



## U2010B Phase-Control IC – Current Feedback & Overload Protection

### Description

The U2010B is designed as a phase-control circuit in bipolar technology. It enables load-current detection and has a soft-start function as well as reference voltage

output. Motor control with load-current feedback and overload protection are preferred applications.

### Features

- Full wave current sensing
- Mains supply variation compensated
- Programmable load-current limitation with over- and high-load output
- Variable soft-start
- Voltage and current synchronization
- Automatic retriggering switchable
- Triggering pulse typical 125 mA
- Internal supply voltage monitoring
- Current requirement  $\leq 3$  mA
- Temperature compensated reference voltage

### Applications

- Advanced motor control
- Grinder
- Drilling machine



**Package:** DIP16, SOP16

### Block Diagram

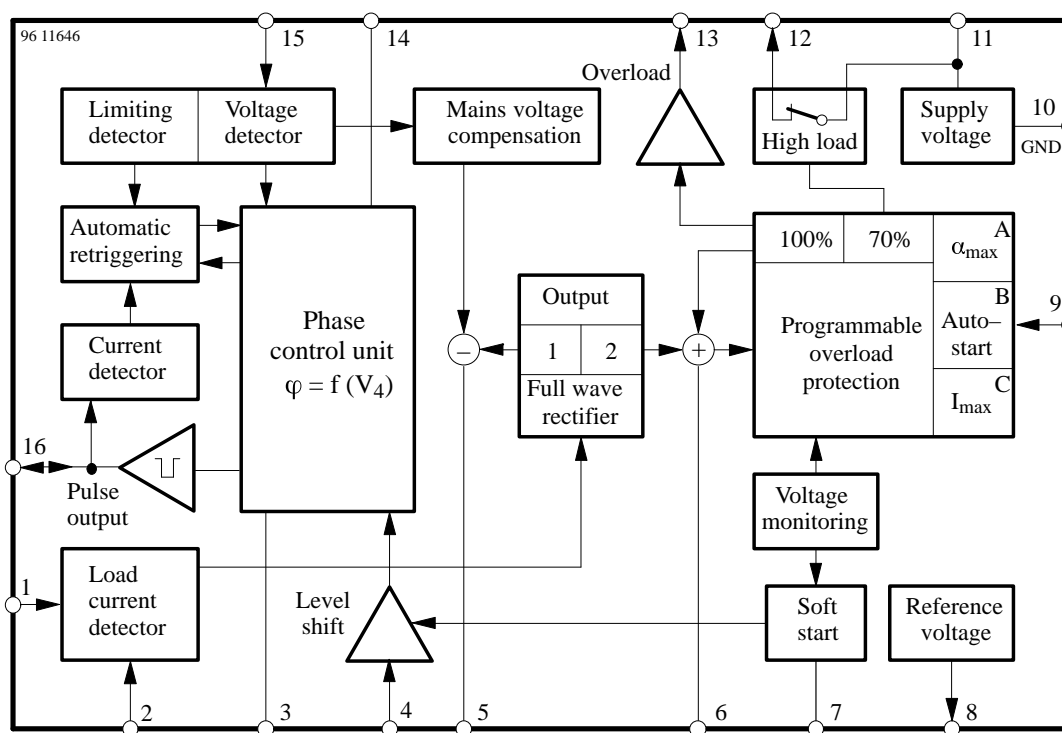


Figure 1. Block diagram

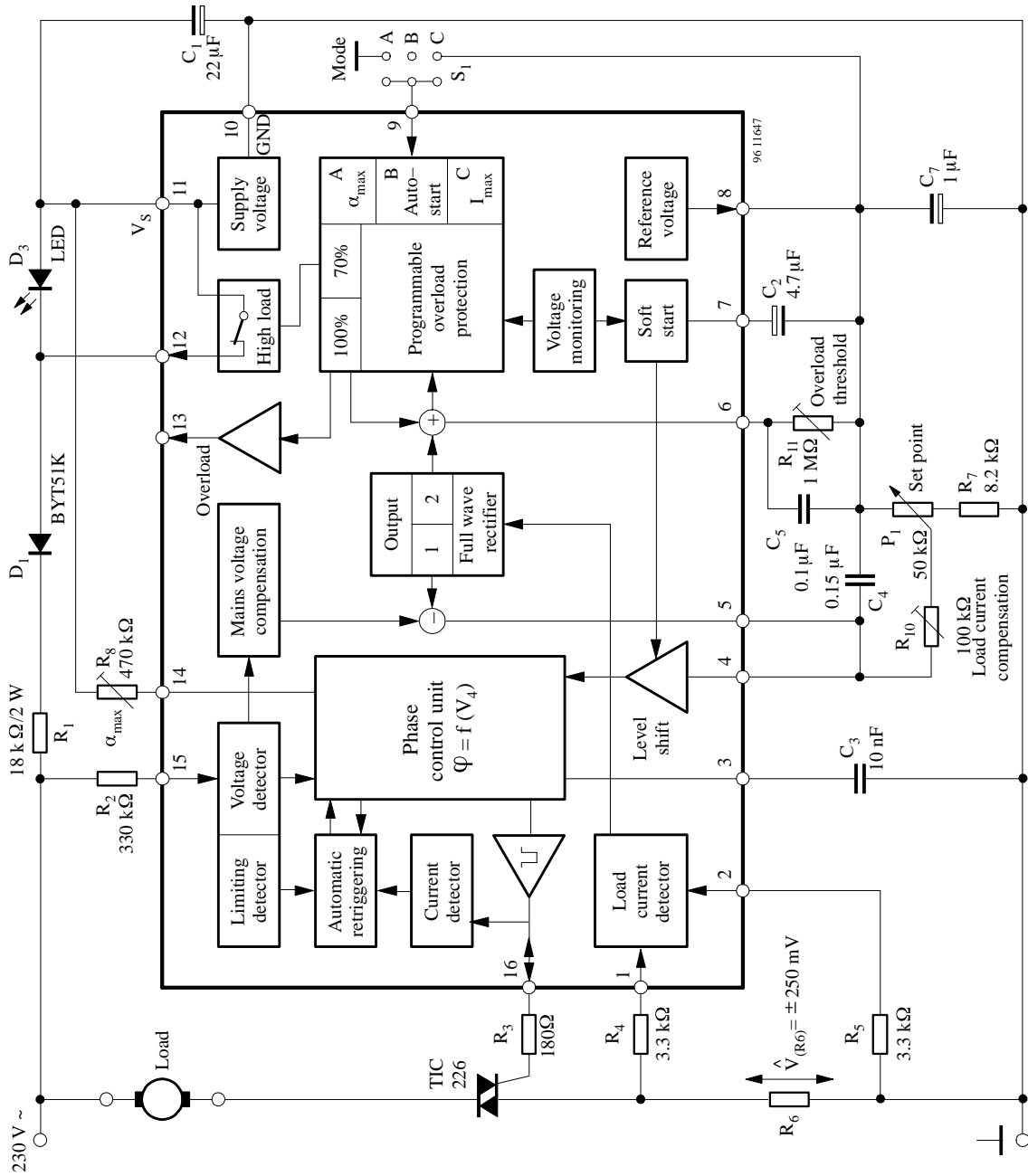


Figure 2. Block diagram with external circuit

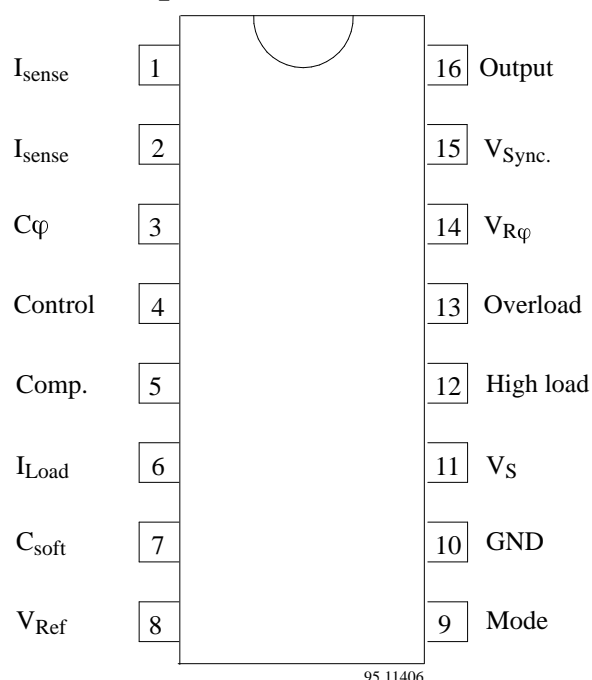
## General Description

### Mains Supply

The U2010B contains voltage limiting and can be connected with the mains supply via  $D_1$  and  $R_1$ . Supply voltage – between Pin 10 and Pin 11 – is smoothed by  $C_1$ .

In the case of  $V_6 \leq (70\% \text{ of overload threshold voltage})$ , Pins 11 and 12 are connected internally whereby  $V_{\text{sat}} \leq 1.2 \text{ V}$ . When  $|V_6| \geq |V_{T70}|$ , the supply current flows across  $D_3$ .

## Pin Description



Pin	Symbol	Function
1	$I_{sense}$	Load current sensing
2	$I_{sense}$	Load current sensing
3	$C_{\phi}$	Ramp voltage
4	Control	Control input
5	Comp.	Compensation output
6	$I_{Load}$	Load current limitation
7	$C_{soft}$	Soft start
8	$V_{Ref}$	Reference voltage
9	Mode	Mode selection
10	GND	Ground
11	$V_S$	Supply voltage
12	High load	High load indication
13	Overload	Overload indication
14	$V_{R\phi}$	Ramp current adjust
15	$V_{Sync.}$	Voltage synchronization
16	Output	Trigger output

Series resistance  $R_1$  can be calculated as follows:

$$R_{1max} = \frac{V_{mains} - V_{Smax}}{2 \times I_{tot}} \text{ whereas}$$

- $V_{mains}$  = Mains supply voltage
- $V_{Smax}$  = Maximum supply voltage
- $I_{tot}$  = Total current consumption =  $I_{Smax} + I_x$
- $I_{Smax}$  = Maximum current consumption of the IC
- $I_x$  = Current consumption of the external components

## Voltage Monitoring

As the voltage is built up, uncontrolled output pulses are avoided by internal voltage monitoring. Apart from that all the latches in the circuit (phase control, load limit regulation) are reset and the soft-start capacitor is short circuited. This guarantees a specified start-up behavior each time the supply voltage is switched on or after short interruptions of the mains supply. Soft-start is initiated after the supply voltage has been built up. This behavior guarantees a gentle start-up for the motor and automatically ensures the optimum run-up time.

## Phase Control

The function of the phase control is largely identical to the well known IC family U211B. The phase angle of the trigger pulse is derived by comparing the ramp voltage  $V_3$  which is mains synchronized by the voltage detector with the set value on the control input, Pin 4. The slope of the

ramp is determined by  $C_{\phi}$  and its charging current  $I_{\phi}$ . The charging current can be varied using  $R_{\phi}$  at Pin 14. The maximum phase angle,  $\alpha_{max}$ , can also be adjusted by using  $R_{\phi}$  (minimum current flow angle  $\phi_{min}$ ) see figure 4.

When the potential on Pin 3 reaches the set point level of Pin 4, a trigger pulse width,  $t_p$ , is determined from the value of  $C_{\phi}$  ( $t_p = 9 \mu s/nF$ ). At the same time, a latch is set with the output pulse, as long as the automatic retriggering has not been activated, then no more pulses can be generated in that half cycle. Control input at Pin 4 (with respect to Pin 10) has an active range from  $V_8$  to  $-1$  V. When  $V_4 = V_8$ , then the phase angle is at its maximum,  $\alpha_{max}$ , i.e., the current flow angle is minimum. The minimum phase angle,  $\alpha_{min}$ , is set with  $V_4 \geq -1$  V.

## Automatic Retriggering

The current-detector circuit monitors the state of the triac after triggering by measuring the voltage drop at the triac gate. A current flow through the triac is recognized, when the voltage drop exceeds a thres hold level of  $t_{yp} \cdot 40$  mV.

If the triac is quenched within the relevant half-wave after triggering; for example owing to low load currents before or after the zero crossing of current wave or; for commutator motors, owing to brush lifters. Then the automatic retriggering circuit ensures immediate retriggering, if necessary with a high repetition rate,  $t_{pp}/t_p$ , until the triac remains reliably triggered.

### Current Synchronization

Current synchronization fulfils two functions:

- Monitoring the current flow after triggering.  
In case the triac extinguishes again or it does not switch on, automatic triggering is activated until the triggering is successful.
- Avoiding a triggering due to inductive load.  
In the case of inductive load operation the current synchronization ensures that in the new half wave no pulse is enabled as long as there is a current available which from the previous half-wave, which flows from the opposite polarity to the actual supply voltage.

A special feature of the integrated circuit is the realization of this current synchronization. The device evaluates the voltage at the pulse output between gate and reference electrode of the triac. This results in saving separate current synchronization input with specified series resistance.

### Voltage Synchronization with Mains Voltage Compensation

The voltage detector synchronizes the reference ramp with the mains-supply voltage. At the same time, the mains dependent input current at Pin 15 is shaped and rectified internally. This current activates the automatic retriggering and at the same time is available at Pin 5. By suitable dimensioning, it is possible to attain the specified compensation effect. Automatic retriggering and mains voltage compensation are not activated until  $|V_{15} - 10|$  increases to 8 V. Resistance,  $R_{sync}$ , defines the width of the zero voltage cross over pulse, synchronization current, and hence the mains supply voltage compensation current.

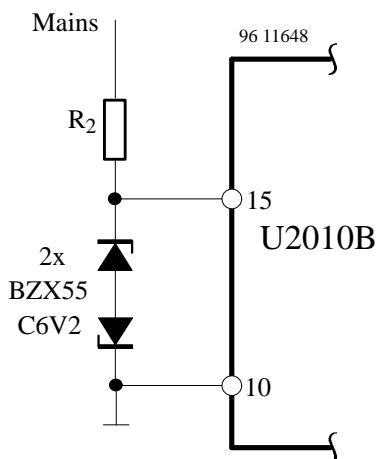


Figure 3.

If the mains voltage compensation and the automatic retriggering are not required, both functions can be suppressed by limiting  $|V_{15} - 10| \leq 7 \text{ V}$  (figure 3).

### Load Current Compensation

The circuit continuously measures the load current as a voltage drop at resistance  $R_6$ . The evaluation and use of both half waves results in a quick reaction to load current change. Due to voltage at resistance  $R_6$ , there is a difference between both input currents at Pins 1 and 2. This difference controls the internal current source, whose positive current values are available at Pins 5 and 6. The output current generated at Pin 5 contains the difference from the load-current detection and from the mains-voltage compensation (see figure 1).

The effective control voltage at Pin 4 is the final current at Pin 5 together with the desired value network. An increase of mains voltage causes the increase of control angle  $\alpha$ , an increase of load current results in a decrease in the control angle. This avoiding a decrease in revolution by increasing the load as well as the increase of revolution by the increment of mains supply voltage.

### Load Current Limitation

The total output load current is available at Pin 6. It results in a voltage drop across  $R_{11}$ . When the potential of the load current reaches about 70% of the threshold value ( $V_{T70}$ ) i.e., ca. 4.35 V at Pin 6, it switches the high load comparator and opens the switch between Pins 11 and 12. By using an LED between these pins, (11 and 12) a high load indication can be realized.

If the potential at Pin 6 increases to ca. 6.2 V ( $= V_{T100}$ ), it switches the overload comparator. The result is programmable at Pin 9 (operation mode).

### Mode selection:

- a)  $\alpha_{max}$  ( $V_9 = 0$ )  
In this mode of operation, after  $V_6$  has reached the threshold  $V_{T100}$ , Pin 13 switches to  $-V_S$  (Pin 11) and Pin 6 to GND (Pin 10). A soft-start capacitor is then shorted and the control angle is switched to  $\alpha_{max}$ . This position is maintained until the supply voltage is switched off. The motor can be started again with soft-start function when the power is switched on again. As the overload condition switches Pin 13 to Pin 11, it is possible to set in a smaller control angle,  $\alpha_{max}$ , by connecting a further resistance between Pins 13 and 14.

**b) Auto start (Pin 9 – open)**

The circuit behaves as written under  $\alpha_{\max}$  ( $V_9 = 0$ ), with the exception that Pin 6 is not connected to GND. If the value of  $V_6$  decreases to 25% of the threshold value ( $V_{T25}$ ), the circuit becomes active again with soft-start.

**c)  $I_{\max}$  ( $V_9 = V_8$ )**

When  $V_6$  has attained the overload threshold maximum value i.e.  $V_6 = V_{T100}$ ; Pin 13 is switched to Pin 8 ( $V_{\text{Ref}}$ ) through the resistance  $R$  ( $= 2 \text{ k}\Omega$ ) without soft-start capacitor discharging at Pin 7. With this mode of operation, direct load current control ( $I_{\max}$ ) is possible. A recommended circuit is shown in figure 18.

## Absolute Maximum Ratings

Reference point Pin 10, unless otherwise specified

Parameters	Symbol	Value	Unit
Sink current Pin 11 $t \leq 10 \mu\text{s}$	$-I_S$ $-i_s$	30 100	mA
Sync. currents Pin 15 $t \leq 10 \mu\text{s}$	$\pm I_{\text{syncV}}$ $\pm i_{\text{syncV}}$	5 20	mA
<b>Phase control</b>			
Control voltage Pins 4 and 8	$-V_I$	$0 - V_8$	V
Input current Pin 4	$\pm I_I$	500	$\mu\text{A}$
Charging current Pin 14	$-I_{\phi \text{ max}}$	0.5	mA
<b>Soft-start</b>			
Input voltage Pins 7 and 8	$-V_I$	$0 - V_8$	V
<b>Pulse output</b>			
Input voltage Pin 16	$+V_I$ $-V_I$	2 $V_{11}$	V
<b>Reference voltage source</b>			
Output current Pin 8 $t \leq 10 \mu\text{s}$	$I_0$	10 30	mA
<b>Load current sensing</b>			
Input currents Pins 1 and 2	$\pm I_i$	1	mA
Input voltages Pins 5 and 6	$-V_i$	$0 - V_8$	V
Overload output Pin 13	$I_L$	1	mA
High-load output Pin 12 $t \leq 10 \mu\text{s}$	$I_L$	30 100	mA
Storage temperature range	$T_{\text{stg}}$	$-40$ to $+125$	$^{\circ}\text{C}$
Junction temperature range	$T_j$	125	$^{\circ}\text{C}$
Ambient temperature range	$T_{\text{amb}}$	$-10$ to $+100$	$^{\circ}\text{C}$

## Thermal Resistance

Parameters	Symbol	Value	Unit
Junction ambient DIP16 SOP16 on p.c. SOP16 on ceramic	$R_{\text{thJA}}$	120 180 100	K/W

## Electrical Characteristics

$V_S = -13\text{ V}$ ,  $T_{\text{amb}} = 25^\circ\text{C}$ , reference point Pin 10, unless otherwise specified

Parameters	Test Conditions / Pins	Symbol	Min.	Typ.	Max.	Unit
<b>Supply</b> Pin 11						
Supply voltage limitation	$-I_S = 3.5\text{ mA}$ $-I_S = 30\text{ mA}$	$-V_S$	14.5 14.6		16.5 16.8	V
Current requirement	$-V_S = 13.0\text{ V}$ (Pins 1, 2, 8 and 15 open)	$-I_S$			3.2	mA
<b>Reference voltage source</b> Pin 8						
Reference voltage	$I_L = 10\text{ }\mu\text{A}$ $I_L = 2.5\text{ mA}$	$-V_{\text{Ref}}$	8.6 8.4	8.9 8.8	9.2 9.1	V
Temperature coefficient	$I_S = 2.5\text{ mA}$ $I_S = 10\text{ }\mu\text{A}$	$\text{TC}_{V_{\text{Ref}}}$		-0.004 +0.006		%/K
<b>Voltage monitoring</b> Pin 11						
Turn-on threshold		$-V_{\text{Son}}$		11.3	12.3	V
<b>Phase control – synchronization</b> Pin 15						
Input current	Voltage sync.	$\pm I_{\text{syncV}}$	0.15		2	mA
Voltage limitation	$\pm I_L = 2\text{ mA}$	$\pm V_{\text{syncV}}$	8.0	8.5	9.0	V
Input current	Current sync. Pin 16	$\pm I_{\text{syncI}}$	3		30	$\mu\text{A}$
<b>Reference ramp, figure 4</b>						
Charging current	Pin 14	$-I_\phi$	1		100	$\mu\text{A}$
Start voltage	Pin 3	$-V_{\text{max}}$	1.85	1.95	2.05	V
Temperature coefficient of start voltage	Pin 3	$\text{TC}_R$		-0.003		%/K
Final voltage	Pin 3	$-V_{\text{min}}$	$(V_8 \pm 200\text{ mV})$			
$R_\phi$ – reference voltage	$I_\phi = 10\text{ }\mu\text{A}$ Pins 14 and 11	$V_{R\phi}$	0.96	1.02	1.10	V
Temperature coefficient	$I_\phi = 10\text{ }\mu\text{A}$ Pin 14 $I_\phi = 1\text{ }\mu\text{A}$	$\text{TC}_{V_{R\phi}}$		0.03 0.06		%/K
Pulse output current	$V_{16} = -1.2\text{ V}$ , figure 5, Pin 16	$I_0$	100	125	150	mA
Output pulse width	$V_S = V_{\text{limit}}$ , $C_3 = 3.3\text{ nF}$ , figure 6, Pin 16	$t_p$		30		$\mu\text{s}$
<b>Automatic retriggering</b>						
Repetition rate	$I_{15} \geq 150\text{ }\mu\text{A}$	$t_{pp}$	3	5	7.5	$t_p$
Threshold voltage	Pin 16	$\pm V_I$	20		60	mV
<b>Soft start, figure 7 and 8</b> Pin 7						
Starting current	$V_7 = V_8$	$-I_0$	5	10	15	$\mu\text{A}$
Final current	$V_{7-10} = -1\text{ V}$	$-I_0$	15	25	40	$\mu\text{A}$
Discharge current		$+I_0$	0.5			mA
Output current	Pin 4	$+I_0$	0.2		2	mA
<b>Supply voltage compensation, figure 9</b> Pin 15						
Transfer gain	$I_{15}/I_5$ Pin 15/5 (Pins 1 and 2 open)	$G_i$	14	17	20	
Output offset current	$V_{(R6)} = V_{15} = V_5 = 0$	$\pm I_0$			2	$\mu\text{A}$
<b>Load current detection, <math>R_1 = R_2 = 3\text{ k}\Omega</math>, <math>V_{15} = 0</math>, <math>V_5 = V_6 = V_8</math>, figure 10</b>						
Transfer gain	$I_5/150\text{ mV}$ , $I_6/150\text{ mV}$	$G_I$	0.28	0.32	0.37	$\mu\text{A/mV}$
Output offset currents	Pin 5, Pin 6 - 8	$-I_0$	0	3	6	$\mu\text{A}$
Reference voltage	$I_1, I_2 = 100\text{ }\mu\text{A}$ Pins 1 and 2	$-V_{\text{Ref}}$	300		400	mV
Shunt voltage amplitude	see figure 2	$\pm V_{(R6)}$			250	mV

Parameters	Test Conditions / Pins	Symbol	Min.	Typ.	Max.	Unit
<b>Load current limitation, Pin 6-8, figs. 11 to 14</b>						
High load switching	Threshold $V_{T70}$	$V_{T70}$	4	4.35	4.7	V
Overload switching	Threshold $V_{T100}$	$V_{T100}$	5.8	6.2	6.6	V
Restart switching	Threshold $V_{T25}$	$V_{T25}$	1.25	1.55	1.85	V
Input current	Enquiry mode	$I_i$			1	$\mu\text{A}$
Output impedance	Switching mode	$R_0$	2	4	8	$\text{k}\Omega$
<b>Programming input, figure 2, Pin 9</b>						
Input voltage - auto-start	Pin 9 open	$-V_9$	3.8	4.3	4.7	V
Input current	$V_9 = 0$ ( $\alpha_{\text{max}}$ )	$-I_9$	5	10	20	$\mu\text{A}$
	$V_9 = V_8$ ( $I_{\text{max}}$ )	$I_9$	5	10	20	
<b>High load output, <math>V_{T70}</math>, figure 12, <math>I_{12} = -3</math> mA, Pin 11-12</b>						
Saturation voltages	$V_{6-8} \leq V_{T70}$	$V_{\text{sat}}$	0.5	0.75	1.0	V
	$V_{6-8} \geq V_{T70}$	$V_{\text{lim}}$	7.0	7.4	7.8	
<b>Overload output, <math>V_{T100}</math>, <math>V_9 = \text{open}</math> or <math>V_9 = V_{10}</math>, fig. 13</b>						
Leakage current	$V_{6-8} \leq V_{T25}$ $V_{13} = (V_{11}+1)\text{V}$ Pin 13	$I_{\text{lk}}$			0.5	$\mu\text{A}$
Saturation voltages	$V_{6-8} \geq V_{T100}$ , $I_{13} = 10 \mu\text{A}$ Pins 11-13	$V_{\text{sat}}$			0.1	V
Output current, max. load	$V_9 = V_8$ , fig. 13 Pin 13	$I_{13}$			1	mA
Leakage current	$V_6 \leq V_{T100}$ Pin 13	$I_{\text{lk}}$			4	$\mu\text{A}$
Output impedance	Open collector $V_6 \geq V_{T100}$ Pin 13	$R_0$	2	4	8	$\text{k}\Omega$
Saturation voltage	$V_{6-8} \geq V_{T100}$ , $I_{13} = 10 \mu\text{A}$ Pin 13	$V_{13-8}$		100		mV

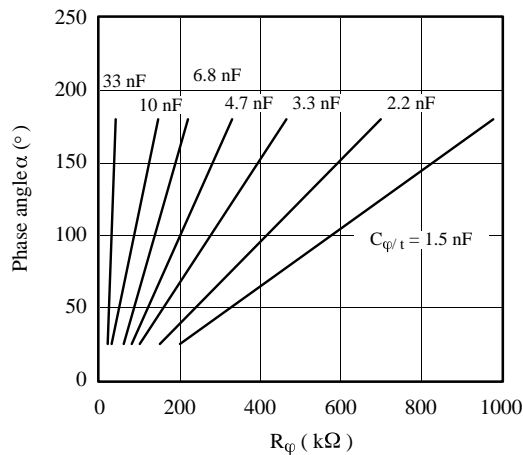


Figure 4.

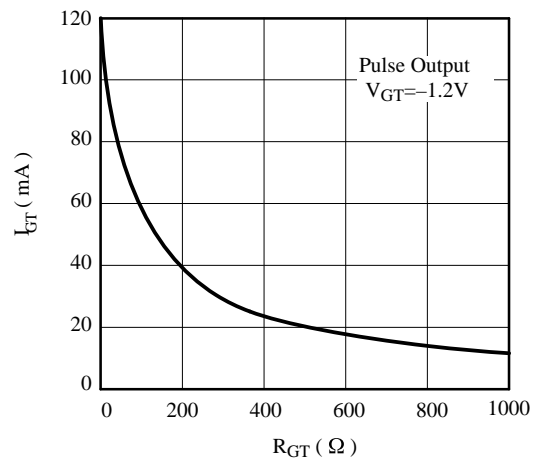


Figure 5.

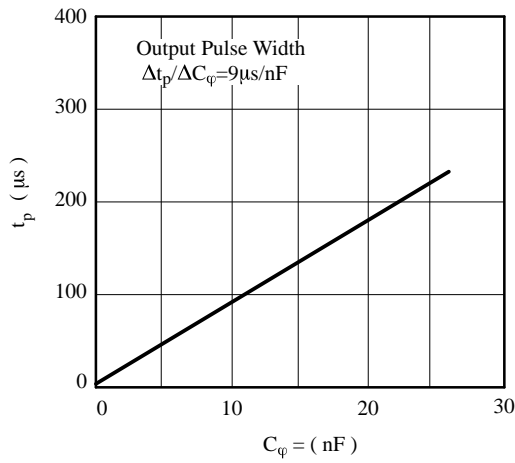


Figure 6.

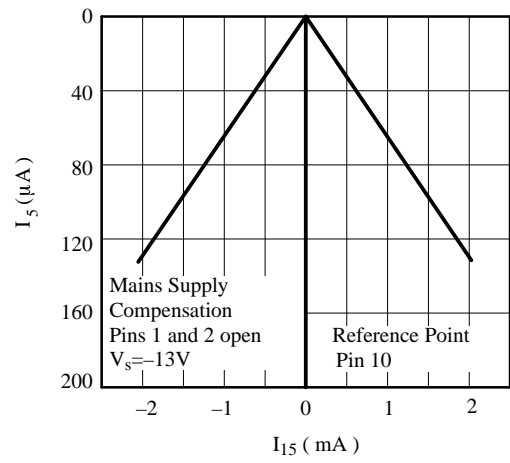


Figure 9.

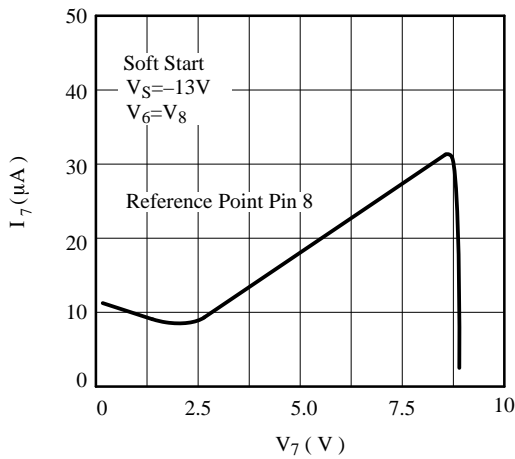


Figure 7.

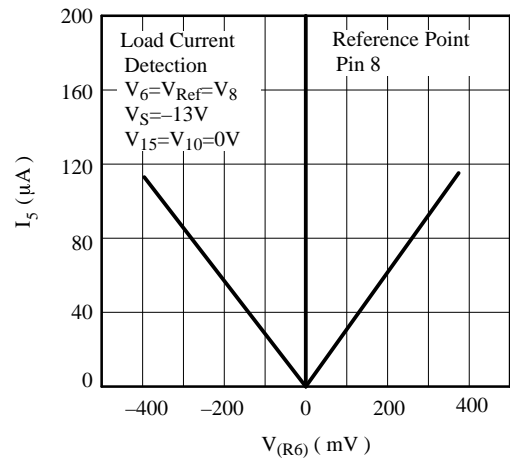


Figure 10.

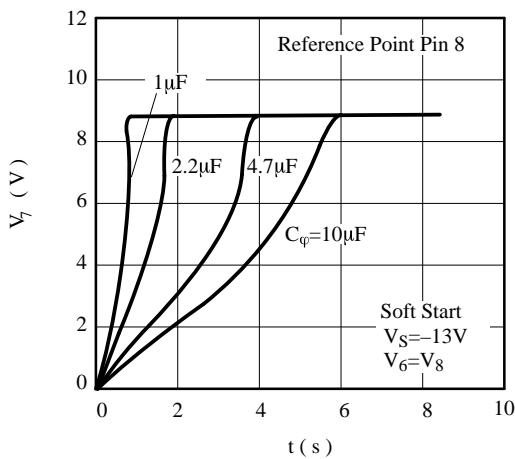


Figure 8.

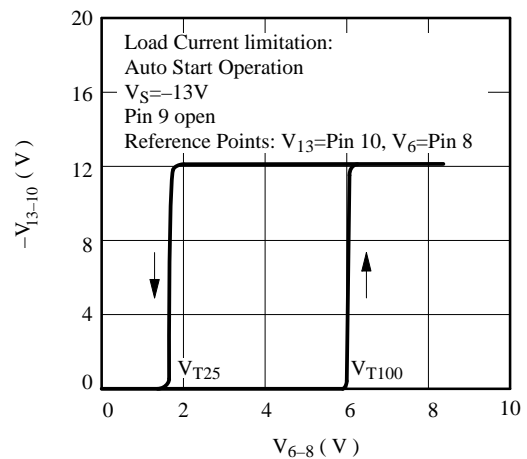


Figure 11.



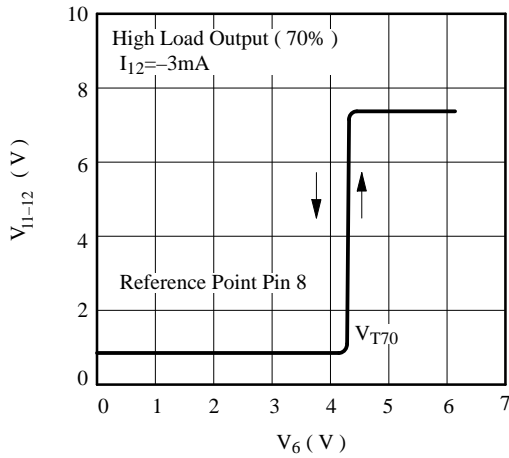


Figure 12.

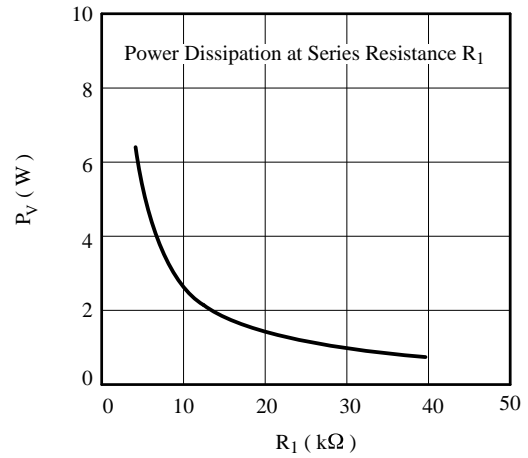


Figure 15.

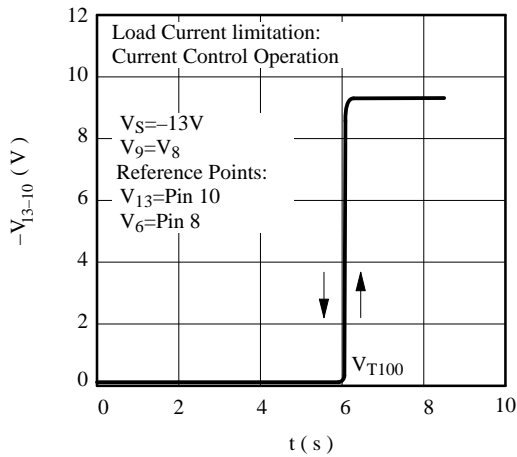


Figure 13.

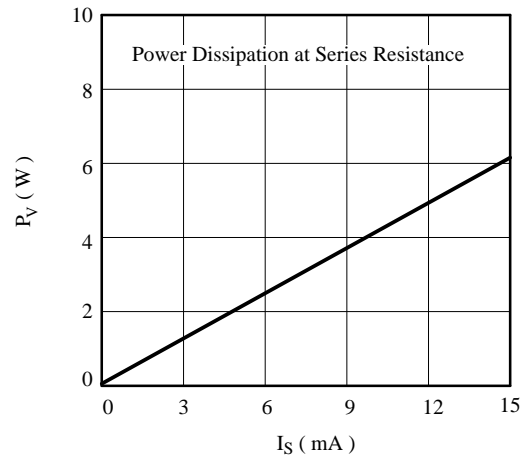


Figure 16.

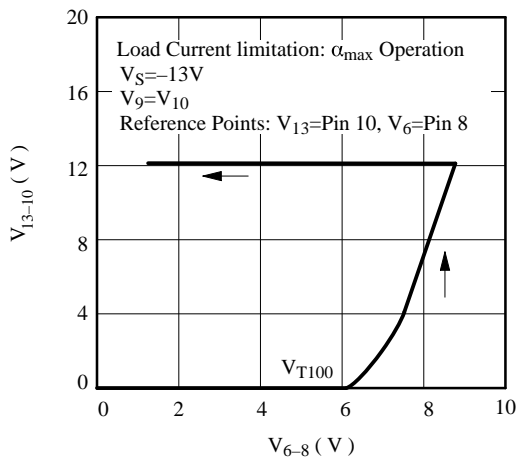


Figure 14.

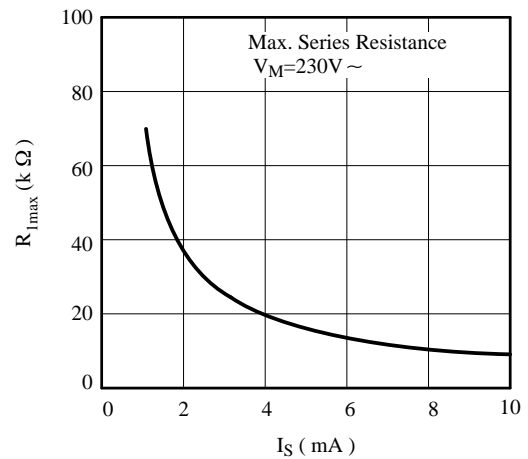


Figure 17.

## Application Circuit

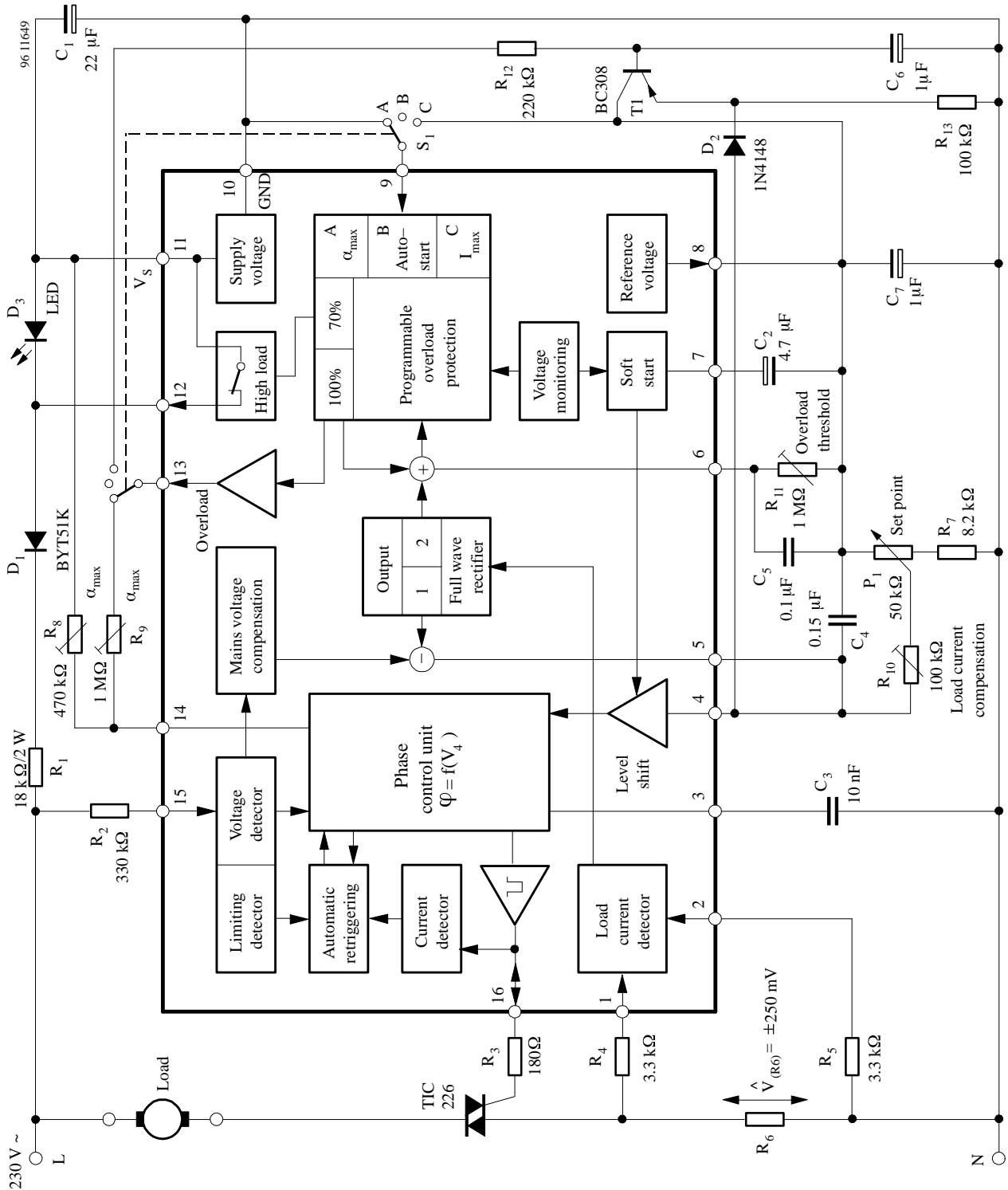
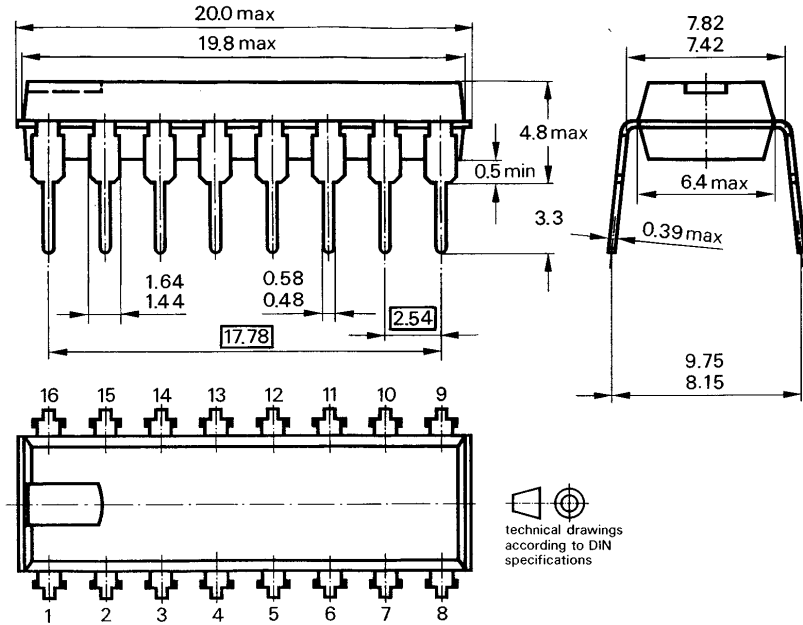


Figure 18.

Dimensions in mm

Package: DIP16



Package: SOP16

