PWM Speed Control for Permanent Excited DC Motors

General Description

The monolithic integrated bipolar circuit CCU2350 is a MOSFET or IGBT-control circuit which works on the principle of pulse width modulation (PMW). 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.

1.1 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

1.2 Applications

- Domestic equipment, Household appliances, Toys
- Tools

1.3 Schematic

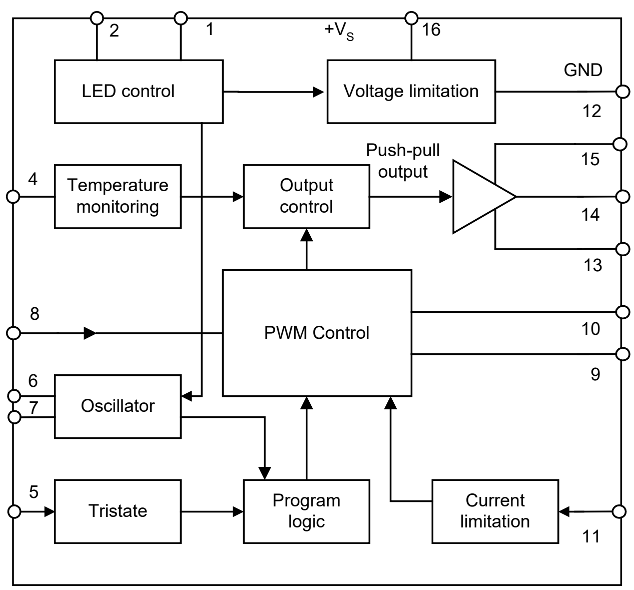


Figure 1: Block diagram CCU2350

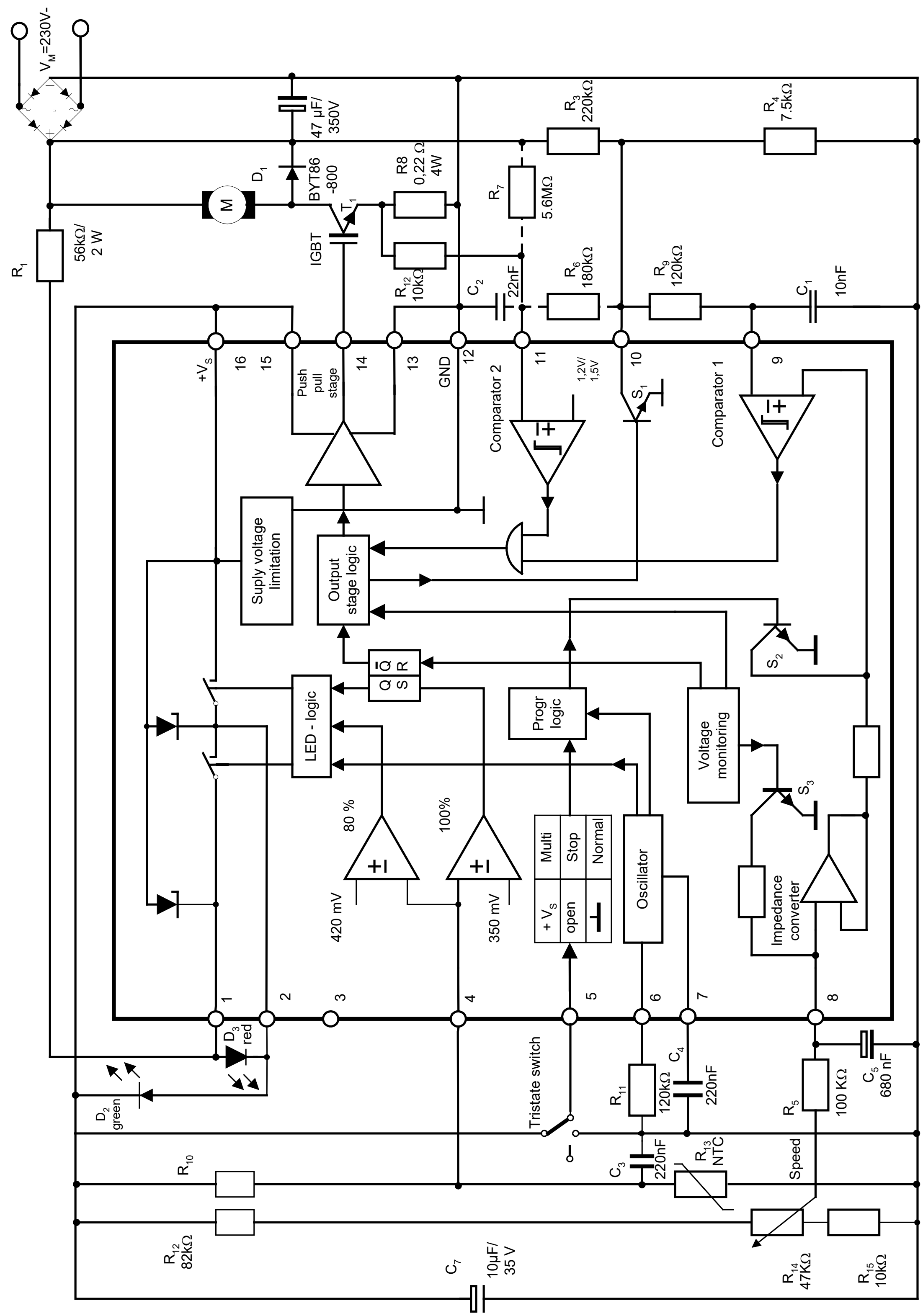
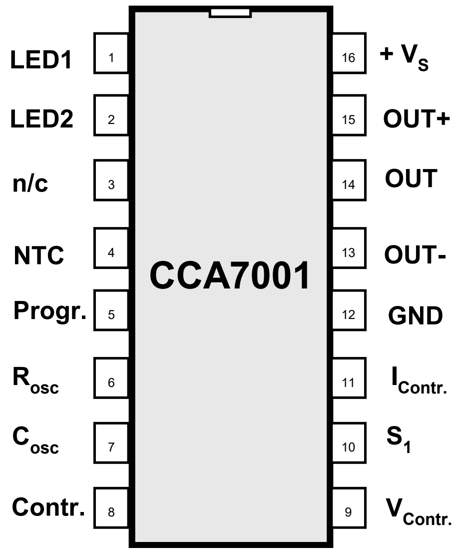


Figure 2: Block diagram with external circuit

2 Pinout

2.1 Pin Description



Supply, Pin 16

Pin no.	Symbol	Function
1	LED1	LED output 1
2	LED2	LED output 2
3	n.c.	Not connected
4	NTC	Monitoring input
5	Progr.	Tristate programming
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

The internal voltage limiter in the CCU2350 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 (Vsat $\leq$ 1.2V).

Series resistor, R_1, can be calculated as follows:

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

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.

2.2 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.

2.3 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 R3 and R4 and lead in Pin 10. The capacitor C1 is charged via R9 until the voltage V9, which is present at the inventing input of Comp.1, is more positive than the control voltage V8 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 an 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 magnitude of the control voltage.

2.4 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).

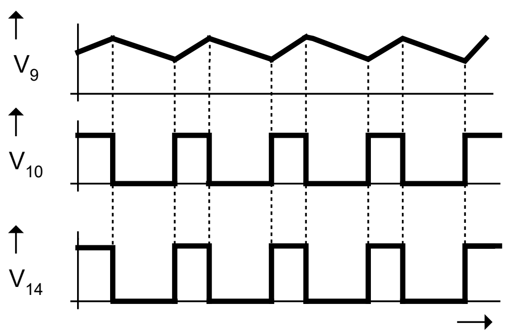


Figure 3: Pulse width control signal characteristics

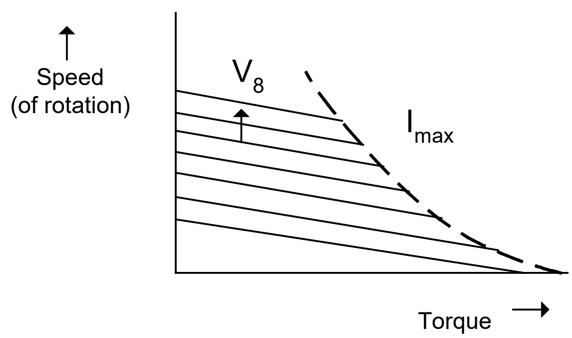


Figure 4: Influence of current control on the characteristic (curve) of a motor

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.

2.5 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.

2.6 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.

3 Absolute Maximum Ratings

Reference point Pin 12, unless otherwise specified.

Parameters		Symbol	Value	Unit
Supply Current t ≤ 10 µs	Pin 16	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

4 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 I_S = 20 mA	Pin 16	V_S	16 16		17.2 17.8	V
Current consumption			I_S			3.5	mA
Voltage monitoring		Pin 16					
Switch-on threshold			V_{SON}	10	14.0	14.5	V
Switch-off threshold			V_{SOFF}	12.0	12.5	16	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}	320	355	390	mV
Delay time		Pin 9-14	t_d			3	µs
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	1.23	V
Switch-off threshold			V_{TOFF}	1.45	1.50	1.54	V
Delay time (output)		Pin 11-14	t_d			3	µs
Push-pull stage		Pin 14					
Saturation voltage	High side I_{14} = –10mA, V_{15} = V_{16} Low side I_{14} = 10mA, V_{13} = V_{12}	Pin 14-16	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		$-I_O$	75		250	mA
	V_{14} = V_{16}, V_8 = 0 V, V_9 = 3 V, t ≤ 1 µs		I_O	75		250	mA

Parameters	Test Conditions/	Pins	Symbol	Min.	Typ.	Max.	Unit
Rise time	$V_{15} = V_{16}$, $V_{13} = V_{12}$, C_{Gate} = 1 nF		t_r		250		ns
Fall time	C_{Gate} = 1 nF		t_f		600		ns
Operating indicator	I_2 = 5 mA						
Saturation voltage	$V_{16} \leq V_{Soff}$ or ($V_4 \leq V_{T100}$)	Pin 2-16	V_{Sat}		1.0		V
Voltage limitation	$V_{16} \geq V_{Son}$, ($V_4 > V_{T100}$)	Pin 2-16	V_{limit}		6.6		V
Overload output	I_1 = 5 mA						
Saturation voltage	$V_4 > V_{T80}$	Pin 1-2	V_{Sat}		1.0		V
Voltage limitation	$V_4 \leq V_{T80}$	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			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
Oscillator frequency	$C_4 = C_{osc}$ = 220 nF, see figure 2 $R_{11} = R_{osc}$ = 120 kΩ	Pin 7	f_{osc}		1.1		Hz
Blink frequency	$V_{T100} < V_4 \leq V_{T80}$	Pin 1	f_{blink}		2.2		Hz
Switching frequency	$V_5 = V_{16}$ interval operation	Pin 14	f_s		1.1		Hz
Pulse ratio switch		Pin 14	t_p/T	0.2	0.23	0.26	

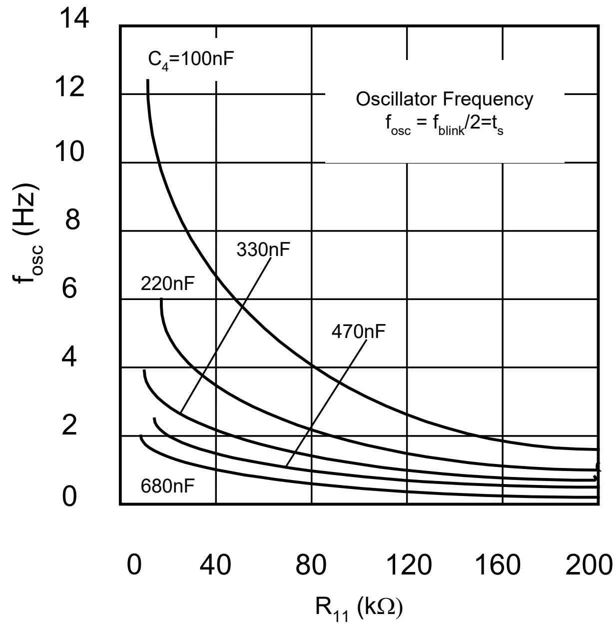


Figure 5

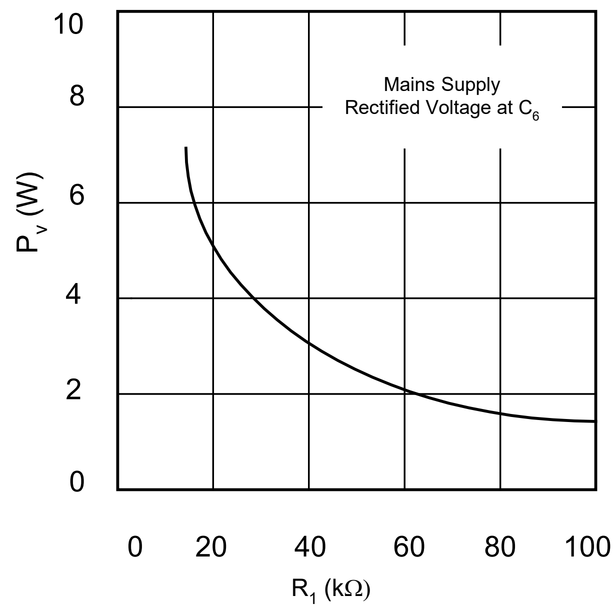


Figure 7

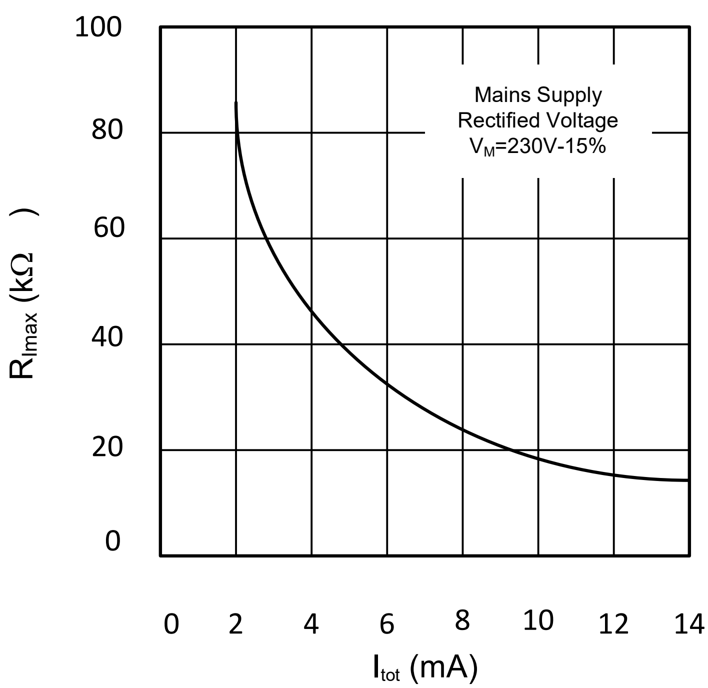


Figure 6

5 Revision History

Revision	Date	Description
1.1	31-Oct-2019	Updated Template
1.0	30-Jun-2005	Initial version

Contents

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