

## PWM Power Control with Automatic Duty Cycle Reduction

### Description

The U6084B is a bipolar technology PWM IC designed for the control of an N-channel power MOSFET used as a high side switch. The IC is ideal for the use in the brightness control (dimming) of lamps such as, in dashboard

applications. For a constant brightness the preselected duty cycle is automatically reduced as a function of the supply voltage.

### Features

- Pulse width modulation up to 2 kHz clock frequency
- Protection against short circuit, load dump overvoltage and reverse  $V_S$
- Duty cycle 0 to 100 % continuously
- Output stage for power MOSFET
- Interference and damage protection according to VDE 0839 and ISO/TR 7637/1.
- Charge pump noise suppressed
- Ground wire breakage protection

**Package:** SO16

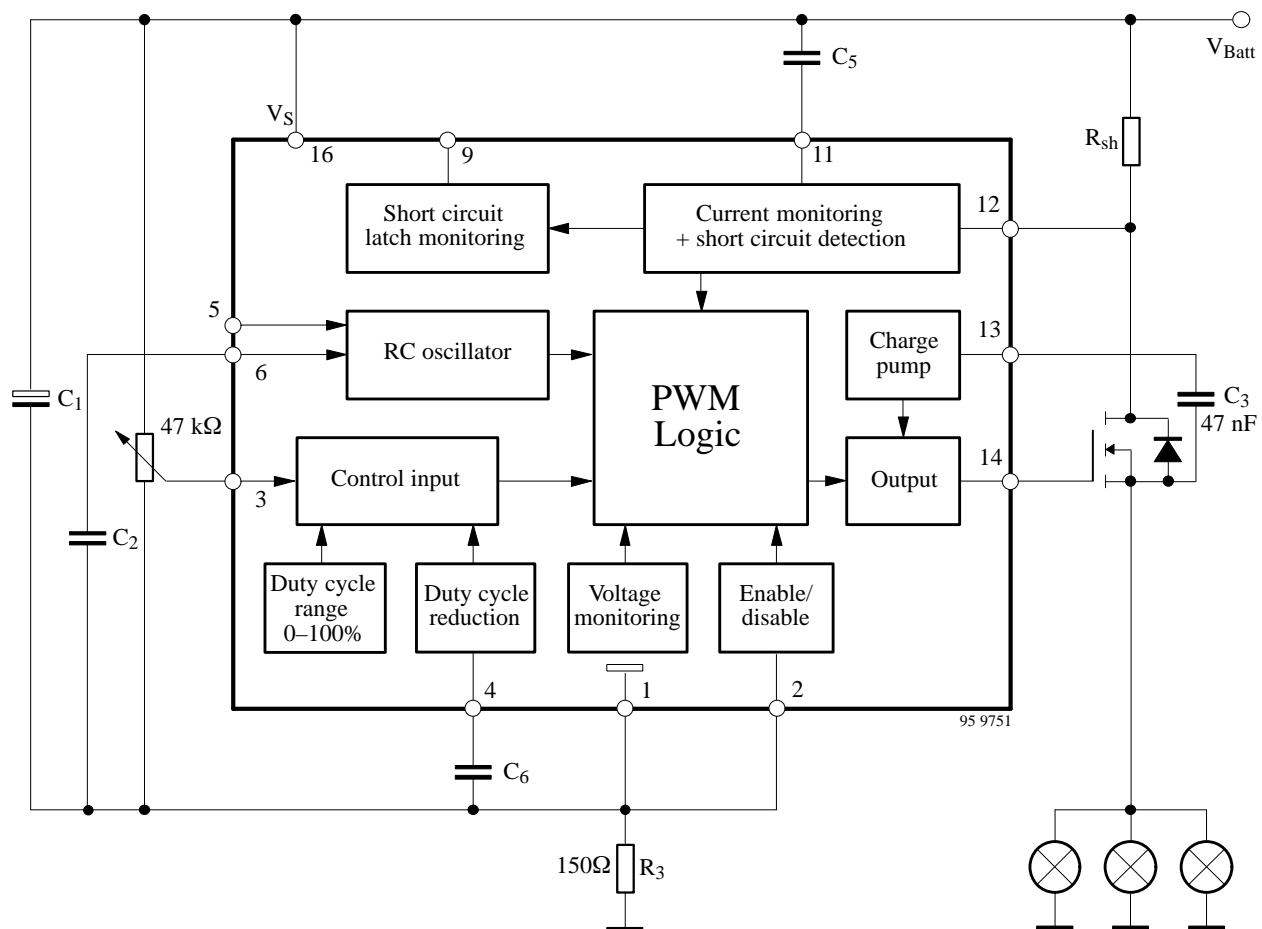
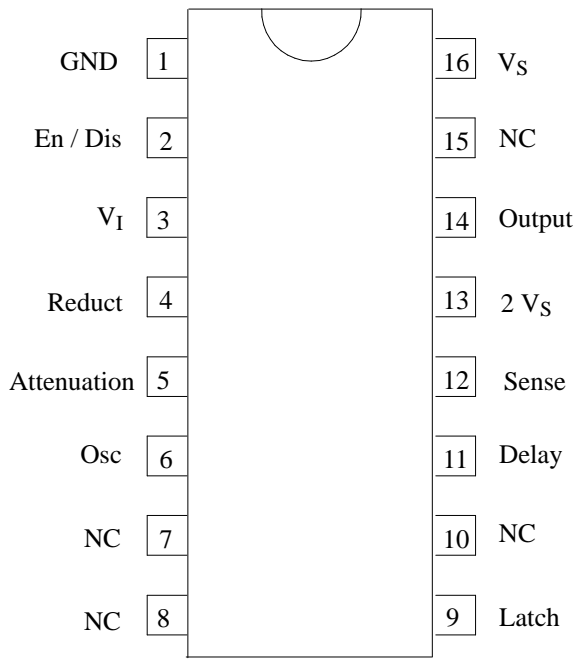


Figure 1. Block diagram with external circuit

## Pin Description



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Pin	Symbol	Function
1	GND	IC ground
2	En / Dis	Enable/disable
3	V <sub>I</sub>	Control input (duty cycle)
4	Reduct	Duty cycle reduction
5	NC	Attenuation
6	Osc	Oscillator
7	NC	Not connected
8	NC	Not connected
9	Latch	Status short circuit latch
10	NC	Not connected
11	Delay	Short circuit protection delay
12	Sense	Current sensing
13	2V <sub>S</sub>	Voltage doubler
14	Output	Output
15	NC	Not connected
16	V <sub>S</sub>	Supply voltage V <sub>S</sub>

## Functional Description

### GND, Pin 1

### Enable/Disable, Pin 2

The dimmer can be switched on or off with pin 2 independently of the set duty cycle.

V <sub>2</sub>	Function
Approx. >0.7 V or open	Disable
<0.7 V or connected to Pin 1	Enable

### Control Input, Pin 3

The pulse width is controlled by means of an external potentiometer (47 kΩ). The characteristic (angle of rotation/duty cycle) is linear. The duty cycle can be varied from 0 to 100%. It is possible to further restrict the duty cycle with the resistors R<sub>1</sub> and R<sub>2</sub>.

Pin 3 is protected against short-circuit to V<sub>Batt</sub> and ground GND (V<sub>Batt</sub> ≤ 16.5 V).

### Duty Cycle Reduction, Pin 4

With Pin 4 connected according to figure 2, the set duty cycle is reduced as from V<sub>Batt</sub> ≈ 12.5 V. This causes a power reduction in the FET and in the lamps. In addition,

the brightness of the lamps is largely independent of the supply voltage range, V<sub>Batt</sub> = 12.5 to 16 V.

### Output Slope Control

The rise and fall time (t<sub>r</sub>, t<sub>f</sub>) of the lamp voltage can be limited to reduce radio interference. This is done with an integrator which controls a power MOSFET as source follower. The slope time is controlled by an external capacitor and the oscillator current.

Calculation:

$$t_f = t_r = V_{Batt} \cdot \frac{C_4}{I_{osc}}$$

With V<sub>Batt</sub> = 12 V, C<sub>4</sub> = 470 pF and I<sub>osc</sub> = 40 μA, we thus obtain a controlled slope of

$$t_f = t_r = 12 \text{ V} \cdot \frac{470 \text{ pF}}{40 \text{ μA}} = 141 \text{ μs}$$

### Attenuation, Pin 5

Capacitor C<sub>4</sub> connected to Pin 5 damps oscillation tendencies.

### Oscillator, Pin 6

The oscillator determines the frequency of the output voltage. This is defined by an external capacitor, C<sub>2</sub>. It is

charged with a constant current,  $I$ , until the upper switching threshold is reached. A second current source is then activated which taps a double current,  $2I$ , from the charging current. The capacitor,  $C_2$ , is thus discharged by the current,  $I$ , until the lower switching threshold is reached. The second source is then switched off again and the procedure starts once more.

### Example for oscillator frequency calculation

$$V_{T100} = V_S \cdot \alpha_1 = (V_{Batt} - I_S \cdot R_3) \cdot \alpha_1$$

$$V_{T<100} = V_S \cdot \alpha_2 = (V_{Batt} - I_S \cdot R_3) \cdot \alpha_2$$

$$V_{TL} = V_S \cdot \alpha_3 = (V_{Batt} - I_S \cdot R_3) \cdot \alpha_3$$

where

$$V_{T100} = \text{High switching threshold (100\% duty cycle)}$$

$$V_{T<100} = \text{High switching threshold (< 100\% duty cycle)}$$

$$V_{TL} = \text{Low switching threshold}$$

$\alpha_1, \alpha_2$  and  $\alpha_3$  are fixed constant.

The above mentioned threshold voltages are calculated for the following values given in the data sheet.

$$V_{Batt} = 12 \text{ V}, I_S = 4 \text{ mA}, R_3 = 150 \Omega, \\ \alpha_1 = 0.7, \alpha_2 = 0.67 \text{ and } \alpha_3 = 0.28.$$

$$V_{T100} = (12 \text{ V} - 4 \text{ mA} \cdot 150 \Omega) \cdot 0.7 \approx 8 \text{ V}$$

$$V_{T<100} = 11.4 \text{ V} \cdot 0.67 = 7.6 \text{ V}$$

$$V_{TL} = 11.4 \text{ V} \cdot 0.28 = 3.2 \text{ V}$$

For a duty cycle of 100%, an oscillator frequency,  $f$ , is as follows:

$$f = \frac{I_{osc}}{2 \cdot (V_{T100} - V_{TL}) \cdot C_2}, \text{ where } C_2 = 22 \text{ nF} \\ \text{and } I_{osc} = 40 \mu\text{A}$$

Therefore:

$$f = \frac{40 \mu\text{A}}{2 \cdot (8 \text{ V} - 3.2 \text{ V}) \cdot 22 \text{ nF}} = 189 \text{ Hz}$$

For a duty cycle of less than 100%, the oscillator frequency,  $f$ , is as follows:

$$f = \frac{I_{osc}}{2 \cdot (V_{T<100} - V_{TL}) \cdot C_2 + 2 \cdot V_{Batt} \cdot C_4}$$

whereas  $C_4 = 470 \text{ pF}$

$$= \frac{I_{osc}}{2 \cdot (7.6 \text{ V} - 3.2 \text{ V}) \cdot 22 \text{ nF} + 2 \cdot 12 \text{ V} \cdot 470 \text{ pF}} \\ = 195 \text{ Hz}$$

A selection of different values of  $C_2$  and  $C_4$ , provides a range of oscillator frequency,  $f$ , from 10 to 2000 Hz.

### Pins 7, 8, 10 and 15

Not connected.

### Status Short Circuit Latch, Pin 9

#### Overvoltage Detection

##### Stage 1

If overvoltages  $V_{Batt} > 20 \text{ V}$  (typ.) occur, the external transistor is switched off and on at  $V_{Batt} < 18.5 \text{ V}$  (hysteresis).

##### Stage 2

If  $V_{Batt} > 28.5 \text{ V}$  (typ), the voltage limitation of the IC is reduced from 26 V to 20 V. The gate of the external transistor remains at the potential of the IC ground, thus producing voltage sharing between FET and lamps in the event of overvoltage pulses occurring (e.g., load dump). The short-circuit protection is not in operation. At  $V_{Batt} < 23 \text{ V}$ , the overvoltage detection stage 2 is switched off.

### Short-Circuit Protection and Current Sensing, Pins 11 and 12

#### 1. Short-Circuit Detection and Time Delay, $t_d$

The lamp current is monitored by means of an external shunt resistor. If the lamp current exceeds the threshold for the short-circuit detection circuit ( $V_{T2} \approx 90 \text{ mV}$ ), the duty cycle is switched over to 100% and the capacitor  $C_5$  is charged by a current source of  $20 \mu\text{A}$  ( $I_{dis} - I_{ch}$ ). The external FET is switched off after the cut-off threshold ( $V_{TL}$ ) is reached. Renewed switching on the FET is possible only after a power-on reset. The current source,  $I_{ch}$ , ensures that the capacitor  $C_5$  is not charged by parasitic currents. The capacitor  $C_5$  is discharged by  $I_{ch}$  to typ. 0.7 V.

Time delay,  $t_d$ , is as follows:

$$t_d = C_5 \cdot (V_{TL} - 0.7 \text{ V}) / (I_{dis} - I_{ch})$$

With  $C_5 = 330 \text{ nF}$  and  $V_{Batt} = 12 \text{ V}$ , we have

$$t_d = 330 \text{ nF} \cdot (9.8 \text{ V} - 0.7 \text{ V}) / 20 \mu\text{A} \\ = 150 \text{ ms.}$$

The status of the short-circuit latch can be monitored via Pin 9 (open collector output).

Pin 9	Function
L	Short-circuit detected
H	No short-circuit detected

## U6084B-FP

### 2. Current Limitation

The lamp current is limited by a control amplifier that protects the external power transistor. The voltage drop across an external shunt resistor acts as the measured variable. Current limitation takes place for a voltage drop of  $V_{T1} \approx 100$  mV. Owing to the difference  $V_{T1} - V_{T2} \approx 10$  mV, current limitation occurs only when the short-circuit detection circuit has responded.

After a power-on reset, the output is inactive for half an oscillator cycle. During this time, the supply voltage capacitor can be charged so that current limitation is guaranteed in the event of a short circuit when the IC is switched on for the first time.

### Ground-Wire Breakage

To protect the FET in the case of ground-wire breakage, a 820 k $\Omega$  resistor between gate and source it is recommended to provide proper switch-off conditions.

### Charge Pump and Output, Pins 13 and 14

Output, Pin 14, is suitable for controlling a power MOSFET. During the active integration phase, the supply current of the operational amplifier is mainly supplied by the capacitor  $C_3$  (bootstrapping). Additionally, a trickle charge is generated by an integrated oscillator ( $f_{13} \approx 400$  kHz) and a voltage doubler circuit. This permits a gate voltage supply at a duty cycle of 100%.

### Undervoltage Detection:

In the event of voltages of approx.  $V_{Batt} < 5.0$  V, the external FET is switched off and the latch for short-circuit detection is reset.

A hysteresis ensures that the FET is switched on again at approximately  $V_{Batt} \geq 5.4$  V.

### Supply Voltage, $V_S$ or $V_{Batt}$ , Pin 16

## Absolute Maximum Ratings

Parameters	Symbol	Value	Unit
Supply voltage	$V_S$	25	V
Junction temperature	$T_j$	150	$^{\circ}\text{C}$
Ambient temperature range	$T_{amb}$	-40 to +110	$^{\circ}\text{C}$
Storage temperature range	$T_{stg}$	-55 to +125	$^{\circ}\text{C}$

## Thermal Resistance

Parameters	Symbol	Value	Unit
Junction ambient	$R_{thJA}$	120	K/W

## Electrical Characteristics

$T_{amb} = -40$  to  $+110^{\circ}\text{C}$ ,  $V_{Batt} = 9$  to  $16.5$  V, (basic function is guaranteed between  $6.0$  V to  $9.0$  V) reference point Pin GND, unless otherwise specified (figure 1).

Parameters	Test Conditions / Pins	Symbol	Min.	Typ.	Max.	Unit
Current consumption	Pin 16	$I_S$			6.8	mA
Supply voltage	Overvoltage detection, stage 1	$V_{Batt}$			25	V
Stabilized voltage	$I_S = 10$ mA Pin 16	$V_Z$	24.5		27.0	V
Battery undervoltage detection	ON	$V_{Batt}$	4.4	5.0	5.6	V
	OFF		4.8	5.4	6.0	

Parameters	Test Conditions / Pins	Symbol	Min.	Typ.	Max.	Unit
<b>Oscillator</b> $f = 10$ to $2000$ Hz <span style="float: right;">Pin 6</span>						
Threshold cycle Upper	$V_{14} = \text{High}, \alpha_1 = \frac{V_{T100}}{V_S}$	$\alpha_1$	0.68	0.7	0.72	
	$V_{14} = \text{Low}, \alpha_2 = \frac{V_{T<100}}{V_S}$	$\alpha_2$	0.65	0.67	0.69	
	$\alpha_3 = \frac{V_{TL}}{V_S}$	$\alpha_3$	0.26	0.28	0.3	
Constant oscillator current	$V_{\text{Batt}} = 12$ V	$\pm I_{\text{osc}}$	26	40	54	$\mu\text{A}$
Frequency tolerance	$C_4$ open, $C_2 = 470$ nF, duty cycle = 50%	$\Delta f$	6.0	9.9	13.5	Hz
<b>Battery overvoltage detection</b> <span style="float: right;">Pin 2</span>						
Stage 1:	Gate output: – switched off – switched on	$V_{\text{Batt}}$	18.3 16.7	20.0 18.5	21.7 20.3	V
Stage 2:	Detection: – on – off	$V_{\text{Batt}}$	25.5 19.5	28.5 23.0	32.5 26.5	V
Stabilized voltage	$I_S = 30$ mA <span style="float: right;">Pin 16</span>	$V_Z$	18.5	20.0	21.5	V
<b>Gate output</b> <span style="float: right;">Pin 14</span>						
Voltages Reference point, battery GND	Low level	$V_{14}$	0.35	0.70	0.95	V
	$V_{\text{Batt}} = 16.5$ V, $T_{\text{amb}} = 110$ °C, $R_3 = 150$ $\Omega$					
	High level, duty cycle 100%	$V_{14}$		$V_{13}$		
Current:	$V_{14} = \text{Low level}$	$I_{14}$	1.0			mA
	$V_{14} = \text{High level},$ $I_{13} >  I_{14} $		-1.0			
<b>Short-circuit protection</b> <span style="float: right;">Pin 12</span>						
Short-circuit current regulation	$V_{T1} = V_S - V_{12}$	$V_{T1}$	85	100	120	mV
Short-circuit detection	$V_{T2} = V_S - V_{12}$	$V_{T2}$	75	90	105	mV
		$V_{T1} - V_{T2}$	3	10	30	mV
Short circuit recognition, $V_{\text{Batt}} = 12$ V <span style="float: right;">Pin 11</span>						
Switched off threshold	$V_{TL} = V_S - V_{11}$	$V_{TL}$	9.5	9.8	10.1	V
Charge current		$I_{\text{ch}}$		23		$\mu\text{A}$
Discharge current		$I_{\text{dis}}$		3		$\mu\text{A}$
Capacitance current	$I_5 = I_{\text{ch}} - I_{\text{dis}}$	$I_5$	13	20	27	mA
<b>Output short-circuit latch</b> <span style="float: right;">Pin 9</span>						
Saturation voltage		$V_{\text{sat}}$		150	350	mV
<b>Voltage doubler</b> <span style="float: right;">Pin 13</span>						
Voltage	Duty cycle 100%	$V_{13}$	$2 V_S$			
Oscillator frequency	$I_9 = 100$ $\mu\text{A}$	$f_{13}$	280	400	520	kHz
Internal voltage limitation	$I_{13} = 5$ mA	$V_{13}$	26	27.5	30.0	V
	or whichever is lower	$V_{13}$	$(V_{S+14})$	$(V_{S+15})$	$(V_{S+16})$	
<b>Enable/ Disable</b> <span style="float: right;">Pin 2</span>						
Current	$V_2 = 0$ V	$I_2$	-20	-40	-60	$\mu\text{A}$
<b>Duty cycle reduction</b> <span style="float: right;">Pin 4</span>						
Z-voltage	Duty factor reduction Pin 4 $I_4 = 500$ $\mu\text{A}$	$V_Z$	6.9	7.4	8.0	V

## Application

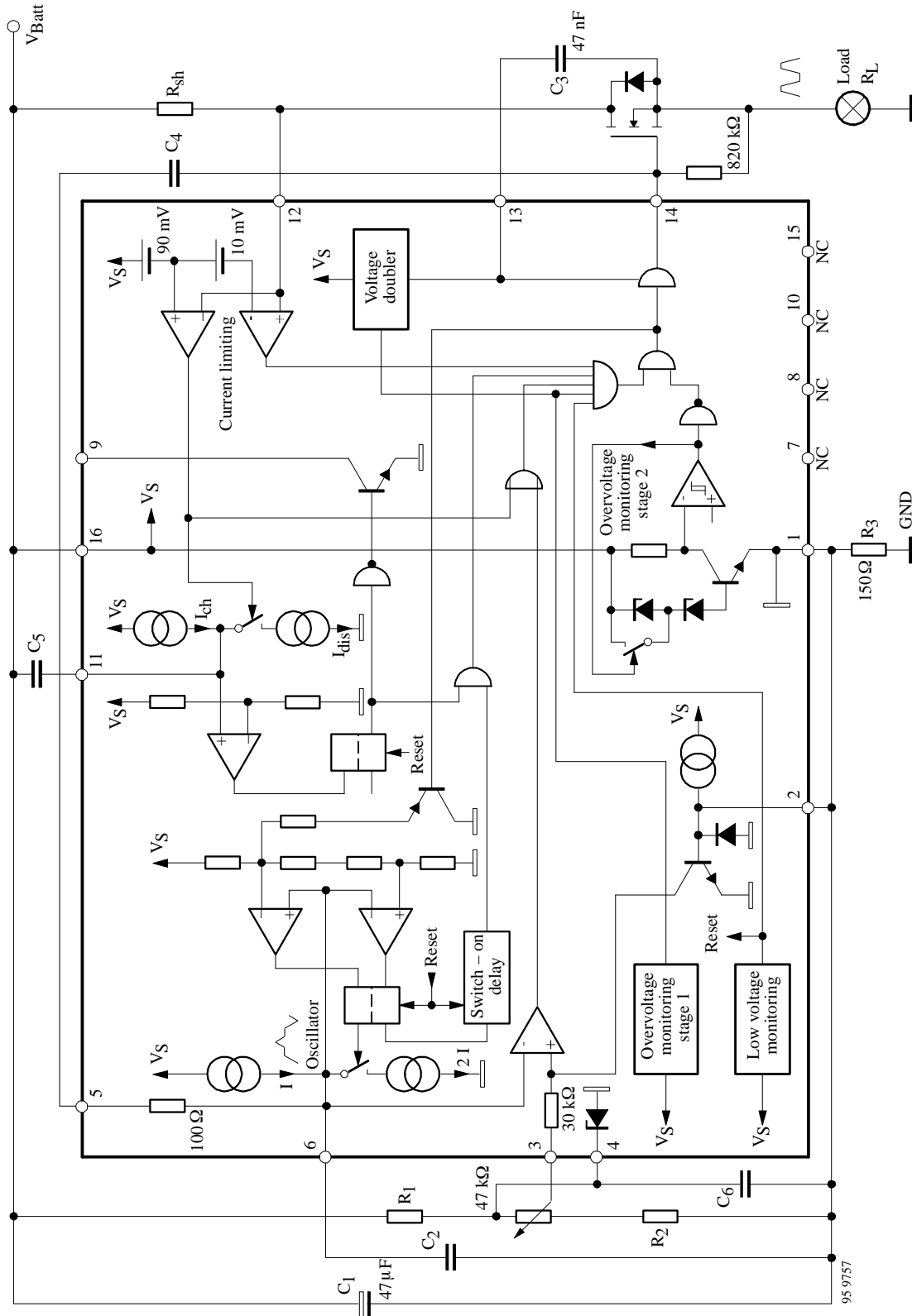
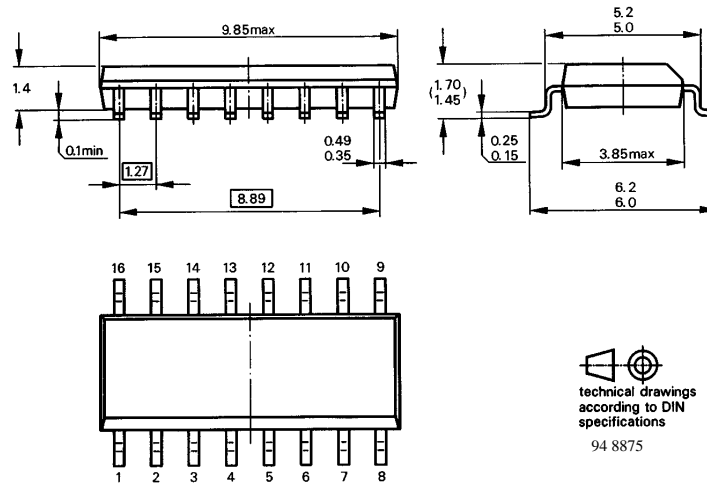


Figure 2.

## Dimensions in mm

Package: SO 16



## 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.

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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.

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TEMIC TELEFUNKEN microelectronic GmbH, P.O.B. 3535, D-74025 Heilbronn, Germany  
Telephone: 49 (0)7131 67 2831, Fax number: 49 (0)7131 67 2423