Applications Knowledge Base

Application Note KB-@@

Information: Designing buck converters with ***TinySwitch***
Devices: ***TinySwitch*** TNY253/254
Addresses: Minimum acceptable inductance values for buck converters and general guidelines
Keywords: TinySwitch, Minimum inductance, Buck converters, leading edge blanking

Introduction

As TinySwitch is competely self power it provides a very simple and compelling buck converter implementation. This is ideal for non-isolated power supplies for use in white goods such as refridgerators, household goods such as vaccum cleaner and many industrial control applications.

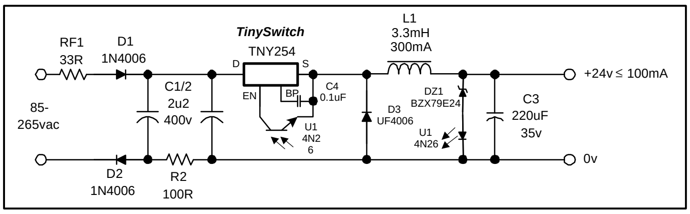

Figure 1 Typical non-isolated TinySwitch buck converter.

General Guidelines

I_{out} must be <50% of minimum device current limit. For **TNY253 Iout≤50mA** and for **TNY254 Iout≤100mA**.

TinySwitch operates an on-off control scheme, either ramping current in the inductor to current limit or not switching at all. This leaves the possibility of a cycle commensing when current is still flowing in the inductor ie having a very continuous drain current waveform. This can trigger current limit, causing a short cycle. By limting the output current to <50% of the minimum current limit it is guaranteed that the next cycle will be discontinuous. This guarantees that the rated power will always be delivered.

TNY253 - L_{min}=680uH
TNY254 – L_{min}=820uH
This is discussed in detail below. In summary to meet the 400mA maximum drain figure being exceeded during current limit delay a minimum inductor value must be used.

Minimum acceptable inductor value

The minimum inductor value is calculated based on the peak drain current not exceeding 400mA after maximum current limit delay with the highest input voltage. For the analysis done here the input voltage is assumed to be 350vdc (265vac).

TNY253

Below is a chart displaying a series of simulated TinySwitch drain current waveforms for different inductor values. At time=0, the internal MOSFET turns on and 350v is applied across the inductor. From V=Ldi/dt the current ramps linearly up from 0 (initial inductor current is 0). At some time, t_{Ilimit}, the current limit for the device is reached. After the current limit delay time (datasheet t_{ILD}) the MOSFET is turned off and the drain current falls to zero.

Figure 2 shows the worst case conditions for this, where both the device current limit and current limit delay are at the upper limits. As a result we see that there is an appreciable 'overshoot', the maximum drain current increasing beyond current limit, reaching 300mA (680uH inductor).
As the figure of 300mA is below the 400mA datasheet maximum this is not of concern but should be taken into account when designing the buck converter.

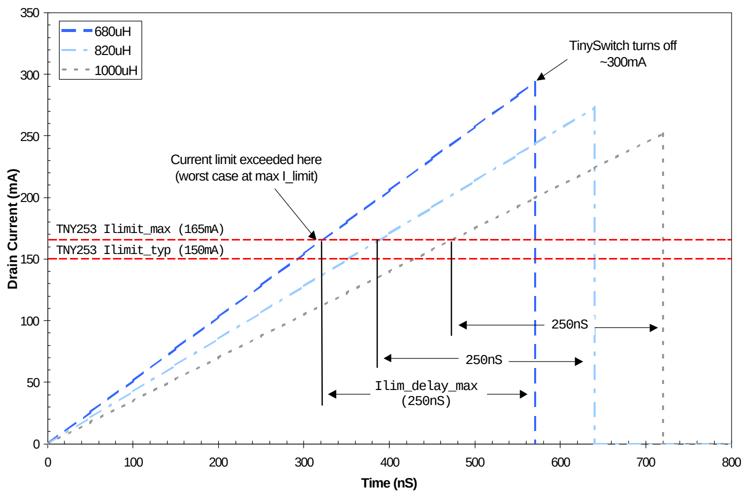

Figure 2 TNY253 drain current waveforms for 680uH, 820uH & 1000uH @ 350vdc.

Due to this effect smaller inductor values are not recommended for 230vac inputs as the 400mA maximum will be reached. Smaller values may be acceptable at lower input voltage. Verify using the formula below.

$$L \geq V_{\max} \times \frac{t_{ILD\_MAX}}{I_{drain\_\max} - I_{\lim it\_\max}}$$

$$L \geq V_{\max(DC)} \times \frac{250nS}{0.235}$$

Equation 1 - Minimum inductor value for TNY253

This does not take into account a continuous current waveform (such as during start-up) so the current through the drain must be verified to ensure that it is always <400mA at the highest input voltage.

Preliminary

TNY254

The same analysis was performed for the TNY254. The resulting chart is shown below as Figure 3.

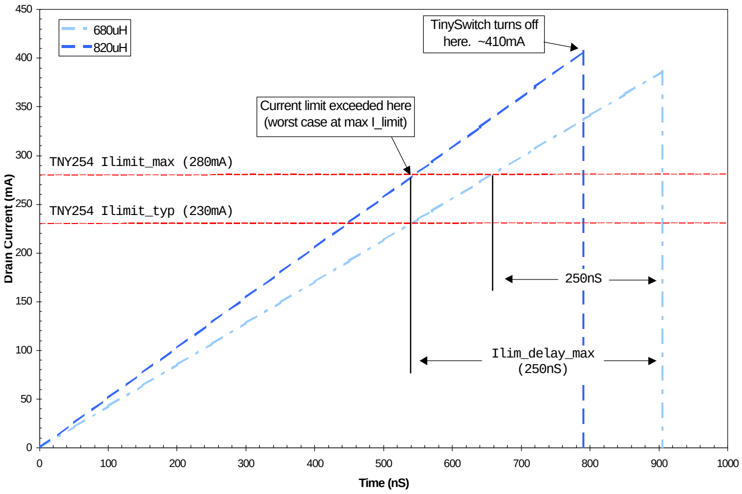

Figure 3 TNY254 drain current waveforms for 820uH & 1000uH @ 350vdc.

As the TNY254 has a higher current limit but the same current limit delay as the TNY253 we see that 400mA maximum drain current limit is exceeded when a 680uH inductor is used. Thus the minimum inductor value for the TNY254 is increased to 820uH.

At lower input voltage the equation below can be used to calculate the theoreticla minimum inductor value. However the 400mA must be respected and verified by measurement at the applications highest input voltage.

$$L \geq V_{\max} \times \frac{t_{ILD\_MAX}}{I_{drain\_\max} - I_{\lim it\_\max}}$$

$$L \geq V_{\max(DC)} \times \frac{250nS}{0.12}$$

Equation 2 - Minimum inductor value for TNY254

Leading Edge Blanking Considerations

One potential problem when implimenting a TinySwitch based buck converter is initial current limit. Below is the typical current limit envelope curve from the TinySwitch datasheet. Immediately after current limit the actual current limit can be a low as 65% of the final value.

Hence the slope of any drain current waveform should be such that after leading edge blanking the drain current is less than 65% of minimum current limit – i.e. after Tleb the drain current must be below 0.65 x Ilim_min.

Figure shows that immediately after minimum leading edge blanking the 680uH inductor ramp exceeds 65% of minimum current limit (indicated by red circle).

This would imply that the power supply would fail to operate correct with a TNY253 that had a current limit at the lower tolerance limit, whilst operaitng at maximum line voltage.

However even after the current limit is triggered the inductor current continues to rise. With a minimum current limit delay of 150nS the drain/inductor current ramps to above the typical TNY253 current limit (green line).

Essentially triggering current limit after Tleb_min doesn't prevent corrrect operation.

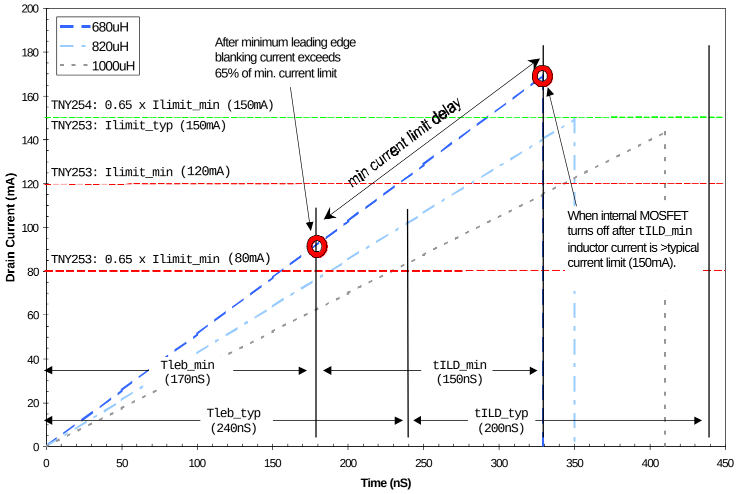

Figure 4 Drain current waveforms for 680, 820uH & 1000uH @ 350vdc.

With the TNY254 there is no problem. After Tleb all three current ramps are below the minimum TNY254 current limit (green line also 150mA).