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NCL30088 and NCL30085 Safety Test Considerations

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APPLICATION NOTE

Introduction

NCL30088 and NCL30085 are controllers targeting isolated and non−isolated constant current LED drivers. These highly integrated devices are optimized for an efficient and accurate light control with a minimum number of external components. Details on their operation can be found at www.onsemi.com. These devices also tend to ease the manufacturing and compliance with safety requirements. Elements of a LED driver can be accidentally shorted, badly soldered or damaged as a result of manufacturing or handling incidents, excessive operating stress or other troubles. In particular, adjacent pins of controllers can be shorted together or a pin can be grounded or badly connected. It is common to expect that such open/short situations do not cause fire, smoke nor loud noise.

Testing Conditions

Safety tests have been performed in an open−frame, wide−mains, 10 W, 500 mA LED driver at 25°C ambient temperature. Figure 1 provides its application schematic. The experiments have been made with **NCL30088B** samples (auto−recovery protection mode and 250 mV reference voltage).

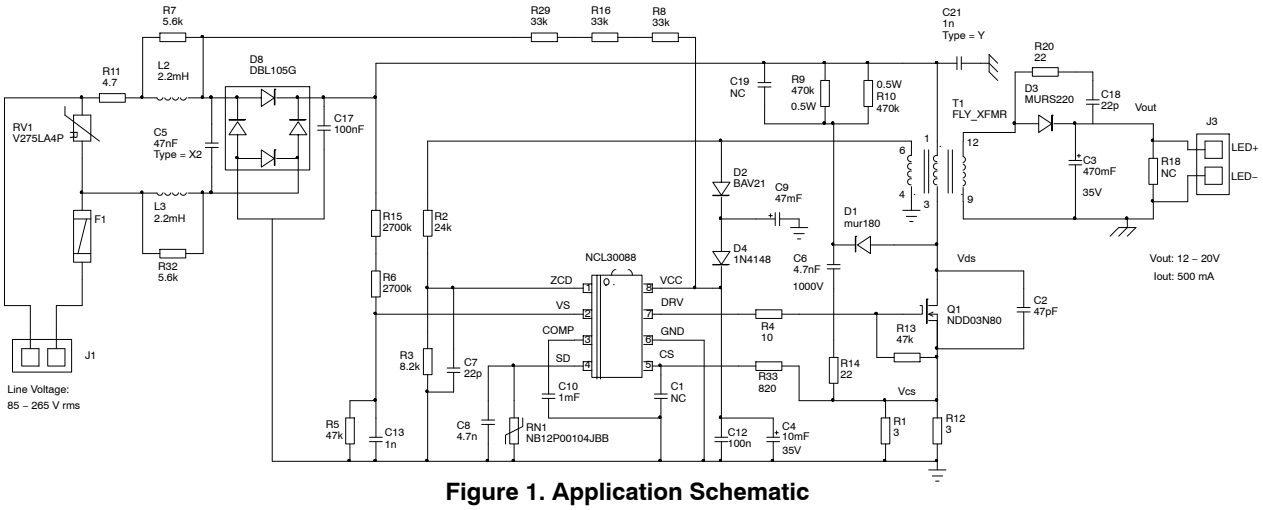

Figure 1. Application Schematic

SHORT faults were made by means of a manual switch so that SHORT conditions could be applied before and during operation. Pin floating conditions were created by inserting a socket between the board and the socket the circuit was soldered to. The appropriate pin of the intermediate socket was removed to test the floating fault under interest. The manual switch gave the possibility to reconnect the NCL30088 pin. Tests were made at 25°C ambient temperature.

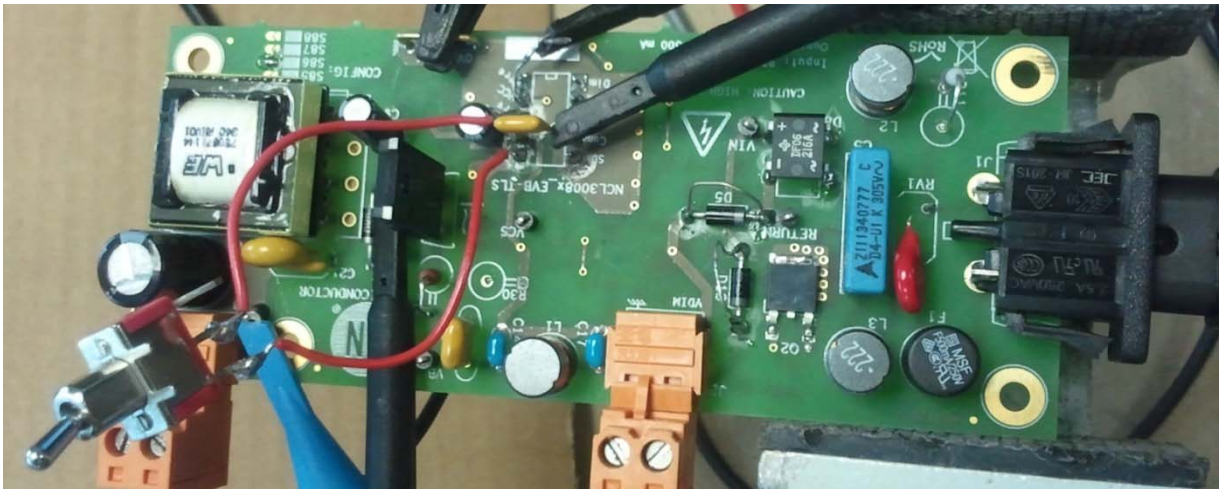

Figure 2. Shorts are Made by Means of a Manual Switch

This report is not intended to guarantee that the part can pass all safety tests in all boards and conditions since the performance can vary with respect to the application and test conditions. The purpose of this application note is to illustrate the typical behavior of the part under particular fault situations using a particular NCL30088 evaluation board, highlighting the protection functions that help pass the safety tests. It remains, nonetheless, the responsibility of the NCL30088 user to check that the system he builds using the NCL30088, properly meets the safety requirements it must be compliant with.

The following table summarizes the results.

Green "OK" labels are for tests which appeared to be safely managed by the circuit. Typically, the circuit stops operating and recovers normal operation when the fault condition is removed.

Orange "OK" labels are for tests which did not lead to an unsafe situation but caused a degraded operation, a loss of functionality and/or board/circuit damages.

No red "NOK" was observed. They would have been relevant to tests leading to unsafe situations like the continuous heating of the LED driver.

Recall. Below results were obtained with the application under test and discussed tests may lead to different conclusions in another application.

RESULTS SUMMARY

	Fault Applied Before Start−up	Fault Applied in Operation	Comments
ADJACENT PINS SHORT TESTS			
ZCD and V_S	**OK**	**OK**	The low−impedance external components applied to the ZCD pin reduce the V_S pin voltage below the level necessary to enter operation (1 V typically). Hence, in our application, the circuit cannot enter operation when the two pins are shortened. If the two pins happen to be shortened while the LED driver is operating, the power supply stops operating either because a brown−out fault is detect (low line) or simply because the ZCD pin is hold above the ZCD lower threshold (high line). In both cases, the circuit recovers normal operation when the short is removed.
V_S and V_{COMP}	**OK**	**OK**	If the short is made before the LED driver is plugged in, there is no operation if the line voltage is below 125 V rms (because V_S pin cannot exceed the 1−V threshold). A high line, the circuit enters operation but the output current is affected as it is when the short is made in operation. If the short is made while the LED driver operates, the COMP voltage stabilizes at around 1.9 V leading the output current to be an increasing function of the line magnitude. At the highest line, the output current was 5% above target. Note that the brown−out detection function is lost in this case. The LED driver recovers operation when the short is removed.

RESULTS SUMMARY

	Fault Applied Before Start−up	Fault Applied in Operation	Comments
ADJACENT PINS SHORT TESTS			
V_{COMP} and V_{SD}	OK	OK	Al low line, the COMP pin voltage tends to be high and the circuit stops operation as the short leads the SD pin OVP to trip. At a high enough line (leading V_{COMP} to be below 2.5 V), the voltage on the SD and COMP pins stabilize at the 1.3 V clamp level making the output current be an increasing function of the line magnitude. @ 260 V rms, the output is still below the target and is 5% above target at 280 V rms. The system cannot enter operation if the fault is made before the LED driver is plugged in. The LED driver recovers operation when the short is removed.
V_{SD} and V_{CS}	OK	OK	The CS pin low impedance prevents the SD pin voltage from rising and hence, the circuit detects an OTP condition. The LED driver recovers operation when the short is removed.
V_{CS} and GND	OK	OK	If the short is made before the LED driver is plugged in, the circuit detects the fault condition and does not enter operation. If the short is made while the LED driver is operating, the circuit detects the fault and stops operation. Note that a 36−μs DRV pulse will take place just before the fault is detected. The application and (in particular the MOSFET and the current sense resistor) must be able to sustain the probable transformer saturation occurring during this pulse. The LED driver recovers operation when the short is removed.
GND and DRV	OK	OK	The LED driver stops operation. The LED driver is hence safe. The controller itself could survive several on/off sequences of the manual switch without apparent degradation at low and high line. Note that however, the NCL30088 driver stage is highly stressed during this test and may be damaged in some cases.
DRV and V_{CC}	OK	OK	The LED driver can sustain the fault at low line but is damaged at high line. At low line, the V_{CC} capacitor can be discharged safely without board damage (several on/off of the manual switch could be made @ 90 V rms). At high line, the long time to discharge the V_{CC} capacitor (note that there is a split V_{CC} configuration in our board) leads to an excessive MOSFET stress.
SHORT TO VCC			
V_{CC} and ZCD	OK	OK	If the short is made before the LED driver is plugged in, the internal impedance of the pin under test or the impedance of the external components applied to the pin under test, prevents V_{CC} from charging up. Hence, the system cannot enter operation until the short is removed. If the short is made while the LED driver is operating, the pin under test is damaged and becomes low impedance. As a result the V_{CC} capacitor is discharged and the circuit stops operating as long as the short is maintained (V_{CC} cannot charged up). When the short is removed, the circuit behaves the same as when the tested pin is grounded (see below).
V_{CC} and V_S	OK	OK	
V_{CC} and V_{COMP}	OK	OK	
V_{CC} and V_{SD}	OK	OK	
V_{CC} and V_{CS}	OK	OK	
V_{CC} and DRV	OK	OK	The LED driver can sustain the fault at low line but is damaged at high line. At low line, the V_{CC} capacitor can be discharged safely without board damage (several on/off of the manual switch could be made @ 90 V rms). At high line, the long time to discharge the V_{CC} capacitor (note that there is a split V_{CC} configuration in our board) leads to an excessive MOSFET stress.
V_{CC} and GND	OK	OK	The LED driver stops operating as soon and as long as the short is applied (no V_{CC} voltage). The LED driver recovers normal operation when the short is removed.
SHORT TO GND			
ZCD pin and GND	OK	OK	The AUX_SCP protection makes the circuit enter a safe, low duty−ratio burst mode (<2.5%). Valley detection is lost during the active part of the burst. The circuit recovers operation as soon as the short is removed.
V_S and GND	OK	OK	The circuit detects a brown−out fault. No excessive line current is noted during the brown−out blanking time. The circuit recovers normal operation when the short is removed.

RESULTS SUMMARY

	Fault Applied Before Start−up	Fault Applied in Operation	Comments
SHORT TO GND			
V_{COMP} and GND	OK	OK	The circuit continues operating but the output current capability is reduced. The circuit only provides 10 mA @ 90 V rms and 220 mA @ 265 V rms. Normal operation is recovered when the short is removed.
SD and GND	OK	OK	The OTP protects the application in this case. The circuit recovers normal operation when the short is removed.
V_{CS} and GND	OK	OK	If the short is made before the LED driver is plugged in, the circuit detects the fault condition and does not enter operation. If the short is made while the LED driver is operating, the circuit detects the fault and stops operation. Note that a 36−μs DRV pulse will take place just before the fault is detected. The application and (in particular the MOSFET and the current sense resistor) must be able to sustain the probable transformer saturation occurring during this pulse. The LED driver recovers operation when the short is removed.
DRV and GND	OK	OK	The LED driver stops operation. The LED driver is hence safe. The controller itself could survive several on/off sequences of the manual switch without apparent degradation at low and high line. Note that however, the NCL30088 driver stage is highly stressed during this test and may be damaged in some cases.
V_{CC} and GND	OK	OK	The LED driver stops operating as soon and as long as the short is applied (no V_{CC} voltage). The LED driver recovers normal operation when the short is removed.
FLOATING PIN			
ZCD floating	OK	OK	The pin is naturally pulled down by a 200 kΩ internal resistor. The circuit behaves like if the pin was grounded. The circuit recovers normal operation as soon as the pin is reconnected.
V_S floating	OK	OK	The pin is naturally pulled down by a 250 nA internal resistor. The circuit behaves like if the pin was grounded. The circuit recovers normal operation as soon as the pin is reconnected.
COMP floating	OK	OK	Operation is instable. At low line, the output current is in average below the target. At high line, the output current still instable tends to be above the target. It is important to check that the OVP threshold is well adjusted so that the LED string is not overstressed. The circuit recovers normal operation as soon as the pin is reconnected.
SD floating	OK	OK	Normal operation but the SD pin OVP and OTP protections are lost.
CS floating	OK	OK	A 1 μA current source pulls−up the CS pin and stops operation. The circuit recovers normal operation as soon as the pin is reconnected.
GND floating	OK	OK	The fault is detected and the circuit stops operation in this case. Normal operation is recovered when the GND is connected.
DRV floating	OK	OK	The LED driver is off since an external resistor maintains the MOSFET in low state (R_{13} 47 kΩ resistor of Figure 1).
V_{CC} floating	OK	OK	The NCL30088 being not fed, the LED driver remains off. However, beware of two things: • The V_{CC} capacitor is traditionally charged by means of a resistor placed between the input voltage rail and the V_{CC} pin. If there is no V_{CC} consumption, the V_{CC} capacitor voltage can reach the input voltage level. If the circuit V_{CC} pin is not connected and if no Zener diode is used for SD pin OVP or another component able to contain its rise, the voltage across the V_{CC} capacitor can get very high • Do not reconnect abruptly the V_{CC} pin. The excessive V_{CC} capacitor voltage (see above bullet) and/or the high dV/dt can damage the part.

As seen throughout the testing, simulated faults resulted in predicable safety responses and the enhanced safety features built in to the NCL30088 in the majority of causes resulted in events that were recoverable when the fault condition was removed. Note that as aforementioned, these tests have been made with NCL30088B samples. However, this report can help predict the expected behavior of the other NCL30088 versions (A, C, D) and also that of the NCL30085 under the same conditions by indicating the protection features in play. Note however, that some of the faults would latch off the latching−off versions (NCL30088A, NCL30088C and NCL30085A), causing operation recovery to be impossible until the LED driver is unplugged for the time necessary to reset the controller. For instance, if the NCL30088A SD pin is grounded, the OTP protection will trip and maintain the circuit off until both the fault is cleared AND the V_{CC} voltage is discharged below the $V_{CC(reset)}$ level (5 V typically).

Please further note that all NCL30088 and NCL30085 versions embed specific functions which protect the LED driver if:

- The LED string is shorted
- The LED string is open
- The output diode is shorted
- A winding is shorted and/or the inductor saturates
- The temperature is excessive.

Detailed information are available in the respective data sheet and application notes which can be found at:

- http://www.onsemi.com/PowerSolutions/product.do?id=NCL30088 for NCL30088
- http://www.onsemi.com/PowerSolutions/product.do?id=NCL30085 for NCL30085.

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