Application Note

AN-SMPS-ICE3DS01-1

CoolSET™
ICE3DS01 Current Mode Controller for OFF – Line Switch Mode Power Supply (SMPS)

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Contents:

INTRODUCTION .......................................................................................................... 3

BLOCK DIAGRAM ....................................................................................................... 4

PROTECTION FUNCTIONS ........................................................................................... 5

  Auto- Restart- Mode ............................................................................................ 6

  Overvoltage Protection ........................................................................................ 7

ACTIVE BURST MODE ................................................................................................ 8

  VCC Supply during Burst Mode Operation .......................................................... 9

  Calculation of Burst Mode Operation boundaries .............................................. 11

SOFTSTART............................................................................................................. 13

BLANKING WINDOW FOR LOAD JUMP ................................................................. 14

TYPICAL APPLICATION.............................................................................................. 15

REFERENCES: ......................................................................................................... 16
Introduction

The **ICE3DS01** is a SMPS Current Mode Controller based on ICE2XXXX family with some new additional features. This Application Note describes how to use this new feature set of this IC. All other functions and calculations can be made according to AN-SMPS-ICE2AXXX-1 [2].

Additional to the ICE2XXXX features this controller provides **Active Burst Mode** to meet lowest Standby Power Requirements. The continuous monitoring of Feedback Input leads to immediate response in case of a load jump on the output. The point of entering and leaving the Burst Mode is only a function of the Feedback Voltage.

An **Integrated Startup Cell** allows to supply the VCC capacitor with regulated current taken from the high voltage DC input. This Startup Cell is only switched on to charge up the VCC capacitor and for supplying the IC during Latched OFF Mode.

Furthermore this Controller incorporates a **Latched Off Mode** function in case of Overvoltage due to Open-Loop, Short Winding and Overtemperature failures. For resetting this Off Mode the mains voltage has to be switched off until the VCC voltage declines below 6V.

For supporting applications which need peak power for limited time (switching on capacitive loads), the **ICE3DS01** offers a **Blancking Window** which delays the Overload Protection. During this time frame the SMPS delivers the peak power which is set by the sense resistor.
**Protection Functions**

The ICE3DS01 provides several protection functions which lead to two different failure modes. Overload, Short Circuit and VCC Undervoltage lead to **Auto-Restart-Mode**. If the IC enters this mode, it is immediately switched off and starts operation again automatically after discharging the VCC capacitor down to 8.5V and then charging up to 15V.

Overvoltage, Open Loop, Overtemperature and Short Winding lead to **Latched OFF Mode**.

Within this mode the IC is also switched off immediately but will not start again automatically. The internal current source is used to supply the IC in order to keep it latched off.

To leave this mode usually the power supply has to be plugged off of the mains for a certain time to discharge the Bulk- and VCC capacitor.

<table>
<thead>
<tr>
<th>Function</th>
<th>Limit</th>
<th>Protection</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overload</td>
<td>$V_{FB} &gt; 4.8V$</td>
<td>Auto-Restart-Mode</td>
<td>Blanking window til $VSS &gt; 5.35V$</td>
</tr>
<tr>
<td>Short Circuit</td>
<td>$V_{FB} &gt; 4.8V$</td>
<td>Auto-Restart-Mode</td>
<td></td>
</tr>
<tr>
<td>VCC Undervoltage</td>
<td>$VCC &lt; 8.5V$</td>
<td>Auto-Restart-Mode</td>
<td></td>
</tr>
<tr>
<td>Overvoltage</td>
<td>$VCC \geq 21V$</td>
<td>Latch Mode</td>
<td>$V_{FB} &gt; 4.8V$</td>
</tr>
<tr>
<td>Open Loop</td>
<td></td>
<td>Latch Mode</td>
<td></td>
</tr>
<tr>
<td>Overtemperature</td>
<td>$T_{JSD} &gt; 140 ^\circ \text{C}$</td>
<td>Latch Mode</td>
<td></td>
</tr>
<tr>
<td>Short Winding</td>
<td>$V_{CS} &gt; 1.66V$</td>
<td>Latch Mode</td>
<td></td>
</tr>
</tbody>
</table>

If not otherwise mentioned all values are typical values taken from the datasheet.

For resetting the Latch Mode Function the voltage at VCC pin has to decline below 6V.

Calculation of resetting time:

$$t_{reset} \approx \frac{C_{IN} \cdot (V_{DC,\text{max}} - V_{CCPD})}{I_{VCClatch}} \quad (\text{Eq 1})$$
Auto-Restart Mode

In Auto-Restart Mode the transferred power is reduced according to the Duty cycle shown below. Due to the internal startup current source the charging time of the VCC capacitor is independent of the input voltage. This means also that the transferred power is independent of the input voltage.

Fig. 1: Short Circuit @ Output

(measured with a 80W, 24V application)

Ch1: Voltage at VCC Pin
Ch2: Voltage at Feedback Pin
Overvoltage Protection

In case of overvoltage behaviour the VCC voltage has to rise from a normal level of about 15V to 21V in order to trigger the overvoltage comparator. As it can be seen on Fig.2 this needs a certain time to charge the VCC capacitor to this value. It has to be considered that during this time the output voltage also rises up to a higher level.

Fig. 2: Overvoltage due to Open Loop
(measured with a 80W, 24V application)
Ch1: Voltage at VCC Pin
Ch2: Voltage at Feedback Pin
Ch3: Output Voltage
**Active Burst Mode**

In order to get lowest input power values during low-/no load condition, the ICE3DS01 provides a **Active Burst Mode** function. The burst duty cycle and burst frequency is only controlled by the voltage at Feedback pin.

The Burst Cycle starts if the voltage at feedback pin stays below 1,32V typ. for a timeframe set by the blanking time. The Burst Cycle stops if this voltage exceeds 4,0V typ. If feedback voltage exceeds 4,8V typ. the IC changes immediately over to normal mode operation.

This function ensures, that if during the inactive state a load jump occurs ($V_{FB} >4,8V$) the IC switches back into active mode without any delay.

During Burst Mode the peak current is limited to 25% of maximal peak current.

![Fig. 1: Jump from normal operation to Burst Mode](image)

(measured with a 80W, 24V application)

**Ch1:** Voltage at VCC Pin  
**Ch2:** Output Voltage  
**Ch3:** Voltage at Feedback Pin
During Burst Mode operation with no load condition at the output, the supply voltage for VCC has to be designed for being above $V_{VCCoff}$ limit. This can lead to a high voltage at VCC pin during max load operation. If the voltage exceeds 21V typ. the overvoltage detection will become active and switches off the IC immediately. The insertion of an resistor (R12) between the electrolytic VCC capacitor (C4) and the ceramic capacitor (C12) at the VCC pin can help to overcome this problem. During normal mode operation a current of $I_{VCCsup1} + I_{Gate}$ is drawn from the VCC supply winding. At the resistor R12 the voltage drops according the resistor value.

**VCC Supply during Burst Mode Operation**

Fig. 2: Burst Mode operation at 85Vac with lowload condition
(measured with a 80W, 24V application)

Ch1: Voltage at VCC Pin
Ch2: Output Voltage
Ch3: Voltage at Feedback Pin
During Burst Mode operation the average value of the VCC current drops down with the ratio of the burst duty cycle. In this case also the voltage drop at R12 is reduced and the VCC voltage level can stay above the UVLO limit. Additional a zener diode can be used to make sure that the voltage on VCC pin never exceeds the $V_{VCC_{\text{max}}}$ voltage of 22V.

Calculation of $R_{12}$:

$$R_{12} = \frac{(U_{C4_{\text{max}}} - V_{VCC_{\text{OVP}}})}{(I_{VCC_{\text{sup1}}} + I_{\text{Gate}})} \quad (\text{Eq} \ 2)$$

$U_{C4_{\text{max}}}$ = maximum voltage at capacitor C4 (has to be measured in the real application)

$V_{VCC_{\text{OVP}}}$ = Overvoltage detection limit

$I_{VCC_{\text{sup1}}}$ = IC supply current

$I_{\text{Gate}}$ = Mosfet gate drive current : $Q_g \times f_s$
Calculation of Burst Mode Operation boundaries

Operating point of entering Burst Mode:
Condition: \( V_{FB} < 1,32V \)

\[
P_{Burst\,min} = 0,5 * Lp * \left( \frac{(V_{FB \, c6} - V_{Max\,-\, Ramp})}{R_{Sense \, * \, A_V}} \right)^2 * f
\]  

(Eq 3)
Operating point of leaving Burst Mode:
Condition: \( V_{FB} > 4.8V \)

\[
P_{\text{burst max}} = 0.5 \cdot Lp \cdot (V_{CS2} \cdot \frac{1}{R_{\text{Sense}}})^2 \cdot f \quad \text{(Eq 4)}
\]

During Burst Mode operation the peak current is limited to 25% of maximal value. As this peak current is not compensated, the internal delay leads to a input voltage dependent overshoot. This leads to a higher transferred power at 230V mains compared to 85V mains voltage.

Calculation of sensevoltage – time ratio:

\[
\frac{dV_{\text{Sense}}}{dt} = \frac{V_{dc \ max}}{Lp} \cdot R_{\text{Sense}} \quad \text{(Eq 5)}
\]

Fig. 6 of the datasheet describes this dependency. For the accurate calculation of the maximal power in Burst Mode operation (Eq. 4) the \( V_{CS1} \) value has to be multiplied with a factor out of the diagram below using the dotted line.

Fig. 4: Peak Current Limitation
**Softstart**

During the Softstart Phase the Mosfet Drain Current is limited to the voltage at the Softstart Pin. If this voltage reaches $V_{SoftSC2}$ (4.00V typ.) the peak current limit is released to the value set by the voltage at Feedback Pin or limited to the value which is set with the sense resistor. If the Softstart is finished and no overload occurs the voltage is clamped to (4.4V typ.).

![Graph](image)

**Fig. 3: Softstart behaviour with nominal load**

(measured with a 80W, 24V application)

Ch1: Voltage at Softstart Pin  
Ch2: Voltage at Current Sense Pin  
Ch3: Voltage at Feedback Pin

**Fig. 5 Example for $C_{ss} = 100\text{nF}$**

The maximum Startup time can be calculated:

$$t_{ss\ max} = R_{Softs} \times C_{SS} \times 1.52$$  \hspace{1cm} (Eq 6)
**Blanking Window for Load Jump**

In case of Load Jumps the Controller provides a blanking window before activating the Overvoltage Protection and entering the Auto Restart Mode. This time is generated by charging up the Softstart capacitor from 4.4V to max. 5.35V. Within this timeframe the voltage at feedback pin can rise up above 4.8V, without switching off due to overload protection.

During this operation the transferred power is limited to the maximum peak current defined by the value of the sense resistor.

The time for the blanking window can be calculated:

\[ tbl = R_{\text{Softs}} \times C_{SS} \times 0.51 \]  

(Eq 7)

![Fig. 3: Load Jump Behaviour](image)

(measured with a 80W, 24V application)

Ch1: Voltage at VCC Pin
Ch2: Voltage at Softstart Pin
Ch3: Voltage at Feedback Pin
References:

[1] Infineon Technologies, Datasheet
   F3 ICE3DS01
   Off-Line SMPS Current Mode Controller with integrated 500V Startup Cell

[2] Infineon Technologies, Application Note
   AN-SMPS-ICE2AXXX-1
   CoolSET
   ICE2AXXX for Off-Line Switch Mode Power Supply (SMPS)
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Infineon goes for Business Excellence

“Business excellence means intelligent approaches and clearly defined processes, which are both constantly under review and ultimately lead to good operating results. Better operating results and business excellence mean less idleness and wastefulness for all of us, more professional success, more accurate information, a better overview and, thereby, less frustration and more satisfaction.”

Dr. Ulrich Schumacher