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

EFFICIENT POWER CONVERSION

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}	V_{GS} (max)	Max $R_{DS(ON)}$ @5V_{GS}	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	Q_{RR} (nC)	I_D (A) Pulsed	I_D (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
New! 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
New! EPC2014	LGA 1.7x1.1	Yes	150	40	6	16	2.5	2.8	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
New! EPC2001	LGA 4.1x1.6	Yes	125	100	6	7	8	10	2.3	2.8	2.2	2.7	35	40	1.4	0	150	25
EPC1007	LGA 1.7x1.1	No	125	100	6	30	2.7	N/A	0.75	N/A	1	N/A	8	N/A	1.4	0	25	6
New! EPC2007	LGA 1.7x1.1	Yes	125	100	6	30	2.1	2.7	0.5	0.7	0.6	1.2	10	15	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
New! 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
New! 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 $V_{GS(MAX)}$ of 6 V. V_{GS} necessary for significant conduction current has also increased, thereby reducing turn off time and increasing dv/dt immunity.

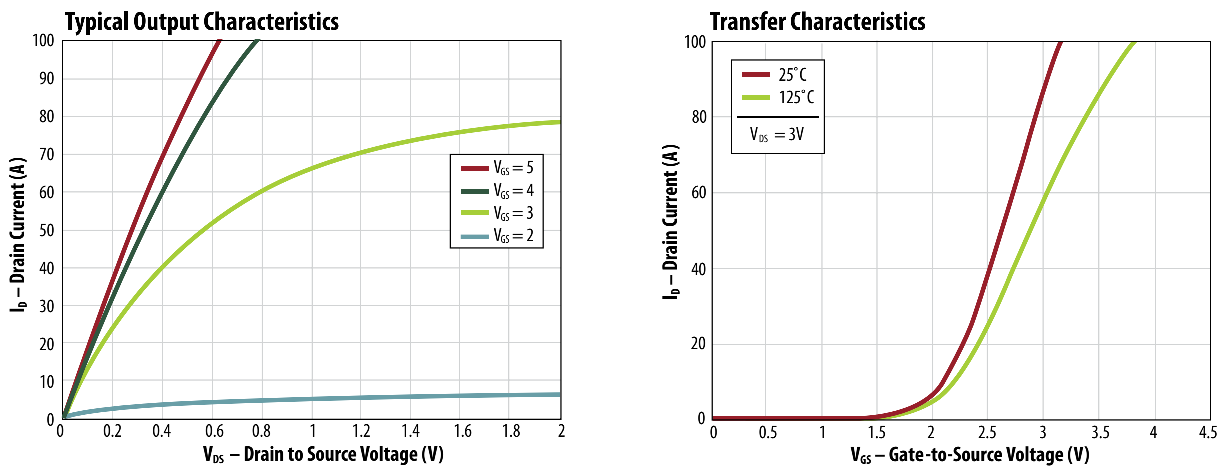

Figure 1: EPC2001(RoHS) typical output and transfer characteristics

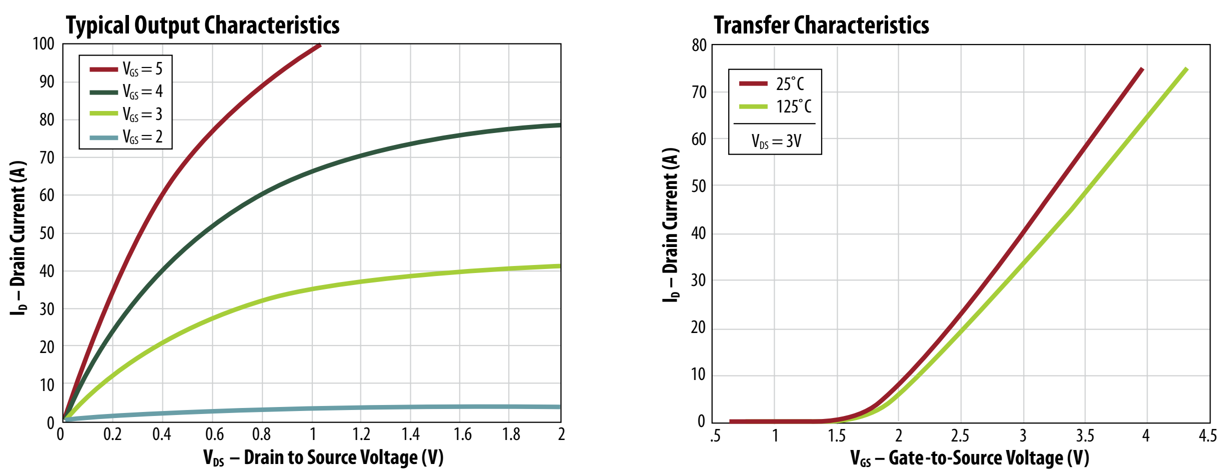

Figure 2: EPC1001 typical output and transfer characteristics

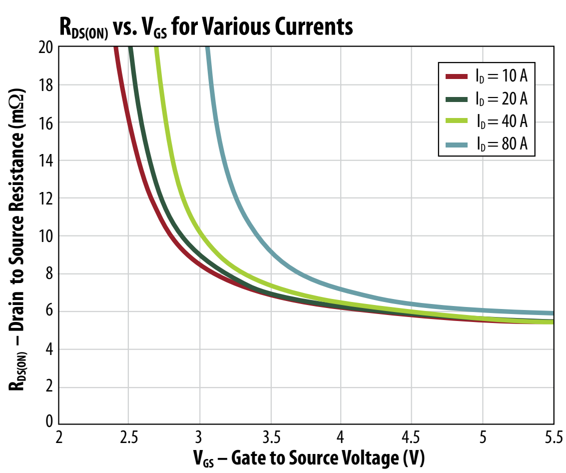

Figure 3: EPC2001 $R_{DS(ON}$ vs V_{GS} for various current levels. These RoHS parts are fully enhanced at 40 A with 4 V on the gate.

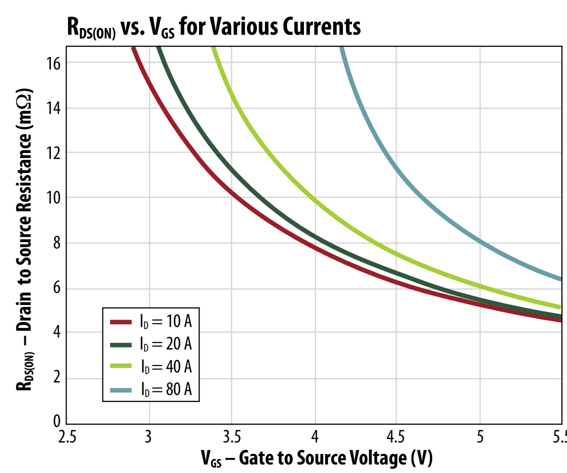

Figure 4: EPC1001 $R_{DS(ON}$ vs V_{GS} for various current levels. These older generation parts require 5 V applied to the gate to be fully enhanced at 40 A.

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 $V_{GS(MAX)}$ of 6 V. V_{GS} necessary for significant conduction current has also increased, thereby reducing turn off time and increasing dv/dt immunity.

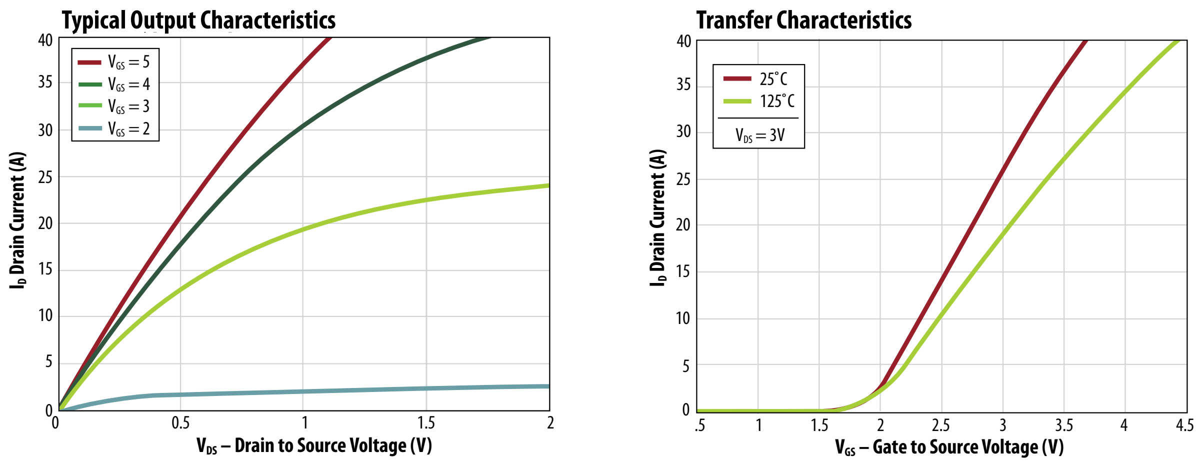

Figure 5: EPC2007 (RoHS) typical output and transfer characteristics

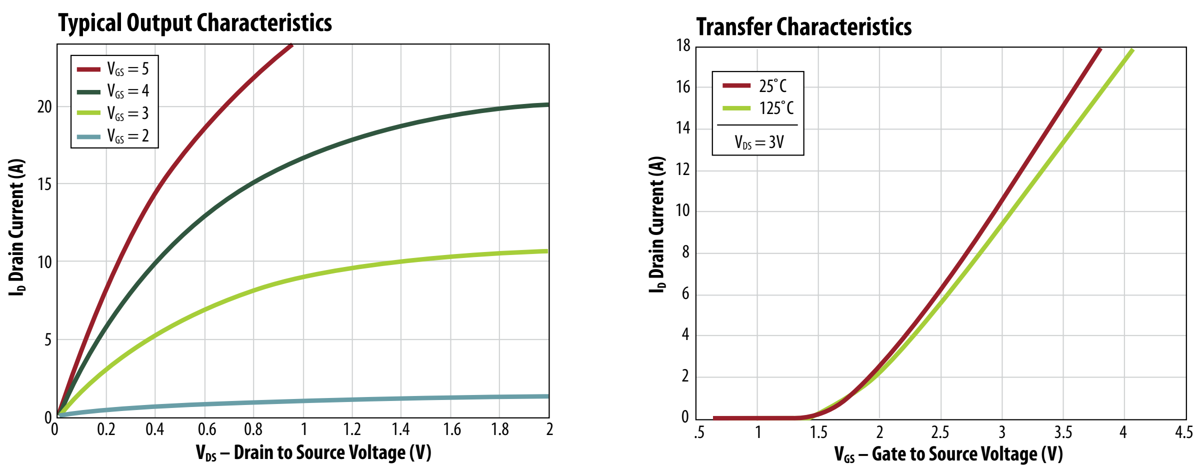

Figure 6: EPC1007 typical output and transfer characteristics

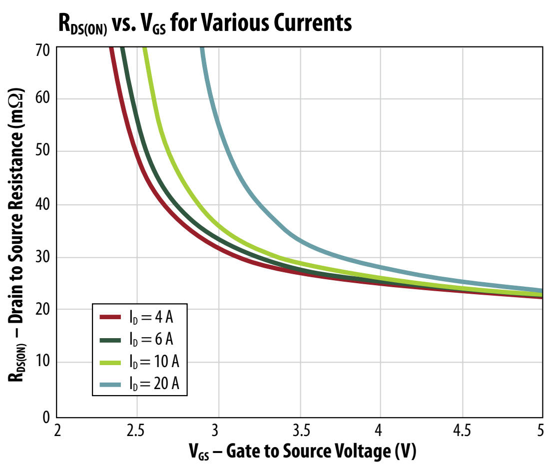

Figure 7: EPC2007 $R_{DS(ON)}$ vs V_{GS} for various current levels. These RoHS parts are fully enhanced at 10 A with 4 V on the gate.

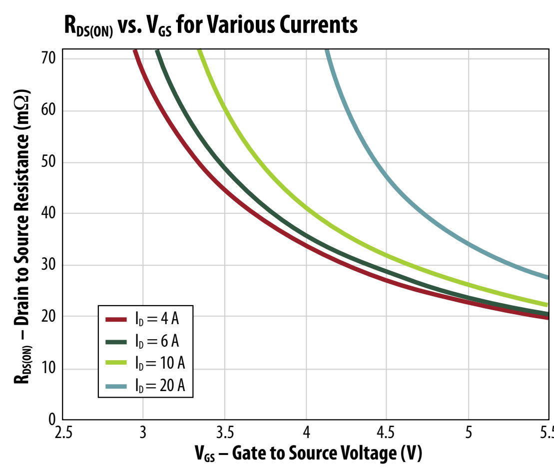

Figure 8: EPC1007 $R_{DS(ON)}$ vs V_{GS} for various current levels. These older generation parts require 5 V applied to the gate to be fully enhanced at 10 A.

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 V_{GS} necessary for significant current conduction. The new-generation EPC2015 also has improved $R_{DS(ON)}$ at lower gate-source voltages (see comparisons in Figures 11 and 12).

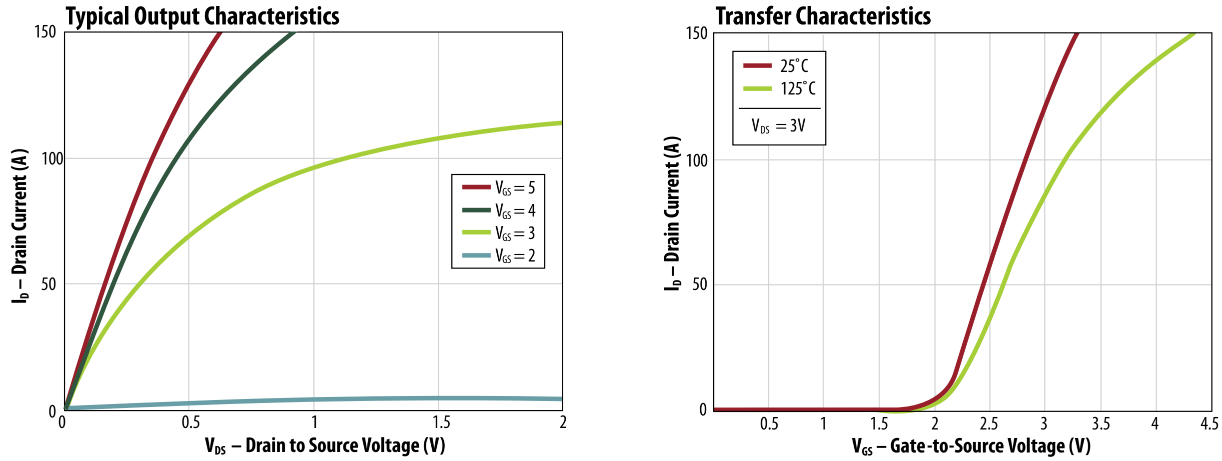

Figure 9: EPC2015 (RoHS) typical output and transfer characteristics

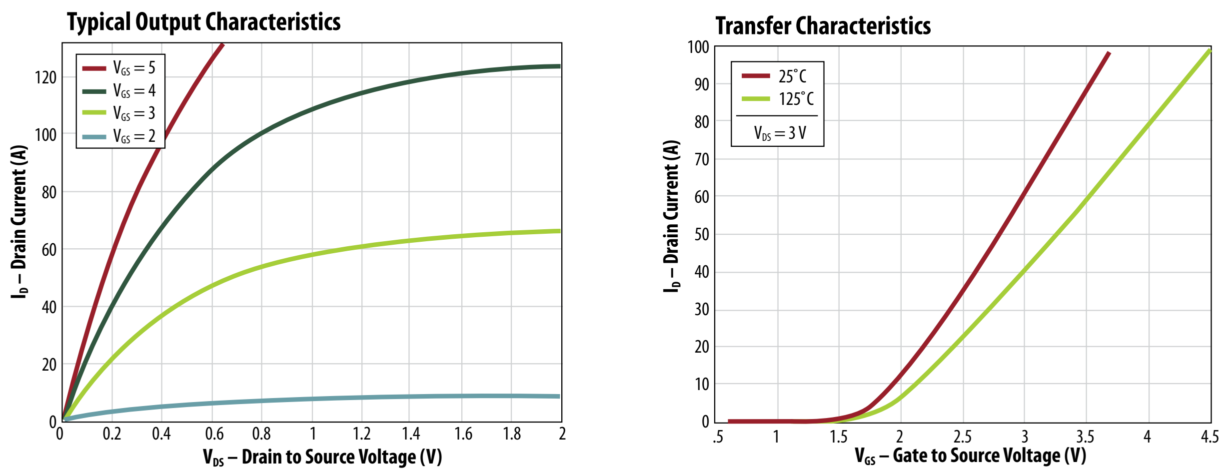

Figure 10: EPC1015 (RoHS) typical output and transfer characteristics

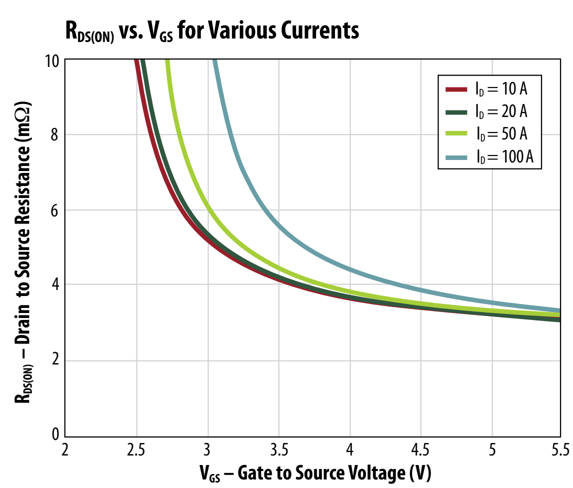

Figure 11: EPC2015 $R_{DS(ON)}$ vs V_{GS} for various current levels. These RoHS parts are fully enhanced at 50 A with 4 V on the gate.

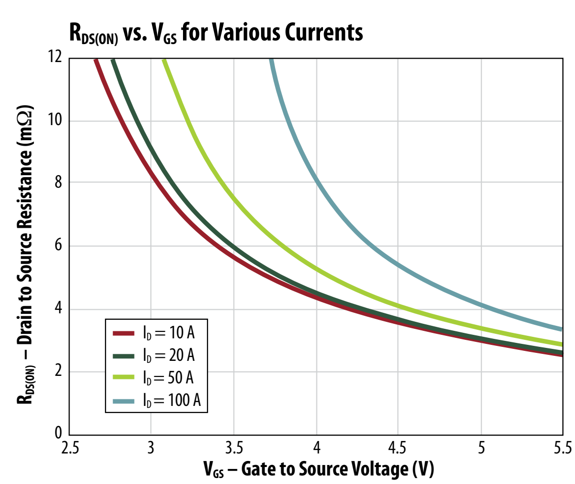

Figure 12: EPC1015 $R_{DS(ON)}$ vs V_{GS} for various current levels. These older generation parts require 5 V applied to the gate to be fully enhanced at 50 A.

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).

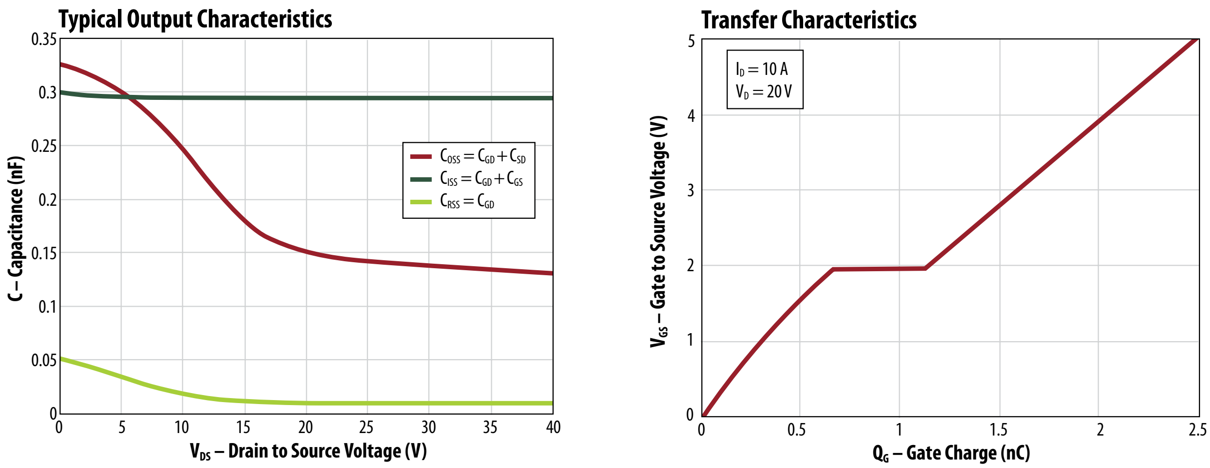

Figure 13: EPC2014 (RoHS) typical output and transfer characteristics

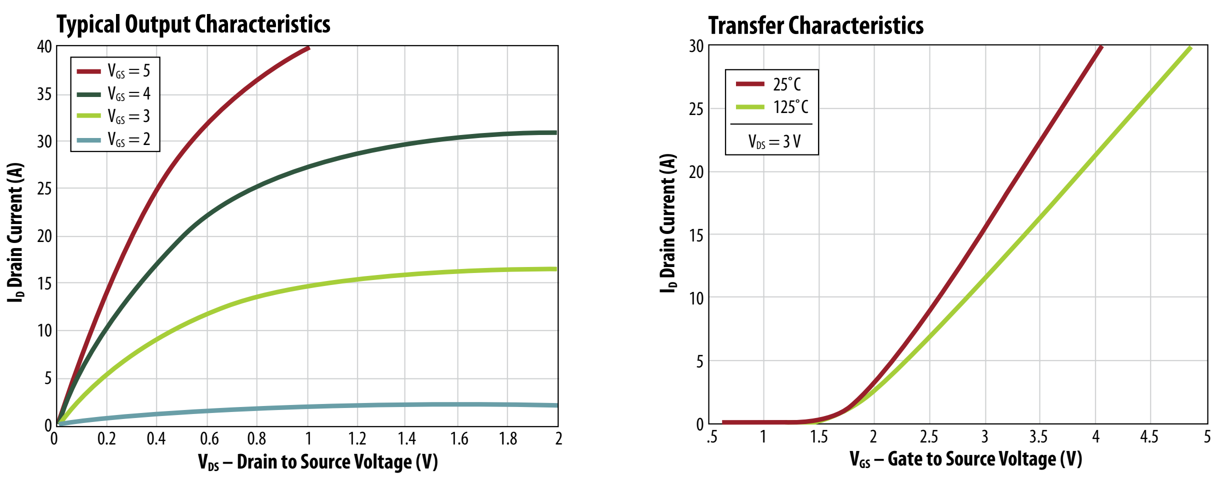

Figure 14: EPC1014 typical output and transfer characteristics

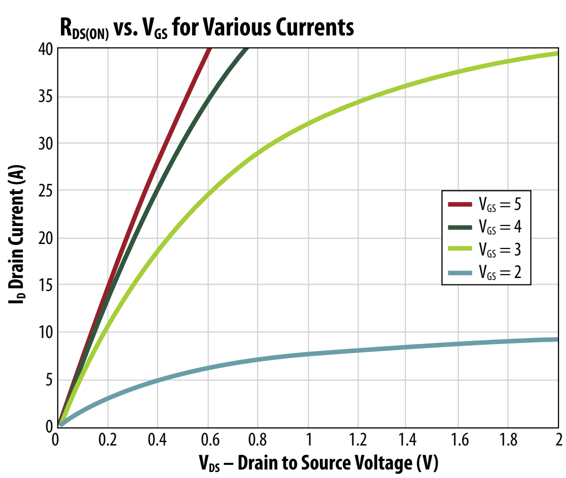

Figure 15: EPC2014 $R_{DS(ON)}$ vs V_{GS} for various current levels. These RoHS parts are fully enhanced at 15 A with 4 V on the gate.

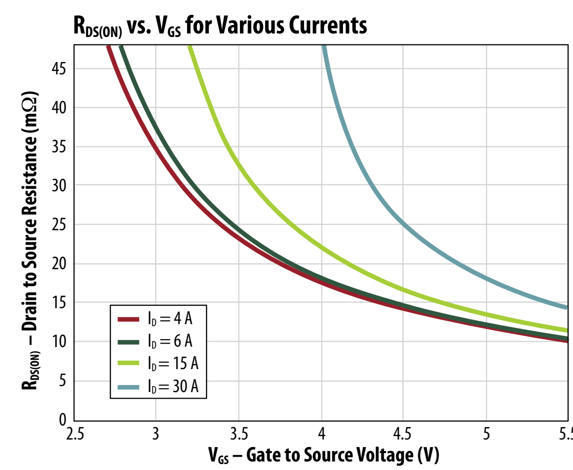

Figure 16: EPC1014 $R_{DS(ON)}$ vs V_{GS} for various current levels. These older generation parts require 5 V applied to the gate to be fully enhanced at 15 A.

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.

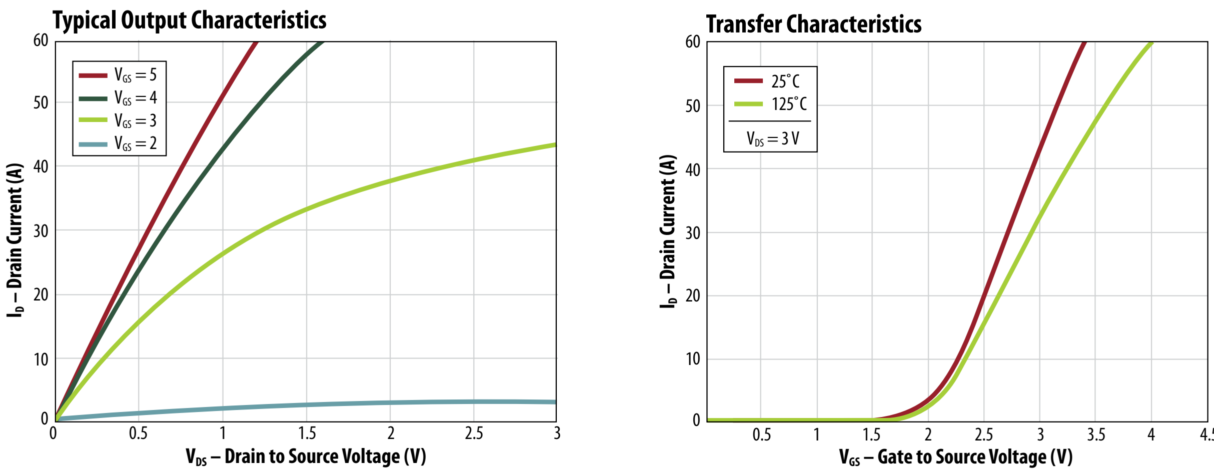

Figure 17: EPC2010 (RoHS) typical output and transfer characteristics. Note that the EPC2010 is rated up to 60 A pulsed.

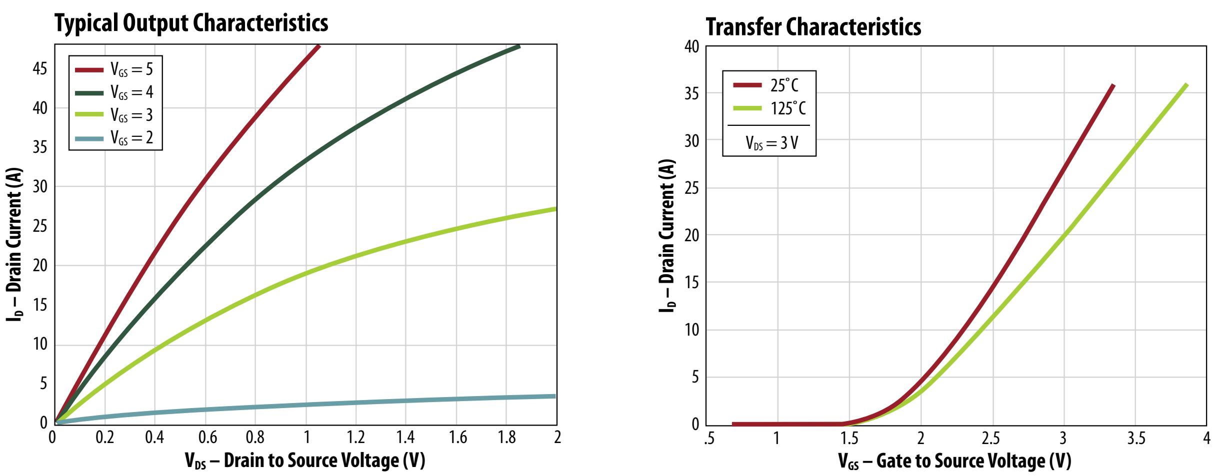

Figure 18: EPC1010 typical output and transfer characteristics

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 Figure19 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.

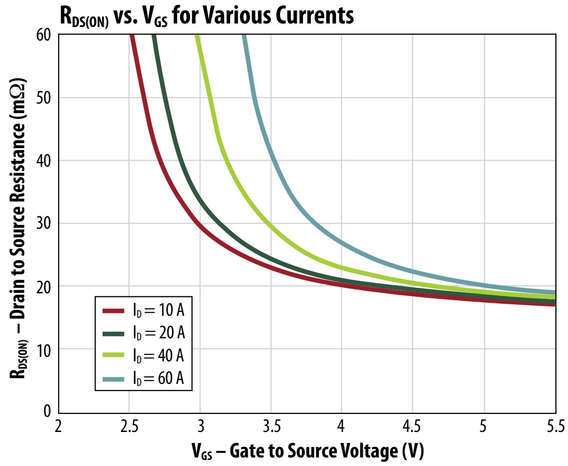

Figure 19: EPC2010 $R_{DS(ON)}$ vs V_{GS} for various current levels. These RoHS parts are fully enhanced at 20 A with 4 V on the gate.

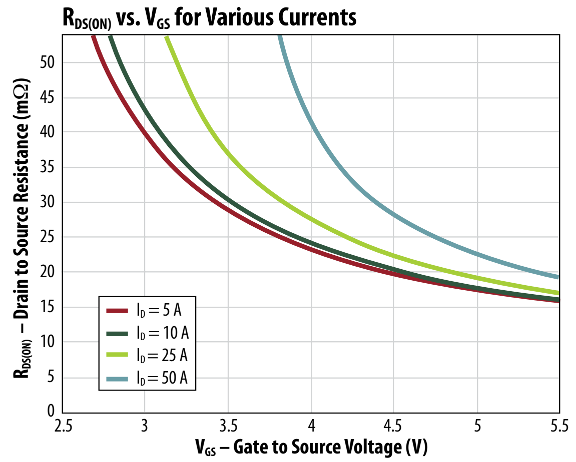

Figure 20: EPC1010 $R_{DS(ON)}$ vs V_{GS} for various current levels. These older generation parts require 5 V applied to the gate to be fully enhanced at 20 A.

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 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.

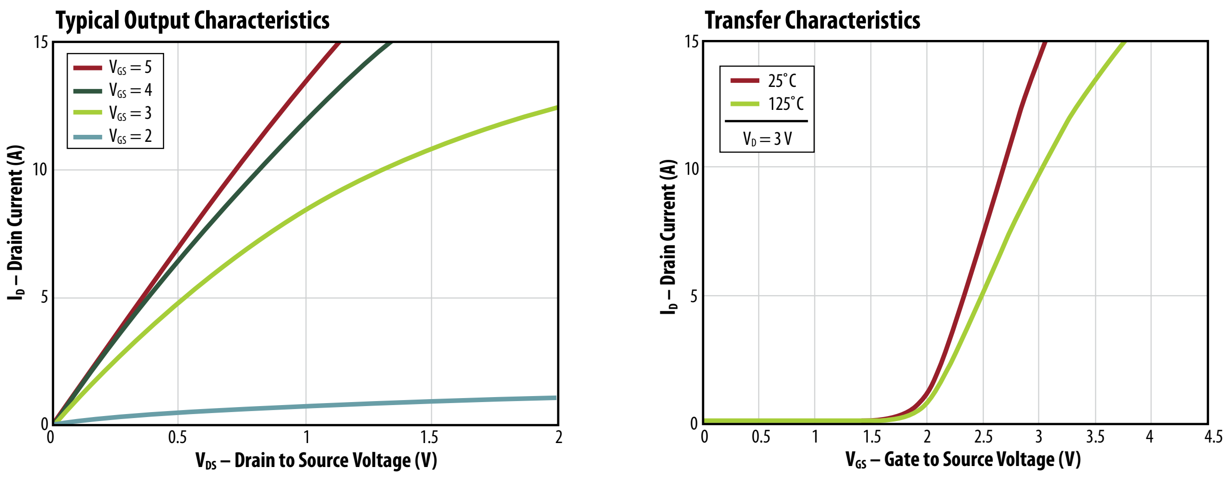

Figure 21: EPC2012 (RoHS) typical output and transfer characteristics. Note that the EPC2012 is rated up to 15 A pulsed.

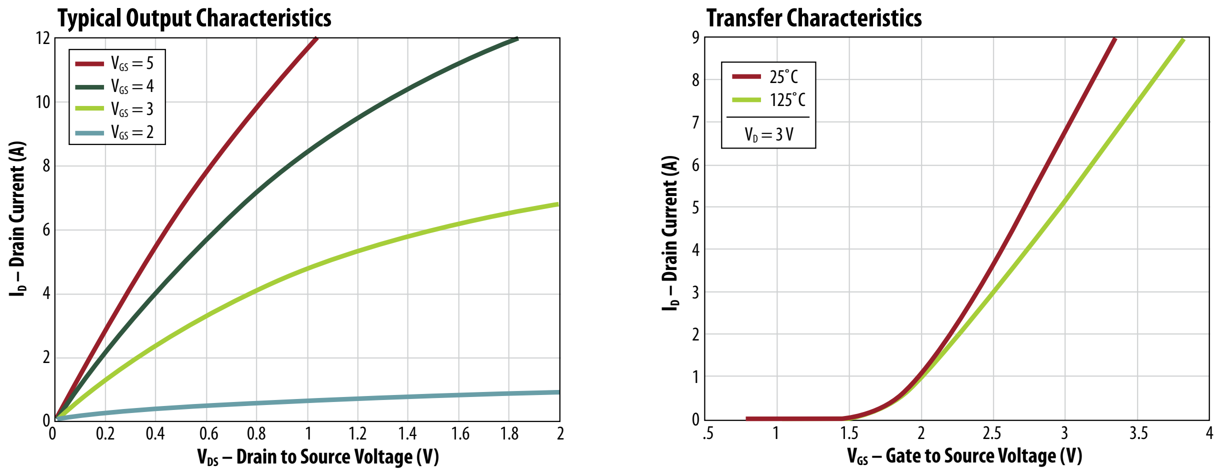

Figure 22: EPC1012 typical output and transfer characteristics

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.

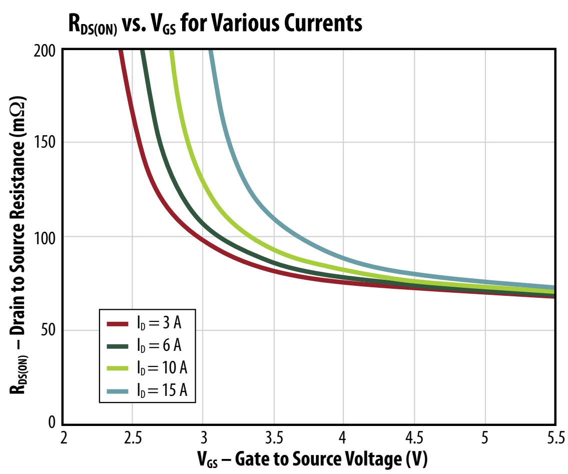

Figure 23: EPC2012 $R_{DS(ON)}$ vs V_{GS} for various current levels. These RoHS parts are fully enhanced at 10 A with 4 V on the gate.

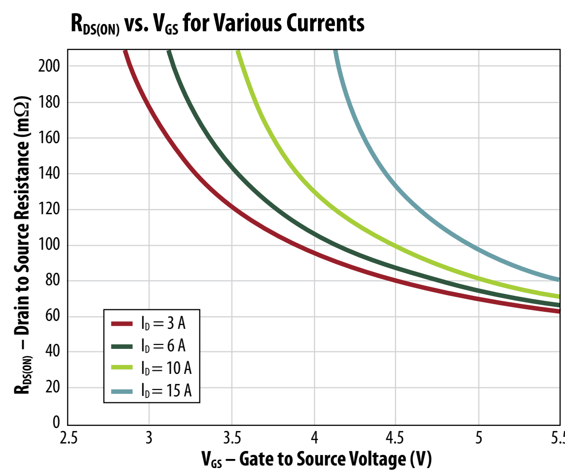

Figure 24: EPC1012 $R_{DS(ON)}$ vs V_{GS} for various current levels. These older generation parts require 5 V applied to the gate to be fully enhanced at 10 A.

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 ($Q_{GD}/Q_{GS}(V_{TH})$) 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

Thermal Characteristics			
		TYP	
$R_{\theta JC}$	Thermal Resistance, Junction to Case	1.6	°C/W
$R_{\theta JB}$	Thermal Resistance, Junction to Board	15	°C/W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient (Note 1)	54	°C/W

EPC2010

Thermal Characteristics			
		TYP	
$R_{\theta JC}$	Thermal Resistance, Junction to Case	1.8	°C/W
$R_{\theta JB}$	Thermal Resistance, Junction to Board	16	°C/W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient (Note 1)	56	°C/W

EPC2012, EPC2014 and EPC2007

Thermal Characteristics			
		TYP	
$R_{\theta JC}$	Thermal Resistance, Junction to Case	8.2	°C/W
$R_{\theta JB}$	Thermal Resistance, Junction to Board	36	°C/W
$R_{\theta JA}$	Thermal Resistance, Junction to Ambient (Note 1)	85	°C/W

Note 1: $R_{\theta JA}$ is determinged 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.

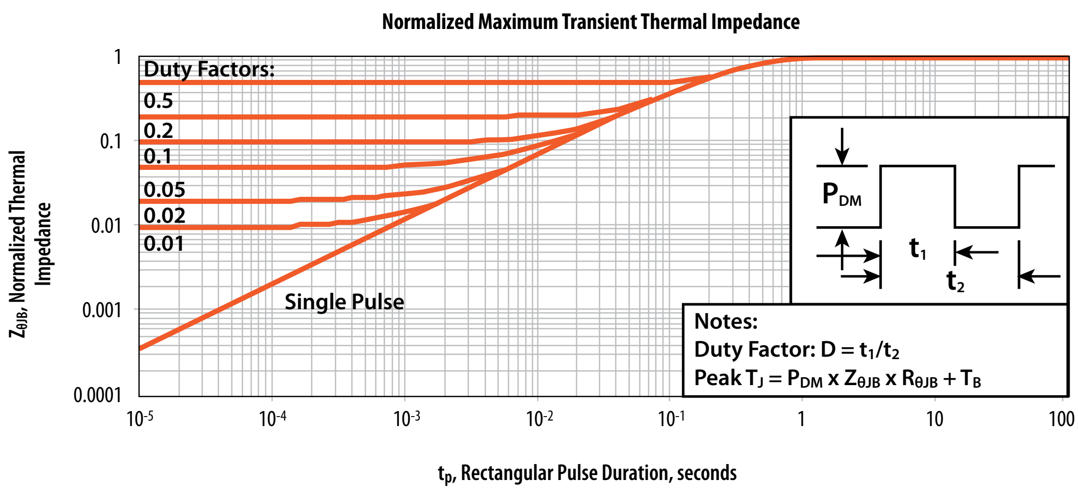

Figure 26: Normalized ZθJB Curve Set for EPC2XXX Products

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].

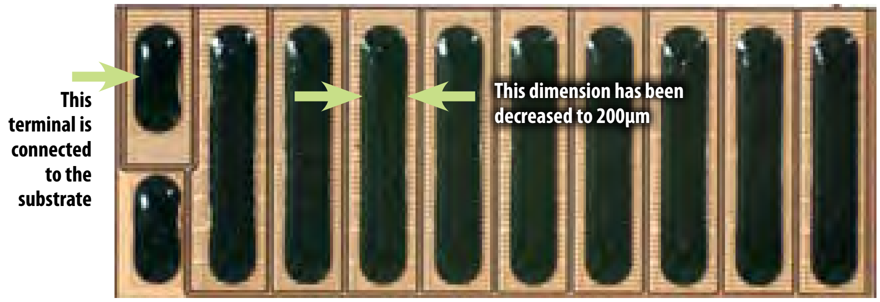

Figure 27: Magnified die photo of EPC2015 or EPC2001 indicating the solder bar that is connected to the silicon substrate and the decreased solder bar width.

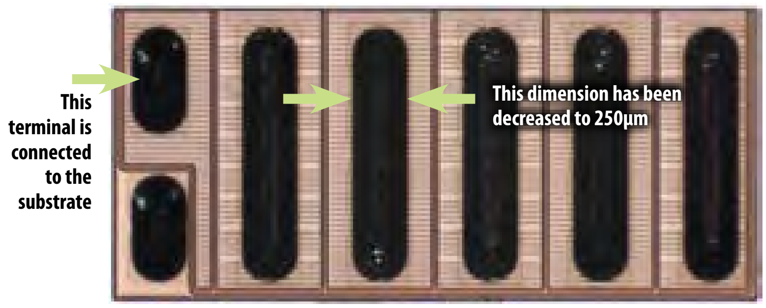

Figure 28: Magnified die photo of EPC2010 indicating the solder bar that is connected to the silicon substrate and the decreased solder bar width.

Figure 29: Magnified die photo of EPC2014 and EPC2007 indicating the solder bar that is connected to the silicon substrate and the decreased solder bar width.

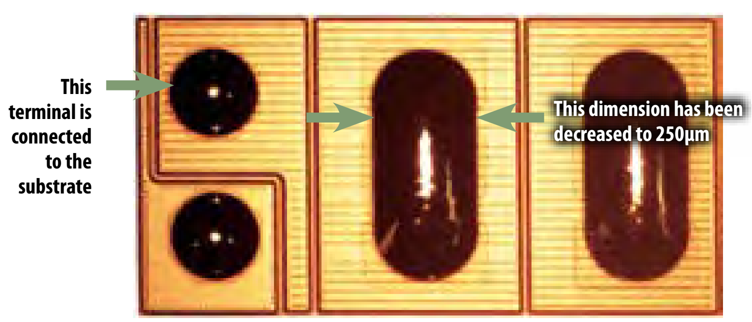

Figure 30: Magnified die photo of EPC2012 indicating the solder bar that is connected to the silicon substrate and the decreased solder bar width.

[1] http://epc-co.com/epc/documents/datasheets/EPC1001_datasheet_final.pdf

[2] http://epc-co.com/epc/documents/datasheets/EPC2001_datasheet_final.pdf

[3] http://epc-co.com/epc/documents/datasheets/EPC1015_datasheet_final.pdf

[4] http://epc-co.com/epc/documents/datasheets/EPC2015_datasheet_final.pdf

[5] http://epc-co.com/epc/documents/datasheets/EPC1010_datasheet_final.pdf

[6] http://epc-co.com/epc/documents/datasheets/EPC2010_datasheet_final.pdf

[7] http://epc-co.com/epc/documents/datasheets/EPC1012_datasheet_final.pdf

[8] http://epc-co.com/epc/documents/datasheets/EPC2012_datasheet_final.pdf

[9] http://epc-co.com/epc/documents/datasheets/EPC1014_datasheet_final.pdf

[10] http://epc-co.com/epc/documents/datasheets/EPC2014_datasheet_final.pdf

[11] http://epc-co.com/epc/documents/datasheets/EPC1007_datasheet_final.pdf

[12] http://epc-co.com/epc/documents/datasheets/EPC2007_datasheet_final.pdf

[13] Johan Strydom, "The eGaN FET-Silicon Power Shoot-Out: 2: Drivers, Layout", Power Electronics Technology, January 1, 2011, http://powerelectronics.com/power_semiconductors/first-article-series-gallium-nitride-201101/

[14] John Worman and Yanping Ma, "Thermal Performance of EPC eGaN™ FETs", http://epc-co.com/epc/documents/product-training/Appnote_Thermal_Performance_of_eGaN_FETs.pdf

[15] http://epc-co.com/epc/Products/eGaNFETs.aspx