

# EPC eGaN<sup>®</sup> FET

## Automotive Qualification Report

### EPC2252



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*This report summarizes the Product Qualification results for EPC part numbers EPC2252, EPC2204A and EPC2218A. EPC2252, EPC2204A and EPC2218A meet all required qualification requirements and are released for production.*

#### Scope

The testing matrix in this qualification report covers the qualification of EPC2218A and EPC2204A according to the component level AEC-Q101 Rev D1 requirements.

Part Number	Voltage (V)	R <sub>DS(on)</sub> (mΩ)	Die Size (mm x mm)	Maximum Operating Temperature (°C)
EPC2252	80	11	S (1.5 x 1.5)	150
EPC2218A	80	3.2	L (3.5 x 1.95)	150
EPC2204A	80	6	S (2.5 x 1.5)	150

#### Qualification Test Overview

EPC's EPC2252 eGaN FETs were subjected to a wide variety of stress tests following the specifications of AEC-Q101 (Rev D1) developed for silicon-based power MOSFETs. These tests include:

- Preconditioning: Parts undergo the following steps in sequence: (1) 125°C bake for a minimum of 24 hours; (2) Moisture Sensitivity Level 1 (MSL1); (3) 3 times reflow.
- Parametric Verification: Device parameters are measured at -40°C, 25°C, and 150°C to ensure compliance with datasheet limits over the entire temperature range.
- Electrostatic Discharge (ESD) Characterization: Parts are tested under both Human Body Model (HBM) and Charged Device Model (CDM) to assess device susceptibility to electrostatic discharge events.
- High temperature reverse bias (HTRB): Parts are subjected to a drain-source voltage at the maximum rated temperature and maximum rated voltage (80 V).
- High temperature gate bias (HTGB): Parts are subjected to a gate-source voltage at the maximum rated temperature and maximum rated gate voltage (6 V).
- Biased highly accelerated test (bHAST): Parts are subjected to a drain-source voltage at the maximum drain voltage rating (80V) for 96 hours at 130°C, 85% humidity, and vapor pressure of 33.3 psia.

- Temperature cycling (TC): Parts are subjected to alternating high and low temperature extremes from -55°C to 150°C for a total of 1000 cycles
- Moisture sensitivity level 1 (MSL1): Parts are subjected to moisture, temperature, and three cycles of reflow. MSL1 is the most stringent of the moisture sensitivity levels, requiring 85°C and 85% humidity for 168 hours.
- Intermittent Operating Life (IOL): Parts are temperature cycled with short period and device heating through internal electrical power dissipation.

All devices put on test as part of this qualification underwent external visual inspection prior to test. This microscope inspection checks for physical damage to the chip-scale package, such as edge chipping or cracks, that may have resulted from assembly or transit. Damaged parts are removed from the test population.

For all qualification tests, the stability of the devices is verified with DC electrical tests before and after stress. In many cases, interim readouts are also performed. Electrical parameters are measured at room temperature. The parameters include: gate-source threshold voltage ( $V_{TH}$ ), on-state resistance  $R_{DS(on)}$ , off-state drain leakage ( $I_{DSS}$ ), and gate leakage ( $I_{GSS}$ ). For  $V_{TH}$  and  $R_{DS(on)}$ , a failure is recorded when either of the following occurs: (1) the measurement exceeds the datasheet specifications; or (2) the measurement has changed by more than 20% of its initial value. For  $I_{DSS}$  and  $I_{GSS}$ , a failure is recorded if the measurement exceeds datasheet limit, or if it has increased by more than 5x during test. All testing requirements and specifications for AEC-Q101 (Rev D1) were followed.

For certain qualification tests, parts were mounted onto FR5 (high Tg FR4) PCB adaptor cards. These cards simplify the process of post-screening and electrically stressing the parts. Adaptor cards (1.6 mm in thickness) with two copper layers were used. The top copper layer was 1 oz. or 2 oz., and the bottom copper layer was 1 oz. Kester NXG1 type 3 SAC305 solder water soluble flux was used in mounting the part onto an adaptor card. After assembly, parts were flux-cleaned and subsequently subjected to oven bake at 125°C.

For other qualifications tests, including MSL1 and TC, parts were not mounted to adaptor cards. Electrical tests were performed using sockets or probe needles touching the solder pads of the bare die.

**High Temperature Reverse Bias**

One lot of EPC2252 parts were subjected to 100% of the rated drain-source voltage (80 V) at the maximum rated temperature (150°C) for a stress period of 1000 hours, as shown in Table 1. This, in conjunction with the matrix of HTRB results from other in-family AEC products EPC2218A and EPC2204A, satisfies AEC-Q101 requirements for an 80 V 150°C rating.

Parts were mounted on FR5 adapter cards. Testing was conducted in accordance with MIL-STD-750-1 (M1038 Method A). This standard requires the parts to be under bias during temperature ramp up and cool down. In addition, post-screening must occur within 24 hours after bias has been removed.

Stress Test	Part Number	Voltage (V)	Die Size (mm x mm)	Test Condition	# of Failure	Sample Size (sample x lot)	Duration (Hours)
HTRB	<a href="#">EPC2218A</a>	80	L (3.5 x 1.95)	T = 150°C, V <sub>DS</sub> = 80 V	0	77 x 3	1000
HTRB	<a href="#">EPC2204A</a>	80	S (2.5 x 1.5)	T = 150°C, V <sub>DS</sub> = 80 V	0	77 x 1	1000
HTRB	<a href="#">EPC2252</a>	80	S (1.5 x 1.5)	T = 150°C, V <sub>DS</sub> = 80 V	0	77 x 1	1000

Table 1. High Temperature Reverse Bias Test

**High Temperature Gate Bias**

EPC2252 was qualified by matrix with EPC2218A and EPC2204A that have identical gate structural design and share the same manufacturing process. EPC2218A and EPC2204A were subjected to maximum rated gate-source bias (6 V) at the maximum rated temperature (150°C) for a stress period of 1000 hours. This test duration and temperature satisfies the AEC-Q101 requirements for a 150°C rating. Parts were mounted on FR5 adapter cards. Testing was conducted in accordance with JESD22-A108. This standard requires the parts to be under bias during temperature ramp up and cool down. In addition, post-screening must occur within 96 hours after bias has been removed.

Stress Test	Part Number	Voltage (V)	Die Size (mm x mm)	Test Condition	# of Failure	Sample Size (sample x lot)	Duration (Hours)
HTGB	<a href="#">EPC2218A</a>	80	L (3.5 x 1.95)	T = 150°C, V <sub>GS</sub> = 6 V	0*	77 x 3	1000
HTGB	<a href="#">EPC2204A</a>	80	S (2.5 x 1.5)	T = 150°C, V <sub>GS</sub> = 6 V	0	77 x 1	1000

\* Among all 308 parts tested, there is one device in the first lot of EPC2218A that showed 5.8x increase in gate leakage (I<sub>GSS</sub>) post 1000 hours as compared to the initial reading. The final I<sub>GSS</sub> of the part is 33.5 μA, where the mean and the medium I<sub>GSS</sub> value of the lot at 1000 hours read point is 101 μA and 41.2 μA, respectively. Therefore, the final gate leakage value is well within the distribution, and all the other parametric values passed the AEC-Q101 requirements. In addition, we subjected this unit to failure analysis, where we did not find any solid emission spots up to the rated gate voltage. This device is a slight deviation from the 5x AEC shift requirement for leakages.

Table 2. High Temperature Gate Bias Test

**Biased Highly Accelerated Test**

Three lots of EPC2252 parts were subjected to 100% of the rated drain-source voltage (80 V) at a temperature of 130°C, relative humidity of 85%, and vapor pressure of 33.3 psia for a duration of 96 hours. All parts were mounted on FR5 adaptor boards. Per AEC requirements, all parts went through pre-conditioning before biased HAST.

Stress Test	Part Number	Voltage (V)	Die Size (mm x mm)	Test Condition	# of Failure	Sample Size (unit x lot)	Duration (Hours)
bHAST	<a href="#">EPC2252</a>	80	S (1.5 x 1.5)	T = 130°C, RH = 85%, VP = 33.3 psia	0	77 x 1	96
bHAST	<a href="#">EPC2252</a>	80	S (1.5 x 1.5)	T = 130°C, RH = 85%, VP = 33.3 psia	0	77 x 1	96
bHAST	<a href="#">EPC2252</a>	80	S (1.5 x 1.5)	T = 130°C, RH = 85%, VP = 33.3 psia	0	77 x 1	96

Table 3. Unbiased Highly Accelerated Test

**Temperature Cycling**

One lot of EPC2252 was subjected to temperature cycling between -55°C and +150°C for a total of 1000 cycles. EPC2252 was qualified by matrix with EPC2218A and EPC2204A, where parts were subjected to temperature cycling between -55°C and +175°C for a total of 400 cycles. A ramp rate of 15°C/min and a dwell time of 5 minutes were used in accordance with the JEDEC Standard JESD22A104. All parts went through pre-conditioning prior to TC. All parts were loaded into trays.

Stress Test	Part Number	Voltage (V)	Die Size (mm x mm)	Test Condition	# of Failure	Sample Size (sample x lot)	Duration (Cycles)
TC	EPC2218A	80	L (3.5 x 1.95)	-55 to +175°C, Air	0	77 x 2	400
TC	EPC2204A	80	S (2.5 x 1.5)	-55 to +175°C, Air	0	77 x 1	400
TC	EPC2252	80	S (1.5 x 1.5)	-55 to +150°C, Air	0	77 x 1	1000

Table 4. Temperature Cycling Test

**Moisture Sensitivity Level**

Parts were subjected to 85% RH at 85°C for a soak period of 168 hours. Within 4 hours after the soak, the parts underwent three cycles of Pb-free reflow in accordance with the IPC/JEDEC joint Standard J-STD-020. These conditions correspond to a moisture sensitivity level 1, the most stringent level of moisture sensitivity testing.

Stress Test	Part Number	Voltage (V)	Die Size (mm x mm)	Test Condition	# of Failure	Sample Size (unit x lot)	Duration (Hours)
MSL1	EPC2218A	80	L (3.5 x 1.95)	T = 85°C, RH = 85%, 3x reflow	0	77 x 2	168
MSL1	EPC2204A	80	S (2.5 x 1.5)	T = 85°C, RH = 85%, 3x reflow	0	77 x 1	168
MSL1	EPC2252	80	S (1.5 x 1.5)	T = 85°C, RH = 85%, 3x reflow	0	77 x 3	168

Table 5. Moisture Sensitivity Level Test

**Electrostatic Discharge (ESD) Sensitivity Testing**

EPC2252 was tested for ESD sensitivity using both the human body model (HBM). Testing was conducted according to AEC Q101-001 and Q101-005 standards. Device parameters were measured before and after ESD testing. Results are shown in Table 6 below. EPC2252 passed HBM with a rating of 500 V. EPC2218A passed CDM with a 1000 V rating. Because smaller die size device is less susceptible to CDM damage at a given voltage compared to a larger die size device from the same product family. Therefore, EPC2252 and EPC2204A shall pass CDM with a 1000 V rating by matrix.

Stress Test	Part Number	Voltage (V)	Die Size (mm x mm)	Test Condition	# of Failure	Sample Size (unit x lot)
ESD-HBM	EPC2218A	80	L (3.5 x 1.95)	1000 V	0	10 x 1
ESD-HBM	EPC2204A	80	S (2.5 x 1.5)	500 V	0	10 x 1
ESD-HBM	EPC2252	80	S (1.5 x 1.5)	500 V	0	10 x 1
ESD-CDM	EPC2218A	80	L (3.5 x 1.95)	1000 V	0	10 x 1

Table 6. ESD HBM and CDM Tests

**Parametric Verification**

In accordance with AEC-Q101 requirements, device parameters were measured at -40°C, 25°C, and 150°C to ensure compliance with datasheet specifications over the entire temperature range. Additional parametric verification was performed 1 lot x 25 parts, for EPC2252.

Stress Test	Part Number	Voltage (V)	Die Size (mm x mm)	Test Condition	# of Failure	Sample Size (unit x lot)
PV	EPC2218A	80	L (3.5 x 1.95)	T = 40°C, T = 25°C, T = 150°C	0	25 x 3
PV	EPC2252	80	S (1.5 x 1.5)	T = 40°C, T = 25°C, T = 150°C	0	25 x 1

Table 7. Parametric Verification Tests

**Intermittent Operating Life**

In accordance with MIL-STD-750 (Method 1037), parts are power cycled over a  $\Delta T = 125^{\circ}\text{C}$  temperature range. Devices are heated through internal electrical power dissipation by biasing them in the linear mode, with combined gate and drain bias and a regulated drain current. With a 1-minute temperature ramp, and a 5-minute cool down, a minimum of 5000 cycles are required. Parts were assembled onto FR5 (high Tg FR4) adapter board with underfill material applied. (Underfill manufacturer: Henkels and part number: ECCOBOND-UF1173). The application of underfill material is to improve board level reliability, since it reduces the stress on the solder joints resulting from coefficient of thermal expansion (CTE) mismatches between the die and PCB. As seen in Table 8, one lot of EPC2252 were tested and all parts passed 5000 cycles.

Stress Test	Part Number	Voltage (V)	Die Size (mm x mm)	Test Condition	# of Failure	Sample Size (unit x lot)	Duration (Cycles)
IOL	<b>EPC2218A</b>	80	L (3.5 x 1.95)	$\Delta T_J = 125^{\circ}\text{C}$ ; ton / toff = 1 min / 5 min	0	77 x 3	5000
IOL	<b>EPC2252</b>	80	S (1.5 x 1.5)	$\Delta T_J = 125^{\circ}\text{C}$ ; ton / toff = 1 min / 5 min	0	77 x 1	5000

Table 8. Intermittent Operating Life Tests