AND8370/D

Load Limits for Octal High Side Drivers

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APPLICATION NOTE

Introduction

AMIS−39100 and AMIS−39101 are general purpose ICs with eight integrated high side drivers. The device is designed to control virtually any type of loads, such as transistor gates, relays, LEDs etc., either in an automotive 12 V environment (AMIS−39100) or in industrial 24 V environment (AMIS−39101).

The loads which can be controlled have to fulfill some limitations fostered mainly by thermal and reliability aspects of the integrated circuit. The purpose of the present application note is to explain these limitations and to show on examples, how evaluation of the driver loading can be done.

Load Limitations

The current which can be driven by AMIS−39100/39101 is limited by the following aspects explained in the below paragraphs:

- Short−circuit protection in the drivers
- Reliability of bonding and metallization
- Steady power dissipation due to the non−zero on−resistance of the drivers
- Thermal peaking during flyback
- Temporary increase of the junction temperature during flyback

Short−Circuit Protection

Each high side driver in AMIS−39100/39101 is featured with a short−circuit protection limiting the driven current in case an output is shorted to ground. This current limit is guaranteed to be above **650 mA** for each driver separately. As a consequence, no load can be foreseen which needs more than 650 mA steady current.

This limitation applies to all types of loads.

Reliability of Bonding and Metallization

Current in the outputs is also limited by the reliability of the metal tracks on the silicon and of the bonding wires. These limitations are expressed by the following datasheet parameters:

C. RESISTIVE LOAD AND $T_{AMBIANT}$ UP TO 85°C

Symbol			Unit
I_OUT_ON_max	Maximum output per HS driver, all eight drivers might be active simultaneously	350	mA
	Maximum output per one HS driver, only one can be active	650	mA
	Maximum output per HS driver, only two HS drivers from a different pair can be active simultaneously	500	mA
	Maximum output per one HS driver pair	830	mA

The above maximum values should be respected for all types of loads – as soon as the current in one load exceeds 350 mA (which might be the case also for an inductive load of, e.g., 50 mH), the number of simultaneously driven loads must be limited either by hardware connection or by software algorithm.

Steady Power Dissipation

During ON state of a driver, the load current flows through the driving transistor with a non−zero on−resistance. The resulting power dissipation increases the junction temperature of the integrated circuit. Under all circumstances, the junction temperature should stay below the guaranteed thermal shutdown threshold, which is **130°C**.

In order to evaluate this limitation, the total dissipation in all drivers has to be taken into account together with the application PCB influencing the thermal resistance. To quantify the dissipation, the closed high side driver can be modeled by a resistance of **1.48 Ω**, which corresponds to the on−resistance of the switching transistor. This value is different from the specified on−resistance of the driver, as it does not include the resistance of metallization, bonding and package leads.

This limitation applies to all types of loads.

Peak Temperature During Flyback

AMIS−39100/39101 includes a flyback clamping circuit which is activated in case an inductive load is being switched off. The voltage over the clamp can very between 35 V − 60 V. Compared to a flyback diode, the switching−off transition is faster, but induces an important dissipation peak at the beginning of the switching−off transition. As an example, switching−off a current of 100 mA through an inductor involves a more−or−less steady dissipation of 100 mW through a flyback diode (assuming a 1 V drop) while the same load will cause an initial dissipation peak of 6 W over a 60 V flyback clamp.

This high peak dissipation results in a high temperature increase inside the driving transistors. Although this thermal peak is only very short in time, it can lead to decreased reliability in case excessive temperatures are reached repeatedly.

The value of the thermal peak is strongly dependent on the current being switched off in an inductive load, while it is very weakly dependent on the inductance value itself. Furthermore, the thermal peak value is virtually independent on the number of drivers simultaneously switching, as the phenomenon is faster than the heat propagation delays between the drivers on the silicon.

As a guideline, the maximum currents through different inductances are depicted in .

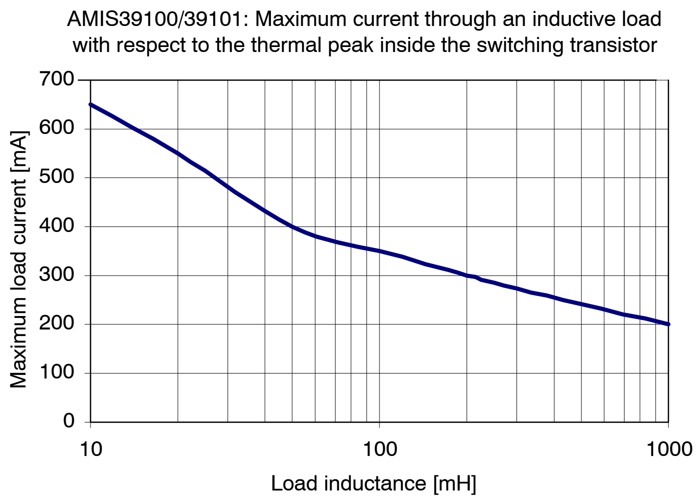

Figure 1. Maximum Load Current in Function of Load Inductance as Limited by the Thermal Peaking Inside the Switching Transistors

This limitation applies only to inductive loads (starting from ca 10 mH) and only in cases where no external flyback diode is used (in which the inductor energy is dissipated in the external flyback element).

Increase of the Junction Temperature Due to Flyback

Besides the thermal peaking inside the switching transistors, as described in paragraph , dissipation of the inductor energy in the flyback clamp causes a temporary temperature increase of the entire integrated circuit which might cause a thermal shutdown. Therefore the steady junction temperature should provide sufficient margin towards the guaranteed thermal shutdown level, which allows accommodating for the temporary temperature increase. As a guideline, the following formula can be used to estimate the flyback influence on the junction temperature:

$$dT_{TSD} = 75k \cdot E_{LOAD}$$

Where d_{TTSD} is the junction temperature increase in the place of the thermal shutdown block and E_{LOAD} is the total energy to be dissipated during flyback (all loads together). Note that the temperature increase does not depend on the thermal resistance of the package and the PCB, as this is still a dynamic thermal effect (with settling time in the order of ms).

This limitation applies only to inductive loads (starting from ca 10 mH) and only in case when no external flyback diode is used (in which case the inductor energy is dissipated in the external flyback element).

Examples

Example 1: Switching Inductive Loads

Application: switching inductive loads of 100 mH, each with 250 mA. PCB with R_{thja} = 53 K/W is used

Verifying the limitations:

- Short−circuit protection in the drivers: the required current is below 650 mA −> OK
- Current per one load is lower than 350 mA, thus reliability−related limitations do not intervene (see Section “Reliability of Bonding Metallization”)
- Steady power dissipation: worst case (all 8 drivers on) dissipation is:

$$P_{dissip} = 8 \cdot 1.48\ \Omega(0.25\ A)^2 = 0.74\ W$$

Resulting junction temperature increase is

$$dT_{dissip} = P_{dissip} \times R_{thja} = 39^\circ C$$

- As can be found from , maximum recommended current for 100 mH load is 350 mA, which is above the considered value in this example −> OK
- The energy stored in all 8 loads (in case all drivers are on) is:

$$E_{LOAD} = 8 \times \frac{1}{2} \times 100\ mH \times (250\ mA)^2 = 25\ mJ$$

In case this energy is dissipated in the flyback clamps simultaneously, the junction temperature will temporarily increase by (see Section “Reliability of Bonding and Metallization”:

$$dT_{TSD} = 75k \times E_{LOAD} \cong 2^\circ C$$

Conclusion: in order to comply with the guaranteed thermal shutdown level (130°C), the ambient temperature has to be limited to ca 89°C (= 130 − 39 − 2).

Example 2: Switching Resistive Loads Lower than 350 mA

Application: switching resistive loads of 300 mA. PCB with R_{thja} = 24 K/W is used

Verifying the limitations:

- Short−circuit protection in the drivers: the required current is below 650 mA −> OK
- Current per one load is lower than 350 mA, thus reliability−related limitations do not intervene (see Sections “Peak Temperature During Flyback” and “Increase of the Junction Temperature Due to the Flyback”)
- Steady power dissipation: worst case (all 8 drivers on) dissipation is:

$$P_{dissip} = 8 \times 1.48\ \Omega(0.3\ A)^2 = 1.07\ W$$

Resulting junction temperature increase is:

$$dT_{dissip} = P_{dissip} \times R_{thja} = 25^\circ C$$

- As the load has resistive character, the thermal considerations due to flyback (as per par. and) are not applicable

Conclusion: in order to comply with the guaranteed thermal shutdown level (130°C), the ambient temperature has to be limited to 105°C (= 130 − 25).

Example 3: Switching Resistive Loads with Different Currents

Application: Switching resistive loads of 500 mA (4 loads on OUT1−OUT4) and 350 mA (4 loads on OUT5−OUT8). PCB with R_{thja} = 40 K/W is used

Verifying the Limitations:

- Short−circuit protection in the drivers: the required current is below 650 mA −> OK
- Current per one load exceeds (for some loads) 350 mA, thus reliability limitations listed in Section “Reliability of Bonding and Metallization” must be considered. The software must ensure, that two 500 mA loads from the same driver pair cannot be activated – e.g. switching OUT1 and OUT2 or OUT3 and OUT4 simultaneously is not allowed. Allowed combinations are: OUT1 together with OUT3 or OUT2 together with OUT4. On the other hand, the 350 mA loads on OUT5−OUT8 can be switched without restrictions.
- Steady power dissipation: worst case dissipation corresponds to four 350 mA loads and two 500 mA loads on (more is not allowed for reliability reasons – see above):

$$R_{dissip} = 4 \times 1.48\ \Omega(0.35\ A)^2 + 2 \times 1.48\ \Omega(0.5\ A)^2 = 1.47\ W$$

Resulting junction temperature increase is

$$dT_{dissip} = P_{dissip} \times R_{thja} = 59^\circ C$$

- As the load has resistive character, the thermal considerations due to flyback (as per par. and) are not applicable

Conclusion: In order to comply with the guaranteed thermal shutdown level (130°C), the ambient temperature has to be limited to 71°C (= 130 − 59).

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