PWM Speed Control for Permanent Excited DC Motors

Description

The monolithic integrated bipolar circuit U2350B is a MOSFET or IGBT-control circuit which works on the principle of pulse width modulation (PWM). The overall concept enables the construction of a power controller with mains voltage compensation where intermittent operation is also possible. In addition, the circuit also enables mains-voltage compensated current control, which maintains the power supplied at a constant level after the preset threshold has been exceeded.

Features

- Pulse width control up to 30 kHz clock frequency
- Mains supply compensation
- Current regulation
- Temperature monitoring with indicator
- Active operation indicator
- Blink-warn indicator
- Switchable to interval operation
- Push-pull output stage for separate supply
- Supply voltage monitoring
- Temperature compensated supply voltage limitation

Applications

- Domestic equipment
- Tools

Package: SO16

Block Diagram

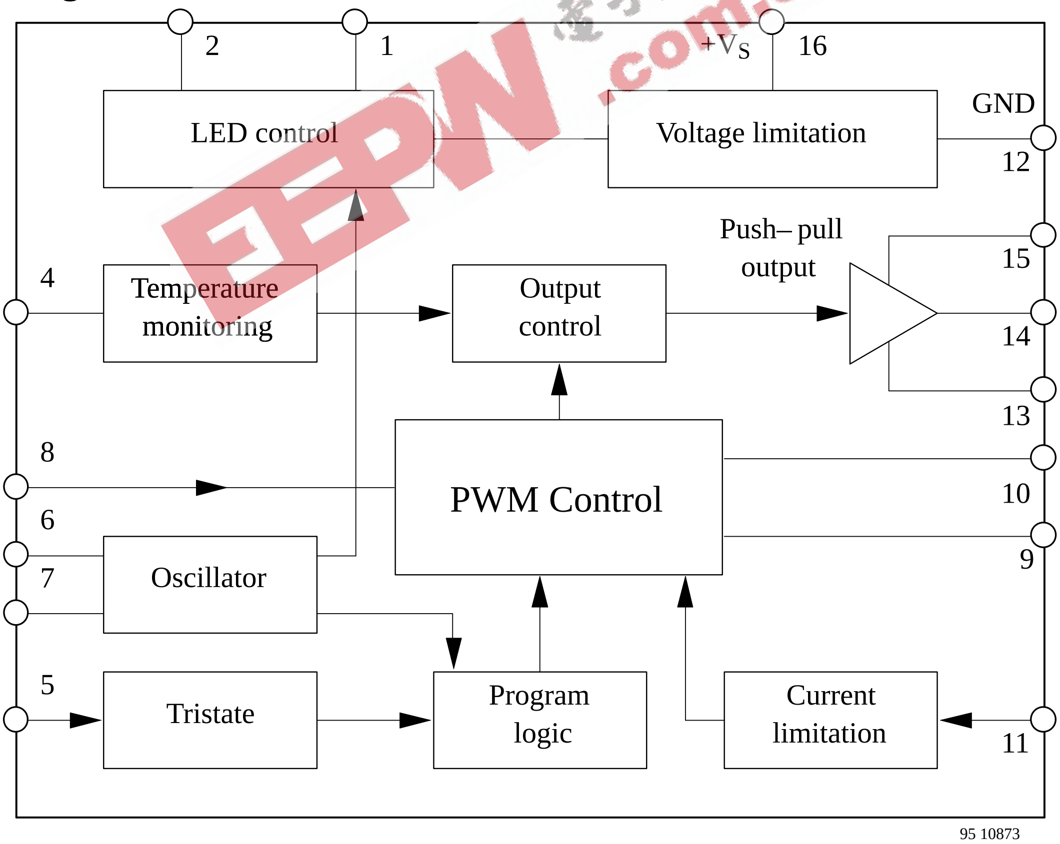


Figure 1. Block diagram

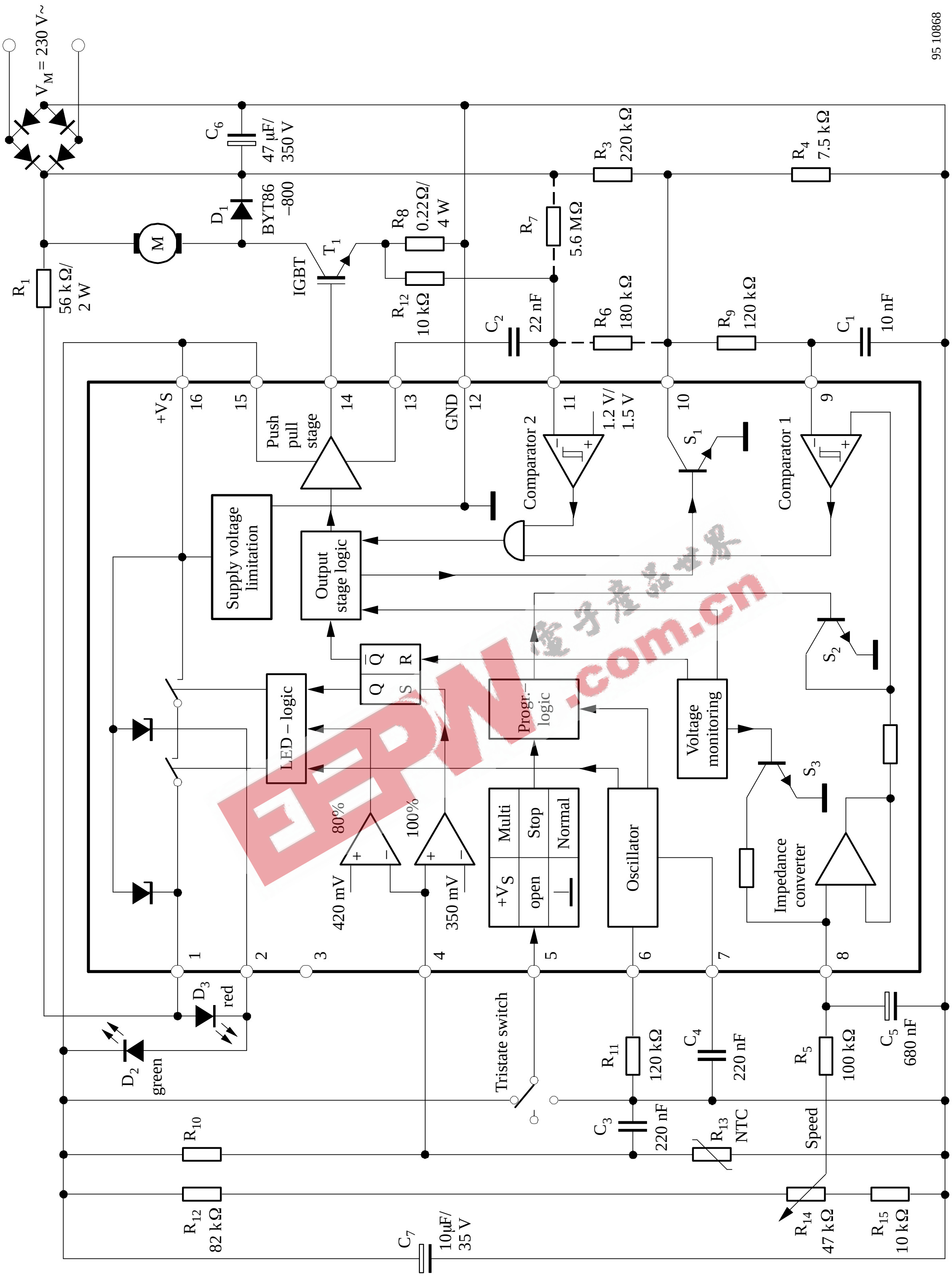
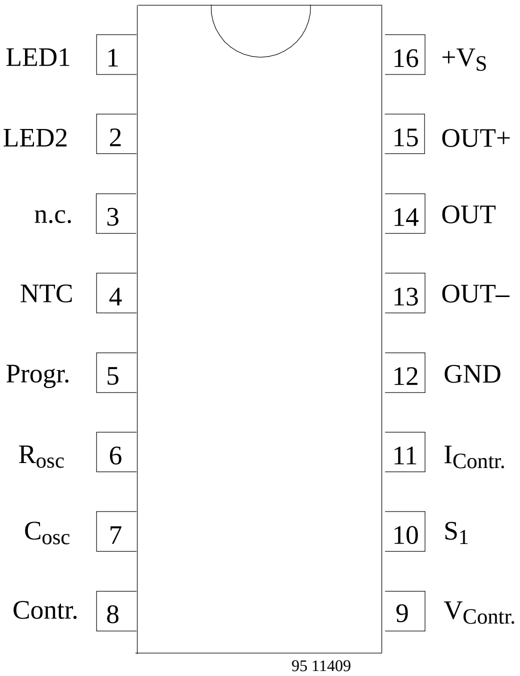


Figure 2. Block diagram with external circuit

Pin Description



Pin	Symbol	Function
1	LED1	LED output 1
2	LED2	LED output 2
3	n.c.	Not connected
4	NTC	Monitoring input
5	Progr.	Tristate programing
6	R_{osc}	Resistor for oscillator
7	C_{osc}	Capacitor for oscillator
8	Contr.	Control input
9	$V_{Contr.}$	Voltage regulation input
10	S_1	Switching output, output S1
11	$I_{Contr.}$	Current regulation input
12	GND	Ground
13	OUT–	– supply for output stage
14	OUT	Output
15	OUT+	+ supply for output stage
16	$+V_S$	Supply voltage

Supply, Pin 16

The internal voltage limiter in the U2350B enables a simple supply from the rectified line voltage. The supply voltage between Pin 16 ($+V_S$) and Pin 12 (ground) is built up via R_1 and is smoothed by C_7. The typically 5 mA supply current is simultaneously used to operate the two LEDs D_2, D_3, which can both be bridged internally. The supply current therefore reaches Pin 16 either via LEDs or the internal switches ($V_{sat} \leq 1.2$ V).

Series resistor, R_1, can be calculated as follows:

$$R_{1max} = \frac{V_{Mmin} - V_{Smax}}{I_{tot}}$$

whereas

$V_{Mmin} = V_{mains} - 15\%$

V_{Smax} = maximum supply voltage

$I_{tot} = I_{Smax} + I_x$

I_{Smax} = Max. current consumption of the IC

I_x = Current consumption of the external components

Here, C_6 must be selected in this way that the voltage at C_7 (figure 2) is not noticeably affected by the load in any mode of operation. For further information regarding mains power supply, refer to figures 6 and 7.

Voltage Monitoring

Whilst the operating voltage is being built up or reduced, uncontrolled output pulses of insufficient amplitude are suppressed by the internal monitoring circuit. The latch is also reset, the LED D_2 (operating indicator) between Pin 2 and Pin 16 is switched off and the control input "Pin 8" is connected to ground via switch S_3 and a 1 kΩ resistor. In connection with a switching hysteresis of approximately 2 V, this mode of operation guarantees fail-safe start-up each time the operating voltage is switched on, in the same way as after short mains interruptions.
Connecting the control input Pin 8 with a capacitor can therefore make a soft start with rapid recovery possible.

Pulse Width Control with Mains Voltage Compensation, Pins 8, 9, 10

Average value of the voltage over the load is controlled to an infinitely selectable value by the comparator Comp. 1 with hysteresis. The rectified mains voltage is divided by R_3 and R_4 and lead in Pin 10. The capacitor C_1 is charged via R_9 until the voltage V_9, which is present at the inverting input of Comp. 1, is more positive than the control voltage V_8 arriving at the non-inverting input via an impedance converter. During the charge time, which is dependent of the mains voltage, the pulse output is at high potential and the switching output Pin 10 is open. If V_9 now becomes greater than V_{10}, the output from Comp. 1 switches over the output stage logic via an AND gate.

The output stage logic now brings V_{14} to low potential and closes the switching output Pin 10. This has the effect of discharging C_1 via R_9 and the switch S_1 until the approximately 300 mV hysteresis of the comparator is completed. The discharge time is dependent on the control voltage V_8.

Comp. 1 then switches over again and the cycle begins once more (see figure 3). This two-state controller compensates the influence of the mains voltage, with the result that the motor voltage or motor speed is largely determined by the magnitude of the control voltage.

Current Control, Pin 11

If the current flowing through the IGBT (or MOSFET) and the shunt resistor R_8 becomes so high that a voltage higher than 1.5 V arises at Pin 11, a second control loop formed with the comparator Comp. 2 becomes active, and overrides the first control loop via an AND gate. This causes the average value of the current, fed to the motor, to be controlled to a constant value. This in turn results in a speed which decreases greatly with the increasing torque (see figure 4).

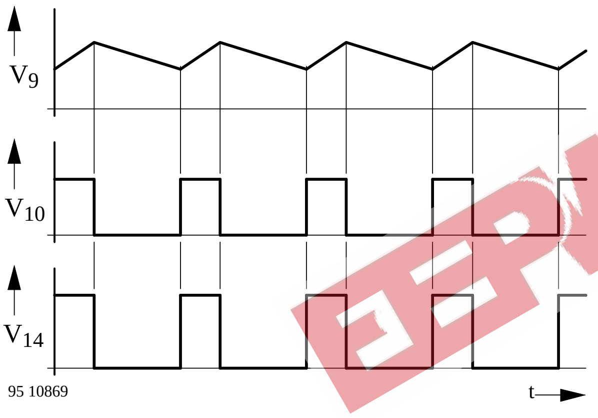


Figure 3. Pulse width control signal characteristics

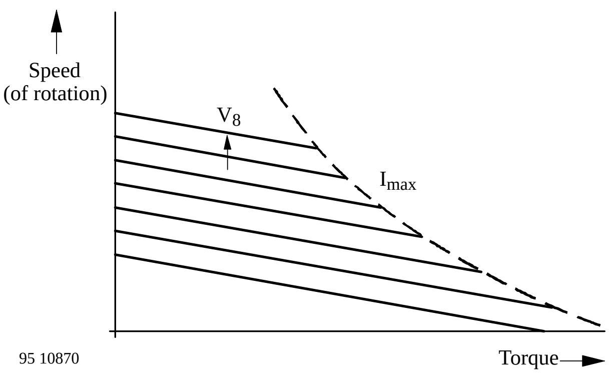


Figure 4. Influence of current control on the characteristic (curve) of a motor

By exceeding the maximum current which is adjustable with R_8, the control dependent voltage V_8 (shunt characteristic) reaches the dotted lines (series characteristic). By applying a current which depends on the load voltage across R_6, the constant value of the current can be further influenced. In addition, the current control limits the starting current.

In the case of effective current limiting, alteration of the rectified mains voltage has an effect on the power taken up. In order to compensate for this influence, the resistor R_7 is connected to Pin 11. If dimensioned appropriately, the consumed power is independent of changes in the mains voltage within a wide range of this voltage.

Operation Mode Selection, Pin 5

It is possible to program three modes of operation with the tristate input, as follows:

a) Intermittent operation (Pin 5 connected to $+V_S$)
A signal emitted by an internal oscillator (see figure 5) switches the output stage ON and OFF periodically via S_2. This intermittent operation is very suitable for certain uses.

b) Stop function (Pin 5 open)
The output is continuously switched off, the motor is at reset.

c) Normal function (Pin 5 connected to V_{12})
The motor runs continuously.

Temperature Monitoring, Pin 4

The circuit also has a monitoring input. If a NTC-resistor is connected to this input, for example, it functions as a temperature sensor. If the voltage V_4 falls below the first threshold V_{T80} (approximately 420 mV) as a result of the increasing temperature, an external LED D_3, which is connected between Pin 1 and Pin 2, starts to blink. If the temperature increases further and the voltage V_4 falls below a second threshold V_{T100} (approximately 350 mV), a latch is set. The latch makes this LED light up continuously, the output stage is blocked. The motor is switched-OFF and remains switched-OFF until the temperature has fallen and until the mains voltage is switched-OFF and switched-ON again (the latch is solely reset by the voltage monitoring). A second LED D_2, which is connected between Pin 2 and Pin 16 and which is continuously illuminated (switch-ON) during normal operation, is switched-OFF.

In the event of wire breakage in the sensor branch, Pin 4 is pulled up to $+V_S$. After the switch-OFF threshold V_{TOFF} (approximately V_S–1.8 V) has been exceeded, the circuit ensures that the latch is set here too. This guarantees safe operation.

Absolute Maximum Ratings

Reference point Pin 12, unless otherwise specified.

Parameters	Symbol	Value	Unit
Supply Current Pin 16 t ≤ 10 µs	I_S i_s	30 60	mA
Push-pull output $V_{13} \leq V_{14} \leq V_{15}$, $V_{15} \leq V_{16}$, $V_{13} \leq V_{12}$ Output current t ≤ 2 ms	I_O i_o	20 200	mA
Signal outputs Input current t ≤ 10 µs	I_I i_i	30 60	mA
Input currents Pin 6, 8 Pin 10	I_I	1 10	mA
Input voltages Pin 4, 5, 7, 9, 10, 11	V_I	0 V to V_{16}	
Storage temperature range	T_{stg}	–40 to +125	°C
Junction temperature	T_j	+125	°C
Ambient temperature range	T_{amb}	–10 to +100	°C

Thermal Resistance

Parameters	Symbol	Value	Unit
Junction ambient DIP16 SO16 on PC board SO16 on ceramic	R_{thJA}	120 180 100	K/W K/W K/W

Electrical Characteristics

V_S = 15.5 V, T_{amb} = 25°C, reference point Pin 12, figure 2, unless otherwise specified.

Parameters	Test Conditions / Pins	Symbol	Min.	Typ.	Max.	Unit
Supply voltage limitation	I_S = 5 mA Pin 16 I_S = 20 mA	V_S	16.2 16.3		17.2 17.8	V
Current consumption		I_S			3.5	mA
Voltage monitoring	Pin 16					
Switch-on threshold		V_{SON}		14.0	14.5	V
Switch-off threshold		V_{SOFF}	12.0	12.5		V
Control input	Pin 8					
Input voltage range		V_I	0		7.5	V
Input quiescent current		I_{IB}			250	nA
Impedance at lower voltage		R_I		1		kΩ
Comparator 1	Pin 9					
Input voltage range		V_{IC}	0		7.5	V
Input quiescent current		I_{IB}			250	nA
Hysteresis	V_8 = 1.5 V Pin 8 – 9	V_{hys}	270	300	330	mV
Delay time	Pin 9 –14	t_d			3	µs

Parameters	Test Conditions / Pins	Symbol	Min.	Typ.	Max.	Unit
Switch S_1	Pin 10					
Leakage current	V_{10} = 15.5 V, V_8 = 3 V, V_9 = 0 V, V_{11} = 0 V	I_R			1	µA
Saturation voltage	I_{10} = 2 mA, V_8 = 0 V, V_9 = 3 V	V_{Sat}			0.25	V
Delay time	Pin 10 – 14	$t_{d(r)}$ $t_{d(f)}$			3 3	µs
Comparator 2	Pin 11					
Input current		I_I			1	µA
Switch-on threshold		V_{TON}	1.12	1.20	1.28	V
Switch-off threshold		V_{TOFF}	1.42	1.50	1.58	V
Delay time (output)	Pin 11 – 14	t_d			3	µs
Push-pull stage	Pin 14					
Saturation voltage	High side Pin 14 – 16 I_{14} = –10 mA, V_{15} = V_{16} Low side I_{14} = 10 mA, V_{13} = V_{12}	V_{SatH} V_{SatL}			2.4 1.2	V
Output current limitation	V_{14} = V_{12}, V_{11} = 0 V, V_8 = 3 V, V_9 = 0 V, t ≤ 1 µs	$–I_O$	100	150	250	mA
	V_{14} = V_{16} , V_8 = 0 V, V_9 = 3 V, t ≤ 1 µs	I_O	100	150	250	mA
Rise time	V_{15} = V_{16}, V_{13} = V_{12}, C_{Gate} = 1 nF	t_r		300		ns
Fall time	C_{Gate} = 1 nF	t_f		800		ns
Operating indicator	I_2 = 5 mA					
Saturation voltage	V_{16} ≤ V_{Soff} or (V_4 ≤ V_{T100}) Pin 2 – 16	V_{Sat}		1.0		V
Voltage limitation	V_{16} ≥ V_{Son}, (V_4 > V_{T100}) Pin 2 – 16	V_{limit}		6.6		V
Overload outputI	I_1 = 5 mA					
Saturation voltage	V_4 > V_{T80} Pin 1 – 2	V_{Sat}		1.0		V
Voltage limitation	V_4 ≤ V_{T80} Pin 1 – 16	V_{limit}		8.6		V
Temperature monitoring	Pin 4					
Input current		I_I			500	nA
80%-threshold		V_{T80}	390	420	450	mV
100%-threshold		V_{T100}	325	350	375	mV
Switch-off threshold		V_{TOFF}		V_S – 1.8		V
Operation mode selection	Pin 5					
Voltage	Pin 5 open (I_5 = 0)	V_5		V_S/2		
Input current	V_5 = V_{16}	I_I		15		µA
	V_5 = V_{12}	$–I_I$		15		µA
Oscillator						
Input current	Pin 6	I_I	1		40	µA
Source voltage	I_6 = – 10 µA Pin 6	V_6		0.9		V
Upper saw tooth threshold	Pin 7	V_{Tmax}		9		V
Lower saw tooth threshold	Pin 7	V_{Tmin}		1.8		V

Parameters	Test Conditions / Pins	Symbol	Min.	Typ.	Max.	Unit
Oscillator frequency	$C_4 = C_{osc} = 220$ nF, see figure 2 Pin 7 $R_{11} = R_{osc} = 120$ kΩ	f_{osc}		1.1		Hz
Blink frequency	$V_{T100} < V_4 \leq V_{T80}$ Pin 1	f_{blink}		2.2		Hz
Switching frequency	$V_5 = V_{16}$ Pin 14 interval operation	f_s		1.1		Hz
Pulse ratio switch	Pin 14	t_p/T	0.2	0.23	0.26	–

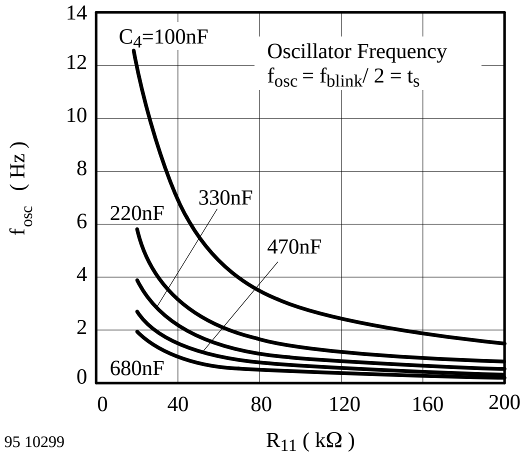


Figure 5.

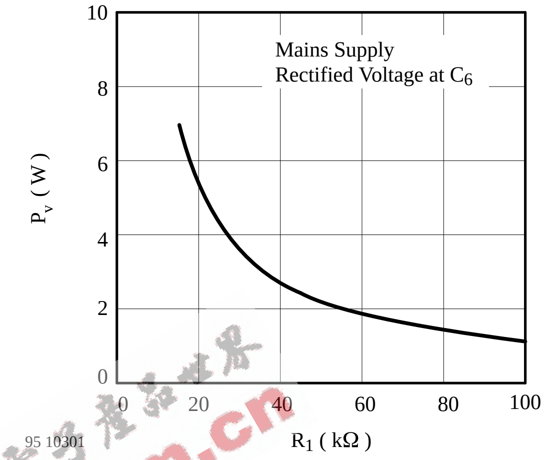


Figure 7.

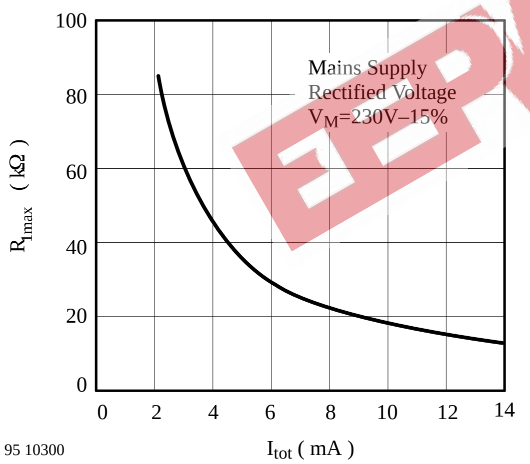
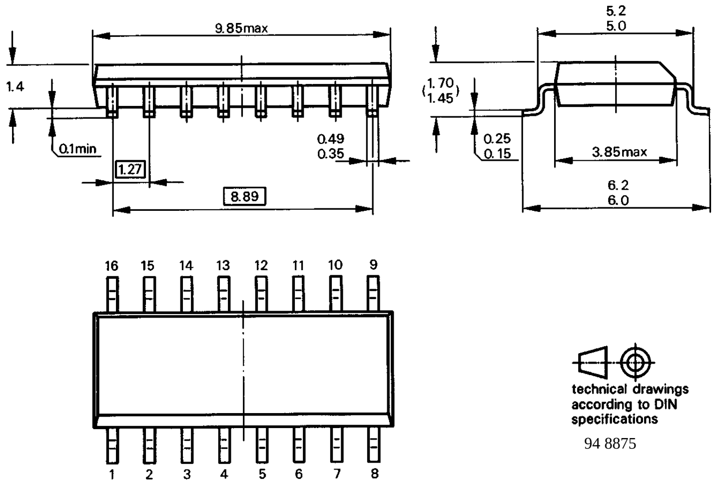


Figure 6.

Dimensions in mm:

Package: SO16



Ozone Depleting Substances Policy Statement

It is the policy of **TEMIC TELEFUNKEN microelectronic 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 TELEFUNKEN microelectronic GmbH semiconductor division 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 can certify that our semiconductors are not manufactured with ozone depleting substances and do not contain such substances.

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