | 0.201 |
| L | | 3.30 | | | 0.130 | |
| Z | | | 1.27 | | | 0.050 |



L4972A-L4972AD

SO20 PACKAGE MECHANICAL DATA

| DIM. | mm | | | inch | | |
|------|-----------|-------|-------|-------|-------|-------|
| | MIN. | TYP. | MAX. | MIN. | TYP. | MAX. |
| A | | | 2.65 | | | 0.104 |
| a1 | 0.1 | | 0.3 | 0.004 | | 0.012 |
| a2 | | | 2.45 | | | 0.096 |
| b | 0.35 | | 0.49 | 0.014 | | 0.019 |
| b1 | 0.23 | | 0.32 | 0.009 | | 0.013 |
| C | | 0.5 | | | 0.020 | |
| c1 | 45 (typ.) | | | | | |
| D | 12.6 | | 13.0 | 0.496 | | 0.512 |
| E | 10 | | 10.65 | 0.394 | | 0.419 |
| e | | 1.27 | | | 0.050 | |
| e3 | | 11.43 | | | 0.450 | |
| F | 7.4 | | 7.6 | 0.291 | | 0.299 |
| L | 0.5 | | 1.27 | 0.020 | | 0.050 |
| M | | | 0.75 | | | 0.030 |
| S | 8 (max.) | | | | | |



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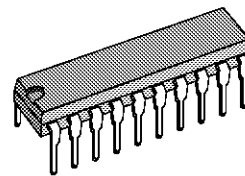
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3.5A SWITCHING REGULATOR

- 3.5A OUTPUT CURRENT
- 5.1V TO 40V OUTPUT VOLTAGE RANGE
- 0 TO 90% DUTY CYCLE RANGE
- INTERNAL FEED-FORWARD LINE REG.
- INTERNAL CURRENT LIMITING
- PRECISE 5.1V ± 2% ON CHIP REFERENCE
- RESET AND POWER FAIL FUNCTIONS
- INPUT/OUTPUT SYNC PIN
- UNDER VOLTAGE LOCK OUT WITH HYS-TERETIC TURN-ON
- PWM LATCH FOR SINGLE PULSE PER PE-RIOD
- VERY HIGH EFFICIENCY
- SWITCHING FREQUENCY UP TO 200KHz
- THERMAL SHUTDOWN
- CONTINUOUS MODE OPERATION

MULTIPOWER BCD TECHNOLOGY



POWERDIP (16 + 2 + 2)

ORDERING NUMBER : L4974A

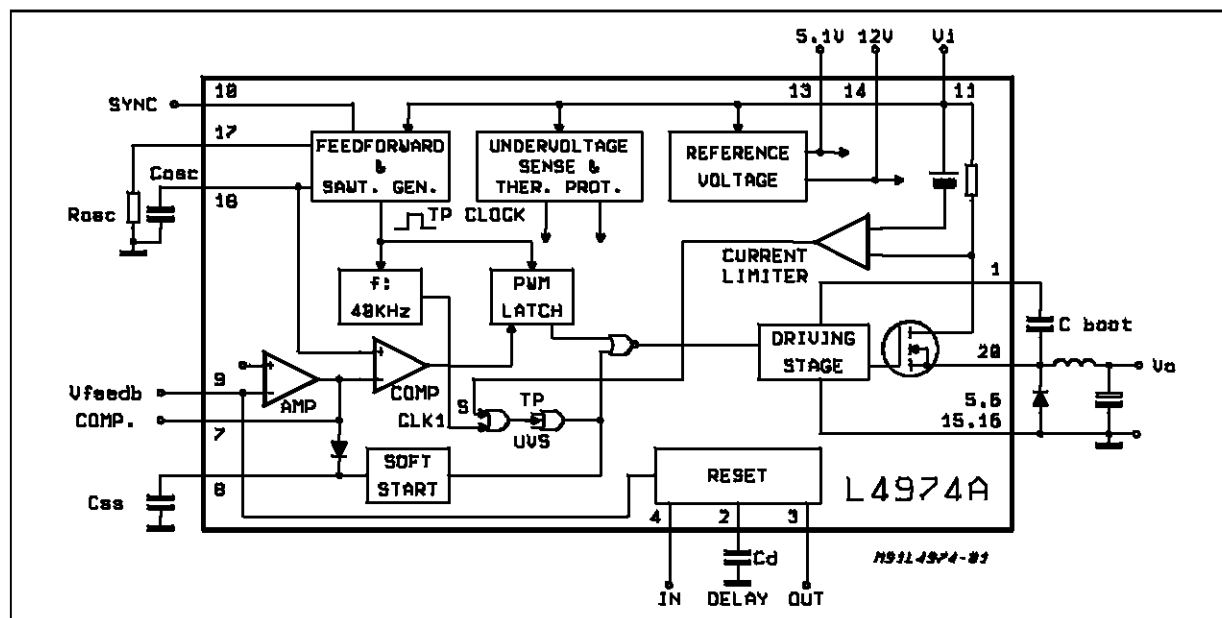
DESCRIPTION

The L4974A is a stepdown monolithic power switching regulator delivering 3.5A at a voltage variable from 5.1 to 40V.

Realized with BCD mixed technology, the device uses a DMOS output transistor to obtain very high efficiency and very fast switching times. Features of

the L4974A include reset and power fail for micro-processors, feed forward line regulation, soft start, limiting current and thermal protection. The device is mounted in a Powerdip 16 + 2 + 2 plastic package and requires few external components. Efficient operation at switching frequencies up to 200KHz allows reduction in the size and cost of external filter component.

BLOCK DIAGRAM

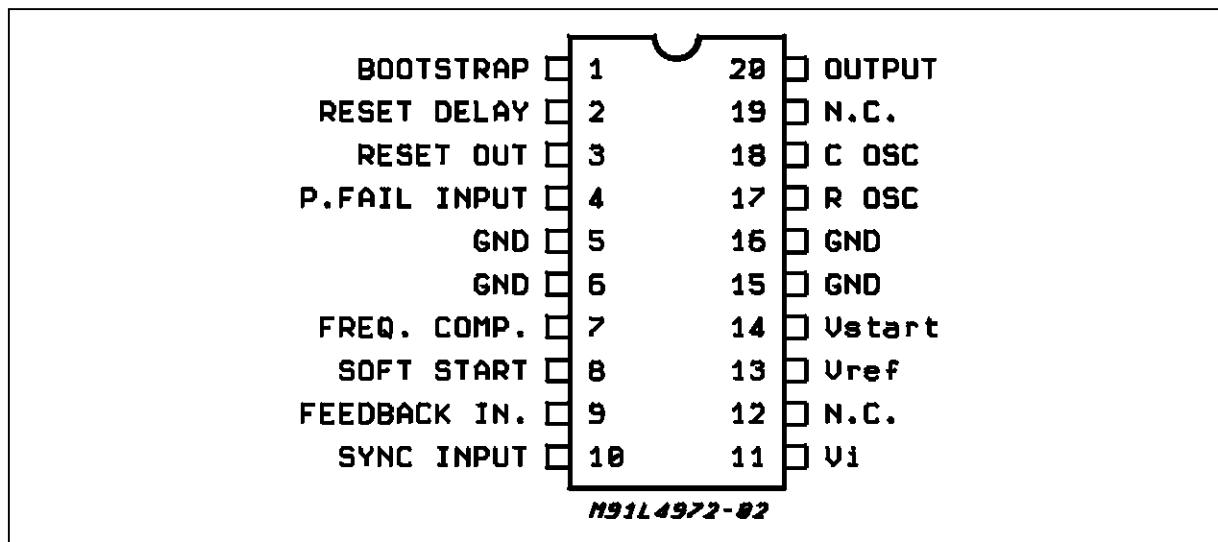


L4974A

ABSOLUTE MAXIMUM RATINGS

| Symbol | Parameter | Value | Unit |
|--|---|----------------------|------|
| V ₁₁ | Input Voltage | 55 | V |
| V ₁₁ | Input Operating Voltage | 50 | V |
| V ₂₀ | Output DC Voltage | -1 | V |
| | Output Peak Voltage at t = 0.1μs f = 200khz | -5 | V |
| I ₂₀ | Maximum Output Current | Internally Limited | |
| V ₁ | Bootstrap Voltage | 65 | V |
| | Bootstrap Operating Voltage | V ₁₁ + 15 | V |
| V ₄ , V ₈ | Input Voltage at Pins 4, 12 | 12 | V |
| V ₃ | Reset Output Voltage | 50 | V |
| I ₃ | Reset Output Sink Current | 50 | mA |
| V ₂ , V ₇ , V ₉ , V ₁₀ | Input Voltage at Pin 2, 7, 9, 10 | 7 | V |
| I ₂ | Reset Delay Sink Current | 30 | mA |
| I ₇ | Error Amplifier Output Sink Current | 1 | A |
| I ₈ | Soft Start Sink Current | 30 | mA |
| P _{tot} | Total Power Dissipation at T _{PINS} ≤ 90°C | 5 | W |
| | at T _{amb} = 70°C (No copper area on PCB) | 1.3 | W |
| T _J , T _{stg} | Junction and Storage Temperature | -40 to 150 | °C |

PIN CONNECTION (top view)



THERMAL DATA

| Symbol | Parameter | Value | Unit |
|------------------------|-------------------------------------|--------|------|
| R _{th j-pins} | Thermal Resistance Junction-Pins | max 12 | °C/W |
| R _{th j-amb} | Thermal Resistance Junction-ambient | max 60 | °C/W |

PIN FUNCTIONS

| N° | Name | Function |
|----------------|------------------------|---|
| 1 | BOOTSTRAP | A C_{boot} capacitor connected between this terminal and the output allows to drive properly the internal D-MOS transistor. |
| 2 | RESET DELAY | A C_d capacitor connected between this terminal and ground determines the reset signal delay time. |
| 3 | RESET OUT | Open Collector Reset/power Fail Signal Output. This output is high when the supply and the output voltages are safe. |
| 4 | RESET INPUT | Input of Power Fail Circuit. The threshold is 5.1V. It may be connected via a divider to the input for power fail function. It must be connected to the pin 14 an external 30K Ω resistor when power fail signal not required. |
| 5, 6 15, 16 | GROUND | Common Ground Terminal |
| 7 | FREQUENCY COMPENSATION | A series RC network connected between this terminal and ground determines the regulation loop gain characteristics. |
| 8 | SOFT START | Soft Start Time Constant. A capacitor is connected between this terminal and ground to define the soft start time constant. |
| 9 | 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. |
| 10 | SYNC INPUT | Multiple L4974A's are synchronized by connecting pin 10 inputs together or via an external syncr. pulse. |
| 11 | SUPPLY VOLTAGE | Unregulated Input Voltage. |
| 12, 19 | N.C. | Not Connected. |
| 13 | V_{ref} | 5.1V V_{ref} Device Reference Voltage. |
| 14 | V_{start} | Internal Start-up Circuit to Drive the Power Stage. |
| 17 | OSCILLATOR | R_{osc} . External resistor connected to ground determines the constant charging current of C_{osc} . |
| 18 | OSCILLATOR | C_{osc} . External capacitor connected to ground determines (with R_{osc}) the switching frequency. |
| 20 | OUTPUT | Regulator Output. |

CIRCUIT OPERATION

The L4974A is a 3.5A monolithic stepdown switching regulator working in continuous mode realized in the new BCD Technology. This technology allows the integration of isolated vertical DMOS power transistors plus mixed CMOS/Bipolar transistors.

The device can deliver 3.5A at an output voltage adjustable from 5.1V to 40V and contains diagnostic and control functions that make it particularly suitable for microprocessor based systems.

BLOCK DIAGRAM

The block diagram shows the DMOS power transistors and the PWM control loop. Integrated functions include a reference voltage trimmed to $5.1V \pm 2\%$, soft start, undervoltage lockout, oscillator with feedforward control, pulse by pulse current limit, thermal shutdown and finally the reset and power fail circuit. The reset and power fail circuit provides an output signal for a microprocessor indicating the status of the system.

Device turn on is around 11V with a typical 1V hysteresis, this threshold provides a correct voltage for the driving stage of the DMOS gate and the hysteresis prevents instabilities.

An external bootstrap capacitor charge to 12V by an internal voltage reference is needed to provide correct gate drive to the power DMOS. The driving circuit is able to source and sink peak currents of around 0.5A to the gate of the DMOS transistor. A typical switching time of the current in the DMOS transistor is 50ns. Due to the fast commutation switching frequencies up to 200kHz are possible.

The PWM control loop consists of a sawtooth oscillator, error amplifier, comparator, latch and the output stage. An error signal is produced by comparing the output voltage with the precise $5.1V \pm 2\%$ on chip reference. This error signal is then compared with the sawtooth oscillator in order to generate fixed frequency pulse width modulated drive for the output stage. A PWM latch is included to eliminate multiple pulsing within a period even in noisy environments.

The gain and stability of the loop can be adjusted by

an external RC network connected to the output of the error amplifier. A voltage feedforward control has been added to the oscillator, this maintains superior line regulation over a wide input voltage range. Closing the loop directly gives an output voltage of 5.1V, higher voltages are obtained by inserting a voltage divider.

At turn on, output overcurrents are prevented by the soft start function (fig. 2). The error amplifier is initially clamped by an external capacitor, C_{ss} , and allowed to rise linearly under the charge of an internal constant current source.

Output overload protection is provided by a current limit circuit. The load current is sensed by a internal metal resistor connected to a comparator. When the load current exceeds a preset threshold, the output of the comparator sets a flip flop which turns off the power DMOS. The next clock pulse, from an internal 40kHz oscillator, will reset the flip flop and the power DMOS will again conduct. This current protection method, ensures a constant current output when the system is overloaded or short circuited and limits the switching frequency, in this condition, to 40kHz. The Reset and Power fail circuit (fig. 4), generates an output signal when the supply voltage exceeds a threshold programmed by an external voltage divider. The reset signal, is generated with a delay time programmed by a external capacitor on the delay pin. When the supply voltage falls below the threshold or the output voltage goes below 5V, the reset output goes low immediately. The reset output is an open drain.

Fig. 4A shows the case when the supply voltage is higher than the threshold, but the output voltage is not yet 5V.

Fig. 4B shows the case when the output is 5.1V, but the supply voltage is not yet higher than the fixed threshold.

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

Figure 1 : Feedforward Waveform.

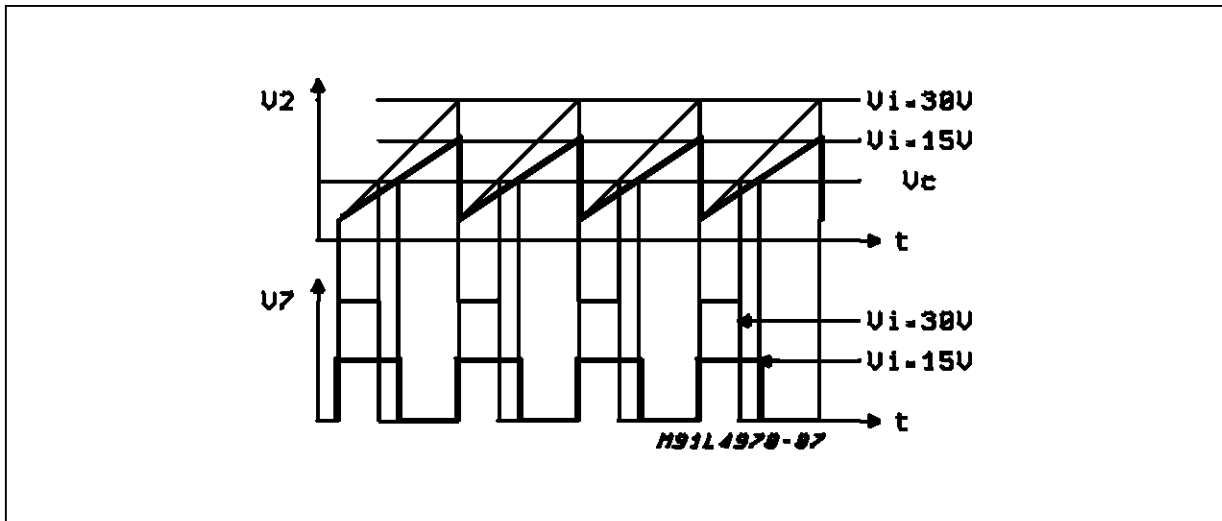


Figure 2 : Soft Start Function.

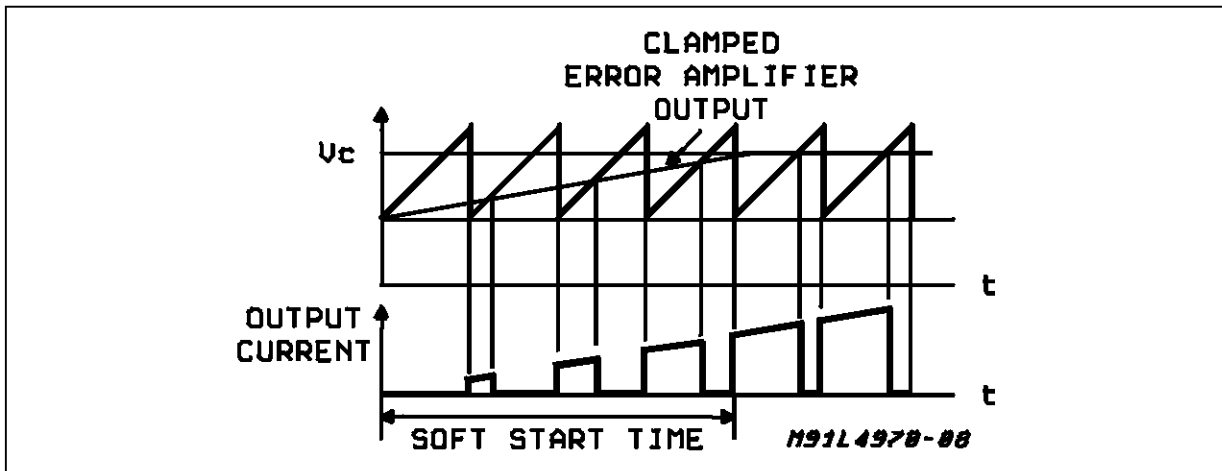


Figure 3 : Limiting Current Function.

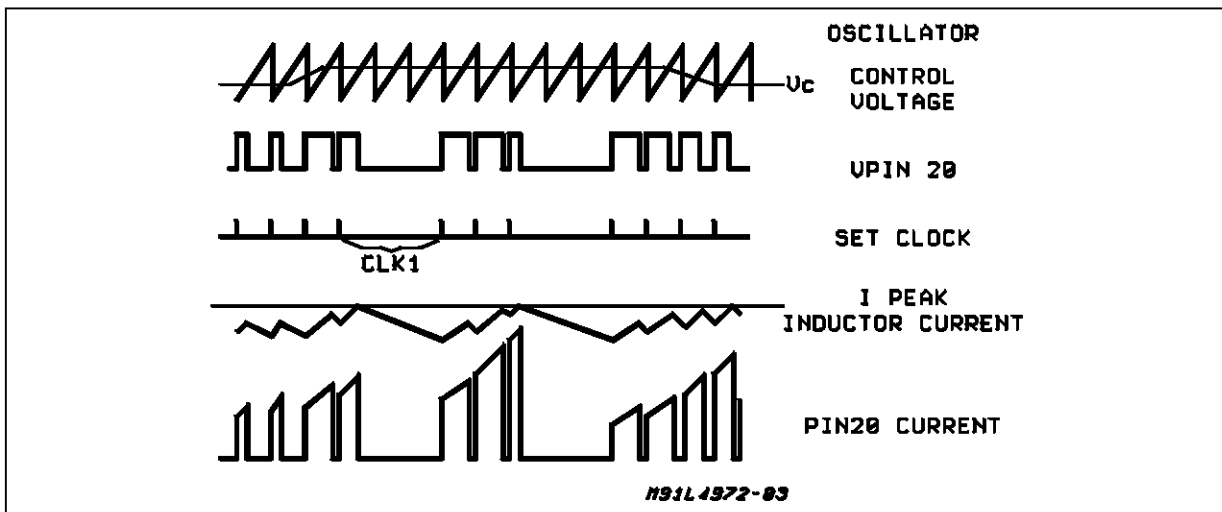
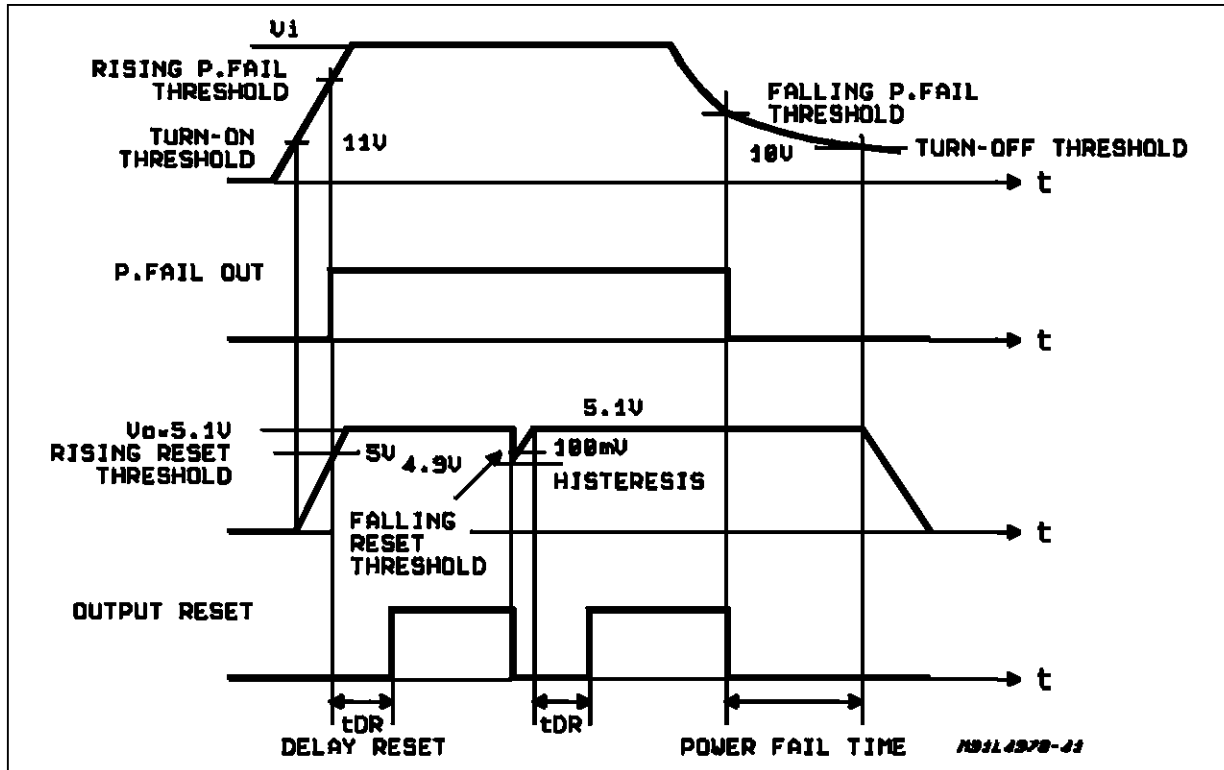
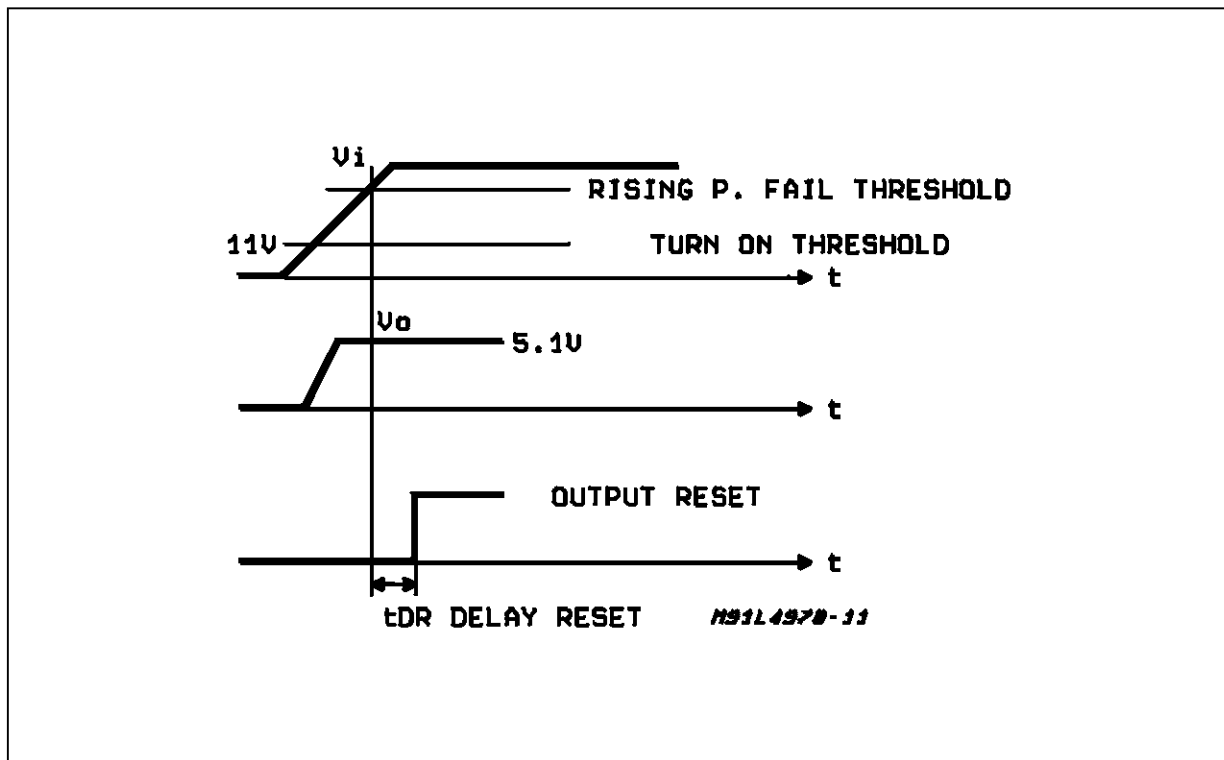


Figure 4 : Reset and Power Fail Functions.

A



B



ELECTRICAL CHARACTERISTICS (refer to the test circuit, $T_J = 25^\circ\text{C}$, $V_i = 35\text{V}$, $R_4 = 30\text{K}\Omega$, $C_9 = 2.7\text{nF}$, $f_{\text{SW}} = 100\text{KHz}$ typ, unless otherwise specified)

DYNAMIC CHARACTERISTICS

| Symbol | Parameter | Test Conditions | Min. | Typ. | Max. | Unit | Fig. |
|-----------------------|--|---|------|--------------|------------|--------|------|
| V_i | Input Volt. Range (pin 11) | $V_o = V_{\text{ref}}$ to 40V $I_o = 3.5\text{A}$ (*) | 15 | | 50 | V | 5 |
| V_o | Output Voltage | $V_i = 15\text{V}$ to 50V $I_o = 2\text{A}$; $V_o = V_{\text{ref}}$ | 5 | 5.1 | 5.2 | V | 5 |
| ΔV_o | Line Regulation | $V_i = 15\text{V}$ to 50V $I_o = 1\text{A}$; $V_o = V_{\text{ref}}$ | | 12 | 30 | mV | |
| ΔV_o | Load Regulation | $V_o = V_{\text{ref}}$ $I_o = 1\text{A}$ to 3.5A $I_o = 2\text{A}$ to 3A | | 8 | 25 | mV | |
| | | | | 4 | 10 | mV | |
| V_d | Dropout Voltage between Pin 11 and 20 | $I_o = 2\text{A}$ $I_o = 3.5\text{A}$ | | 0.25 0.45 | 0.4 0.7 | V | |
| I_{20L} | Max Limiting Current | $V_i = 15\text{V}$ to 50V $V_o = V_{\text{ref}}$ to 40V | 4 | 4.75 | 5.5 | A | |
| η | Efficiency | $I_o = 3.5\text{A}$, $f = 100\text{KHz}$ $V_o = V_{\text{ref}}$ $V_o = 12\text{V}$ | 80 | 85 90 | | % % | |
| SVR | Supply Voltage Ripple Rejection | $V_i = 2\text{VRMS}$; $I_o = 5\text{A}$ $f = 100\text{Hz}$; $V_o = V_{\text{ref}}$ | 56 | 60 | | dB | 5 |
| f | Switching Frequency | | 90 | 100 | 110 | KHz | 5 |
| $\Delta f/\Delta V_i$ | Voltage Stability of Switching Frequency | $V_i = 15\text{V}$ to 45V | | 2 | 6 | % | 5 |
| $\Delta f/T_j$ | Temperature Stability of Switching Frequency | $T_j = 0$ to 125°C | | 1 | | % | 5 |
| f_{max} | Maximum Operating Switching Frequency | $V_o = V_{\text{ref}}$ $R_4 = 15\text{K}\Omega$ $I_o = 3.5\text{A}$ $C_9 = 2.2\text{nF}$ | 200 | | | KHz | 5 |

(*) Pulse testing with a low duty cycle

V_{ref} SECTION (pin 13)

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|----------------------------------|---|--|------|------|------|----------------------|------|
| V_{13} | Reference Voltage | | 5 | 5.1 | 5.2 | V | 7 |
| ΔV_{13} | Line Regulation | $V_i = 15\text{V}$ to 50V | | 10 | 25 | mV | 7 |
| ΔV_{13} | Load Regulation | $I_{13} = 0$ to 1mA | | 20 | 40 | mV | 7 |
| $\frac{\Delta V_{13}}{\Delta T}$ | Average Temperature Coefficient Reference Voltage | $T_j = 0^\circ\text{C}$ to 125°C | | 0.4 | | mV/ $^\circ\text{C}$ | 7 |
| $I_{13\text{short}}$ | Short Circuit Current Limit | $V_{13} = 0$ | | 70 | | mA | 7 |

V_{START} SECTION (pin 15)

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|----------------------|-----------------------------|----------------------|------|------|------|------|------|
| V_{14} | Reference Voltage | | 11.4 | 12 | 12.6 | V | 7 |
| ΔV_{14} | Line Regulation | $V_i = 15$ to 50V | | 0.6 | 1.4 | V | 7 |
| ΔV_{14} | Load Regulation | $I_{14} = 0$ to 1mA | | 50 | 200 | mV | 7 |
| $I_{14\text{short}}$ | Short Circuit Current Limit | $V_{15} = 0\text{V}$ | | 80 | | mA | 7 |

L4974A

ELECTRICAL CHARACTERISTICS (continued)

DC CHARACTERISTICS

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|---------------|--------------------------|------------------------------|------|------|------|------|------|
| V_{11on} | Turn-on Threshold | | 10 | 11 | 12 | V | 7A |
| $V_{11 Hyst}$ | Turn-off Hysteresys | | | 1 | | V | 7A |
| I_{11Q} | Quiescent Current | $V_8 = 0; S1 = D$ | | 13 | 19 | mA | 7A |
| I_{11OQ} | Operating Supply Current | $V_8 = 0; S1 = B; S2 = B$ | | 16 | 23 | mA | 7A |
| I_{20L} | Out Leak Current | $V_i = 55V; S3 = A; V_8 = 0$ | | | 2 | mA | 7A |

SOFT START (pin 8)

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|--------|---------------------------|--|------|------|----------|---------|----------|
| I_8 | Soft Start Source Current | $V_8 = 3V; V_9 = 0V$ | 80 | 115 | 150 | μA | 7B |
| V_8 | Output Saturation Voltage | $I_8 = 20mA; V_{11} = 10V$ $I_8 = 200\mu A; V_{11} = 10V$ | | | 1 0.7 | V V | 7B 7B |

ERROR AMPLIFIER

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|-----------|--------------------------|---|------|------|------|---------|------|
| V_{7H} | High Level Out Voltage | $I_7 = -100\mu A; S1 = C$ $V_9 = 4.7V$ | 6 | | | V | 7C |
| V_{7L} | Low Level Out Voltage | $I_7 = 100\mu A; S1 = C$ $V_9 = 5.3V;$ | | | 1.2 | V | 7C |
| I_{7H} | Source Output Current | $V_7 = 1V; V_7 = 4.7V$ | 100 | 150 | | μA | 7C |
| $-I_{7L}$ | Sink Output Current | $V_7 = 6V; V_9 = 5.3V$ | 100 | 150 | | μA | 7C |
| I_9 | Input Bias Current | $S1 = B; R_S = 10K\Omega$ | | 0.4 | 3 | μA | 7C |
| G_V | DC Open Loop Gain | $S1 = A; R_S = 10\Omega$ | 60 | | | dB | 7C |
| SVR | Supply Voltage Rejection | $15 < V_i < 50V$ | 60 | 80 | | dB | 7C |
| V_{OS} | Input Offset Voltage | $R_S = 50\Omega S1 = A$ | | 2 | 10 | mV | 7C |

RAMP GENERATOR (pin 18)

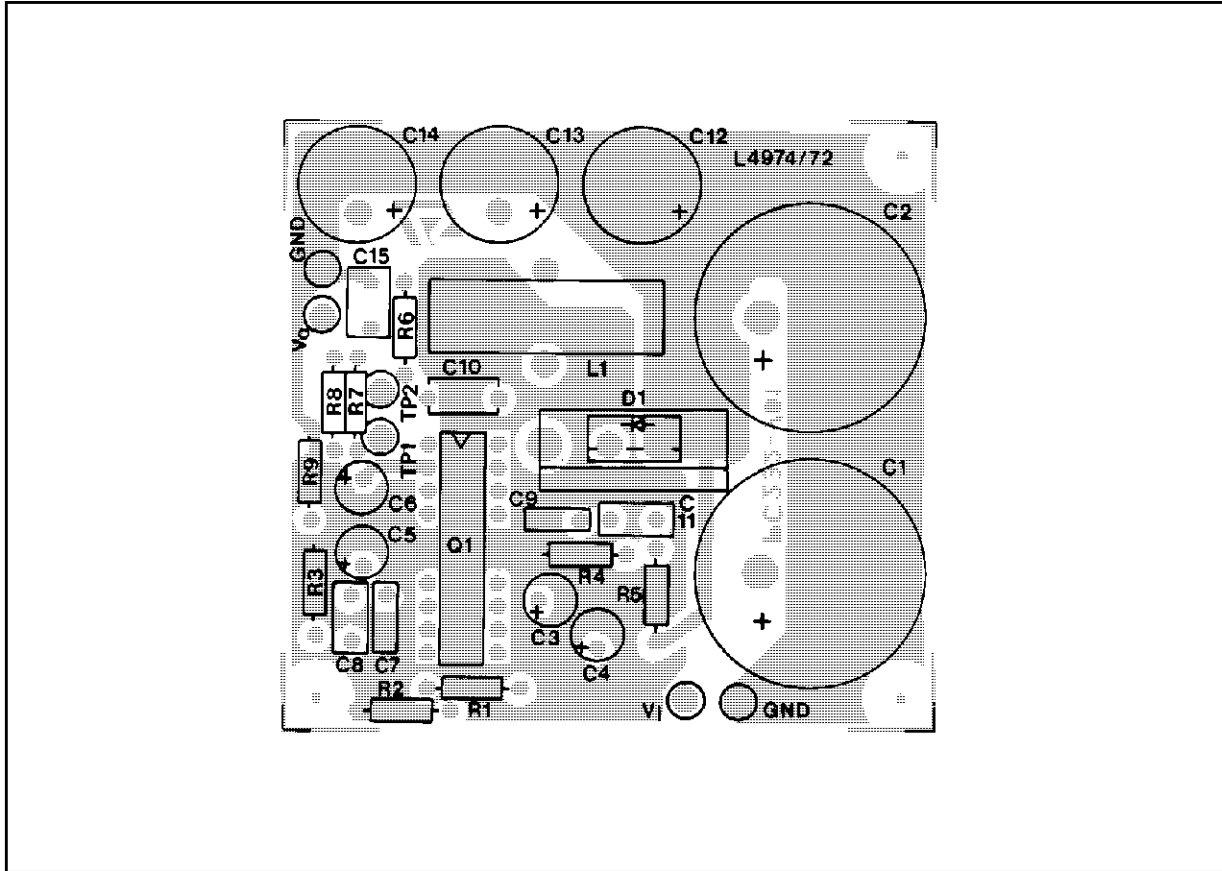
| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|----------|-------------------|-----------------------------|------|----------------------------|------|---------|----------|
| V_{18} | Ramp Valley | $S1 = B; S2 = B$ | 1.2 | 1.5 | | V | 7A |
| V_{18} | Ramp Peak | $S1 = B$ $S2 = B$ | | $V_i = 15V$ $V_i = 45V$ | | V V | 7A 7A |
| I_{18} | Min. Ramp Current | $S1 = A; I_{17} = 100\mu A$ | | 270 | 300 | μA | 7A |
| I_{18} | Max. Ramp Current | $S1 = A; I_{17} = 1mA$ | 2.4 | 2.7 | | mA | 7A |

SYNC FUNCTION (pin 10)

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|------------|---|---|------|------|------|---------|------|
| V_{10} | Low Input Voltage | $V_i = 15V \text{ to } 50V; V_8 = 0;$ $S1 = B; S2 = B; S4 = B$ | -0.3 | | 0.9 | V | 7A |
| V_{10} | High Input voltage | $V_8 = 0;$ $S1 = B; S2 = B; S4 = B$ | 2.5 | | 5.5 | V | 7A |
| $+I_{10L}$ | Sync Input Current with Low Input Voltage | $V_{10} = V_{18} = 0.9V; S4 = B;$ $S1 = B; S2 = B$ | | | 0.4 | mA | 7A |
| $+I_{10H}$ | Input Current with High Input Voltage | $V_{10} = 2.5V$ | | | 1.5 | mA | 7A |
| V_{10} | Output Amplitude | | 4 | 5 | | V | - |
| t_w | Output Pulse Width | $V_{thr} = 2.5V$ | 0.3 | 0.5 | 0.8 | μs | - |

L4974A

Figure 6a : Component Layout of fig.5 (1 : 1 scale). Evaluation Board Available



PART LIST

R₁ = 30K Ω
 R₂ = 10K Ω
 R₃ = 15K Ω
 R₄ = 30K Ω
 R₅ = 22 Ω
 R₆ = 4.7K Ω
 R₇ = see table A
 R₈ = OPTION
 R₉ = 4.7K Ω

* C₁ = C₂ = 1000 μ F 63V EYF (ROE)
 C₃ = C₄ = C₅ = C₆ = 2,2 μ F 50V
 C₇ = 390pF Film
 C₈ = 22nF MKT 1837 (ERO)
 C₉ = 2.7nF KP 1830 (ERO)
 C₁₀ = 0.33 μ F Film
 C₁₁ = 1nF

** C₁₂ = C₁₃ = C₁₄ = 100 μ F 40V EKR (ROE)
 C₁₅ = 1 μ F Film

D1 = SB 560 (OR EQUIVALENT)

L1 = 150 μ H
 core 58310 MAGNETICS
 45 TURNS 0.91mm (AWG 19)
 COGEMA 949181

* 2 capacitors in parallel to increase input RMS current capability.

** 3 capacitors in parallel to reduce total output ESR.

Table A

| V ₀ | R ₉ | R ₇ |
|----------------|----------------|----------------|
| 12V | 4.7k Ω | 6.2kW |
| 15V | 4.7k Ω | 9.1k Ω |
| 18V | 4.7k Ω | 12 Ω |
| 24V | 4.7k Ω | 18 Ω |

Table B

SUGGESTED BOOSTRAP CAPACITORS

| Operating Frequency | Bootstrap Cap.c10 |
|---------------------|-------------------|
| f = 20KHz | \geq 680nF |
| f = 50KHz | \geq 470nF |
| f = 100KHz | \geq 330nF |
| f = 200KHz | \geq 220nF |
| f = 500KHz | \geq 100nF |

Figure 6b: P.C. Board and Component Layout of the Circuit of Fig. 5. (1:1 scale)

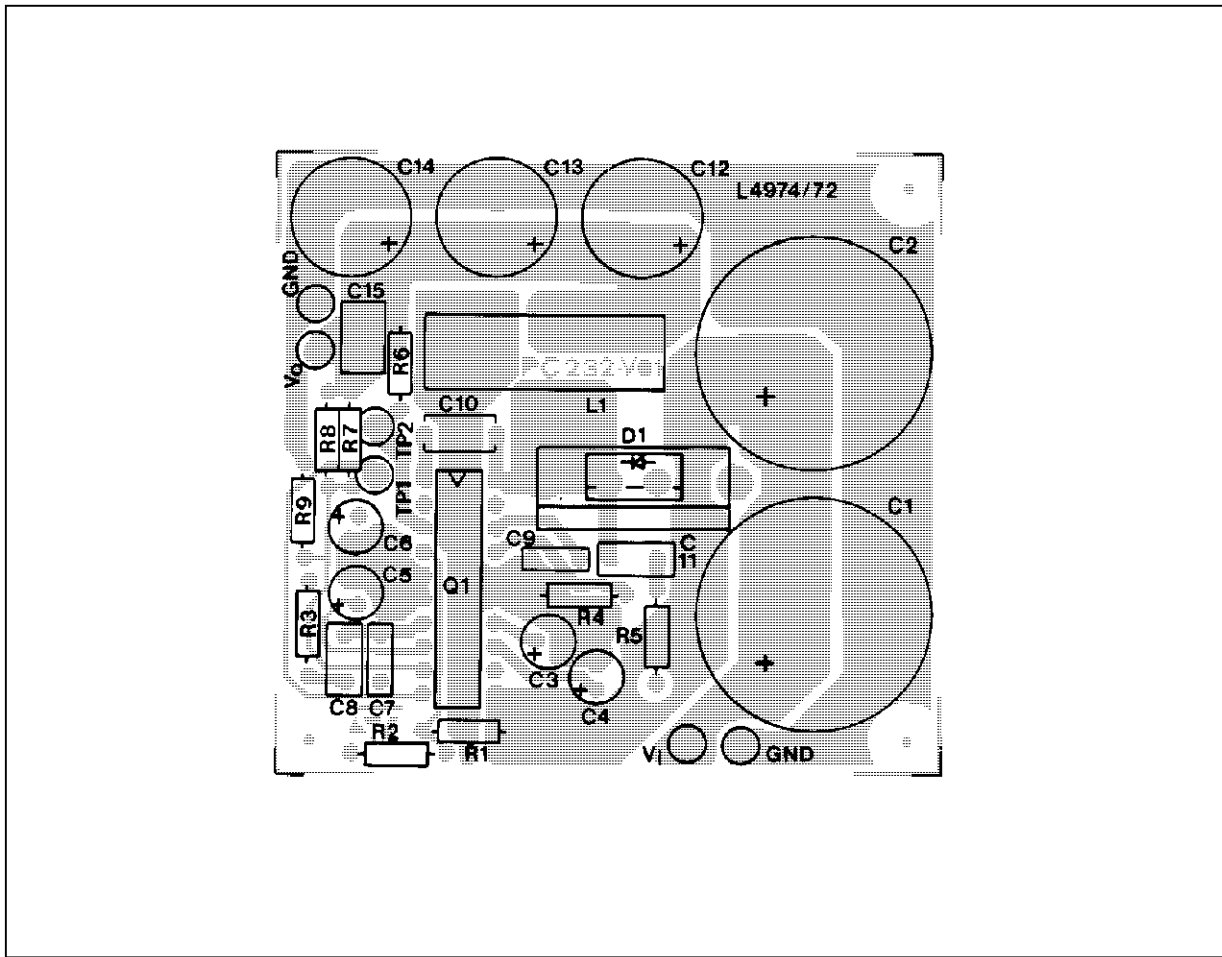
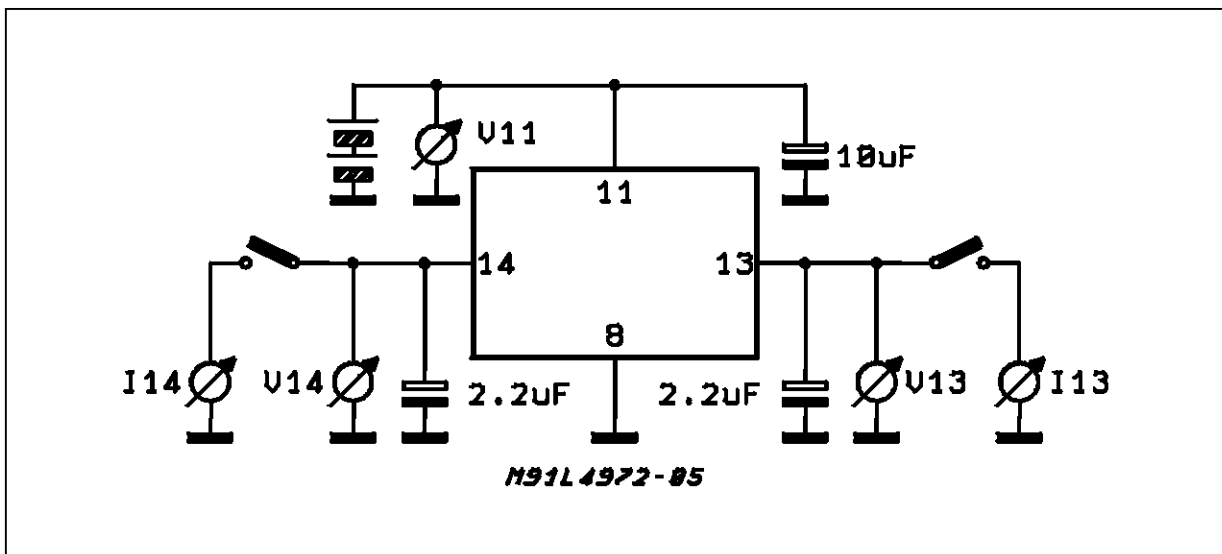


Figure 7 : DC Test Circuits.



L4974A

Figure 7A.

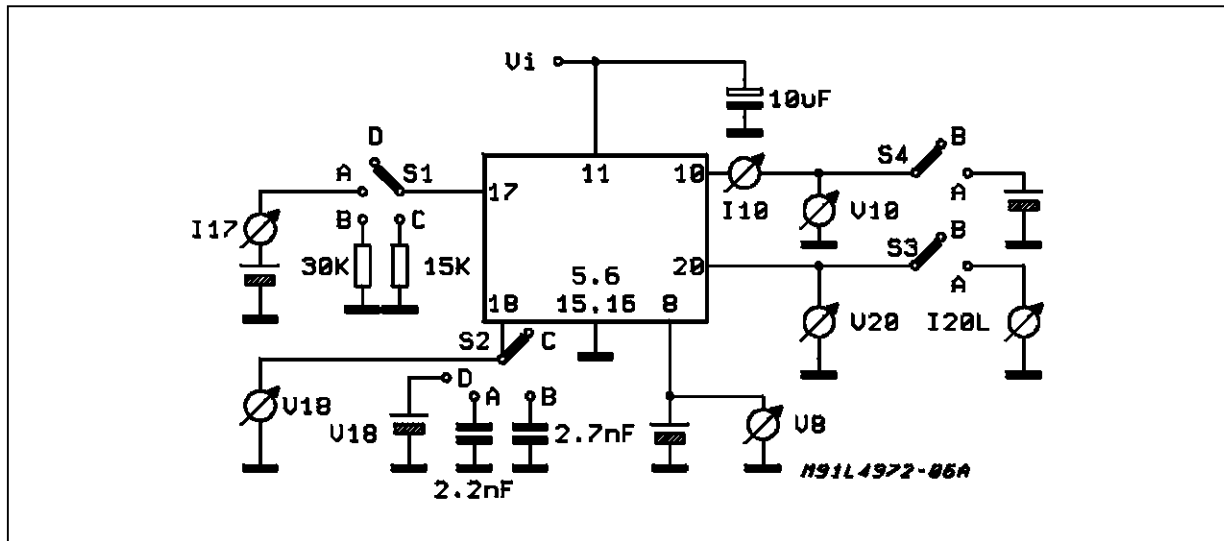


Figure 7B.

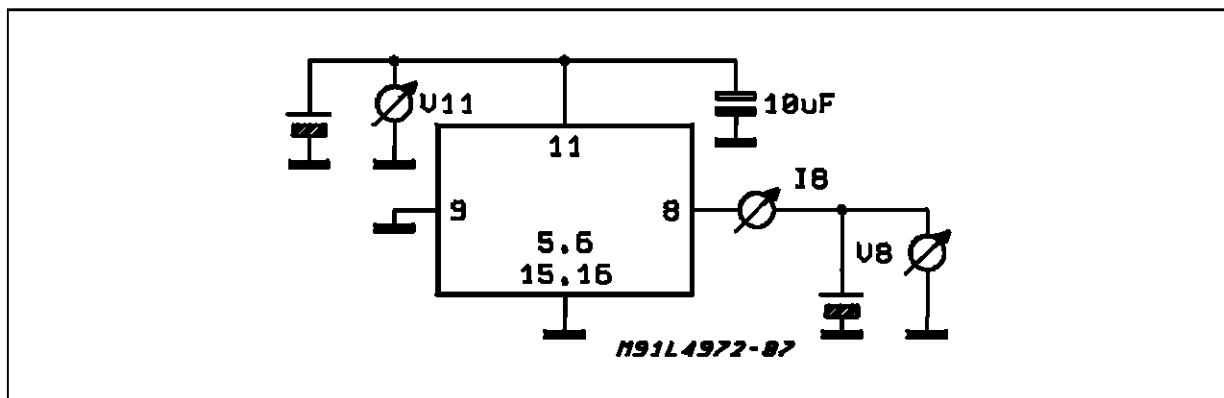


Figure 7C.

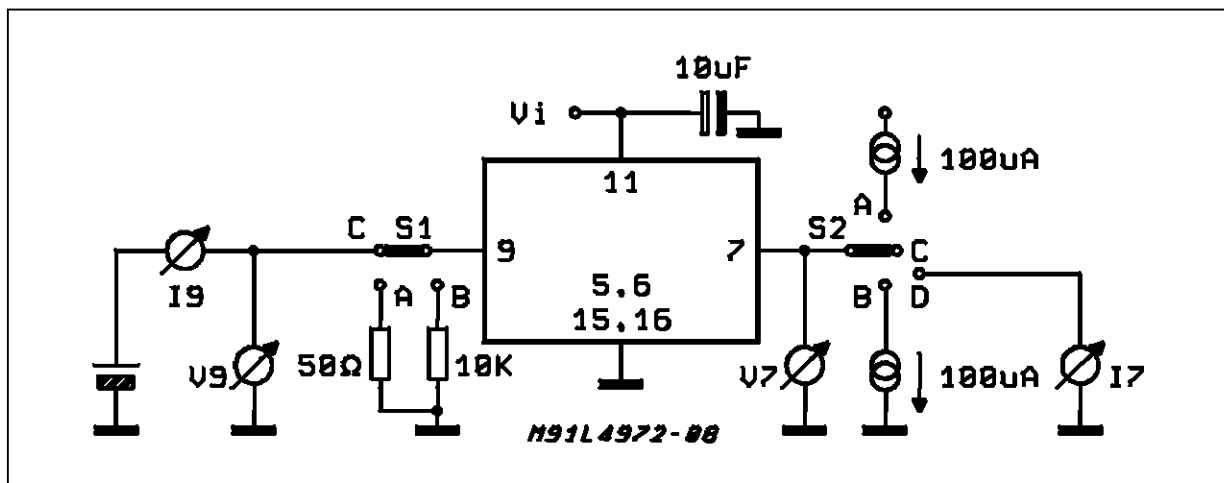


Figure 7D.

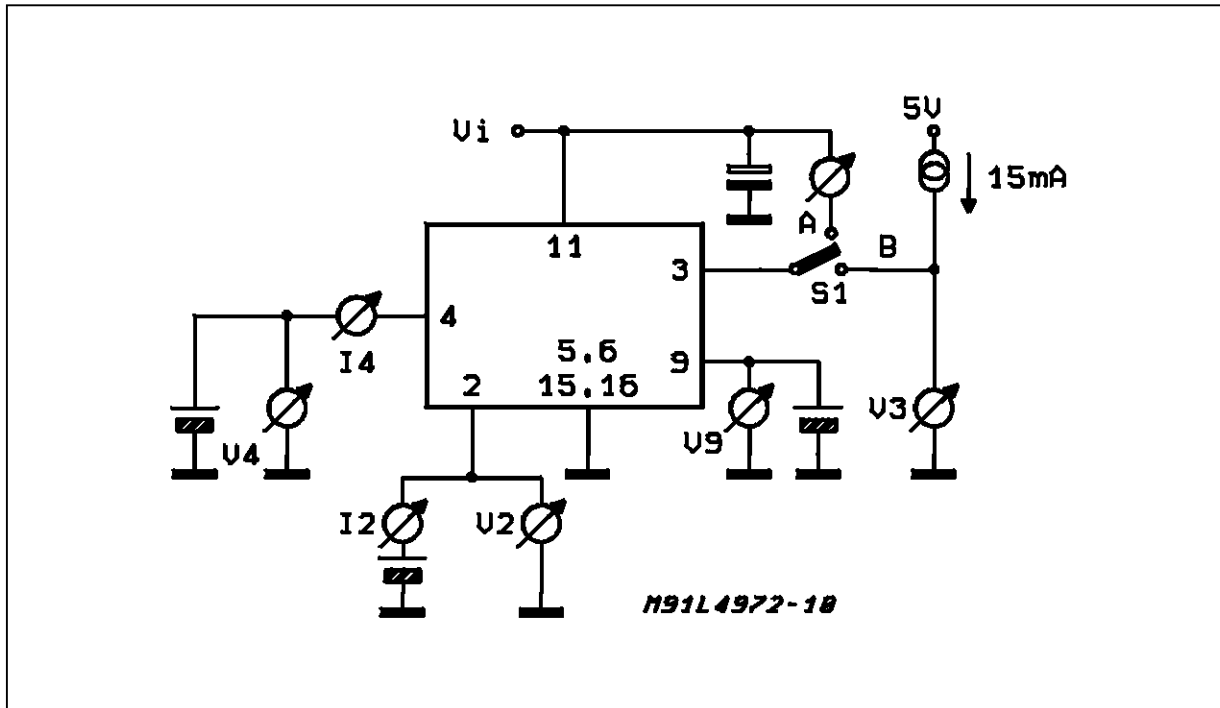


Figure 8 : Quiescent Drain Current vs. Supply Voltage (0% duty cycle - see fig. 7A).

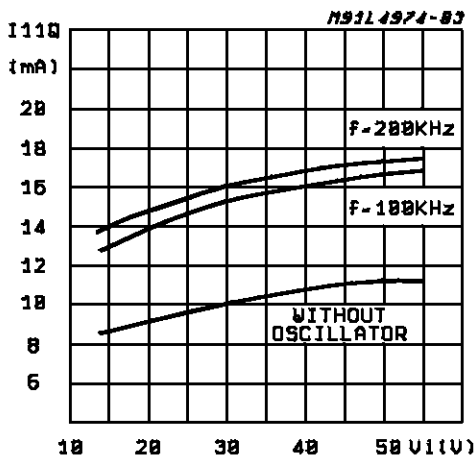


Figure 9 : Quiescent Drain Current vs. Junction Temperature (0% duty cycle).

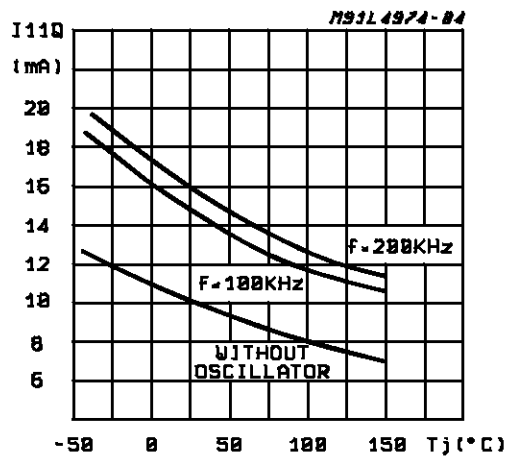


Figure 10 : Quiescent Drain Current vs. Duty Cycle.

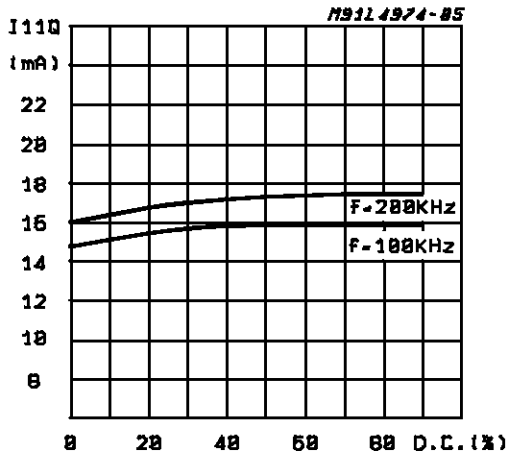


Figure 11 : Reference Voltage (pin 13) vs. V_i (see fig. 7).

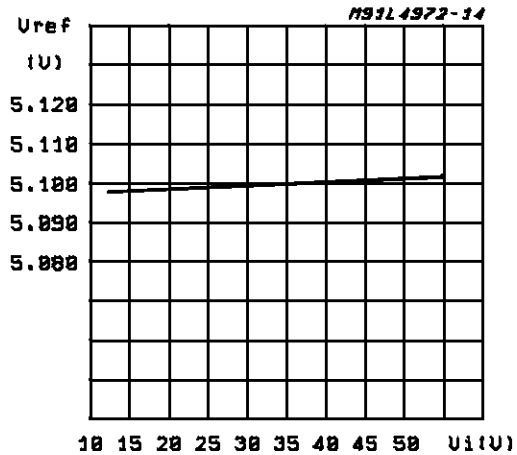


Figure 12 : Reference Voltage (pin 13) vs. Junction Temperature (see fig. 7).

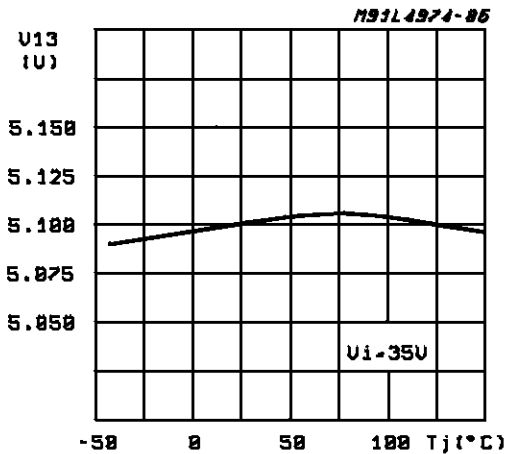


Figure 13 : Reference Voltage (pin 14) vs. V_i (see fig. 7).

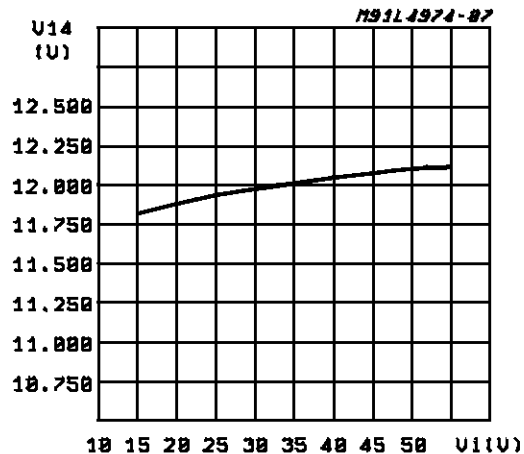


Figure 14 : Reference Voltage (pin 14) vs. Junction Temperature (see fig. 7).

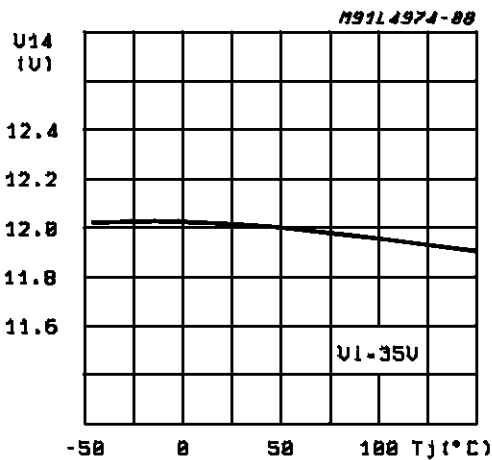


Figure 15 : Reference Voltage 5.1V (pin 13) Supply Voltage Ripple Rejection vs. Frequency.

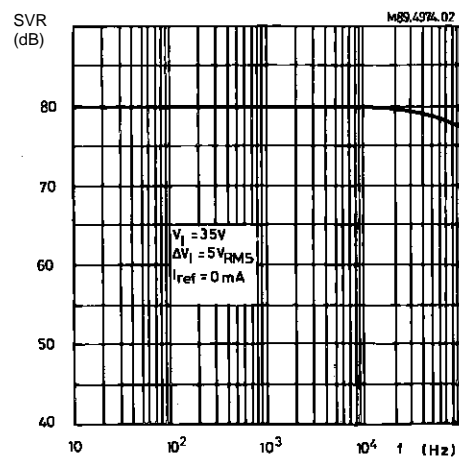


Figure 16 : Switching Frequency vs. Input Voltage (see fig. 5).

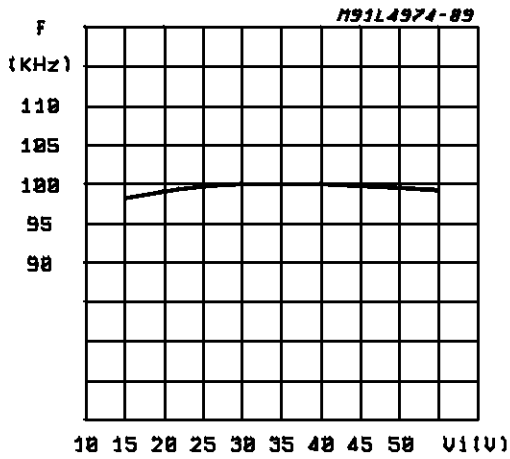


Figure 17 : Switching Frequency vs. Junction Temperature (see fig. 5).

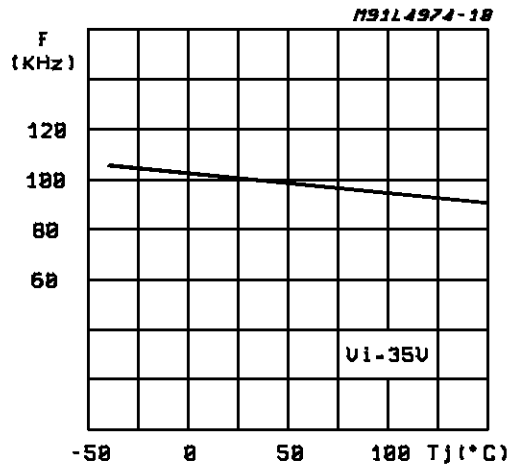


Figure 18 : Switching Frequency vs. R4 (see fig.5).

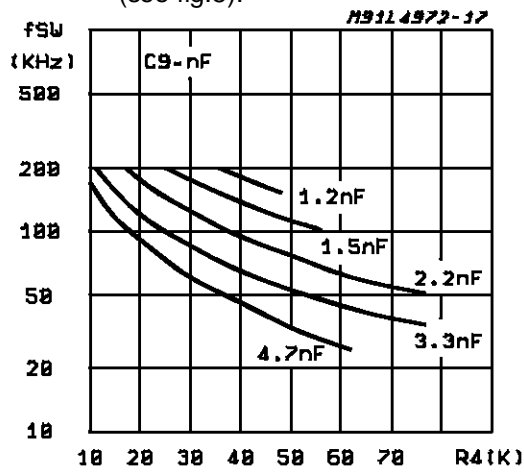


Figure 19 : Maximum Duty Cycle vs. Frequency.

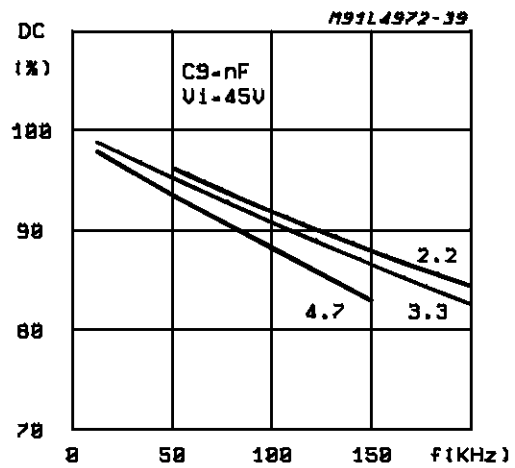


Figure 20 : Supply Voltage Ripple Rejection vs. Frequency (see fig. 5).

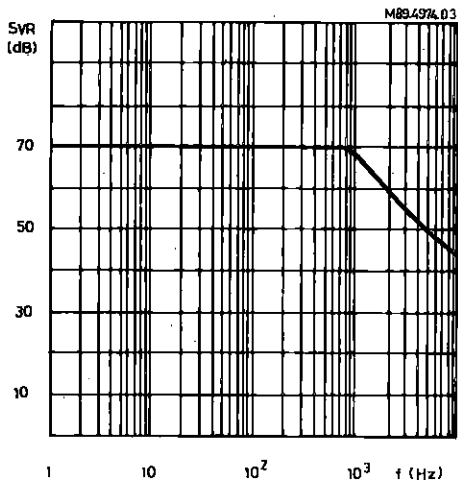


Figure 21 : Efficiency vs. Output Voltage.

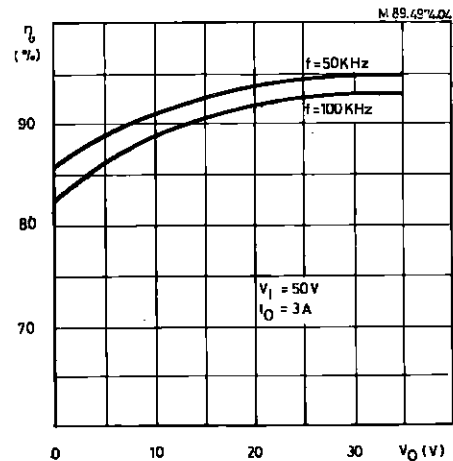


Figure 22 : Line Transient Response (see fig. 5).

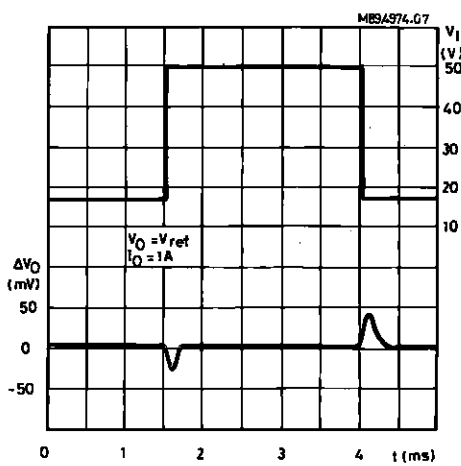


Figure 23 : Load Transient Response (see fig. 5).

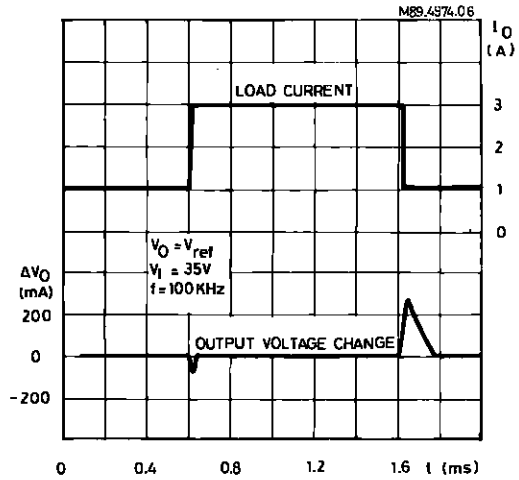


Figure 24 : Dropout Voltage between Pin 11 and Pin 20 vs. Current at Pin 20.

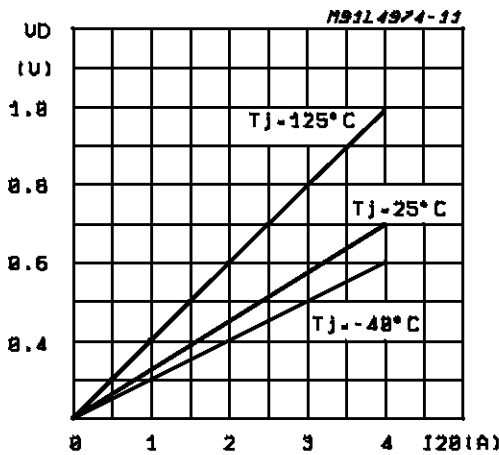


Figure 25 : Dropout Voltage between Pin 11 and Pin 20 vs. Junction Temperature.

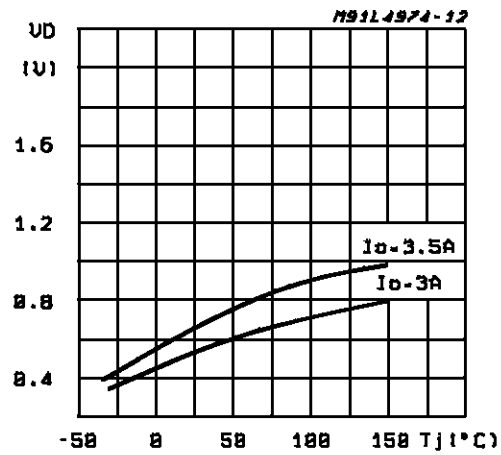


Figure 26 : Power Dissipation (device only) vs. Input Voltage.

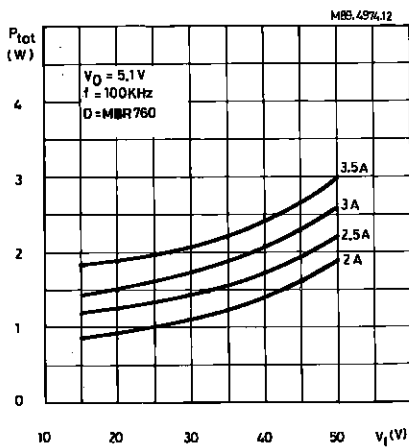


Figure 27 : Power Dissipation (device only) vs. Input Voltage.

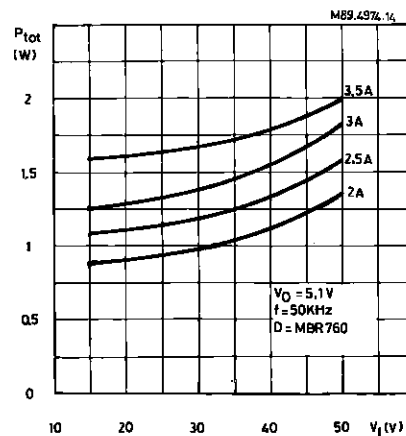


Figure 28 : Power Dissipation (device only) vs. Output Voltage.

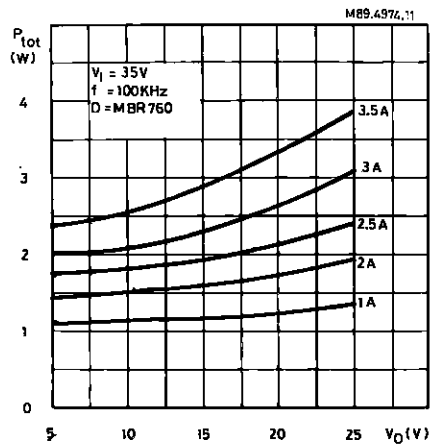


Figure 29 : Power Dissipation (device only) vs. Output Voltage.

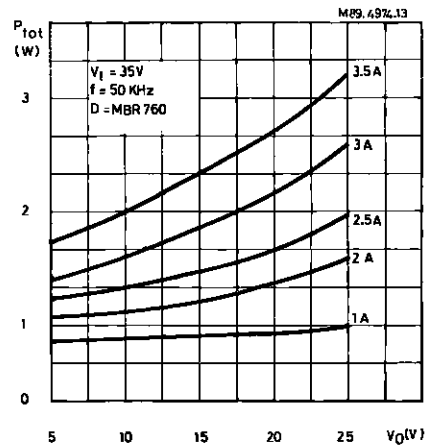


Figure 30 : Power Dissipation (device only) vs. Output Current.

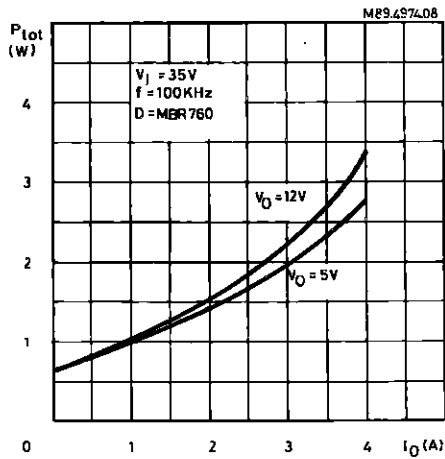


Figure 31 : Power Dissipation (device only) vs. Output Current.

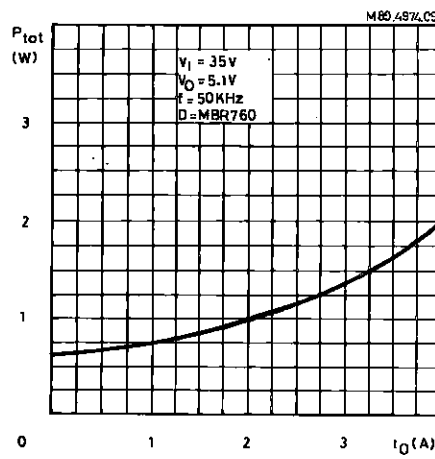


Figure 32 : Efficiency vs. Output Current.

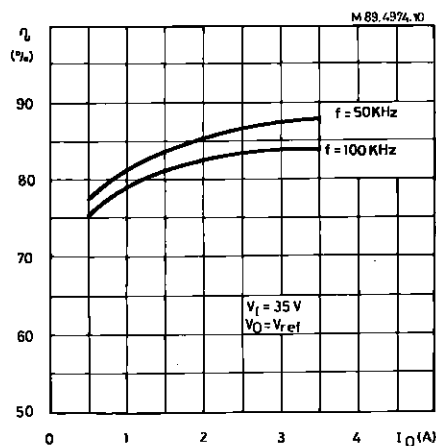


Figure 33 : Test PCB Thermal Characteristic.

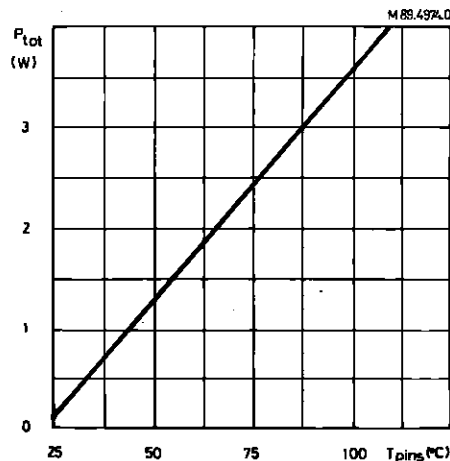


Figure 34 : Junction to Ambient Thermal Resistance vs. Area on Board Heatsink (DIP 16+2+2)

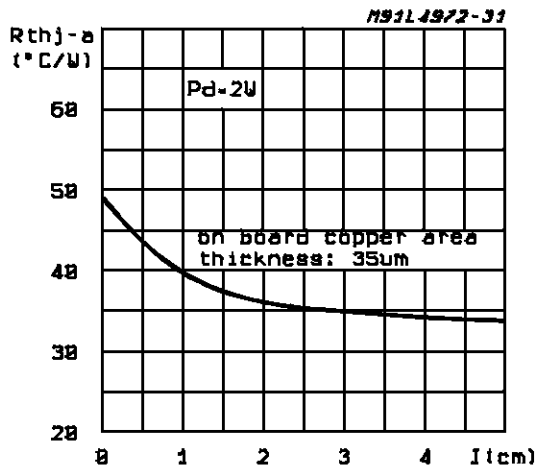


Figure 35: Maximum Allowable Power Dissipation vs. Ambient Temperature (Pow-erdip)

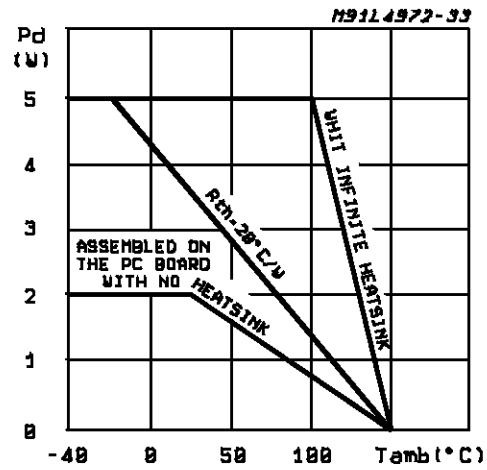


Figure 36: Open Loop Frequency and Phase of Error Amplifier (see fig. 7C).

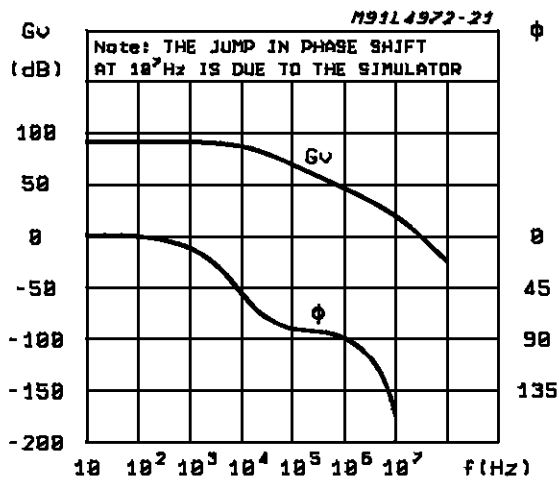


Figure 37 : 3.5A – 5.1V Low Cost Application Circuit.

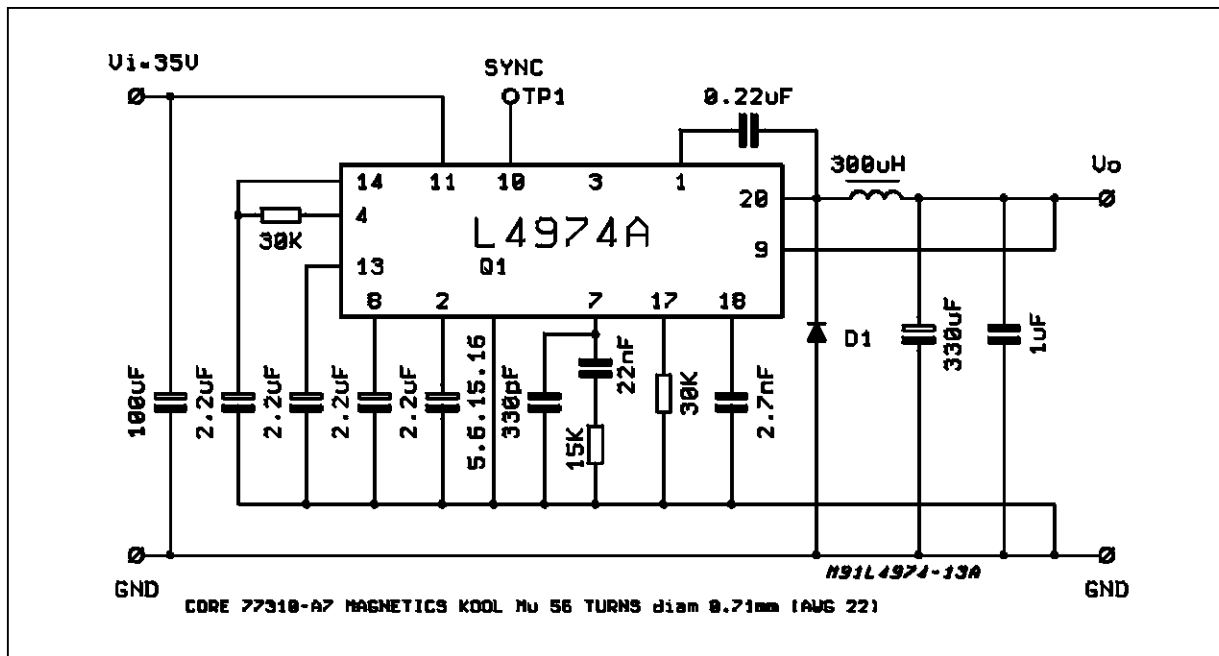
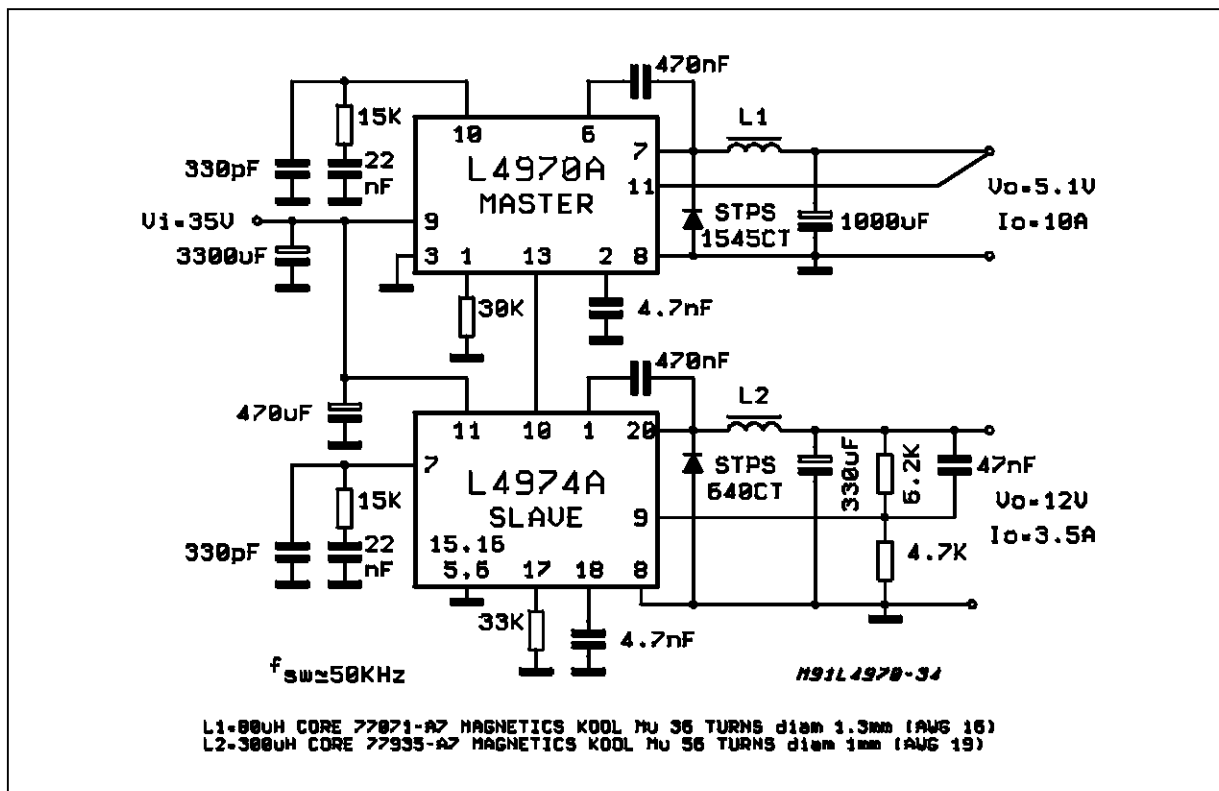


Figure 38 : A 5.1V/12V Multiple Supply. Note the Synchronization between the L4974A and L4970A.



L4974A

Figure 39 : L4974A's Sync. Example.

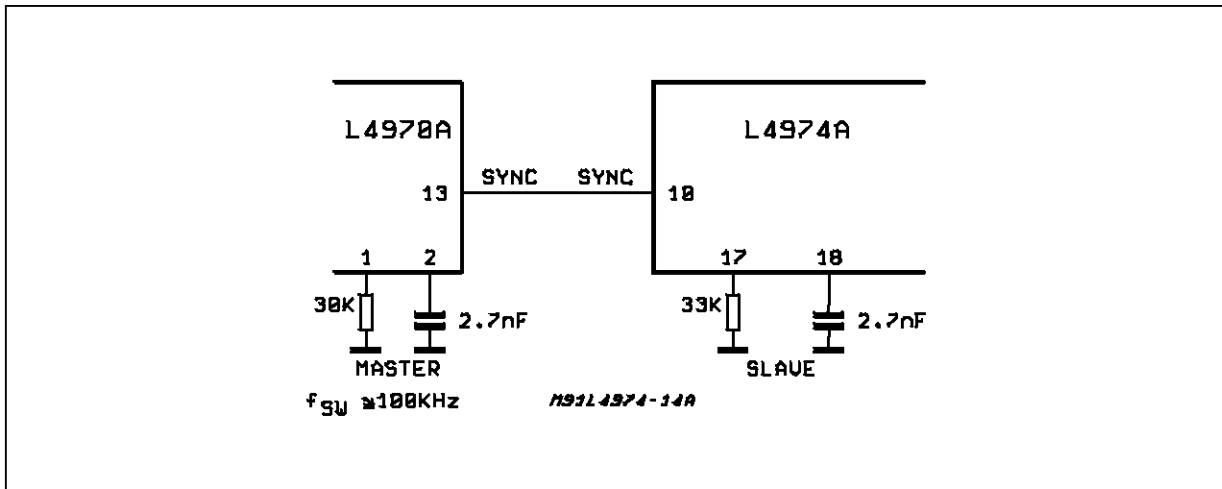
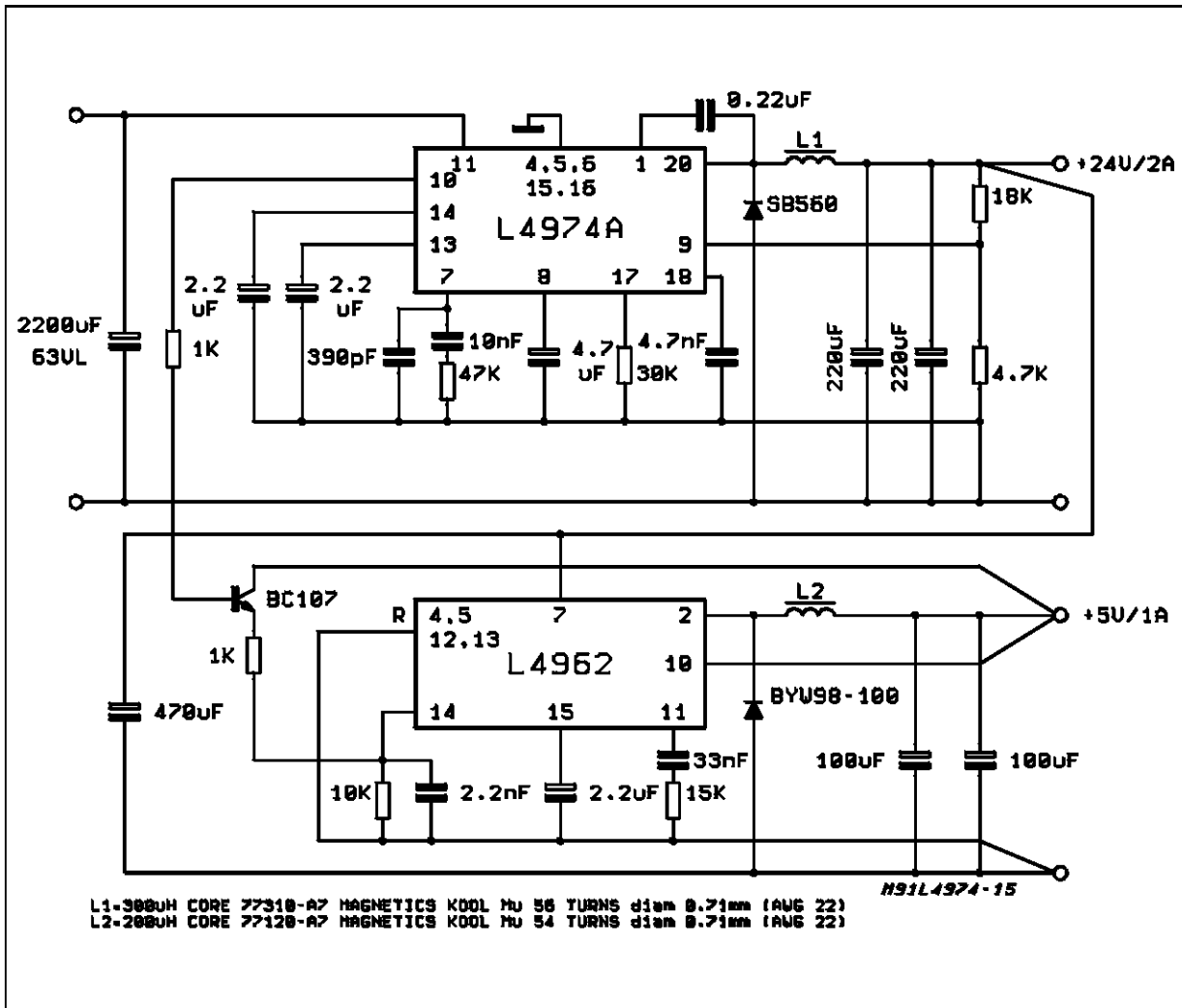
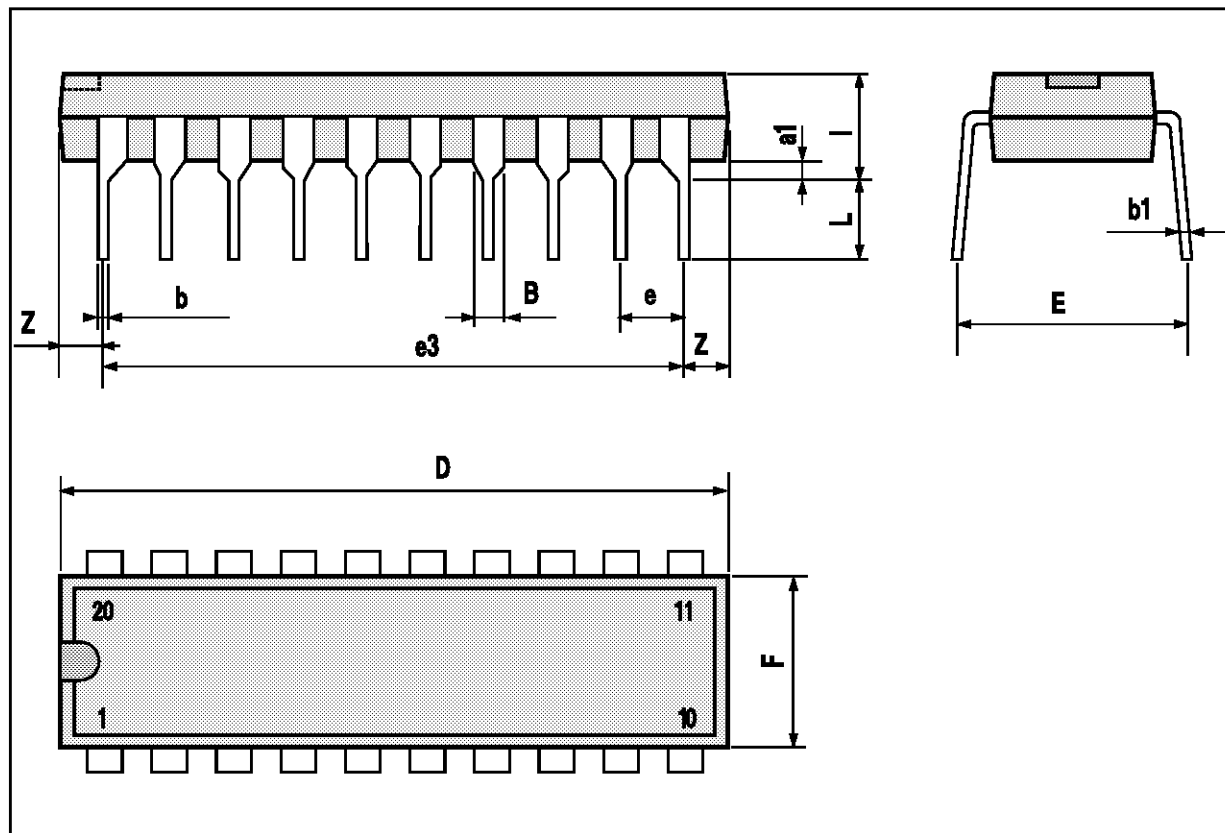


Figure 40: 1A/24V Multiple Supply. Note the synchronization between the L4974A and L4962



POWERDIP20 PACKAGE MECHANICAL DATA

| DIM. | mm | | | inch | | |
|------|------|-------|-------|-------|-------|-------|
| | MIN. | TYP. | MAX. | MIN. | TYP. | MAX. |
| a1 | 0.51 | | | 0.020 | | |
| B | 0.85 | | 1.40 | 0.033 | | 0.055 |
| b | | 0.50 | | | 0.020 | |
| b1 | 0.38 | | 0.50 | 0.015 | | 0.020 |
| D | | | 24.80 | | | 0.976 |
| E | | 8.80 | | | 0.346 | |
| e | | 2.54 | | | 0.100 | |
| e3 | | 22.86 | | | 0.900 | |
| F | | | 7.10 | | | 0.280 |
| I | | | 5.10 | | | 0.201 |
| L | | 3.30 | | | 0.130 | |
| Z | | | 1.27 | | | 0.050 |



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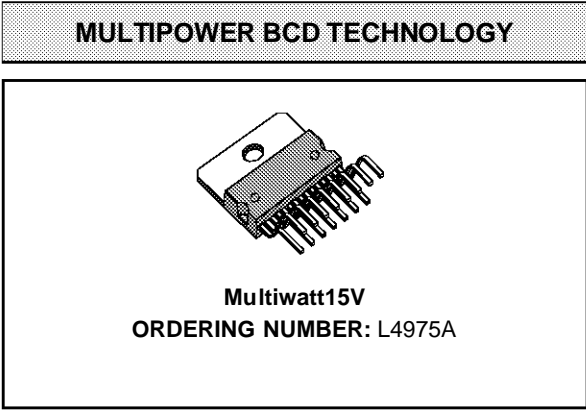
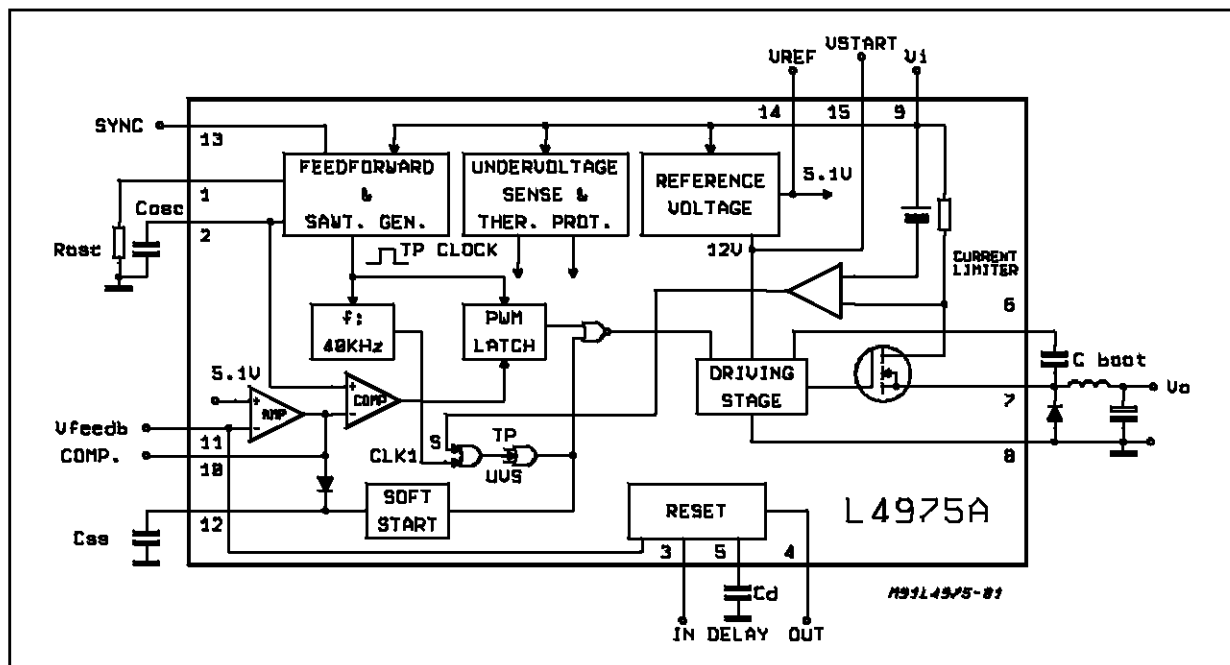
5A SWITCHING REGULATOR

- 5A OUTPUT CURRENT
- 5.1V TO 40V OUTPUT VOLTAGE RANGE
- 0 TO 90% DUTY CYCLE RANGE
- INTERNAL FEED-FORWARD LINE REGULATION
- INTERNAL CURRENT LIMITING
- PRECISE 5.1V ± 2% ON CHIP REFERENCE
- RESET AND POWER FAIL FUNCTIONS
- SOFT START
- INPUT/OUTPUT SYNC PIN
- UNDER VOLTAGE LOCK OUT WITH HYSTERETIC TURN-ON
- PWM LATCH FOR SINGLE PULSE PER PERIOD
- VERY HIGH EFFICIENCY
- SWITCHING FREQUENCY UP TO 500KHz
- THERMAL SHUTDOWN
- CONTINUOUS MODE OPERATION

DESCRIPTION

The L4975A is a stepdown monolithic power switching regulator delivering 5A at a voltage variable from 5.1 to 40V.

BLOCK DIAGRAM



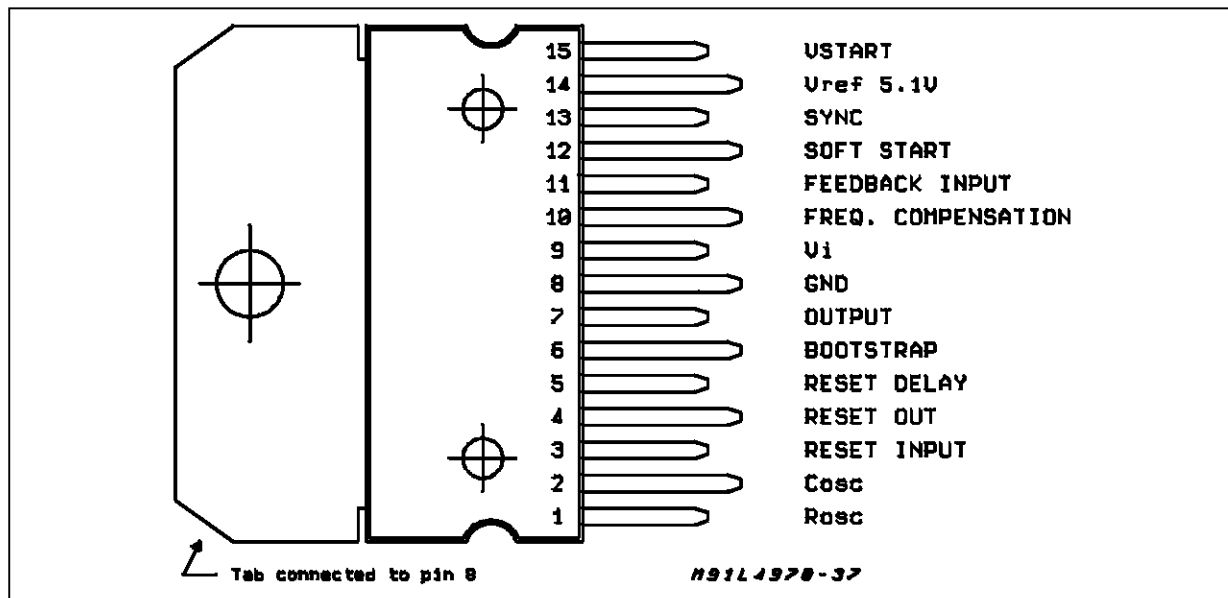
Realized with BCD mixed technology, the device uses a DMOS output transistor to obtain very high efficiency and very fast switching times. Features of the L4975A include reset and power fail for microprocessors, feed forward line regulation, soft start, limiting current and thermal protection. The device is mounted in a 15-lead multiwatt plastic power package and requires few external components. Efficient operation at switching frequencies up to 500KHz allows reduction in the size and cost of external filter components.

L4975A

ABSOLUTE MAXIMUM RATINGS

| Symbol | Parameter | Value | Unit |
|--|--|---------------------|------|
| V ₉ | Input Voltage | 55 | V |
| V ₉ | Input Operating Voltage | 50 | V |
| V ₇ | Output DC Voltage | -1 | V |
| | Output Peak Voltage at t = 0.1μs f = 200KHz | -7 | V |
| I ₇ | Maximum Output Current | Internally Limited | |
| V ₆ | Bootstrap Voltage | 65 | V |
| | Bootstrap Operating Voltage | V ₉ + 15 | V |
| V ₃ , V ₁₂ | Input Voltage at Pins 3, 12 | 12 | V |
| V ₄ | Reset Output Voltage | 50 | V |
| I ₄ | Reset Output Sink Current | 50 | mA |
| V ₅ , V ₁₀ , V ₁₁ , V ₁₃ | Input Voltage at Pin 5, 10, 11, 13 | 7 | V |
| I ₅ | Reset Delay Sink Current | 30 | mA |
| I ₁₀ | Error Amplifier Output Sink Current | 1 | A |
| I ₁₂ | Soft Start Sink Current | 30 | mA |
| P _{tot} | Total Power Dissipation at T _{case} < 120°C | 30 | W |
| T _j , T _{stg} | Junction and Storage Temperature | -40 to 150 | °C |

PIN CONNECTION (Top view)



THERMAL DATA

| Symbol | Parameter | Value | Unit |
|------------------------|-------------------------------------|-------|------|
| R _{th j-case} | Thermal Resistance Junction-case | 1 | °C/W |
| R _{th j-amb} | Thermal Resistance Junction-ambient | 35 | °C/W |

PIN FUNCTIONS

| N° | Name | Function |
|----|------------------------|---|
| 1 | OSCILLATOR | R_{osc} . External resistor connected to ground determines the constant charging current of C_{osc} . |
| 2 | OSCILLATOR | C_{osc} . External capacitor connected to ground determines (with R_{osc}) the switching frequency. |
| 3 | RESET INPUT | Input of Power Fail Circuit. The threshold is 5.1V. It may be connected via a divider to the input for power fail function. It must be connected to the pin 14 an external 30K Ω resistor when power fail signal not required. |
| 4 | RESET OUT | Open Collector Reset/power Fail Signal Output. This output is high when the supply and the output voltages are safe. |
| 5 | RESET DELAY | A C_d capacitor connected between this terminal and ground determines the reset signal delay time. |
| 6 | BOOTSTRAP | A C_{boot} capacitor connected between this terminal and the output allows to drive properly the internal D-MOS transistor. |
| 7 | OUTPUT | Regulator Output. |
| 8 | GROUND | Common Ground Terminal |
| 9 | SUPPLY VOLTAGE | Unregulated Input Voltage. |
| 10 | FREQUENCY COMPENSATION | A series RC network connected between this terminal and ground determines the regulation loop gain characteristics. |
| 11 | 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. |
| 12 | SOFT START | Soft Start Time Constant. A capacitor is connected between this terminal and ground to define the soft start time constant. |
| 13 | SYNC INPUT | Multiple L4975A are synchronized by connecting pin 13 inputs together or via an external syncr. pulse. |
| 14 | V_{ref} | 5.1V V_{ref} Device Reference Voltage. |
| 15 | V_{start} | Internal Start-up Circuit to Drive the Power Stage. |

CIRCUIT OPERATION (refer to the block diagram)

The L4975A is a 5A monolithic stepdown switching regulator working in continuous mode realized in the new BCD Technology. This technology allows the integration of isolated vertical DMOS power transistors plus mixed CMOS/Bipolar transistors.

The device can deliver 5A at an output voltage adjustable from 5.1V to 40V, and contains diagnostic and control functions that make it particularly suitable for microprocessor based systems.

BLOCK DIAGRAM

The block diagram shows the DMOS power transistor and the PWM control loop. Integrated functions include a reference voltage trimmed to $5.1V \pm 2\%$, soft start, undervoltage lockout, oscillator with feedforward control, pulse by pulse current limit, thermal shutdown and finally the reset and power fail circuit. The reset and power fail circuit provides an output signal for a microprocessor indicating the status of the system.

Device turn on is around 11V with a typical 1V hysteresis, this threshold provides a correct voltage for the driving stage of the DMOS gate and the hysteresis prevents instabilities.

An external bootstrap capacitor charged to 12V by an internal voltage reference is needed to provide correct gate drive to the power DMOS. The driving circuit is able to source and sink peak currents of around 0.5A to the gate of the DMOS transistor. A typical switching time of the current in the DMOS transistor is 50ns. Due to the fast commutation switching frequencies up to 500kHz are possible.

The PWM control loop consists of a sawtooth oscillator, error amplifier, comparator, latch and the output stage. An error signal is produced by comparing the output voltage with the precise $5.1V \pm 2\%$ on chip reference. This error signal is then compared with the sawtooth oscillator, in order to generate a fixed frequency pulse width modulated drive for the output stage. A PWM latch is included to eliminate multiple pulsing within a period even in noisy environments. The gain and

Figure 1: Feedforward Waveform

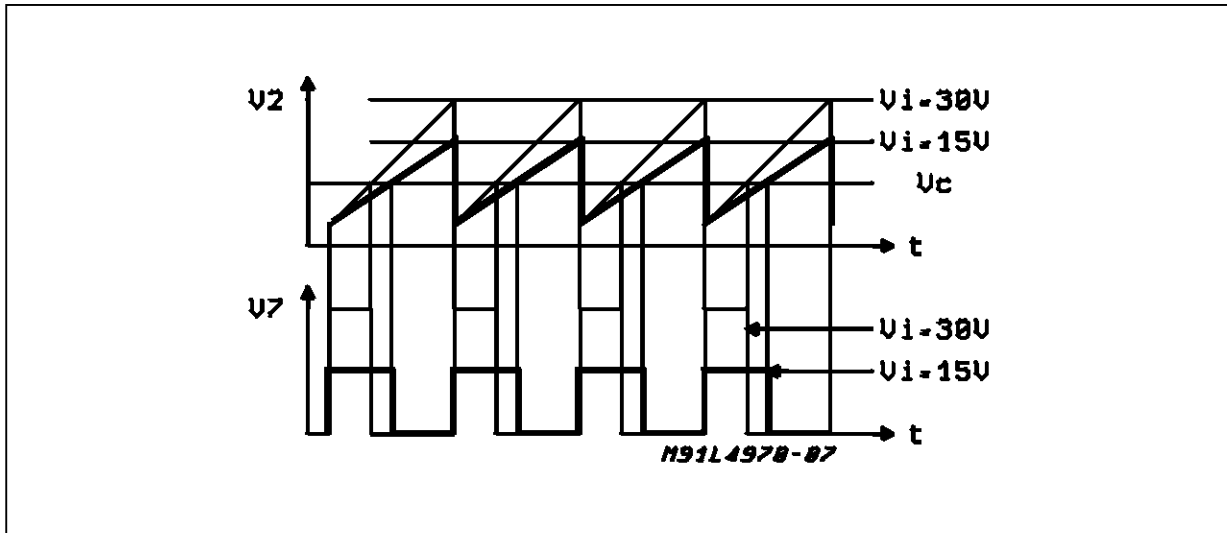


Figure 2: Soft Start Function

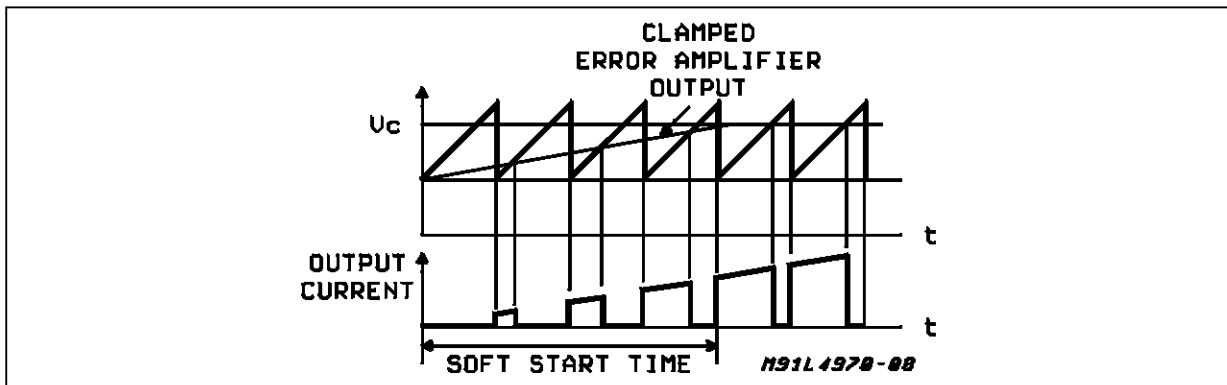
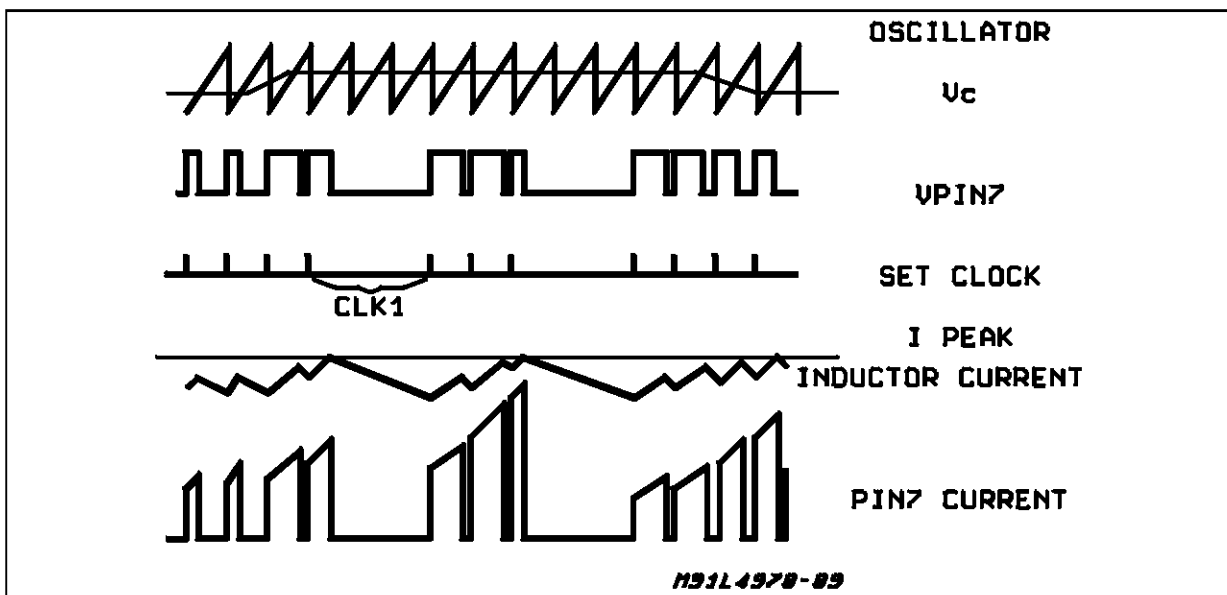


Figure 3: Limiting Current Function



stability of the loop can be adjusted by an external RC network connected to the output of the error amplifier. A voltage feedforward control has been added to the oscillator, this maintains superior line regulation over a wide input voltage range. Closing the loop directly gives an output voltage of 5.1V, higher voltages are obtained by inserting a voltage divider.

At turn on output overcurrents are prevented by the soft start function (fig. 2). The error amplifier is initially clamped by an external capacitor C_{ss} and allowed to rise linearly under the charge of an internal constant current source.

Output overload protection is provided by a current limit circuit (fig. 3). The load current is sensed by an internal metal resistor connected to a comparator. When the load current exceeds a preset threshold the output of the comparator sets a flip flop which turns off the power DMOS. The next clock pulse, from an internal 40kHz oscillator will reset the flip flop and the power DMOS will again conduct. This current protection method, ensures

a constant current output when the system is overloaded or short circuited and limits the switching frequency, in this condition, to 40kHz.

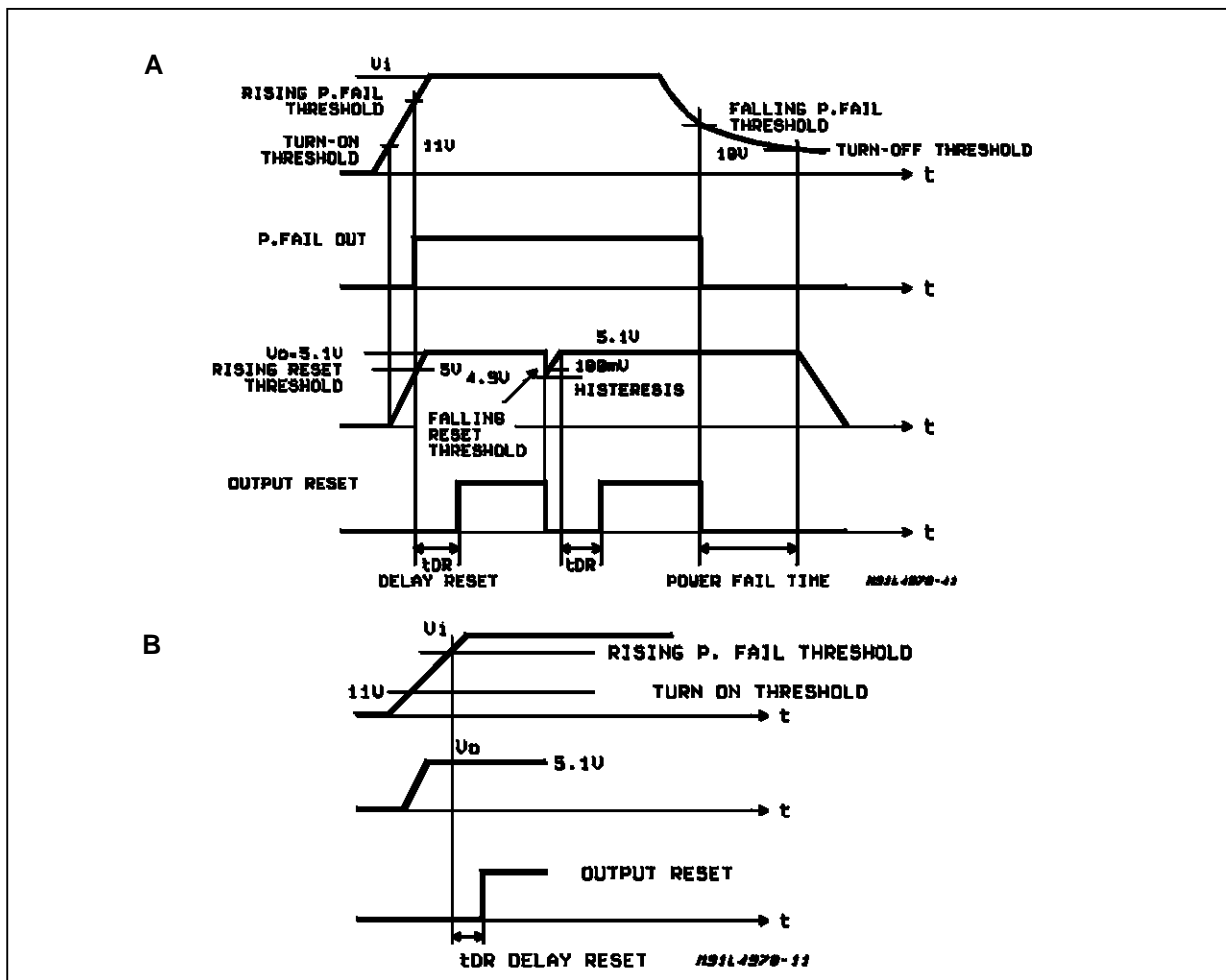
The Reset and Power fail circuitry (fig 4) generates an output signal when the supply voltage exceeds a threshold programmed by an external voltage divider. The reset signal, is generated with a delay time programmed by an external capacitor on the delay pin. When the supply voltage falls below the threshold or the output voltage goes below 5V the reset output goes low immediately. The reset output is an open collector-drain.

Fig 4A shows the case when the supply voltage is higher than the threshold, but the output voltage is not yet 5V.

Fig 4B shows the case when the output is 5.1V but the supply voltage is not yet higher than the fixed threshold.

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

Figure 4: Reset and Power Fail Functions.



L4975A

ELECTRICAL CHARACTERISTICS (Refer to the test circuit, $T_j = 25^\circ\text{C}$, $V_i = 35\text{V}$, $R_4 = 16\text{K}\Omega$, $C_9 = 2.2\text{nF}$, $f_{\text{SW}} = 200\text{KHz}$ typ, unless otherwise specified)

DYNAMIC CHARACTERISTICS

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|-------------------------------|--|---|------|-------------|------------|----------|------|
| V_i | input Voltage Range (pin 9) | $V_o = V_{\text{ref}}$ to 40V $I_o = 5\text{A}$ | 15 | | 50 | V | 5 |
| V_o | Output Voltage | $V_i = 15\text{V}$ to 50V $I_o = 3\text{A}$; $V_o = V_{\text{ref}}$ | 5 | 5.1 | 5.2 | V | 5 |
| ΔV_o | Line Regulation | $V_i = 15\text{V}$ to 50V $I_o = 2\text{A}$; $V_o = V_{\text{ref}}$ | | 12 | 30 | mV | 5 |
| ΔV_o | Load Regulation | $V_o = V_{\text{ref}}$ $I_o = 2\text{A}$ to 4A $I_o = 1\text{A}$ to 5A | | 10 20 | 30 50 | mV mV | 5 |
| V_d | Dropout Voltage Between Pin 9 and 7 | $I_o = 3\text{A}$ $I_o = 5\text{A}$ | | 0.4 0.55 | 0.6 0.8 | V V | 5 |
| I_{7L} | Max. Limiting Current | $V_i = 15$ to 50V $V_o = V_{\text{ref}}$ to 40V | 5.5 | 6.5 | 7.5 | A | 5 |
| η | Efficiency | $I_o = 3\text{A}$ $V_o = V_{\text{ref}}$ $V_o = 12\text{V}$ | 70 | 75 80 | | % % | 5 |
| | | $I_o = 5\text{A}$ $V_o = V_{\text{ref}}$ $V_o = 12\text{V}$ | 80 | 85 92 | | % % | 5 |
| SVR | Supply Voltage Ripple Reject. | $V_i = 2\text{VRMS}$; $I_o = 3\text{A}$ $f = 100\text{Hz}$; $V_o = V_{\text{ref}}$ | 56 | 60 | | dB | 5 |
| f | Switching Frequency | | 180 | 200 | 220 | KHz | 5 |
| $\frac{\Delta f}{\Delta V_i}$ | Voltage Stability of Switching Frequency | $V_i = 15\text{V}$ to 45V | | 2 | 6 | % | 5 |
| $\frac{\Delta f}{T_j}$ | Temperature Stability of Switching Frequency | $T_j = 0$ to 125°C | | 1 | | % | 5 |
| f_{max} | Maximum Operating Switching Frequency | $V_o = V_{\text{ref}}$; $R_4 = 10\text{K}\Omega$ $I_o = 5\text{A}$; $C_9 = 1\text{nF}$ | 500 | | | KHz | 5 |

V_{ref} SECTION (pin 14)

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|----------------------------------|---|--|------|------|------|----------------------|------|
| V_{14} | Reference Voltage | | 5 | 5.1 | 5.2 | V | 7 |
| ΔV_{14} | Line Regulation | $V_i = 15\text{V}$ to 50V | | 10 | 25 | mV | 7 |
| ΔV_{14} | Load Regulation | $I_{14} = 0$ to 1mA | | 20 | 40 | mV | 7 |
| $\frac{\Delta V_{14}}{\Delta T}$ | Average Temperature Coefficient Reference Voltage | $T_j = 0^\circ\text{C}$ to 125°C | | 0.4 | | mV/ $^\circ\text{C}$ | 7 |
| $I_{14 \text{ short}}$ | Short Circuit Current Limit | $V_{14} = 0$ | | 70 | | mA | 7 |

V_{START} SECTION (pin 15)

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|------------------------|-----------------------------|----------------------|------|------|------|------|------|
| V_{15} | Reference Voltage | | 11.4 | 12 | 12.6 | V | 7 |
| ΔV_{15} | Line Regulation | $V_i = 15$ to 50V | | 0.6 | 1.4 | V | 7 |
| ΔV_{15} | Load Regulation | $I_{15} = 0$ to 1mA | | 50 | 200 | mV | 7 |
| $I_{15 \text{ short}}$ | Short Circuit Current Limit | $V_{15} = 0\text{V}$ | | 80 | | mA | 7 |

ELECTRICAL CHARACTERISTICS (continued)**DC CHARACTERISTICS**

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|-------------|--------------------------|---------------------------------------|------|------|------|------|------|
| V_{9on} | Turn-on Threshold | | 10 | 11 | 12 | V | 7A |
| V_{9Hyst} | Turn-off Hysteresys | | | 1 | | V | 7A |
| I_{9Q} | Quiescent Current | $V_{12} = 0$; $S1 = D$ | | 13 | 19 | mA | 7A |
| I_{9OQ} | Operating Supply Current | $V_{12} = 0$; $S1 = C$; $S2 = B$ | | 16 | 23 | mA | 7A |
| I_{7L} | Out Leak Current | $V_i = 55V$; $S3 = A$; $V_{12} = 0$ | | | 2 | mA | 7A |

SOFT START

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|----------|---------------------------|-----------------------------------|------|------|------|---------|------|
| I_{12} | Soft Start Source Current | $V_{12} = 3V$; $V_{11} = 0V$ | 70 | 100 | 130 | μA | 7B |
| V_{12} | Output Saturation Voltage | $I_{12} = 20mA$; $V_9 = 10V$ | | | 1 | V | 7B |
| | | $I_{12} = 200\mu A$; $V_9 = 10V$ | | | 0.7 | V | 7B |

ERROR AMPLIFIER

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|-----------|--------------------------|--|------|------|------|---------|------|
| V_{10H} | High Level Out Voltage | $I_{10} = -100\mu A$; $S1 = C$ $V_{11} = 4.7V$ | 6 | | | V | 7C |
| V_{10L} | Low Level Out Voltage | $I_{10} = +100\mu A$; $S1 = C$ $V_{11} = 5.3V$; | | | 1.2 | V | 7C |
| I_{10H} | Source Output Current | $V_{10} = 1V$; $S1 = E$ $V_{11} = 4.7V$ | 100 | 150 | | μA | 7C |
| I_{10L} | Sink Output Current | $V_{10} = 6V$; $S1 = D$ $V_{11} = 5.3V$ | 100 | 150 | | μA | 7C |
| I_{11} | Input Bias Current | $R_S = 10K\Omega$ | | 0.4 | 3 | μA | – |
| G_V | DC Open Loop Gain | $V_{VCM} = 4V$; $R_S = 10\Omega$ | 60 | | | dB | – |
| SVR | Supply Voltage Rejection | $15 < V_i < 50V$; $R_S = 10\Omega$ | 60 | 80 | | dB | – |
| V_{OS} | Input Offset Voltage | $R_S = 50\Omega$ | | 2 | 10 | mV | – |

RAMP GENERATOR (pin 2)

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|--------|-------------------|-----------------------------|------|------|------|---------|------|
| V_2 | Ramp Valley | $S1 = C$; $S2 = B$ | 1.2 | 1.5 | | V | 7A |
| V_2 | Ramp Peak | $S1 = C$ $V_i = 15V$ | | 2.5 | | V | 7A |
| | | $S2 = B$ $V_i = 45V$ | | 5.5 | | V | 7A |
| I_2 | Min. Ramp Current | $S1 = A$; $I_1 = 100\mu A$ | | 270 | 300 | μA | 7A |
| I_2 | Max. Ramp Current | $S1 = A$; $I_1 = 1mA$ | 2.4 | 2.7 | | mA | 7A |

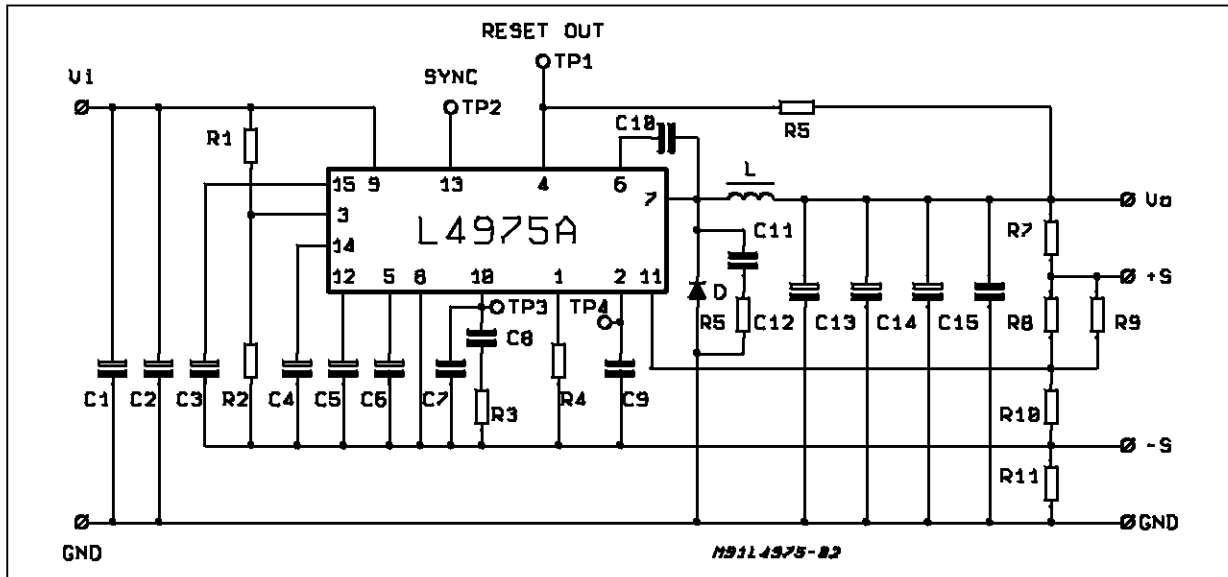
SYNC FUNCTION (pin 13)

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|-----------|---|---|------|------|------|---------|------|
| V_{13} | Low Input Voltage | $V_i = 15V$ to $50V$; $V_{12} = 0$; $S1 = C$; $S2 = B$; $S4 = B$ | -0.3 | | 0.9 | V | 7A |
| V_{13} | High Input voltage | $V_{12} = 0$; $S1 = C$; $S2 = B$; $S4 = B$ | 3.5 | | 5.5 | V | 7A |
| I_{13L} | Sync Input Current with Low Input Voltage | $V_2 = V_{13} = 0.9V$; $S4 = A$; $S1 = C$; $S2 = B$ | | | 0.4 | mA | 7A |
| I_{13H} | Input Current with High Input Voltage | $V_{13} = 3.5V$; $S4 = A$; $S1 = C$; $S2 = B$ | | | 1.5 | mA | 7A |
| V_{13} | Output Amplitude | | 4 | 5 | | V | – |
| t_W | Output Pulse Width | $V_{thr} = 2.5V$ | 0.3 | 0.5 | 0.8 | μs | – |

ELECTRICAL CHARACTERISTICS (continued)
RESET AND POWER FAIL FUNCTIONS

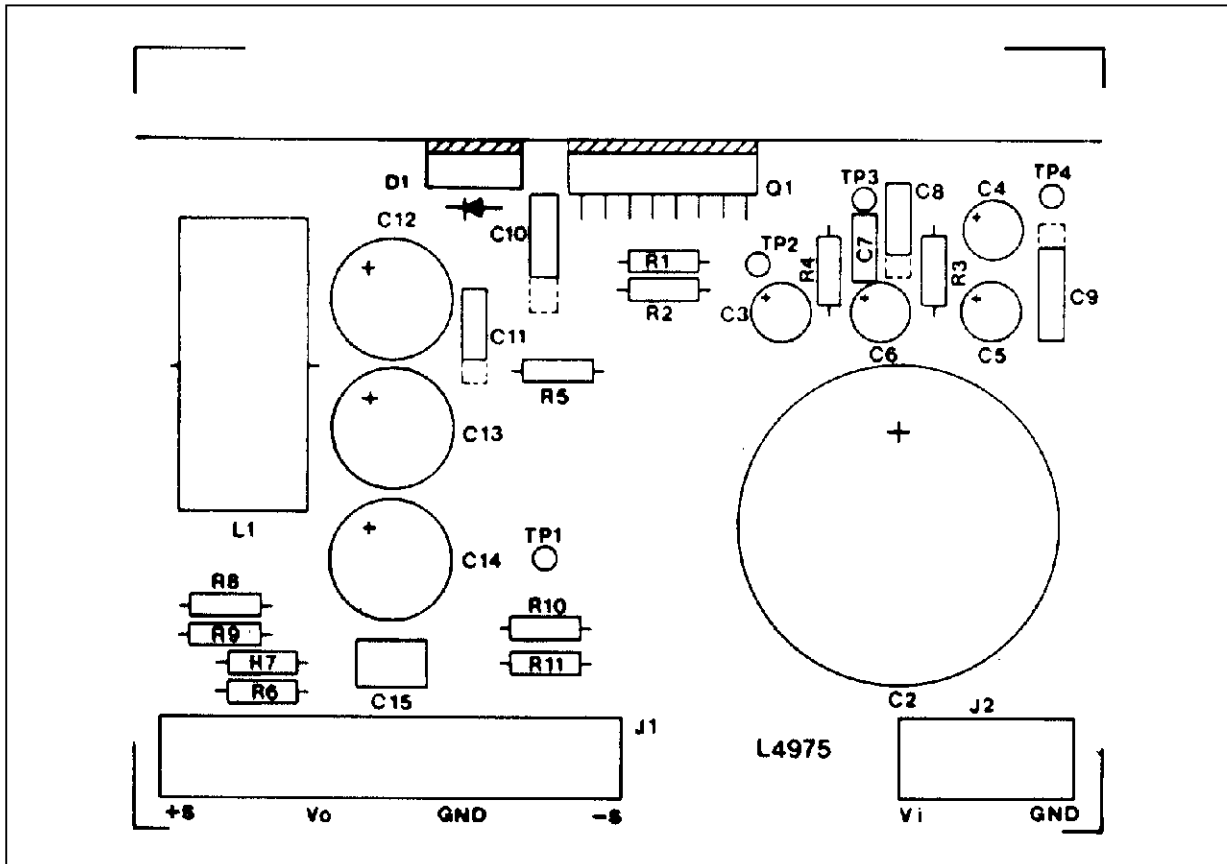
| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|-------------------|------------------------------------|---|--------------------------|--------------------------|--------------------------|---------|------|
| V _{11R} | Rising Threshold Voltage (pin 11) | V _i = 15 to 50V V ₃ = 5.3V | V _{ref} -120 | V _{ref} -100 | V _{ref} -80 | V mV | 7D |
| V _{11F} | Falling Threshold Voltage (pin 11) | V _i = 15 to 50V V ₃ = 5.3V | 4.77 | V _{ref} -200 | V _{ref} -160 | V mV | 7D |
| V _{5H} | Delay High Threshold Voltage | V _i = 15 to 50V V ₁₁ = V ₁₄ | 4.95 | 5.1 | 5.25 | V | 7D |
| V _{5L} | Delay Low Threshold Voltage | V _i = 15 to 50V V ₁₁ = V ₁₄ V ₃ = 5.3V | 1 | 1.1 | 1.2 | V | 7D |
| -I _{SSO} | Delay Source Current | V ₃ = 5.3V; V ₅ = 3V | 40 | 60 | 80 | μA | 7D |
| I _{SSI} | Delay Sink Current | V ₃ = 4.7V; V ₅ = 3V | 10 | | | mA | 7D |
| V _{4S} | Out Saturation Voltage | I ₄ = 15mA; S1 = B V ₃ = 4.7V | | | 0.4 | V | 7D |
| I ₄ | Output Leak Current | V ₄ = 50V; S1 = A V ₃ = 5.3V | | | 100 | μA | 7D |
| V _{3R} | Rising Threshold Voltage | V ₁₁ = V ₁₄ | 4.95 | 5.1 | 5.25 | V | 7D |
| V _{3H} | Hysteresis | | 0.4 | 0.5 | 0.6 | V | 7D |
| I ₃ | Input Bias Current | | | 1 | 3 | μA | 7D |

Figure 5: Test and Evaluation Board Circuit



TYPICAL PERFORMANCES (using evaluation board) :
 $\eta = 83\%$ ($V_i = 35V$; $V_o = V_{REF}$; $I_o = 5A$; $f_{sw} = 200KHz$)
 V_o RIPPLE = 30mV (at 5A) with output filter capacitor ESR $\leq 60m\Omega$
 Line regulation = 5mV ($V_i = 15$ to 50V)
 Load regulation = 15mV ($I_o = 2$ to 5A)
 For component values, refer to test circuit part list.

Figure 6a: P.C. Board (components side) and Components Layout of Figure 5 (1:1 scale).



PARTS LIST

| | |
|--|--|
| R ₁ = 30KΩ | C ₁ , C ₂ = 3300μF 63V _L EYF (ROE) |
| R ₂ = 10KΩ | C ₃ , C ₄ , C ₅ , C ₆ = 2.2μF |
| R ₃ = 15KΩ | C ₇ = 390pF Film |
| R ₄ = 16KΩ | C ₈ = 22nF MKT 1817 (ERO) |
| R ₅ = 22Ω 0,5W | |
| R ₆ = 4K7 | C ₉ = 2.2nF KP1830 |
| R ₇ = 10Ω | C ₁₀ = 220nF MKT |
| R ₈ = see tab. A | C ₁₁ = 2.2nF MP1830 |
| R ₉ = OPTION | **C ₁₂ , C ₁₃ , C ₁₄ = 220μF 40V _L EKR |
| R ₁₀ = 4K7 | C ₁₅ = 1μF Film |
| R ₁₁ = 10Ω | |
| D1 = MBR 760CT (or 7.5A/60V or equivalent) | |
| L1 = 80μH | core 58930 MAGNETICS 24 TURNS Ø 1.1mm (AWG 17) COGEMA 949178 |

* 2 capacitors in parallel to increase input RMS current capability
 ** 3 capacitors in parallel to reduce total output ESR

Table A

| V ₀ | R ₉ | R ₇ |
|----------------|----------------|----------------|
| 12V | 4.7kΩ | 6.2kΩ |
| 15V | 4.7kΩ | 9.1kΩ |
| 18V | 4.7kΩ | 12kΩ |
| 24V | 4.7kΩ | 18kΩ |

Table B
 SUGGESTED BOOTSTRAP CAPACITORS

| Operating Frequency | Bootstrap Cap.c10 |
|---------------------|-------------------|
| f = 20KHz | ≥680nF |
| f = 50KHz | ≥470nF |
| f = 100KHz | ≥330nF |
| f = 200KHz | ≥220nF |
| f = 500KHz | ≥100nF |

Figure 6b: P.C. Board (Back side) and Components Layout of the Circuit of Fig. 5. (1:1 scale)

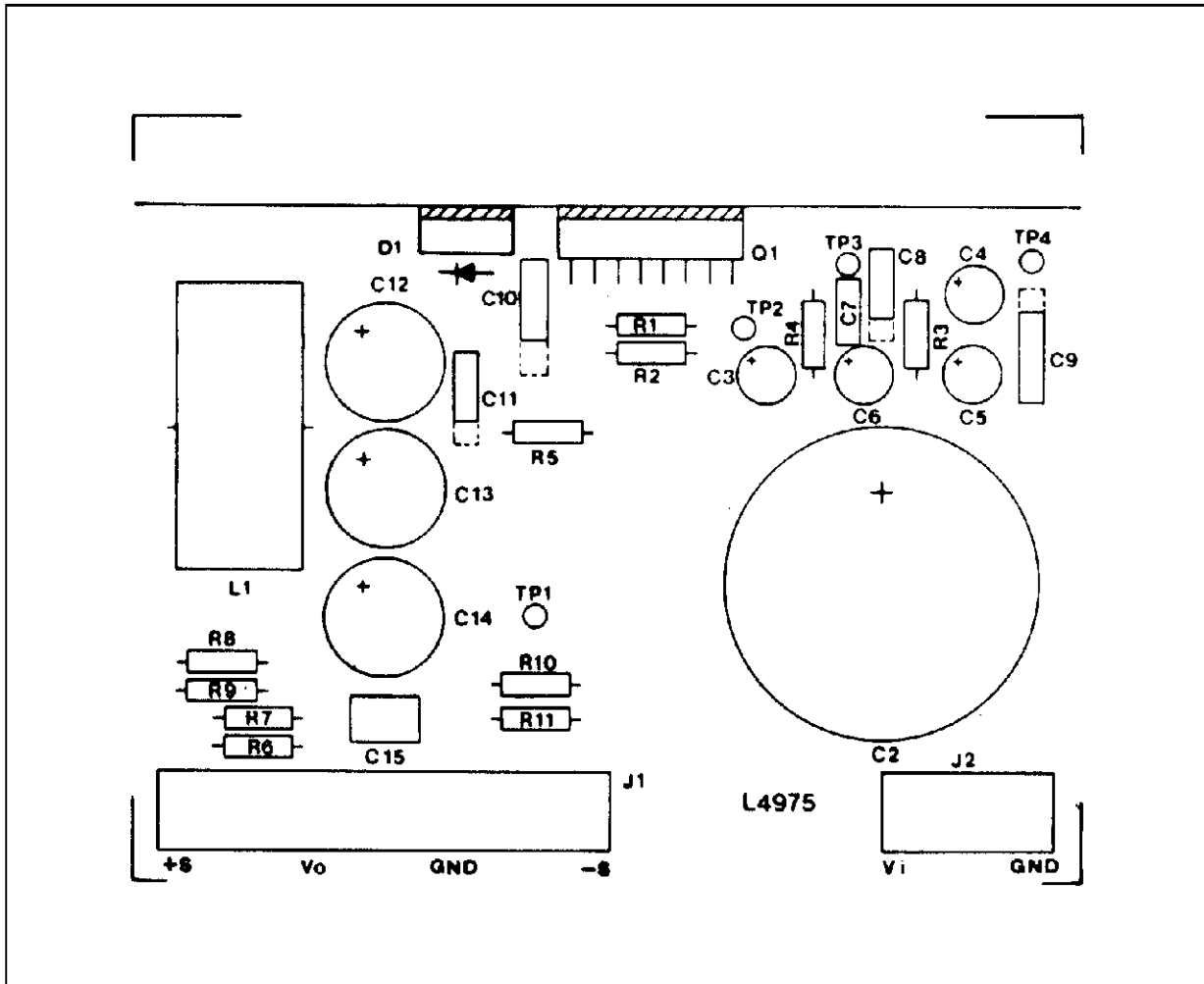


Figure 7: DC Test Circuits

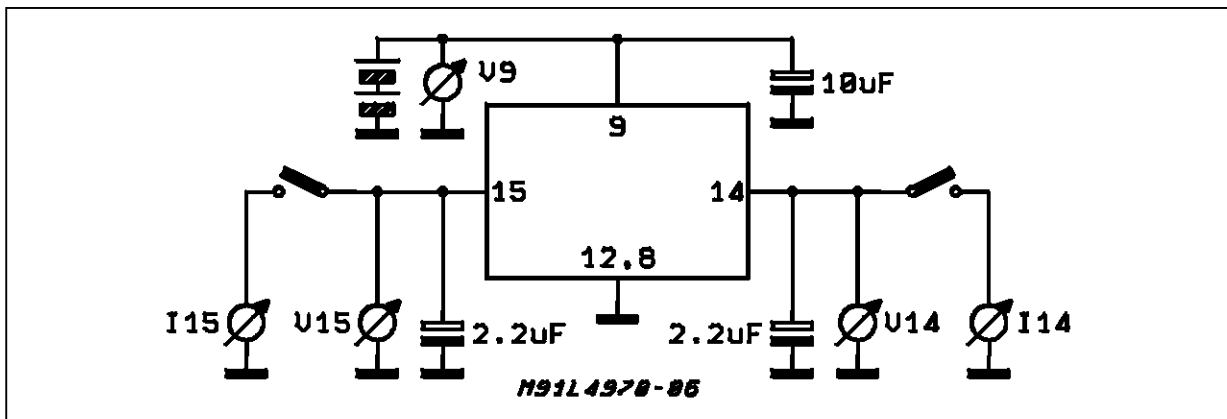


Figure 7A

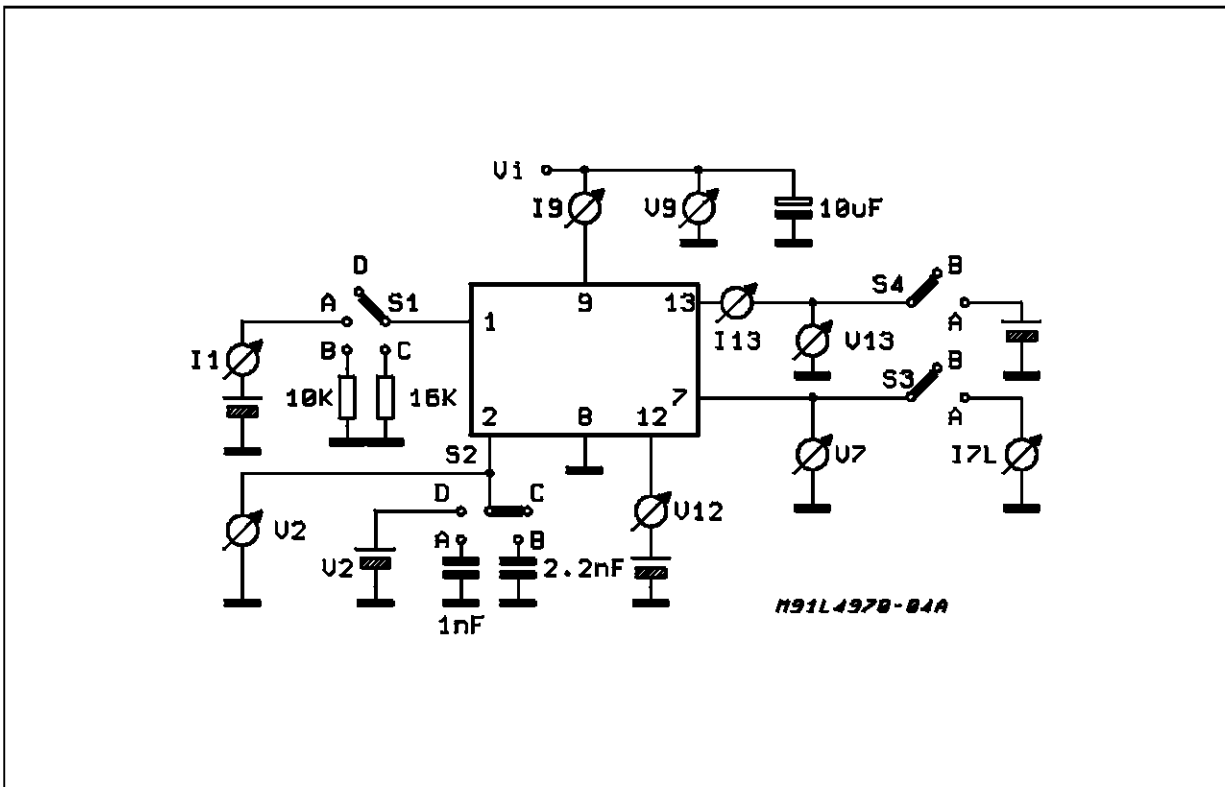


Figure 7B

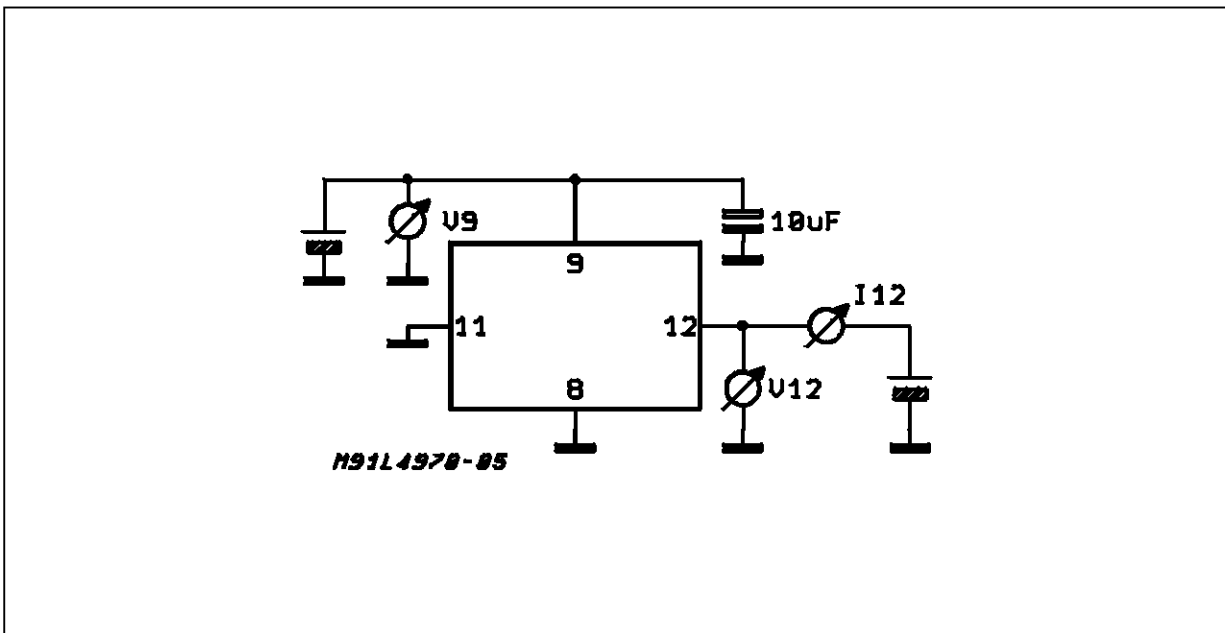


Figure 7D

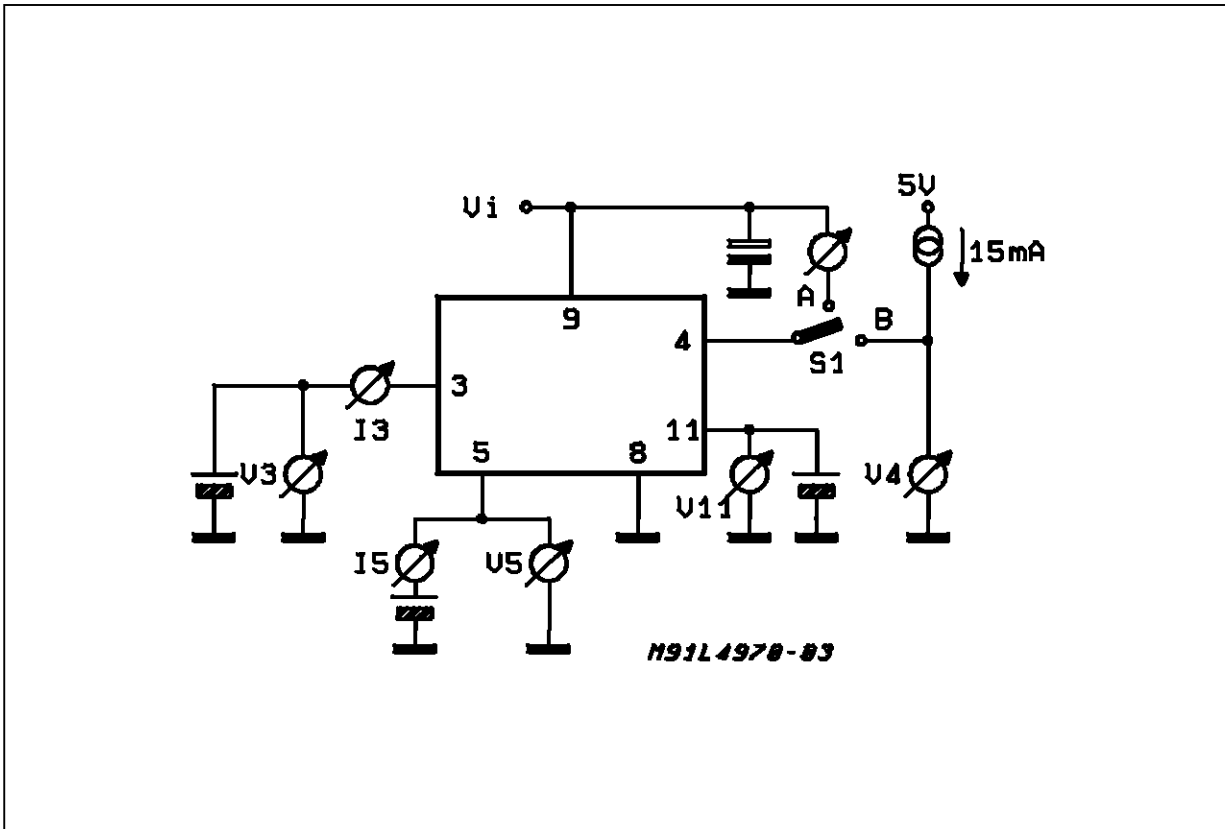


Figure 7C

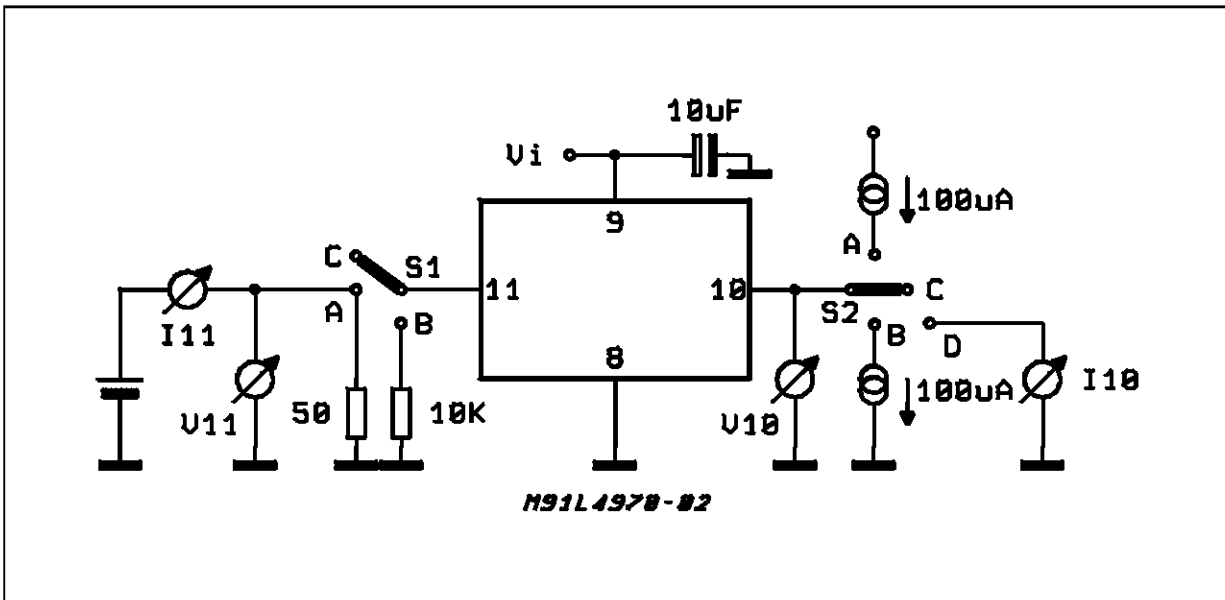


Figure 8: Quiescent Drain Current vs. Supply Voltage (0% duty cycle - see fig. 7A).

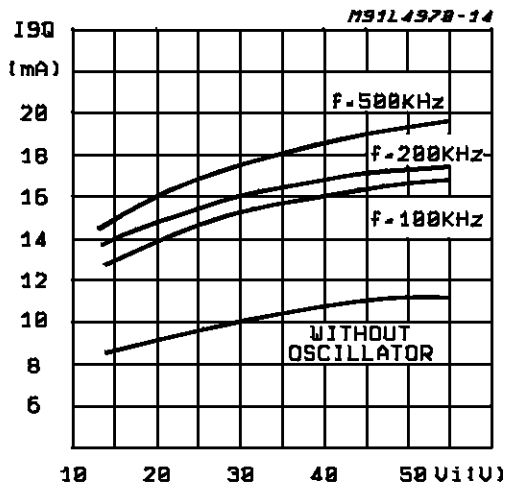


Figure 9: Quiescent Drain Current vs. Junction Temperature (0% duty cycle).

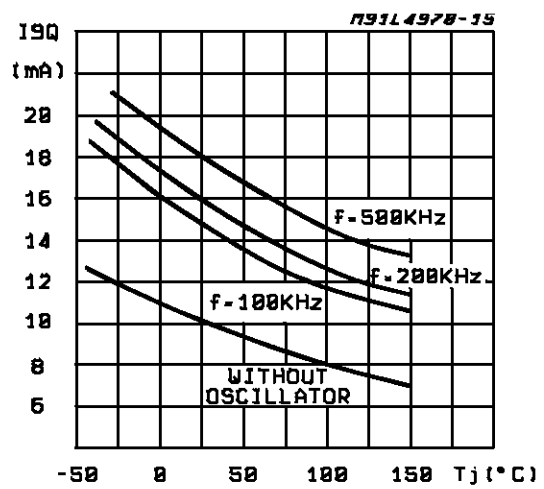


Figure 10: Quiescent Drain Current vs. Duty Cycle

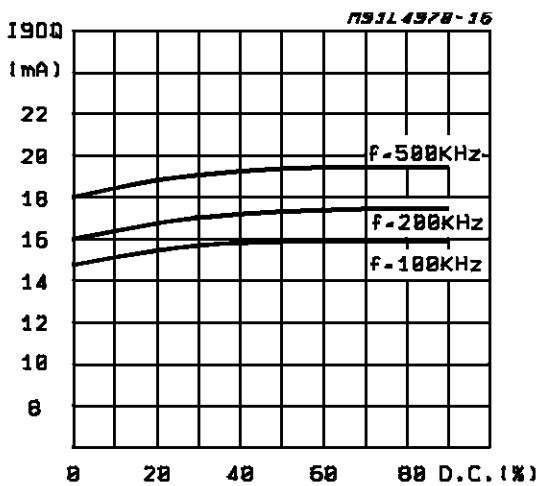


Figure 11: Reference Voltage (pin14) vs. V_i (see fig. 7)

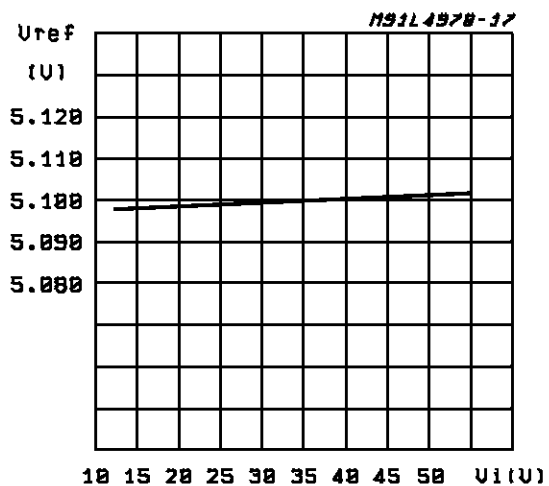


Figure 12: Reference Voltage (pin 14) vs. Junction Temperature (see fig. 7)

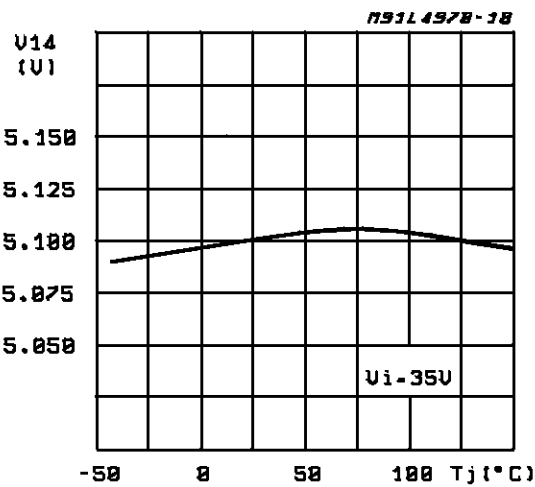


Figure 13: Reference Voltage (pin15) vs. V_i (see fig. 7)

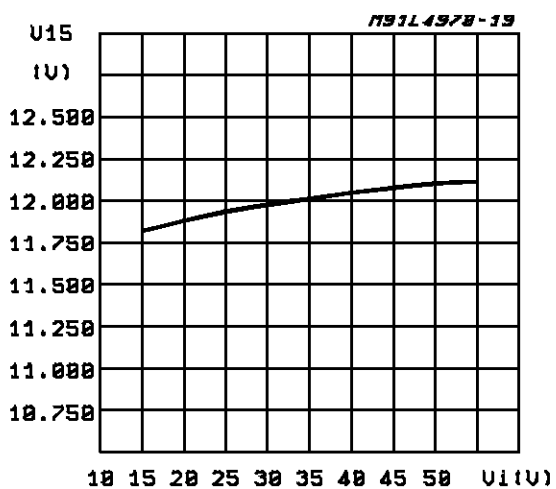


Figure 14: Reference Voltage (pin 15) vs. Junction Temperature (see fig. 7)

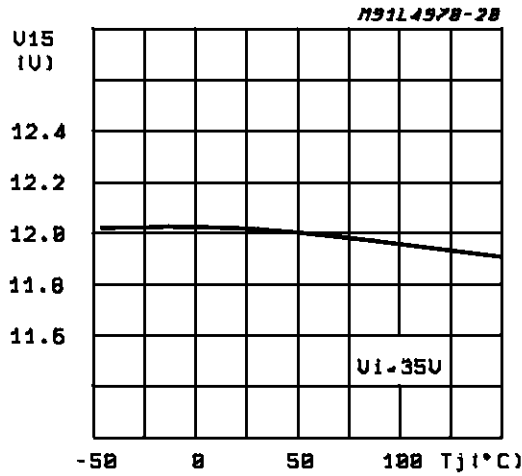


Figure 15: Reference Voltage 5.1V (pin 14) Supply Voltage Ripple Rejection vs. Frequency

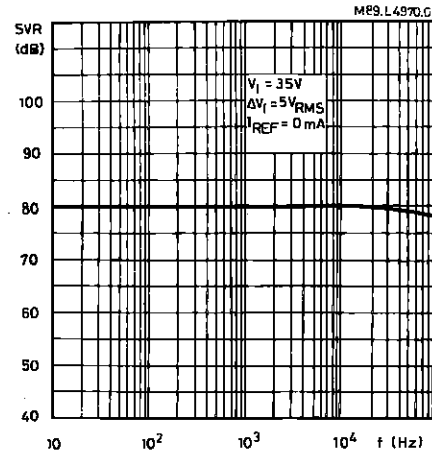


Figure 16: Switching Frequency vs. Input Voltage (see fig. 5)

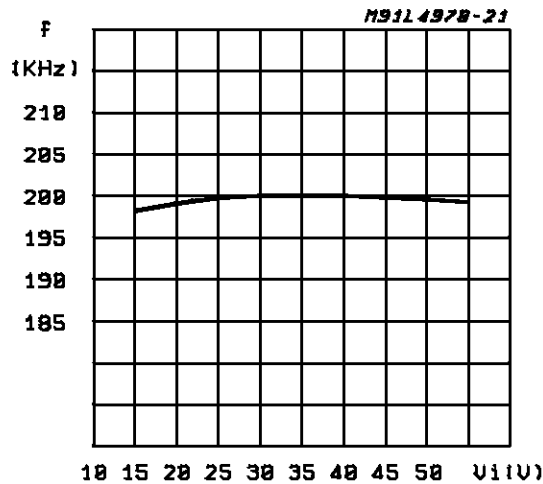


Figure 17: Switching Frequency vs. Junction Temperature (see fig. 5)

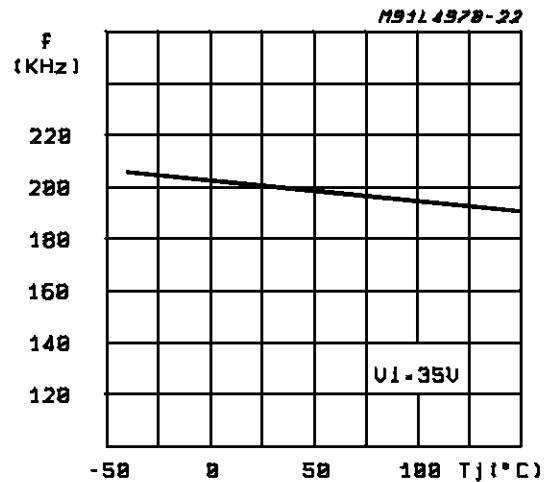


Figure 18: Switching Frequency vs. R4 (see fig. 5)

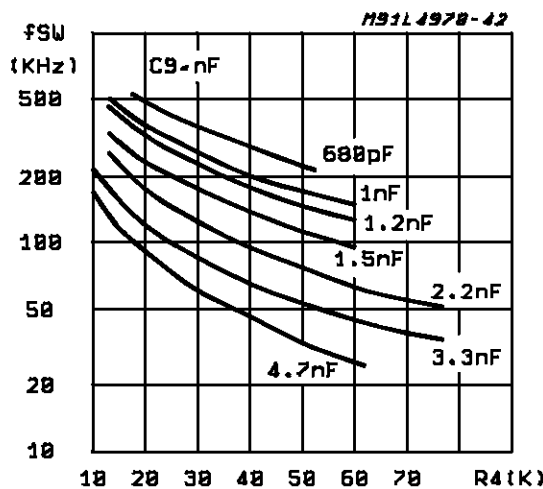


Figure 19: Max. Duty Cycle vs. Frequency

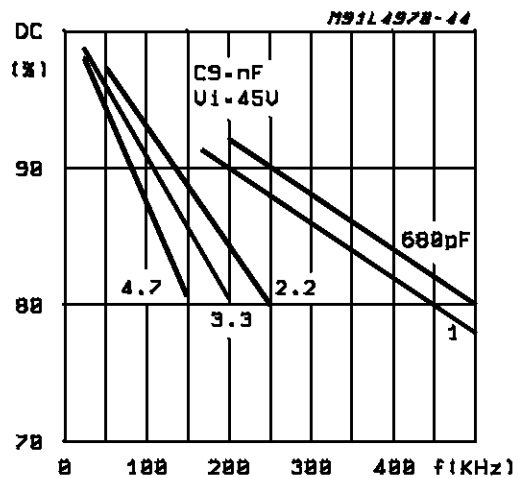


Figure 20: Supply Voltage Ripple Rejection vs. Frequency (see fig. 5)

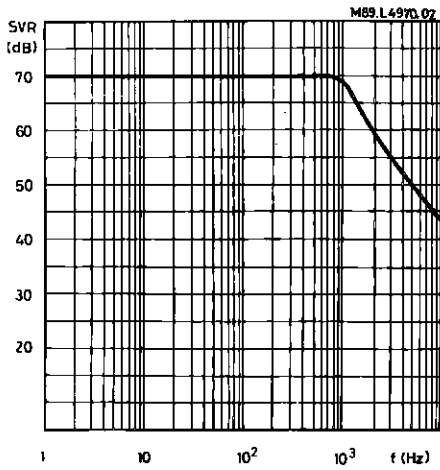


Figure 21: Line Transient Response (see fig. 5)

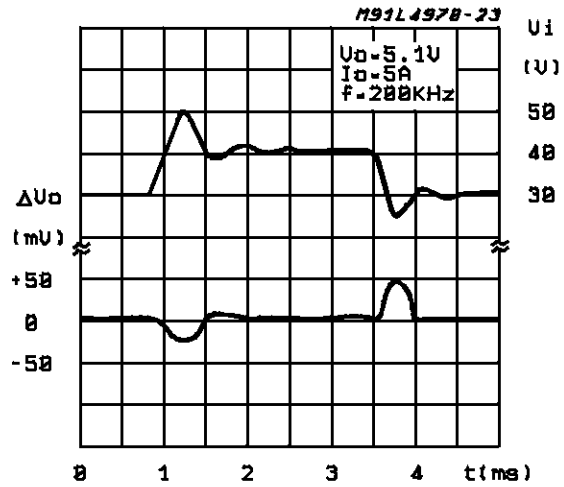


Figure 22: Load Transient Response (see fig. 5)

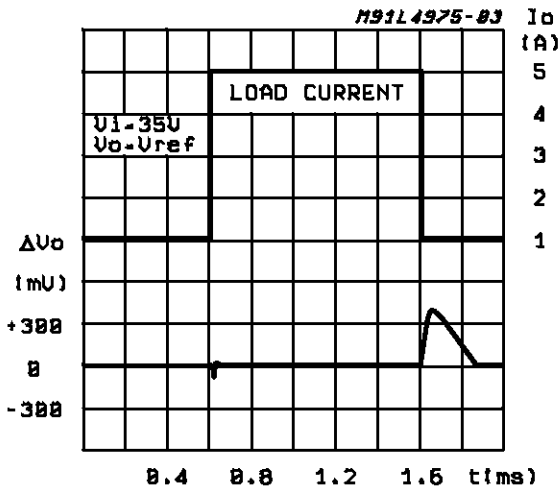


Figure 23: Dropout Voltage Between Pin 9 and Pin 7 vs. Current at Pin 7

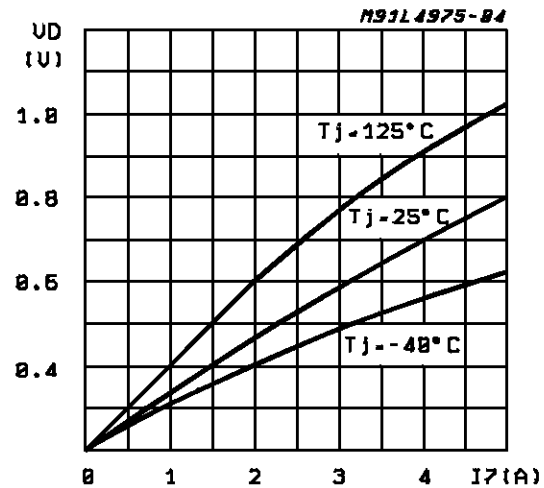


Figure 24: Dropout Voltage Between Pin 9 and Pin 7 vs. Junction Temperature

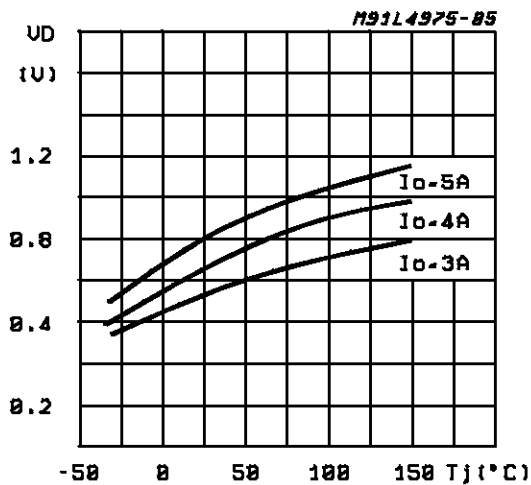


Figure 25: Power Dissipation (device only) vs. Input Voltage

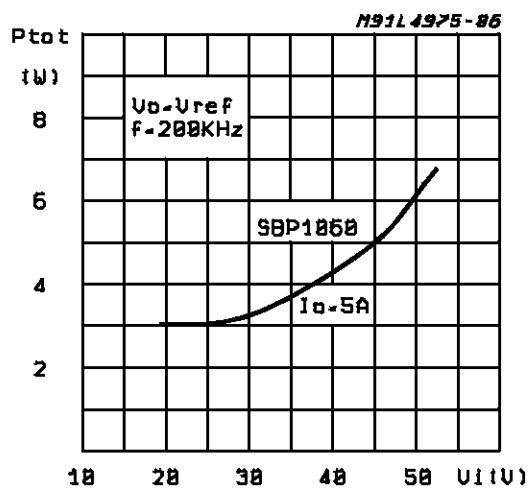


Figure 26: Power Dissipation (device only) vs. Output Voltage

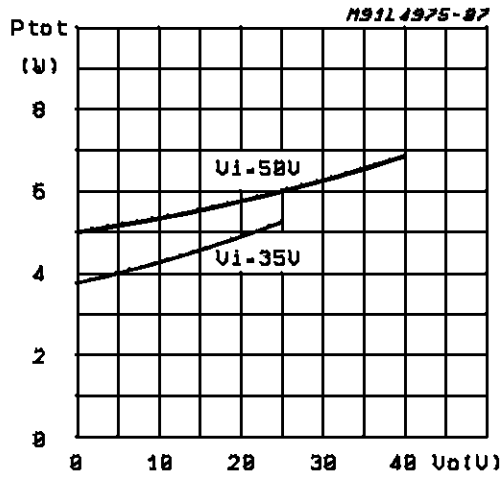


Figure 28: Efficiency vs. Output Current

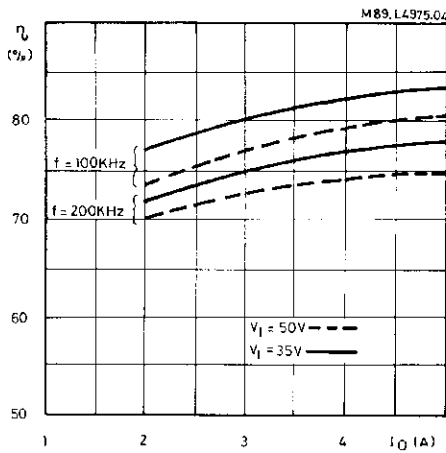


Figure 30: Efficiency vs. Output Voltage

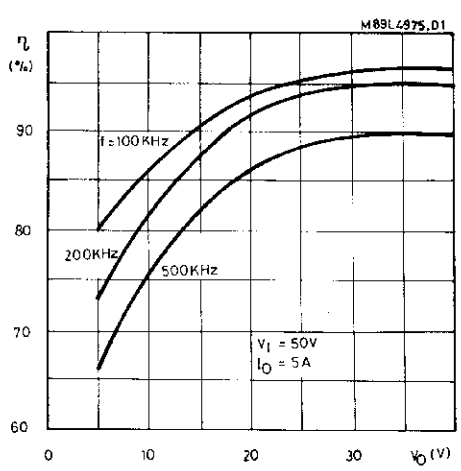


Figure 27: Heatsink Used to Derive the Device's Power Dissipation

$$R_{th} - \text{Heatsink} = \frac{T_{case} - T_{amb}}{P_d}$$

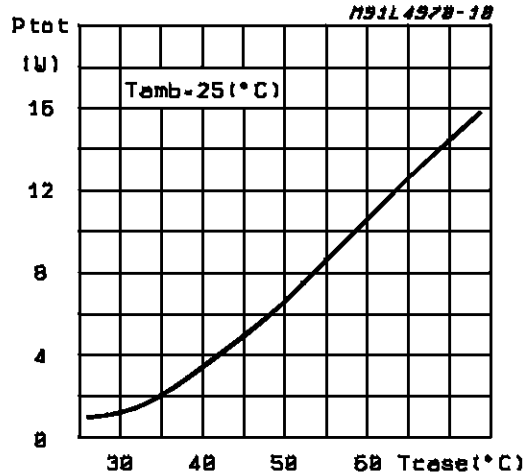


Figure 29: Efficiency vs. Output Voltage

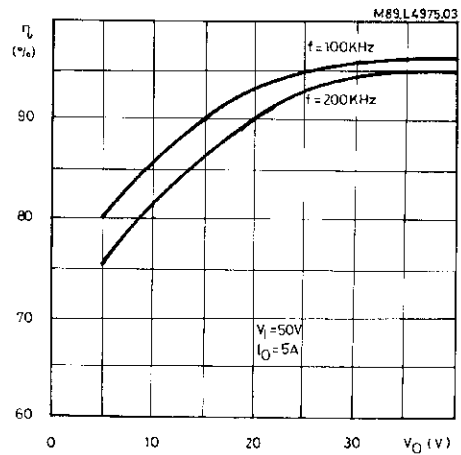


Figure 31: Open Loop Frequency and Phase Response of Error Amplifier (see fig.7C)

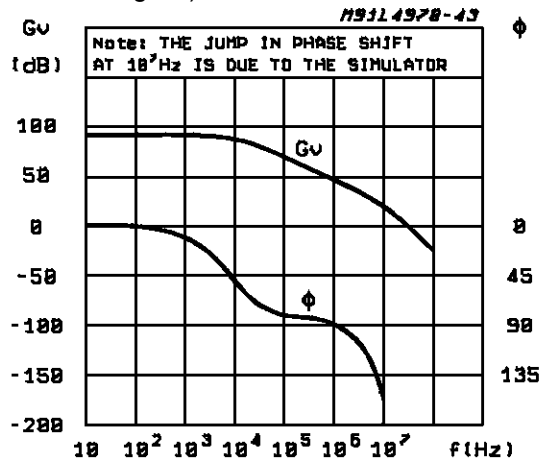


Figure 32: Power Dissipation Derating Curve

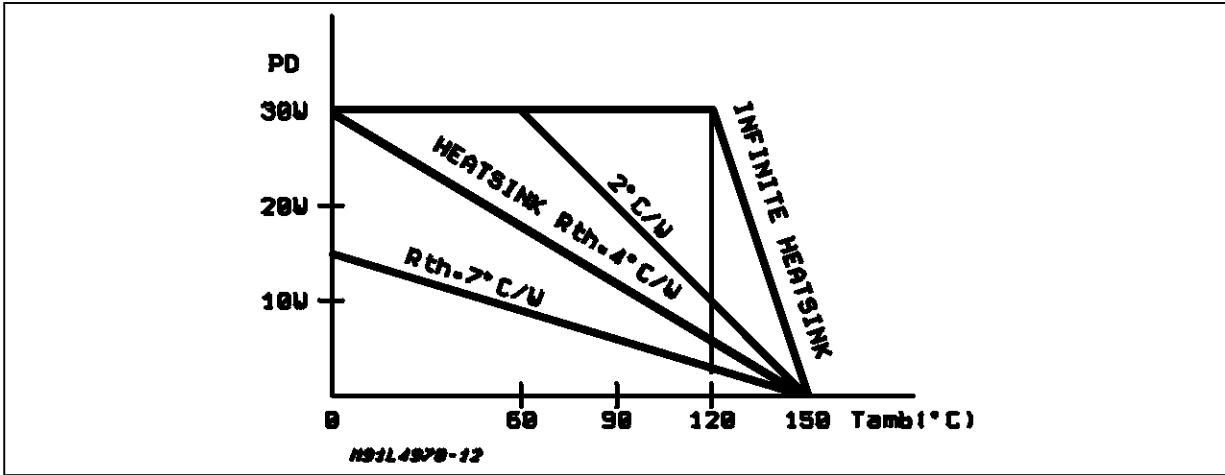
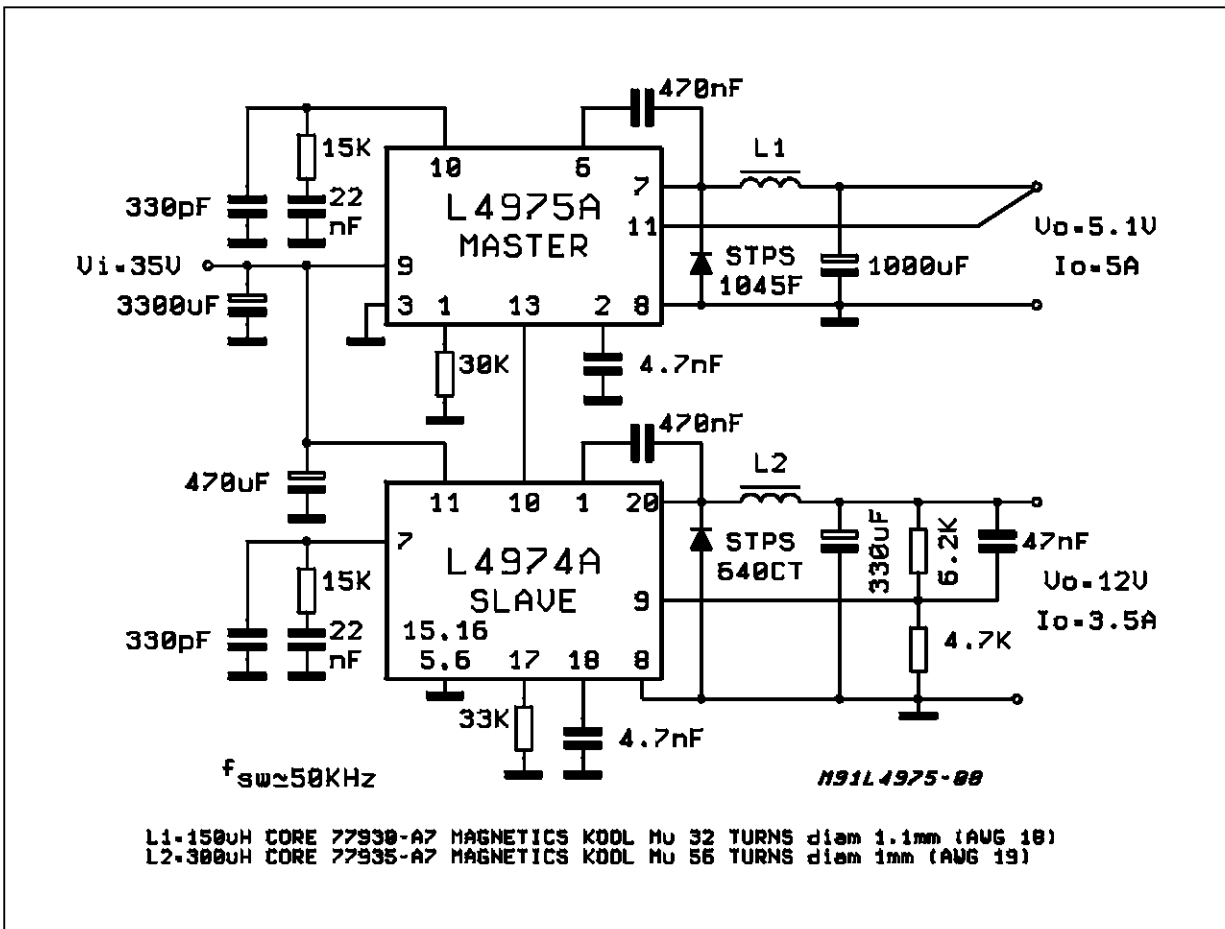


Figure 33: 5.1V/12V Multiple Supply. Note the Synchronization between the L4975A and the L4974A



L4975A

Figure 34: 5.1V / 5A Low Cost Application

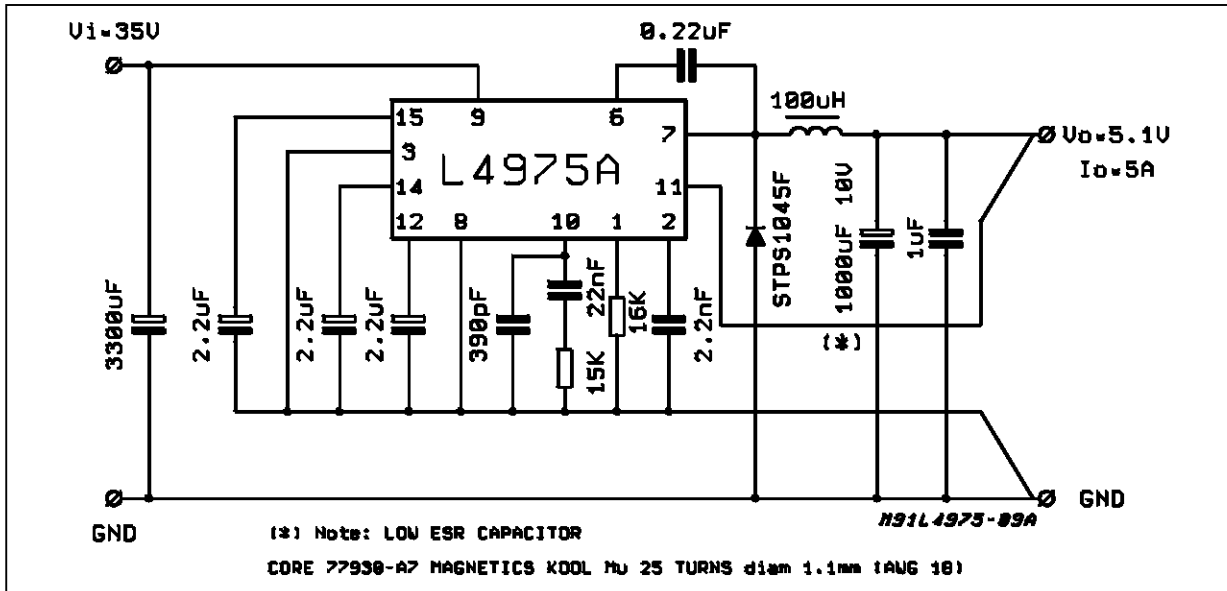


Figure 35: 5A Switching Regulator, Adjustable from 0V to 25V.

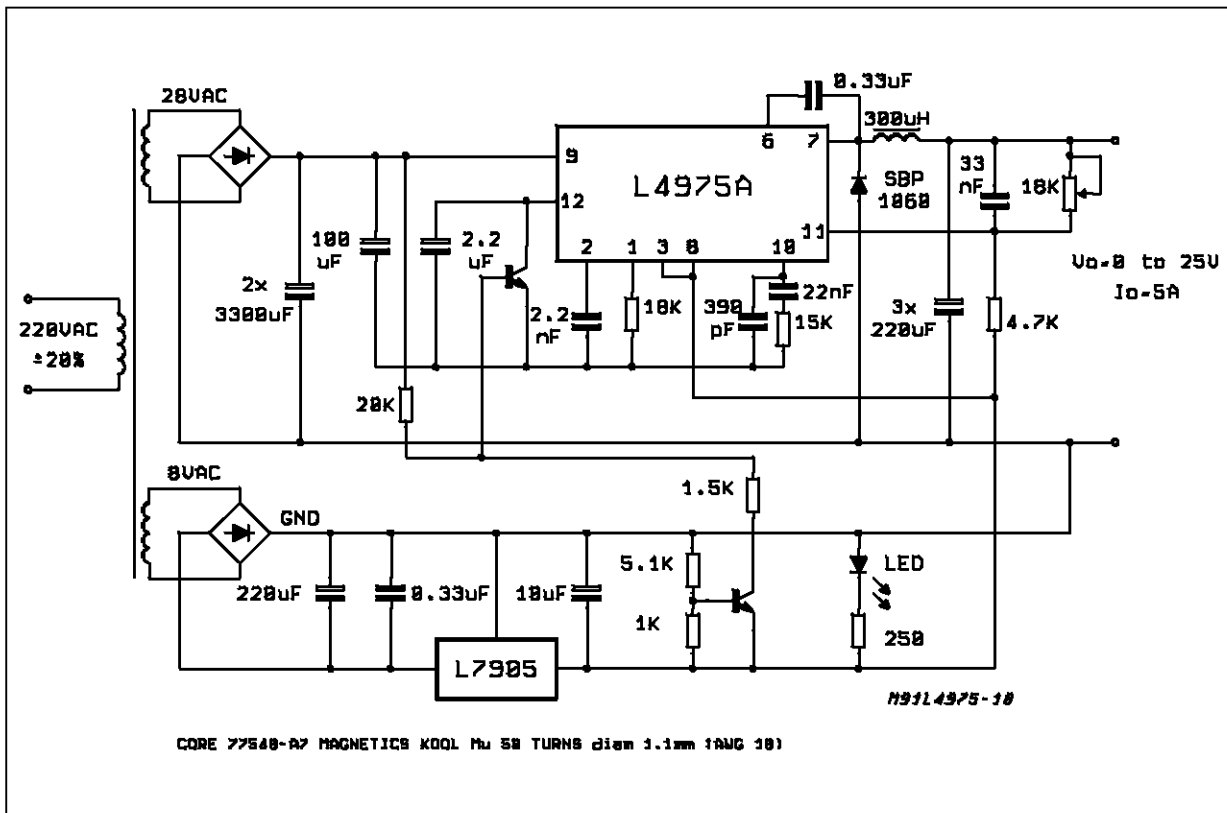
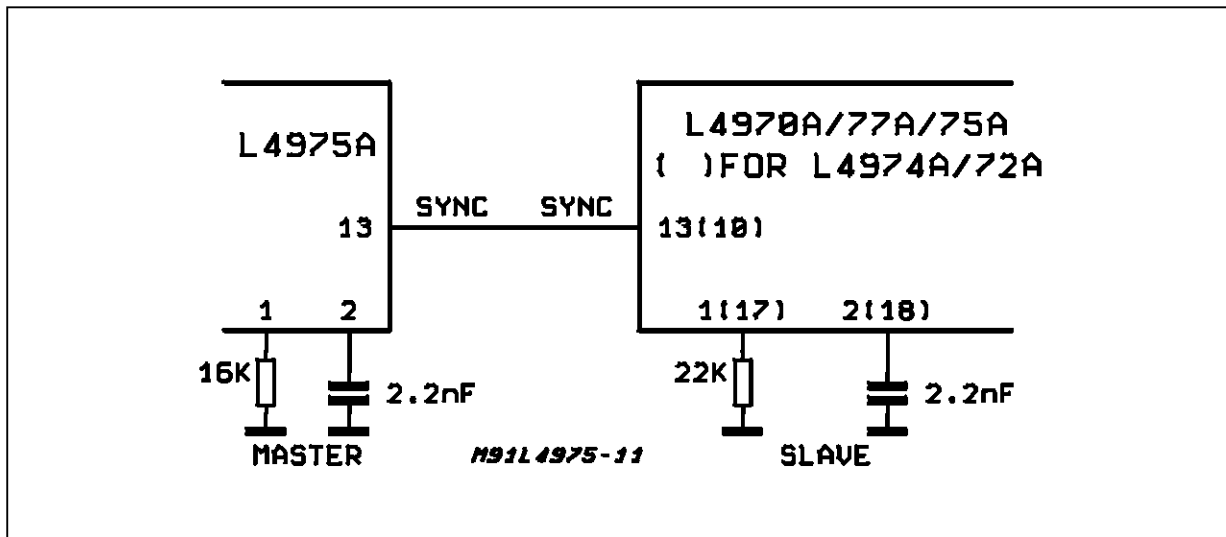
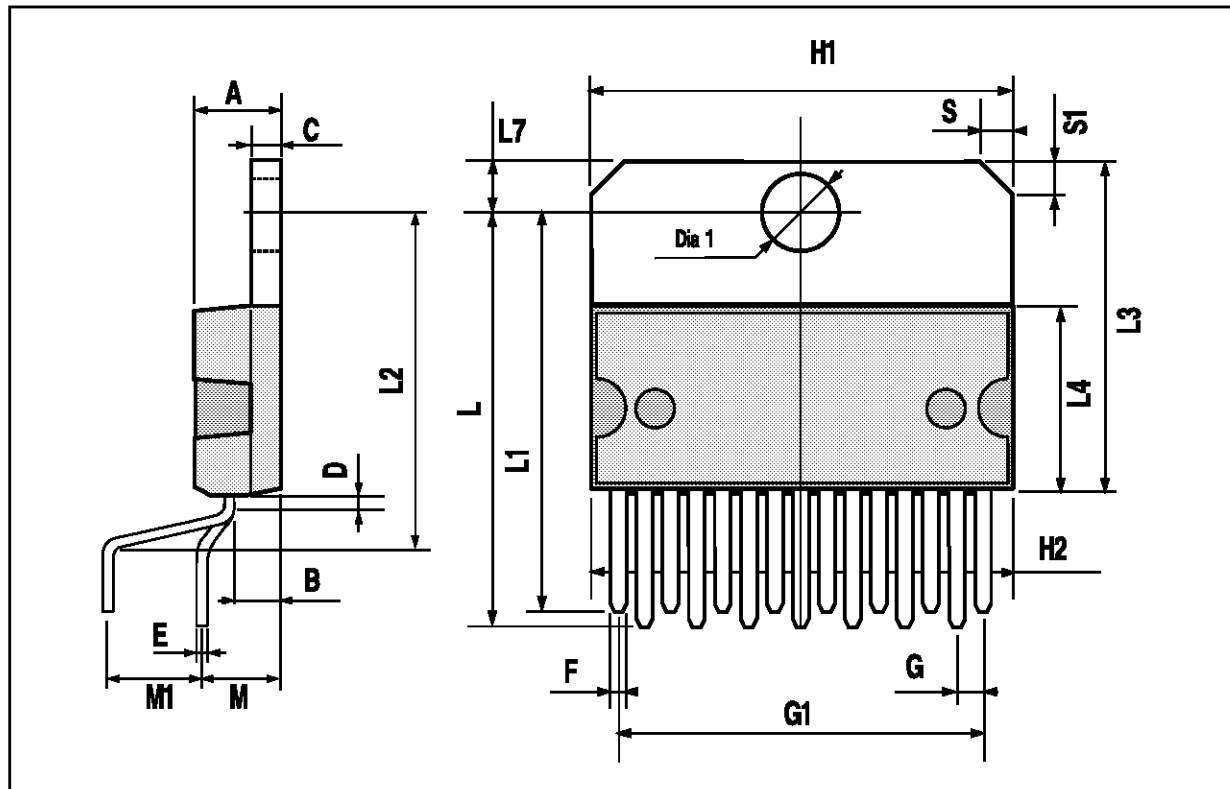


Figure 36: L4975A's Sync. Example



MULTIWATT15 PACKAGE MECHANICAL DATA

| DIM. | mm | | | inch | | |
|------|-------|-------|-------|-------|-------|-------|
| | MIN. | TYP. | MAX. | MIN. | TYP. | MAX. |
| A | | | 5 | | | 0.197 |
| B | | | 2.65 | | | 0.104 |
| C | | | 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 |
| M | 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 |
| Dia1 | 3.65 | | 3.85 | 0.144 | | 0.152 |



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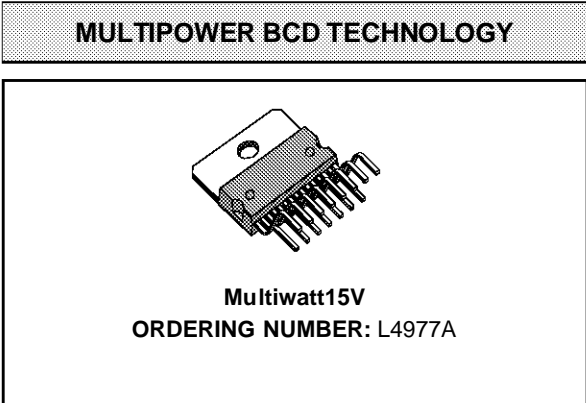
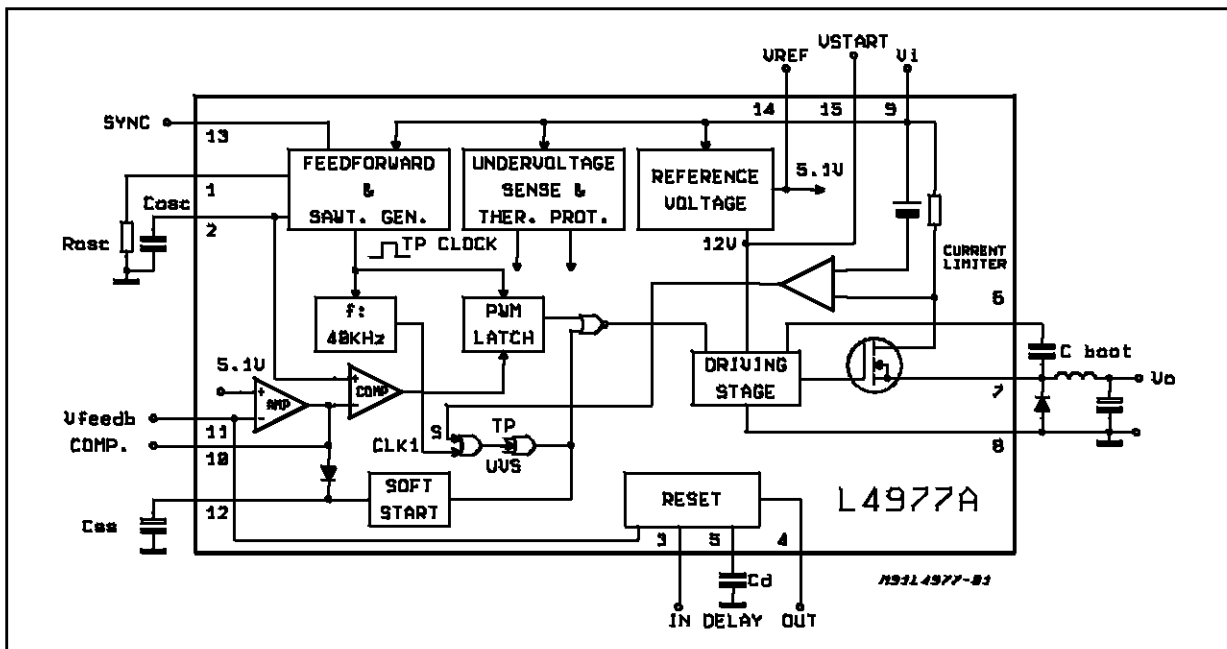
7A SWITCHING REGULATOR

- 7A OUTPUT CURRENT
- 5.1V TO 40V OUTPUT VOLTAGE RANGE
- 0 TO 90% DUTY CYCLE RANGE
- INTERNAL FEED-FORWARD LINE REGULATION
- INTERNAL CURRENT LIMITING
- PRECISE 5.1V ± 2% ON CHIP REFERENCE
- RESET AND POWER FAIL FUNCTIONS
- SOFT START
- INPUT/OUTPUT SYNC PIN
- UNDER VOLTAGE LOCK OUT WITH HYSTERETIC TURN-ON
- PWM LATCH FOR SINGLE PULSE PER PERIOD
- VERY HIGH EFFICIENCY
- SWITCHING FREQUENCY UP TO 500KHZ
- THERMAL SHUTDOWN
- CONTINUOUS MODE OPERATION

DESCRIPTION

The L4977A is a stepdown monolithic power switching regulator delivering 7A at a voltage variable from 5.1 to 40V.

BLOCK DIAGRAM



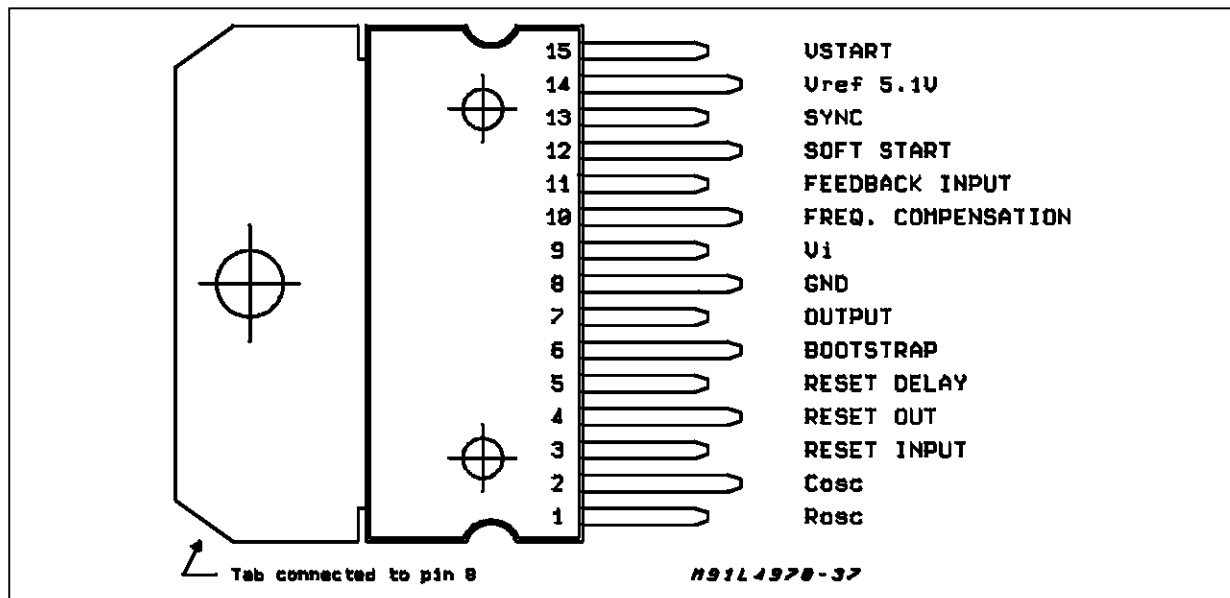
Realized with BCD mixed technology, the device uses a DMOS output transistor to obtain very high efficiency and very fast switching times. Features of the L4977A include reset and power fail for microprocessors, feed forward line regulation, soft start, limiting current and thermal protection. The device is mounted in a 15-lead multiwatt plastic power package and requires few external components. Efficient operation at switching frequencies up to 500KHz allows reduction in the size and cost of external filter components.

L4977A

ABSOLUTE MAXIMUM RATINGS

| Symbol | Parameter | Value | Unit |
|--|--|---------------------|------|
| V ₉ | Input Voltage | 55 | V |
| V ₉ | Input Operating Voltage | 50 | V |
| V ₇ | Output DC Voltage | -1 | V |
| | Output Peak Voltage at t = 0.1μs f = 200KHz | -7 | V |
| I ₇ | Maximum Output Current | Internally Limited | |
| V ₆ | Bootstrap Voltage | 65 | V |
| | Bootstrap Operating Voltage | V ₉ + 15 | V |
| V ₃ , V ₁₂ | Input Voltage at Pins 3, 12 | 12 | V |
| V ₄ | Reset Output Voltage | 50 | V |
| I ₄ | Reset Output Sink Current | 50 | mA |
| V ₅ , V ₁₀ , V ₁₁ , V ₁₃ | Input Voltage at Pin 5, 10, 11, 13 | 7 | V |
| I ₅ | Reset Delay Sink Current | 30 | mA |
| I ₁₀ | Error Amplifier Output Sink Current | 1 | A |
| I ₁₂ | Soft Start Sink Current | 30 | mA |
| P _{tot} | Total Power Dissipation at T _{case} < 120°C | 30 | W |
| T _j , T _{stg} | Junction and Storage Temperature | -40 to 150 | °C |

PIN CONNECTION (Top view)



THERMAL DATA

| Symbol | Parameter | Value | Unit |
|------------------------|-------------------------------------|-------|------|
| R _{th j-case} | Thermal Resistance Junction-case | 1 | °C/W |
| R _{th j-amb} | Thermal Resistance Junction-ambient | 35 | °C/W |

PIN FUNCTIONS

| N° | Name | Function |
|----|------------------------|---|
| 1 | OSCILLATOR | R_{osc} . External resistor connected to ground determines the constant charging current of C_{osc} . |
| 2 | OSCILLATOR | C_{osc} . External capacitor connected to ground determines (with R_{osc}) the switching frequency. |
| 3 | RESET INPUT | Input of Power Fail Circuit. The threshold is 5.1V. It may be connected via a divider to the input for power fail function. It must be connected to the pin 14 an external 30K Ω resistor when power fail signal not required. |
| 4 | RESET OUT | Open Collector Reset/power Fail Signal Output. This output is high when the supply and the output voltages are safe. |
| 5 | RESET DELAY | A C_d capacitor connected between this terminal and ground determines the reset signal delay time. |
| 6 | BOOTSTRAP | A C_{boot} capacitor connected between this terminal and the output allows to drive properly the internal D-MOS transistor. |
| 7 | OUTPUT | Regulator Output. |
| 8 | GROUND | Common Ground Terminal |
| 9 | SUPPLY VOLTAGE | Unregulated Input Voltage. |
| 10 | FREQUENCY COMPENSATION | A series RC network connected between this terminal and ground determines the regulation loop gain characteristics. |
| 11 | 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. |
| 12 | SOFT START | Soft Start Time Constant. A capacitor is connected between this terminal and ground to define the soft start time constant. |
| 13 | SYNC INPUT | Multiple L4977A are synchronized by connecting pin 13 inputs together or via an external syncr. pulse. |
| 14 | V_{ref} | 5.1V V_{ref} Device Reference Voltage. |
| 15 | V_{start} | Internal Start-up Circuit to Drive the Power Stage. |

CIRCUIT OPERATION (refer to the block diagram)

The L4977A is a 7A monolithic stepdown switching regulator working in continuous mode realized in the new BCD Technology. This technology allows the integration of isolated vertical DMOS power transistors plus mixed CMOS/Bipolar transistors.

The device can deliver 7A at an output voltage adjustable from 5.1V to 40V, and contains diagnostic and control functions that make it particularly suitable for microprocessor based systems.

BLOCK DIAGRAM

The block diagram shows the DMOS power transistor and the PWM control loop. Integrated functions include a reference voltage trimmed to $5.1V \pm 2\%$, soft start, undervoltage lockout, oscillator with feedforward control, pulse by pulse current limit, thermal shutdown and finally the reset and power fail circuit. The reset and power fail circuit provides an output signal for a microprocessor indicating the status of the system.

Device turn on is around 11V with a typical 1V hysteresis, this threshold provides a correct voltage for the driving stage of the DMOS gate and the hysteresis prevents instabilities.

An external bootstrap capacitor charged to 12V by an internal voltage reference is needed to provide correct gate drive to the power DMOS. The driving circuit is able to source and sink peak currents of around 0.5A to the gate of the DMOS transistor. A typical switching time of the current in the DMOS transistor is 50ns. Due to the fast commutation switching frequencies up to 500kHz are possible.

The PWM control loop consists of a sawtooth oscillator, error amplifier, comparator, latch and the output stage. An error signal is produced by comparing the output voltage with the precise $5.1V \pm 2\%$ on chip reference. This error signal is then compared with the sawtooth oscillator, in order to generate a fixed frequency pulse width modulated drive for the output stage. A PWM latch is included to eliminate multiple pulsing within a period even in noisy environments. The gain and

Figure 1: Feedforward Waveform

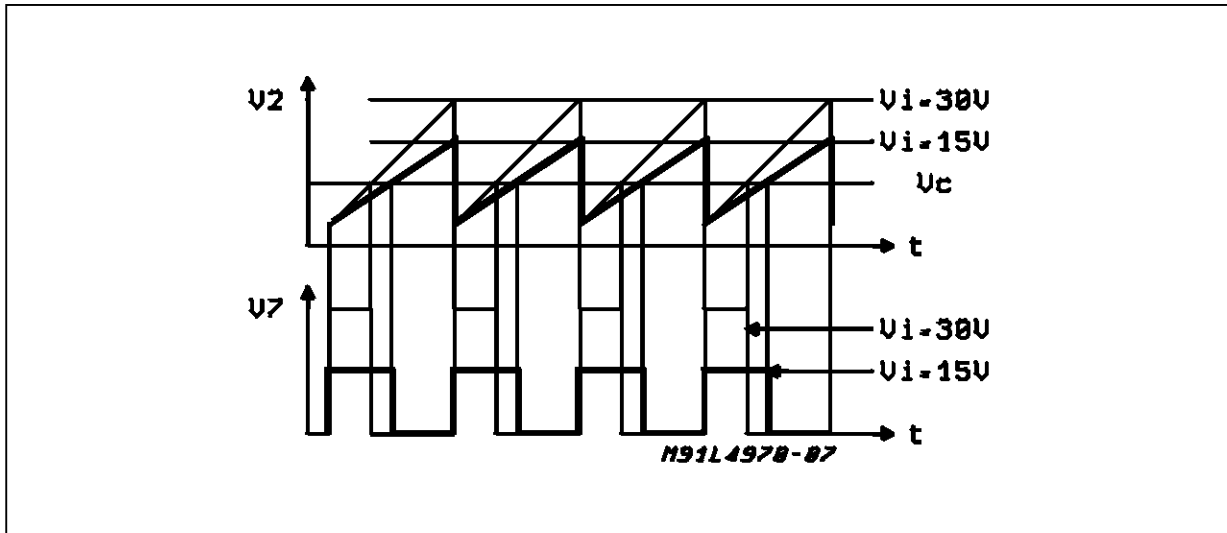


Figure 2: Soft Start Function

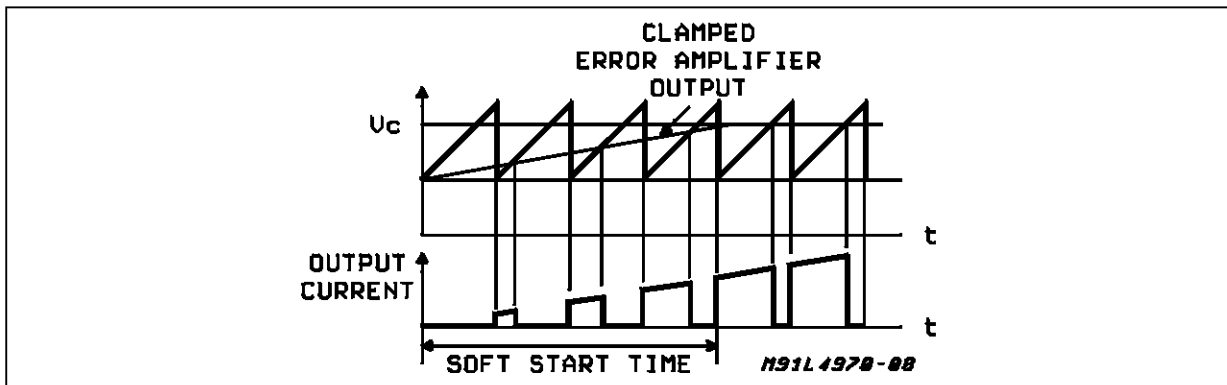
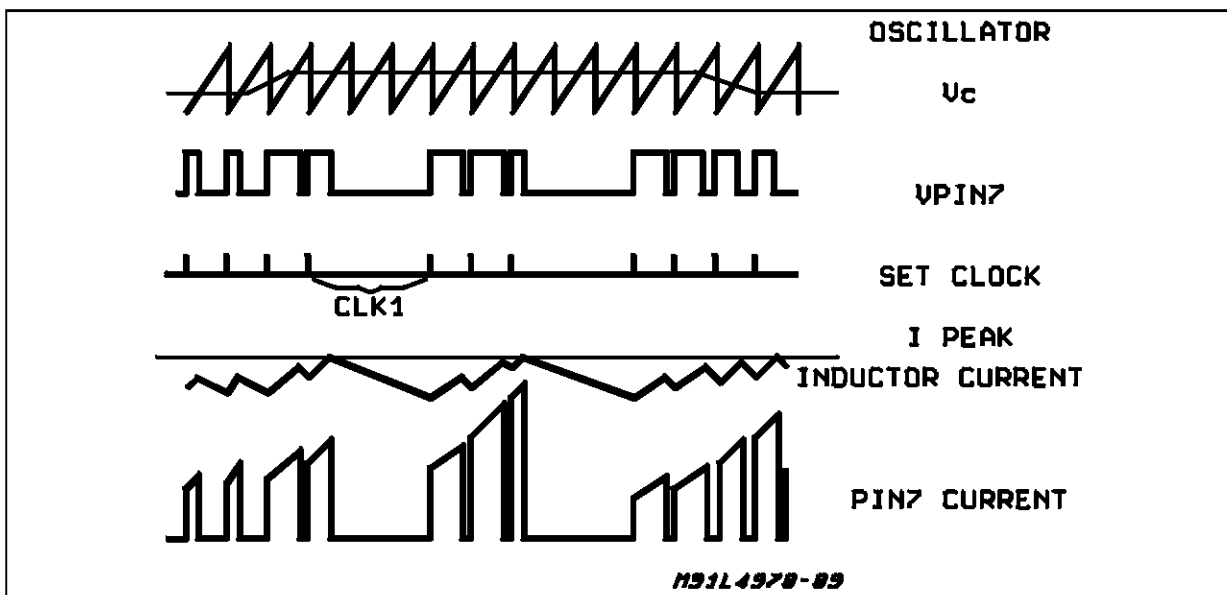


Figure 3: Limiting Current Function



stability of the loop can be adjusted by an external RC network connected to the output of the error amplifier. A voltage feedforward control has been added to the oscillator, this maintains superior line regulation over a wide input voltage range. Closing the loop directly gives an output voltage of 5.1V, higher voltages are obtained by inserting a voltage divider.

At turn on output overcurrents are prevented by the soft start function (fig. 2). The error amplifier is initially clamped by an external capacitor C_{ss} and allowed to rise linearly under the charge of an internal constant current source.

Output overload protection is provided by a current limit circuit (fig. 3). The load current is sensed by an internal metal resistor connected to a comparator. When the load current exceeds a preset threshold the output of the comparator sets a flip flop which turns off the power DMOS. The next clock pulse, from an internal 40kHz oscillator will reset the flip flop and the power DMOS will again conduct. This current protection method, ensures

a constant current output when the system is overloaded or short circuited and limits the switching frequency, in this condition, to 40kHz.

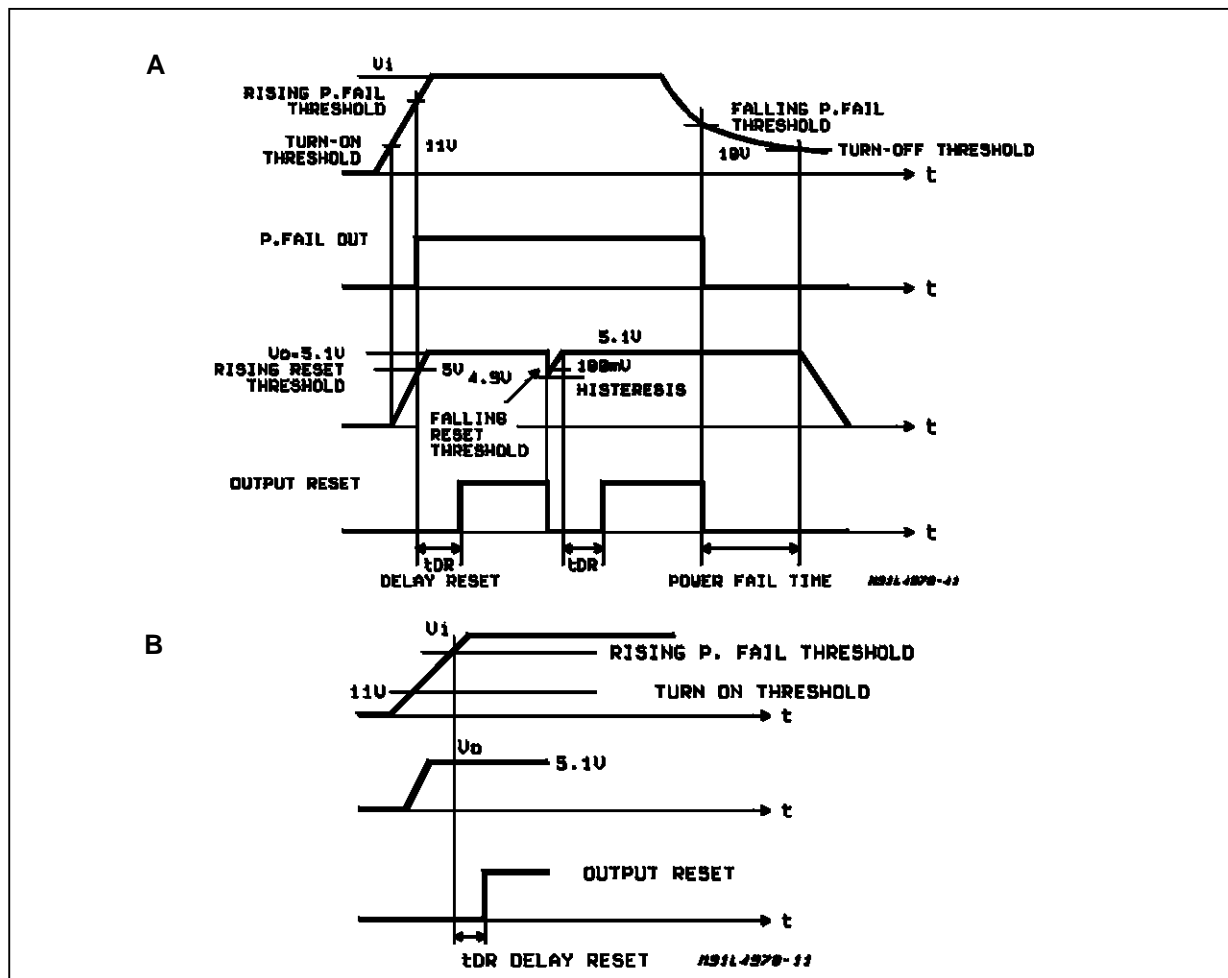
The Reset and Power fail circuitry (fig 4) generates an output signal when the supply voltage exceeds a threshold programmed by an external voltage divider. The reset signal, is generated with a delay time programmed by an external capacitor on the delay pin. When the supply voltage falls below the threshold or the output voltage goes below 5V the reset output goes low immediately. The reset output is an open collector-drain.

Fig 4A shows the case when the supply voltage is higher than the threshold, but the output voltage is not yet 5V.

Fig 4B shows the case when the output is 5.1V but the supply voltage is not yet higher than the fixed threshold.

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

Figure 4: Reset and Power Fail Functions.



L4977A

ELECTRICAL CHARACTERISTICS (Refer to the test circuit, $T_j = 25^\circ\text{C}$, $V_i = 35\text{V}$, $R_4 = 16\text{K}\Omega$, $C_9 = 2.2\text{nF}$, $f_{\text{SW}} = 200\text{KHz}$ typ, unless otherwise specified)

DYNAMIC CHARACTERISTICS

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|-------------------------------|--|---|------|------------|------------|----------|------|
| V_i | input Voltage Range (pin 9) | $V_o = V_{\text{ref}}$ to 40V $I_o = 7\text{A}$ | 15 | | 50 | V | 5 |
| V_o | Output Voltage | $V_i = 15\text{V}$ to 50V $I_o = 3\text{A}$; $V_o = V_{\text{ref}}$ | 5 | 5.1 | 5.2 | V | 5 |
| ΔV_o | Line Regulation | $V_i = 15\text{V}$ to 50V $I_o = 2\text{A}$; $V_o = V_{\text{ref}}$ | | 12 | 30 | mV | 5 |
| ΔV_o | Load Regulation | $V_o = V_{\text{ref}}$ $I_o = 3\text{A}$ to 5A $I_o = 2\text{A}$ to 7A | | 10 20 | 25 40 | mV mV | 5 |
| V_d | Dropout Voltage Between Pin 9 and 7 | $I_o = 5\text{A}$ $I_o = 7\text{A}$ | | 0.4 0.8 | 0.6 1.1 | V V | 5 |
| I_{7L} | Max. Limiting Current | $V_o = V_{\text{ref}}$ to 40V $V_i = 15$ to 50V | 8 | 9.5 | 11 | A | 5 |
| η | Efficiency | $I_o = 3\text{A}$ $V_o = V_{\text{ref}}$ $V_o = 12\text{V}$ | 70 | 75 80 | | % % | 5 |
| | | $I_o = 7\text{A}$ $V_o = V_{\text{ref}}$ $V_o = 12\text{V}$ | 75 | 80 87 | | % % | 5 |
| SVR | Supply Voltage Ripple Reject. | $V_i = 2\text{VRMS}$; $I_o = 3\text{A}$ $f = 100\text{Hz}$; $V_o = V_{\text{ref}}$ | 56 | 60 | | dB | 5 |
| f | Switching Frequency | | 180 | 200 | 220 | KHz | 5 |
| $\frac{\Delta f}{\Delta V_i}$ | Voltage Stability of Switching Frequency | $V_i = 15\text{V}$ to 45V | | 2 | 6 | % | 5 |
| $\frac{\Delta f}{T_j}$ | Temperature Stability of Switching Frequency | $T_j = 0$ to 125°C | | 1 | | % | 5 |
| f_{max} | Maximum Operating Switching Frequency | $V_o = V_{\text{ref}}$; $R_4 = 10\text{K}\Omega$ $I_o = 7\text{A}$; $C_9 = 1\text{nF}$ | 500 | | | KHz | 5 |

V_{ref} SECTION (pin 14)

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|----------------------------------|---|--|------|------|------|----------------------|------|
| V_{14} | Reference Voltage | | 5 | 5.1 | 5.2 | V | 7 |
| ΔV_{14} | Line Regulation | $V_i = 15\text{V}$ to 50V | | 10 | 25 | mV | 7 |
| ΔV_{14} | Load Regulation | $I_{14} = 0$ to 1mA | | 20 | 40 | mV | 7 |
| $\frac{\Delta V_{14}}{\Delta T}$ | Average Temperature Coefficient Reference Voltage | $T_j = 0^\circ\text{C}$ to 125°C | | 0.4 | | mV/ $^\circ\text{C}$ | 7 |
| $I_{14 \text{ short}}$ | Short Circuit Current Limit | $V_{14} = 0$ | | 70 | | mA | 7 |

V_{START} SECTION (pin 15)

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|------------------------|-----------------------------|----------------------|------|------|------|------|------|
| V_{15} | Reference Voltage | | 11.4 | 12 | 12.6 | V | 7 |
| ΔV_{15} | Line Regulation | $V_i = 15$ to 50V | | 0.6 | 1.4 | V | 7 |
| ΔV_{15} | Load Regulation | $I_{15} = 0$ to 1mA | | 50 | 200 | mV | 7 |
| $I_{15 \text{ short}}$ | Short Circuit Current Limit | $V_{15} = 0\text{V}$ | | 80 | | mA | 7 |

ELECTRICAL CHARACTERISTICS (continued)

DC CHARACTERISTICS

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|-------------|--------------------------|---------------------------------------|------|------|------|------|------|
| V_{9on} | Turn-on Threshold | | 10 | 11 | 12 | V | 7A |
| V_{9Hyst} | Turn-off Hysteresys | | | 1 | | V | 7A |
| I_{9Q} | Quiescent Current | $V_{12} = 0$; $S1 = D$ | | 13 | 19 | mA | 7A |
| I_{9OQ} | Operating Supply Current | $V_{12} = 0$; $S1 = C$; $S2 = B$ | | 16 | 23 | mA | 7A |
| I_{7L} | Out Leak Current | $V_i = 55V$; $S3 = A$; $V_{12} = 0$ | | | 2 | mA | 7A |

SOFT START

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|----------|---------------------------|-----------------------------------|------|------|------|---------|------|
| I_{12} | Soft Start Source Current | $V_{12} = 3V$; $V_{11} = 0V$ | 70 | 100 | 130 | μA | 7B |
| V_{12} | Output Saturation Voltage | $I_{12} = 20mA$; $V_9 = 10V$ | | | 1 | V | 7B |
| | | $I_{12} = 200\mu A$; $V_9 = 10V$ | | | 0.7 | V | 7B |

ERROR AMPLIFIER

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|-----------|--------------------------|--|------|------|------|---------|------|
| V_{10H} | High Level Out Voltage | $I_{10} = -100\mu A$; $S1 = C$ $V_{11} = 4.7V$ | 6 | | | V | 7C |
| V_{10L} | Low Level Out Voltage | $I_{10} = +100\mu A$; $S1 = C$ $V_{11} = 5.3V$; | | | 1.2 | V | 7C |
| I_{10H} | Source Output Current | $V_{10} = 1V$; $S1 = E$ $V_{11} = 4.7V$ | 100 | 150 | | μA | 7C |
| I_{10L} | Sink Output Current | $V_{10} = 6V$; $S1 = D$ $V_{11} = 5.3V$ | 100 | 150 | | μA | 7C |
| I_{11} | Input Bias Current | $R_S = 10K\Omega$ | | 0.4 | 3 | μA | – |
| G_V | DC Open Loop Gain | $V_{VCM} = 4V$; $R_S = 10\Omega$ | 60 | | | dB | – |
| SVR | Supply Voltage Rejection | $15 < V_i < 50V$; $R_S = 10\Omega$ | 60 | 80 | | dB | – |
| V_{OS} | Input Offset Voltage | $R_S = 50\Omega$ | | 2 | 10 | mV | – |

RAMP GENERATOR (pin 2)

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|--------|-------------------|-----------------------------|-------------|------|------|---------|------|
| V_2 | Ramp Valley | $S1 = C$; $S2 = B$ | 1.2 | 1.5 | | V | 7A |
| V_2 | Ramp Peak | $S1 = C$ $S2 = B$ | $V_i = 15V$ | 2.5 | | V | 7A |
| | | | $V_i = 45V$ | 5.5 | | V | 7A |
| I_2 | Min. Ramp Current | $S1 = A$; $I_1 = 100\mu A$ | | 270 | 300 | μA | 7A |
| I_2 | Max. Ramp Current | $S1 = A$; $I_1 = 1mA$ | 2.4 | 2.7 | | mA | 7A |

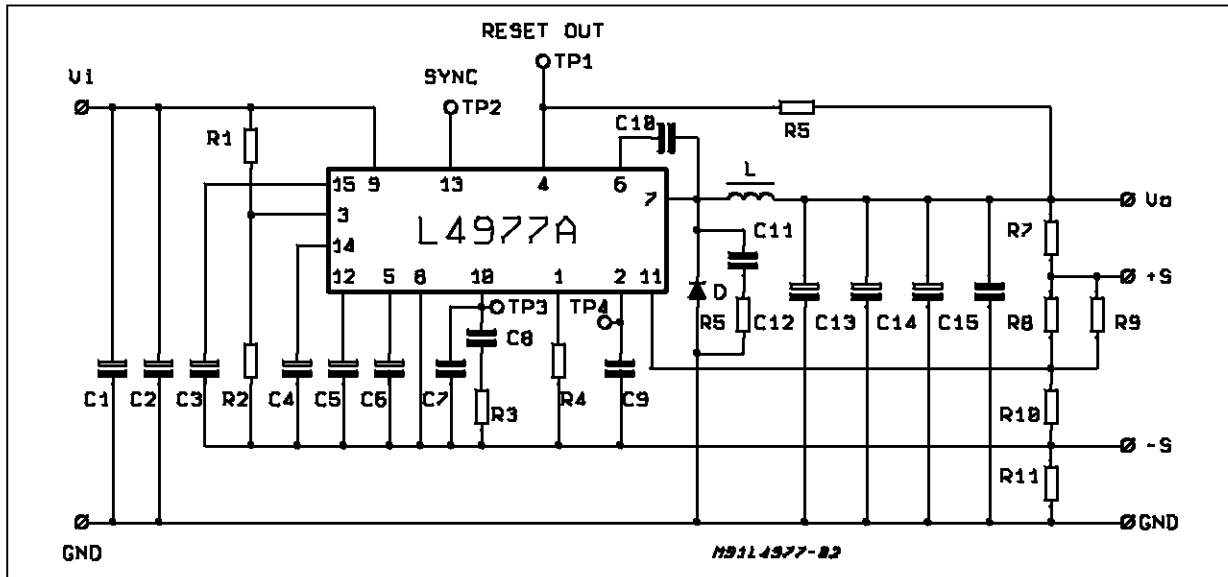
SYNC FUNCTION (pin 13)

| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|-----------|---|---|------|------|------|---------|------|
| V_{13} | Low Input Voltage | $V_i = 15V$ to $50V$; $V_{12} = 0$; $S1 = C$; $S2 = B$; $S4 = B$ | -0.3 | | 0.9 | V | 7A |
| V_{13} | High Input voltage | $V_{12} = 0$; $S1 = C$; $S2 = B$; $S4 = B$ | 3.5 | | 5.5 | V | 7A |
| I_{13L} | Sync Input Current with Low Input Voltage | $V_{13} = V_2 = 0.9V$; $S4 = A$; $S1 = C$; $S2 = B$ | | | 0.4 | mA | 7A |
| I_{13H} | Input Current with High Input Voltage | $V_{13} = 3.5V$; $S4 = A$; $S1 = C$; $S2 = B$ | | | 1.5 | mA | 7A |
| V_{13} | Output Amplitude | | 4 | 5 | | V | – |
| t_W | Output Pulse Width | $V_{thr} = 2.5V$ | 0.3 | 0.5 | 0.8 | μs | – |

ELECTRICAL CHARACTERISTICS (continued)
RESET AND POWER FAIL FUNCTIONS

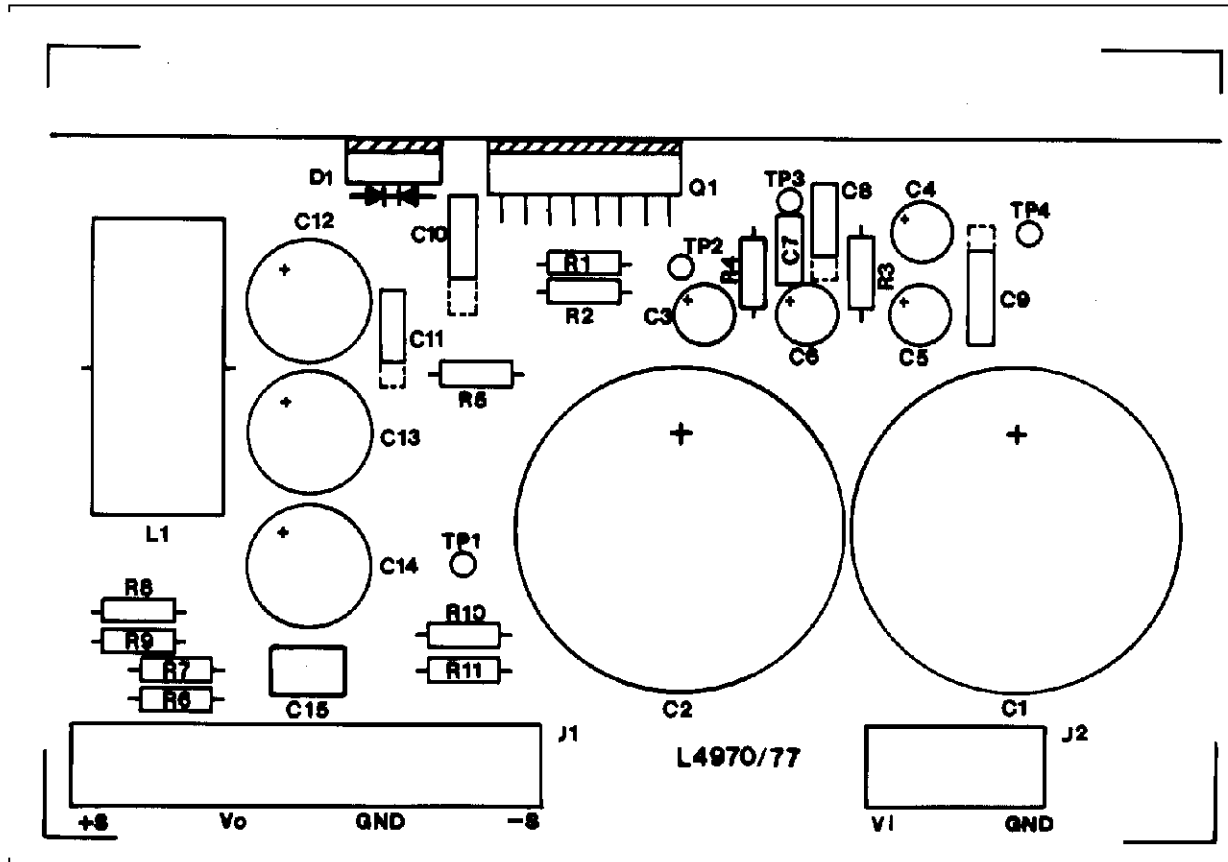
| Symbol | Parameter | Test Condition | Min. | Typ. | Max. | Unit | Fig. |
|-------------------|------------------------------------|---|--------------------------|--------------------------|--------------------------|---------|------|
| V _{11R} | Rising Threshold Voltage (pin 11) | V _i = 15 to 50V V ₃ = 5.3V | V _{ref} -120 | V _{ref} -100 | V _{ref} -80 | V mV | 7D |
| V _{11F} | Falling Threshold Voltage (pin 11) | V _i = 15 to 50V V ₃ = 5.3V | 4.77 | V _{ref} -200 | V _{ref} -160 | V mV | 7D |
| V _{5H} | Delay High Threshold Voltage | V _i = 15 to 50V V ₁₁ = V ₁₄ V ₃ = 5.3V | 4.95 | 5.1 | 5.25 | V | 7D |
| V _{5L} | Delay Low Threshold Voltage | V _i = 15 to 50V V ₁₁ = V ₁₄ V ₃ = 5.3V | 1 | 1.1 | 1.2 | V | 7D |
| -I _{SSO} | Delay Source Current | V ₃ = 5.3V; V ₅ = 3V | 40 | 60 | 80 | μA | 7D |
| I _{SSI} | Delay Sink Current | V ₃ = 4.7V; V ₅ = 3V | 10 | | | mA | 7D |
| V _{4S} | Out Saturation Voltage | I ₄ = 15mA; S1 = B V ₃ = 4.7V | | | 0.4 | V | 7D |
| I ₄ | Output Leak Current | V ₄ = 50V; S1 = A V ₃ = 5.3V | | | 100 | μA | 7D |
| V _{3R} | Rising Threshold Voltage | V ₁₁ = V ₁₄ | 4.95 | 5.1 | 5.25 | V | 7D |
| V _{3H} | Hysteresis | | 0.4 | 0.5 | 0.6 | V | 7D |
| I ₃ | Input Bias Current | | | 1 | 3 | μA | 7D |

Figure 5: Test and Evaluation Board Circuit



TYPICAL PERFORMANCES (using evaluation board) :
 $\eta = 83\%$ ($V_i = 35V$; $V_o = V_{REF}$; $I_o = 7A$; $f_{sw} = 200KHz$)
 V_o RIPPLE = 30mV (at 7A) with output filter capacitor ESR $\leq 60m\Omega$
 Line regulation = 5mV ($V_i = 15$ to 50V)
 Load regulation = 15mV ($I_o = 2$ to 7A)
 For component values, refer to test circuit part list.

Figure 6a: P.C. Board (components side) and Components Layout of Figure 5 (1:1 scale).



PARTS LIST

| | |
|--|--|
| R ₁ = 30KΩ | C ₁ , C ₂ = 3300μF 63V _L EYF (ROE) |
| R ₂ = 10KΩ | C ₃ , C ₄ , C ₅ , C ₆ = 2.2μF |
| R ₃ = 15KΩ | C ₇ = 390pF Film |
| R ₄ = 16KΩ | C ₈ = 22nF MKT 1817 (ERO) |
| R ₅ = 22Ω 0,5W | |
| R ₆ = 4K7 | C ₉ = 2.2nF KP1830 |
| R ₇ = 10Ω | C ₁₀ = 220nF MKT |
| R ₈ = see tab. A | C ₁₁ = 2.2nF MP1830 |
| R ₉ = OPTION | **C ₁₂ , C ₁₃ , C ₁₄ = 220μF 40V _L EKR |
| R ₁₀ = 4K7 | C ₁₅ = 1μF Film |
| R ₁₁ = 10Ω | |
| D1 = MBR 1560CT (or 16A/60V or equivalent) | |
| L1 = 40μH | core 58071 MAGNETICS 27 TURNS Ø 1,3mm (AWG 16) COGEMA 949178 |

* 2 capacitors in parallel to increase input RMS current capability
 ** 3 capacitors in parallel to reduce total output ESR

Table A

| V ₀ | R ₉ | R ₇ |
|----------------|----------------|----------------|
| 12V | 4.7kΩ | 6.2kΩ |
| 15V | 4.7kΩ | 9.1kΩ |
| 18V | 4.7kΩ | 12kΩ |
| 24V | 4.7kΩ | 18kΩ |

Table B
SUGGESTED BOOTSTRAP CAPACITORS

| Operating Frequency | Bootstrap Cap.c10 |
|---------------------|-------------------|
| f = 20KHz | ≥680nF |
| f = 50KHz | ≥470nF |
| f = 100KHz | ≥330nF |
| f = 200KHz | ≥220nF |
| f = 500KHz | ≥100nF |

Figure 6b: P.C. Board (Back side) and Components Layout of the Circuit of Fig. 5. (1:1 scale)

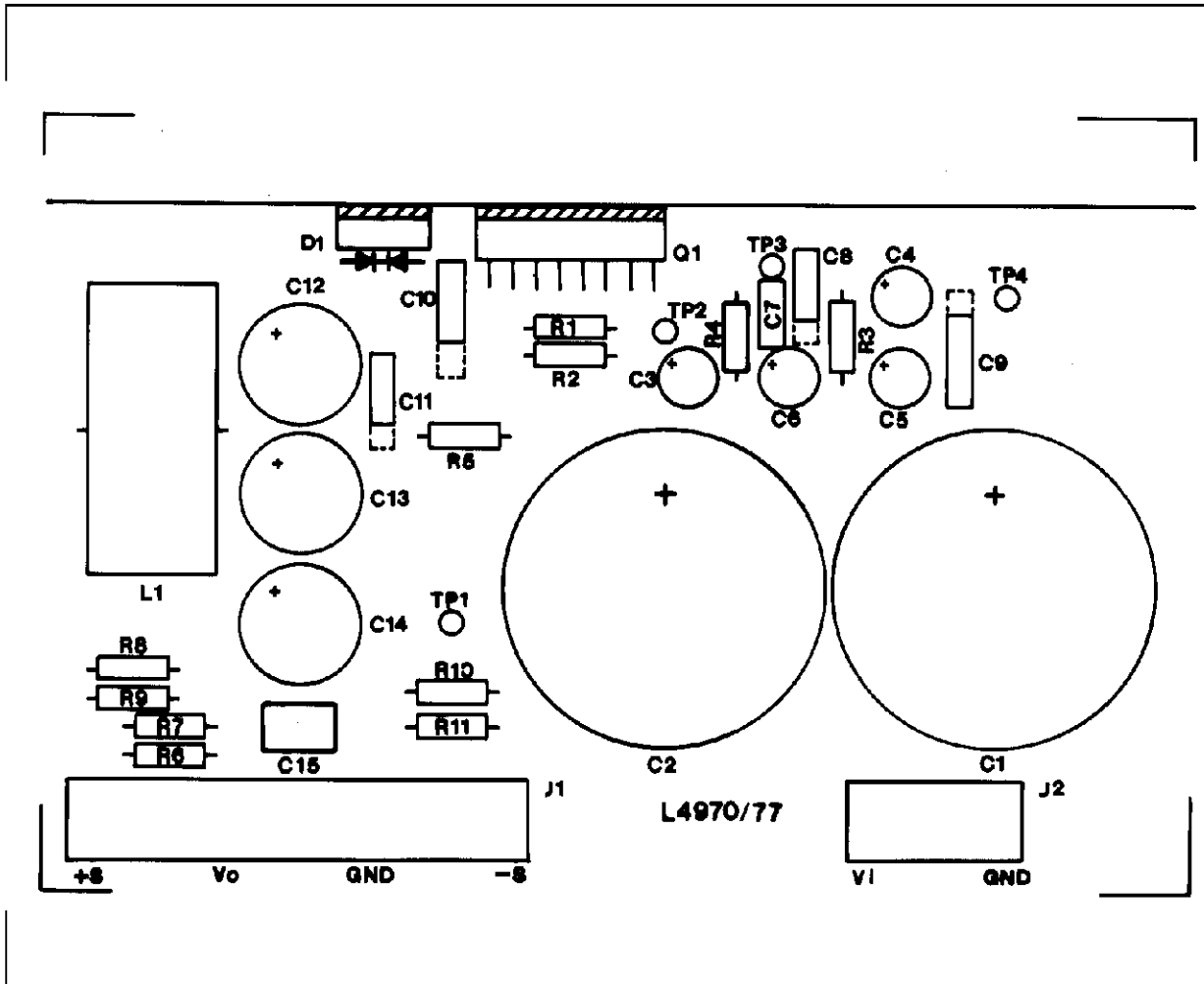


Figure 7: DC Test Circuits

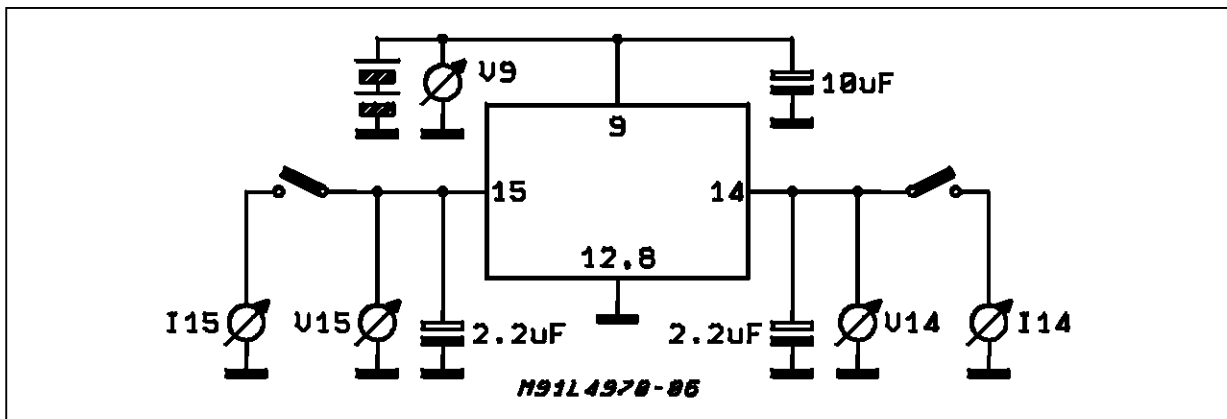


Figure 7A

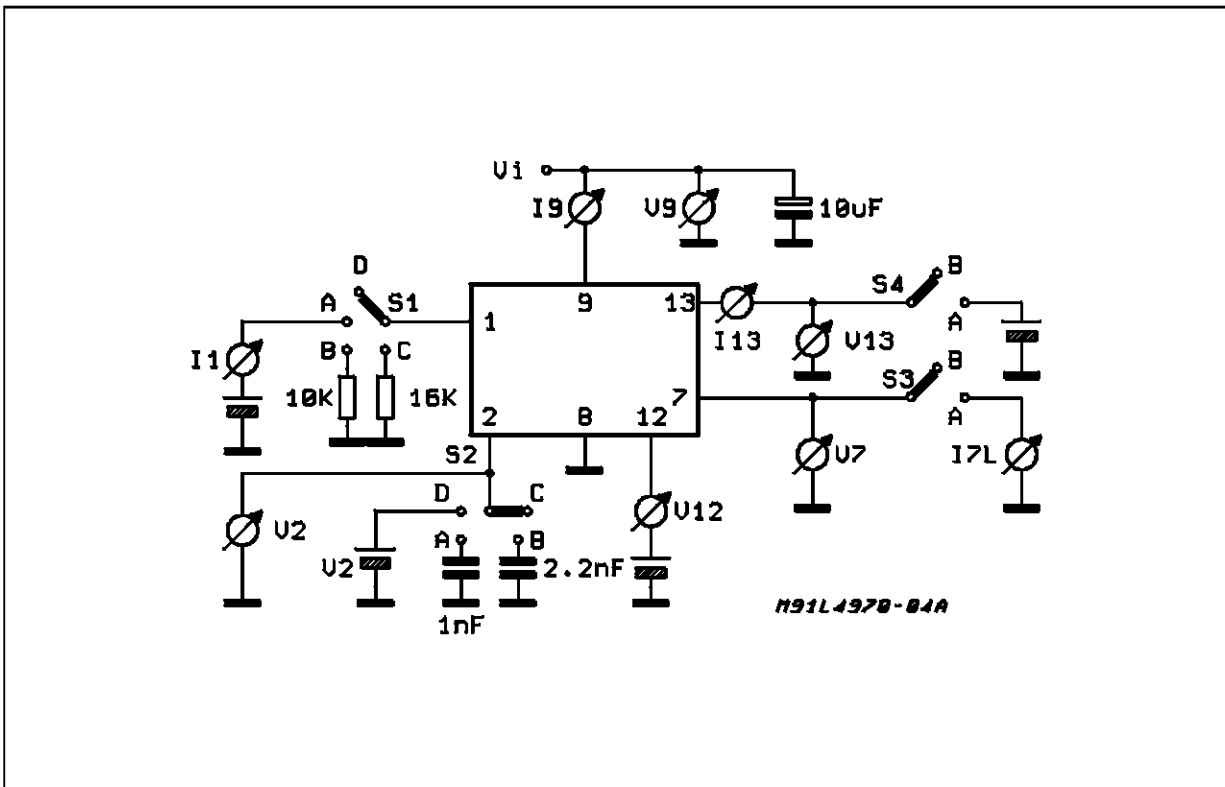


Figure 7B

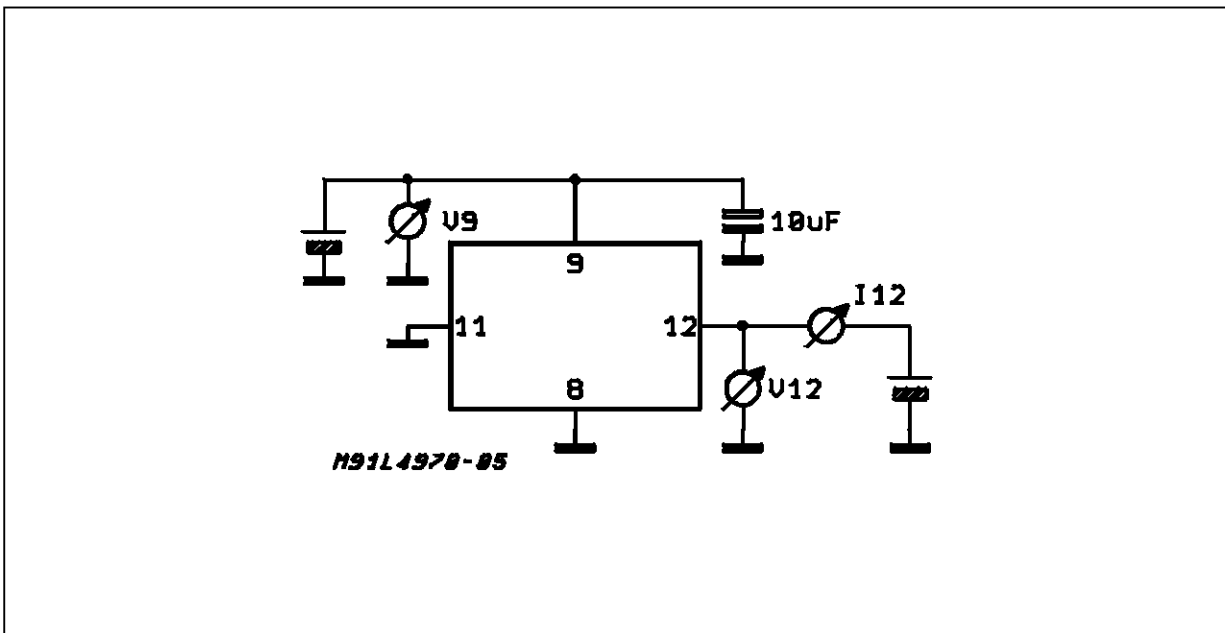


Figure 7D

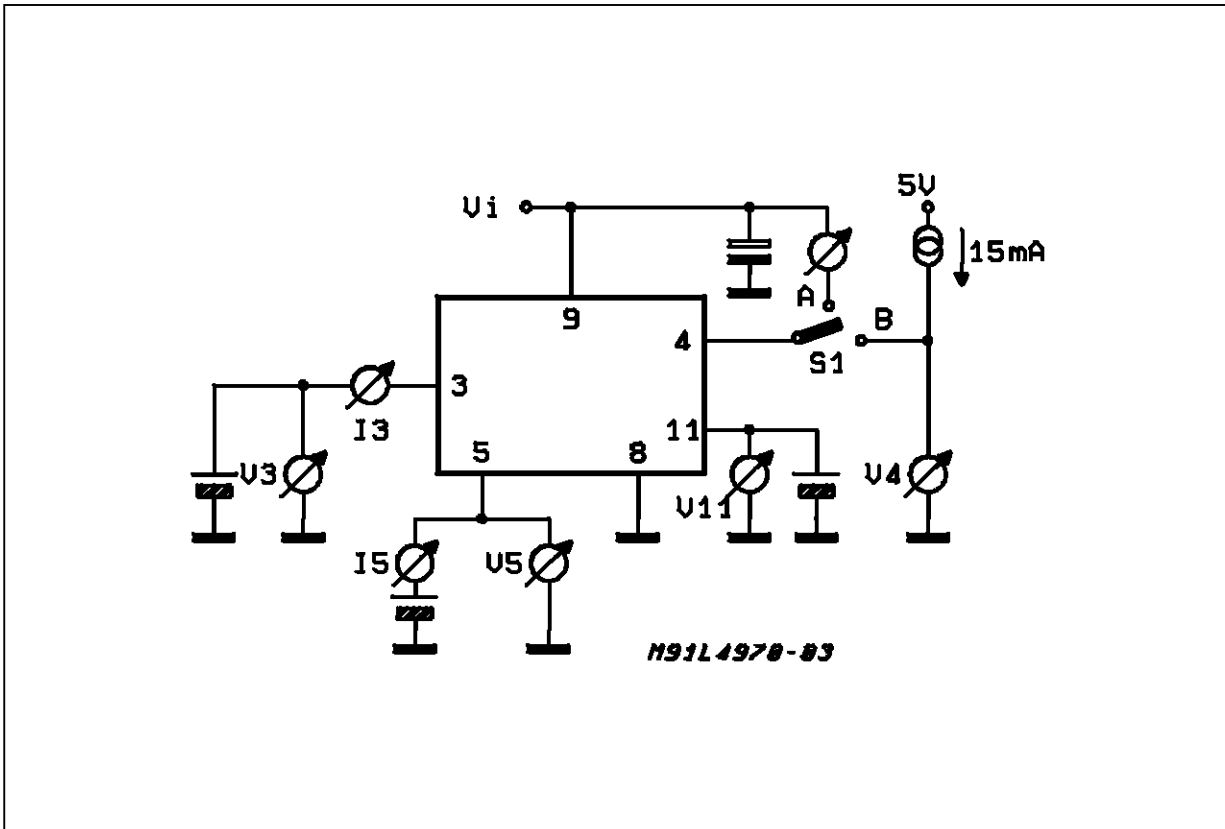


Figure 7C

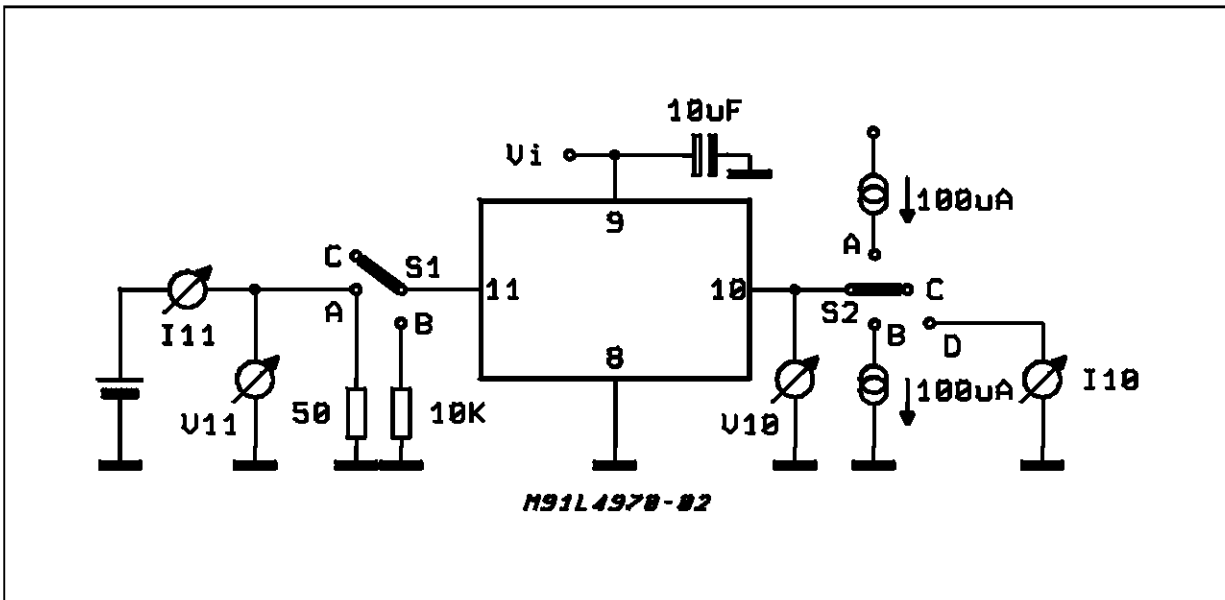


Figure 8: Quiescent Drain Current vs. Supply Voltage (0% duty cycle - see fig. 7A).

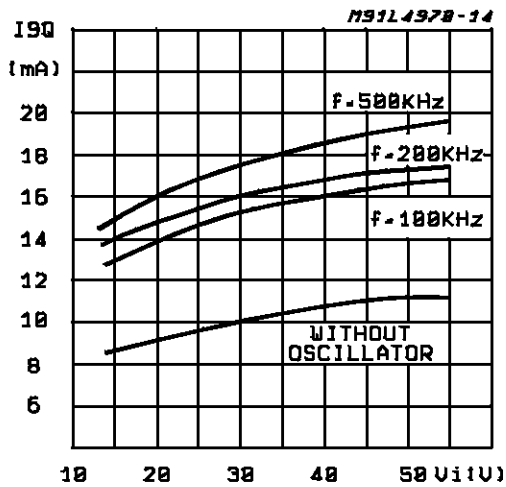


Figure 9: Quiescent Drain Current vs. Junction Temperature (0% duty cycle).

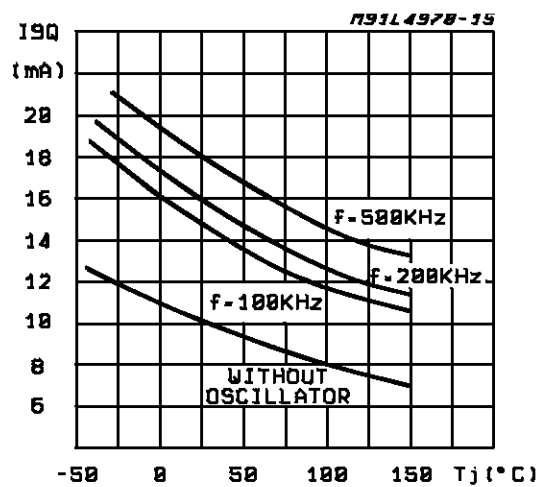


Figure 10: Quiescent Drain Current vs. Duty Cycle

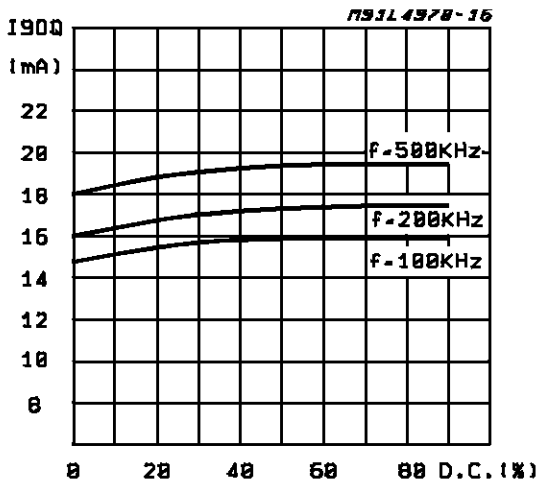


Figure 11: Reference Voltage (pin14) vs. V_i (see fig. 7)

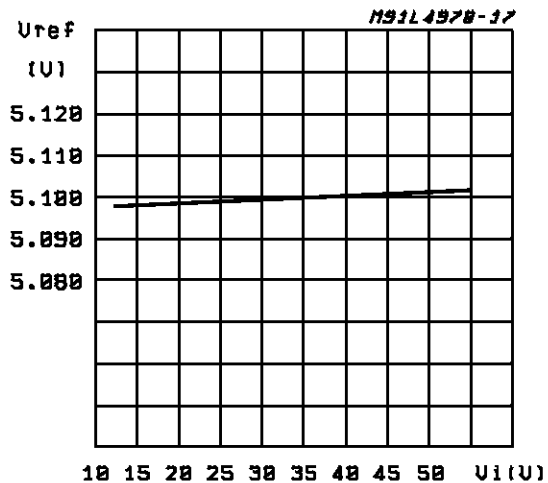


Figure 12: Reference Voltage (pin 14) vs. Junction Temperature (see fig. 7)

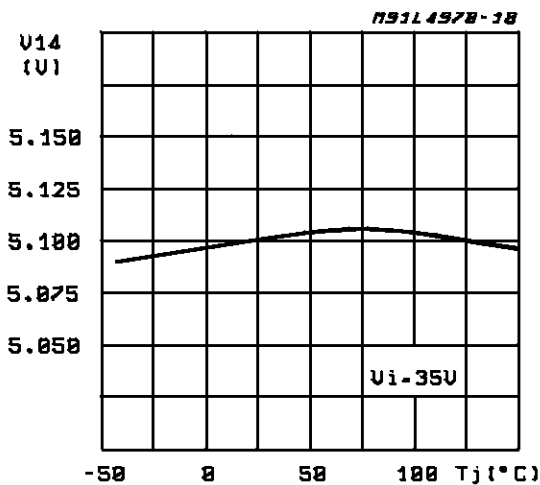


Figure 13: Reference Voltage (pin15) vs. V_i (see fig. 7)

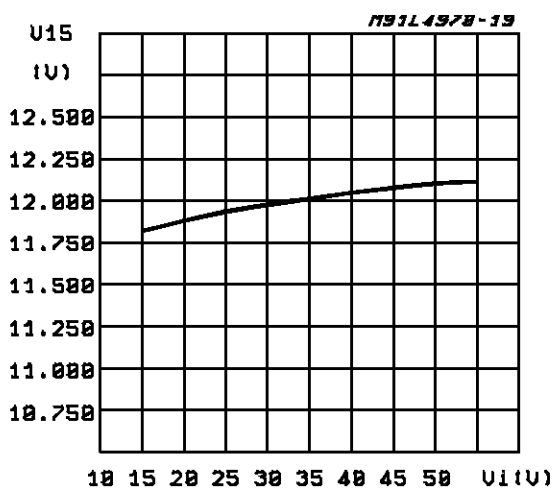


Figure 14: Reference Voltage (pin 15) vs. Junction Temperature (see fig. 7)

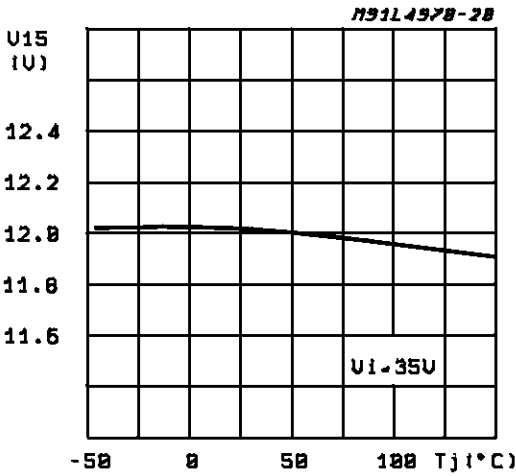


Figure 15: Reference Voltage 5.1V (pin 14) Supply Voltage Ripple Rejection vs. Frequency

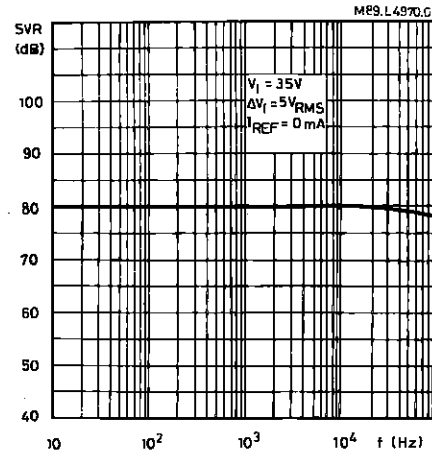


Figure 16: Switching Frequency vs. Input Voltage (see fig. 5)

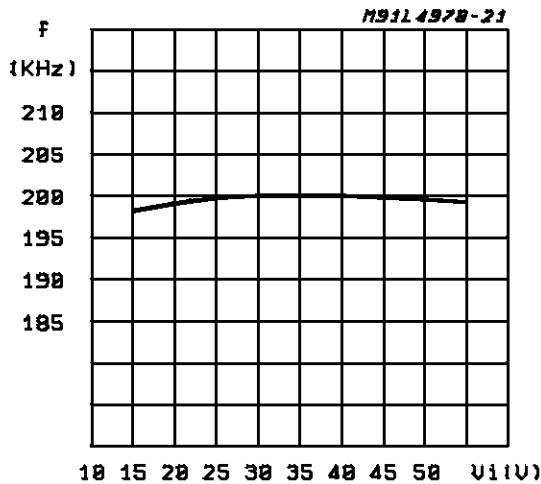


Figure 17: Switching Frequency vs. Junction Temperature (see fig. 5)

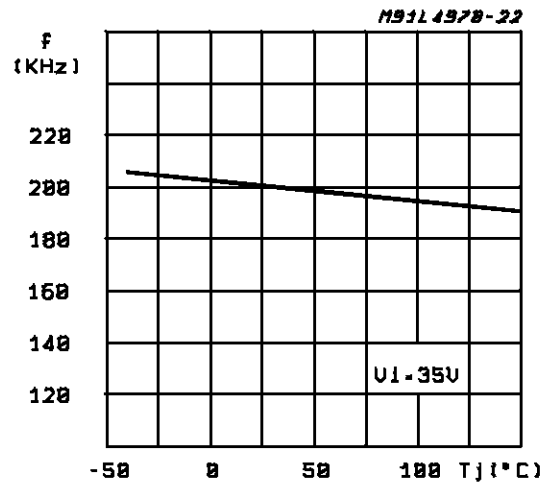


Figure 18: Switching Frequency vs. R4 (see fig. 5)

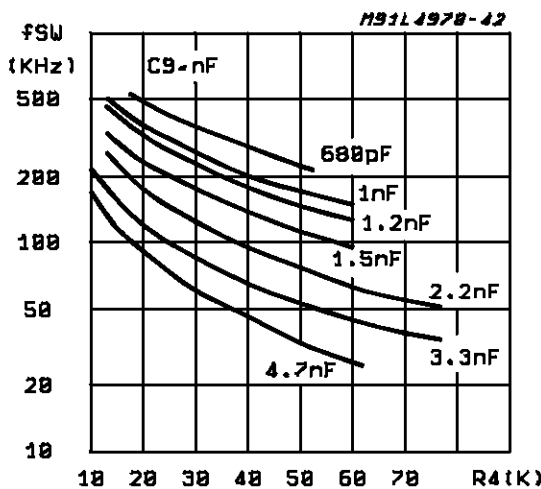


Figure 19: Max. Duty Cycle vs. Frequency

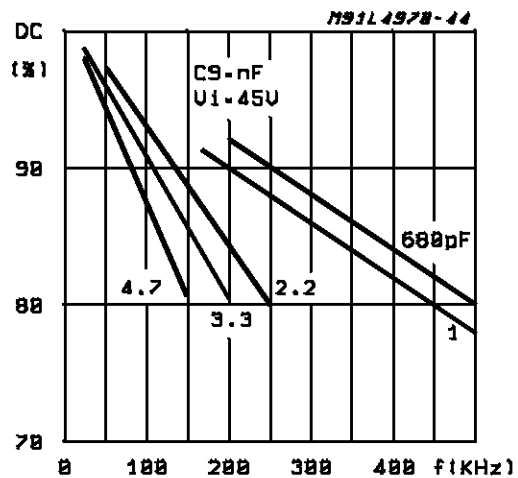


Figure 20: Supply Voltage Ripple Rejection vs. Frequency (see fig. 5)

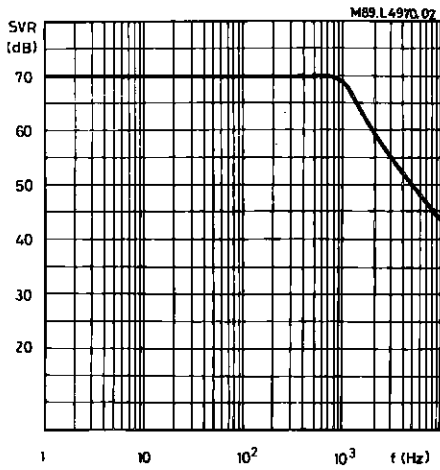


Figure 21: Line Transient Response (see fig. 5)

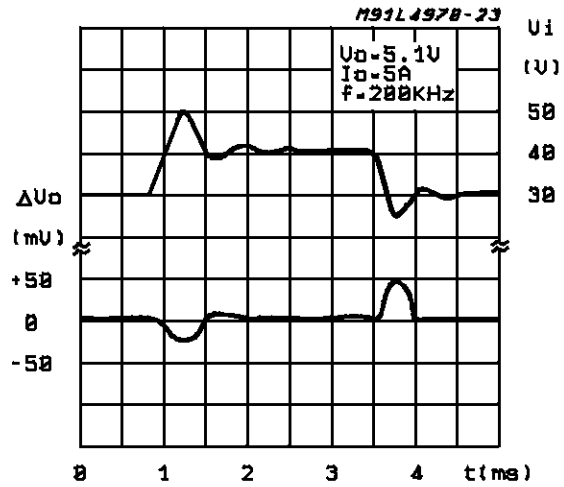


Figure 22: Load Transient Response (see fig. 5)

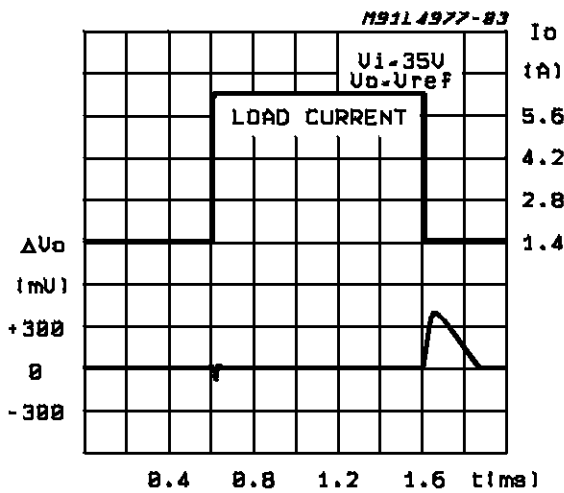


Figure 23: Dropout Voltage Between Pin 9 and Pin 7 vs. Current at Pin 7

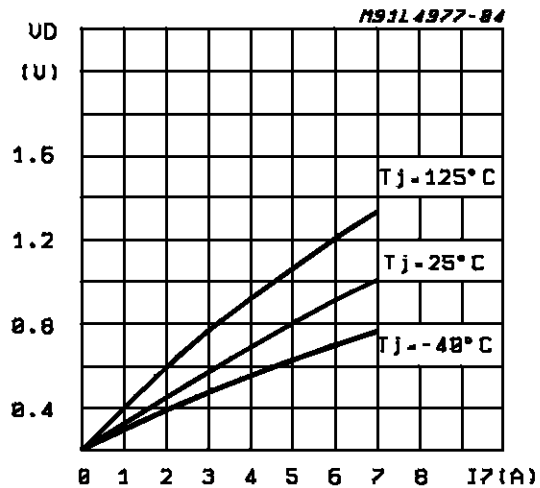


Figure 24: Dropout Voltage Between Pin 9 and Pin 7 vs. Junction Temperature

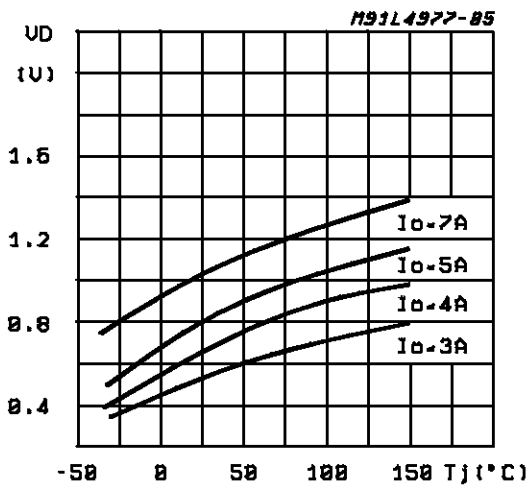


Figure 25: Power Dissipation (device only) vs. Input Voltage

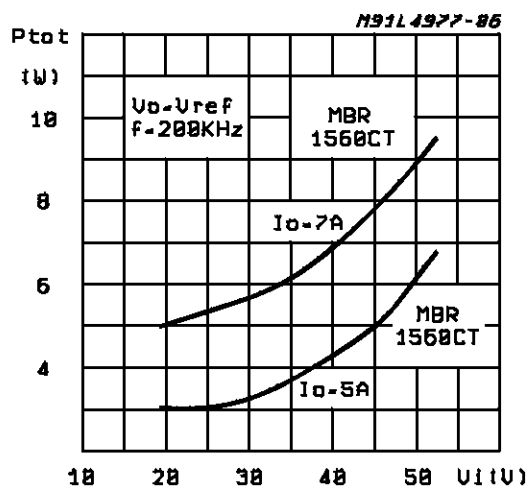


Figure 26: Power Dissipation (device only) vs. Output Voltage

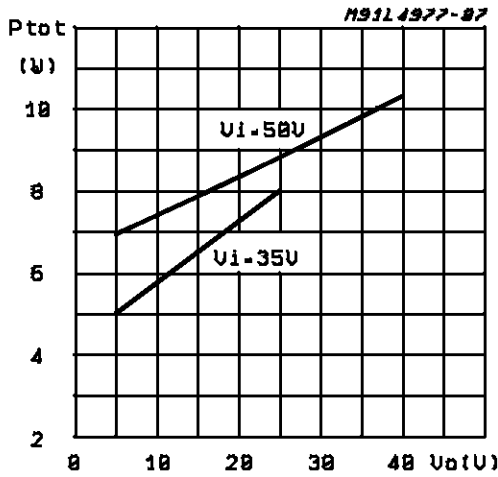


Figure 28: Efficiency vs. Output Current

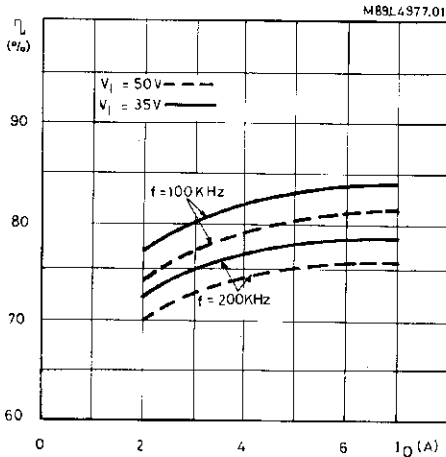


Figure 30: Efficiency vs. Output Voltage

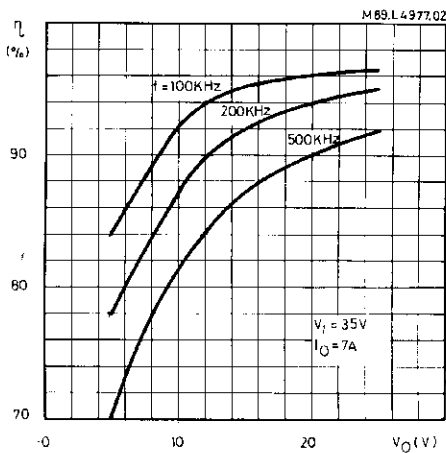


Figure 27: Heatsink Used to Derive the Device's Power Dissipation

$$R_{th} - \text{Heatsink} = \frac{T_{case} - T_{amb}}{P_d}$$

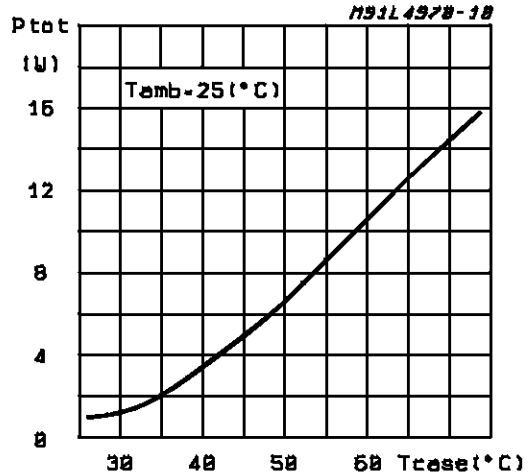


Figure 29: Efficiency vs. Output Voltage

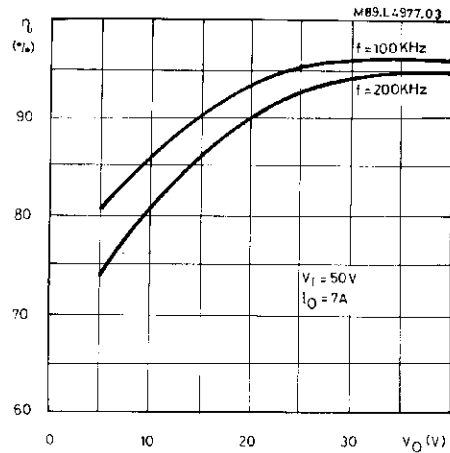


Figure 31: Open Loop Frequency Response of Error Amplifier (see fig.7C)

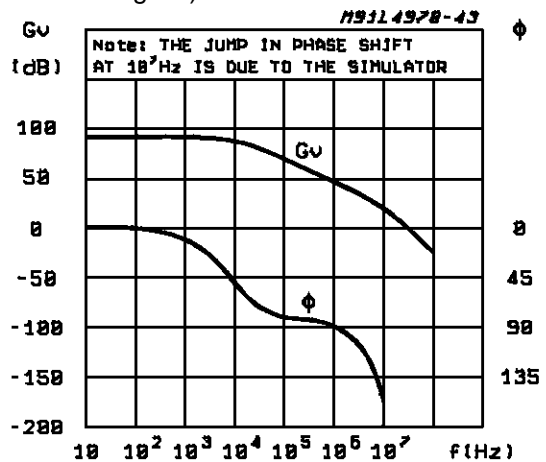


Figure 32: Power Dissipation Derating Curve

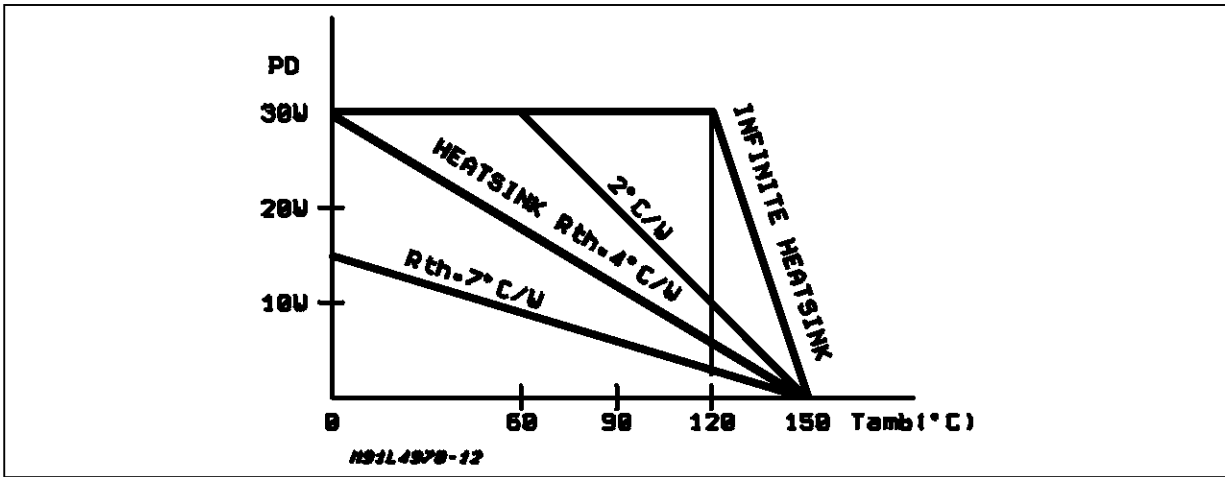
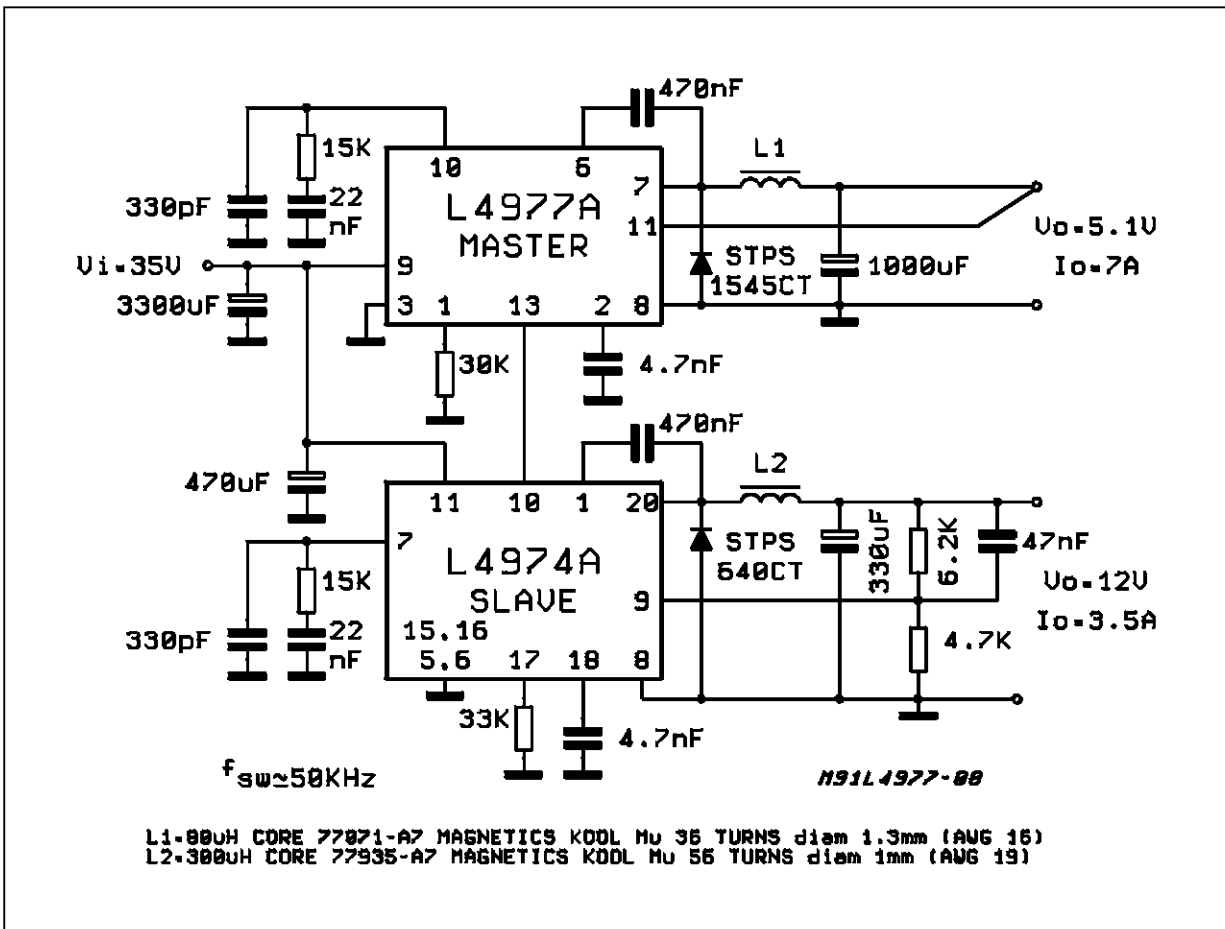


Figure 33: A5.1V/12V Multiple Supply. Note the Synchronization between the L4977A and the L4974A



L4977A

Figure 34: 5.1V/ 7A Low Cost Application

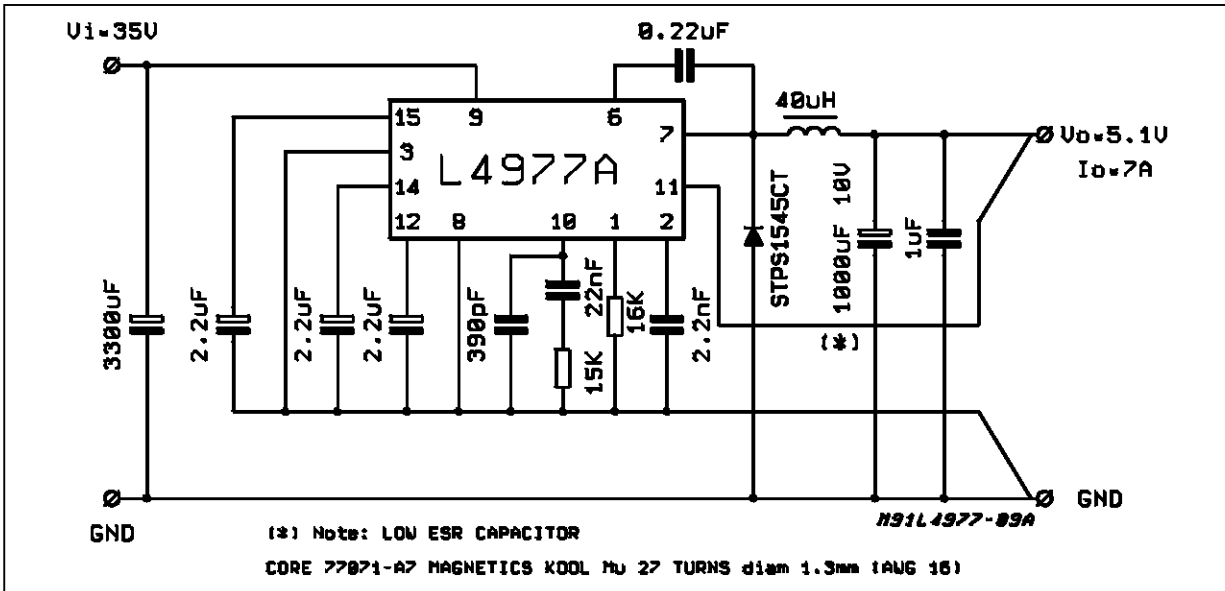


Figure 35: 7A Switching Regulator, Adjustable from 0V to 25V.

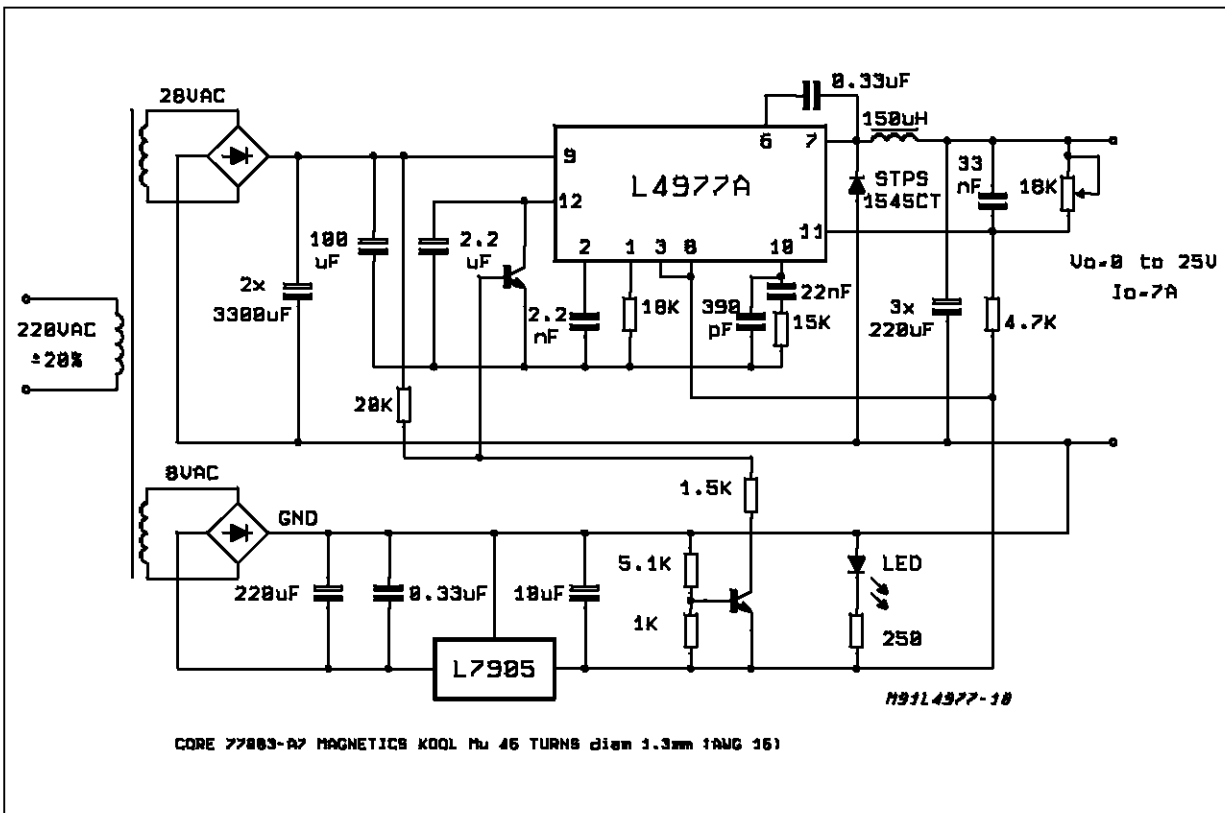
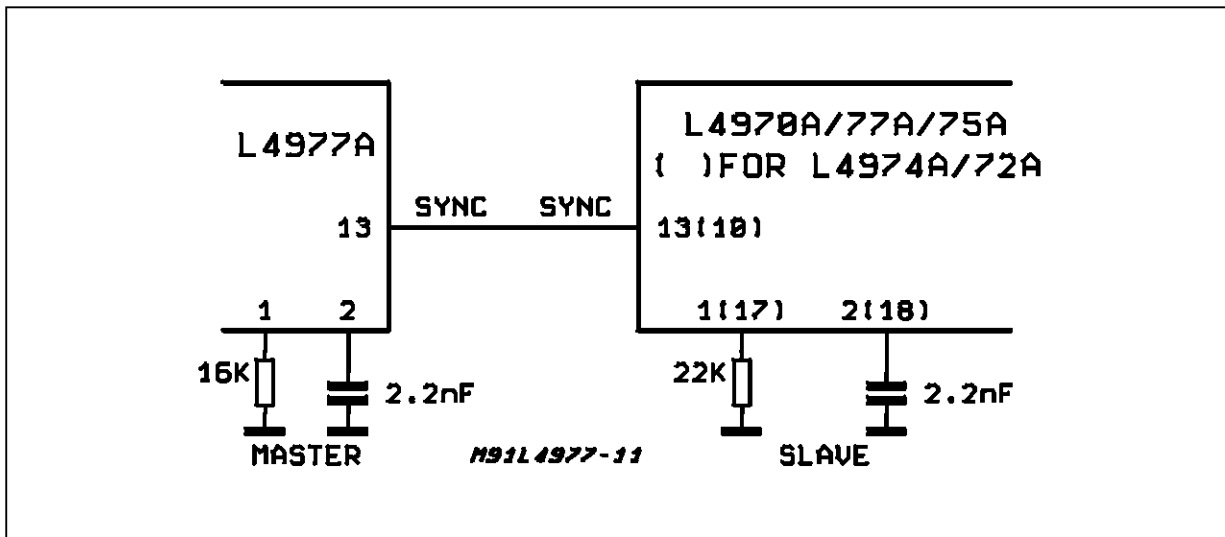


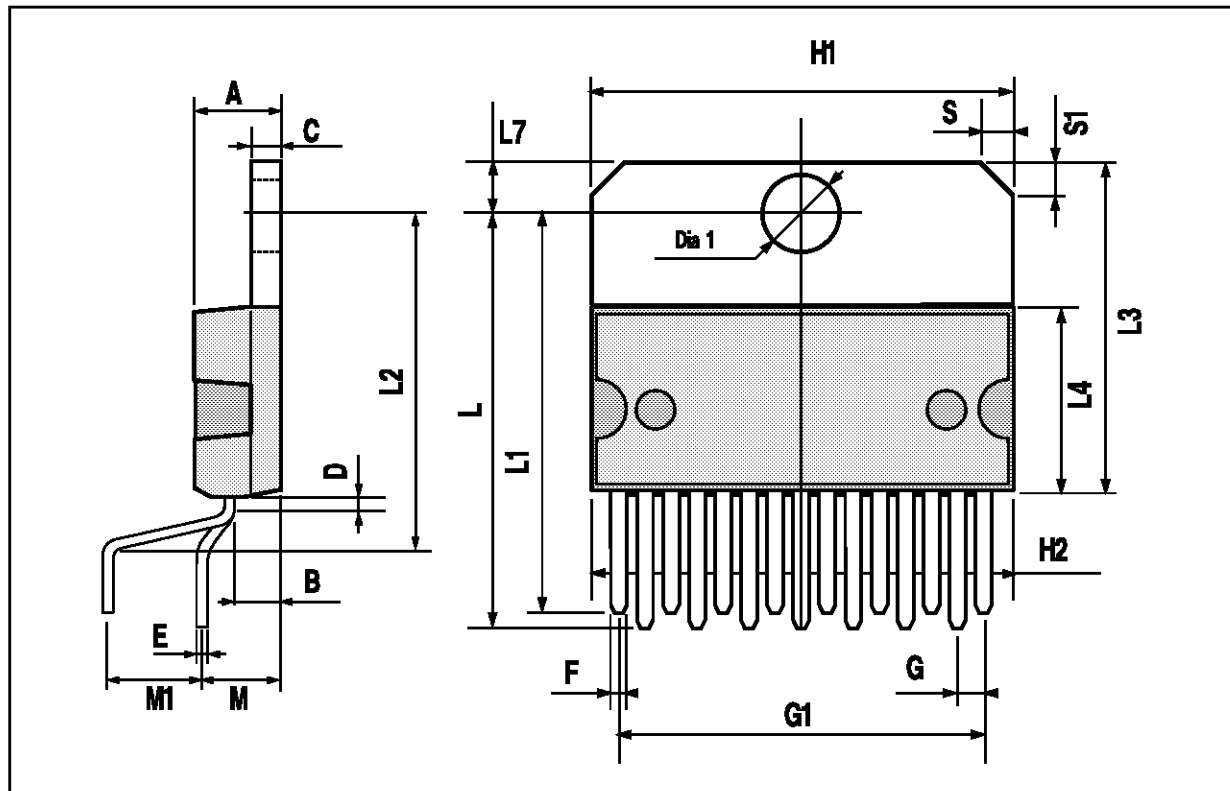
Figure 36: L4977A's Sync. Example



L4977A

MULTIWATT15 PACKAGE MECHANICAL DATA

| DIM. | mm | | | inch | | |
|------|-------|-------|-------|-------|-------|-------|
| | MIN. | TYP. | MAX. | MIN. | TYP. | MAX. |
| A | | | 5 | | | 0.197 |
| B | | | 2.65 | | | 0.104 |
| C | | | 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 |
| M | 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 |
| Dia1 | 3.65 | | 3.85 | 0.144 | | 0.152 |



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SG2525A/27A-SG3525A/27A

ABSOLUTE MAXIMUM RATINGS

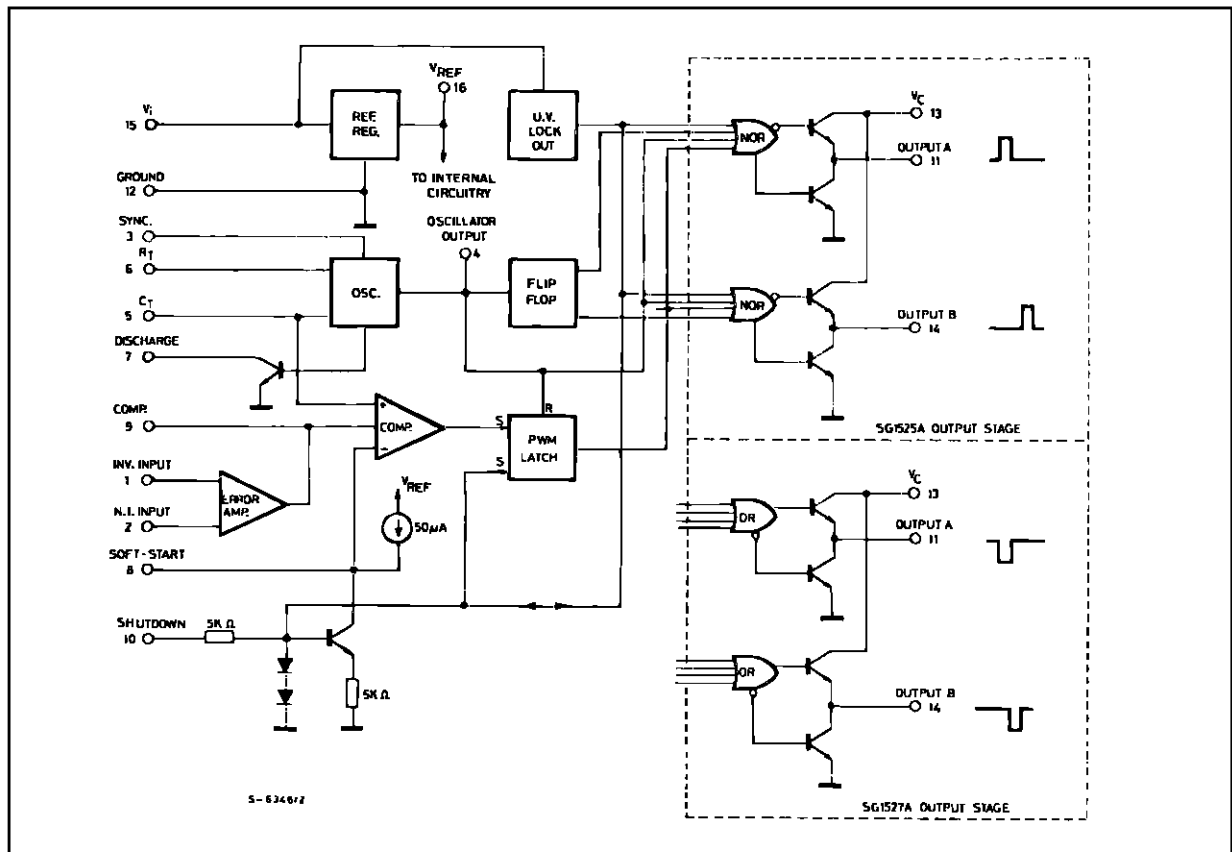
| Symbol | Parameter | Value | Unit |
|-----------|--|-----------------------|--------------------------------------|
| V_i | Supply Voltage | 40 | V |
| V_C | Collector Supply Voltage | 40 | V |
| I_{OSC} | Oscillator Charging Current | 5 | mA |
| I_o | Output Current, Source or Sink | 500 | mA |
| I_R | Reference Output Current | 50 | mA |
| I_T | Current through C_T Terminal | 5 | mA |
| | Logic Inputs | - 0.3 to + 5.5 | V |
| | Analog Inputs | - 0.3 to V_i | V |
| P_{tot} | Total Power Dissipation at $T_{amb} = 70^\circ\text{C}$ | 1000 | mW |
| T_j | Junction Temperature Range | - 55 to 150 | $^\circ\text{C}$ |
| T_{stg} | Storage Temperature Range | - 65 to 150 | $^\circ\text{C}$ |
| T_{op} | Operating Ambient Temperature : SG2525A/27A SG3525A/27A | - 25 to 85 0 to 70 | $^\circ\text{C}$ $^\circ\text{C}$ |

THERMAL DATA

| Symbol | Parameter | | SO16 | DIP16 | Unit |
|---------------------|---|-----|------|-------|---------------------------|
| $R_{th\ j-pins}$ | Thermal Resistance Junction-pins | Max | | 50 | $^\circ\text{C}/\text{W}$ |
| $R_{th\ j-amb}$ | Thermal Resistance Junction-ambient | Max | | 80 | $^\circ\text{C}/\text{W}$ |
| $R_{th\ j-alumina}$ | Thermal Resistance Junction-alumina (*) | Max | 50 | | $^\circ\text{C}/\text{W}$ |

* Thermal resistance junction-alumina with the device soldered on the middle of an alumina supporting substrate measuring 15x 20 mm ; 0.65 mm thickness with infinite heatsink.

BLOCK DIAGRAM



ELECTRICAL CHARACTERISTICS

($V_i = 20\text{ V}$, and over operating temperature, unless otherwise specified)

| Symbol | Parameter | Test Conditions | SG2525A SG2527A | | | SG3525A SG3527A | | | Unit |
|---|--------------------------|--|--------------------|-----------|---------|--------------------|---------|---------|---------------------|
| | | | Min. | Typ. | Max. | Min. | Typ. | Max. | |
| REFERENCE SECTION | | | | | | | | | |
| V_{REF} | Output Voltage | $T_j = 25\text{ }^\circ\text{C}$ | 5.05 | 5.1 | 5.15 | 5 | 5.1 | 5.2 | V |
| ΔV_{REF} | Line Regulation | $V_i = 8\text{ to }35\text{ V}$ | | 10 | 20 | | 10 | 20 | mV |
| ΔV_{REF} | Load Regulation | $I_L = 0\text{ to }20\text{ mA}$ | | 20 | 50 | | 20 | 50 | mV |
| $\Delta V_{REF}/\Delta T^*$ | Temp. Stability | Over Operating Range | | 20 | 50 | | 20 | 50 | mV |
| * | Total Output Variation | Line, Load and Temperature | 5 | | 5.2 | 4.95 | | 5.25 | V |
| | Short Circuit Current | $V_{REF} = 0\text{ } T_j = 25\text{ }^\circ\text{C}$ | | 80 | 100 | | 80 | 100 | mA |
| * | Output Noise Voltage | $10\text{ Hz} \leq f \leq 10\text{ kHz}$, $T_j = 25\text{ }^\circ\text{C}$ | | 40 | 200 | | 40 | 200 | μV_{rms} |
| ΔV_{REF}^* | Long Term Stability | $T_j = 125\text{ }^\circ\text{C}$, 1000 hrs | | 20 | 50 | | 20 | 50 | mV |
| OSCILLATOR SECTION ** | | | | | | | | | |
| *, • | Initial Accuracy | $T_j = 25\text{ }^\circ\text{C}$ | | ± 2 | ± 6 | | ± 2 | ± 6 | % |
| *, • | Voltage Stability | $V_i = 8\text{ to }35\text{ V}$ | | ± 0.3 | ± 1 | | ± 1 | ± 2 | % |
| $\Delta f/\Delta T^*$ | Temperature Stability | Over Operating Range | | ± 3 | ± 6 | | ± 3 | ± 6 | % |
| f_{MIN} | Minimum Frequency | $R_T = 200\text{ K}\Omega$ $C_T = 0.1\text{ }\mu\text{F}$ | | | 120 | | | 120 | Hz |
| f_{MAX} | Maximum Frequency | $R_T = 2\text{ K}\Omega$ $C_T = 470\text{ pF}$ | 400 | | | 400 | | | KHz |
| | Current Mirror | $I_{RT} = 2\text{ mA}$ | 1.7 | 2 | 2.2 | 1.7 | 2 | 2.2 | mA |
| *, • | Clock Amplitude | | 3 | 3.5 | | 3 | 3.5 | | V |
| *, • | Clock Width | $T_j = 25\text{ }^\circ\text{C}$ | 0.3 | 0.5 | 1 | 0.3 | 0.5 | 1 | μs |
| | Sync Threshold | | 1.2 | 2 | 2.8 | 1.2 | 2 | 2.8 | V |
| | Sync Input Current | Sync Voltage = 3.5 V | | 1 | 2.5 | | 1 | 2.5 | mA |
| ERROR AMPLIFIER SECTION ($V_{CM} = 5.1\text{ V}$) | | | | | | | | | |
| V_{OS} | Input Offset Voltage | | | 0.5 | 5 | | 2 | 10 | mV |
| I_b | Input Bias Current | | | 1 | 10 | | 1 | 10 | μA |
| I_{OS} | Input Offset Current | | | | 1 | | | 1 | μA |
| | DC Open Loop Gain | $R_L \geq 10\text{ M}\Omega$ | 60 | 75 | | 60 | 75 | | dB |
| * | Gain Bandwidth Product | $G_v = 0\text{ dB}$ $T_j = 25\text{ }^\circ\text{C}$ | 1 | 2 | | 1 | 2 | | MHz |
| *, \square | DC Transconduct. | $30\text{ K}\Omega \leq R_L \leq 1\text{ M}\Omega$ $T_j = 25\text{ }^\circ\text{C}$ | 1.1 | 1.5 | | 1.1 | 1.5 | | ms |
| | Output Low Level | | | 0.2 | 0.5 | | 0.2 | 0.5 | V |
| | Output High Level | | 3.8 | 5.6 | | 3.8 | 5.6 | | V |
| CMR | Comm. Mode Reject. | $V_{CM} = 1.5\text{ to }5.2\text{ V}$ | 60 | 75 | | 60 | 75 | | dB |
| PSR | Supply Voltage Rejection | $V_i = 8\text{ to }35\text{ V}$ | 50 | 60 | | 50 | 60 | | dB |

SG2525A/27A-SG3525A/27A

ELECTRICAL CHARACTERISTICS (continued)

| Symbol | Parameter | Test Conditions | SG2525A SG2527A | | | SG3525A SG3527A | | | Unit |
|--|------------------------|---|--------------------|------|------|--------------------|------|------|------|
| | | | Min. | Typ. | Max. | Min. | Typ. | Max. | |
| PWM COMPARATOR | | | | | | | | | |
| | Minimum Duty-cycle | | | | 0 | | | 0 | % |
| | Maximum Duty-cycle | | 45 | 49 | | 45 | 49 | | % |
| • | Input Threshold | Zero Duty-cycle | 0.7 | 0.9 | | 0.7 | 0.9 | | V |
| | | Maximum Duty-cycle | | 3.3 | 3.6 | | 3.3 | 3.6 | V |
| * | Input Bias Current | | | 0.05 | 1 | | 0.05 | 1 | μA |
| SHUTDOWN SECTION | | | | | | | | | |
| | Soft Start Current | $V_{SD} = 0\text{ V}, V_{SS} = 0\text{ V}$ | 25 | 50 | 80 | 25 | 50 | 80 | μA |
| | Soft Start Low Level | $V_{SD} = 2.5\text{ V}$ | | 0.4 | 0.7 | | 0.4 | 0.7 | V |
| | Shutdown Threshold | To outputs, $V_{SS} = 5.1\text{ V}$ $T_j = 25\text{ °C}$ | 0.6 | 0.8 | 1 | 0.6 | 0.8 | 1 | V |
| | Shutdown Input Current | $V_{SD} = 2.5\text{ V}$ | | 0.4 | 1 | | 0.4 | 1 | mA |
| * | Shutdown Delay | $V_{SD} = 2.5\text{ V } T_j = 25\text{ °C}$ | | 0.2 | 0.5 | | 0.2 | 0.5 | μs |
| OUTPUT DRIVERS (each output) ($V_C = 20\text{ V}$) | | | | | | | | | |
| | Output Low Level | $I_{\text{sink}} = 20\text{ mA}$ | | 0.2 | 0.4 | | 0.2 | 0.4 | V |
| | | $I_{\text{sink}} = 100\text{ mA}$ | | 1 | 2 | | 1 | 2 | V |
| | Output High Level | $I_{\text{source}} = 20\text{ mA}$ | 18 | 19 | | 18 | 19 | | V |
| | | $I_{\text{source}} = 100\text{ mA}$ | 17 | 18 | | 17 | 18 | | V |
| | Under-Voltage Lockout | V_{comp} and $V_{\text{ss}} = \text{High}$ | 6 | 7 | 8 | 6 | 7 | 8 | V |
| I_C | Collector Leakage | $V_C = 35\text{ V}$ | | | 200 | | | 200 | μA |
| t_r^* | Rise Time | $C_L = 1\text{ nF}, T_j = 25\text{ °C}$ | | 100 | 600 | | 100 | 600 | ns |
| t_f^* | Fall Time | $C_L = 1\text{ nF}, T_j = 25\text{ °C}$ | | 50 | 300 | | 50 | 300 | ns |
| TOTAL STANDBY CURRENT | | | | | | | | | |
| I_S | Supply Current | $V_i = 35\text{ V}$ | | 14 | 20 | | 14 | 20 | mA |

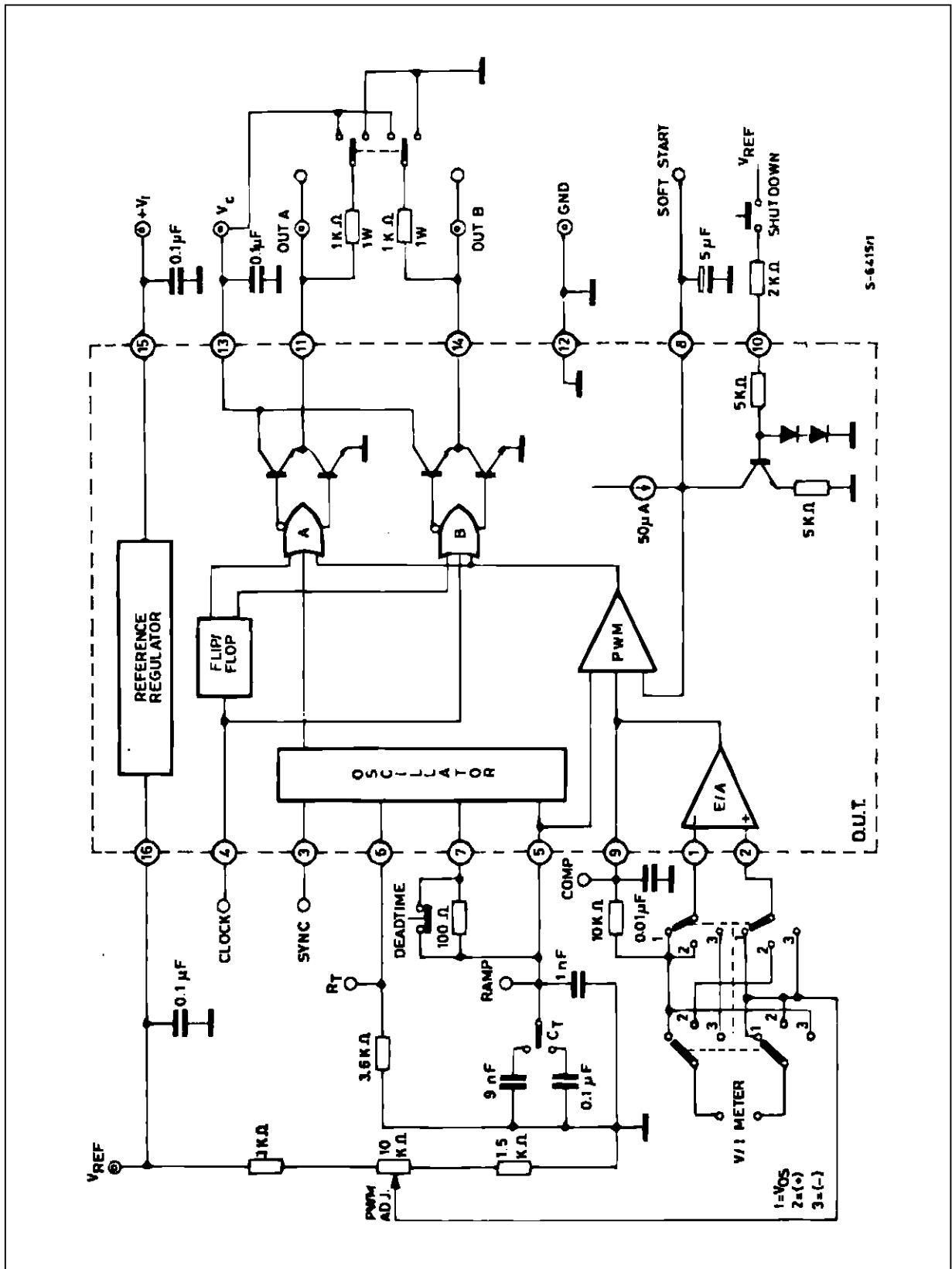
* These parameters, although guaranteed over the recommended operating conditions, are not 100% tested in production.

• Tested at $f_{\text{osc}} = 40\text{ KHz}$ ($R_T = 3.6\text{ K}\Omega$, $C_T = 0.1\text{ }\mu\text{F}$, $R_D = 0\text{ }\Omega$). Approximate oscillator frequency is defined by:

$$f = \frac{1}{C_T(0.7 R_T + 3 R_D)}$$

■ DC transconductance (g_M) relates to DC open-loop voltage gain (G_v) according to the following equation: $G_v = g_M R_L$ where R_L is the resistance from pin 9 to ground. The minimum g_M specification is used to calculate minimum G_v when the error amplifier output is loaded.

TEST CIRCUIT



RECOMMENDED OPERATING CONDITIONS (•)

| Parameter | Value |
|---|--------------------------------|
| Input Voltage (V_i) | 8 to 35 V |
| Collector Supply Voltage (V_C) | 4.5 to 35 V |
| Sink/Source Load Current (steady state) | 0 to 100 mA |
| Sink/Source Load Current (peak) | 0 to 400 mA |
| Reference Load Current | 0 to 20 mA |
| Oscillator Frequency Range | 100 Hz to 400 KHz |
| Oscillator Timing Resistor | 2 K Ω to 150 K Ω |
| Oscillator Timing Capacitor | 0.001 μ F to 0.1 μ F |
| Dead Time Resistor Range | 0 to 500 Ω |

(•) Range over which the device is functional and parameter limits are guaranteed.

Figure 1 : Oscillator Charge Time vs. R_T and C_T .

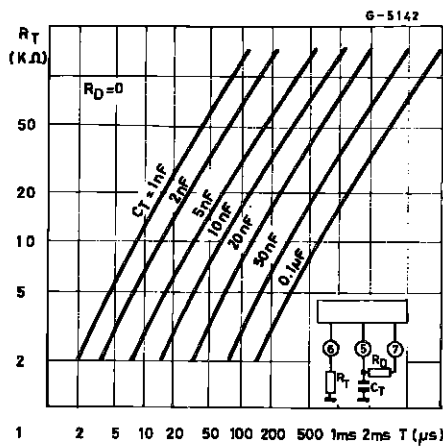


Figure 2 : Oscillator Discharge Time vs. R_D and C_T .

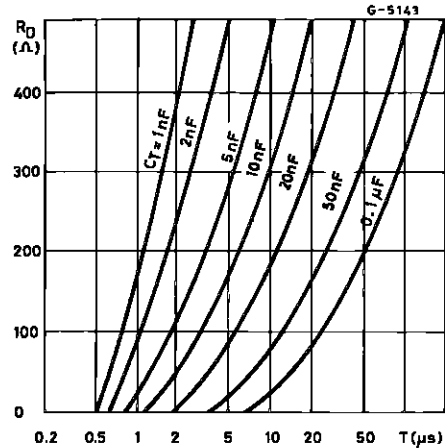


Figure 3 : SG1525A Output Saturation Characteristics.

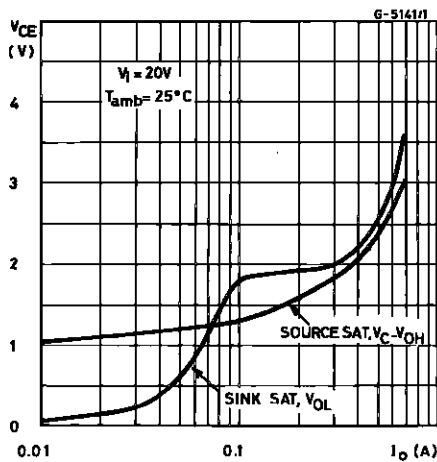


Figure 4 : Error Amplifier Voltage Gain and Phase vs. Frequency.

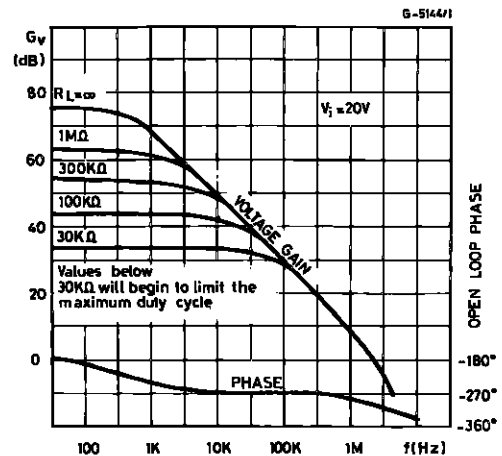
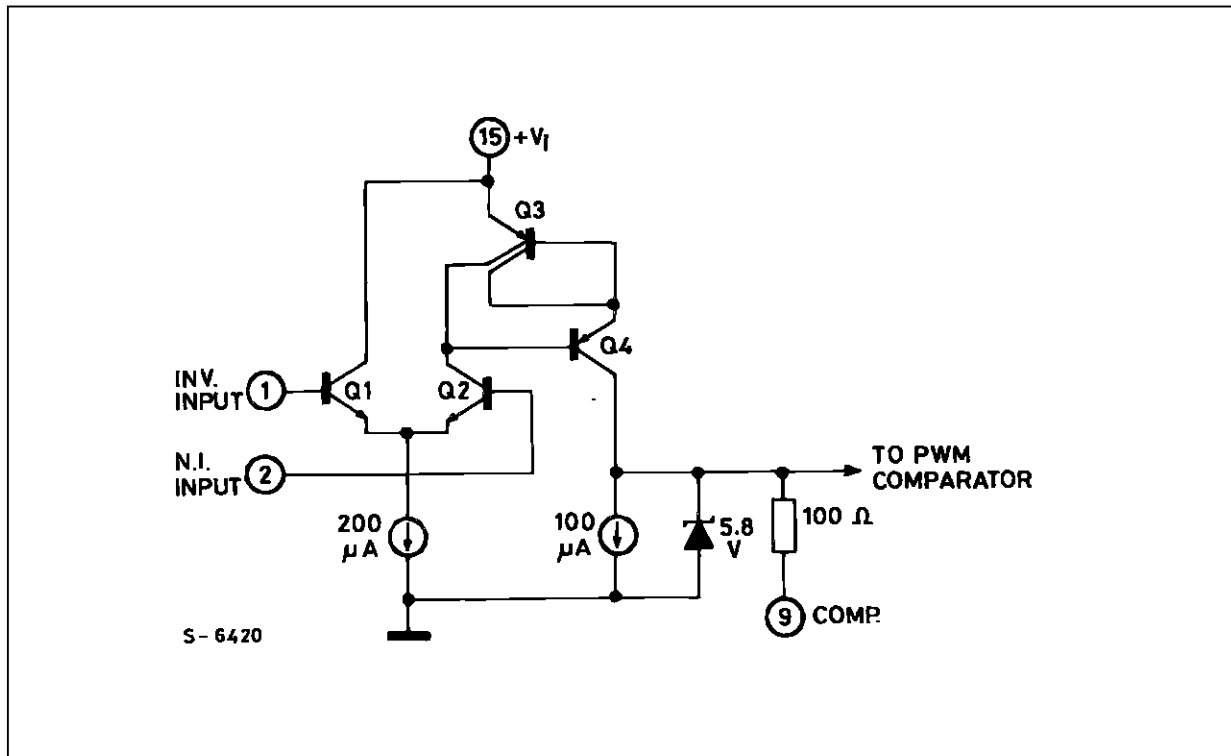


Figure 5 : SG1525A Error Amplifier.



PRINCIPLES OF OPERATION

SHUTDOWN OPTIONS (see Block Diagram)

Since both the compensation and soft-start terminals (Pins 9 and 8) have current source pull-ups, either can readily accept a pull-down signal which only has to sink a maximum of 100 μA to turn off the outputs. This is subject to the added requirement of discharging whatever external capacitance may be attached to these pins.

An alternate approach is the use of the shutdown circuitry of Pin 10 which has been improved to enhance the available shutdown options. Activating this circuit by applying a positive signal on Pin 10 performs two functions : the PWM latch is immedi-

ately set providing the fastest turn-off signal to the outputs ; and a 150 μA current sink begins to discharge the external soft-start capacitor. If the shutdown command is short, the PWM signal is terminated without significant discharge of the soft-start capacitor, thus, allowing, for example, a convenient implementation of pulse-by-pulse current limiting. Holding Pin 10 high for a longer duration, however, will ultimately discharge this external capacitor, recycling slow turn-on upon release.

Pin 10 should not be left floating as noise pickup could conceivably interrupt normal operation.

Figure 6 : SG1525A Oscillator Schematic.

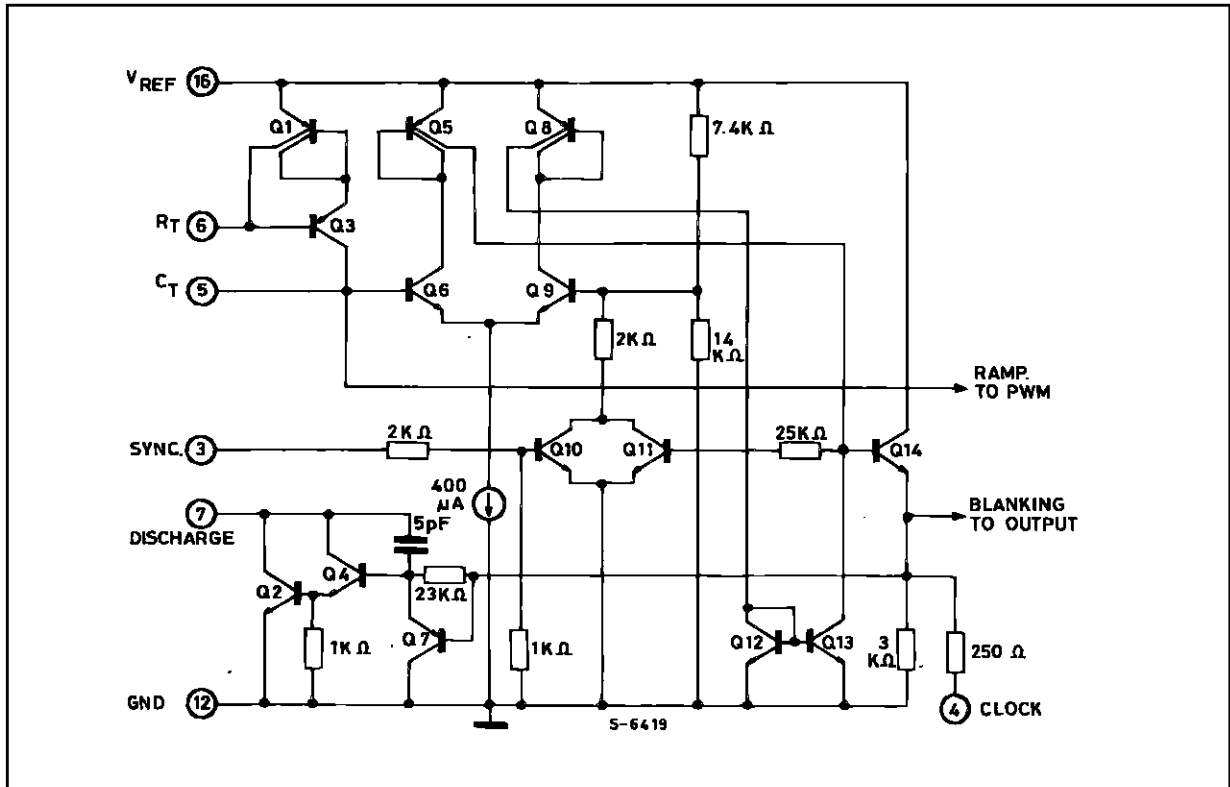


Figure 7 : SG1525A Output Circuit (1/2 circuit shown).

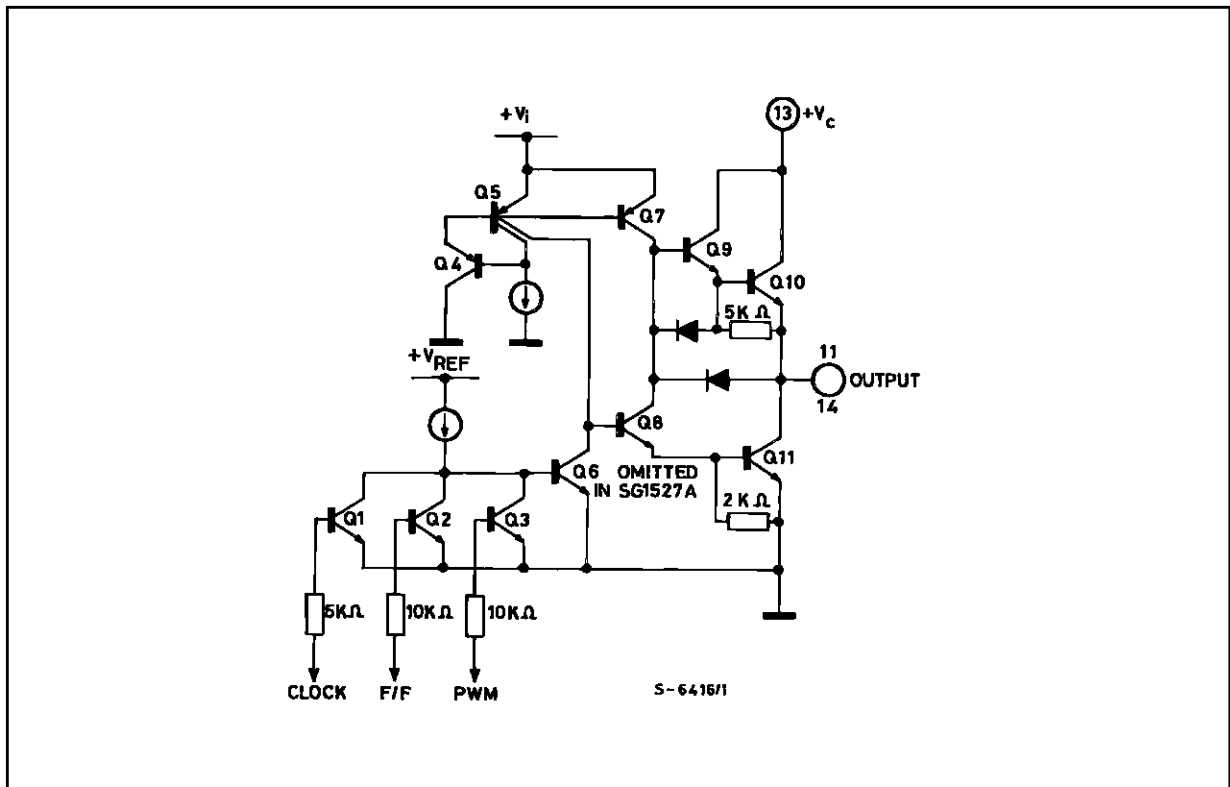
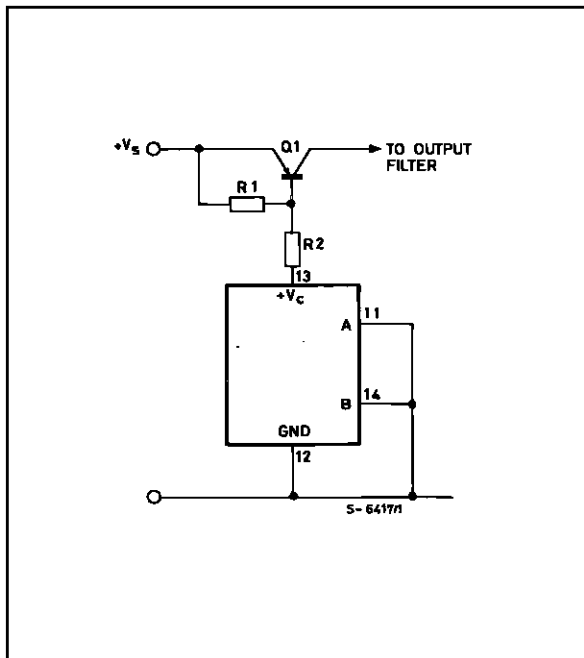
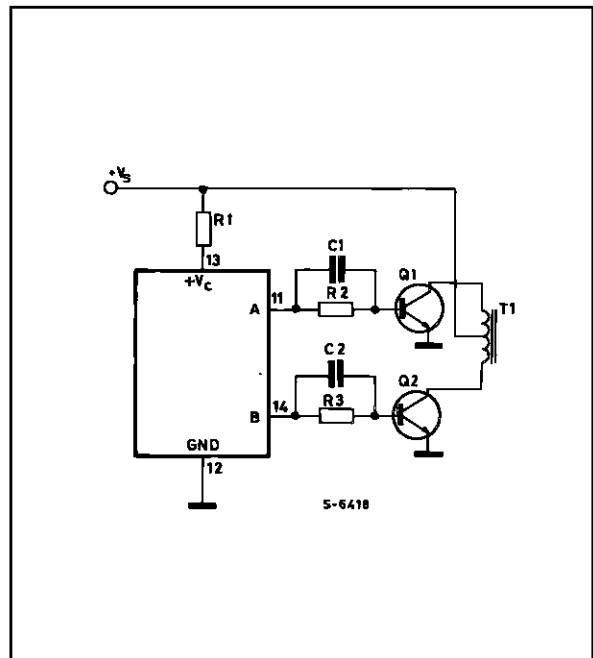


Figure 8.



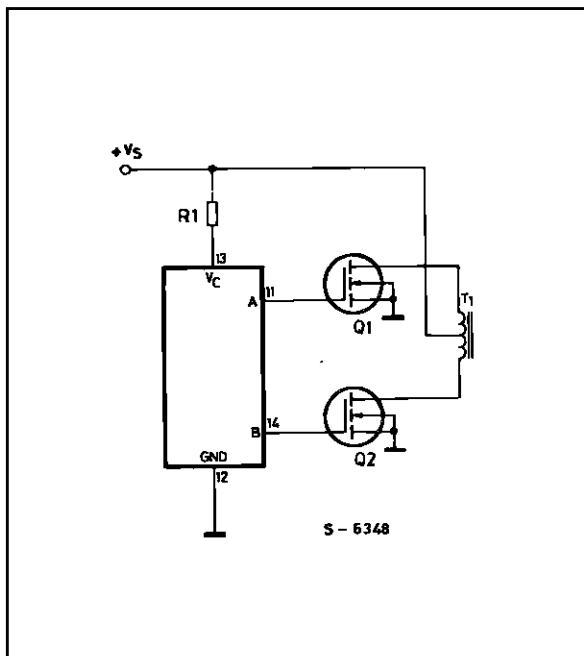
For single-ended supplies, the driver outputs are grounded. The Vc terminal is switched to ground by the totem-pole source transistors on alternate oscillator cycles.

Figure 9.



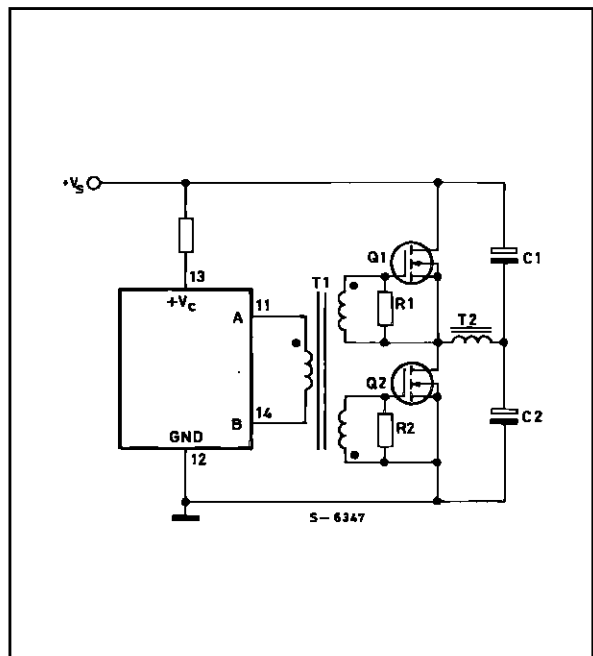
In conventional push-pull bipolar designs, forward base drive is controlled by R1 - R3. Rapid turn-off times for the power devices are achieved with speed-up capacitors C1 and C2.

Figure 10.



The low source impedance of the output drivers provides rapid charging of Power Mos input capacitance while minimizing external components.

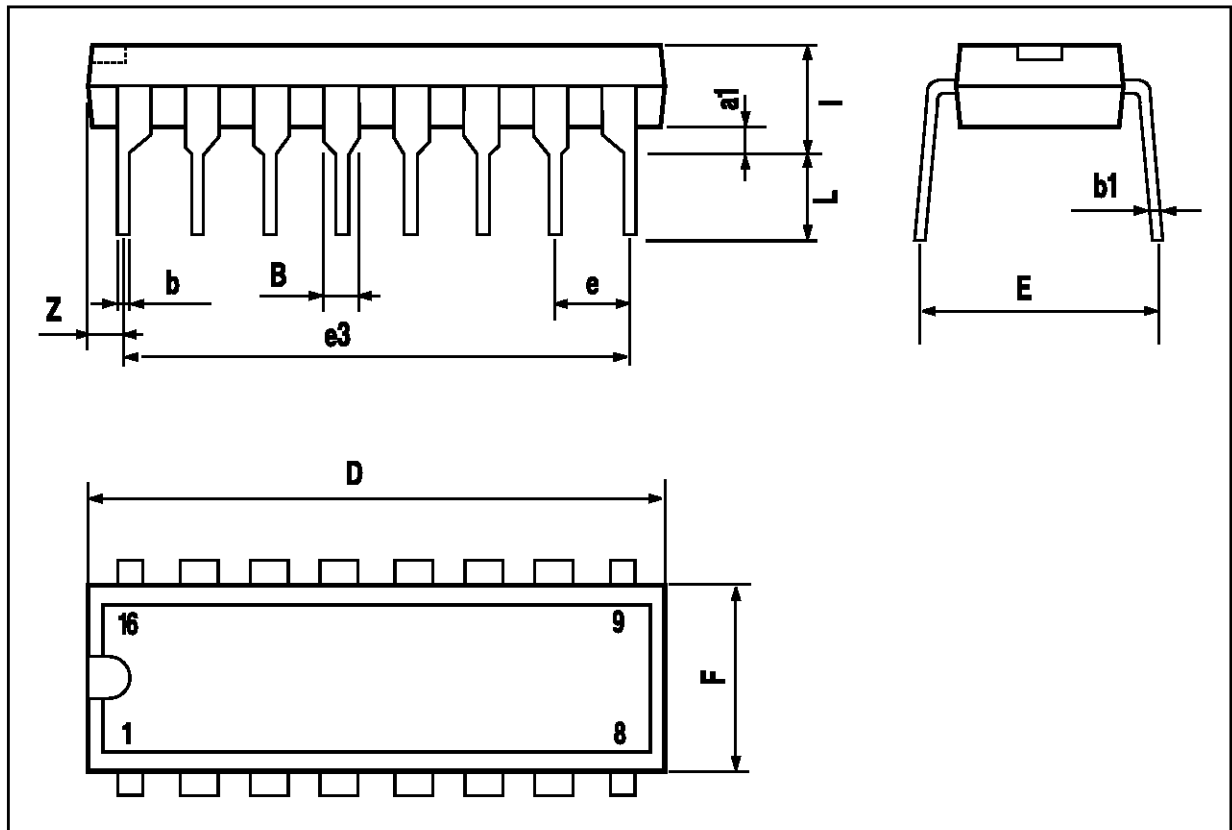
Figure 11.



Low power transformers can be driven directly by the SG1525A. Automatic reset occurs during dead time, when both ends of the primary winding are switched to ground.

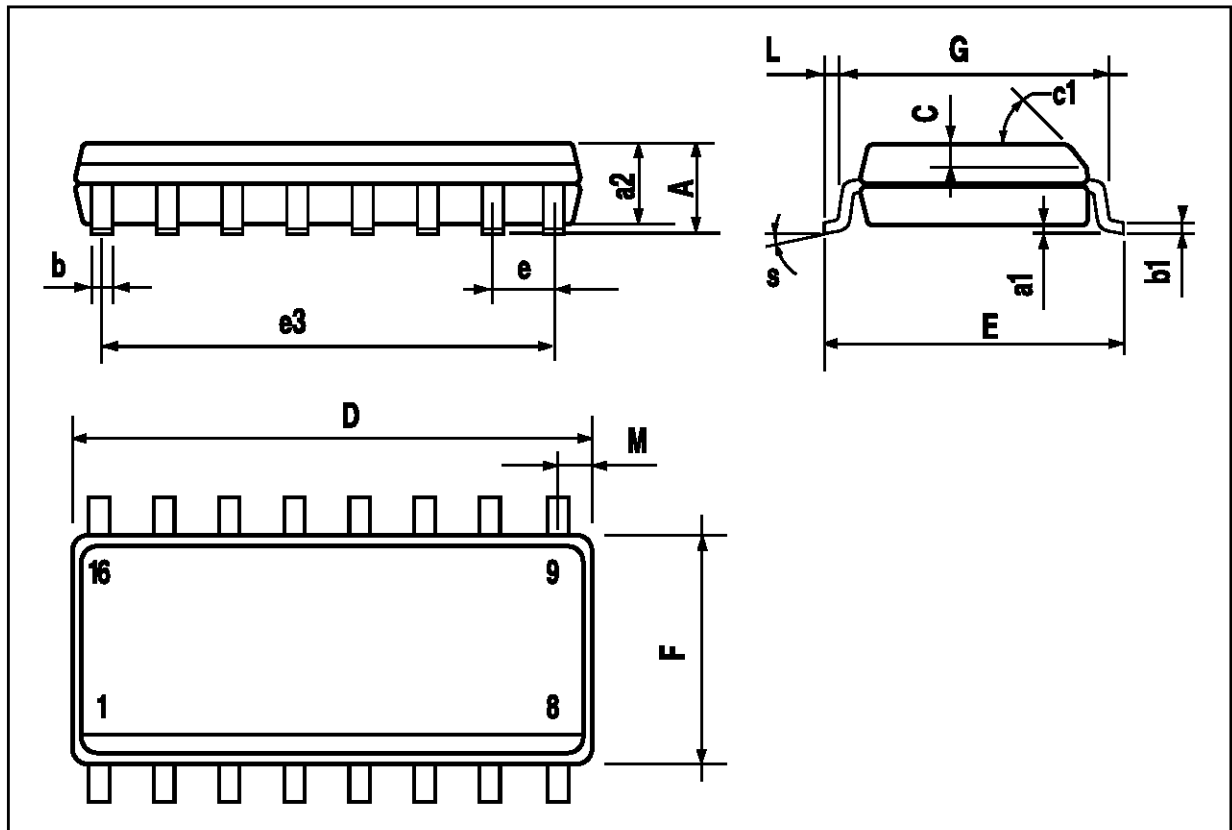
DIP16 PACKAGE MECHANICAL DATA

| DIM. | mm | | | inch | | |
|------|------|-------|------|-------|-------|-------|
| | MIN. | TYP. | MAX. | MIN. | TYP. | MAX. |
| a1 | 0.51 | | | 0.020 | | |
| B | 0.77 | | 1.65 | 0.030 | | 0.065 |
| b | | 0.5 | | | 0.020 | |
| b1 | | 0.25 | | | 0.010 | |
| D | | | 20 | | | 0.787 |
| E | | 8.5 | | | 0.335 | |
| e | | 2.54 | | | 0.100 | |
| e3 | | 17.78 | | | 0.700 | |
| F | | | 7.1 | | | 0.280 |
| l | | | 5.1 | | | 0.201 |
| L | | 3.3 | | | 0.130 | |
| Z | | | 1.27 | | | 0.050 |



SO16 NARROW PACKAGE MECHANICAL DATA

| DIM. | mm | | | inch | | |
|------|------------|------|------|-------|-------|-------|
| | MIN. | TYP. | MAX. | MIN. | TYP. | MAX. |
| A | | | 1.75 | | | 0.069 |
| a1 | 0.1 | | 0.25 | 0.004 | | 0.009 |
| a2 | | | 1.6 | | | 0.063 |
| b | 0.35 | | 0.46 | 0.014 | | 0.018 |
| b1 | 0.19 | | 0.25 | 0.007 | | 0.010 |
| C | | 0.5 | | | 0.020 | |
| c1 | 45° (typ.) | | | | | |
| D | 9.8 | | 10 | 0.386 | | 0.394 |
| E | 5.8 | | 6.2 | 0.228 | | 0.244 |
| e | | 1.27 | | | 0.050 | |
| e3 | | 8.89 | | | 0.350 | |
| F | 3.8 | | 4.0 | 0.150 | | 0.157 |
| L | 0.4 | | 1.27 | 0.150 | | 0.050 |
| M | | | 0.62 | | | 0.024 |
| S | 8° (max.) | | | | | |



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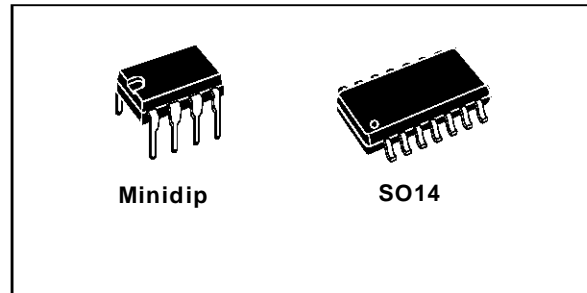
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CURRENT MODE PWM CONTROLLER

- OPTIMIZED FOR OFF-LINE AND DC TO DC CONVERTERS
- LOW START-UP CURRENT (< 1 mA)
- AUTOMATIC FEED FORWARD COMPENSATION
- PULSE-BY-PULSE CURRENT LIMITING
- ENHANCED LOAD RESPONSE CHARACTERISTICS
- UNDER-VOLTAGE LOCKOUT WITH HYSTERESIS
- DOUBLE PULSE SUPPRESSION
- HIGH CURRENT TOTEM POLE OUTPUT
- INTERNALLY TRIMMED BANDGAP REFERENCE
- 500 KHz OPERATION
- LOW R_o ERROR AMP



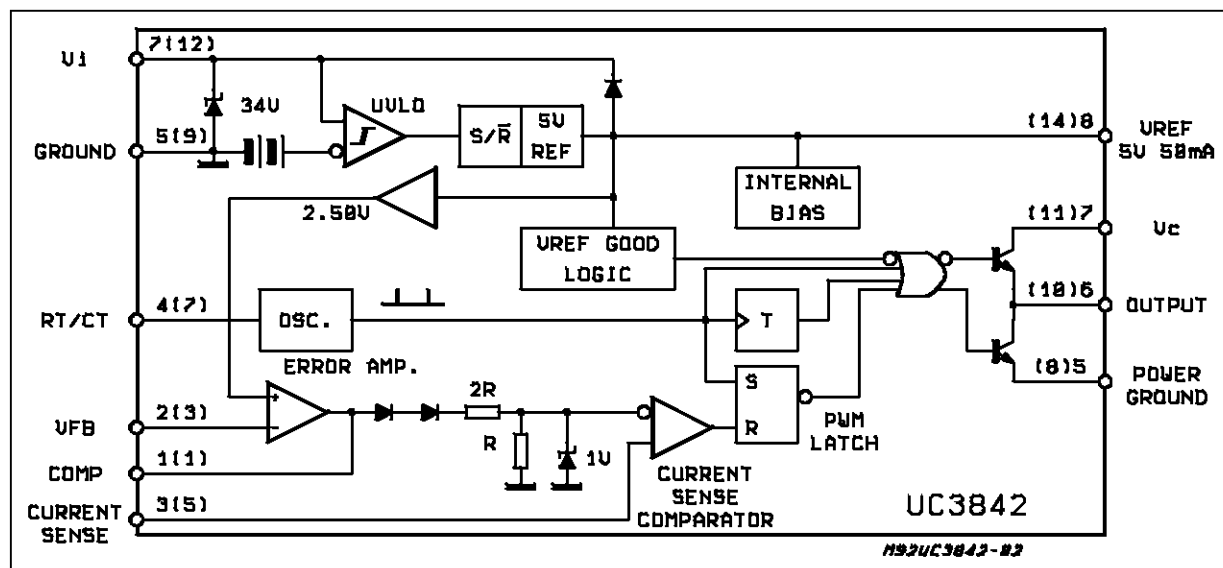
logic to insure latched operation, a PWM comparator which also provides current limit control, and a totem pole output stage designed to source or sink high peak current. The output stage, suitable for driving N-Channel MOSFETs, is low in the off-state.

Differences between members of this family are the under-voltage lockout thresholds and maximum duty cycle ranges. The UC3842 and UC3844 have UVLO thresholds of 16V (on) and 10V (off), ideally suited off-line applications. The corresponding thresholds for the UC3843 and UC3845 are 8.5 V and 7.9 V. The UC3842 and UC3843 can operate to duty cycles approaching 100%. A range of the zero to < 50 % is obtained by the UC3844 and UC3845 by the addition of an internal toggle flip flop which blanks the output off every other clock cycle.

DESCRIPTION

The UC3842/3/4/5 family of control ICs provides the necessary features to implement off-line or DC to DC fixed frequency current mode control schemes with a minimal external parts count. Internally implemented circuits include under voltage lockout featuring start-up current less than 1 mA, a precision reference trimmed for accuracy at the error amp input,

BLOCK DIAGRAM (toggle flip flop used only in U3844 and UC3845)



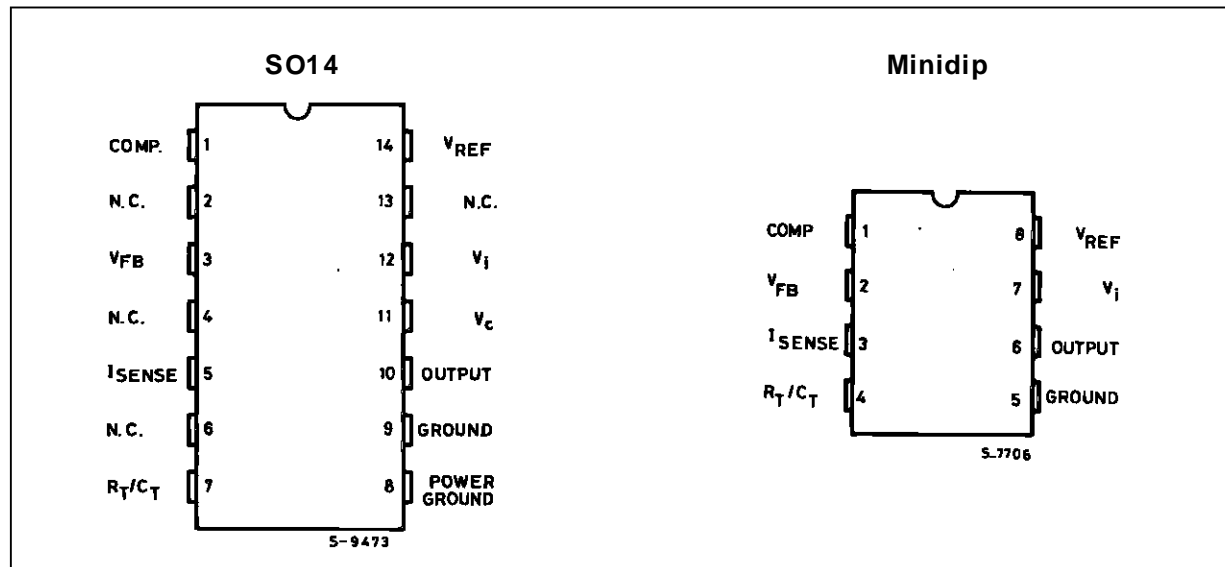
UC2842/3/4/5-UC3842/3/4/5

ABSOLUTE MAXIMUM RATINGS

| Symbol | Parameter | Value | Unit |
|------------------|---|---------------|------------------|
| V_i | Supply Voltage (low impedance source) | 30 | V |
| V_i | Supply Voltage ($I_i < 30\text{mA}$) | Self Limiting | |
| I_o | Output Current | ± 1 | A |
| E_o | Output Energy (capacitive load) | 5 | μJ |
| | Analog Inputs (pins 2, 3) | -0.3 to 6.3 | V |
| | Error Amplifier Output Sink Current | 10 | mA |
| P_{tot} | Power Dissipation at $T_{\text{amb}} \leq 50\text{ }^\circ\text{C}$ (minidip, DIP-14) | 1 | W |
| P_{tot} | Power Dissipation at $T_{\text{amb}} \leq 25\text{ }^\circ\text{C}$ (SO14) | 725 | mW |
| T_{stg} | Storage Temperature Range | -65 to 150 | $^\circ\text{C}$ |
| T_L | Lead Temperature (soldering 10s) | 300 | $^\circ\text{C}$ |

* All voltages are with respect to pin 5, all currents are positive into the specified terminal.

PIN CONNECTIONS (top views)



ORDERING NUMBERS

| Type | Minidip | SO14 |
|--------|---------|---------|
| UC2842 | UC2842N | UC2842D |
| UC3843 | UC2843N | UC2843D |
| UC2844 | UC2844N | UC2844D |
| UC2845 | UC2845N | UC2845D |
| UC3842 | UC3842N | UC3842D |
| UC3843 | UC3843N | UC3843D |
| UC3844 | UC3844N | UC3844D |
| UC3845 | UC3845N | UC3845D |

THERMAL DATA

| Symbol | Description | Minidip | SO14 | Unit |
|-----------------------------|---|---------|------|------------------|
| $R_{\text{th}j-\text{amb}}$ | Thermal Resistance Junction-ambient. max. | 100 | 165 | $^\circ\text{C}$ |

ELECTRICAL CHARACTERISTICS (Unless otherwise stated, these specifications apply for $-25 \leq T_{amb} \leq 85^{\circ}\text{C}$ for UC2824X; $0 \leq T_{amb} \leq 70^{\circ}\text{C}$ for UC384X; $V_i = 15\text{V}$ (note 5); $R_T = 10\text{K}$; $C_T = 3.3\text{nF}$)

| Symbol | Parameter | Test Conditions | UC284X | | | UC384X | | | Unit |
|------------------------------|--------------------------|--|--------|------|------|--------|------|------|------------------------|
| | | | Min. | Typ. | Max. | Min. | Typ. | Max. | |
| REFERENCE SECTION | | | | | | | | | |
| V_{REF} | Output Voltage | $T_j = 25^{\circ}\text{C}$ $I_o = 1\text{mA}$ | 4.95 | 5.00 | 5.05 | 4.90 | 5.00 | 5.10 | V |
| ΔV_{REF} | Line Regulation | $12\text{V} \leq V_i \leq 25\text{V}$ | | 6 | 20 | | 6 | 20 | mV |
| ΔV_{REF} | Load Regulation | $1 \leq I_o \leq 20\text{mA}$ | | 6 | 25 | | 6 | 25 | mV |
| $\Delta V_{REF}/\Delta T$ | Temperature Stability | (Note 2) | | 0.2 | 0.4 | | 0.2 | 0.4 | mV/ $^{\circ}\text{C}$ |
| | Total Output Variant | Line, Load, Temperature (2) | 4.9 | | 5.1 | 4.82 | | 5.18 | V |
| e_N | Output Noise Voltage | $10\text{Hz} \leq f \leq 10\text{KHz}$ $T_j = 25^{\circ}\text{C}$ (2) | | 50 | | | 50 | | μV |
| | Long Term Stability | $T_{amb} = 125^{\circ}\text{C}$, 1000Hrs (2) | | 5 | 25 | | 5 | 25 | mV |
| I_{SC} | Output Short Circuit | | -30 | -100 | -180 | -30 | -100 | -180 | mA |
| OSCILLATOR SECTION | | | | | | | | | |
| f_s | Initial Accuracy | $T_j = 25^{\circ}\text{C}$ (6) | 47 | 52 | 57 | 47 | 52 | 57 | KHz |
| | Voltage Stability | $12 \leq V_i \leq 25\text{V}$ | | 0.2 | 1 | | 0.2 | 1 | % |
| | Temperature Stability | $T_{MIN} \leq T_{amb} \leq T_{MAX}$ (2) | | 5 | | | 5 | | % |
| V_4 | Amplitude | V_{PIN4} Peak to Peak | | 1.7 | | | 1.7 | | V |
| ERROR AMP SECTION | | | | | | | | | |
| V_2 | Input Voltage | $V_{PIN1} = 2.5\text{V}$ | 2.45 | 2.50 | 2.55 | 2.42 | 2.50 | 2.58 | V |
| I_b | Input Bias Current | | | -0.3 | -1 | | -0.3 | -2 | μA |
| | A_{VOL} | $2 \leq V_o \leq 4\text{V}$ | 65 | 90 | | 65 | 90 | | dB |
| B | Unity Gain Bandwidth | (2) | 0.7 | 1 | | 0.7 | 1 | | MHz |
| SVR | Supply Voltage Rejection | $12\text{V} \leq V_i \leq 25\text{V}$ | 60 | 70 | | 60 | 70 | | dB |
| I_o | Output Sink Current | $V_{PIN2} = 2.7\text{V}$ $V_{PIN1} = 1.1\text{V}$ | 2 | 6 | | 2 | 6 | | V |
| I_o | Output Source Current | $V_{PIN2} = 2.3\text{V}$ $V_{PIN1} = 5\text{V}$ | -0.5 | -0.8 | | -0.5 | -0.8 | | mA |
| | V_{OUT} High | $V_{PIN2} = 2.3\text{V}$; $R_L = 15\text{K}\Omega$ to Ground | 5 | 6 | | 5 | 6 | | V |
| | V_{OUT} Low | $V_{PIN2} = 2.7\text{V}$; $R_L = 15\text{K}\Omega$ to Pin 8 | | 0.7 | 1.1 | | 0.7 | 1.1 | V |
| CURRENT SENSE SECTION | | | | | | | | | |
| G_v | Gain | (3 & 4) | 2.85 | 3 | 3.15 | 2.8 | 3 | 3.2 | V/V |
| V_3 | Maximum Input Signal | $V_{PIN1} = 5\text{V}$ (3) | 0.9 | 1 | 1.1 | 0.9 | 1 | 1.1 | V |
| SVR | Supply Voltage Rejection | $12 \leq V_i \leq 25\text{V}$ (3) | | 70 | | | 70 | | dB |
| I_b | Input Bias Current | | | -2 | -10 | | -2 | -10 | μA |
| | Delay to Output | | | 150 | 300 | | 150 | 300 | ns |
| OUTPUT SECTION | | | | | | | | | |
| I_{OL} | Output Low Level | $I_{SINK} = 20\text{mA}$ | | 0.1 | 0.4 | | 0.1 | 0.4 | V |
| | | $I_{SINK} = 200\text{mA}$ | | 1.5 | 2.2 | | 1.5 | 2.2 | V |
| I_{OH} | Output High Level | $I_{SOURCE} = 20\text{mA}$ | 13 | 13.5 | | 13 | 13.5 | | V |
| | | $I_{SOURCE} = 200\text{mA}$ | 12 | 13.5 | | 12 | 13.5 | | V |
| t_r | Rise Time | $T_j = 25^{\circ}\text{C}$ $C_L = 1\text{nF}$ (2) | | 50 | 150 | | 50 | 150 | ns |
| t_f | Fall Time | $T_j = 25^{\circ}\text{C}$ $C_L = 1\text{nF}$ (2) | | 50 | 150 | | 50 | 150 | ns |

UC2842/3/4/5-UC3842/3/4/5

ELECTRICAL CHARACTERISTICS (continued)

| Symbol | Parameter | Test Conditions | UC284X | | | UC384X | | | Unit |
|--------------------------------------|-------------------------------------|----------------------------|--------|------|------|--------|------|------|------|
| | | | Min. | Typ. | Max. | Min. | Typ. | Max. | |
| UNDER-VOLTAGE LOCKOUT SECTION | | | | | | | | | |
| | Start Threshold | X842/4 | 15 | 16 | 17 | 14.5 | 16 | 17.5 | V |
| | | X843/5 | 7.8 | 8.4 | 9.0 | 7.8 | 8.4 | 9 | V |
| | Min Operating Voltage After Turn-on | X842/4 | 9 | 10 | 11 | 8.5 | 10 | 11.5 | V |
| | | X843/5 | 7.0 | 7.6 | 8.2 | 7.0 | 7.6 | 8.2 | V |
| PWM SECTION | | | | | | | | | |
| | Maximum Duty Cycle | X842/3 | 93 | 97 | 100 | 93 | 97 | 100 | % |
| | | X844/5 | 46 | 48 | 50 | 47 | 48 | 50 | % |
| | Minimum Duty Cycle | | | | 0 | | | 0 | % |
| TOTAL STANDBY CURRENT | | | | | | | | | |
| I_{st} | Start-up Current | | | 0.5 | 1 | | 0.5 | 1 | mA |
| I_i | Operating Supply Current | $V_{PIN2} = V_{PIN3} = 0V$ | | 11 | 20 | | 11 | 20 | mA |
| V_{iz} | Zener Voltage | $I_i = 25mA$ | | 34 | | | 34 | | V |

- Notes :**
2. These parameters, although guaranteed, are not 100% tested in production.
 3. Parameter measured at trip point of latch with $V_{PIN2} = 0$.
 4. Gain defined as :

$$A = \frac{\Delta V_{PIN1}}{\Delta V_{PIN3}} ; 0 \leq V_{PIN3} \leq 0.8V$$
 5. Adjust V_i above the start threshold before setting at 15 V.
 6. Output frequency equals oscillator frequency for the UC3842 and UC3843.
 Output frequency is one half oscillator frequency for the UC3844 and UC3845.

Figure 1 : Error Amp Configuration.

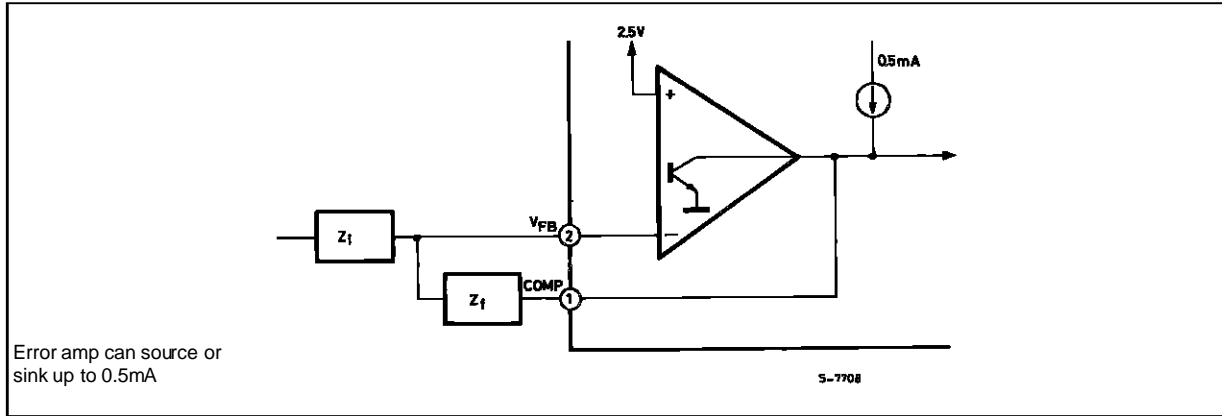
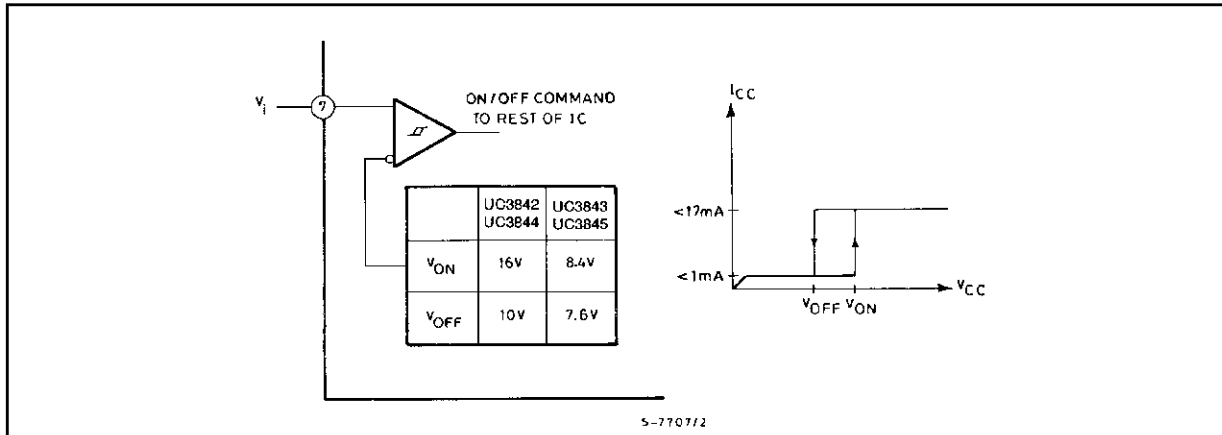


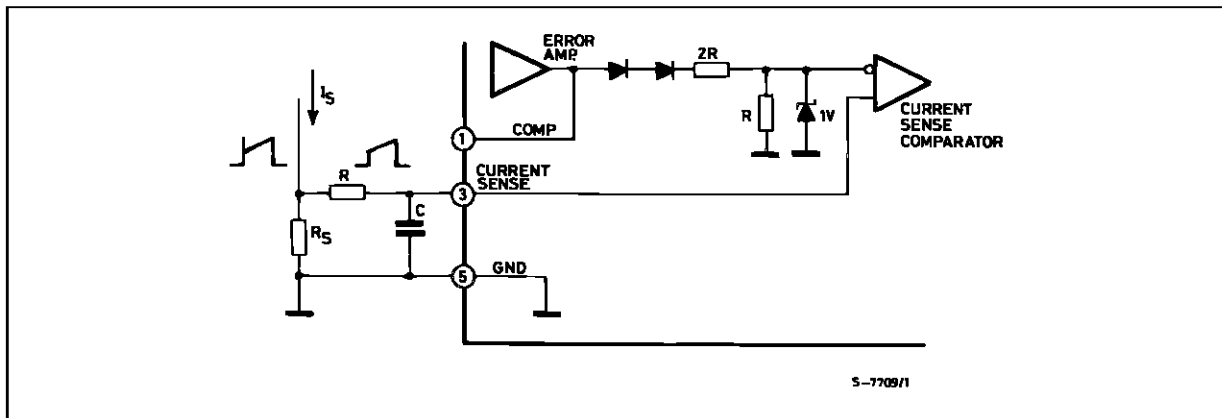
Figure 2 : Under Voltage Lockout.



During Under-Voltage Lockout, the output driver is biased to sink minor amounts of current. Pin 6 should be shunted to ground with a bleeder resistor

to prevent activating the power switch with extraneous leakage currents.

Figure 3 : Current Sense Circuit.



Peak current (i_s) is determined by the formula

$$I_{S \max} \approx \frac{1.0 \text{ V}}{R_S}$$

A small RC filter may be required to suppress switch transients.

Figure 4.

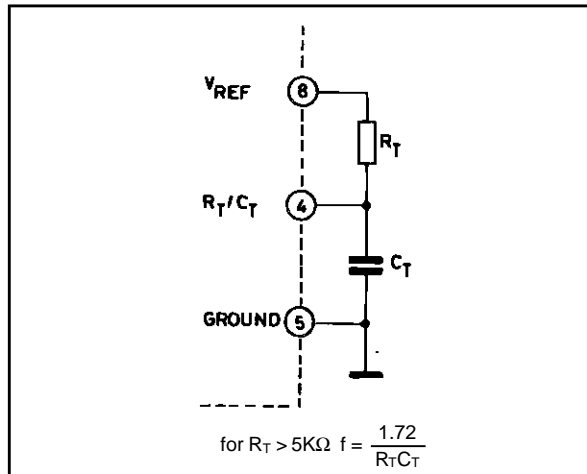


Figure 6 : Timing Resistance vs. Frequency.

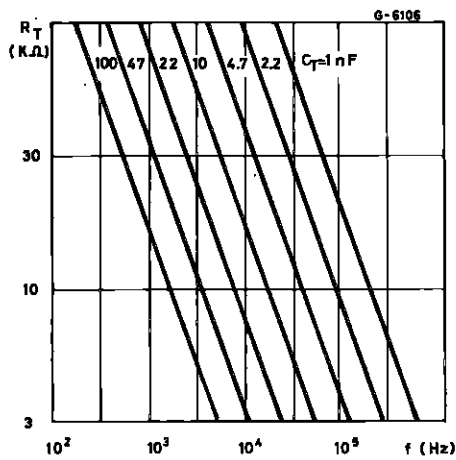


Figure 8 : Error Amplifier Open-loop Frequency Response.

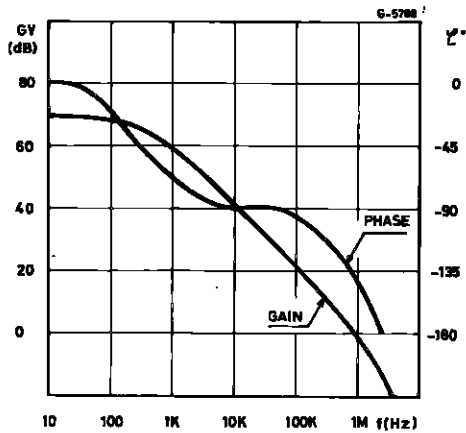


Figure 5 : Deadtime vs. C_T ($R_T > 5K\Omega$).

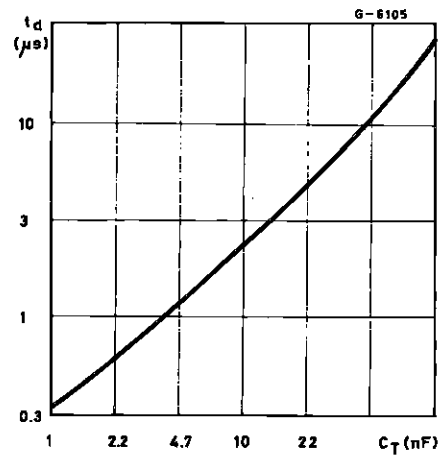


Figure 7 : Output Saturation Characteristics.

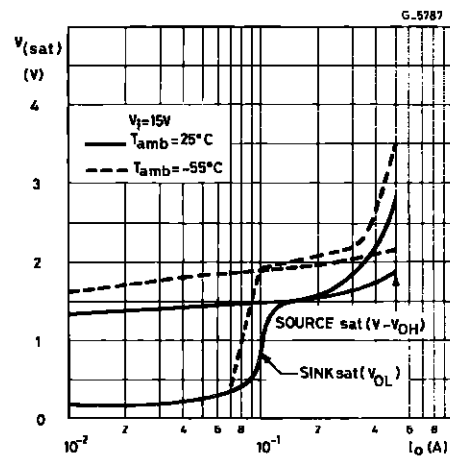
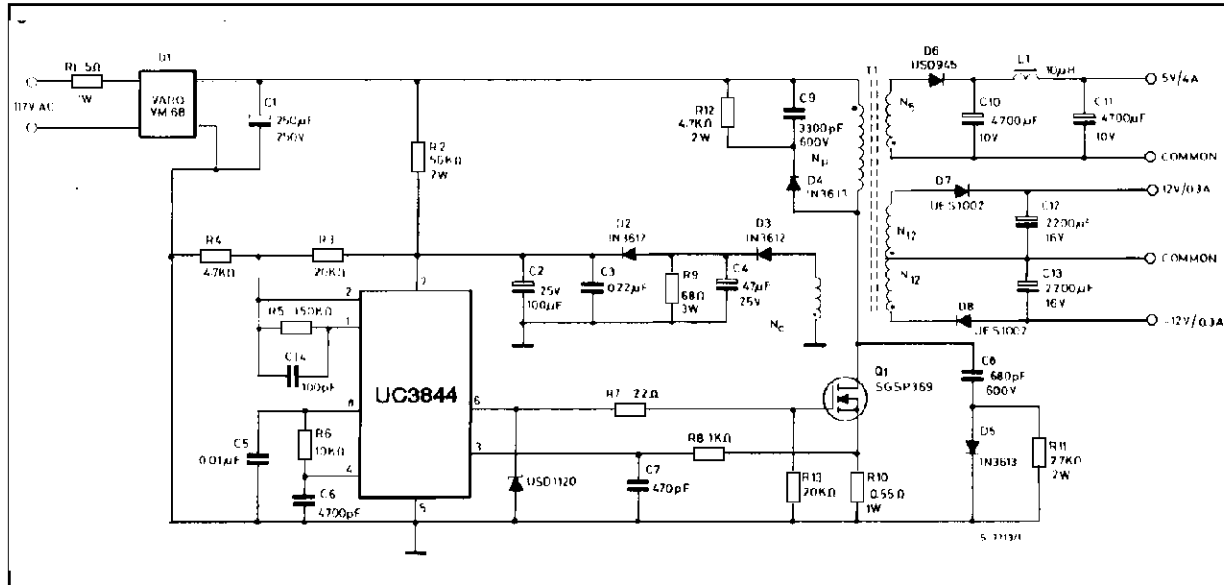


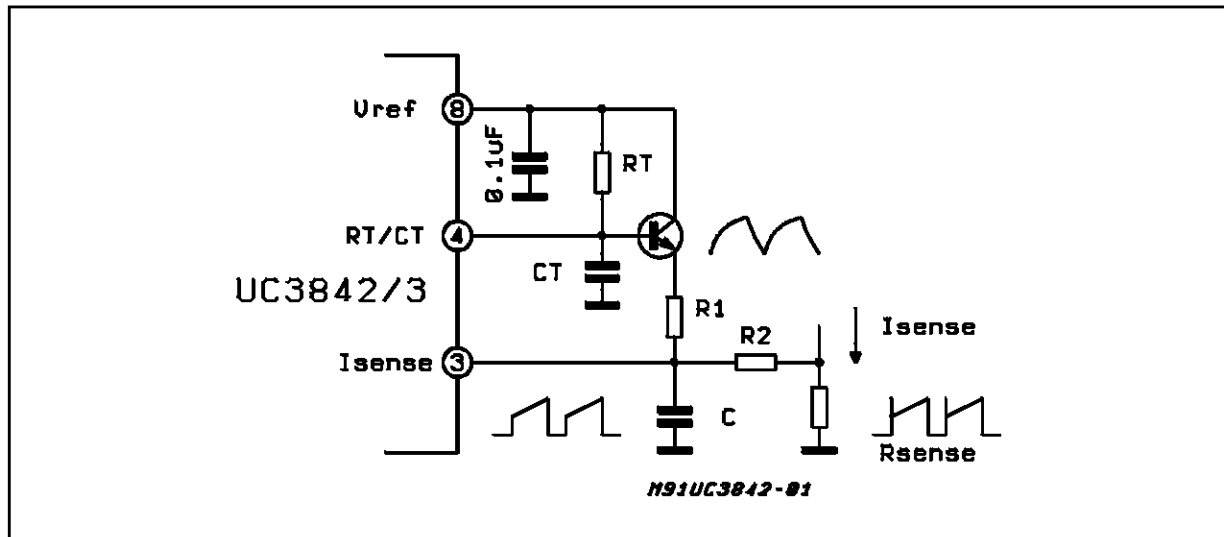
Figure 11 : Off-line Flyback Regulator.



Power Supply Specifications

- | | |
|---|--|
| <ol style="list-style-type: none"> 1. Input Voltage : 95 VAC to 130 VAC (50 Hz/60 Hz) 2. Line Isolation : 3750 V 3. Switching Frequency : 40 KHz 4. Efficiency @ Full Load : 70 % | <ol style="list-style-type: none"> 5. Output Voltage : <ul style="list-style-type: none"> A. + 5 V, ± 5 % : 1 A to 4 A load Ripple voltage : 50 mV P-P Max. B. + 12 V, ± 3 % : 0.1 A to 0.3 A load Ripple voltage : 100 mV P-P Max. C. - 12 V, ± 3 % : 0.1 A to 0.3 A load Ripple voltage : 100 mV P-P Max. |
|---|--|

Figure 12 : Slope Compensation.

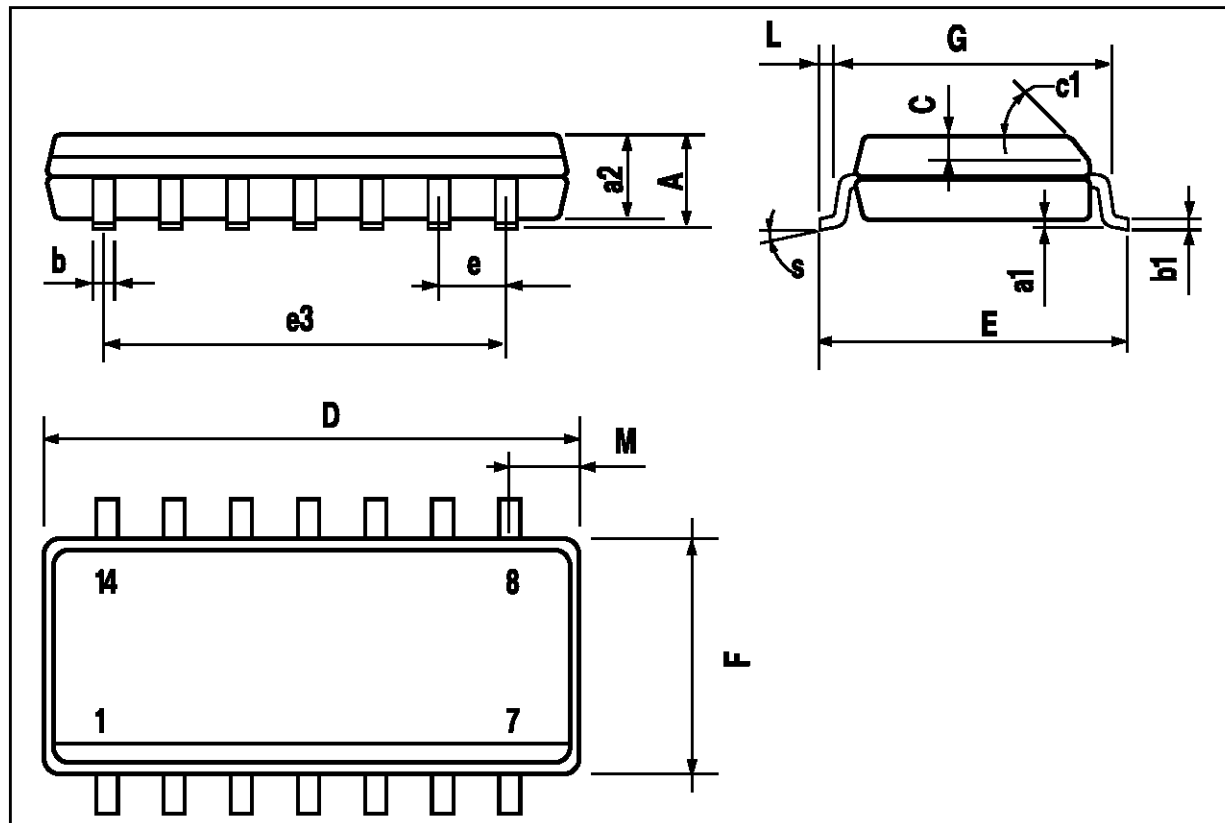


A fraction of the oscillator ramp can be resistively summed with the current sense signal to provide slope compensation for converters requiring duty cycles over 50 %.

Note that capacitor, C, forms a filter with R₂ to suppress the leading edge switch spikes.

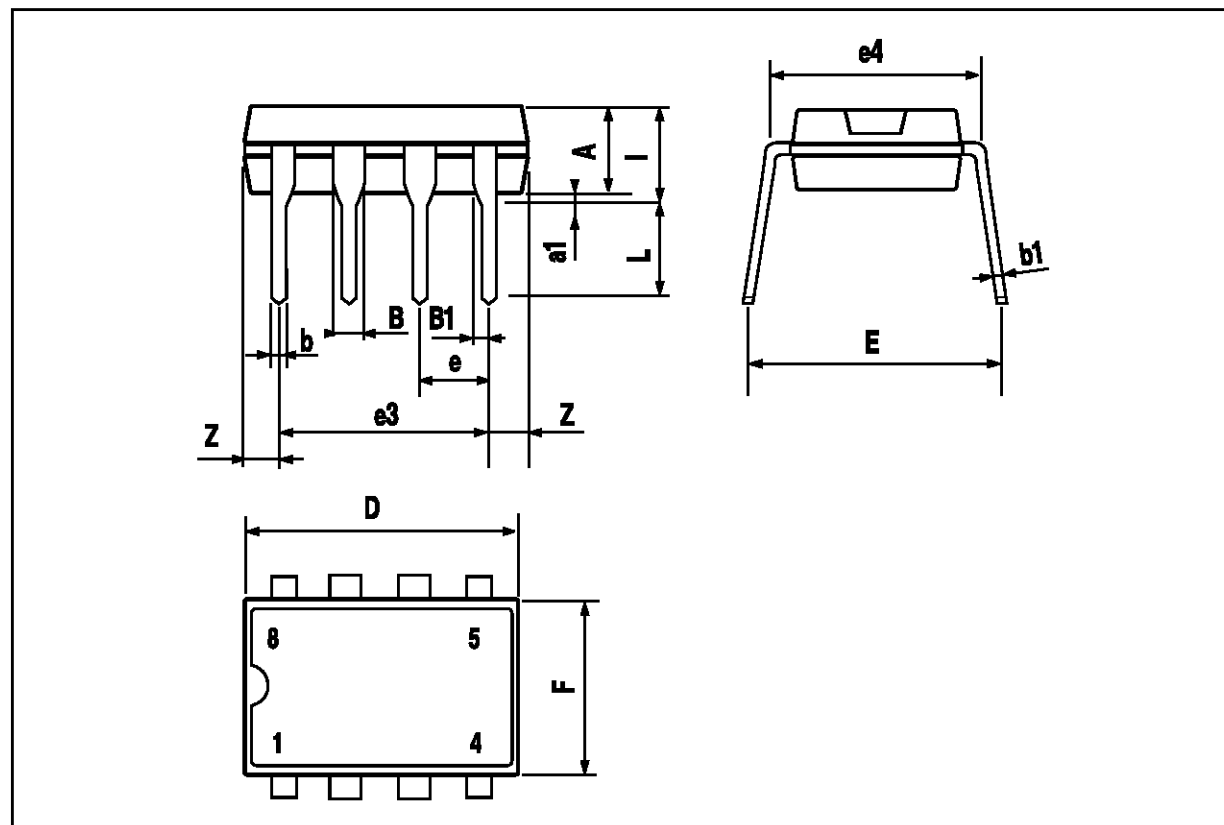
SO14 PACKAGE MECHANICAL DATA

| DIM. | mm | | | inch | | |
|------|-----------|------|------|-------|-------|-------|
| | MIN. | TYP. | MAX. | MIN. | TYP. | MAX. |
| A | | | 1.75 | | | 0.069 |
| a1 | 0.1 | | 0.25 | 0.004 | | 0.009 |
| a2 | | | 1.6 | | | 0.063 |
| b | 0.35 | | 0.46 | 0.014 | | 0.018 |
| b1 | 0.19 | | 0.25 | 0.007 | | 0.010 |
| C | | 0.5 | | | 0.020 | |
| c1 | 45 (typ.) | | | | | |
| D | 8.55 | | 8.75 | 0.336 | | 0.344 |
| E | 5.8 | | 6.2 | 0.228 | | 0.244 |
| e | | 1.27 | | | 0.050 | |
| e3 | | 7.62 | | | 0.300 | |
| F | 3.8 | | 4.0 | 0.15 | | 0.157 |
| L | 0.4 | | 1.27 | 0.016 | | 0.050 |
| M | | | 0.68 | | | 0.027 |
| S | 8 (max.) | | | | | |



DIP14 PACKAGE MECHANICAL DATA

| DIM. | mm | | | inch | | |
|------|-------|------|-------|-------|-------|-------|
| | MIN. | TYP. | MAX. | MIN. | TYP. | MAX. |
| A | | 3.32 | | | 0.131 | |
| a1 | 0.51 | | | 0.020 | | |
| B | 1.15 | | 1.65 | 0.045 | | 0.065 |
| b | 0.356 | | 0.55 | 0.014 | | 0.022 |
| b1 | 0.204 | | 0.304 | 0.008 | | 0.012 |
| D | | | 10.92 | | | 0.430 |
| E | 7.95 | | 9.75 | 0.313 | | 0.384 |
| e | | 2.54 | | | 0.100 | |
| e3 | | 7.62 | | | 0.300 | |
| e4 | | 7.62 | | | 0.300 | |
| F | | | 6.6 | | | 0.260 |
| I | | | 5.08 | | | 0.200 |
| L | 3.18 | | 3.81 | 0.125 | | 0.150 |



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