

## 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

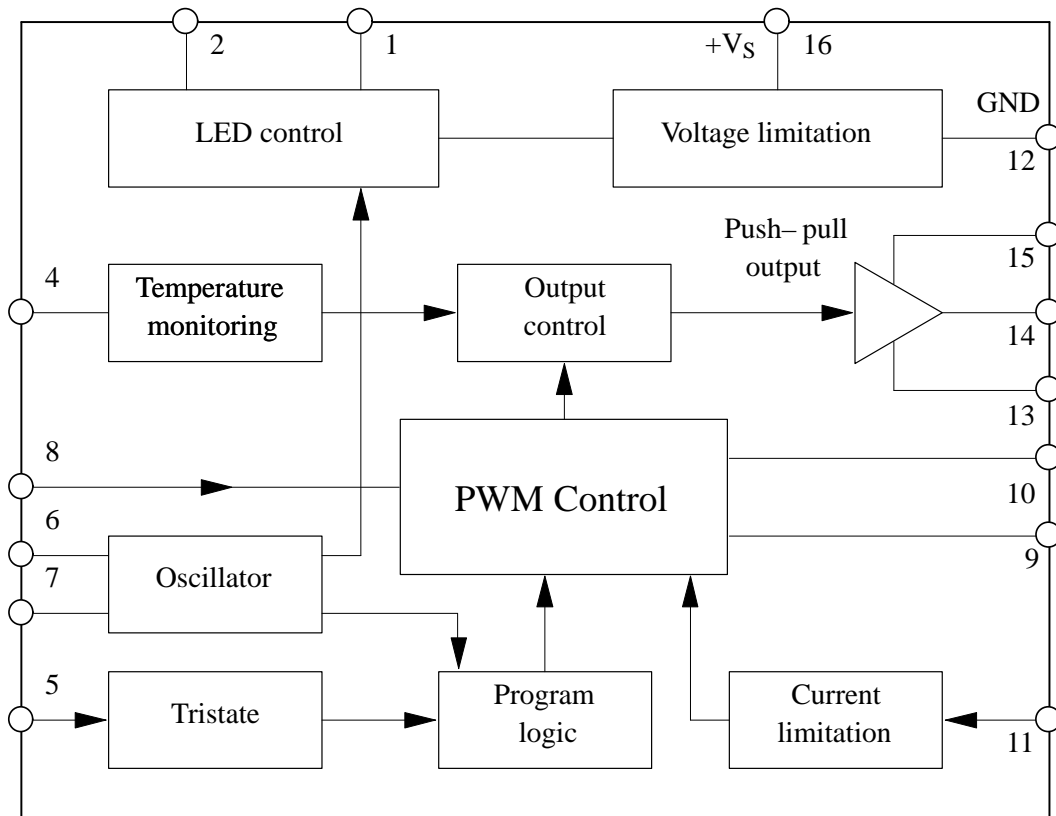
- Supply voltage monitoring
- Temperature compensated supply voltage limitation

### Applications

- Domestic equipment
- Tools

**Package:** SO16

### Block Diagram



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Figure 1. Block diagram

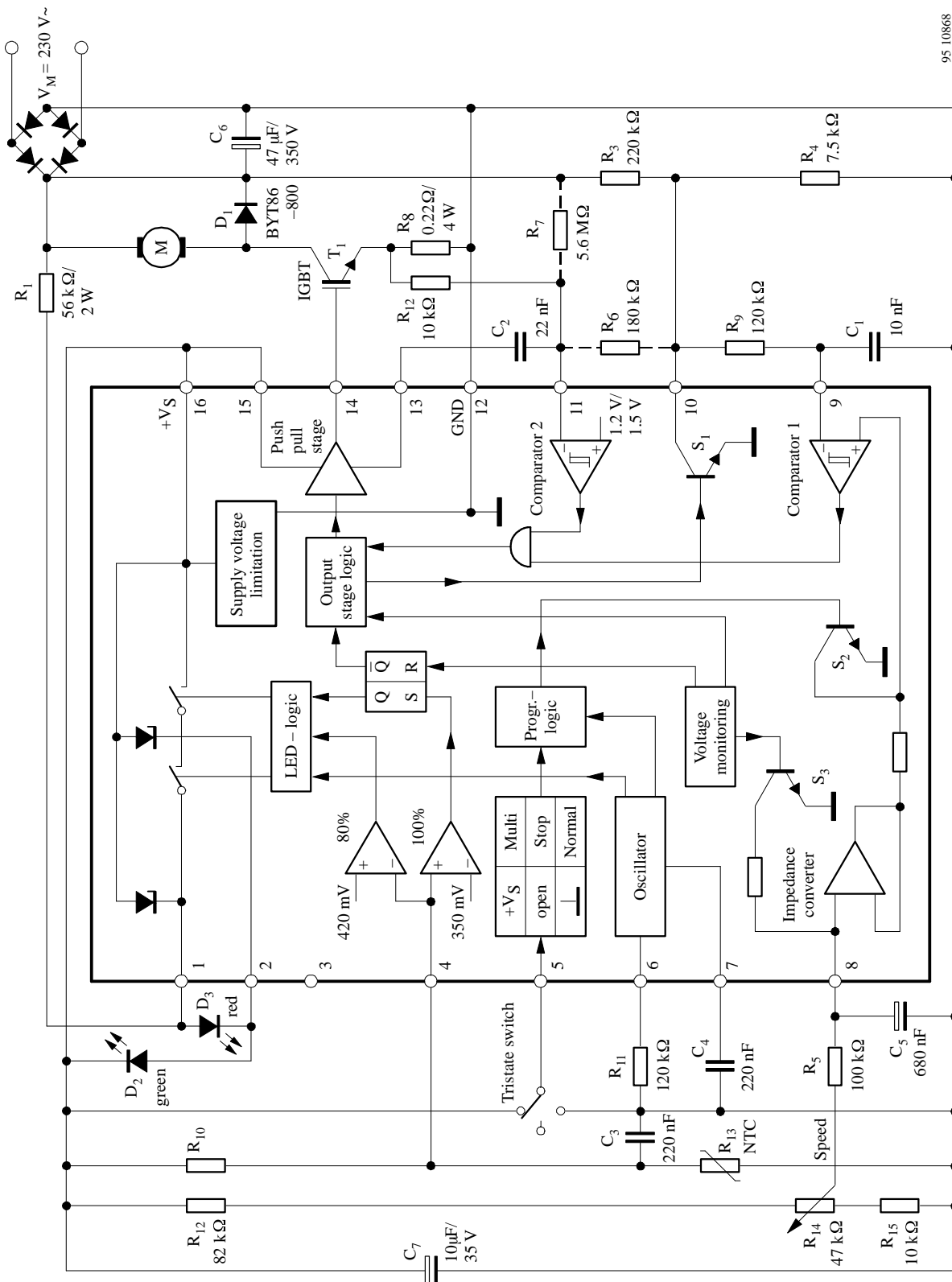
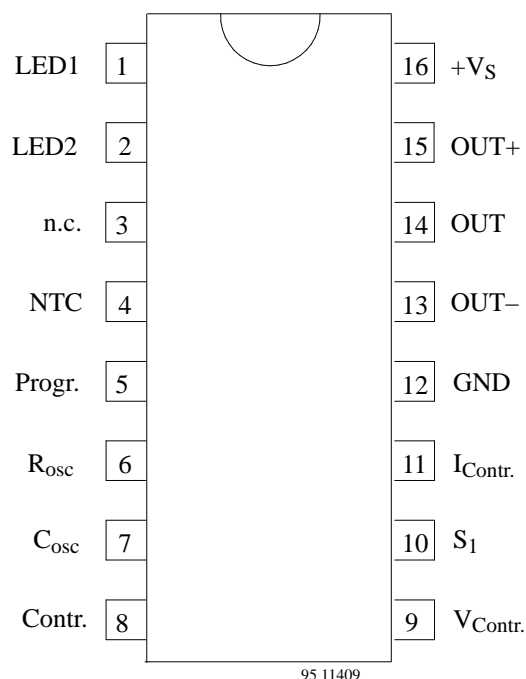


Figure 2. Block diagram with external circuit

## 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 <sub>osc</sub>	Resistor for oscillator
7	C <sub>osc</sub>	Capacitor for oscillator
8	Contr.	Control input
9	V <sub>Contr.</sub>	Voltage regulation input
10	S <sub>1</sub>	Switching output, output S1
11	I <sub>Contr.</sub>	Current regulation input
12	GND	Ground
13	OUT-	- supply for output stage
14	OUT	Output
15	OUT+	+ supply for output stage
16	+V <sub>S</sub>	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<sub>S</sub>) and Pin 12 (ground) is built up via R<sub>1</sub> and is smoothed by C<sub>7</sub>. The typically 5 mA supply current is simultaneously used to operate the two LEDs D<sub>2</sub>, D<sub>3</sub>, which can both be bridged internally. The supply current therefore reaches Pin 16 either via LEDs or the internal switches (V<sub>sat</sub> ≤ 1.2 V).

Series resistor, R<sub>1</sub>, can be calculated as follows:

$$R_{1\max} = \frac{V_{M\min} - V_{S\max}}{I_{\text{tot}}}$$

whereas

$$V_{M\min} = V_{\text{mains}} - 15\%$$

V<sub>Smax</sub> = maximum supply voltage

$$I_{\text{tot}} = I_{S\max} + I_x$$

I<sub>Smax</sub> = Max. current consumption of the IC

I<sub>x</sub> = Current consumption of the external components

Here, C<sub>6</sub> must be selected in this way that the voltage at C<sub>7</sub> (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<sub>2</sub> (operating indicator) between Pin 2 and Pin 16 is switched off and the control input "Pin 8" is connected to ground via switch S<sub>3</sub> 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<sub>3</sub> and R<sub>4</sub> and lead in Pin 10. The capacitor C<sub>1</sub> is charged via R<sub>9</sub> until the voltage V<sub>9</sub>, which is present at the inverting input of Comp. 1, is more positive than the control voltage V<sub>8</sub> 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<sub>9</sub> now becomes greater than V<sub>10</sub>, 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).

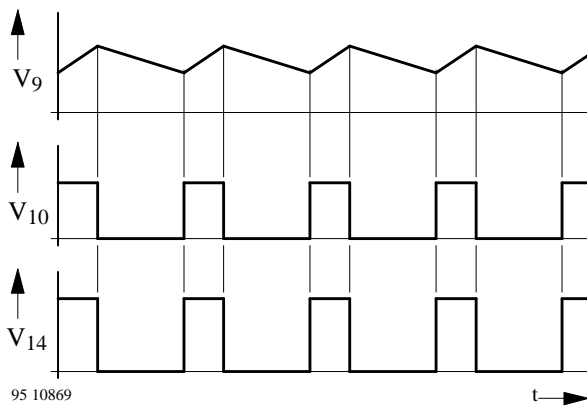


Figure 3. Pulse width control signal characteristics

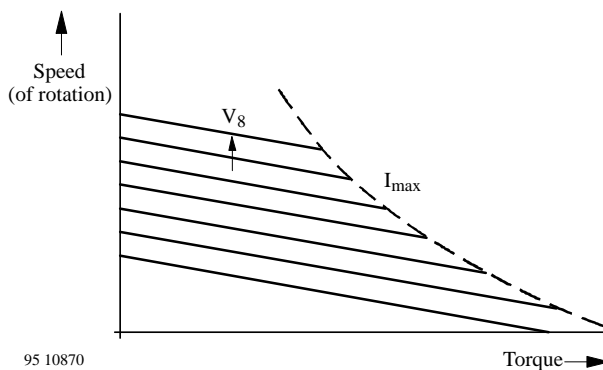


Figure 4. Influence of current control on the characteristic (curve) of a motor

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:

- 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.
- Stop function (Pin 5 open)  
The output is continuously switched off, the motor is at reset.
- 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 $t \leq 10 \mu\text{s}$	$I_S$ $i_s$	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 $t \leq 2 \text{ ms}$	$I_O$ $i_o$	20 200	mA
Signal outputs Input current $t \leq 10 \mu\text{s}$	$I_I$ $i_i$	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	$T_{\text{stg}}$	-40 to +125	$^{\circ}\text{C}$
Junction temperature	$T_j$	+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 SO16 on PC board SO16 on ceramic	$R_{\text{thJA}}$	120 180 100	K/W K/W K/W

## Electrical Characteristics

$V_S = 15.5 \text{ V}$ ,  $T_{\text{amb}} = 25^{\circ}\text{C}$ , reference point Pin 12, figure 2, unless otherwise specified.

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

Parameters	Test Conditions / Pins	Symbol	Min.	Typ.	Max.	Unit
<b>Switch S<sub>1</sub></b> Pin 10						
Leakage current	V <sub>10</sub> = 15.5 V, V <sub>8</sub> = 3 V, V <sub>9</sub> = 0 V, V <sub>11</sub> = 0 V	I <sub>R</sub>			1	μA
Saturation voltage	I <sub>10</sub> = 2 mA, V <sub>8</sub> = 0 V, V <sub>9</sub> = 3 V	V <sub>Sat</sub>			0.25	V
Delay time	Pin 10 – 14	t <sub>d(r)</sub>			3	μs
		t <sub>d(f)</sub>			3	
<b>Comparator 2</b> Pin 11						
Input current		I <sub>I</sub>			1	μA
Switch-on threshold		V <sub>TON</sub>	1.12	1.20	1.28	V
Switch-off threshold		V <sub>TOFF</sub>	1.42	1.50	1.58	V
Delay time (output)	Pin 11 – 14	t <sub>d</sub>			3	μs
<b>Push-pull stage</b> Pin 14						
Saturation voltage	High side Pin 14 – 16 I <sub>14</sub> = -10 mA, V <sub>15</sub> = V <sub>16</sub>	V <sub>SatH</sub>			2.4	V
	Low side I <sub>14</sub> = 10 mA, V <sub>13</sub> = V <sub>12</sub>	V <sub>SatL</sub>			1.2	
Output current limitation	V <sub>14</sub> = V <sub>12</sub> , V <sub>11</sub> = 0 V, V <sub>8</sub> = 3 V, V <sub>9</sub> = 0 V, t ≤ 1 μs	-I <sub>O</sub>	100	150	250	mA
	V <sub>14</sub> = V <sub>16</sub> , V <sub>8</sub> = 0 V, V <sub>9</sub> = 3 V, t ≤ 1 μs	I <sub>O</sub>	100	150	250	mA
Rise time	V <sub>15</sub> = V <sub>16</sub> , V <sub>13</sub> = V <sub>12</sub> , C <sub>Gate</sub> = 1 nF	t <sub>r</sub>		300		ns
Fall time	C <sub>Gate</sub> = 1 nF	t <sub>f</sub>		800		ns
<b>Operating indicator</b> I <sub>2</sub> = 5 mA						
Saturation voltage	V <sub>16</sub> ≤ V <sub>Soff</sub> or (V <sub>4</sub> ≤ V <sub>T100</sub> ) Pin 2 – 16	V <sub>Sat</sub>		1.0		V
Voltage limitation	V <sub>16</sub> ≥ V <sub>Son</sub> , (V <sub>4</sub> > V <sub>T100</sub> ) Pin 2 – 16	V <sub>limit</sub>		6.6		V
<b>Overload output I</b> I <sub>1</sub> = 5 mA						
Saturation voltage	V <sub>4</sub> > V <sub>T80</sub> Pin 1 – 2	V <sub>Sat</sub>		1.0		V
Voltage limitation	V <sub>4</sub> ≤ V <sub>T80</sub> Pin 1 – 16	V <sub>limit</sub>		8.6		V
<b>Temperature monitoring</b> Pin 4						
Input current		I <sub>I</sub>			500	nA
80%-threshold		V <sub>T80</sub>	390	420	450	mV
100%-threshold		V <sub>T100</sub>	325	350	375	mV
Switch-off threshold		V <sub>TOFF</sub>		V <sub>S</sub> - 1.8		V
<b>Operation mode selection</b> Pin 5						
Voltage	Pin 5 open (I <sub>5</sub> = 0)	V <sub>5</sub>		V <sub>S</sub> /2		
Input current	V <sub>5</sub> = V <sub>16</sub>	I <sub>I</sub>		15		μA
	V <sub>5</sub> = V <sub>12</sub>	-I <sub>I</sub>		15		μA
<b>Oscillator</b>						
Input current	Pin 6	I <sub>I</sub>	1		40	μA
Source voltage	I <sub>6</sub> = -10 μA Pin 6	V <sub>6</sub>		0.9		V
Upper saw tooth threshold	Pin 7	V <sub>Tmax</sub>		9		V
Lower saw tooth threshold	Pin 7	V <sub>Tmin</sub>		1.8		V

Parameters	Test Conditions / Pins	Symbol	Min.	Typ.	Max.	Unit
Oscillator frequency	$C_4 = C_{osc} = 220 \text{ nF}$ , see figure 2 Pin 7 $R_{11} = R_{osc} = 120 \text{ k}\Omega$	$f_{osc}$		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	–

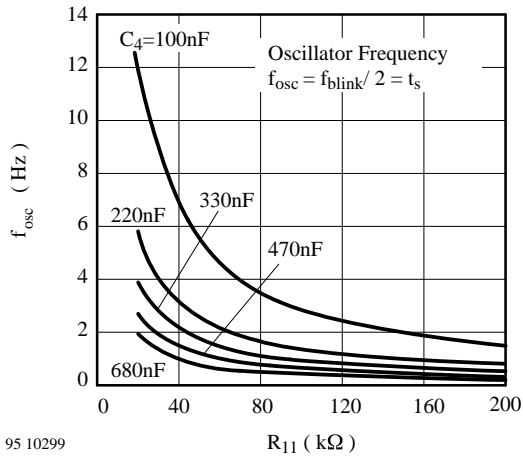


Figure 5.

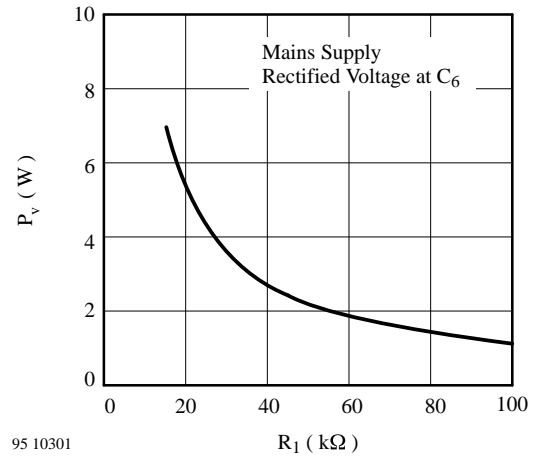


Figure 7.

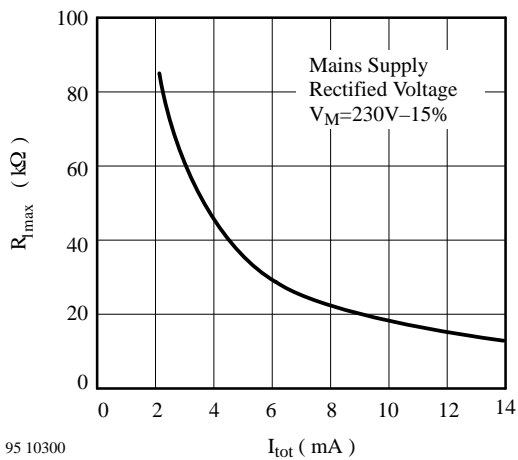
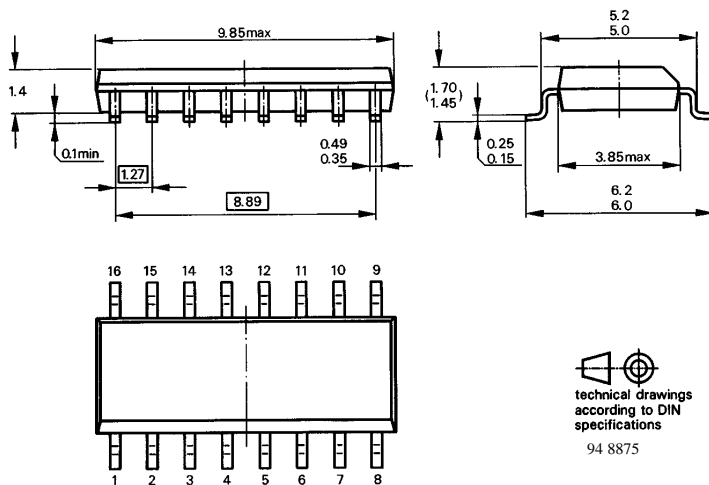


Figure 6.

# U2350B-FP

## Dimensions in mm:

Package: SO16





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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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