Introduction

The L99DZ100G(P) integrates six Half Bridges and three of them (Output 4, 5 and 6) are specifically designed to drive High Current DC Motors as the Car Door Locks.

Even if those Outputs have been designed to support the majority of the Door Lock Modules, currently used in Automotive, some car makers may require to use more powerful loads requiring higher Output current; in this case, an external device connected to the L99DZ100G(P) can be used for the scope.

This Technical Note shows how to connect the L99DZ100G(P) with VNH7070AS in the so-called "Cascaded Motor Solution"; in order to use the VNH7070AS for driving a more powerful Door lock Motor, some analysis has been performed.

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1 The Cascaded Motor Solution

Typical application of the L99DZ100G(P), provided by STMicroelectronics (see *Section A.1: Document references*), makes usage of:

- the Output 4 to drive the Door Lock Motor,
- the Output 6 to drive the Safe Lock Door Motor and
- the Output 5 for the Common Output.

Both the Output 4 and 5 are designed for a maximum current load $I_{ds,max}$ = 7.5A, with $R_{ds(ON)}$ = 150 mΩ for Output 4 and $R_{ds(ON)}$ = 100 mΩ for the Output 5.

The Typical configuration for the L99DZ100G(P) to drive the 2 Door Lock Motors is reported in *Figure 1*.

Figure 1. Typical Door Lock Application using the L99DZ100G(P)
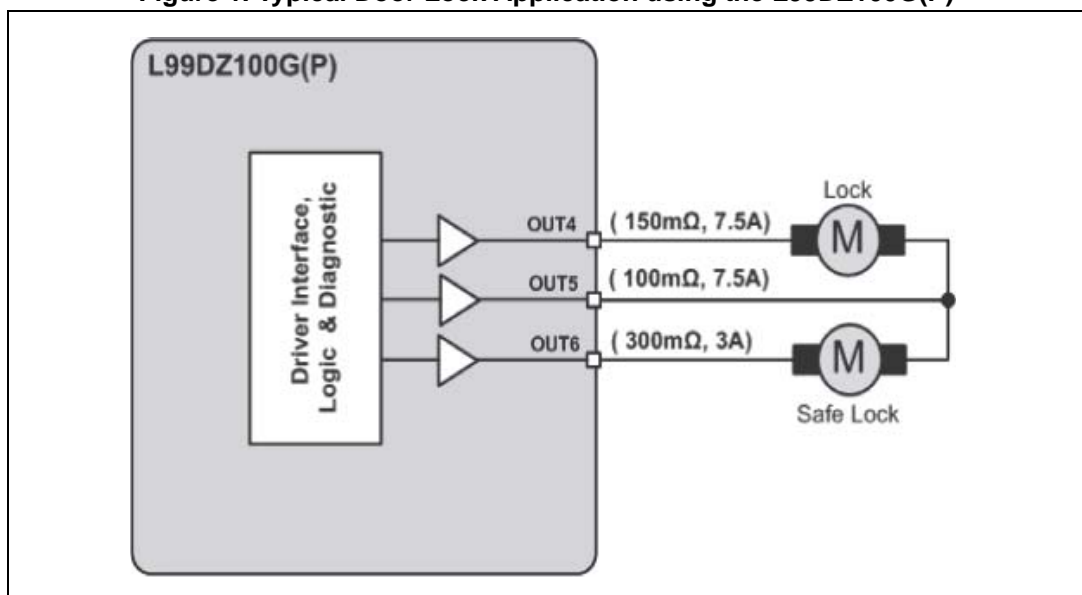
In this configuration, the integrated Half Bridge in the Output 4 drives the Door Lock Motor and the Output 6 ($R_{ds(ON)}$ = 300 mΩ and $I_{ds,max}$ = 3A) can safely drive a Safe Lock Motor. Both Lock and Safe Lock Motors have a common leg for the total current on the Output 5.

The Cascaded Motor Solution (reported in *Figure 2*) here proposed makes usage of a proper configuration in which the VNH7070AS Output B is the common leg for the return current.

Figure 2. Cascaded Motor Solution to drive a powerful Door Lock
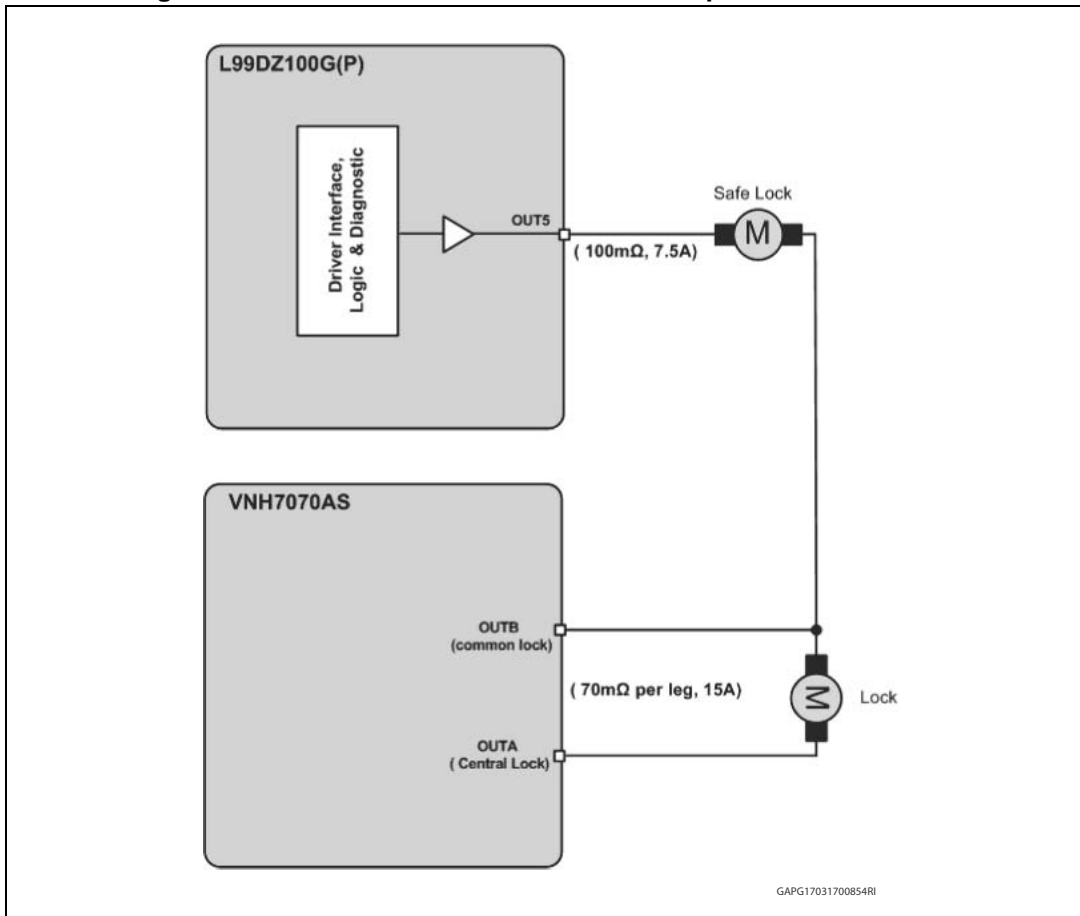
In this configuration, the secondary Safe Lock Motor is driven by Output 5, while the primary Door Lock Motor is driven by means of the fully integrated H-bridge VNH7070AS ($R_{ds(ON)}$ = 70 mΩ and maximum current load $I_{out,min}$ = 15A). One of its 2 Outputs (OUTA in Cascaded Motor Solution to drive a powerful Door Lock) is connected to the Lock Motor and the other one (OUTB) is used by both the Safe Lock and Lock Motors for the return current.

2 Feasibility and robustness of the Cascaded Motor solution

In order to evaluate the feasibility of the proposed Cascaded Motor solution, a set of test cases in which both the Door Lock Motors are repeatedly activated have been set up; no unwanted behavior has been observed with these test cases as detailed in section Activations of the Door Lock Motors and Short Circuit (SC) test cases.

Regarding the robustness of the proposed Cascaded Motor solution, two considerations have been put in place.

Firstly, the L99DZ100G(P) Half Bridges comprise a "hard-off" structure to avoid parasitic turn-on in case of external voltage slopes applied to the output; some simulation results confirming the Slew Rate robustness of the L99DZ100G(P) Half Bridges are reported in section L99DZ100G(P) Slew Rate robustness.

Moreover, in order to prove in a test bench the L99DZ100G(P) Half Bridges robustness, a specific test has been setup; this test measures the current flowing into its Output 5 when fast activations of the VNH7070AS Output B are externally applied (see section L99DZ100G(P) Half Bridge robustness in case of fast slope on VNH7070AS output).

For the test in the following described, the L99DZ100G(P) Auto Recovery mechanism (see *Section A.1: Document references*) has been disabled.

2.1 Activations of the Door Lock Motors and Short Circuit (SC) test cases

Test cases implementing repetitive activations of both the Motors (Door Lock and Safe Lock) have been setup. Main purpose of these test cases is to verify that every activation of the Door Lock Motor doesn't have any influence on the L99DZ100G(P) Output 5, i.e. any unwanted activation of the Safe Lock Motor connected to the Output 5 is observed.

To perform a better evaluation of the feasibility, these test cases have been implemented not only during Normal Operation but also in some corner cases, i.e. in case of SC to VBAT or GND of both the L99DZ100G(P) Output 5 and the VNH7070AS Output B.

The *Table 1* reports the configuration for each of the test cases implemented and the result obtained for the test case.

Table 1. Test Cases to evaluate the feasibility of the Cascaded Motor Solution

Test Condition	Sequence Control[1]	Result
Normal operation	INx -> SPI	PASSED
	SPI -> INx	PASSED
L99DZ100G(P) Output 5 Short Circuit to VBAT	INx -> SPI	PASSED
	SPI -> INx	PASSED
VNH7070AS Output B Short Circuit to VBAT	INx -> SPI	PASSED
	SPI -> INx	PASSED

Table 1. Test Cases to evaluate the feasibility of the Cascaded Motor Solution

Test Condition	Sequence Control[1]	Result
L99DZ100G(P) Output 5 Short Circuit to GND	INx -> SPI	PASSED
	SPI -> INx	PASSED
VNH7070AS Output B Short Circuit to GND	INx -> SPI	PASSED
	SPI -> INx	PASSED
Normal Operation, L99DZ100G(P) Output 5 load R = 3 Ω	INx -> SPI	PASSED
	SPI -> INx	PASSED
L99DZ100G(P) Output 5 Short Circuit on Motor pins	INx -> SPI	PASSED
	SPI -> INx	PASSED

1. The Sequence Control refers to the sequence by which the 2 different Motors are activated; IN->SPI means that VNH7070AS Output is activated before than L99DZ100G; on the other side, SPI->INX means that the L99DZ100G(P) Output 5 is activated at the beginning of the sequence.

No unwanted activation of the Output 5 has been observed in these test cases.

2.2 L99DZ100G(P) Slew Rate robustness

The Hard-off is an in-circuit mechanism of the L99DZ100G(P) conceived to protect its integrated Half Bridges in OFF state when unwanted high and rapidly changing voltages are applied to its Outputs.

The Hard-off mechanism basically disables both the High Side and Low Side MOSFETs of each integrated Half Bridge when it is turned OFF; in this state, whatever is the external voltage applied to the Output, no huge current is allowed to flow inside the HS and LS MOSFETs.

The following simulation results show that no huge current is detected on the Output 4[a] when a voltage ramp with 120V/us slope is applied both in the rising (*Figure 3: Hard-off mechanism when a rising voltage ramp with dV/dt=120V/us slope is applied to Output 4*) and falling (*Figure 4: Hard-off mechanism when a falling voltage ramp with dV/dt=120V/us slope is applied to OUT4*) directions. For each of the two figures, the simulated Voltages that are applied between the Gate and the Source of both HS and LS is drawn too; the reported values highlight that both the MOSFETS cannot be switched ON and hence the Half Bridge cannot drive huge current.

a. Simulation has been carried on the Output 4, but every Half Bridge Outputs (from OUT1 to OUT6) of the L99DZ100G(P) shows the same Hard-off behavior

Figure 3. Hard-off mechanism when a rising voltage ramp with dV/dt=120V/us slope is applied to Output 4
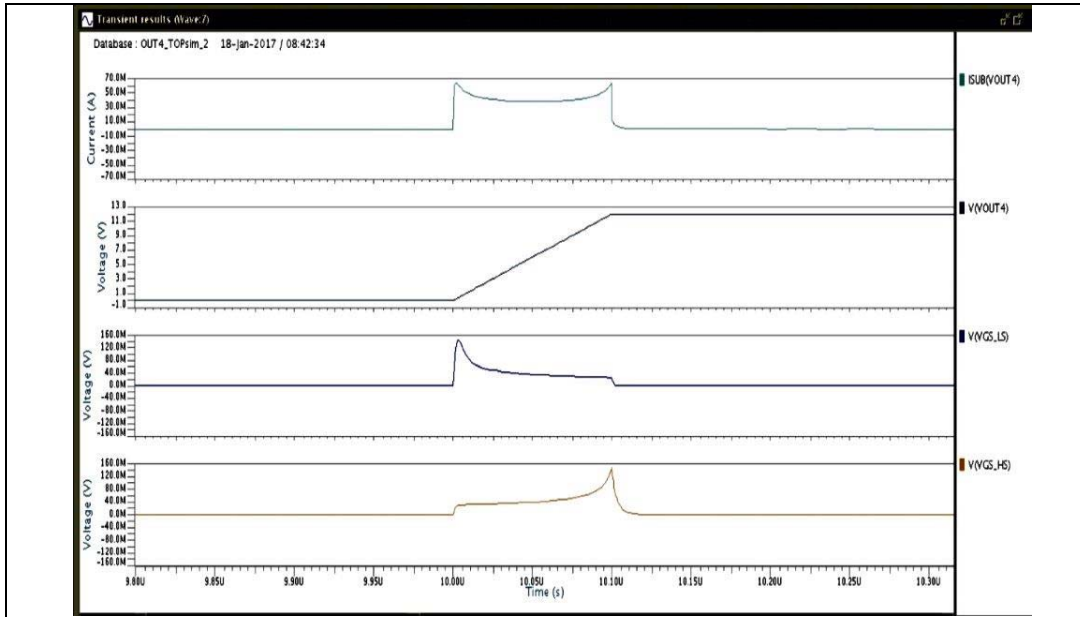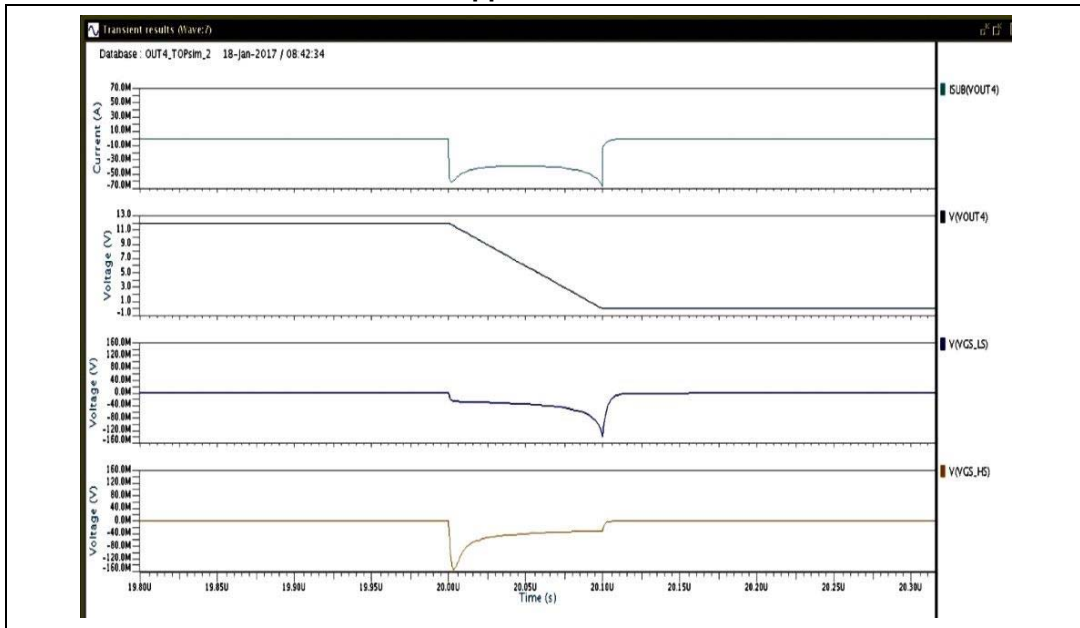

Figure 4. Hard-off mechanism when a falling voltage ramp with dV/dt=120V/us slope is applied to OUT4

To have the Hard-off fully working, the Over Current Recovery (auto-recovery) mechanism to detect and mitigate the Over Current effect on the L99DZ100G(P) outputs (see *Section A.1: Document references*), shall be disabled.

In case the Over Current event occurs (i.e. the current is above the OC threshold), if the OCR mechanism is ON, once the Over Current event disappear, the Hard-off remains disabled; on the other side, if the OCR mechanism is OFF when the Over Current event occurs the Half Bridges is turned OFF (latched) and the Hard-off mechanism is enabled.

For both the simulations previously described, the Over Current Recovery mechanism of the L99DZ100G(P) has been disabled.

2.3 L99DZ100G(P) Half Bridge robustness in case of fast slope on VNH7070AS output

In order to verify the reliability of the proposed Cascaded Motor solution, main concern is the Output 5 behavior in OFF state when fast variations of the Output Voltage occur on the VNH7070AS Output B. This means that fast changes of this Voltage shall not drive significant current inside the L99DZ100G(P) Output 5, in order to avoid unwanted activations of the Safe Lock Motor.

The VNH7070AS is able to rapidly turn OFF its load with a slope of about 70V/µs; L99DZ100G(P) specifies in its datasheet (see *Section A.1: Document references*) that in Active Mode the maximum external slew rate that can be applied without switching ON the HS and LS of the integrated OUT1-OUT6 Half Bridges is 20V/µs, so a new set of measurements have been performed to validate that the L99DZ100G(P) can sustain a more rapid external slew rate.

A set of measurements have been done on the L99DZ100G(P) Output 5, by using a ramp generator; the measurements reported in *Figure 5* show the Voltage applied to the Output 5 (yellow trace) via the ramp generator and the I_{out5} (red trace, i.e. the current flowing in the Output 5 itself.

Figure 5. Fast Voltage ramp applied to L99DZ100G(P) Output 5
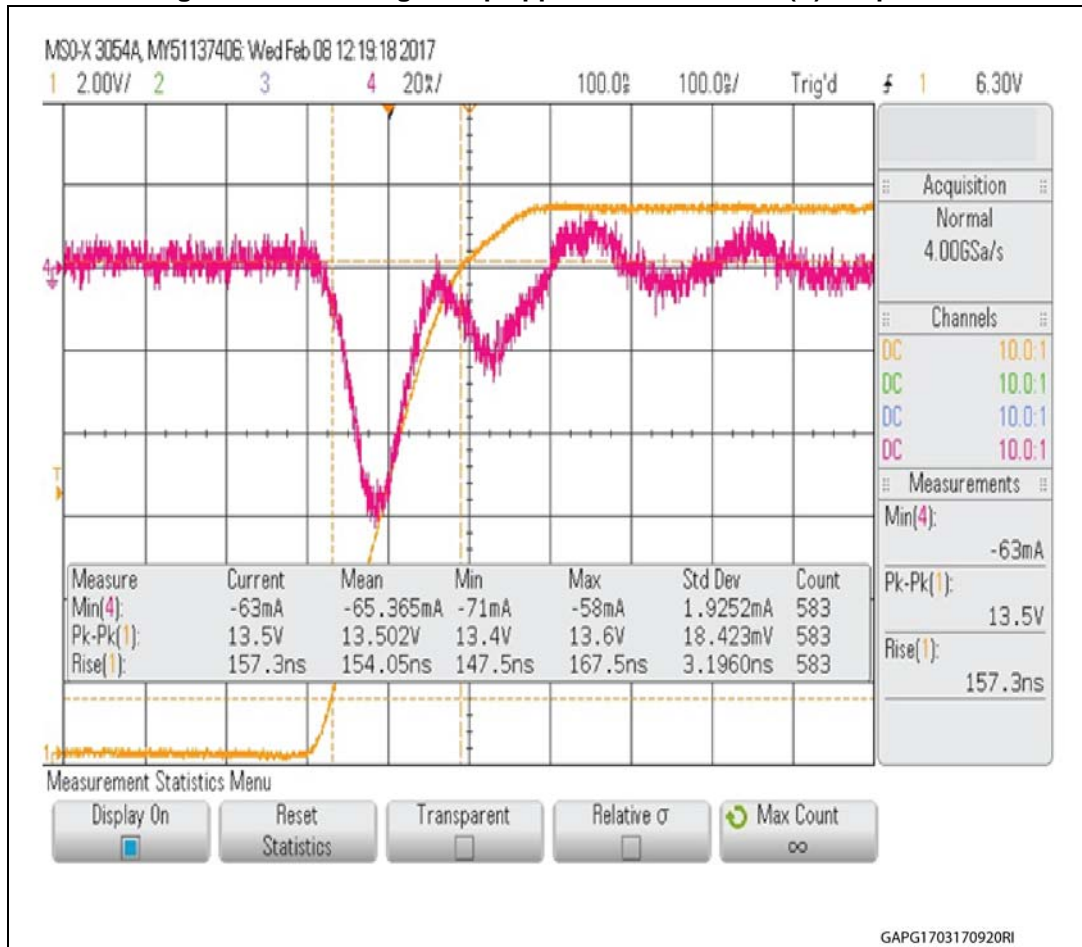
The measurement shows that by applying a fast ramp on Output 5 (dV/dt = 70V/ μs) the current measured on the Output 5 itself is in the range of 63mA, which is a current absolutely not able to activate the HS and LS of the integrated OUT5 Half Bridge.

3 Conclusion

The Technical Note describes a possible Cascaded Motor solution combining Door Zone module L99DZ100G(P) and the VNH7070AS fully integrated H-bridge motor driver, by which the capability in terms of maximum current load of the Door Lock driven by the L99DZ100G(P) can be safely improved.

The feasibility of the proposed Cascaded Motor solution has been evaluated and here detailed.

Appendix A Further documentation

A.1 Document references

- *Automotive door module with LIN and HS-CAN (L99DZ100G) or HS-CAN supporting selective wake up (L99DZ100GP)* (Datasheet, DocID029077)
- Automotive fully integrated H-bridge motor driver (Datasheet, DocID028088)
- Notes about Over Current Recovery mode in L99DZ100G/P (TN1243, DocID030226)

Revision history

Table 2. Document revision history

Date	Revision	Changes
23-Mar-2017	1	Initial release.

IMPORTANT NOTICE – PLEASE READ CAREFULLY