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Enhanced Output Short Circuit Protection on the NCL30051

Table 1. DEVICE DETAILS

Device	Application	Input Voltage	Output Power	Topology	Isolation
NCL30051	LED Driver	Various	Various	CrM PFC + Resonant Half Bridge	Yes

Functional Description

Overview

This design note describes how to incorporate an external circuit to provide dedicated output short circuit protection of the NCL30051. Referring to Figure 1, In the event that the output is accidentally shorted to ground, the leakage inductance of the resonant half bridge transformer limits the current through the half bridge MOSFETS. Therefore, the higher the leakage inductance, the higher the impedance of the resonant tank circuit resulting in lower peak current in the MOSFET switches when the output is shorted. Since this is transformer dependent, it can be highly desirable to add protection that is not dependent on the transformer design and manufacturing variation. The described circuit has been validated on the existing NCL30051LED Demo Board to illustrate actual performance.

Background

The NCL30051 implements LED current regulation by controlling the bulk voltage provided by the PFC converter. The resonant half bridge provides voltage transformation as well as primary to secondary isolation. A minimum operating LED voltage is imposed by the minimum PFC voltage. This level can be no lower than the peak of the applied ac input voltage.

If the LED voltage falls below this minimum operating voltage, the current in the LEDs and therefore the half bridge stage increases being limited only by the leakage inductance of the transformer.

A simple circuit consisting of a resistor and threshold detector could be used to monitor the half bridge current.

Once an abnormal event is validated as a fault, the half bridge switching can be suspended in a controlled fashion to stop the flow of output current.

This half bridge converter uses series-connected capacitors to maintain transformer core volt-second balance by introducing an offset voltage at the midpoint as needed. During normal operation, there is also a small ac component at the half bridge frequency present on the midpoint between these “balancing” capacitors.

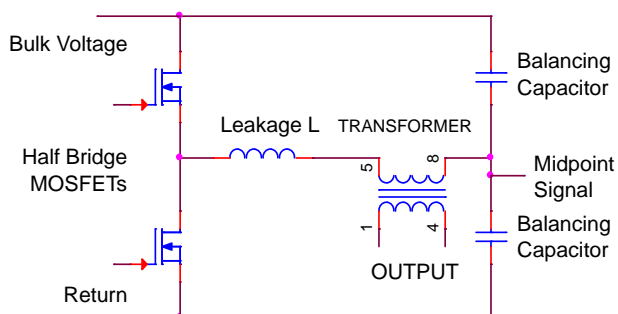


Figure 1. Configuration

In the event of an overload like an output short circuit, the ac voltage at the midpoint between these balancing capacitor increases significantly. Instead of a current sense resistor, it is possible to monitor the ac signal on the capacitor midpoint to detect a shorted output. This method can provide overload sensing with few components and less power loss. This design note describes how to use this approach to implement this on the NCL30051.

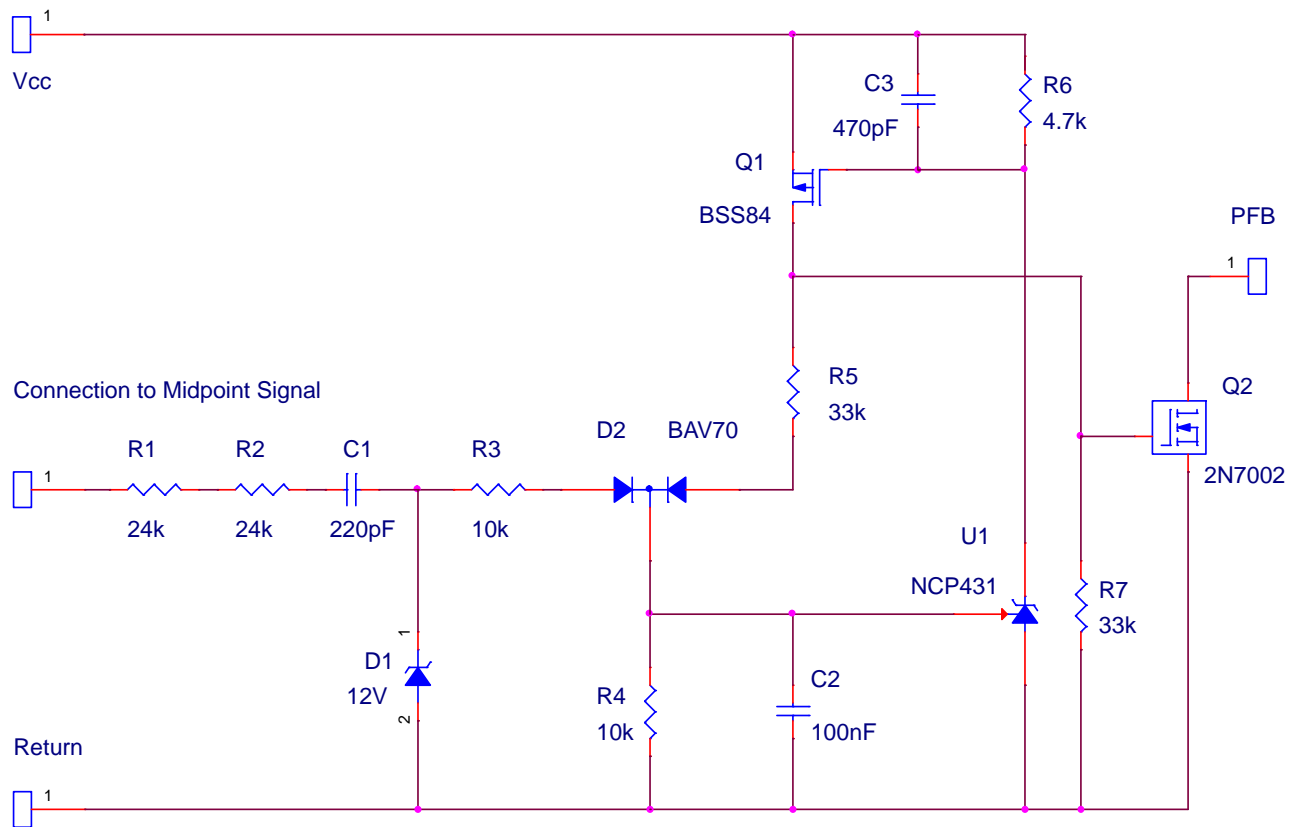


Figure 2. “Short Detector” Circuit Schematic

Circuit Description

The dc offset present at the midpoint of the balancing capacitors should not be considered when determining the presence of an overload. A simple ac coupled filter removes the offset while zener diode D1 limits the peak amplitude and resets the C1 coupling capacitor. Series connected resistors R1 and R2 limit the peak charging current and should be rated to withstand maximum bulk voltage of the half bridge. See the schematic in Figure 2.

The signal across zener diode D1 is coupled to a resistor-capacitor filter R4–C2 via resistor R3 and a diode. This provides a stable time constant which filters out startup and short overload transients.

The smoothing filter is monitored by U1, an NCP431 regulator operating as a simple comparator. This device was selected due to its low quiescent current compared to the TL431. When the voltage at the input of the regulator reaches the 2.5 V threshold, the regulator turns on which biases Q1 on pulling the drain to approximately Vcc. The output of Q1 is fed back to the input of U1 through D2 to latch the overload event.

Resistors R4 and R5 establish a threshold for the latching function. When Vcc falls below the level necessary to maintain 2.5 V on the reference pin, U1 shuts off which in turn allows Q1 to shut off. C3 is a noise filter and R6 provides bias current to U1 which must be maintained over the entire Vcc range.

As previously described, the drain of Q1 is pulled to approximately Vcc level when a short circuit condition is detected. This voltage is applied to the gate of Q2 turning the device on. The drain of Q2 is connected to PFB input (pin 5) on the NCL30051. When this pin is pulled below 175 mV, the controller shuts down suspending gate drive to the PFC MOSFET. The half bridge converter operation is also terminated at the end of the active half cycle.

At this point, the Vcc voltage will decay as the bias is no longer supported by PFC switching. As Vcc falls, the latching function described above releases. Vcc continues to fall to the minimum operating voltage at which point the startup bias regulator in the NCL30051 turns on and begins charging the Vcc capacitor.

When Vcc rises to the startup threshold, the NCL30051 controller resumes normal operation. The delay of discharging and charging the Vcc provides a low duty factor minimizing stress on the power components. If the short circuit condition is still present, the detection circuit will shut off the converter again and initiate the delay provided by Vcc cycle time.

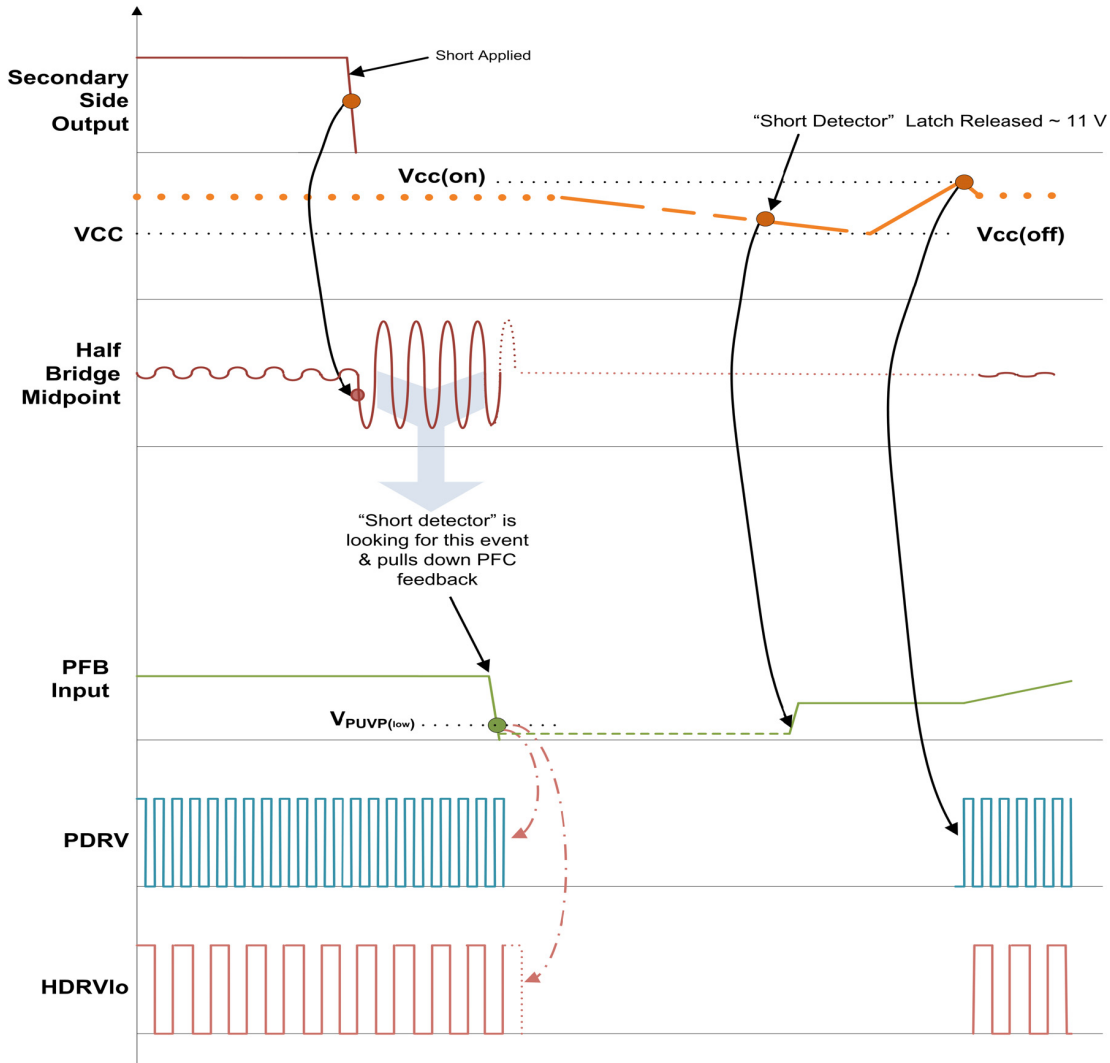
During a short circuit event, the LED current sense resistor is stressed to a high level by the surge. While the duration is short, the peak dissipation could damage the resistor with repeated short circuit application. Adding a Schottky diode across the sense resistor provides a path to bypass excessive current which reduces stress on the resistor. Under normal operation, this diode has no effect on

the circuit since the voltage drop across the sense resistor is below the forward voltage of the diode. The MBRA340 was selected for this application providing a compact solution.

Figure 3 is a timing diagram detailing the operation. The output voltage falls when a short circuit is applied. The ac voltage at the midpoint of the balancing capacitors increases as a result of increased output current. When the detection circuit activates, the PFB input on NCL30051 is pulled low and the PFC MOSFET gate drive signal is terminated. When the half bridge MOSFET driver completes a cycle, half bridge switching is suspended.

With no PFC switching, the Vcc voltage decays. As it crosses ~11 V, the latching function of the short detector is released. Vcc continues to decay until the startup bias circuit of the NCL30051 starts supplying current to Vcc and voltage will rise.

When the Vcc(on) threshold is reached, the converter restarts switching activity. If the short circuit condition is no longer present, normal circuit operation resumes. If the short circuit is still in place, the short detector will once again terminate switching and the cycle repeats.



Notes:

- 1) PDRV and HDRVlo switching frequencies are not related
- 2) PDRV is not operating at fixed frequency

Figure 3. Function Timing Diagram of Short Detector Operation with NCL30051

Figure 4 shows a response of the circuit to a shorted output condition. Trace 2 (blue) shows the application of a short to the LED output at the rising edge. Trace 1 (yellow) shows the PFB (pin 5) of the NCL30051 transitioning low which in this case is used to initiate a shutdown. Trace 3 (purple) is the PFC gate drive. The present cycle is terminated as soon as PFB level falls below the PFC under-voltage protection (UVP) level. Trace 4 (green) shows the gate drive of the lower half bridge FET. When the present half bridge cycle is complete, all switching is terminated.

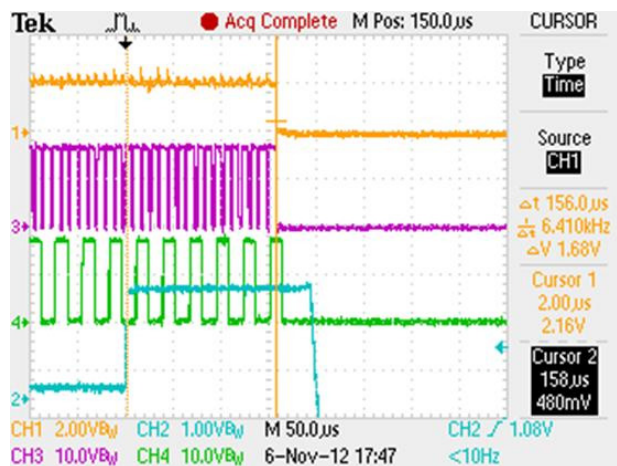



Figure 4. Measurement of Short Circuit Protection Circuit using NCL30051 Evaluation Board

Conclusion

Enhanced short circuit protection can be implemented with the circuit shown above. Enhanced short circuit operation is achieved by detecting an overload condition and shutting down the controller for a short time.

References

- [1] Please refer to the [NCL30051/D](#) data sheet for additional information on this controller.
- [2] Schematic and other information on the NCL30051LED evaluation board can be found at the [ON Semiconductor website](#).

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