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 ≤ 3 mA
- Temperature-compensated reference voltage

Applications

- Advanced motor control
- Grinder
- Drilling machine

Block Diagram

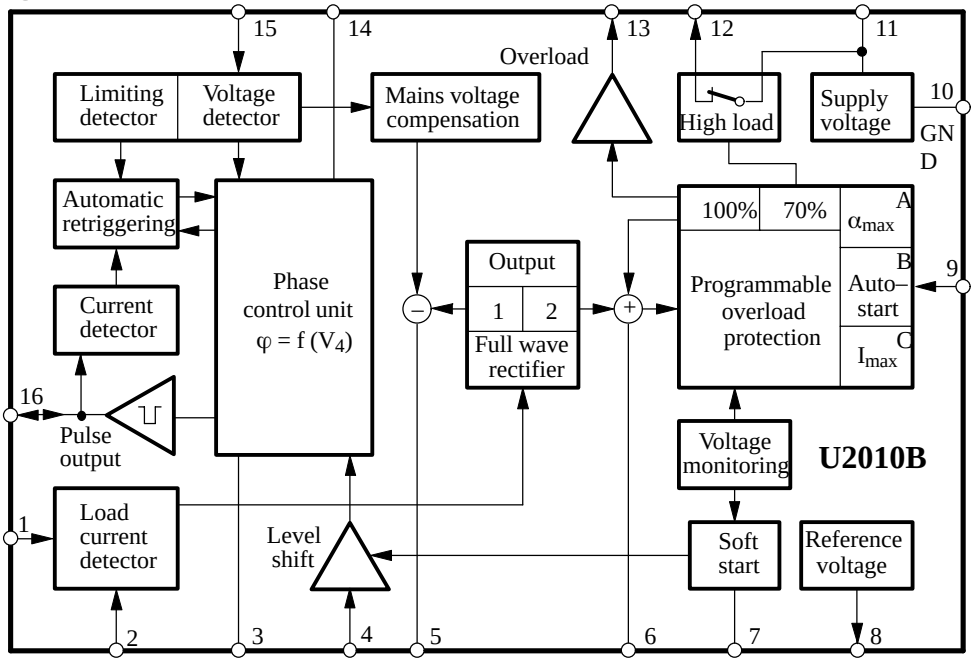


Figure 1. Block diagram

Ordering Information

Extended Type Number	Package	Remarks
U2010B-x	DIP16	Tube
U2010B-xFP	SO16	Tube
U2010B-xFPG3	SO16	Taped and reeled

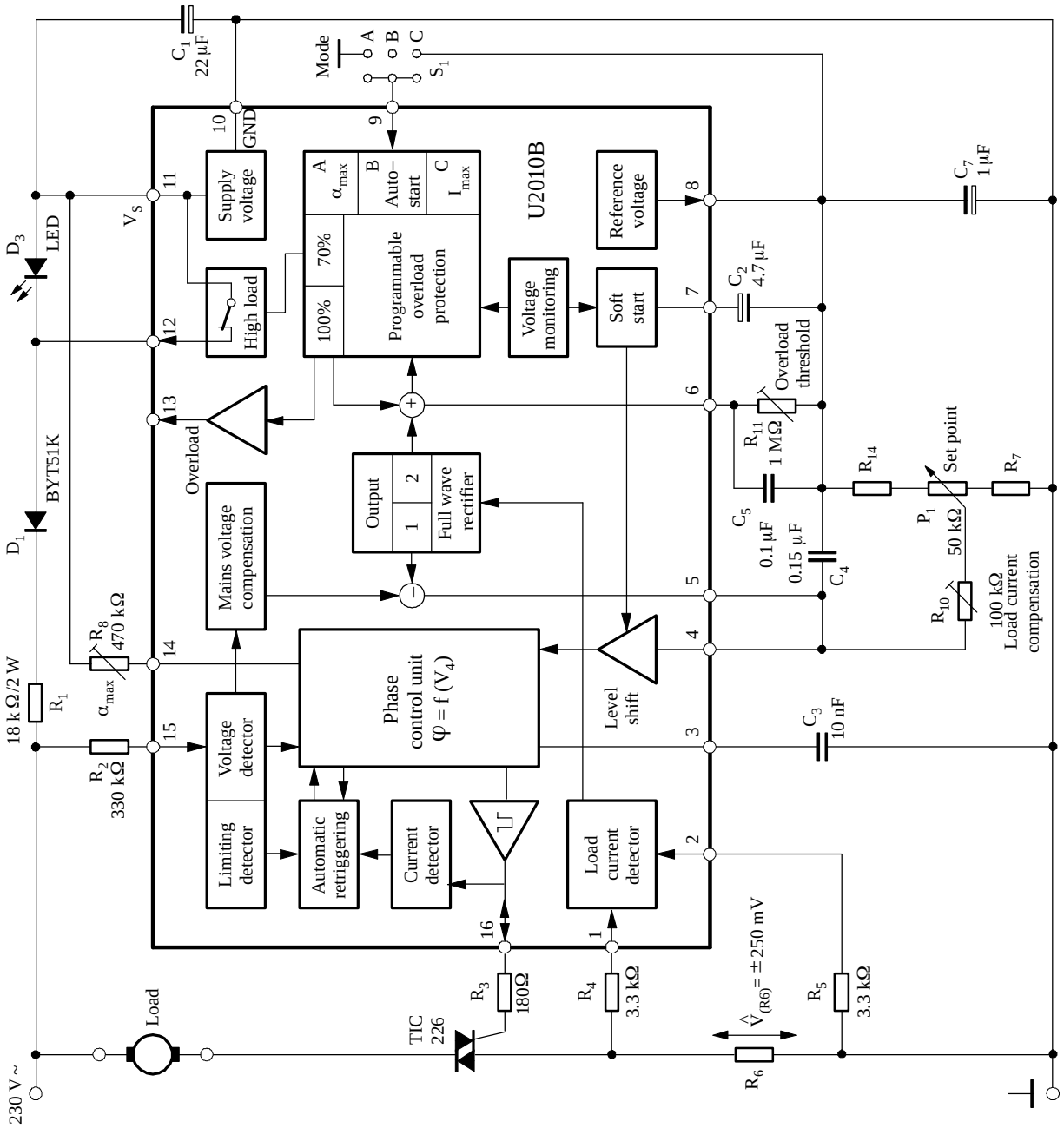


Figure 2. Block diagram with external circuit

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% of overload threshold voltage), Pins 11 and 12 are connected internally whereby $V_{sat} \leq 1.2$ 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	Cφ	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	$V_{Rφ}$	Ramp current adjust
15	$V_{Sync.}$	Voltage synchronization
16	Output	Trigger output

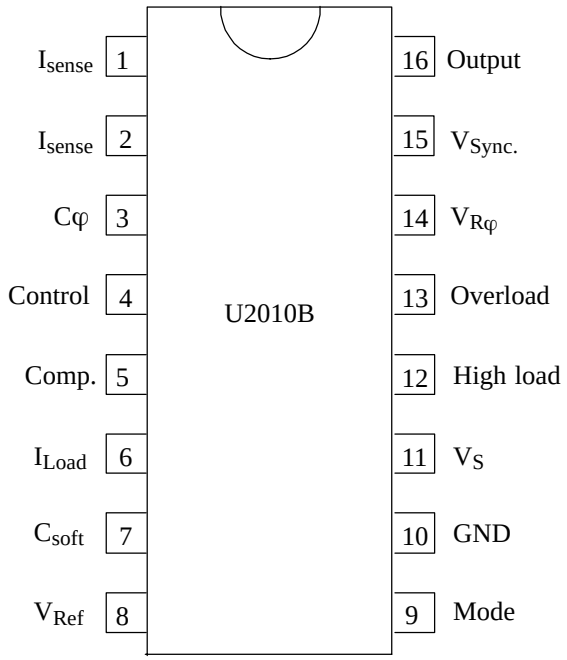


Figure 3. Pinning

Series resistance R_1 can be calculated as follows:

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

where:

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

When the voltage is built up, uncontrolled output pulses are avoided by internal voltage monitoring. Apart from that, all 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 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 $C_φ$ and its charging current $I_φ$. The charging current can be varied using $R_φ$ at Pin 14. The maximum phase angle, $α_{max,}$ can also be adjusted by using $R_φ$ (minimum current flow angle $φ_{min}$), see figure 5.

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 $C_φ$ (t_p = 9 µs/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, $α_{max}$, i.e., the current flow angle is minimum. The minimum phase angle, $α_{min}$, 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 threshold level of typ. 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), 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 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 obtain the specified compensation effect. Automatic retriggering and mains voltage compensation are not activated until $|V_{15-10}|$ increases to 8 V. The resistance $R_{sync.}$ defines the width of the zero voltage cross over pulse, synchronization current, and hence the mains supply voltage compensation current.

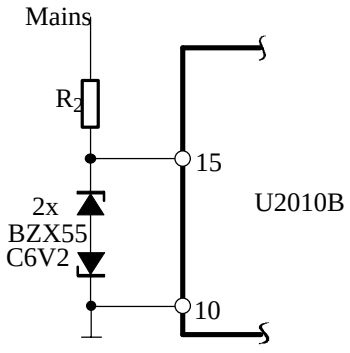


Figure 4. Suppression of mains voltage compensation and retrigger automatic

If the mains voltage compensation and the automatic retriggering are not required, both functions can be suppressed by limiting $|V_{15-10}| \leq 7$ V, see figure 4.

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 2.

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 α, an increase of load current results in a decrease in the control angle. This avoids a decrease in revolution by increasing the load as well as an 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., about 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 about 6.2 V (= V_{T100}), it switches the overload comparator. The result is programmable at Pin 9 (operation mode).

Mode selection:

a) α_{max} ($V_9 = 0$)
   In this mode of operation, Pin 13 switches to $-V_S$ (Pin 11) and Pin 6 to GND (Pin 10) after V_6 has reached the threshold V_{T100}. A soft-start capacitor is then shorted and the control angle is switched to α_{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 use a smaller control angle, α_{max}, by connecting a further resistance between Pins 13 and 14.

b) Auto start (Pin 9 − open), see figure 12
The circuit behaves as described under α_{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} ($V_9 = V_8$), see figure 14
When V_6 has reached the maximum overload threshold value (i.e., $V_6 = V_{T100}$), Pin 13 is switched to Pin 8 (V_{Ref}) through the resistance R (= 2 kΩ) without soft-start capacitor discharging at Pin 7. With this mode of operation, direct load-current control (I_{max}) is possible.

Absolute Maximum Ratings

Reference point Pin 10, unless otherwise specified

Parameter		Symbol	Value	Unit
Sink current	Pin 11	$-I_S$	30	mA
$t \le 10\ \mu s$		$-i_s$	100	mA
Sync. currents	Pin 15	$\pm I_{syncV}$	5	mA
$t \le 10\ \mu s$		$\pm i_{syncV}$	20	mA
Phase control				
Control voltage	Pins 4 and 8	$-V_I$	$0 - V_8$	V
Input current	Pin 4	$\pm I_I$	500	µA
Charging current	Pin 14	$-I_{\varphi\ max}$	0.5	mA
Soft start				
Input voltage	Pins 7 and 8	$-V_I$	$0 - V_8$	V
Pulse output				
Input voltage	Pin 16	$+V_I$	2	V
		$-V_I$	V_{11}	V
Reference voltage source				
Output current	Pin 8	I_0	10	mA
$t \le 10\ \mu s$			30	mA
Load-current sensing				
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	I_L	30	mA
$t \le 10\ \mu s$			100	mA
Storage temperature range		T_{stg}	− 40 to + 125	°C
Junction temperature range		T_j	125	°C
Ambient temperature range		T_{amb}	− 10 to + 100	°C

Thermal Resistance

Parameter		Symbol	Value	Unit
Junction ambient	DIP16	R_{thJA}	120	K/W
	SO16 on p.c.	R_{thJA}	180	K/W
	SO16 on ceramic	R_{thJA}	100	K/W

Electrical Characteristics

V_S = –13 V, T_{amb} = 25°C, reference point Pin 10, unless otherwise specified

Parameter	Test Conditions / Pins	Symbol	Min.	Typ.	Max.	Unit
Supply	Pin 11					
Supply-voltage limitation	$-I_S$ = 3.5 mA $-I_S$ = 30 mA	$-V_S$ $-V_S$	14.5 14.6		16.5 16.8	V V
Current requirement	$-V_S$ = 13.0 V (Pins 1, 2, 8 and 15 open)	$-I_S$			3.5	mA
Reference voltage source	Pin 8					
Reference voltage	I_L = 10 µA I_L = 2.5 mA	$-V_{Ref}$ $-V_{Ref}$	8.6 8.4	8.9 8.8	9.2 9.1	V V
Temperature coefficient	I_S = 2.5 mA I_S = 10 µA	TC_{VRef} TC_{VRef}		–0.004 +0.006		%/K %/K
Voltage monitoring	Pin 11					
Turn-on threshold		$-V_{Son}$		11.3	12.3	V
Phase control – synchronization	Pin 15					
Input current	Voltage sync.	$\pm I_{syncV}$	0.15		2	mA
Voltage limitation	$\pm$ I_L = 2 mA	$\pm V_{syncV}$	8.0	8.5	9.0	V
Input current	Current sync. Pin 16	$\pm I_{syncI}$	3		30	µA
Reference ramp, see figure 5						
Charging current	Pin 14	$-I_\varphi$	1		100	µA
Start voltage	Pin 3	$-V_{max}$	1.85	1.95	2.05	V
Temperature coefficient of start voltage	Pin 3	TC_R		–0.003		%/K
Final voltage	Pin 3	$-V_{min}$	($V_8 \pm 200$ mV)			
R_φ – reference voltage	I_φ = 10 µA Pins 14 and 11	$V_{R\varphi}$	0.96	1.02	1.10	V
Temperature coefficient	I_φ = 10 µA Pin 14 I_φ = 1 µA	$TC_{VR\varphi}$ $TC_{VR\varphi}$		0.03 0.06		%/K %/K
Pulse output current	V_{16} = –1.2 V, fig. 6, Pin 16	I_0	100	125	150	mA
Output pulse width	$V_S = V_{limit,}$ Pin 16 C_3 = 3.3 nF, see figure 7,	t_p		30		µs
Automatic retriggering						
Repetition rate	$I_{15} \geq$ 150 µA	t_{pp}	3	5	7.5	t_p
Threshold voltage	Pin 16	$\pm V_I$	20		60	mV
Soft start, see figures 8 and 9	Pin 7					
Starting current	$V_7 = V_8$	$-I_0$	5	10	15	µA
Final current	V_{7-10} = –1V	$-I_0$	15	25	40	µA
Discharge current		$+I_0$	0.5			mA
Output current	Pin 4	$+I_0$	0.2		2	mA

Electrical Characteristics (continued)

V_S = –13 V, T_{amb} = 25°C, reference point Pin 10, unless otherwise specified

Parameter	Test Conditions / Pins	Symbol	Min.	Typ.	Max.	Unit
Mains voltage compensation, see figure 10 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	µA
Load-current detection, $R_1 = R_2 = 3$ kΩ, $V_{15} = 0$, $V_5 = V_6 = V_8$, see figure 11						
Transfer gain	I_5/150 mV, I_6/150 mV	G_I	0.28	0.32	0.37	µA/mV
Output offset currents	Pin 5, Pin 6 - 8	$-I_0$	0	3	6	µA
Reference voltage	I_1, I_2 = 100 µA Pins 1 and 2	$-V_{Ref}$	330		410	mV
Shunt voltage amplitude	See figure 2	$\pm V_{(R6)}$			250	mV
Load current limitation, Pin 6-8						
High load switching	Threshold V_{T70}, figure 13	V_{T70}	4	4.35	4.7	V
Overload switching	Threshold V_{T100}, figures 14, 15	V_{T100}	5.8	6.2	6.6	V
Restart switching	Threshold V_{T25}, figure 12	V_{T25}	1.25	1.55	1.85	V
Input current	Enquiry mode	I_i			1	µA
Output impedance	Switching mode	R_0	2	4	8	kΩ
Programming input, see figure 2, Pin 9						
Input voltage - auto-start	Pin 9 open	$-V_9$	3.8	4.3	4.7	V
Input current	$V_9 = 0$ (α_{max}) $V_9 = V_8$ (I_{max})	$-I_9$ I_9	5 5	10 10	20 20	µA µA
High load output, V_{T70}, see figure 13, I_{12} = –3 mA, Pin 11-12						
Saturation voltages	$V_{6-8} \le V_{T70}$ $V_{6-8} \ge V_{T70}$	V_{sat} V_{lim}	0.5 7.0	0.75 7.4	1.0 7.8	V V
Overload output, V_{T100}, V_9 = open or $V_9 = V_{10}$, see figure 14						
Leakage current	$V_{6-8} \le V_{T25}$ $V_{13} = (V_{11}+1)V$ Pin 13	I_{lkg}			0.5	µA
Saturation voltages	$V_{6-8} \ge V_{T100}$, I_{13} = 10 µA Pins 11-13	V_{sat}			0.1	V
Output current, max. load	$V_9 = V_8$, see figure 14,Pin 13	I_{13}			1	mA
Leakage current	$V_6 \le V_{T100}$ Pin 13	I_{lkg}			4	µA
Output impedance	Open collector $V_6 \ge V_{T100}$ Pin 13	R_0	2	4	8	kΩ
Saturation voltage	$V_{6-8} \ge V_{T100}$, I_{13} = 10 µA Pin 13	V_{13-8}		100		mV

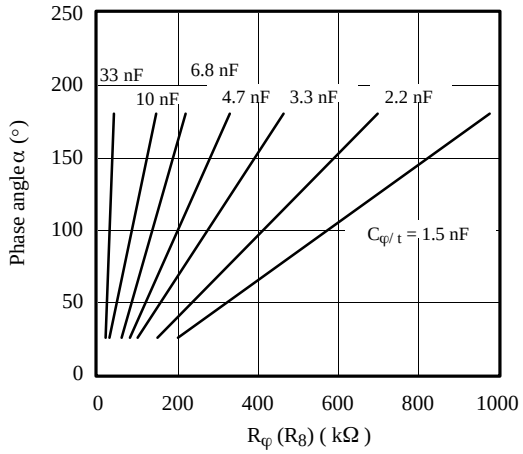


Figure 5. Ramp control

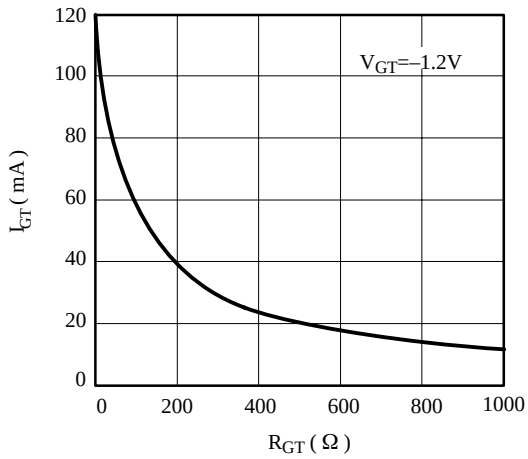


Figure 6. Pulse output

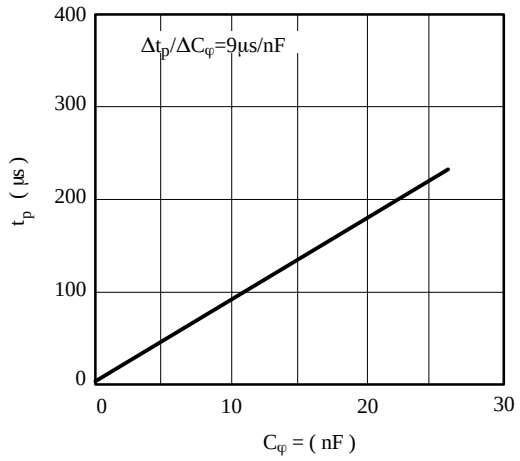


Figure 7. Output pulse width

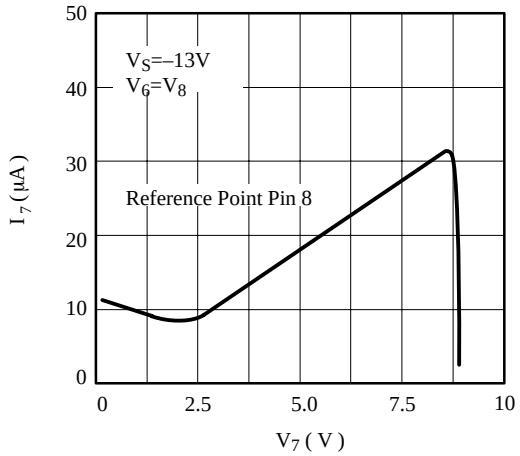


Figure 8. Soft-start charge current

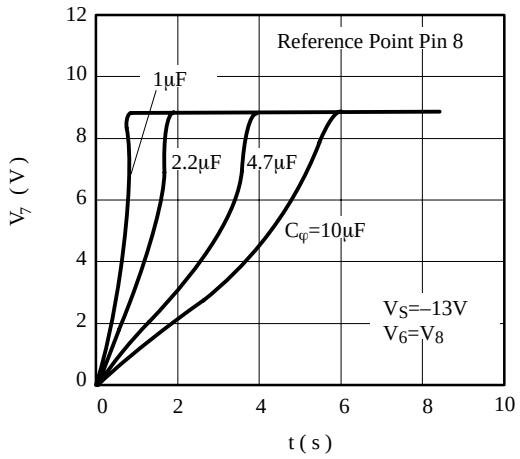


Figure 9. Soft-start characteristic

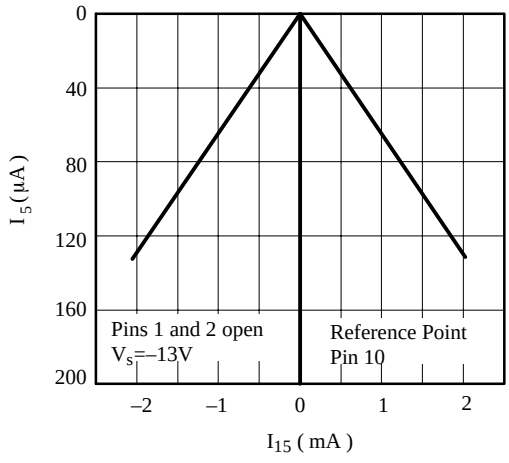


Figure 10. Mains voltage compensation

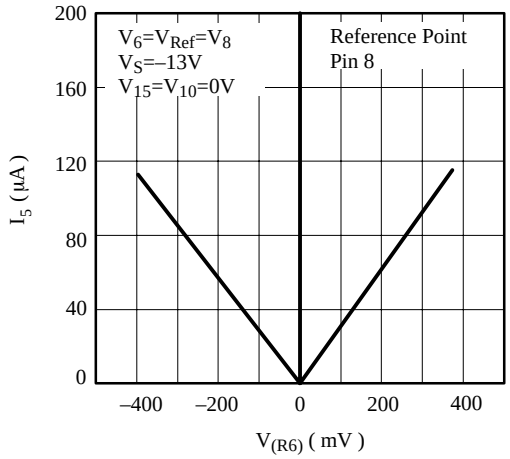


Figure 11. Load-current detection

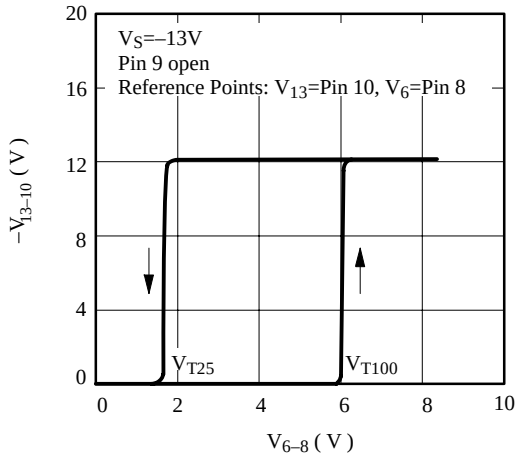


Figure 12. Restart switching auto start mode

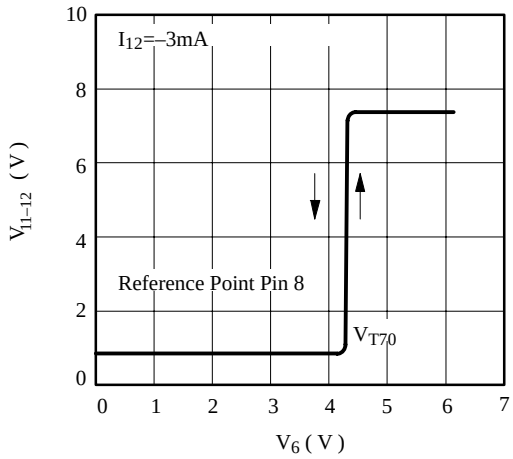


Figure 13. High load switching (70%)

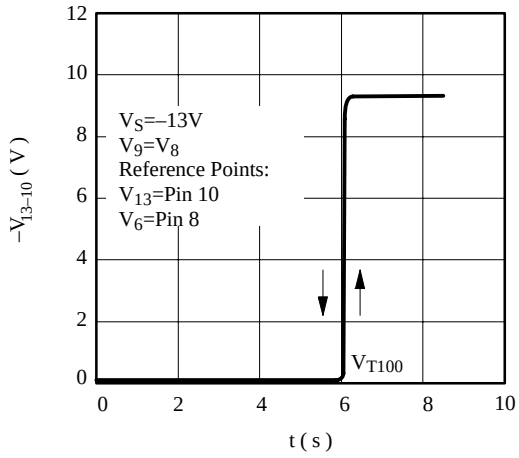


Figure 14. Overload switching

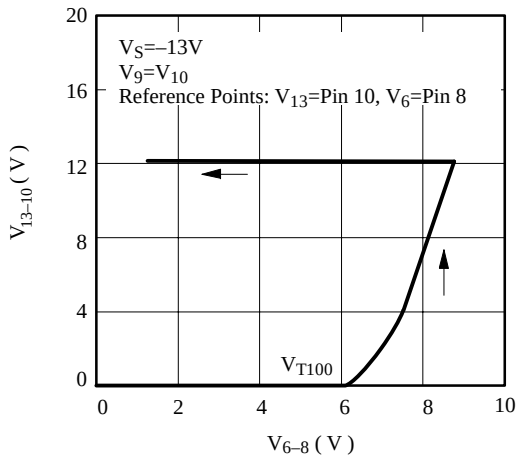


Figure 15. Load limitation

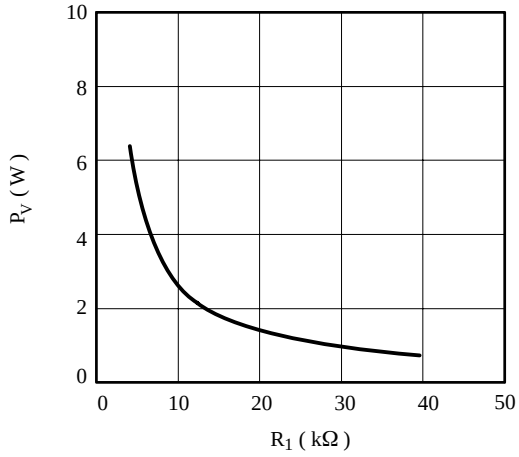


Figure 16. Power dissipation of R_1

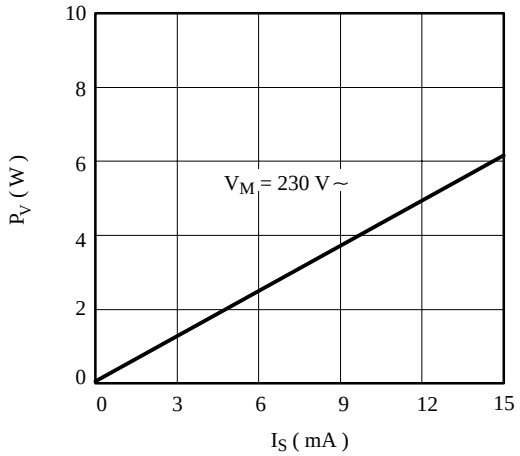


Figure 17. Power dissipation of R_1 according to current consumption

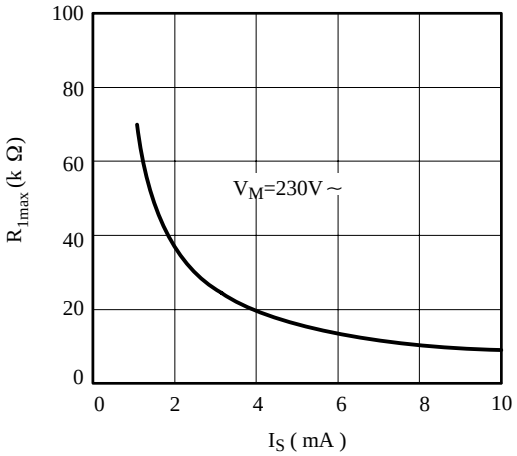


Figure 18. Maximum resistance of R_1

Application Circuit

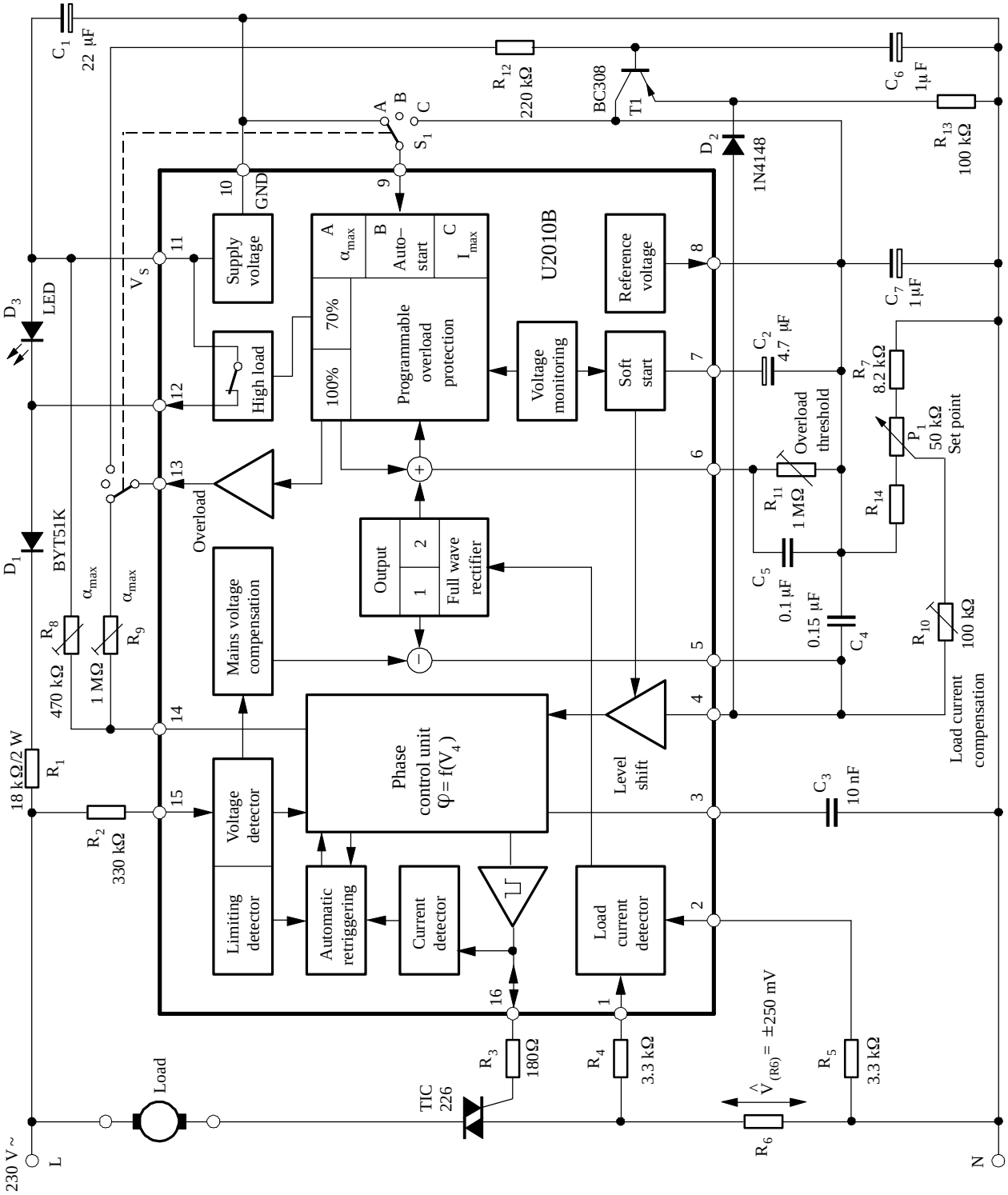
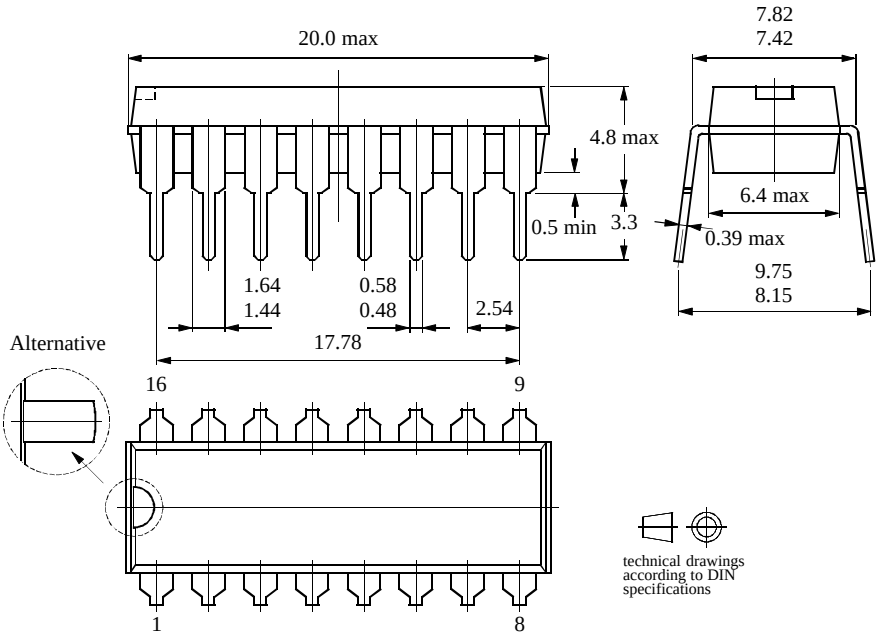


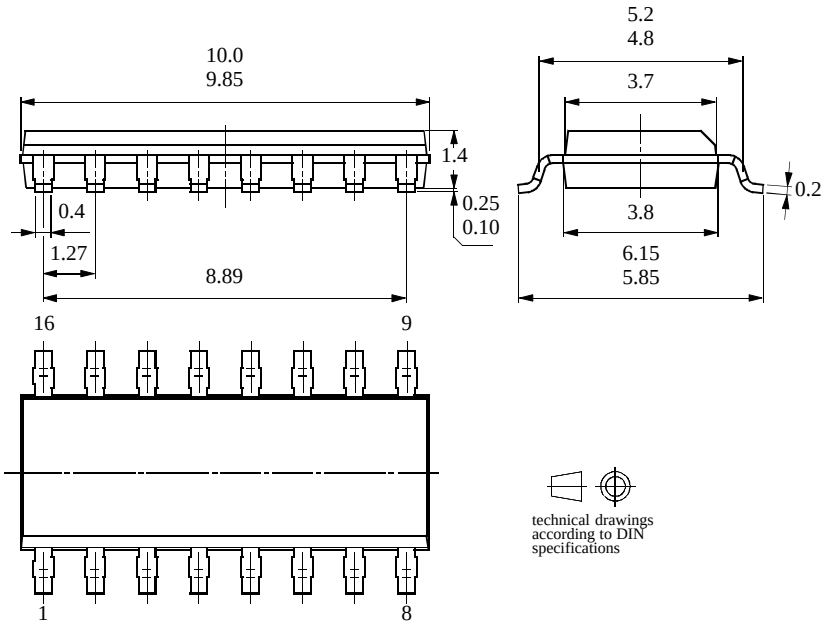
Figure 19. Application circuit

Package Information

Package DIP16
Dimensions in mm



Package SO16
Dimensions in mm



Ozone Depleting Substances Policy Statement

It is the policy of **TEMIC Semiconductor GmbH** to

1. Meet all present and future national and international statutory requirements.

2. Regularly and continuously improve the performance of our products, processes, distribution and operating systems with respect to their impact on the health and safety of our employees and the public, as well as their impact on the environment.

It is particular concern to control or eliminate releases of those substances into the atmosphere which are known as ozone depleting substances (ODSs).

The Montreal Protocol (1987) and its London Amendments (1990) intend to severely restrict the use of ODSs and forbid their use within the next ten years. Various national and international initiatives are pressing for an earlier ban on these substances.

TEMIC Semiconductor GmbH has been able to use its policy of continuous improvements to eliminate the use of ODSs listed in the following documents.

1. Annex A, B and list of transitional substances of the Montreal Protocol and the London Amendments respectively

2. Class I and II ozone depleting substances in the Clean Air Act Amendments of 1990 by the Environmental Protection Agency (EPA) in the USA

3. Council Decision 88/540/EEC and 91/690/EEC Annex A, B and C (transitional substances) respectively.

TEMIC Semiconductor GmbH can certify that our semiconductors are not manufactured with ozone depleting substances and do not contain such substances.

We reserve the right to make changes to improve technical design and may do so without further notice.
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TEMIC Semiconductor GmbH, P.O.B. 3535, D-74025 Heilbronn, Germany
Telephone: 49 (0)7131 67 2594, Fax number: 49 (0)7131 67 2423