Repetitive Clamped Inductive Energy Capability
(for the MC10XS3535)

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1 Introduction

This document describes the functioning of the 10XS3535 smart power switch when switching inductive loads with no freewheeling diode. Also known as Clamp Inductive Switching (CIS), in this case.

The 10XS3535 is one in a family of devices designed for low-voltage automotive lighting applications. Its five low RDS(ON) MOSFETs (triple 10mΩ and dual 35mΩ) can control five separate 55W / 28W bulbs, and/or Xenon modules, and/or LEDs.

Programming, control and diagnostics are accomplished using a 16-bit SPI interface. Its output, with selectable slew-rate, improves electromagnetic compatibility (EMC) behavior. Additionally, each output is controlled through SPI for pulse-width modulation (PWM). The 10XS3535 is programable via the Serial Peripheral Interface (SPI), the fault current trip levels, and duration of acceptable lamp inrush. The device has Fail-safe mode to provide safe functionality of the outputs in case of MCU damaged.

For feature information, refer to the MC10XS3535 data sheet.

Contents

2 Negative Output Clamp Description

At each ON to OFF transition, the demagnetization of inductive load is done through the N-Channel MOSFET as described in **Figure 1**:

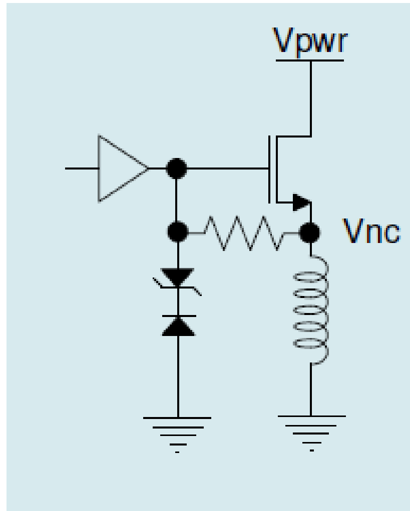

Figure 1. Simplified block Diagram

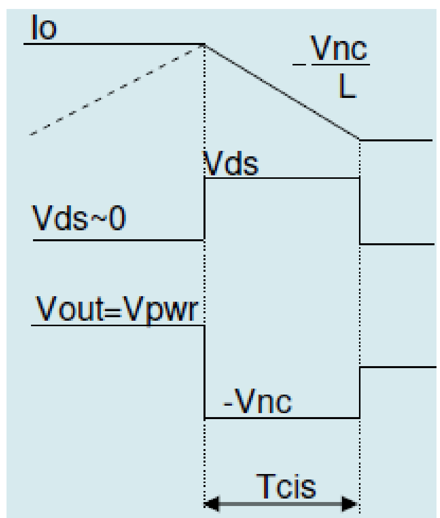

Figure 2. Output Switching Waveforms

The steady-state output voltage is clamped at -Vnc (-18V typ.) and is not dependant on temperature and current. In the case of Tcis (=Io x L / Vnc) > 1msec, the waveforms can be simplified with a rectangle as shown in **Figure 2**. The energy dissipated in the N-Channel MOSFET is:

Formula [1]: $E = \frac{1}{2} \times L \times Io^2 \times (1 + Vpwr / Vnc)$

3 Mono-Pulse CIS

3.1 Mono-pulse CIS test to fail

The CIS device capability depends on electrical parameters mentioned in **Formula [1]**, but the initial junction temperature (T_J) is a key contributor. In **Figure 3**, a decreasing application ambient temperature will gain more margin of device CIS energy capability.

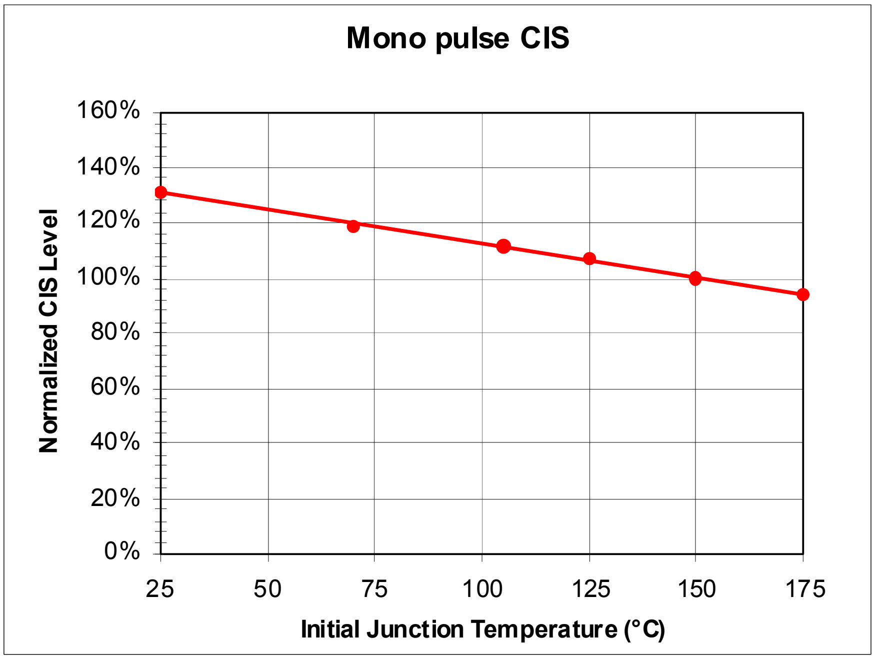

Figure 3. CIS Level Over Junction Temperature

Table 1 presents an example of an experimental destructive CIS level obtained for VPWR=14V and T_J=125°C (10 fresh-out samples were used per test - part soldered on 4 layers PCB with Rthja=18°/W).

Table 1. Maximum CIS Level for 10mΩ Channel

Inductive load value	Peak current	Energy dissipated in the N-channel MOSFET
300µH	35.7A	497mJ during 0.6µ sec
16mH	6.23A	634mJ during 5.5msec

3.2 Mono-pulse CIS level tested in production

Freescale uses the following procedure to guarantee the CIS level during a vehicles life-time (15 years):

- The 10XS3535 parts are tested at 200mJ at T_J=125°C in production (2 times higher in regards to the specified level).
- The CIS energy capabilities are checked at 110mJ at T_J=125°C at the end of the accelerated ageing tests defined by AECQ100 Standard.

Figure 4 describes the test configuration used in production. A current source pulls the source of the MOSFET to a value lower than GND. When applying 38V between the source and drain, the internal circuitry of the control die will clamp the device to around -18V and the gate/source voltage will allow the MOS to turn On the driving current. The time duration will be set to match 200mJ (or 110mJ) energy dissipation (T = 200/((VCL+VPWR)*IOUT)) = pulse duration in ms. The energy pulse is applied at each output separately.

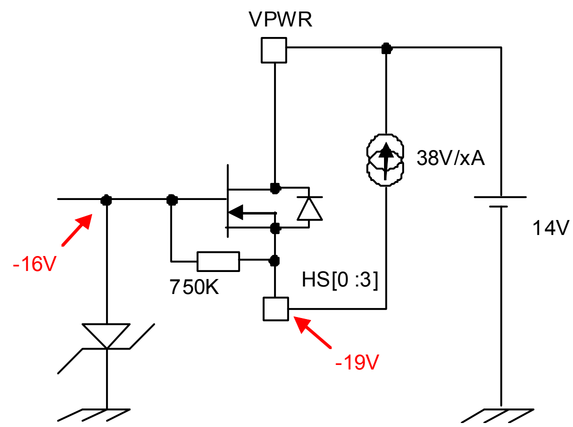

Figure 4. Production Test Configuration

4 Repetitive Output Switching

In the case of repetitive N-Channel MOSFET switching, the failure process is no longer operative and the fatigue-induced ageing mainly affects the active region of the N-Channel MOSFET. Usually the top metal and Al wire bonds.

4.1 Tests to Pass

Table 2 summarizes the repetitive switching “tests-to-pass” which were done for the 10mΩ channel (10 fresh-out samples per test were tested - part soldered on 4 layers PCB with Rthja=18°/W).

Table 2. Repetitive Switching Tests for 10mΩ Channel

Test Name	Condition	Number of cycles without failure
1- Operating Life Time T_J range: -40°C to +85°C	100W lamp inrush 42A DC during 5msec	2.5Mio
2- Overload @ T_J=70°C initial	60A DC / 20msec 30A DC / 150msec	250k 250k
3- Over-current Shutdown @ T_J=70°C initial	92.8A peak / 250µsec	250k
4- Hard short-circuit @ T_J=70°C initial	40A peak / 150µsec	500k 500k

4.2 CIS Tests to Fail

Some “tests-to-fail” were completed for repetitive CIS condition in order to determine the prohibited area for 15mΩ channel with 16mH inductive load at T_J=125°C initial. The off-state duration time was defined to guarantee that junction temperature came back to initial value before the next output switching. Figure 5 depicts the safe area based on experimental trials using a 15mΩ channel (fresh-out samples soldered on 4 layered PCB with Rthja=18°/W).

Note: the energy dissipated in the N-Channel MOSFET is 430mJ during 4.7msec.

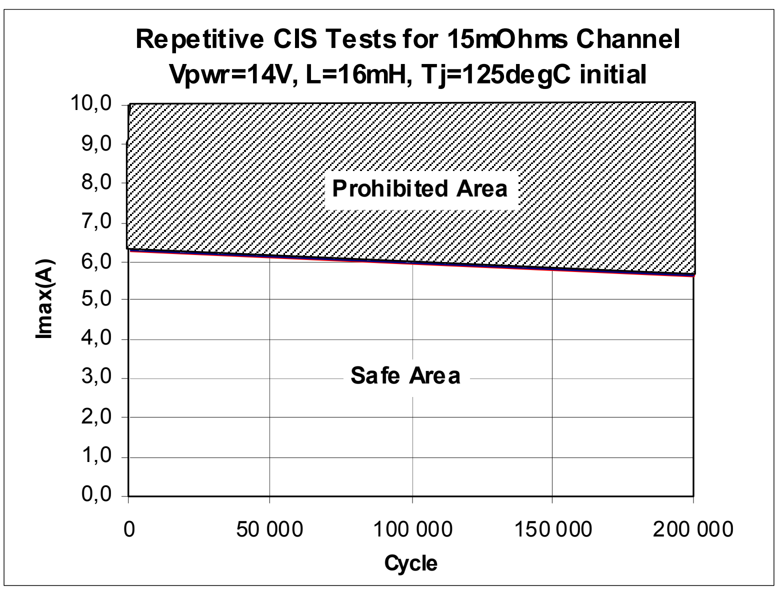

Figure 5. Safe Area for 15mΩ Channel Repetitive CIS Operation

5 References

MC10XS3535 Data Sheet - Smart Front Corner Light Switch (Triple 10mΩ and Dual 35mΩ)

6 Revision History

Revision	Date	Description of Changes
1.0		• Initial Release
2.0		• Corrected typographical error on footers of pages 2 through 7 - no technical changes.

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