

## VIPerPlus family: fixed frequency offline converter

Datasheet - production data

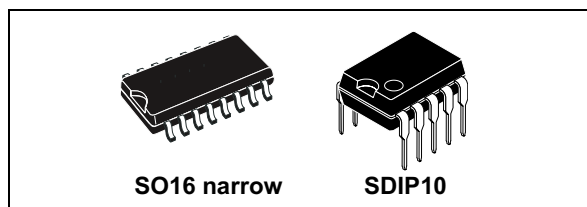
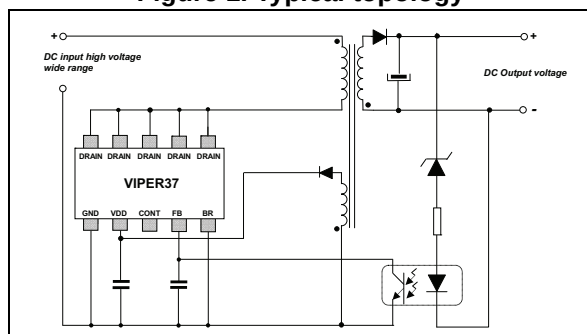


Figure 1. Typical topology



### Features

- 800 V avalanche-rugged power MOSFET allowing ultra wide range input  $V_{ac}$  to be achieved
- PWM operation with adjustable limiting current
- 30 mW standby power at 265 V<sub>ac</sub>
- Operating frequency:
  - 60 kHz (L type), 115 kHz (H type)
- Frequency jittering for low EMC
- Output overvoltage protection

- High primary current protection (2<sup>nd</sup> OCP)
- Input undervoltage setting (brownout)
- Onboard soft-start
- Safe auto-restart after a fault condition
- Hysteretic thermal shutdown

### Applications

- SMPS for set-top boxes, DVD players and recorders, white goods
- Auxiliary power supply for consumer and home equipment
- ATX auxiliary power supply
- Low / medium power AC-DC adapters

### Description

This device is an offline converter with an 800 V rugged power section, a PWM control, two levels of overcurrent protection, overvoltage and overload protection, hysteretic thermal protection, soft-start, and safe auto-restart after the removal of any fault condition. Burst mode operation and very low device consumption help to meet the standby energy saving regulations. Advance frequency jittering reduces EMI filter costs. Brownout function protects the switch mode power supply when the rectified input voltage level is below the normal minimum level specified for the system. The high voltage startup circuit is embedded in the device.

Table 1. Device summary

| Order code  | Package     | Packing       |
|-------------|-------------|---------------|
| VIPER37LE   | SDIP10      | Tube          |
| VIPER37HE   |             |               |
| VIPER37HD   | SO16 narrow | Tape and reel |
| VIPER37LD   |             |               |
| VIPER37HDTR |             |               |
| VIPER37LDTR |             |               |

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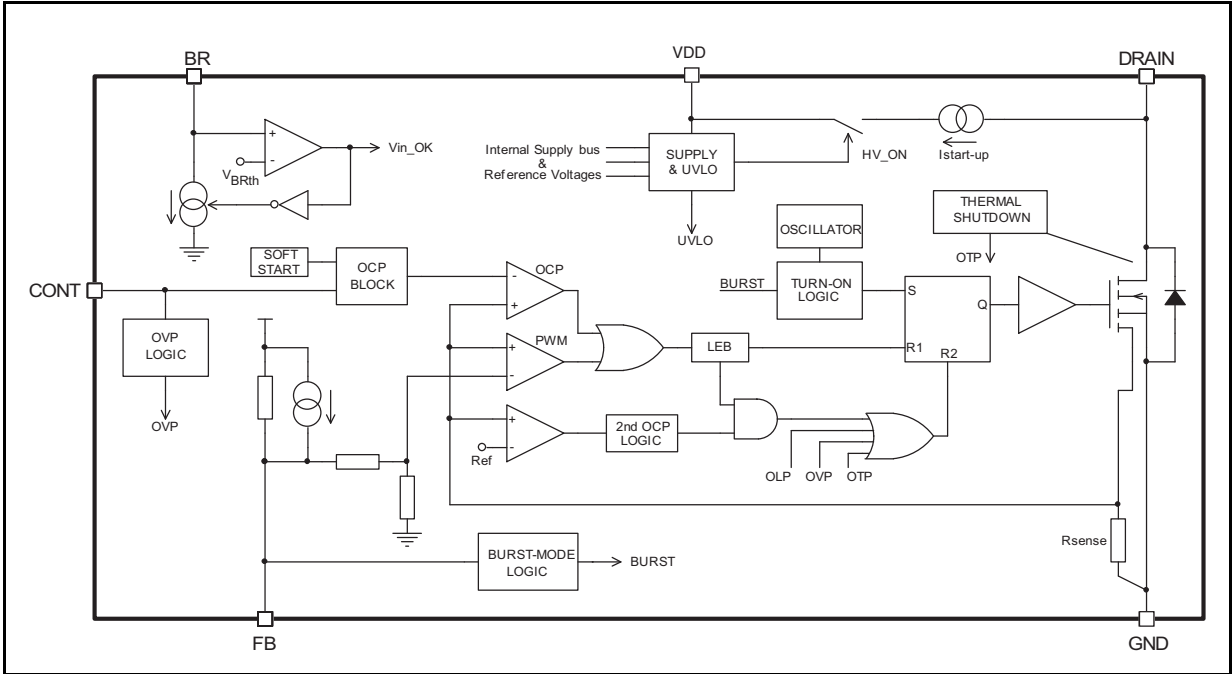
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1      **Block diagram**

Figure 2. Block diagram



2      **Typical power**

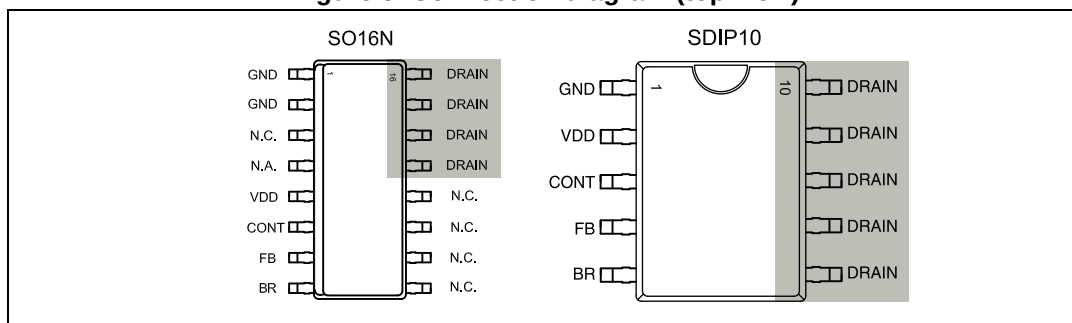
Table 2. Typical power

| Part number | 230 V <sub>AC</sub>    |                           | 85-265 V <sub>AC</sub> |                           |
|-------------|------------------------|---------------------------|------------------------|---------------------------|
|             | Adapter <sup>(1)</sup> | Open frame <sup>(2)</sup> | Adapter <sup>(1)</sup> | Open frame <sup>(2)</sup> |
| VIPER37     | 18 W                   | 20 W                      | 13 W                   | 15 W                      |

1. Typical continuous power in non-ventilated enclosed adapter measured at 50 °C ambient.  
2. Maximum practical continuous power in an open frame design at 50 °C ambient, with adequate heatsinking.

### 3 Pin settings

**Figure 3. Connection diagram (top view)**



*Note:* The copper area for heat dissipation must be designed under the DRAIN pins.

**Table 3. Pin description**

| Pin n.       | Name  | Function                                                                                                                                                                                                                                                                                                                                                                                                                                                                      |
|--------------|-------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>SO16N</b> |       |                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| 1...2        | GND   | This pin represents the device ground and the source of the power section.                                                                                                                                                                                                                                                                                                                                                                                                    |
| 3            | N.C.  | Not connected.                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| 4            | N.A.  | Not available for user.<br>This pin is mechanically connected to the controller die pad of the frame.<br>In order to improve the noise immunity, is highly recommended connect it to GND (pin 1-2).                                                                                                                                                                                                                                                                           |
| 5            | VDD   | Supply voltage of the control section. This pin also provides the charging current of the external capacitor during start-up time.                                                                                                                                                                                                                                                                                                                                            |
| 6            | CONT  | Control pin. The following functions can be selected:<br>1. current limit set point adjustment. The internal set default value of the cycle-by-cycle current limit can be reduced by connecting to ground an external resistor.<br>2. output voltage monitoring. A voltage exceeding $V_{OVP}$ threshold (see <a href="#">Table 8 on page 8</a> ) shuts the IC down reducing the device consumption. This function is strobed and digitally filtered for high noise immunity. |
| 7            | FB    | Control input for duty cycle control. Internal current generator provides bias current for loop regulation. A voltage below the threshold $V_{FBbm}$ activates the burst-mode operation. A level close to the threshold $V_{FBlin}$ means that we are approaching the cycle-by-cycle over-current set point.                                                                                                                                                                  |
| 8            | BR    | Brownout protection input with hysteresis. A voltage below the threshold $V_{BRth}$ shuts down (not latch) the device and lowers the power consumption. Device operation restarts as the voltage exceeds the threshold $V_{BRth} + V_{BRhyst}$ . It can be connected to ground when not used.                                                                                                                                                                                 |
| 9...12       | N.C.  | Not connected.                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| 13...16      | DRAIN | High voltage drain pin. The built-in high voltage switched start-up bias current is drawn from this pin too.<br>Pins connected to the metal frame to facilitate heat dissipation.                                                                                                                                                                                                                                                                                             |

## 4 Electrical data

### 4.1 Maximum ratings

Table 4. Absolute maximum ratings

| Symbol             | Parameter                                                           | Value |              | Unit |
|--------------------|---------------------------------------------------------------------|-------|--------------|------|
|                    |                                                                     | Min.  | Max.         |      |
| $V_{\text{DRAIN}}$ | Drain-to-source (ground) voltage                                    |       | 800          | V    |
| $E_{\text{AV}}$    | Repetitive avalanche energy<br>(limited by $T_J = 150\text{ °C}$ )  |       | 5            | mJ   |
| $I_{\text{AR}}$    | Repetitive avalanche current<br>(limited by $T_J = 150\text{ °C}$ ) |       | 1.5          | A    |
| $I_{\text{DRAIN}}$ | Pulse drain current                                                 |       | 3            | A    |
| $V_{\text{CONT}}$  | Control input pin voltage                                           | -0.3  | 6            | V    |
| $V_{\text{FB}}$    | Feedback voltage                                                    | -0.3  | 5.5          | V    |
| $V_{\text{BR}}$    | Brownout input pin voltage                                          | -0.3  | 5            | V    |
| $V_{\text{DD}}$    | Supply voltage ( $I_{\text{DD}} = 25\text{ mA}$ )                   | -0.3  | Self limited | V    |
| $I_{\text{DD}}$    | Input current                                                       |       | 25           | mA   |
| $P_{\text{TOT}}$   | Power dissipation at $T_A < 60\text{ °C}$                           |       | 1.5          | W    |
| $T_J$              | Operating junction temperature range                                | -40   | 150          | °C   |
| $T_{\text{STG}}$   | Storage temperature                                                 | -55   | 150          | °C   |

### 4.2 Thermal data

Table 5. Thermal data

| Symbol            | Parameter                                                                      | Max. value |        | Unit |
|-------------------|--------------------------------------------------------------------------------|------------|--------|------|
|                   |                                                                                | SO16N      | SDIP10 |      |
| $R_{\text{thJP}}$ | Thermal resistance junction pin<br>(Dissipated power = 1 W)                    | 35         | 35     | °C/W |
| $R_{\text{thJA}}$ | Thermal resistance junction ambient<br>(Dissipated power = 1 W)                | 110        | 100    | °C/W |
| $R_{\text{thJA}}$ | Thermal resistance junction ambient <sup>(1)</sup><br>(Dissipated power = 1 W) | 80         | 85     | °C/W |

1. When mounted on a standard single side FR4 board with 100 mm<sup>2</sup> (0.155 sq. in.) of Cu (35 µm thick).

### 4.3 Electrical characteristics

( $T_J = -25$  to  $125\text{ }^{\circ}\text{C}$ ,  $V_{DD} = 14\text{ V}^{(a)}$ ; unless otherwise specified).

**Table 6. Power section**

| Symbol       | Parameter                                     | Test condition                                                                                                      | Min. | Typ. | Max. | Unit          |
|--------------|-----------------------------------------------|---------------------------------------------------------------------------------------------------------------------|------|------|------|---------------|
| $V_{BVDSS}$  | Breakdown voltage                             | $I_{DRAIN} = 1\text{ mA}$ , $V_{FB} = \text{GND}$<br>$T_J = 25\text{ }^{\circ}\text{C}$                             | 800  |      |      | V             |
| $I_{OFF}$    | OFF state drain current                       | $V_{DRAIN} = \text{max. rating}$ ,<br>$V_{FB} = \text{GND}$ , $T_J = 25\text{ }^{\circ}\text{C}$                    |      |      | 60   | $\mu\text{A}$ |
| $R_{DS(on)}$ | Drain-source on state resistance              | $I_{DRAIN} = 0.4\text{ A}$ , $V_{FB} = 3\text{ V}$ ,<br>$V_{BR} = \text{GND}$ , $T_J = 25\text{ }^{\circ}\text{C}$  |      |      | 4.5  | $\Omega$      |
|              |                                               | $I_{DRAIN} = 0.4\text{ A}$ , $V_{FB} = 3\text{ V}$ ,<br>$V_{BR} = \text{GND}$ , $T_J = 125\text{ }^{\circ}\text{C}$ |      |      | 9    | $\Omega$      |
| $C_{OSS}$    | Effective (energy related) output capacitance | $V_{DRAIN} = 0$ to $640\text{ V}$ ,<br>$T_J = 25\text{ }^{\circ}\text{C}$                                           |      | 17   |      | pF            |

**Table 7. Supply section**

| Symbol             | Parameter                                | Test condition                                                                                                    | Min. | Typ. | Max. | Unit |
|--------------------|------------------------------------------|-------------------------------------------------------------------------------------------------------------------|------|------|------|------|
| <b>Voltage</b>     |                                          |                                                                                                                   |      |      |      |      |
| $V_{DRAIN\_START}$ | Drain-source start voltage               |                                                                                                                   | 60   | 80   | 100  | V    |
| $I_{DDch}$         | Startup charging current                 | $V_{DRAIN} = 120\text{ V}$<br>$V_{BR} = \text{GND}$<br>$V_{FB} = \text{GND}$<br>$V_{DD} = 4\text{ V}$             | -2   | -3   | -4   | mA   |
|                    |                                          | $V_{DRAIN} = 120\text{ V}$<br>$V_{BR} = \text{GND}$<br>$V_{FB} = \text{GND}$<br>$V_{DD} = 5\text{ V after fault}$ | -0.4 | -0.6 | -0.8 | mA   |
| $V_{DD}$           | Operating voltage range                  | After turn-on                                                                                                     | 8.5  |      | 23.5 | V    |
| $V_{DDclamp}$      | $V_{DD}$ clamp voltage                   | $I_{DD} = 20\text{ mA}$                                                                                           | 23.5 |      |      | V    |
| $V_{DDon}$         | $V_{DD}$ startup threshold               | $V_{DRAIN} = 120\text{ V}$<br>$V_{BR} = \text{GND}$<br>$V_{FB} = \text{GND}$                                      | 13   | 14   | 15   | V    |
| $V_{DDoff}$        | $V_{DD}$ undervoltage shutdown threshold |                                                                                                                   | 7.5  | 8    | 8.5  | V    |
| $V_{DD(RESTART)}$  | $V_{DD}$ restart voltage threshold       |                                                                                                                   | 4    | 4.5  | 5    | V    |

a. Adjust  $V_{DD}$  above  $V_{DDon}$  startup threshold before setting to  $14\text{ V}$ .

Table 7. Supply section (continued)

| Symbol          | Parameter                                            | Test condition                                                         | Min. | Typ. | Max. | Unit    |
|-----------------|------------------------------------------------------|------------------------------------------------------------------------|------|------|------|---------|
| <b>Current</b>  |                                                      |                                                                        |      |      |      |         |
| $I_{DD0}$       | Operating supply current, not switching              | $V_{FB} = GND$ , $F_{SW} = 0$ kHz,<br>$V_{BR} = GND$ , $V_{DD} = 10$ V |      |      | 0.9  | mA      |
| $I_{DD1}$       | Operating supply current, switching                  | $V_{DRAIN} = 120$ V,<br>$F_{SW} = 60$ kHz                              |      |      | 2.5  | mA      |
|                 |                                                      | $V_{DRAIN} = 120$ V,<br>$F_{SW} = 115$ kHz                             |      |      | 3.5  | mA      |
| $I_{DD\_FAULT}$ | Operating supply current, with protection tripping   | $V_{DD} = 10$ V                                                        |      |      | 400  | $\mu$ A |
| $I_{DD\_OFF}$   | Operating supply current with $V_{DD} < V_{DD\_OFF}$ | $V_{DD} = 7$ V                                                         |      |      | 270  | $\mu$ A |

Table 8. Controller section

| Symbol                    | Parameter                            | Test condition                                                         | Min. | Typ. | Max. | Unit       |
|---------------------------|--------------------------------------|------------------------------------------------------------------------|------|------|------|------------|
| <b>Feedback pin</b>       |                                      |                                                                        |      |      |      |            |
| $V_{FBolp}$               | Overload shutdown threshold          |                                                                        | 4.5  | 4.8  | 5.2  | V          |
| $V_{FBlin}$               | Linear dynamics upper limit          |                                                                        | 3.2  | 3.5  | 3.7  | V          |
| $V_{FBbm}$                | Burst mode threshold                 | Voltage falling                                                        |      | 0.6  |      | V          |
| $V_{FBbmhys}$             | Burst mode hysteresis                | Voltage rising                                                         |      | 100  |      | mV         |
| $I_{FB}$                  | Feedback sourced current             | $V_{FB} = 0.3$ V                                                       | -150 | -200 | -280 | $\mu$ A    |
|                           |                                      | $3.3$ V $< V_{FB} < 4.8$ V                                             |      | -3   |      | $\mu$ A    |
| $R_{FB(DYN)}$             | Dynamic resistance                   | $V_{FB} < 3.3$ V                                                       | 14   |      | 21   | k $\Omega$ |
| $H_{FB}$                  | $\Delta V_{FB} / \Delta I_D$         |                                                                        | 0.5  |      | 2    | V/A        |
| <b>CONT pin</b>           |                                      |                                                                        |      |      |      |            |
| $V_{CONT\_l}$             | Low level clamp voltage              | $I_{CONT} = -100$ $\mu$ A                                              |      | 0.5  |      | V          |
| $V_{CONT\_h}$             | High level clamp voltage             | $I_{CONT} = 1$ mA                                                      | 5    | 5.5  | 6    | V          |
| <b>Current limitation</b> |                                      |                                                                        |      |      |      |            |
| $I_{Dlim}$                | Max. drain current limitation        | $V_{FB} = 4$ V,<br>$I_{CONT} = -10$ $\mu$ A<br>$T_J = 25$ $^{\circ}$ C | 0.95 | 1    | 1.05 | A          |
| $t_{SS}$                  | Soft-start time                      |                                                                        |      | 8.5  |      | ms         |
| $T_{ON\_MIN}$             | Minimum turn-on time                 |                                                                        | 220  | 400  | 480  | ns         |
| $t_d$                     | Propagation delay                    | (1)                                                                    |      | 100  |      | ns         |
| $t_{LEB}$                 | Leading edge blanking                | (1)                                                                    |      | 300  |      | ns         |
| $I_{D\_BM}$               | Peak drain current during burst mode | $V_{FB} = 0.6$ V                                                       |      | 160  |      | mA         |

Table 8. Controller section (continued)

| Symbol                                             | Parameter                           | Test condition                                               | Min. | Typ.    | Max. | Unit               |
|----------------------------------------------------|-------------------------------------|--------------------------------------------------------------|------|---------|------|--------------------|
| <b>Oscillator section</b>                          |                                     |                                                              |      |         |      |                    |
| $F_{OSC}$                                          | VIPER37L                            | $V_{DD}$ = operating voltage range,<br>$V_{FB} = 1\text{ V}$ | 54   | 60      | 66   | kHz                |
|                                                    | VIPER37H                            |                                                              | 103  | 115     | 127  | kHz                |
| FD                                                 | Modulation depth                    | VIPER37L                                                     |      | $\pm 4$ |      | kHz                |
|                                                    |                                     | VIPER37H                                                     |      | $\pm 8$ |      | kHz                |
| FM                                                 | Modulation frequency                |                                                              |      | 250     |      | Hz                 |
| $D_{MAX}$                                          | Maximum duty cycle                  |                                                              | 70   |         | 80   | %                  |
| <b>Overcurrent protection (2<sup>nd</sup> OCP)</b> |                                     |                                                              |      |         |      |                    |
| $I_{DMAX}$                                         | Second overcurrent threshold        |                                                              |      | 1.7     |      | A                  |
| <b>Overvoltage protection</b>                      |                                     |                                                              |      |         |      |                    |
| $V_{OVP}$                                          | Overvoltage protection threshold    |                                                              | 2.7  | 3       | 3.3  | V                  |
| $T_{STROBE}$                                       | Overvoltage protection strobe time  |                                                              |      | 2.2     |      | us                 |
| <b>Brownout protection</b>                         |                                     |                                                              |      |         |      |                    |
| $V_{BRth}$                                         | Brownout threshold                  | Voltage falling                                              | 0.41 | 0.45    | 0.49 | V                  |
| $V_{BRhyst}$                                       | Voltage hysteresis above $V_{BRth}$ | Voltage rising                                               |      | 50      |      | mV                 |
| $I_{BRhyst}$                                       | Current hysteresis                  |                                                              | 7    |         | 12   | $\mu\text{A}$      |
| $V_{BRclamp}$                                      | Clamp voltage                       | $I_{BR} = 250\text{ }\mu\text{A}$                            |      | 3       |      | V                  |
| $V_{DIS}$                                          | Brownout disable voltage            |                                                              | 50   |         | 150  | mV                 |
| <b>Thermal shutdown</b>                            |                                     |                                                              |      |         |      |                    |
| $T_{SD}$                                           | Thermal shutdown temperature        | (1)                                                          | 150  | 160     |      | $^{\circ}\text{C}$ |
| $T_{HYST}$                                         | Thermal shutdown hysteresis         | (1)                                                          |      | 30      |      | $^{\circ}\text{C}$ |

1. Specification assured by design, characterization and statistical correlation.

Figure 4. Minimum turn-on time test circuit

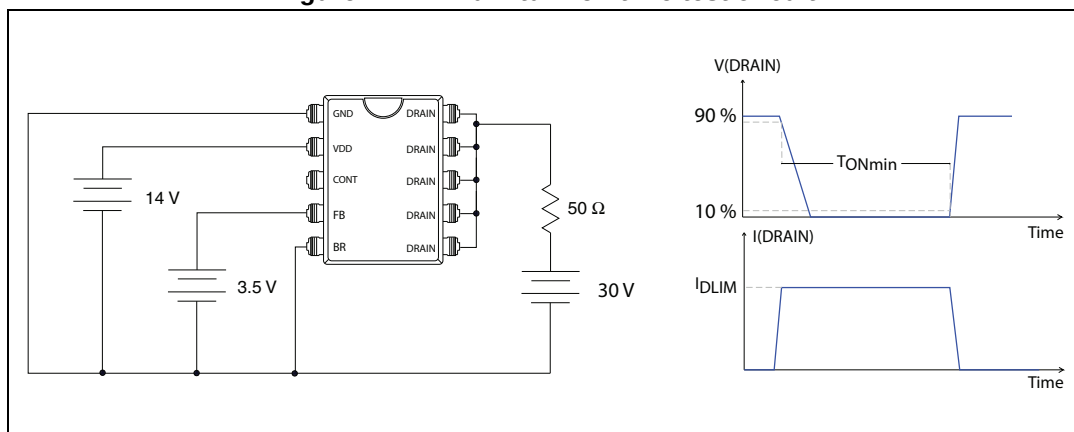


Figure 5. Brownout threshold test circuits

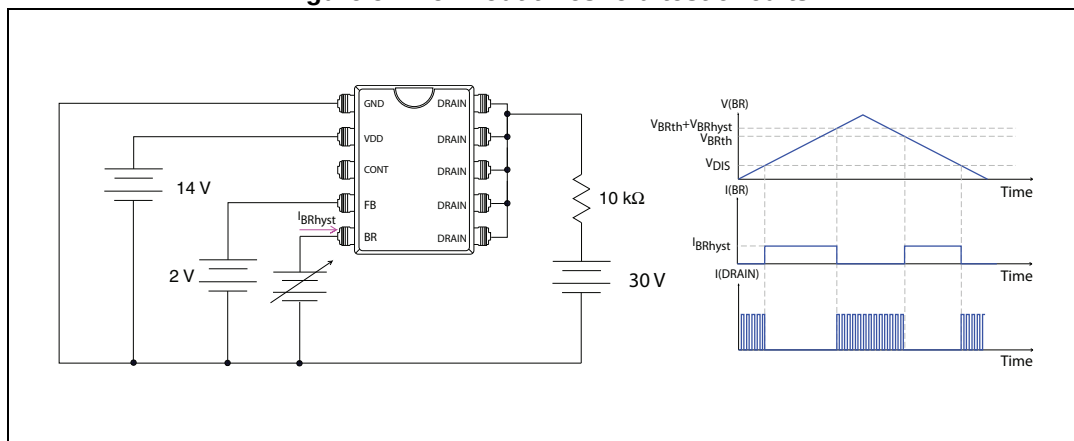
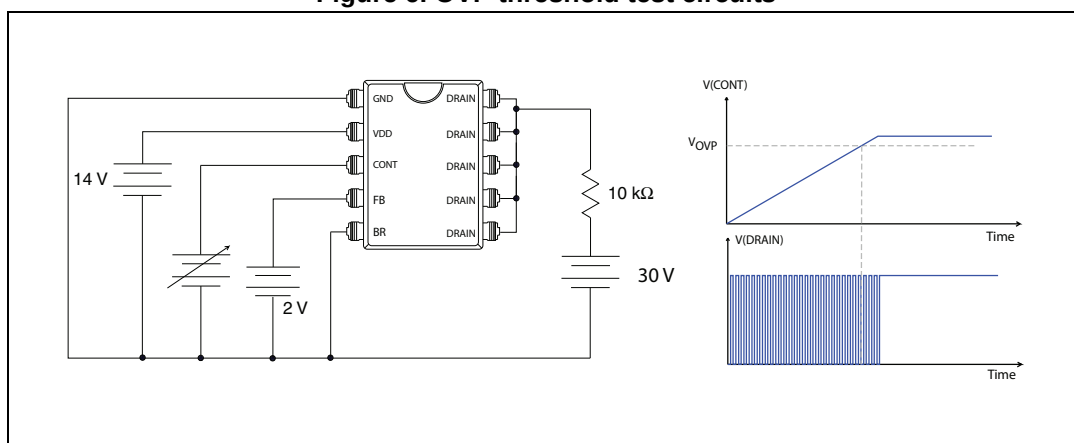


Figure 6. OVP threshold test circuits



Note: Adjust  $V_{DD}$  above  $V_{DDon}$  startup threshold before setting to 14 V.

## 5 Typical electrical characteristics

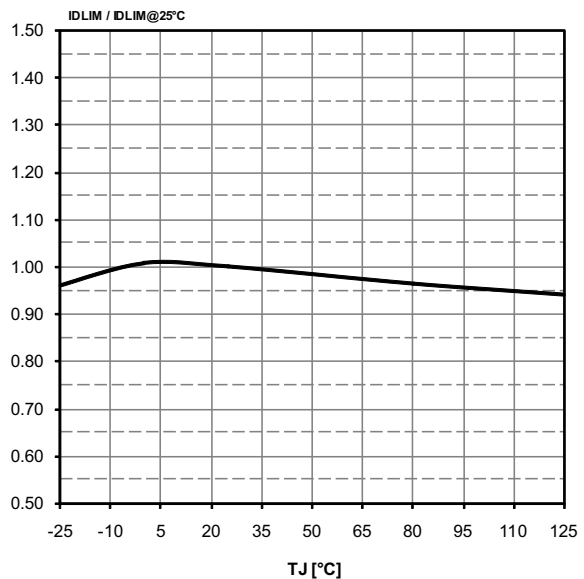
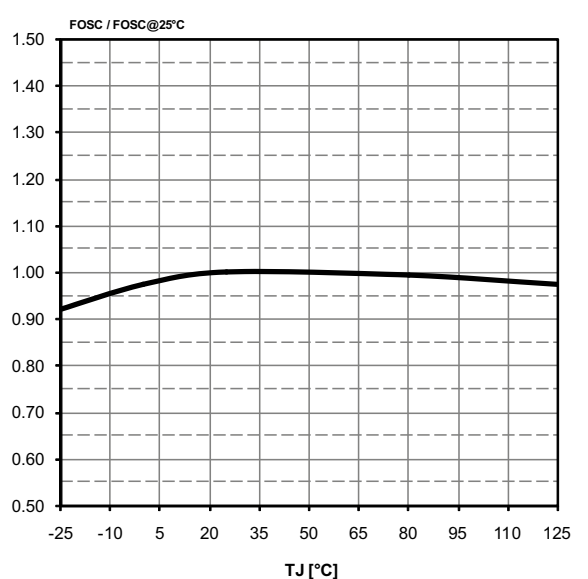
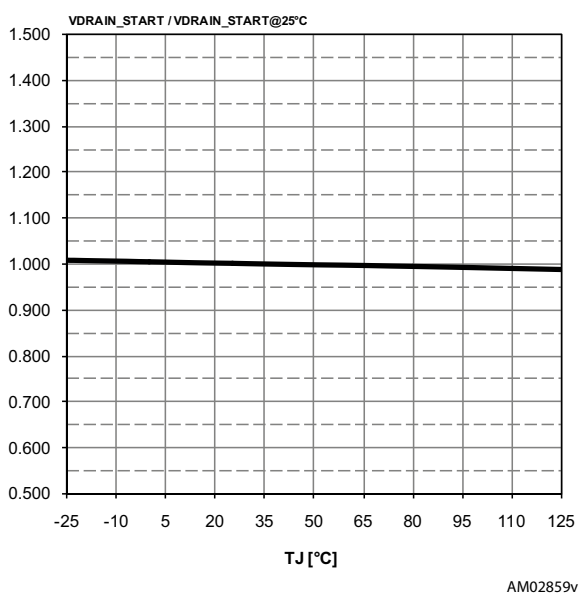
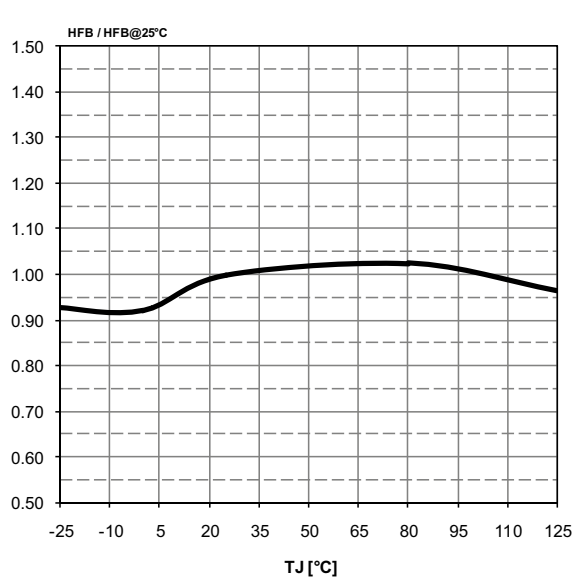
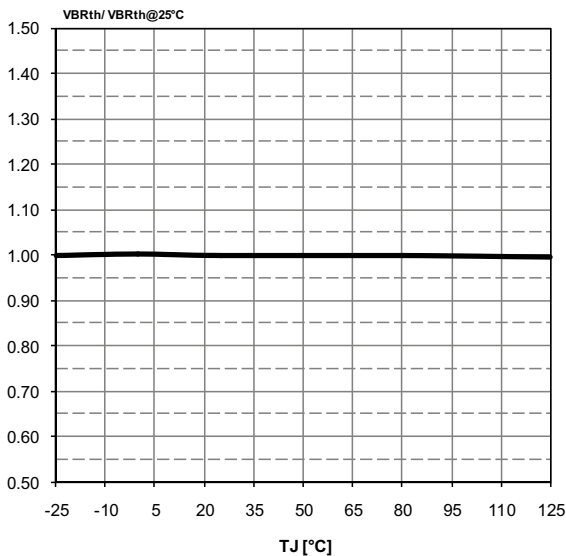
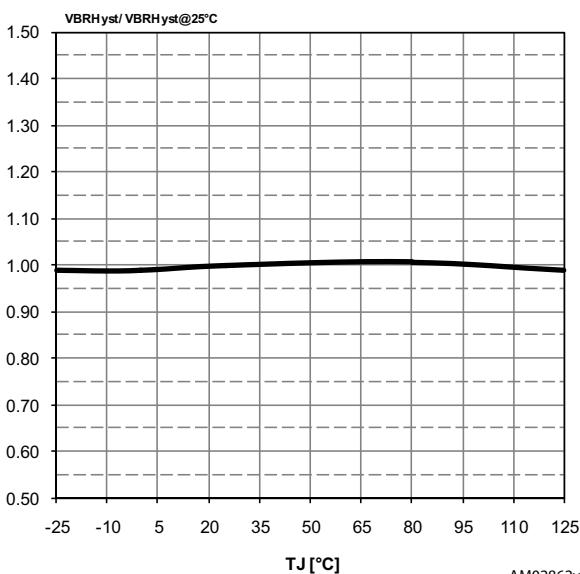
**Figure 7. Current limit vs.  $T_J$** **Figure 8. Switching frequency vs.  $T_J$** **Figure 9. Drain start voltage vs.  $T_J$** **Figure 10. HFB vs.  $T_J$** 

Figure 11. Brownout threshold vs.  $T_J$



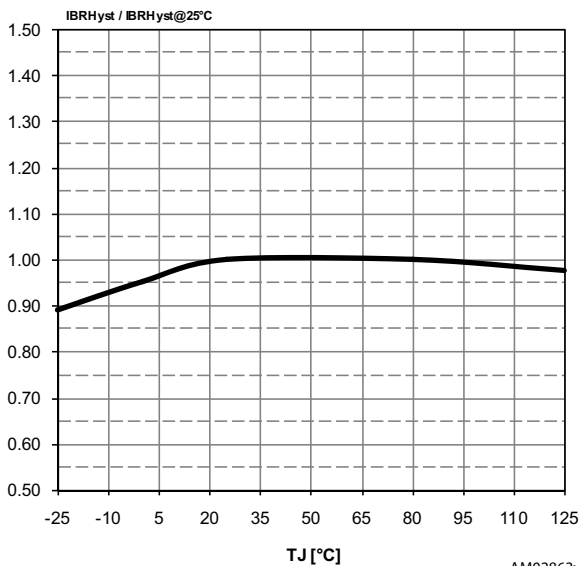
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Figure 12. Brownout hysteresis vs.  $T_J$



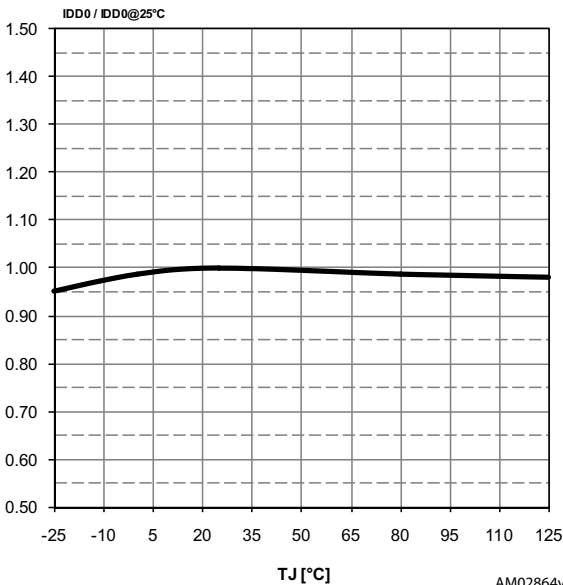
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Figure 13. Brownout hysteresis current vs.  $T_J$



AM02863v1

Figure 14. Operating supply current (not switching) vs.  $T_J$



AM02864v1

Figure 15. Operating supply current (switching) vs.  $T_J$

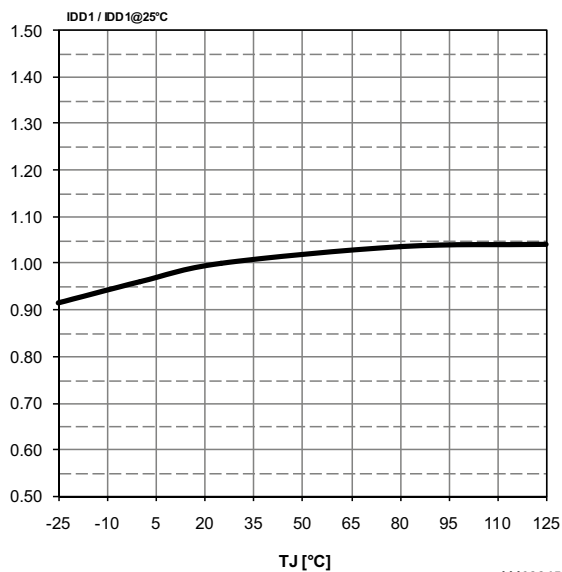


Figure 16. Current limit vs.  $R_{LIM}$

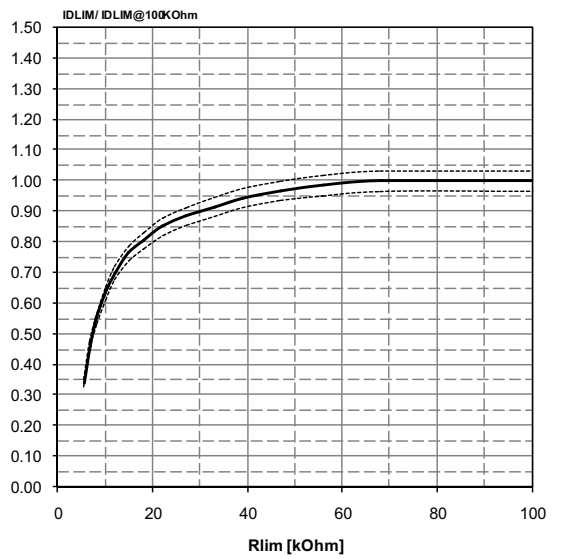


Figure 17. Power MOSFET ON resistance vs.  $T_J$

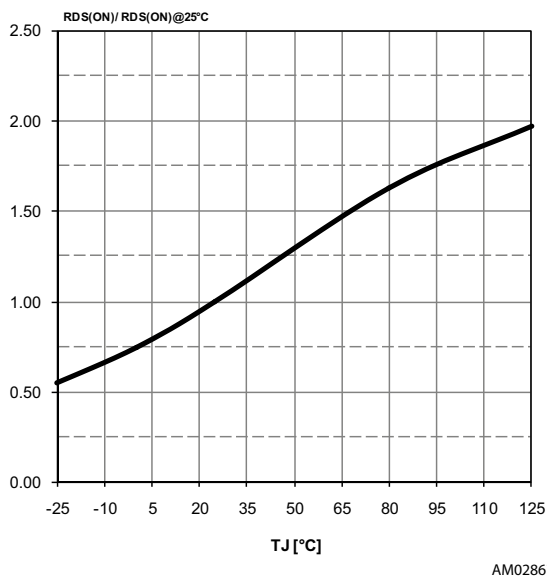


Figure 18. Power MOSFET breakdown voltage vs.  $T_J$

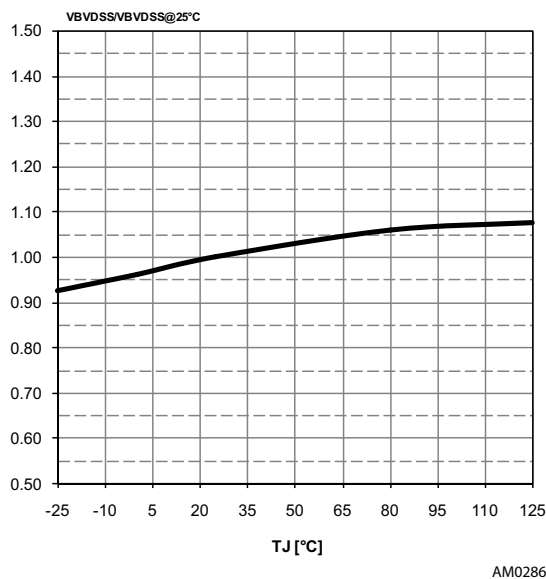
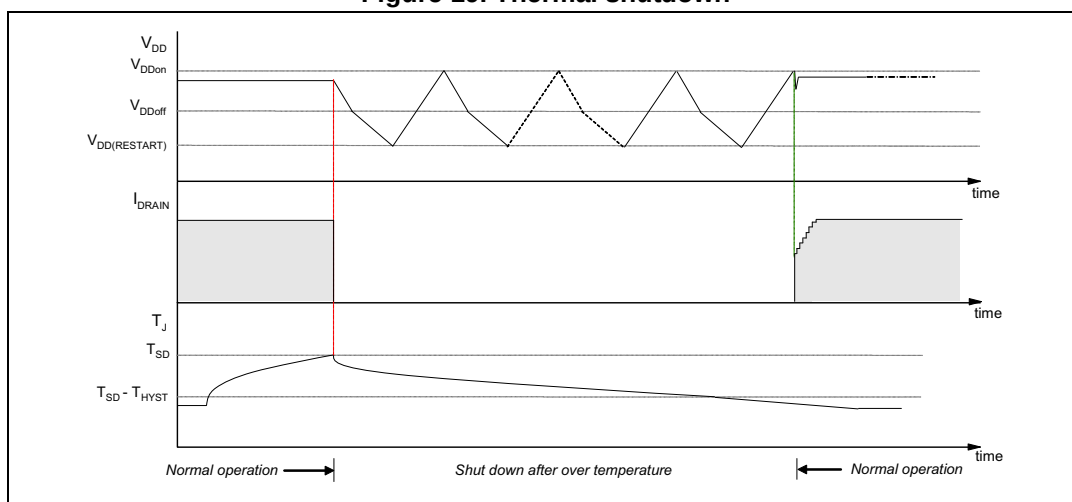


Figure 19. Thermal shutdown



## 6 Typical circuit

Figure 20. Min-features flyback application

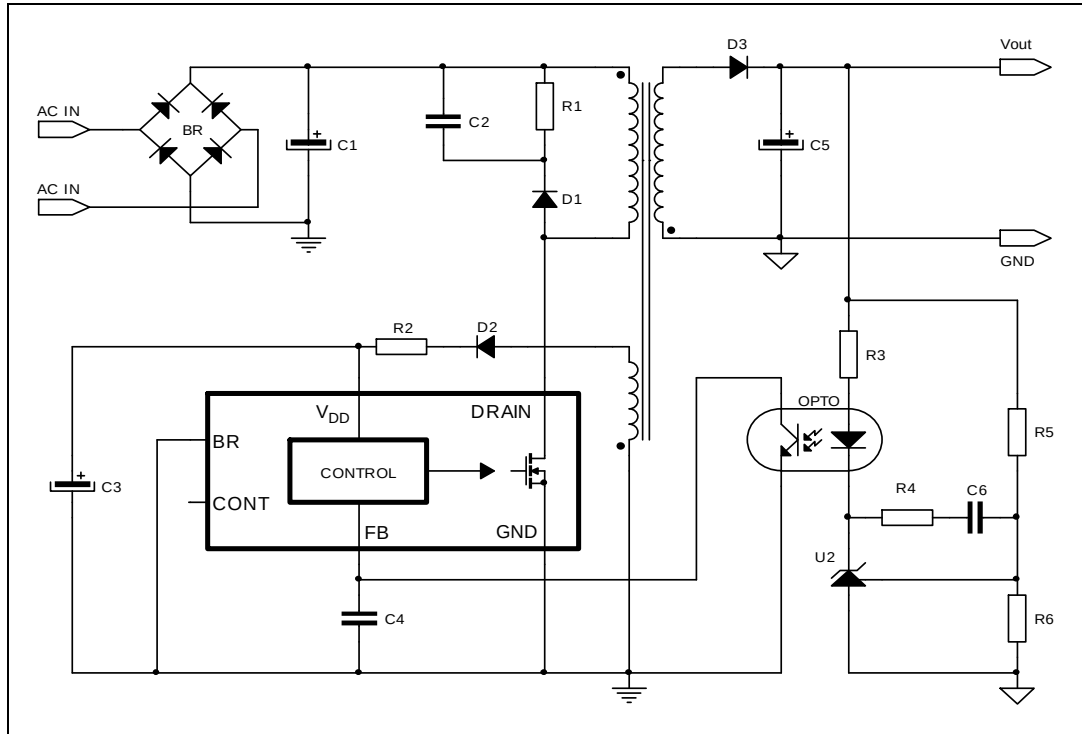
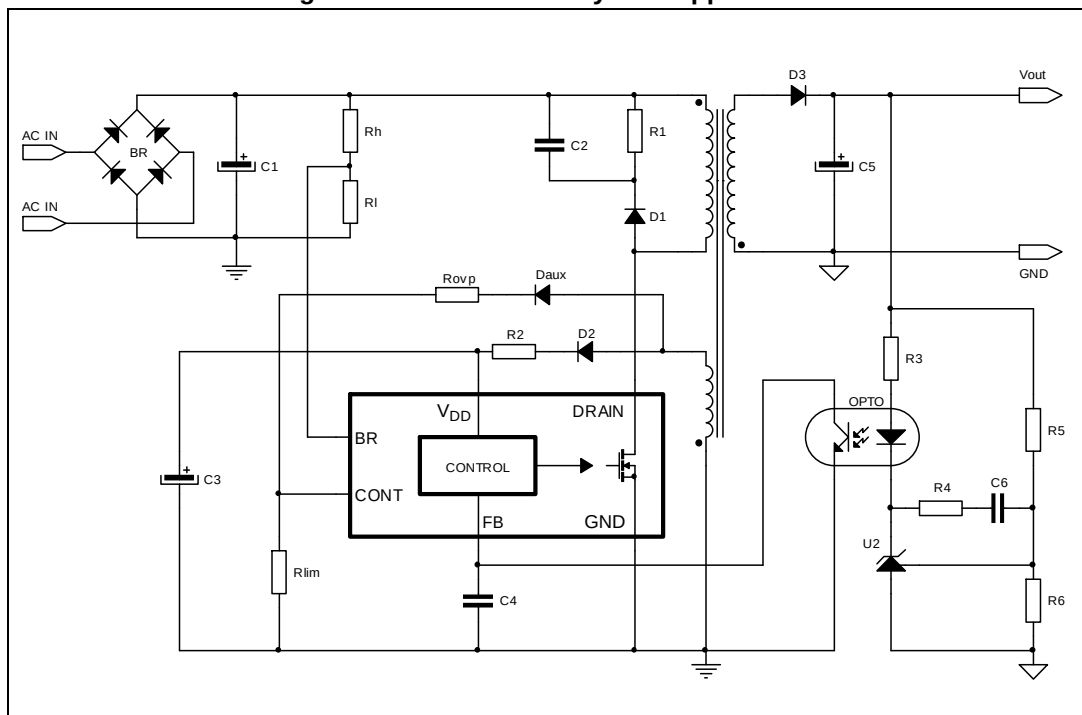


Figure 21. Full-features flyback application



## 7 Efficiency performances for a typical flyback converter

The efficiency of the converter has been measured in different load and line voltage conditions. In accordance with the ENERGY STAR® average active mode testing efficiency method, the efficiency measurements have been performed at 25%, 50% and 75% and 100% of the rated output power, at both 115 V<sub>AC</sub> and 230 V<sub>AC</sub>.

**Table 9. Power supply efficiency, V<sub>OUT</sub> = 5 V, V<sub>IN</sub> = 115 V<sub>AC</sub>**

| %Load              | I <sub>out</sub> [A] | V <sub>out</sub> [V] | P <sub>out</sub> [W] | P <sub>in</sub> [W] | Efficiency [%] |
|--------------------|----------------------|----------------------|----------------------|---------------------|----------------|
| 25%                | 0.75                 | 5.04                 | 3.78                 | 4.83                | 78.26%         |
| 50%                | 1.5                  | 5.04                 | 7.56                 | 9.72                | 77.78%         |
| 75%                | 2.25                 | 5.04                 | 11.34                | 14.84               | 76.42%         |
| 100%               | 3                    | 5.04                 | 15.12                | 20.04               | 75.45%         |
| Average efficiency |                      |                      |                      |                     | 76.97%         |

**Table 10. Power supply efficiency, V<sub>OUT</sub> = 5 V, V<sub>IN</sub> = 230 V<sub>AC</sub>**

| %Load              | I <sub>out</sub> [A] | V <sub>out</sub> [V] | P <sub>out</sub> [W] | P <sub>in</sub> [W] | Efficiency [%] |
|--------------------|----------------------|----------------------|----------------------|---------------------|----------------|
| 25%                | 0.75                 | 5.04                 | 3.78                 | 5.01                | 75.45%         |
| 50%                | 1.5                  | 5.04                 | 7.56                 | 9.76                | 77.46%         |
| 75%                | 2.25                 | 5.04                 | 11.34                | 14.67               | 77.30%         |
| 100%               | 3                    | 5.03                 | 15.09                | 19.59               | 77.03%         |
| Average efficiency |                      |                      |                      |                     | 76.81%         |

**Figure 22. Power supply consumption at light output loads, V<sub>OUT</sub> = 5 V**

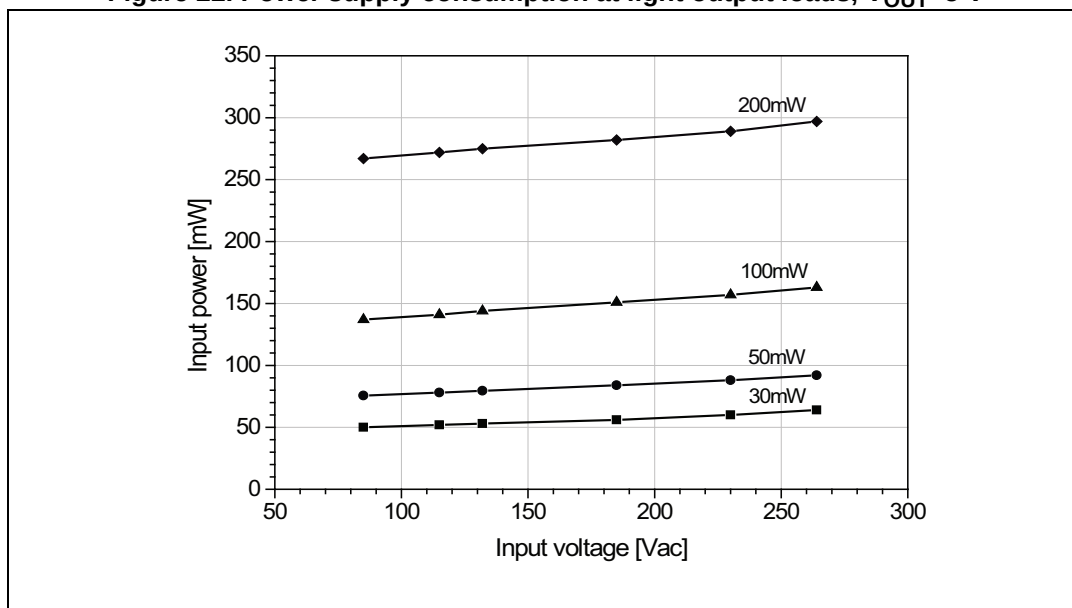
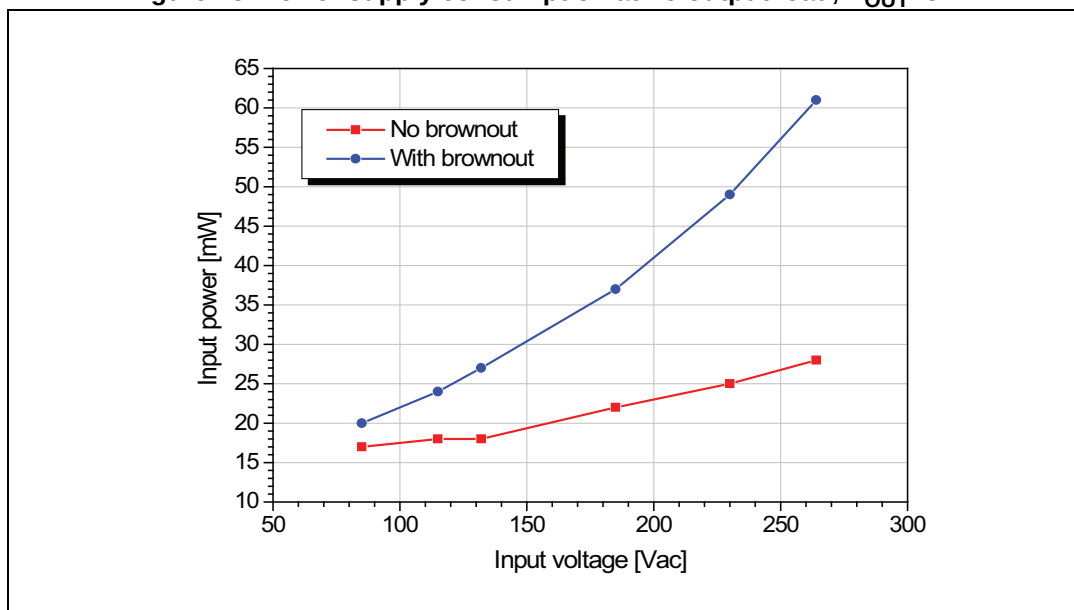


Figure 23. Power supply consumption at no output load,  $V_{OUT}=5\text{ V}$ 

## 8 Operation description

The device is a high-performance low-voltage PWM controller chip with an 800 V avalanche rugged power section.

The controller includes: the oscillator with jittering feature, the startup circuits with soft-start feature, the PWM logic, the current limit circuit with adjustable set point, the second overcurrent circuit, the burst mode management, the brownout circuit, the UVLO circuit, the auto-restart circuit, and the thermal protection circuit.

The current limit set-point is set by the CONT pin. The burst mode operation guarantees high performance in standby mode and helps to accomplish the energy saving norm.

All the fault protections are built in auto-restart mode with very low repetition rate to prevent the IC overheating.

### 8.1 Power section and gate driver

The power section is implemented with an avalanche ruggedness N-channel MOSFET, which guarantees safe operation within the specified energy rating as well as high  $dv/dt$  capability. The power section has a  $B_{VDSS}$  of 800 V min. and a typical  $R_{DS(on)}$  of 4.5  $\Omega$  at 25  $^{\circ}\text{C}$ .

The integrated SenseFET structure allows a virtually loss-less current sensing.

The gate driver is designed to supply a controlled gate current during both turn-on and turn-off in order to minimize common mode EMI. Under UVLO conditions an internal pull-down circuit holds the gate low in order to ensure that the power section cannot be turned on accidentally.

## 8.2 High voltage startup generator

The HV current generator is supplied through the DRAIN pin and is enabled only if the input bulk capacitor voltage is higher than the  $V_{DRAIN\_START}$  threshold, 80 V<sub>DC</sub> (typical). When the HV current generator is ON, the  $I_{DDch}$  current (3 mA typical value) is delivered to the capacitor on the V<sub>DD</sub> pin. In the case of auto-restart mode after a fault event, the  $I_{DDch}$  current is reduced to 0.6 mA, in order to have a slow duty cycle during the restart phase.

## 8.3 Power-up and soft-start

If the input voltage rises up to the device start threshold  $V_{DRAIN\_START}$ , the V<sub>DD</sub> voltage begins to grow due to the  $I_{DDch}$  current (see [Table 7](#)) coming from the internal high voltage startup circuit. If the V<sub>DD</sub> voltage reaches the  $V_{DDon}$  threshold (see [Table 7](#)), the Power MOSFET starts switching and the HV current generator is turned off (see [Figure 25](#)).

The IC is powered by the energy stored in the capacitor on the V<sub>DD</sub> pin, C<sub>VDD</sub>, until the self-supply circuit (typically an auxiliary winding of the transformer and a steering diode) develops a voltage high enough to sustain the operation.

The C<sub>VDD</sub> capacitor must be sized correctly in order to avoid fast discharge and keep the needed voltage value higher than the  $V_{DDoff}$  threshold. In fact, a too low capacitance value could terminate the switching operation before the controller receives any energy from the auxiliary winding.

The following formula can be used for the V<sub>DD</sub> capacitor calculation:

### Equation 1

$$C_{VDD} = \frac{I_{DDch} \times t_{SSaux}}{V_{DDon} - V_{DDoff}}$$

The  $t_{SSaux}$  is the time needed for the steady-state of the auxiliary voltage. This time is estimated by the applicator according to the output stage configurations (transformer, output capacitances, etc.).

During the converter startup time, the drain current limitation is progressively increased to the maximum value. In this way the stress on the secondary diode is considerably reduced. It also helps to prevent transformer saturation. The soft-start time lasts 8.5 ms and the feature is implemented for every attempt of the startup converter or after a fault.

Figure 24.  $I_{DD}$  current during startup and burst mode

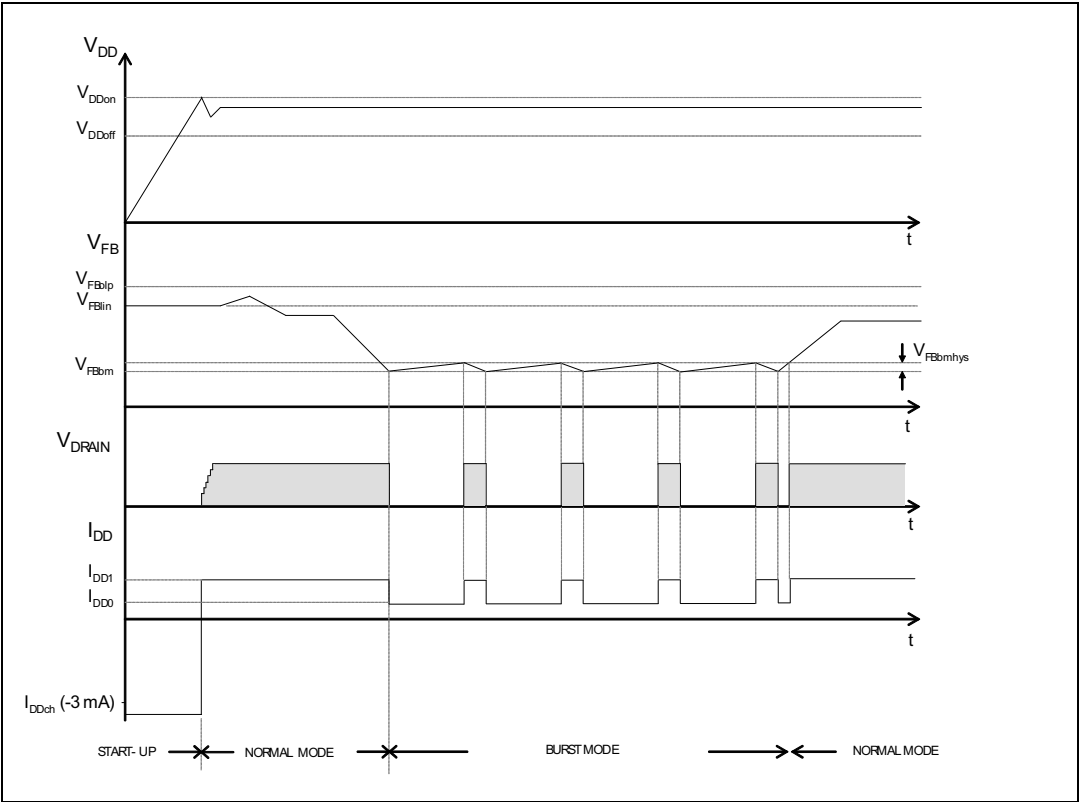


Figure 25. Timing diagram: normal power-up and power-down sequences

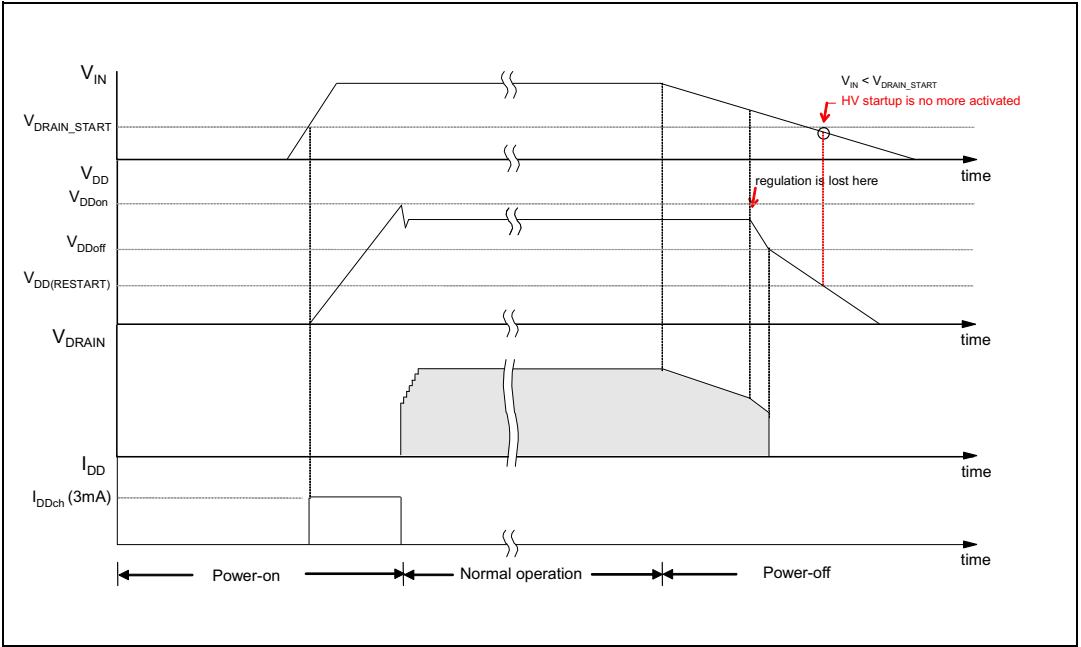
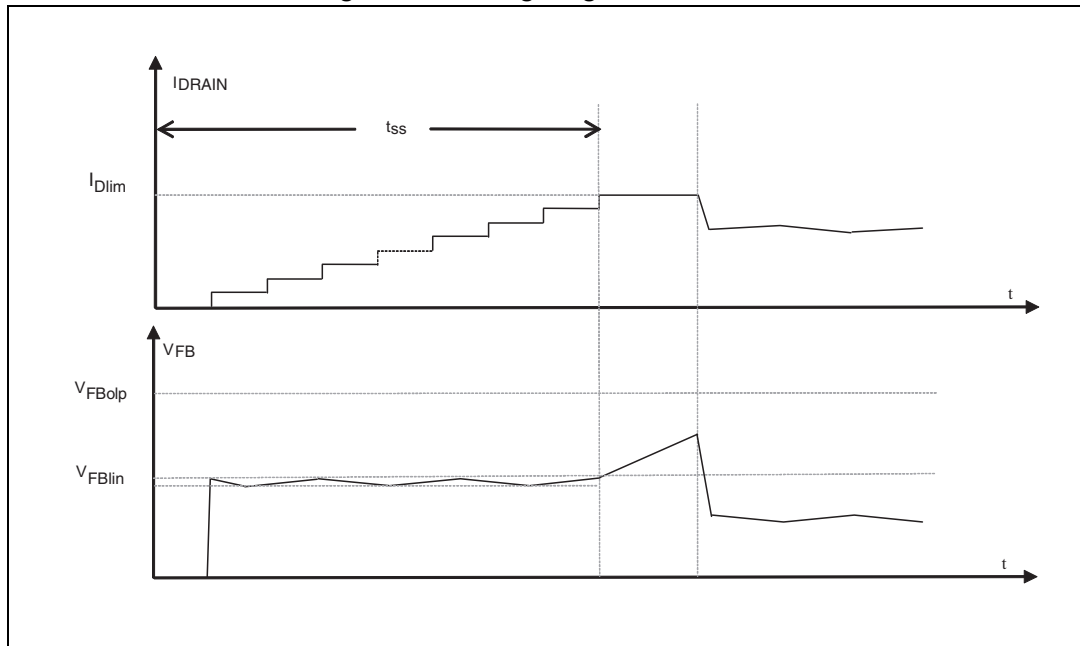


Figure 26. Timing diagram: soft-start



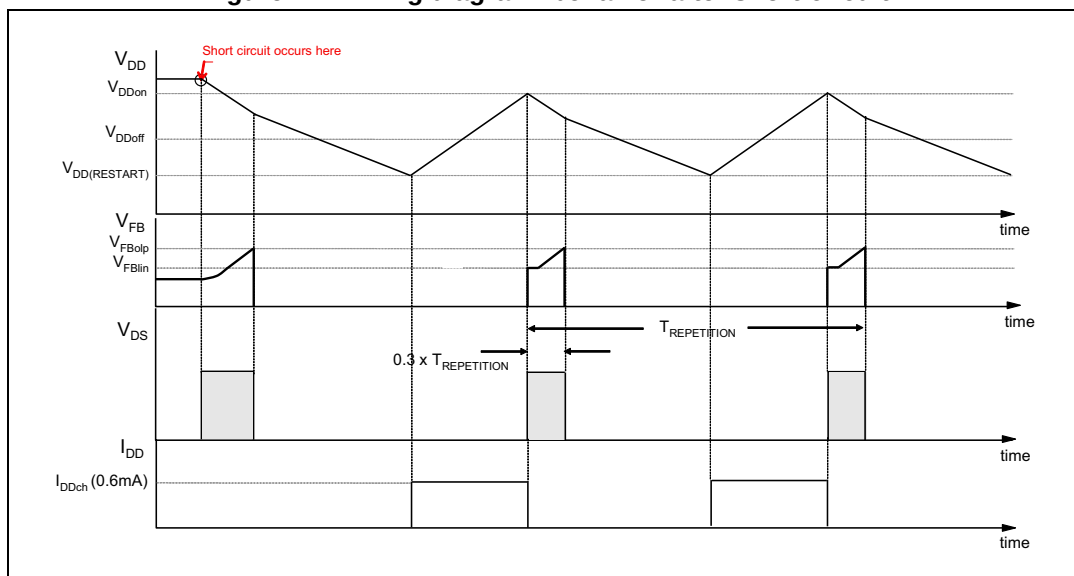
## 8.4 Power down operation

At converter power down, the system loses regulation as soon as the input voltage is so low that the peak current limitation is reached. The  $V_{DD}$  voltage drops and when it falls below the  $V_{DDoff}$  threshold (see [Table 7](#)) the Power MOSFET is switched OFF, the energy transfers to the IC interrupted and consequently the  $V_{DD}$  voltages decrease, [Figure 25](#). Later, if the  $V_{IN}$  is lower than  $V_{DRAIN\_START}$  (see [Table 7](#)), the startup sequence is inhibited and the power down completed. This feature is useful to prevent the converter's restart attempts and ensures monotonic output voltage decay during the system power down.

## 8.5 Auto-restart operation

If, after a converter power down, the  $V_{IN}$  is higher than  $V_{DRAIN\_START}$ , the startup sequence is not inhibited and is activated only when the  $V_{DD}$  voltage drops below the  $V_{DD(RESTART)}$  threshold (see [Table 7](#)). This means that the HV startup current generator restarts the  $V_{DD}$  capacitor charging only when the  $V_{DD}$  voltage drops below  $V_{DD(RESTART)}$ . The scenario described above is, for instance, a power down because of a fault condition. After a fault condition, the charging current  $I_{DDch}$  is 0.6 mA (typ.) instead of the 3 mA (typ.) of a normal startup converter phase. This feature, together with the low  $V_{DD(RESTART)}$  threshold, ensures that, after a fault, the restart attempts of the IC have a very long repetition rate and the converter works safely with extremely low power throughput. [Figure 27](#) shows the IC behavior after a short-circuit event.

Figure 27. Timing diagram: behavior after short-circuit



## 8.6 Oscillator

The switching frequency is internally fixed to 60 kHz or 115 kHz. In both cases the switching frequency is modulated by approximately  $\pm 4$  kHz (60 kHz version) or  $\pm 8$  kHz (115 kHz version) at a 250 Hz (typ.) rate, so that the resulting spread-spectrum action distributes the energy of each harmonic of the switching frequency over a number of side-band harmonics having the same energy on the whole but smaller amplitudes.

## 8.7 Current mode conversion with adjustable current limit set point

This device is a current mode converter: the drain current is sensed and converted into voltage that is applied to the non-inverting pin of the PWM comparator. This voltage is compared with the one on the feedback pin through a voltage divider on a cycle-by-cycle basis.

The device has a default current limit value,  $I_{Dlim}$ , that the user can adjust according to the electrical specifications, through the  $R_{LIM}$  resistor connected to the CONT pin (see [Figure 16](#)).

The CONT pin has a minimum current sunk, needed to activate the  $I_{Dlim}$  adjustment: without  $R_{LIM}$  or with high  $R_{LIM}$  (i.e. 100 k $\Omega$ ), the current limit is fixed to the default value (see  $I_{Dlim}$ , [Table 8](#)).

## 8.8 Overvoltage protection (OVP)

The device can monitor the converter output voltage. This operation is done by the CONT pin during Power MOSFET OFF-time, when the voltage generated by the auxiliary winding tracks the converter's output voltage, through turn ratio  $\frac{N_{AUX}}{N_{SEC}}$  (see [Figure 28](#)).

In order to perform the output voltage monitor, the CONT pin must be connected to the aux. winding through a resistor divider made up of  $R_{LIM}$  and  $R_{OVP}$  (see [Figure 21](#) or [Figure 29](#)). If the voltage applied to the CONT pin exceeds the internal reference  $V_{OVP}$  (see [Table 8](#)) for four consecutive times, the controller recognizes an overvoltage condition. This special feature uses an internal counter; that is to reduce sensitivity to noise and prevent the latch from being erroneously activated (see [Figure 28](#)). The counter is reset every time the OVP signal is not triggered in one oscillator cycle.

Referring to [Figure 21](#), the resistors' divider ratio  $k_{OVP}$  is given by:

### Equation 2

$$k_{OVP} = \frac{V_{OVP}}{\frac{N_{AUX}}{N_{SEC}} \cdot (V_{OUT OVP} + V_{DSEC}) - V_{DAUX}}$$

### Equation 3

$$k_{OVP} = \frac{R_{LIM}}{R_{LIM} + R_{OVP}}$$

where:

- $V_{OVP}$  is the OVP threshold (see [Table 9](#))
- $V_{OUT OVP}$  is the converter output voltage value to activate the OVP set by the user
- $N_{AUX}$  is the auxiliary winding turns
- $N_{SEC}$  is the secondary winding turns
- $V_{DSEC}$  is the secondary diode forward voltage
- $V_{DAUX}$  is the auxiliary diode forward voltage
- $R_{OVP}$  together with  $R_{LIM}$  make up the output voltage divider.

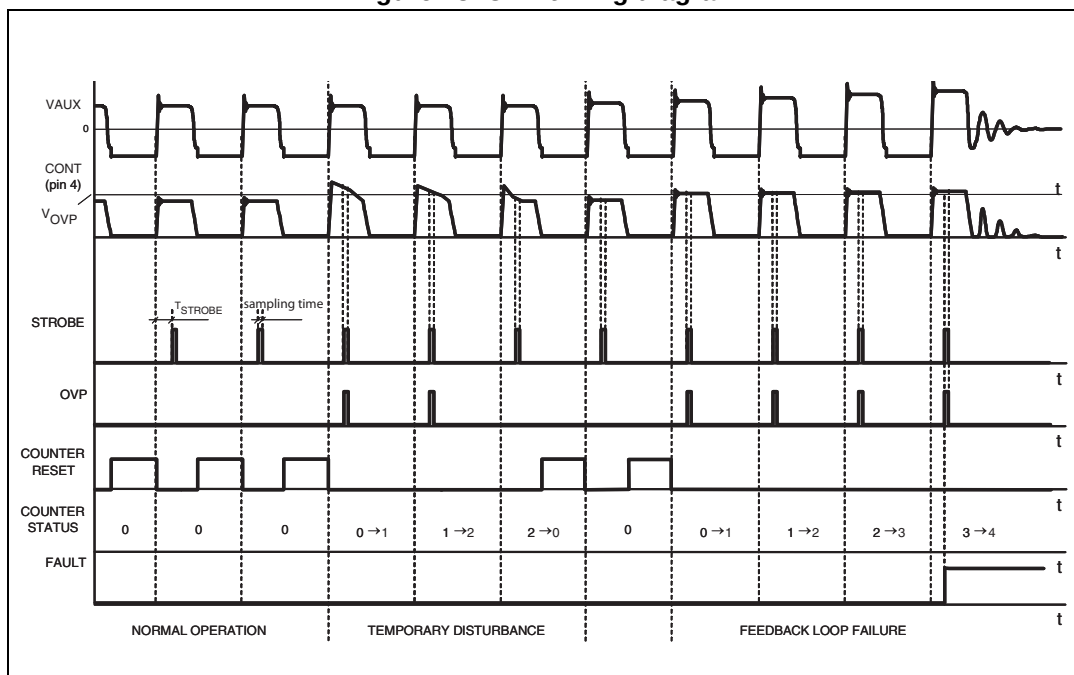
Then, once the  $R_{LIM}$  value is fixed, according to the desired  $I_{Dlim}$ , the  $R_{OVP}$  can be calculated by:

### Equation 4

$$R_{OVP} = R_{LIM} \times \frac{1 - k_{OVP}}{k_{OVP}}$$

The resistor values are such that the current sourced and sunk by the CONT pin are within the rated capability of the internal clamp.

Figure 28. OVP timing diagram



## 8.9 About the CONT pin

Referring to [Figure 29](#), the features below can be implemented through the CONT pin:

1. Current limit set point
2. Overvoltage protection on the converter output voltage

[Table 11](#), referring to [Figure 29](#), lists the external resistance combinations needed to activate one or more of the CONT pin functions.

Figure 29. CONT pin configuration

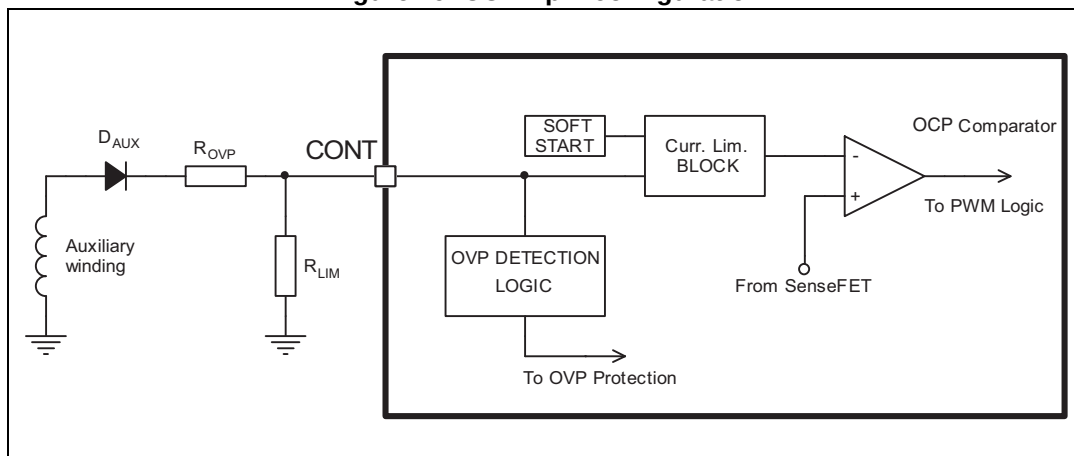


Table 11. CONT pin configurations

| Function / component             | R <sub>LIM</sub> <sup>(1)</sup> | R <sub>OVP</sub>               | D <sub>AUX</sub> |
|----------------------------------|---------------------------------|--------------------------------|------------------|
| I <sub>Dim</sub> reduction       | See <a href="#">Figure 16</a>   | No                             | No               |
| OVP                              | ≥ 80 kΩ                         | See <a href="#">Equation 4</a> | Yes              |
| I <sub>Dim</sub> reduction + OVP | See <a href="#">Figure 16</a>   | See <a href="#">Equation 4</a> | Yes              |

1. R<sub>LIM</sub> must be fixed before R<sub>OVP</sub>.

## 8.10 Feedback and overload protection (OLP)

The device is a current mode converter: the feedback pin controls the PWM operation, controls the burst mode, and activates the overload protection. [Figure 30](#) and [Figure 31](#) show the internal current mode structure.

With the feedback pin voltage between V<sub>FBbm</sub> and V<sub>FBlin</sub>, (see [Table 8](#)) the drain current is sensed and converted into voltage that is applied to the non-inverting pin of the PWM comparator.

This voltage is compared with the one on the feedback pin through a voltage divider on a cycle-by-cycle basis. When these two voltages are equal, the PWM logic orders the switch-off of the Power MOSFET. The drain current is always limited to the I<sub>Dim</sub> value.

In case of overload, the feedback pin increases in reaction to this event and when it goes higher than V<sub>FBlin</sub>, the PWM comparator is disabled and the drain current is limited to I<sub>Dim</sub> by the OCP comparator, see [Figure 2](#).

When the feedback pin voltage reaches the threshold V<sub>FBlin</sub>, an internal current generator starts to charge the feedback capacitor (C<sub>FB</sub>) and when the feedback voltage reaches the V<sub>FBolp</sub> threshold, the converter is turned off and the startup phase is activated with a reduced value of I<sub>DDch</sub> to 0.6 mA, see [Table 7](#).

During the first startup phase of the converter, after the soft-start time (t<sub>SS</sub>), the output voltage may force the feedback pin voltage to rise up to the V<sub>FBolp</sub> threshold that switches off the converter itself.

To avoid this event, the appropriate feedback network must be selected according to the output load. Moreover, the feedback network fixes the compensation loop stability. [Figure 30](#) and [Figure 31](#) show the two different feedback networks.

The time from the overload detection (V<sub>FB</sub> = V<sub>FBlin</sub>) to the device shutdown (V<sub>FB</sub> = V<sub>FBolp</sub>) can be set by the C<sub>FB</sub> value (see [Figure 30](#) and [Figure 31](#)), using the formula:

### Equation 5

$$T_{OLP-delay} = C_{FB} \times \frac{V_{FBolp} - V_{FBlin}}{I_{FB}}$$

where I<sub>FB</sub> is the value, reported in [Table 8](#), when the FB voltage is between V<sub>FBlin</sub> and V<sub>FBolp</sub>.

In [Figure 30](#), the capacitor connected to the FB pin (C<sub>FB</sub>) is part of the compensation circuit as well as being necessary to activate the overload protection.

After the startup time,  $t_{SS}$ , during which the feedback voltage is fixed at  $V_{FBlin}$ , the output capacitor may not be at its nominal value and the controller interprets this situation as an overload condition. In this case, the OLP delay helps to avoid an incorrect device shutdown during the startup phase.

Owing to the above considerations, the OLP delay time must be long enough to bypass the initial output voltage transient and check the overload condition only when the output voltage is in steady-state. The output transient time depends on the value of the output capacitor and on the load.

When the value of the  $C_{FB}$  capacitor calculated for the loop stability is too low and cannot ensure enough OLP delay, an alternative compensation network can be used, shown in [Figure 31](#).

Using this alternative compensation network, two poles ( $f_{PFB}$ ,  $f_{PFB1}$ ) and one zero ( $f_{ZFB}$ ) are introduced by the capacitors  $C_{FB}$  and  $C_{FB1}$  and the resistor  $R_{FB1}$ .

The capacitor  $C_{FB}$  introduces a pole ( $f_{PFB}$ ) at a higher frequency than  $f_{ZB}$  and  $f_{PFB1}$ . This pole is usually used to compensate the high frequency zero due to the ESR (equivalent series resistor) of the output capacitance of the flyback converter.

The mathematical expressions of these poles and zero frequency, considering the scheme in [Figure 31](#), are reported by the equations below:

#### Equation 6

$$f_{ZFB} = \frac{1}{2 \cdot \pi \cdot C_{FB1} \cdot R_{FB1}}$$

#### Equation 7

$$f_{PFB} = \frac{R_{FB(DYN)} + R_{FB1}}{2 \cdot \pi \cdot C_{FB} \cdot (R_{FB(DYN)} \cdot R_{FB1})}$$

#### Equation 8

$$f_{PFB1} = \frac{1}{2 \cdot \pi \cdot C_{FB1} \cdot (R_{FB1} + R_{FB(DYN)})}$$

$R_{FB(DYN)}$  is the dynamic resistance seen by the FB pin.

The  $C_{FB1}$  capacitor fixes the OLP delay and usually  $C_{FB1}$  results much higher than  $C_{FB}$ . [Equation 5](#) can still be used to calculate the OLP delay time but  $C_{FB1}$  must be considered instead of  $C_{FB}$ . Using the alternative compensation network, the user can satisfy, in all cases, the loop stability and the correct OLP delay time alike.

Figure 30. FB pin configuration 1

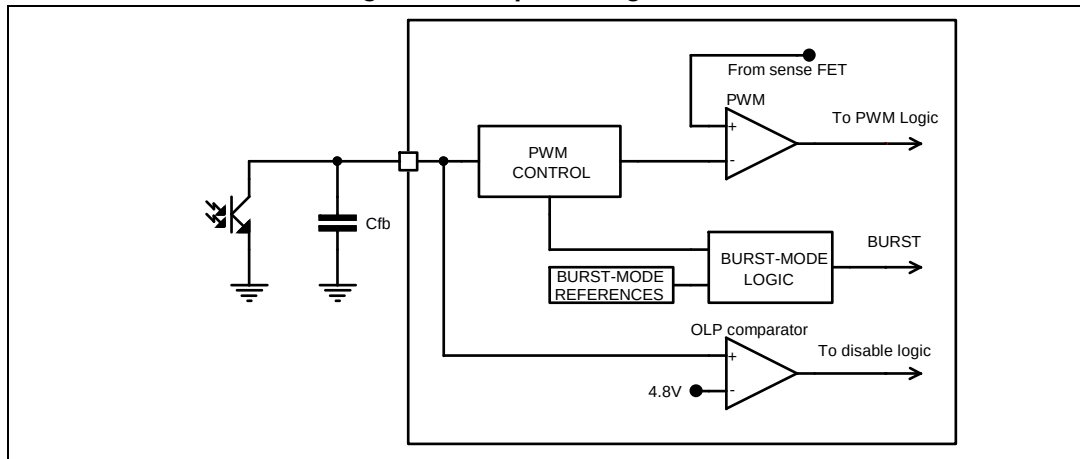
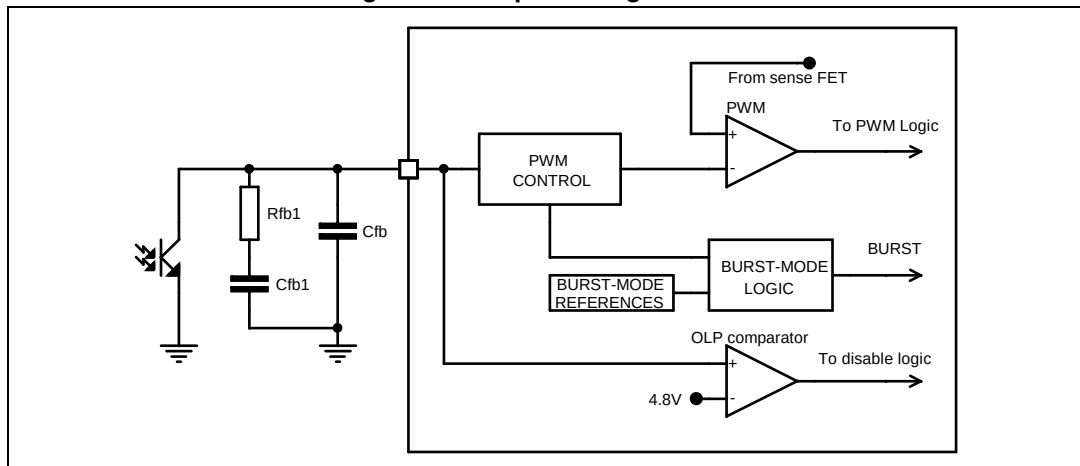


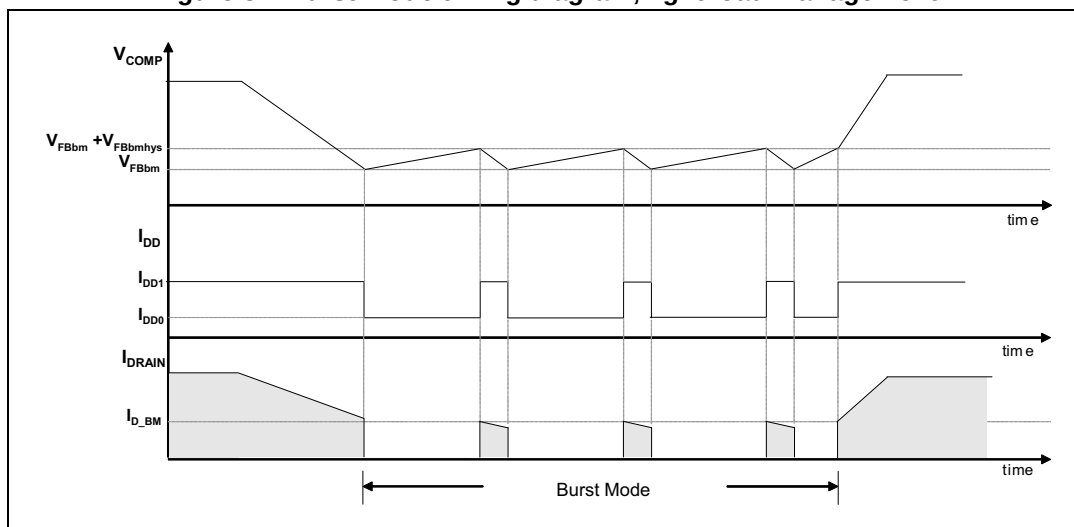
Figure 31. FB pin configuration 2



## 8.11 Burst mode operation at no load or very light load

When the load decreases, the feedback loop reacts by lowering the feedback pin voltage. If it falls below the burst mode threshold,  $V_{FBbm}$ , the Power MOSFET is no longer allowed to be switched on. After the MOSFET stops, as a result of the feedback reaction to the energy delivery stop, the feedback pin voltage increases and when it exceeds the level,  $V_{FBbm} + V_{FBbmhys}$ , the power MOSFET starts switching again. The burst mode thresholds are reported in [Table 8](#) and [Figure 32](#) shows this behavior. Depending on the output load, the power alternates between periods of time in which the Power MOSFET is switching and is enabled, with periods of time when the Power MOSFET is not switching; this working mode is called burst mode. The power delivered to the output during switching periods exceeds the load power demands; the excess of power is balanced from the non-switching period where no power is processed. The advantage of burst mode operation is an average switching frequency much lower than the normal operation working frequency, up to a few hundred hertz, minimizing all frequency related losses. During burst mode the drain current peak is clamped to the level,  $I_{D\_BM}$ , reported in [Table 8](#).

Figure 32. Burst mode timing diagram, light load management



## 8.12 Brownout protection

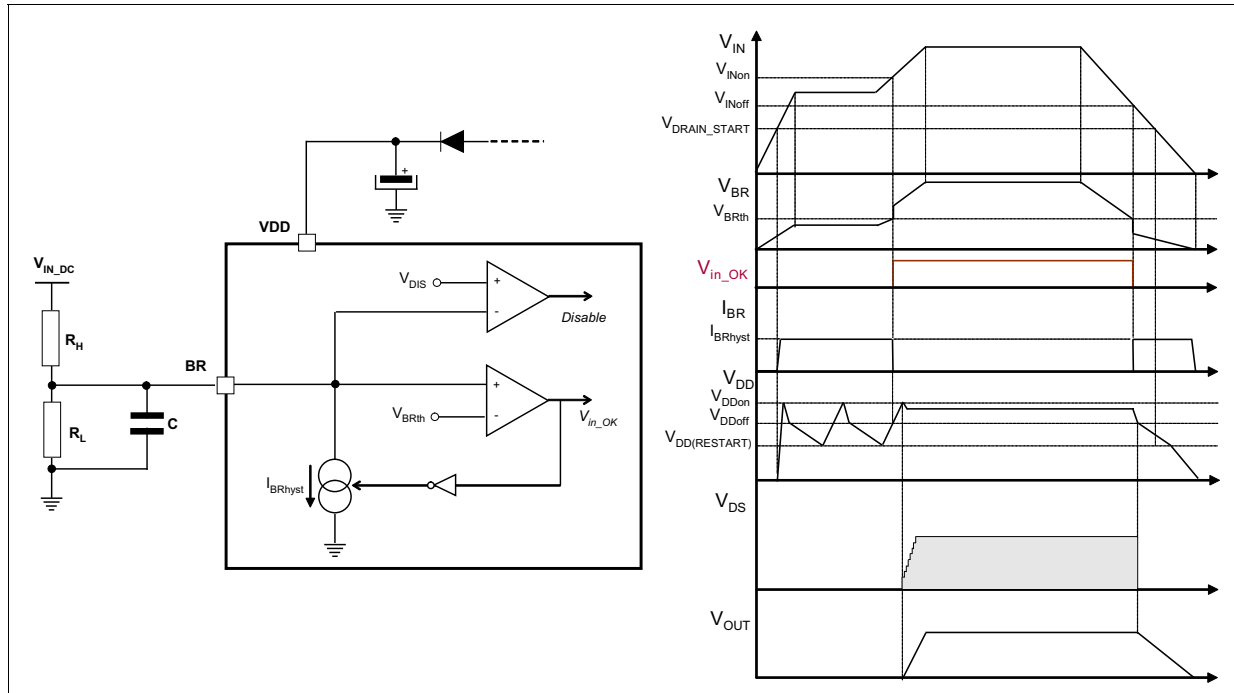
Brownout protection is a not-latched shutdown function activated when a condition of mains undervoltage is detected.

The brownout comparator is internally referenced to  $V_{BRth}$ , [Table 8](#), and disables the PWM if the voltage applied at the BR pin is below this internal reference. Under this condition the Power MOSFET is turned off. Until the brownout condition is present, the VDD voltage continuously oscillates between the  $V_{DDon}$  and the UVLO thresholds, as shown in the timing diagram of [Figure 33](#). A voltage hysteresis is present to improve the noise immunity.

The switching operation is restarted as the voltage on the pin is above the reference plus the previously mentioned voltage hysteresis, see [Figure 5](#).

The brownout comparator is provided also with a current hysteresis,  $I_{BRhyst}$ . The user must set the rectified input voltage above which the Power MOSFET starts switching after brownout event,  $V_{INon}$ , and the rectified input voltage below which the Power MOSFET is switched off,  $V_{INoff}$ . Thanks to the  $I_{BRhyst}$ , see [Table 8](#), these two thresholds can be set separately.

Figure 33. Brownout protection: BR external setting and timing diagram



When the  $V_{INon}$  and the  $V_{INoff}$  levels are fixed, with reference to [Figure 33](#), the following relationships can be established for the calculation of the resistors  $R_H$  and  $R_L$ :

#### Equation 9

$$R_L = -\frac{V_{BRhyst}}{I_{BRhyst}} + \frac{V_{INon} - V_{INoff} - V_{BRhyst}}{V_{INoff} - V_{BRth}} \times \frac{V_{BRth}}{I_{BRhyst}}$$

#### Equation 10

$$R_H = \frac{V_{INon} - V_{INoff} - V_{BRhyst}}{I_{BRhyst}} \times \frac{R_L}{R_L + \frac{V_{BRhyst}}{I_{BRhyst}}}$$

For a proper operation of this function,  $V_{INon}$  must be less than the peak voltage at minimum mains and  $V_{INoff}$  less than the minimum voltage on the input bulk capacitor at minimum mains and maximum load.

The BR pin is a high impedance input connected to high value resistors, it is therefore prone to pick up noise, which might alter the OFF threshold when the converter operates or creates an undesired switch-off of the device during ESD tests.

It is possible to bypass the pin to ground with a small film capacitor (e.g. 1-10 nF) to prevent any malfunctioning of this kind.

If the brownout function is not used, the BR pin must be connected to GND, ensuring that the voltage is lower than the minimum  $V_{DIS}$  threshold (50 mV), see [Table 8](#).

In order to enable the brownout function, the BR pin voltage must be higher than the maximum  $V_{DIS}$  threshold (150 mV), see [Table 8](#).

## 8.13 2<sup>nd</sup> level overcurrent protection and hiccup mode

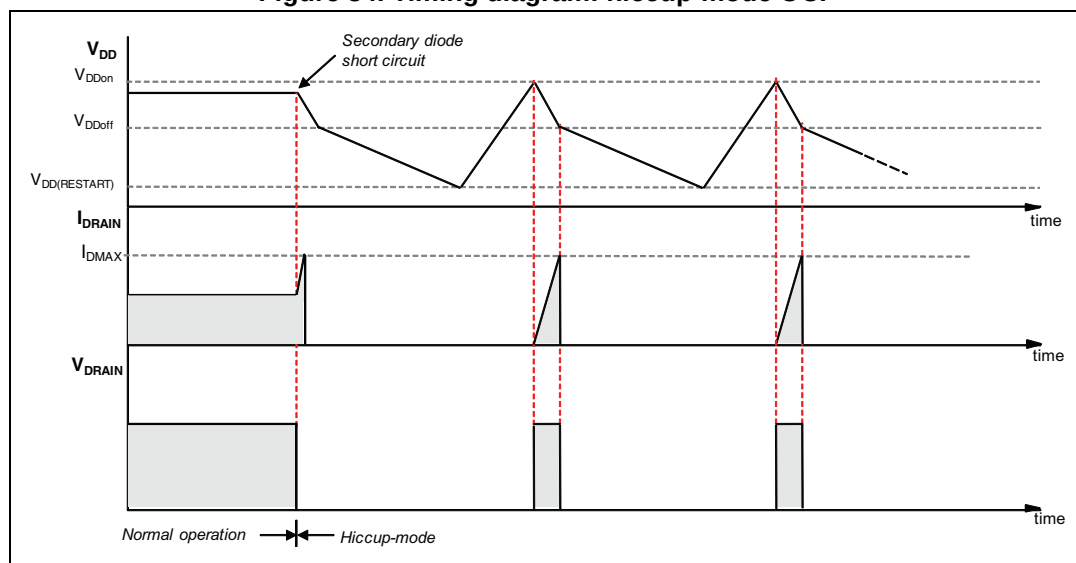
The device is protected against short-circuit of the secondary rectifier, short-circuit on the secondary winding, or a hard-saturation of the flyback transformer. Such an anomalous condition is invoked when the drain current exceeds the threshold  $I_{DMAX}$  (see [Table 8](#)).

To distinguish a real malfunction from a disturbance (e.g. induced during ESD tests) a “warning state” is entered after the first signal trip. If, in the subsequent switching cycle, the signal is not tripped, a temporary disturbance is assumed and the protection logic is reset in its idle state; otherwise, if the  $I_{DMAX}$  threshold is exceeded for two consecutive switching cycles, a real malfunction is assumed and the Power MOSFET is turned off.

The shutdown condition is latched as long as the device is supplied. While it is disabled, no energy is transferred from the auxiliary winding; hence the voltage on the  $V_{DD}$  capacitor decays to the  $V_{DD}$  undervoltage threshold ( $V_{DDoff}$ ), which clears the latch.

The startup HV current generator is still off, until the  $V_{DD}$  voltage goes below its restart voltage,  $V_{DD(RESTART)}$ . After this condition the  $V_{DD}$  capacitor is charged again by a 600  $\mu A$  current, and the converter switching restarts if the  $V_{DDon}$  occurs. If the fault condition is not removed the device enters auto-restart mode. This behavior results in a low-frequency intermittent operation (hiccup-mode operation), with very low stress on the power circuit. See the timing diagram of [Figure 34](#).

Figure 34. Timing diagram: hiccup-mode OCP



## 9 Package information

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK® packages, depending on their level of environmental compliance. ECOPACK specifications, grade definitions and product status are available at: [www.st.com](http://www.st.com). ECOPACK is an ST trademark.

### 9.1 SDIP10 package information

Figure 35. SDIP10 package outline

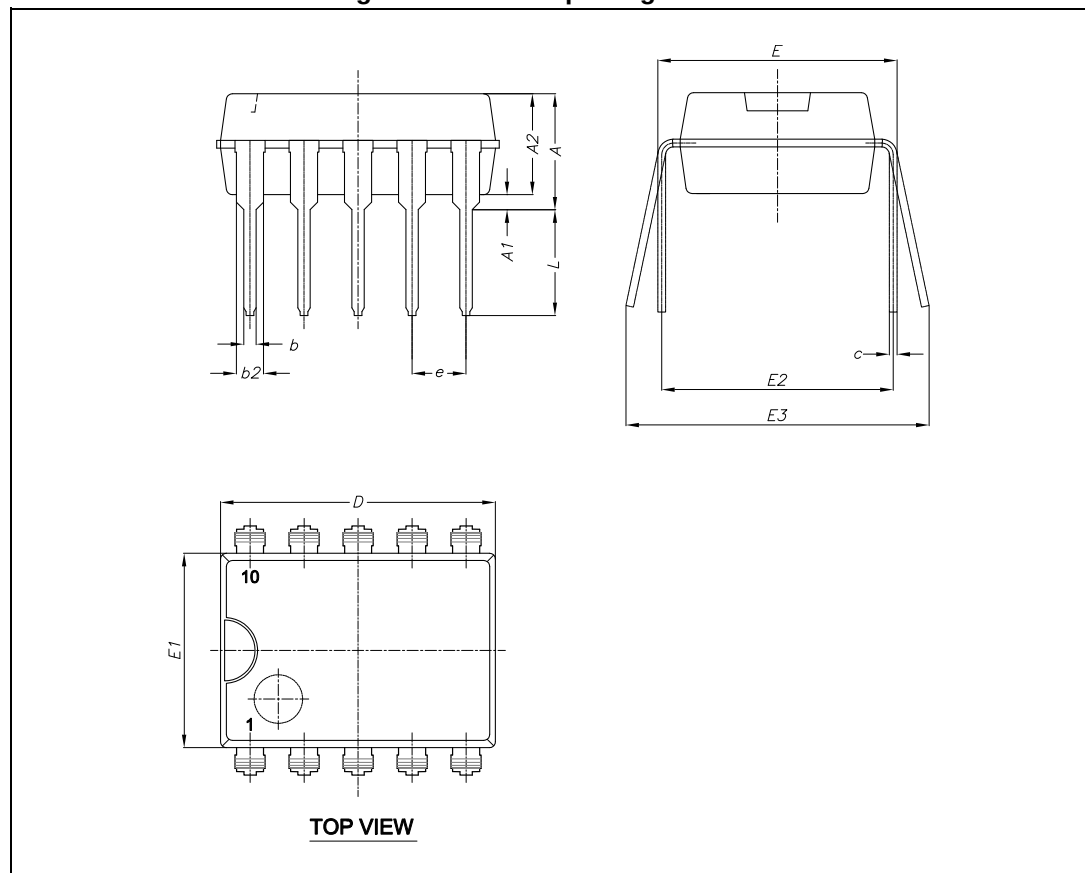


Table 12. SDIP10 mechanical data

| Dim. | mm   |      |       |
|------|------|------|-------|
|      | Min. | Typ. | Max.  |
| A    |      |      | 5.33  |
| A1   | 0.38 |      |       |
| A2   | 2.92 |      | 4.95  |
| b    | 0.36 |      | 0.56  |
| b2   | 0.51 |      | 1.15  |
| c    | 0.2  |      | 0.36  |
| D    | 9.02 |      | 10.16 |
| E    | 7.62 |      | 8.26  |
| E1   | 6.1  |      | 7.11  |
| E2   |      | 7.62 |       |
| E3   |      |      | 10.92 |
| e    |      | 1.77 |       |
| L    | 2.92 |      | 3.81  |

9.2 SO16 narrow package information

Figure 36. SO16 narrow package outline

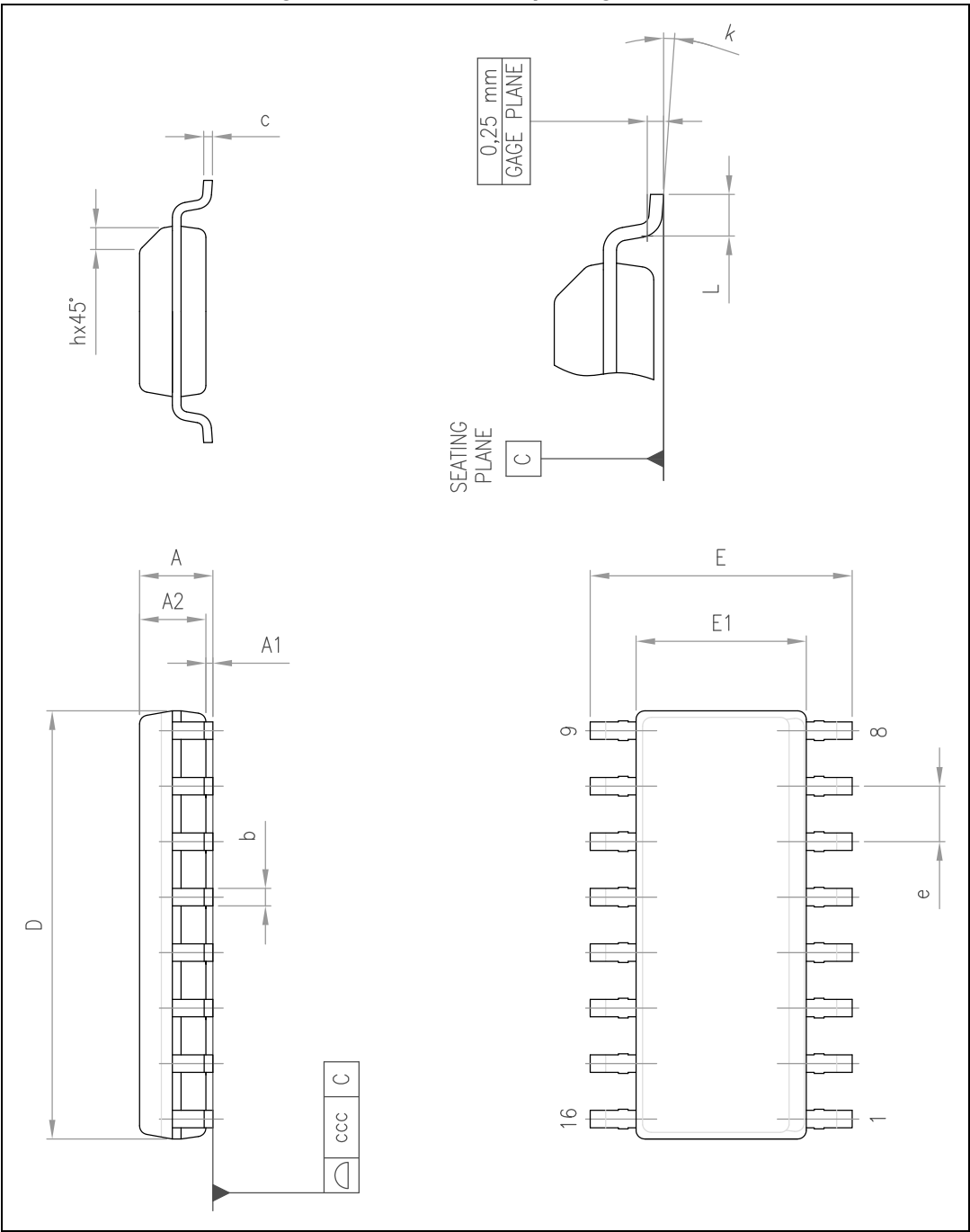


Table 13. SO16 narrow mechanical data

| Dim. | mm   |      |      |
|------|------|------|------|
|      | Min. | Typ. | Max. |
| A    |      |      | 1.75 |
| A1   | 0.1  |      | 0.25 |
| A2   | 1.25 |      |      |
| b    | 0.31 |      | 0.51 |
| c    | 0.17 |      | 0.25 |
| D    | 9.8  | 9.9  | 10   |
| E    | 5.8  | 6    | 6.2  |
| E1   | 3.8  | 3.9  | 4    |
| e    |      | 1.27 |      |
| h    | 0.25 |      | 0.5  |
| L    | 0.4  |      | 1.27 |
| k    | 0    |      | 8    |
| ccc  |      |      | 0.1  |

## 10 Revision history

**Table 14. Document revision history**

| Date        | Revision | Changes                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |
|-------------|----------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 17-Feb-2012 | 1        | Initial release                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
| 20-May-2015 | 2        | Added SO16 narrow package.<br>Updated features in cover page.<br>Updated <a href="#">Table 1: Device summary</a> , <a href="#">Table 2: Typical power</a> ,<br><a href="#">Table 3: Pin description</a> , <a href="#">Section 4.3: Electrical characteristics</a> ,<br><a href="#">Figure 3: Connection diagram (top view)</a> .<br>Modified the HFB parameter in <a href="#">Table 8: Controller section</a> .<br>Added <a href="#">Section 9.2: SO16 narrow package information</a> .<br>Minor text changes. |
| 01-Jul-2015 | 3        | Minor text changes.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            |

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