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Compensating the Negative Voltage Spike on the NCP1250 OPP Pin

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APPLICATION NOTE

The NCP1250 features a multi-function pin in which the user can implement Over Power Protection (OPP) and Over Voltage Protection (OVP). If you add a Negative Temperature Coefficient (NTC) resistor in parallel with the OVP Zener diode, you have a means to protect the adapter against thermal runaway. The typical schematic appears in Figure 1 where a Zener diode featuring a parasitic capacitor is represented. When building and testing this circuit, we noticed on several boards that a negative spike appeared on the OPP pin. We observed that the spike was more pronounced on boards where the layout was poor. The Zener diode type or brand also played a role in the spike amplitude.

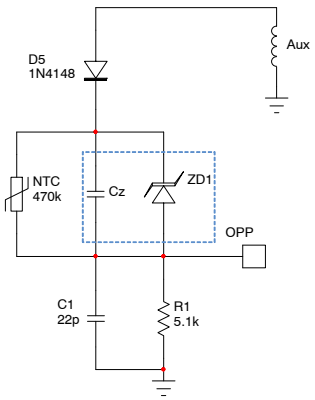

Figure 1. Typical Schematic Around OPP Pin

The OPP pin voltage was captured in Figure 2. As we can see, we measured a negative voltage spike of −450 mV when the plateau is around −200 mV. If this excess of 250 mV is not harmful for the controller, it can in certain conditions, especially when of stronger amplitude, disturb the controller operations. For this reason, it would be interesting to keep this spike down across the whole operating conditions.

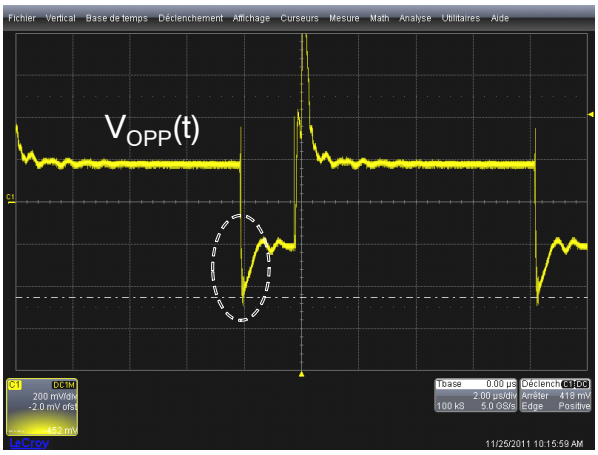

Figure 2. OPP Pin Voltage at High Line and Full Load (Default configuration)

Let's study the equivalent structure around this OPP pin. We have a divider voltage created by the NTC and the OPP pin pull-down resistor (R_1). In parallel with each element, there is a capacitor: either it is purposely placed (C_1) or it manifests itself as a parasitic contributor. This is the case for the Zener diode capacitor (C_z) that is placed in parallel with the NTC. The combination of these four components creates a filter that can induce this negative voltage spike. The equivalent structure is shown in Figure 3.

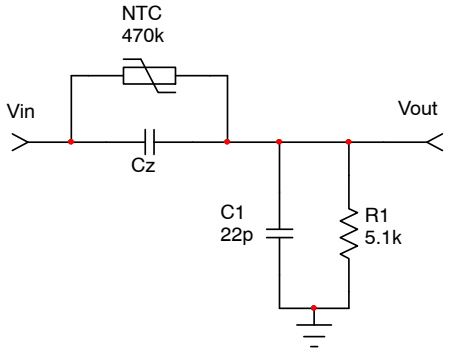

Figure 3. Equivalent Structure Around OPP Pin

This structure is actually similar to an oscilloscope probe – with a divide-by-10 attenuator -in which R_1/C_1 could be the oscilloscope input impedance and NTC/C_Z the oscilloscope probe. Let's derive the transfer function of this block where we call Z_1 R_1 in parallel with C_1 and Z_2 $R_{NTC} \parallel C_Z$.

$$Z_1 = \frac{R_1 \frac{1}{sC_1}}{R_1 + \frac{1}{sC_1}} = \frac{R_1}{1 + sR_1C_1} \qquad \text{(eq. 1)}$$

$$Z_2 = \frac{R_{NTC} \frac{1}{sC_z}}{R_{NTC} + \frac{1}{sC_z}} = \frac{R_{NTC}}{1 + sR_{NTC}C_z} \qquad \text{(eq. 2)}$$

The transfer function is:

$$T(s) = \frac{Z_1}{Z_1 + Z_2} = \frac{\frac{R_1}{1+sR_1C_1}}{\frac{R_1}{1+sR_1C_1} + \frac{R_{NTC}}{1+sR_{NTC}C_z}} \qquad \text{(eq. 3)}$$

By re-arranging:

$$T(s) = \frac{R_1}{R_1 + R_{NTC}} \cdot \frac{1 + sR_{NTC}C_z}{1 + s(R_1 \parallel R_{NTC})(C_1 + C_z)} = \qquad \text{(eq. 4)}$$

$$= T_0 \frac{1 + s/\omega_z}{1 + s/\omega_p}$$

Where we have:

$$T_0 = \frac{R_1}{R_1 + R_{NTC}} \qquad \text{(eq. 5)}$$

$$\omega_z = \frac{1}{R_{NTC}C_z} \qquad \text{(eq. 6)}$$

$$\omega_p = \frac{1}{(R_1 \parallel R_{NTC})(C_1 + C_2)} \qquad \text{(eq. 7)}$$

Our goal is to transmit the auxiliary information with attenuation or overshoot. To fulfill this goal, we will have to make the pole and zero coincident:

$$R_{NTC}C_z = (R_1 \parallel R_{NTC})(C_1 + C_z) \qquad \text{(eq. 8)}$$

Reworking the equation gives:

$$R_{NTC}C_z = R_1C_1 \qquad \text{(eq. 9)}$$

If the condition in Equation 9 is respected, we will have the Bode plot like shown in Figure 4. The attenuation is constant because the pole and zero are coincident.

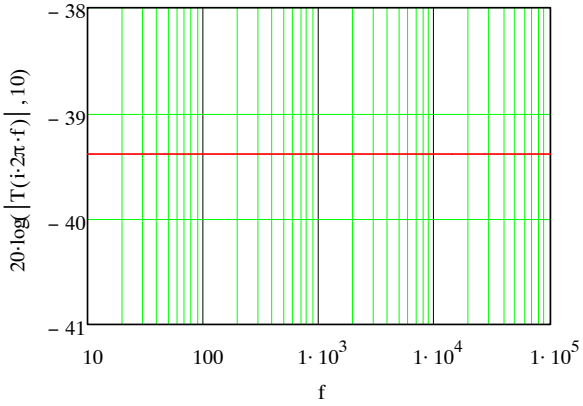

Figure 4. Bode Plot Where Pole and Zero are Coincident

The attenuation level is defined by both resistors R_1 and R_{NTC}. We can calculate T_0 from Equation 5:

$$T_0 = \frac{R_1}{R_1 + R_{NTC}} = \frac{5.1\ k}{5.1\ k + 470\ k} = 0.011 \qquad \text{(eq. 10)}$$

$$T_0 = 20\ \log(T_0) = -39.4\ dB \qquad \text{(eq. 11)}$$

Without knowing the Zener diode parasitic capacitance, we will have to observe the waveform at the OPP pin and adjust the capacitor from that pin to ground. Use an oscilloscope probe where the pig tail has been removed and connect the pins as close as possible to the controller pads. By increasing the OPP capacitor to the right value, you should see a signal as displayed in Figure 5: the negative plateau is flat and the undershoot is gone.

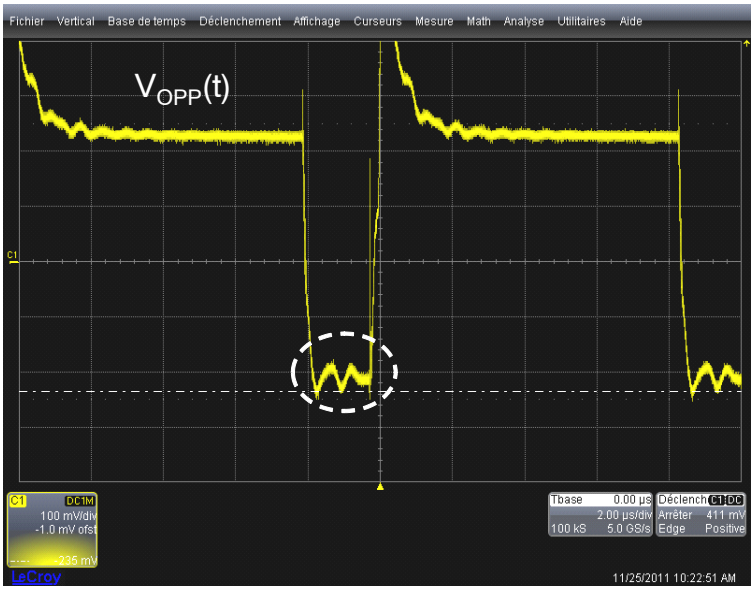

Figure 5. OPP Pin Voltage at High Line and Full Load (Filter effect compensated)

If you increase C_1 beyond a certain value, attenuation is likely to occur, bending the OPP signal. The over power protection information is distorted like shown in Figure 6.

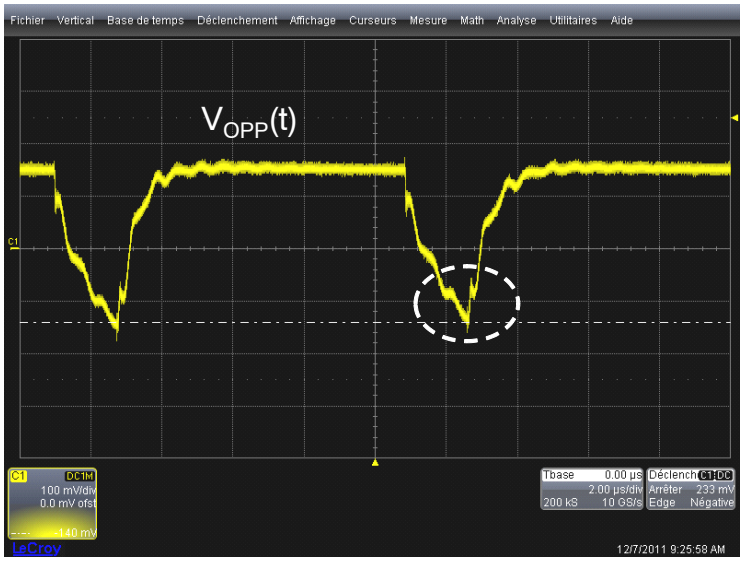

Figure 6. OPP Pin Voltage at High Line and Full Load (Filter effect over compensated)

The plateau level should normally be around 200 mV but as capacitor C_1 is too high, the negative swing is truncated and the OPP no longer works. This is a point that you will have to check.

The OPP Pull-down Resistor

The resistor R_{OPPL} you will connect from the OPP pin to ground together with the above capacitor in parallel have to be located very close to the controller. The same applies to the second resistor that routes the auxiliary winding signal (R_{OPPH}). Both components must be closely located to the controller. If this recommendation is not respected, the pin will pick up noise and the negatively swinging signal may grow stronger.

The OPP pin being a high-impedance pin, it is important to lower its impedance via R_{OPPL}. The lower the resistor, the best noise immunity you will obtain. Selecting a value for R_{OPPL} beyond 3 kΩ is not recommended. Not only the noise immunity can be marginal but the OPP current you inject may conflict with the internal ESD diode leakage at high temperature. For all of these reasons, selecting a pull-down resistor of 1−2 kΩ is a wise choice.

Conclusion

This application note offers a way to compensate the negative voltage spike on NCP1250 OPP pin. Due to the Zener parasitic capacitor within the OPP pin network, a filter is created and induced a severe undershoot, exactly as if you were to compensate x10 oscilloscope probe. By adjusting the pull-down capacitor to make the pole and zero coincident, the negative spike voltage is removed.

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