Robust Automotive 40V Power MOSFETs for Safer Vehicles

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Abstract

The most advanced 40V power MOSFETs from STMicroelectronics properly fulfill all the mechanical, environmental and electrical characteristics requested by automotive safety systems, such as EPS (Electric Power Steering) and EPB (Electric Park Brake). These electro-mechanical systems have to be compliant to the automotive AEC Q101 specifications and, specifically, the low voltage MOSFETs have to sustain both high temperature and high current spikes.

1. Introduction

Both EPS and EPB systems consist of two main components: an electric servo unit and a mechanical gear unit. The electro servo unit transmit the rotation of the electrical machine to the mechanical gear unit in order to perform the mechanical action with amplified torque. The electro servo unit is either a two or three phase inverter realized with power MOSFETs, as shown in Fig.1.

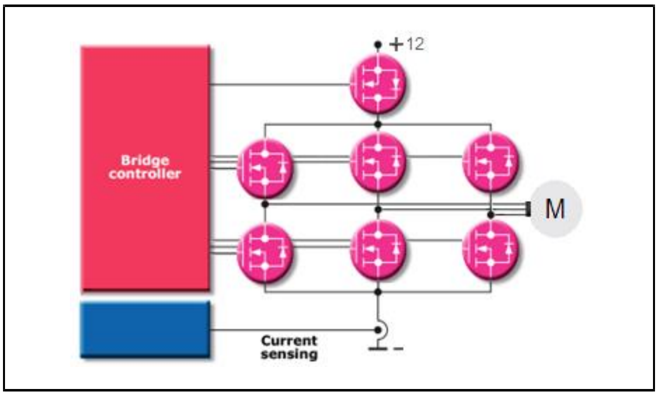


Fig. 1. Servo unit topology for both EPS and EPB systems

The load is an electric motor, typically a BLDC (Brush Less Direct Current) with permanent magnets, and voltage power supply is a 12V battery.

2. Automotive Requirements for Power MOSFETs

The devices used for both EPS and EPB inverters are 40V automotive power MOSFETs, which have to meet all the following requirements:

1. very low switching and conduction losses
2. high current capability
3. low C_{iss}/C_{rss} ratio for EMI immunity
4. high avalanche ruggedness
5. overcurrent and short circuit ruggedness
6. thermal management and heat dissipation
7. assembling in robust SMD packages
8. load dump and ESD ruggedness

in compliance to the AEC Q101 automotive qualification.

2.1. Measured Parameters for AEC Q101 Power MOSFETs

Some lab measurements have been performed in order to compare the performance of 40V automotive power MOSFETs from STMicroelectronics vs competition, selected to meet both EPS and EPB system requirements. The main measured parameters of STL285N4F7AG (automotive 40V power MOSFET from STMicroelectronics) and an equivalent device from a competitor are reported in Tab.1.

	BV_{dss} (V) @250µA	V_{th} (V) @250µA	V_{sd} (mV) @48A	R_{DSon} (mΩ) @10V,48A	R_g (Ω)	C_{iss} (pF) @25V	C_{rss} (pF) @25V	C_{oss} (pF) @25V
Competitor	46.80	2.89	755	0.6	2.5	8450	136	4350
STL285N4F7AG	46.34	3.43	790	1.0	1.2	5600	38	2350

Tab. 1. Measured parameters for STL285N4F7AG vs competitor's device

Since the two safety systems work at 12V-13.5V battery voltage, the appropriate nominal voltage for the power MOSFETs is 40V, thus assuring a breakdown voltage (BV_{dss}) close to 46V. This condition allows the devices to correctly dump the overvoltage due to parasitic inductances during the switching operation. The static on-resistance (R_{DSon}) is preferable to be less than 1mΩ in order to contain the voltage drop during the conduction phase. Both intrinsic capacitances and R_g should be small to minimize the switching losses, thus achieving fast switching speeds. The C_{rss}/C_{iss} ratio is a very sensitive parameter, which helps to prevent any false turn-on due to the Miller effect and allows a better di/dt and dV/dt control. Together with the body-drain diode Q_{rr} and softness, this significantly reduces EMI sensitivity. STL285N4F7AG shows an optimized capacitance ratio (C_{rss}/C_{iss}) tailored for the compliance to both low power dissipation and electromagnetic interference. The measured ratio for STL285N4F7AG vs competition is reported in Fig.2.

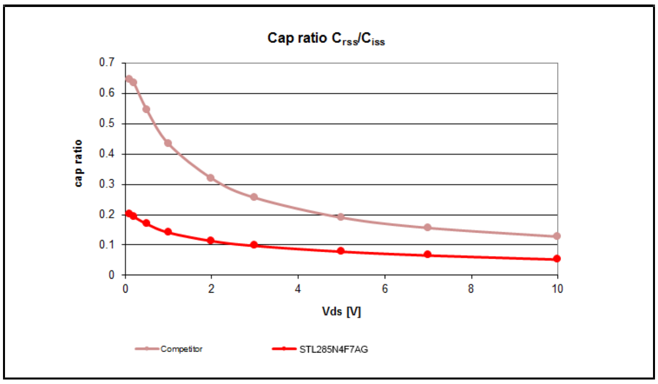


Fig. 2. Measured capacitance ratio C_{rss}/C_{iss} for STL285N4F7AG vs competition

Furthermore, the measured body-drain diode performance of ST's STL285N4F7AG vs competition is reported in Fig. 3.

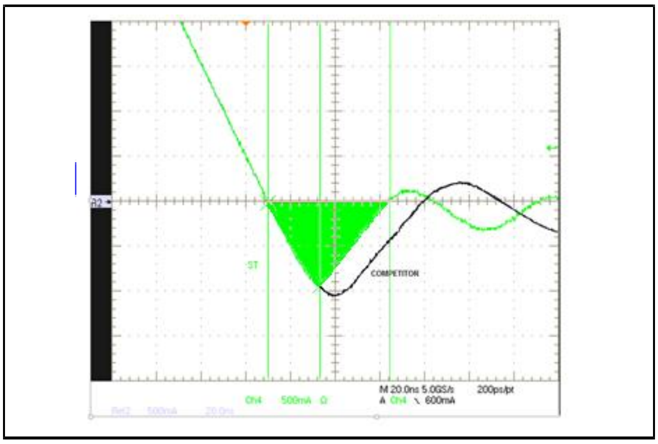
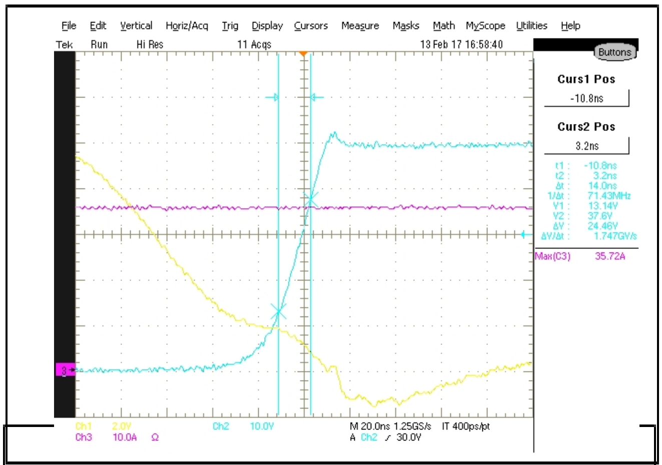


Fig. 3. Measured body-drain diode performance of STL285N4F7AG vs competition

The measured parameters show that, for a fixed di/dt value, both the reverse recovery charge (Q_{rr}) and recovery time (T_{rr}) for STL285N4F7AG are lower than competition. This condition can be summarized as follows:

- the lower Q_{rr} decreases the dynamic losses of the inverter at turn-on and optimizes the EMI behavior of the power stage;
- the better T_{rr} improves the dynamic peak diode recovery voltage slope (dv/dt), which is one of the most common failure root in the power bridges during current free-wheeling trough the body-drain diode.

Then dv/dt is a very important parameter able to guarantee the ruggedness against the latch-up failure. Measurements show the good behavior of ST's device (Fig. 4) vs competition (Fig. 5).



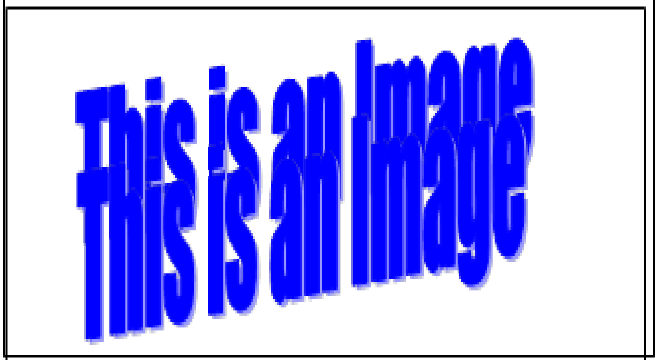


Fig. 4. Measured dv/dt for STL285N4F7AG

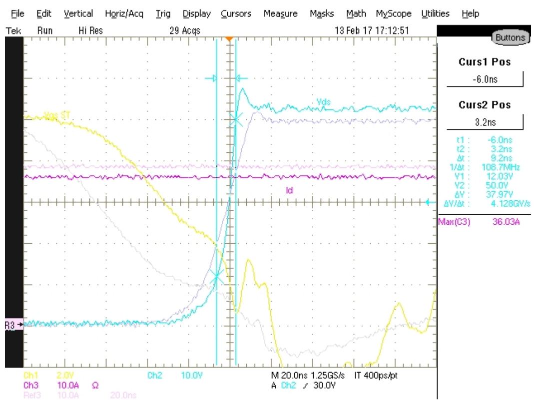


Fig. 5. Measured dv/dt for competitor's device

2.2. Measured Performance with Short Circuit Events

The robustness of the 40V automotive power MOSFETs from STMicroelectronics in safety application has been experimentally verified, by measuring the device behaviour with a short circuit event. This condition could occur in an electronic system for various reasons, like presence of humidity, lack of electric insulation, unintentional contact of electric parts and overvoltage. It is rarely permanent, in general lasts in a few microseconds because the root origin is usually unintentional. During this event the overal system and, in particular, the power stages have to sustain multiple high current events. Laboratory measurements have been performed by using STL285N4F7AG and the board, reported in Fig. 6:

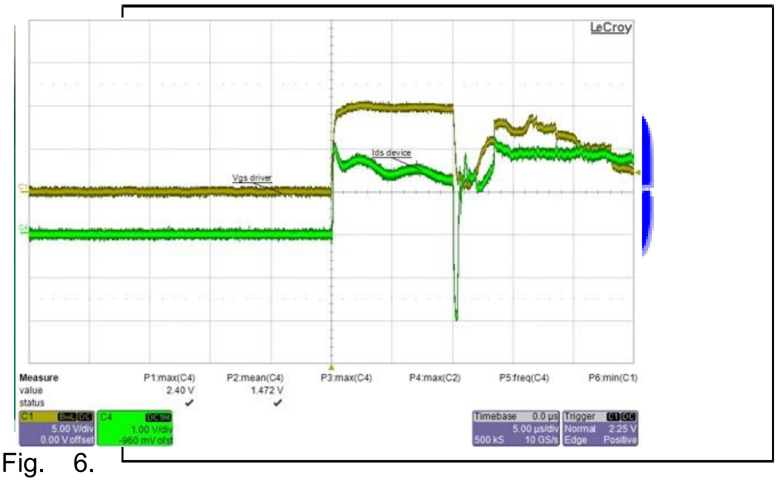


Fig. 6. Testing board

The following procedure has been followed:

1) pre-test the main electrical parameters with a curve tracer;
2) heat up the board up to 135°C and perform two times 10µs short circuit pulse with a time gap less than 1s, with and without current limiter protection activated
3) de-solder the device and post-test the main electrical parameters in order to check either the power MOSFET integrity or degradation.

The measurement results are shown in Fig. 7.

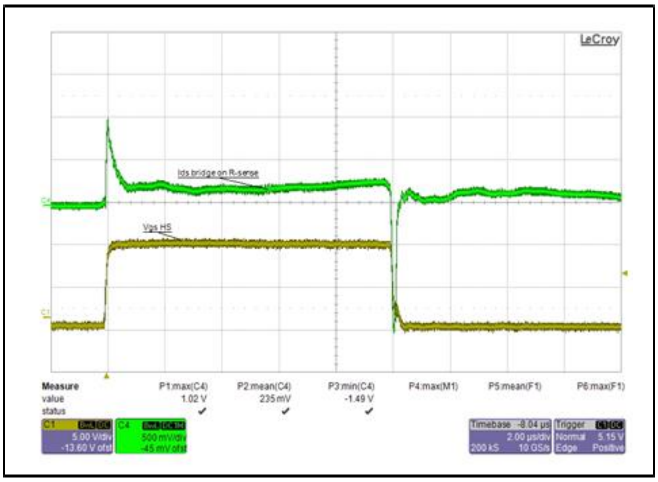


Fig. 7. Short circuit test for STL285N4F7AG

The measured maximum currents during the short circuit event are in the range of 2000A with a 10µs pulse time. The test has been performed ten times with T_{period} = 5s. The device STL285N4F7AG has been able to withstand the short circuit condition without any fail. The failure conditions arise with current values greater than 2400A (Fig. 8).

Fig. 8. Measured failure condition for STL285N4F7AG (I_d > 2400A)

3. Conclusions

The experimental data have shown that the most advanced AEC-Q101 40V power MOSFETs from STMicroelectronics can easily withstand the stringent characteristics required by automotive safety systems. Then the new ST's trench N-channel devices are very good candidates to be used for both EPS and EPB automotive applications.

4. References

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