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Implementing a Simple Brown-out Solution on the NCP101X Series

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APPLICATION NOTE

Introduction

Some AC−DC applications require a clean start−up sequence when the mains reaches a certain level to avoid stressing the power MOSFET at low−line, especially when the bulk capacitor starts to charge up. Also, at power−off, the power supply shall not go into hiccup as the bulk capacitor depletes and can no longer deliver the required energy. To provide such a behavior, the present application note describes a low−cost brown−out circuit successfully tested on the NCP101X switcher series.

The NCP101X series integrates a fixed−frequency current−mode controller and a 700 V MOSFET. Housed in a PDIP−7, PDIP−7 Gull Wing, or SOT−223 package, the NCP101X offers everything needed to build a rugged and low−cost power supply, including soft−start, frequency jittering, short−circuit protection, skip−cycle and a Dynamic Self−Supply (no need for an auxiliary winding). Unlike other monolithic solutions, the NCP101X is quiet by nature: during nominal load operation, the part switches at one of the available frequencies (65 − 100 − 130 kHz). When the current setpoint falls below a given value, e.g. the output power demand diminishes; the IC automatically enters the so−called skip−cycle mode and provides excellent efficiency at light loads. Because this occurs at typically 1/4 of the maximum peak value, no acoustic noise takes place. As a result, standby power is reduced to the minimum without acoustic noise generation. Skip cycle is implemented by monitoring the feedback voltage. As it drops below a certain level, a dedicated comparator blanks the switching events. If a circuit maintains the pin below the skip level, we have a mean to stop the circuit, e.g. for a brown−out implementation…

Brown−out

As explained in the introduction, some particular applications impose a minimum input voltage below which the power supply shall not work. To start the SMPS, a circuit constantly monitors the rectified mains voltage and pulls the feedback pin down to ground until the mains voltage reaches the desired value. When this happens, we need to introduce a certain amount of hysteresis to avoid going into a hiccup mode as the ripple on the bulk increases.

Figure 1 shows a possible implementation where no hysteresis is necessary.

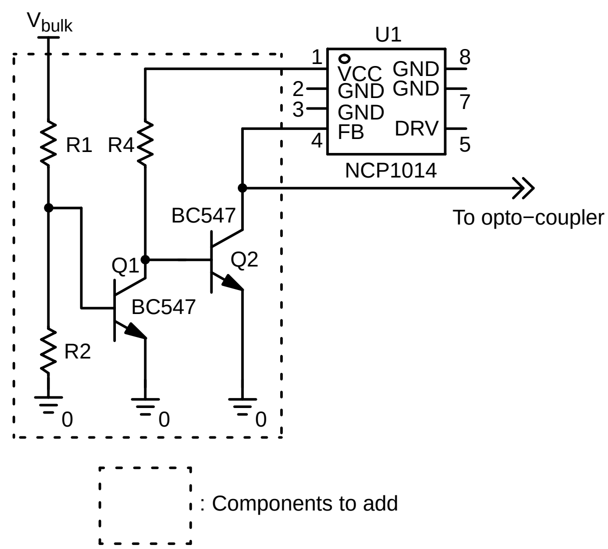

Figure 1. In This Application, There is No Need for Hysteresis

We set the startup V_{bulk} voltage by pulling the feedback pin low until enough voltage builds−up on the bulk capacitor. When V_{bulk} is too low, Q_1 is blocked and Q_2 base is pulled−up by R_4 to V_{CC} (≈ 8 V). Q_2 being saturated, the feedback pin goes directly to ground. As we explained, the product does not start thanks to the presence of the internal skip−cycle comparator. When V_{bulk} reaches the selected value (determined by R_1 and R_2), Q_1 saturates and Q_2 base goes to ground, naturally blocking the transistor. The feedback is now solely driven by the opto−coupler and the system can freely operate.

To implement this brown−out function, highlighted components are used, two standard NPN transistors and three resistors. The remaining components in the design are not modified. The design equations are as follows:

1. select the bridge current flowing in R_1 and R_2: 50 μA to avoid wasting power at high line.

2. calculate R_2 assuming a V_{be} around 650 mV:

$$R_2 = \frac{0.65}{50\ \mu} = 13\ k\Omega \quad \text{(eq. 1)}$$

3. If we want a startup around 100 Vdc, then the upper resistor is found to be:

$$R_1 = \frac{100 - 0.65}{50\ \mu} = 1.98\ M\Omega \quad \text{(eq. 2)}$$

4. R_4 is fixed to 10 kΩ, a choice limiting the Dynamic Self Supply (DSS) loading current to a reasonable value.

Adding Hysteresis to the Brown−out Detection, Auxiliary Winding Solution

Now, let us see how we can add some hysteresis via the usage of the auxiliary winding. Figure 2 portrays the idea:

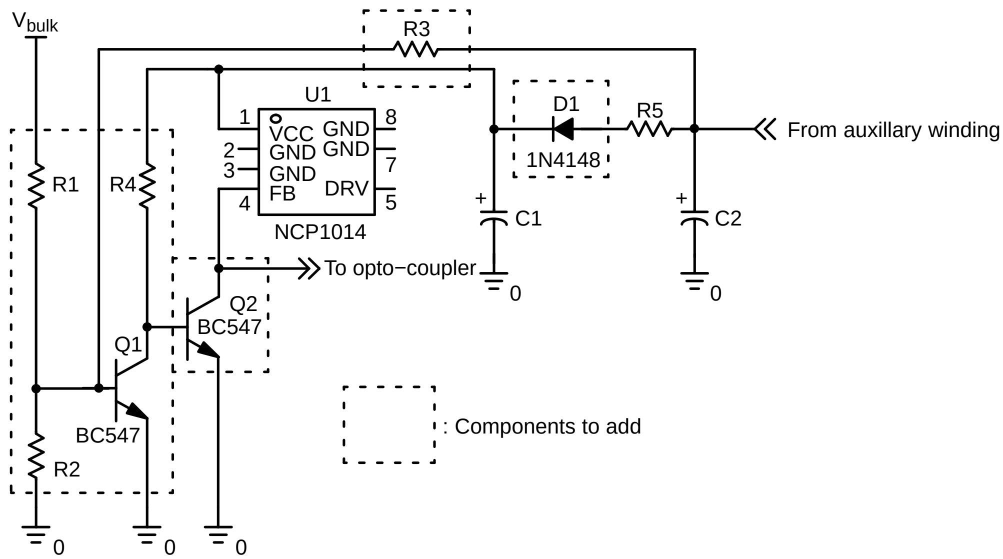

Figure 2. A Small Hysteresis is Added via R_3.

The main circuit actually does not differ compared to that of Figure 1. However, the addition of a small voltage offset changes the behavior at turn−off. During the startup phase, there is no auxiliary voltage. Hence, R_3 right terminal is pulled down to ground. Thanks to D_1 which isolates the device from the NCP1014 DSS level, there is no voltage. When the system starts to work, the auxiliary branch goes up and brings its level around 23 V (in our particular example). Via R_3, it slightly raises Q_1 V_{be} voltage, now forcing V_{bulk} to reduce to a further down level, in comparison with the startup level. To implement this brown−out function, Figure 2 shows the additional components. the highlighted components are used. The other components in the design are not modified.

The design equations now include the presence of R_3, coming in parallel with R_2 during the start−up sequence. However, we can neglect its contribution as its value is much higher than R_2 as we will see:

1. select the bridge current flowing in R_1 and R_2: 50 μA to avoid wasting power at high line.
2. calculate R_2 assuming a V_{be} around 650 mV:

$$R_2 = \frac{0.65}{50\ \mu} = 13\ k\Omega \quad \text{(eq. 3)}$$

3. If we want a startup around 100 Vdc, then the upper resistor is found to be:

$$R_1 = \frac{100 - 0.65}{50\ \mu} = 1.98\ M\Omega \quad \text{(eq. 4)}$$

4. Once the auxiliary voltage comes into play, the voltage over R_2 including R_3 is given by (applying superposition):

$$V_{be} = V_{bulk}\frac{R_2 \parallel R_3}{R_2 \parallel R_3 + R_1} + V_{aux}\frac{R_1 \parallel R_2}{R_1 \parallel R_2 + R_3},$$

solving for R_3 gives:

$$R_3 = \frac{R_1 R_2 (V_{aux} - V_{be})}{V_{be}(R_1 + R_2) - V_{bulk} R_2} \quad \text{(eq. 5)}$$

Keeping similar values as in the above example, if we want a cutoff voltage of 70 Vdc with a 23 V auxiliary level (in this particular example), then R_3 = 1.5 MΩ.

5. R_4 is fixed to 10 kΩ, a choice limiting the Dynamic Self Supply (DSS) loading current to a reasonable value

Adding Hysteresis to the Brown−out Detection, DSS Solution

When using the NCP101X series in a non−auxiliary supply solution, the controller receives its operating supply from the DSS, bringing V_{CC} between 7.5 and 8.5 V. Rather than connecting the hysteresis resistor to the auxiliary voltage, why not wiring it to the DSS supply. The arrangement is then slightly different as the DSS is already present at startup. The trick consists in shunting a resistor in series with the lower side element once the circuit has started: it artificially raises the level on the bottom transistor Q_1 base.

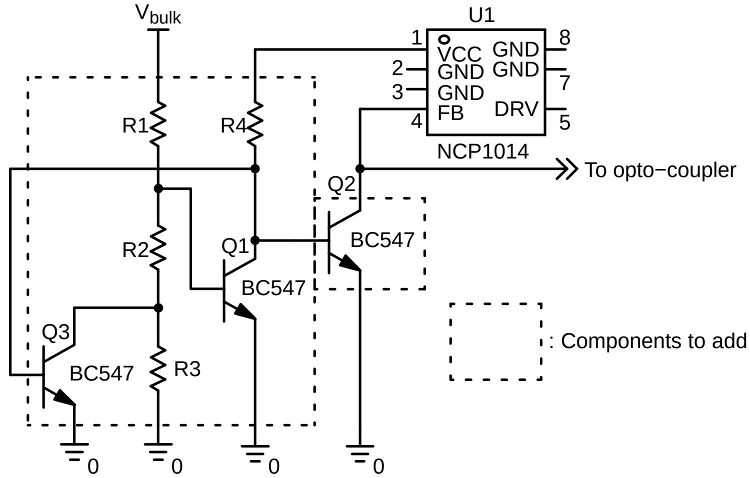

Figure 3. Altering the Bottom Resistor once the Circuit has Started Helps Creating the Necessary Hysteresis

Designs equations are not complicated, compared to the previous calculations. At power−up, Q_3 is biased by R_4 and R_3 goes off the picture (we neglect Q_3 $V_{ce,sat}$):

$$V_{be} = \frac{R_2}{R_2 + R_1} V_{bulk}$$

The method to evaluate R_2 and R_1 is similar to bullets 1 to 3 above.

When the circuits starts to operate, in other words Q_1 collector being low, Q_3 is blocked and R_3 appears in series with R_2. The above equation becomes:

$$V_{be} = \frac{R_2 + R_3}{R_2 + R_3 + R_1} V_{bulk} \qquad \text{(eq. 6)}$$

Solving this equation gives the series resistor value where V_{bulk} represents the turn−off value:

$$R_3 = \frac{V_{be}(R_1 + R_2) - V_{bulk}R_2}{V_{bulk} - V_{be}}$$

Again, if we stick to our 70 Vdc cutoff level, we have R_3 = 5.6 kΩ.

Conclusion

As we have shown here, various possibilities exist to implement brownout protection on NCP101X boards. Despite the natural V_{be} variations with temperature, the obtained results are good for low−cost adapters. For more precise trip points, designer should consider a more efficient solution built around the NCP1027 which features a real programmable brown−out protection.

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