Second Generation eGaN® FETs are Lead Free and Offer Improved Performance

Since March, 2011 Efficient Power Conversion Corporation (EPC) has launched a family of second generation enhancement mode gallium nitride (eGaN) FETs. All of these new products are lead free, halogen free, RoHS compliant, and have significant improvements in their overall performance. These lead free products join the family of eGaN FETs introduced in March, 2010.

Table 1 shows a comparison of key characteristics between the first generation and second generation 40 V, 100V and 200 V eGaN FETs [1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12].

In addition to the improvements shown in Table 1, there are several other areas of performance that have been enhanced in this new generation.

### Table 1

| Part Number | Package (mm) | RoHS & Halogen Free | \(T_{J(MAX)}\) (°C) | \(V_{DS}\) (max) | \(V_{GS}\) (max) | \(R_{DS(ON)}\) @5VGS (nC) | \(Q_{G}\) typ (nC) | \(Q_{G}\) max (nC) | \(Q_{GS}\) typ (nC) | \(Q_{GS}\) max (nC) | \(Q_{GD}\) typ (nC) | \(Q_{GD}\) max (nC) | \(Q_{oss}\) typ (nC) | \(Q_{oss}\) max (nC) | \(V_{TH}\) typ (V) | \(I_{D}\) Pulsed (A) | \(I_{L}\) (A) |
|-------------|-------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|---------------------|
| EPC1015     | LGA 4.1x1.6 | No                  | 125                 | 40                  | 6                   | 4                   | 11.6                | N/A                 | 3.8                 | N/A                 | 2.2                 | N/A                 | 18.5                | N/A                 | 1.4                 | 0                   | 100                 | 33                  |
| EPC2015     | LGA 4.1x1.6 | Yes                 | 150                 | 40                  | 6                   | 4                   | 10.5                | 11.6                | 3                   | 3.5                 | 2.2                 | 2.7                 | 18.5                | 22                  | 1.4                 | 0                   | 100                 | 33                  |
| EPC1014     | LGA 1.7x1.1 | No                  | 125                 | 40                  | 6                   | 16                  | 3                   | N/A                 | 1                   | N/A                 | 0.55                | N/A                 | 4.6                 | N/A                 | 1.4                 | 0                   | 40                  | 10                  |
| EPC2014     | LGA 1.7x1.1 | Yes                 | 150                 | 40                  | 6                   | 16                  | 2.5                 | 3.5                 | 0.57                | 0.7                 | 0.48                | 0.6                 | 4.8                 | 6.0                 | 1.4                 | 0                   | 40                  | 10                  |
| EPC1001     | LGA 4.1x1.6 | No                  | 125                 | 100                 | 6                   | 7                   | 10.5                | N/A                 | 3                   | N/A                 | 3.3                 | N/A                 | 32                  | N/A                 | 1.4                 | 0                   | 150                 | 25                  |
| EPC2001     | LGA 4.1x1.6 | Yes                 | 125                 | 100                 | 6                   | 7                   | 8                   | 10                  | 2.3                 | 2.8                 | 2.2                 | 2.7                 | 35                  | 40                  | 2.0                 | 14                  | 150                 | 25                  |
| EPC1007     | LGA 1.7x1.1 | No                  | 125                 | 100                 | 6                   | 7                   | 3                   | N/A                 | 0.75                | N/A                 | 1                   | N/A                 | 8                   | N/A                 | 1.4                 | 0                   | 25                  | 6                   |
| EPC2007     | LGA 1.7x1.1 | Yes                 | 125                 | 100                 | 6                   | 7                   | 3                   | N/A                 | 0.75                | N/A                 | 1                   | N/A                 | 8                   | N/A                 | 1.4                 | 0                   | 25                  | 6                   |
| EPC1010     | LGA 3.6x1.6 | No                  | 125                 | 200                 | 6                   | 25                  | 7.5                 | N/A                 | 1.5                 | N/A                 | 3.5                 | N/A                 | 40                  | N/A                 | 1.4                 | 0                   | 40                  | 12                  |
| EPC2010     | LGA 3.6x1.6 | Yes                 | 125                 | 200                 | 6                   | 25                  | 5                   | 7.5                 | 1.3                 | 2                   | 1.7                 | 2.2                 | 41                  | 48                  | 1.4                 | 0                   | 60                  | 12                  |
| EPC1012     | LGA 1.7x0.9 | No                  | 125                 | 200                 | 6                   | 100                 | 1.9                 | N/A                 | 0.37                | N/A                 | 0.9                 | N/A                 | 10                  | N/A                 | 1.4                 | 0                   | 12                  | 3                   |
| EPC2012     | LGA 1.7x0.9 | Yes                 | 125                 | 200                 | 6                   | 100                 | 1.5                 | 1.8                 | 0.33                | 0.41                | 0.57                | 0.75                | 11                  | 14                  | 1.4                 | 0                   | 15                  | 3                   |
EPC2001 Compared with EPC1001

The four figures on the following page compare the 100 V, 25 A EPC2001 (Figure 1) with the prior-generation EPC1001 (Figure 2) typical output and transfer characteristics. The new generation product performs significantly better at higher currents. In addition to less conduction loss at higher current, the new-generation EPC2001 has improved $R_{DS(ON)}$ at lower gate-source voltages (see Figures 3 and 4 comparisons below). This allows the user to realize the low $R_{DS(ON)}$ capability of the FETs with greater margin between the applied gate voltage and the $V_{GS(on)}$ of 6 V. $V_{GS}$ necessary for significant conduction current has also increased, thereby reducing turn off time and increasing dv/dt immunity.

**Figure 1:** EPC2001 (RoHS) typical output and transfer characteristics

**Figure 2:** EPC1001 typical output and transfer characteristics

**Figure 3:** EPC2001 $R_{DS(ON)}$ vs $V_{GS}$ for various current levels. These RoHS parts are fully enhanced at 40 A with 4 V on the gate.

**Figure 4:** EPC1001 $R_{DS(ON)}$ vs $V_{GS}$ for various current levels. These older generation parts require 5 V applied to the gate to be fully enhanced at 40 A.
EPC2007 Compared with EPC1007

The four figures below compare the 100 V, 6 A EPC2007 (Figure 5) with the prior-generation EPC1007 (Figure 6) typical output and transfer characteristics. The new generation product performs significantly better at higher currents. In addition to less conduction loss at higher current, the new-generation EPC2001 has improved $R_{DS(ON)}$ at lower gate-source voltages (see Figure 7 and 8 comparisons below). This allows the user to realize the low $R_{DS(ON)}$ capability of the FETs with greater margin between the applied gate voltage and the $V_{G(TEAM)}$ of 6 V. $V_{GS}$ necessary for significant conduction current has also increased, thereby reducing turn off time and increasing dv/dt immunity.

**Figure 5:** EPC2007 (RoHS) typical output and transfer characteristics

**Figure 6:** EPC1007 typical output and transfer characteristics

**Figure 7:** EPC2007 $R_{DS(ON)}$ vs $V_{GS}$ for various current levels. These RoHS parts are fully enhanced at 10 A with 4 V on the gate.

**Figure 8:** EPC1007 $R_{DS(ON)}$ vs $V_{GS}$ for various current levels. These older generation parts require 5 V applied to the gate to be fully enhanced at 10 A.
EPC2015 Compared with EPC1015

The EPC2015 is a 40 V, 33 A FET. The new generation product has been upgraded to an operating temperature of 150°C compared with 125°C for the prior generation, allowing the user more operating headroom. The graphs below compare the EPC2015 (Figure 9) with the prior-generation EPC1015 (Figure 10) typical output and transfer characteristics. As with the 100 V FETs discussed above, the new generation 40 V product performs significantly better at higher currents and increased VGS necessary for significant current conduction. The new-generation EPC2015 also has improved RDS(ON) at lower gate-source voltages (see comparisons in Figures 11 and 12).

![Figure 9: EPC2015 (RoHS) typical output and transfer characteristics](image)

![Figure 10: EPC1015 (RoHS) typical output and transfer characteristics](image)

![Figure 11: EPC2015 R_DS(ON) vs VGS for various currents. These RoHS parts are fully enhanced at 50 A with 4 V on the gate.](image)

![Figure 12: EPC1015 R_DS(ON) vs VGS for various currents. These older generation parts require 5 V applied to the gate to be fully enhanced at 50 A.](image)
EPC2014 Compared with EPC1014

The EPC2014 is a 40 V, 10 A FET. The new generation product has been upgraded to an operating temperature of 150°C compared with 125°C for the prior generation, allowing the user more operating headroom. The graphs below compare the EPC2014 (Figure 13) with the prior-generation EPC1014 (Figure 14) typical output and transfer characteristics. As with the FETs discussed above, the new generation 40 V product performs significantly better at higher currents and increased \( V_{GS} \), necessary for significant current conduction. The new-generation EPC2014 also has improved \( R_{DS(ON)} \) at lower gate-source voltages (see comparisons in Figures 15 and 16).

![Typical Output Characteristics](image1)

**Figure 13:** EPC2014 (RoHS) typical output and transfer characteristics

![Transfer Characteristics](image2)

**Figure 14:** EPC1014 typical output and transfer characteristics

![R\(_{DS(ON)}\) vs. \( V_{GS} \) for Various Currents](image3)

**Figure 15:** EPC2014 \( R_{DS(ON)} \) vs \( V_{GS} \) for various current levels. These RoHS parts are fully enhanced at 15 A with 4 V on the gate.

![R\(_{DS(ON)}\) vs. \( V_{GS} \) for Various Currents](image4)

**Figure 16:** EPC1014 \( R_{DS(ON)} \) vs \( V_{GS} \) for various current levels. These older generation parts require 5 V applied to the gate to be fully enhanced at 15 A.
EPC2010 Compared with EPC1010

The four figures below compare the 200 V, 12 A EPC2010 (Figure 17) with the prior-generation EPC1010 (Figure 18) typical output and transfer characteristics. Consistent with the four parts discussed above, the new generation 200 V product also performs significantly better at higher currents. The EPC2010 is also rated for 60 A maximum ID (pulsed) compared with only 40 A in the prior generation.

In addition to a higher pulsed current rating and less conduction loss at higher current, the new-generation EPC2010 has improved $R_{DS(ON)}$ at lower gate-source voltages (see Figure 19 and 20 comparisons on the following page). This allows the user to realize the low $R_{DS(ON)}$ capability of the FETs with greater margin between the applied gate voltage and the $V_{GS(MAX)}$ of 6 V. $V_{GS}$ necessary for significant conduction current has also increased, thereby reducing turn off time and increasing $dv/dt$ immunity.

Figure 17: EPC2010 (RoHS) typical output and transfer characteristics. Note that the EPC2010 is rated up to 60 A pulsed.

Figure 18: EPC1010 typical output and transfer characteristics.
EPC2012 Compared with EPC1012

The four figures below and on the following page compare the 200 V, 3 A EPC2012 (Figure 21) with the prior-generation EPC1012 (Figure 22) typical output and transfer characteristics. Consistent with the five parts discussed above, the new generation 200 V product also performs significantly better at higher currents. The EPC2012 is also rated for 15 A maximum ID (pulsed) compared with only 12 A in the prior generation.

EPC2010 Compared with EPC1012

The dv/dt immunity is further improved in the second-generation EPC2010 because of the significantly improved Miller ratio [13]. As can be seen in Table 1 above, the Miller ratio \((Q_{GD}/Q_{GS(VTH)})\) has improved from a typical value of 2.3 down to a value of 1.3 for the EPC2010.

EPC2012 (RoHS) typical output and transfer characteristics. Note that the EPC2012 is rated up to 15 A pulsed.
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RDS(ON) vs. VGS for Various Currents

Transfer Characteristics

In addition to a higher pulsed current rating and less conduction loss at higher current, the new-generation EPC2012 has improved R_{DS(ON)} at lower gate-source voltages (see Figure 23 and 24 comparisons below). This allows the user to realize the low R_{DS(ON)} capability of the FETs with greater margin between the applied gate voltage and the V_{GS(MAX)} of 6 V. V_{GS}, necessary for significant conduction current has also increased, thereby reducing turn off time and increasing dv/dt immunity.

The dv/dt immunity is further improved in the second-generation EPC2012 because of the significantly improved Miller ratio [13]. As can be seen in Table 1 above, the Miller ratio (Q_G/Q_{GS}(V_{TH})) has improved from a typical value of 2.4 down to a value of 1.8 for the EPC2012.
New Technical Information

The data sheets for the EPC2XXX series of lead free eGaN FETs, starting with the EPC2001, EPC2007, EPC2015, EPC2014, EPC2010 and EPC2012 have additional information to help the designer get the maximum performance from the product. Thermal resistance data is supplied for both DC and transient operation as shown in Figures 25 and 26 below [14].

### EPC2001 and EPC2015

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### EPC2010

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### EPC2012, EPC2014 and EPC2007

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Note 1: $R_{JA}$ is determined with the device mounted on one square inch of copper pad, single layer 2 oz. copper on FR4 board. See http://epc-co.com/epc/documents/product-training/Appnote_Thermal_Performance_of_eGaN_FETS.pdf for details.

*Figure 25: Typical thermal resistance for EPC2001, EPC2007, EPC2015, EPC2014, EPC2010 and EPC2012.*

#### Normalized Maximum Transient Thermal Impedance

*Figure 26: Normalized $Z_{JB}$ Curve Set for EPC2XXX Products*
Assembly Considerations for Second Generation eGaN FETs

There are three physical changes to the new generation of lead-free product.

The first change is that there is a connection to the silicon substrate that has been brought to the surface (see Figures 27, 28, 29 and 30). It is advised that the substrate be connected to source potential to get the maximum dynamic performance from the device.

The second change is the width of the solder bars. The EPC2001, EPC2007, EPC2014 and EPC2015 all have 200 μm wide solder bars compared with 250 μm in the prior generation. The EPC2010 and EPC2012 both have a 250 μm wide solder bar compared with 300 μm in the prior generation.

The third change is that the height of the solder bars has been increased from 70μm +/-20 to 100 μm +/- 20 for all the new generation parts. The added height allows for greater post-assembly clearance between the FET and the PCB. This clearance makes it easier to clean out foreign materials and avoids the harmful accumulation of particles.

Summary

The new-generation of eGaN FETs are lead free and halogen free and have improved electrical performance, matched with additional support documentation to help the system designer deliver leading edge eGaN FET based product faster and with less engineering effort. These products maintain “backward compatibility” with the prior generation of eGaN FETs from EPC [15].