

## PWM Power Control with Low Duty Cycle Switch Off

### Description

U6081B is a PWM IC in bipolar technology 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 e.g., in dashboard applications.

### 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%
- Output stage for power MOSFET
- Interference and damage protection according to VDE 0839 and ISO/TR 7637/1.
- Ground wire breakage protection
- Charge pump noise suppressed

### Ordering Information

Extended Type Number	Package	Remarks
U6081B	DIP8	

### Block Diagram

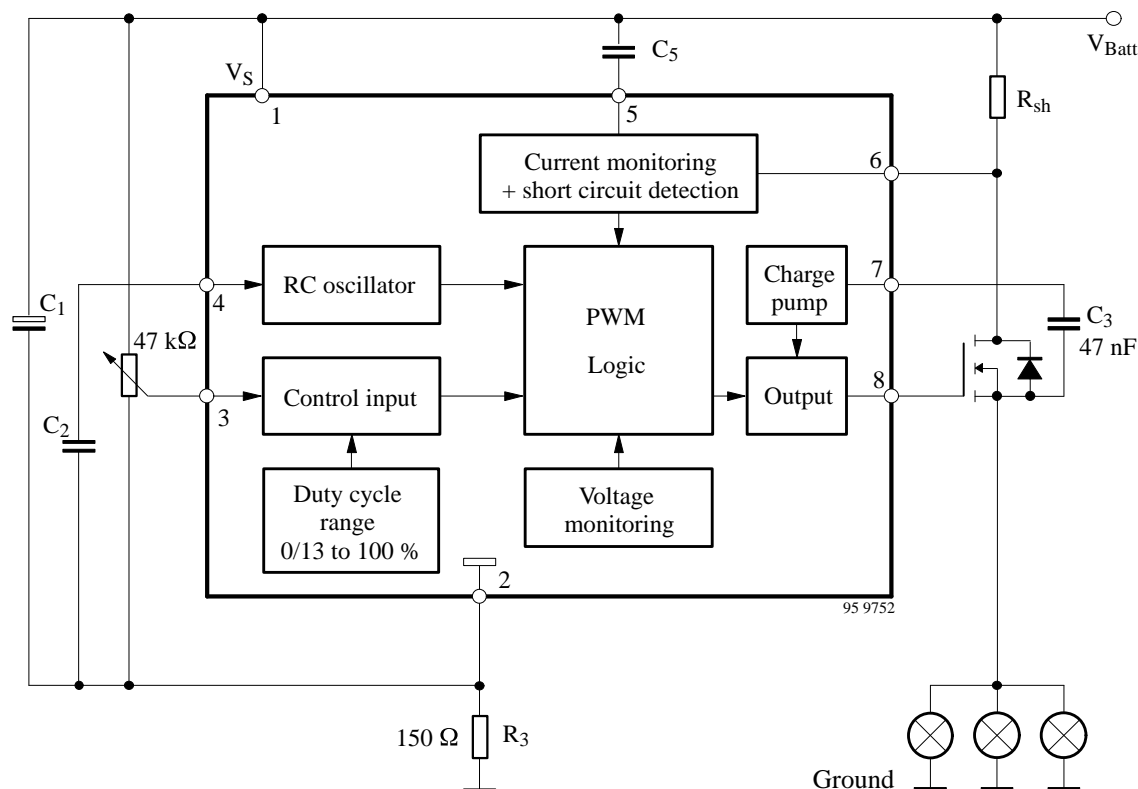
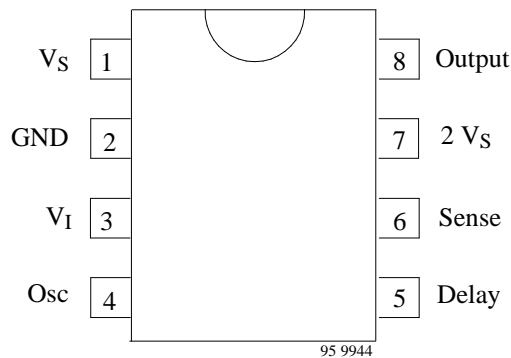


Figure 1. Block diagram with external circuit

## Pin Description



Pin	Symbol	Function
1	V <sub>S</sub>	Supply voltage V <sub>S</sub>
2	GND	IC ground
3	V <sub>I</sub>	Control input (duty cycle)
4	Osc	Oscillator
5	Delay	Short circuit protection delay
6	Sense	Current sensing
7	2 V <sub>S</sub>	Voltage doubler
8	Output	Output

## Functional Description

### Pin 1, Supply Voltage, V<sub>S</sub> or V<sub>Batt</sub>

#### Overvoltage Detection

Stage 1:

If V<sub>Batt</sub> > 20 V occurs the external transistor will be switched off and switched on again at V<sub>Batt</sub> < 18.5 V (hysteresis).

Stage 2:

If V<sub>Batt</sub> > 28 V, the external transistor is switched on again (load-dump protection). At the same time the voltage limitation of the IC is reduced from V<sub>S</sub> ≈ 26 V to V<sub>S</sub> ≈ 20 V. This leads to a hysteresis characteristic so that the load-dump detection is switched off again only at V<sub>Batt</sub> < 23 V. In this case the short-circuit protection is not in operation.

#### Undervoltage Detection

In the event of voltages of approximately V<sub>Batt</sub> < 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<sub>Batt</sub> ≥ 5.4 V.

### Pin 2, GND

#### Ground-Wire Breakage

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

### Pin 3, Control Input

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%. To avoid inadmissibly high filament cold currents, the dimmer is switched off at duty cycles of approximately < 10% or is switched on only at duty cycles of approximately > 13% (hysteresis). It is possible to further restrict the duty cycle with the resistors R<sub>1</sub> and

R<sub>2</sub> (see figure 2). Pin 3 is protected against short-circuit to V<sub>Batt</sub> and ground GND (V<sub>Batt</sub> ≤ 16.5 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 C<sub>4</sub> and the oscillator current (see figure 2).

Calculation:

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

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

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

A 100-Ω resistor in series to C<sub>4</sub> is recommended to damp device oscillations (see figure 2).

### Pin 4, Oscillator

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, 2 × I, from the charging current. The capacitor, C<sub>2</sub>, 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 again.

#### Example for oscillator frequency calculation:

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

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

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

where

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

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

$V_{TL}$  = 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.

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

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

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

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

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

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

Therefore:

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

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

$$f = \frac{I_{osc}}{2 \times (V_{T<100} - V_{TL}) \times C_2 + 4 \times V_{Batt} \times C_4}$$

whereas  $C_4 = 470 \text{ pF}$

$$f = \frac{40 \text{ } \mu\text{A}}{2 \times (7.6 \text{ V} - 3.2 \text{ V}) \times 22 \text{ nF} + 4 \times 12 \text{ V} \times 470 \text{ pF}}$$

$$= 185 \text{ Hz}$$

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

## Pins 5 and 6, Short-Circuit Protection and Current Sensing

### 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  $20 \text{ } \mu\text{A}$  ( $I_{ch} - I_{dis}$ ). The external FET is switched off after the cut-off threshold ( $V_{T5}$ ) is reached. Renewed switching on the FET is possible only after a power-on reset. The current source,  $I_{dis}$ , ensures that the capacitor  $C_5$  is not charged by parasitic currents. The capacitor  $C_5$  is discharged by  $I_{dis}$  to typ.  $0.7 \text{ V}$ .

Time delay,  $t_d$ , is as follows:

$$t_d = C_5 \cdot (V_{T5} - 0.7 \text{ V}) / (I_{ch} - I_{dis})$$

With  $C_5 = 330 \text{ nF}$  and  $V_{T5} = 9.8 \text{ V}$ , ( $I_{ch} - I_{dis}$ ) =  $20 \text{ } \mu\text{A}$ , we have

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

$$= 150 \text{ ms.}$$

### 2. Current Limitation

The lamp current is limited by a control amplifier to protect 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  $V_{T1} \approx 100 \text{ mV}$ . Owing to the difference  $V_{T1} - V_{T2} \approx 10 \text{ mV}$  it is ensured that current limitation occurs only when the short circuit detection circuit has responded.

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

## Pins 7 and 8, Charge Pump and Output

Output, Pin 8, 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 ( $f_7 \approx 400 \text{ kHz}$ ) and a voltage doubler circuit. This permits a gate voltage supply at a duty cycle of 100%.

## Absolute Maximum Ratings

Parameters	Symbol	Value	Unit
Junction temperature	$T_j$	150	°C
Ambient temperature range	$T_{amb}$	-40 to +110	°C
Storage temperature range	$T_{stg}$	-55 to +125	°C

## Thermal Resistance

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

## Electrical Characteristics

$T_{amb} = -40$  to  $+110$ °C,  $V_{Batt} = 9$  to  $16.5$  V, (basic function is guaranteed between  $6.0$  V to  $9.0$  V) reference point is ground, unless otherwise specified (see figure 1). All other values refer to Pin GND (Pin 2).

Parameters	Test Conditions / Pins	Symbol	Min	Typ	Max	Unit
Current consumption	Pin 1	$I_S$			6.8	mA
Supply voltage	Overvoltage detection, stage 1	$V_{Batt}$			25	V
Stabilized voltage	$I_S = 10$ mA Pin 1	$V_Z$	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	
<b>Battery overvoltage detection</b> Pin 2						
Stage 1:	- on	$V_{Batt}$	18.3	20.0	21.7	V
	- off		16.7	18.5	20.3	
Stage 2:	- on	$V_{Batt}$	25.5	28.5	32.5	V
	- off		19.5	23.0	26.5	
Stabilized voltage	$I_S = 30$ mA Pin 1	$V_Z$	18.5	20.0	21.5	V
<b>Short-circuit protection</b> Pin 6						
Short-circuit current limitation	$V_{T1} = V_S - V_6$	$V_{T1}$	85	100	120	mV
Short-circuit detection	$V_{T2} = V_S - V_6$	$V_{T2}$	75	90	105	mV
		$V_{T1} - V_{T2}$	3	10	30	mV
<b>Delay timer short-circuit detection, <math>V_{Batt} = 12</math> V</b> Pin 5						
Switched off threshold	$V_{T5} = V_S - V_5$	$V_{T5}$	9.5	9.8	10.1	V
Charge current		$I_{ch}$		23		μA
Discharge current		$I_{dis}$		3		μA
Capacitance current	$I_5 = I_{ch} - I_{dis}$	$I_5$	13	20	27	mA
<b>Voltage doubler</b> Pin 7						
Voltage	Duty cycle 100%	$V_7$	$2 V_S$			
Oscillator frequency		$f_7$	280	400	520	kHz
Internal voltage limitation	$I_7 = 5$ mA (whichever is lower)	$V_7$	26	27.5	30.0	V
		$V_7$	$V_{S+14}$	$V_{S+15}$	$V_{S+16}$	V

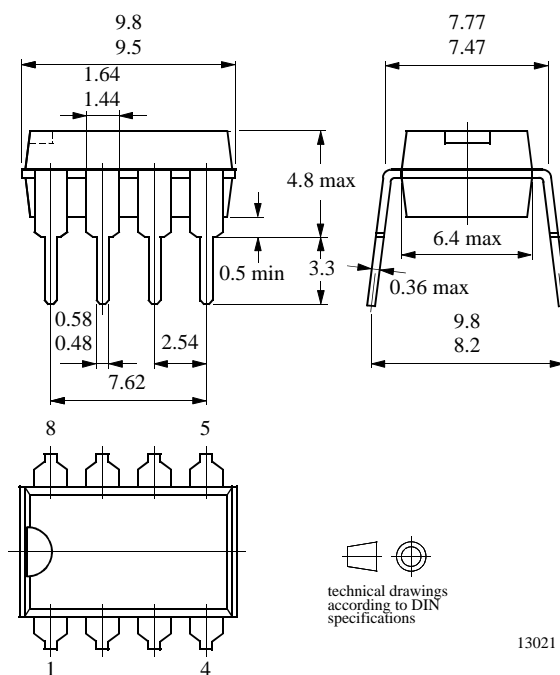
Parameters	Test Conditions / Pins	Symbol	Min	Typ	Max	Unit
<b>Switch-off at small duty cycles</b> $V_{Batt} = 12\text{ V}$ Pin 3						
Output disabled		$V_3/V_S$	0.3	0.32	0.34	
Output active		$V_3/V_S$	0.32	0.34	0.36	
Hysteresis switch-on		$\Delta V_3/V_S$	0.004		0.032	
<b>Gate output</b> Pin 8						
Voltage	Low level	$V_8$	0.35	0.70	0.95	V
	$V_{Batt} = 16.5\text{ V}$ , $T_{amb} = 110^\circ\text{C}$ , $R_3 = 150\ \Omega$				1.5 *)	
	High level, duty cycle 100%	$V_8$		$V_7$		
Current	$V_8 = \text{Low level}$	$I_8$	1.0			mA
	$V_8 = \text{High level}$ , $I_7 >  I_8 $		-1.0			
<b>Oscillator</b>						
Frequency	Pin4	f	10		2000	Hz
Threshold cycle Upper	$V_8 = \text{High}$ , $\alpha_1 = \frac{V_{T100}}{V_S}$	$\alpha_1$	0.68	0.7	0.72	
	$V_8 = \text{Low}$ , $\alpha_2 = \frac{V_{T<100}}{V_S}$	$\alpha_2$	0.65	0.67	0.69	
Lower	$\alpha_3 = \frac{V_{TL}}{V_S}$	$\alpha_3$	0.26	0.28	0.3	
Oscillator current	$V_{Batt} = 12\text{ V}$	$\pm I_{osc}$	34	45	54	$\mu\text{A}$
Frequency tolerance	$C_4$ open, $C_2 = 470\text{ nF}$ , duty cycle = 50%	f	6.0	9.9	13.5	Hz

\*) Reference point is battery ground

## Package Information

Package DIP8

Dimensions in mm



**Application**

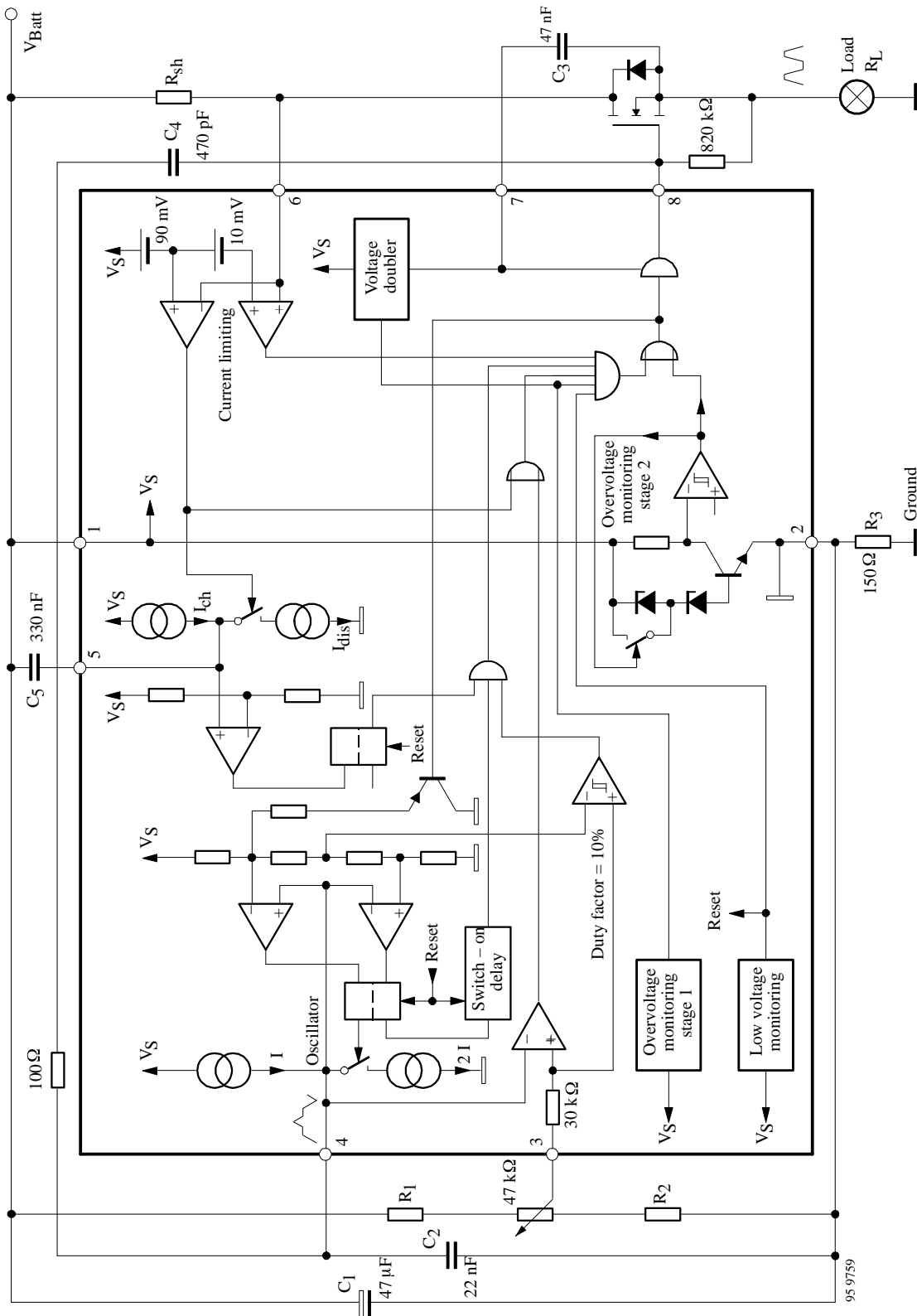


Figure 2.

## 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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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