# Characterization of Gallium-Nitride Based Power Transistors


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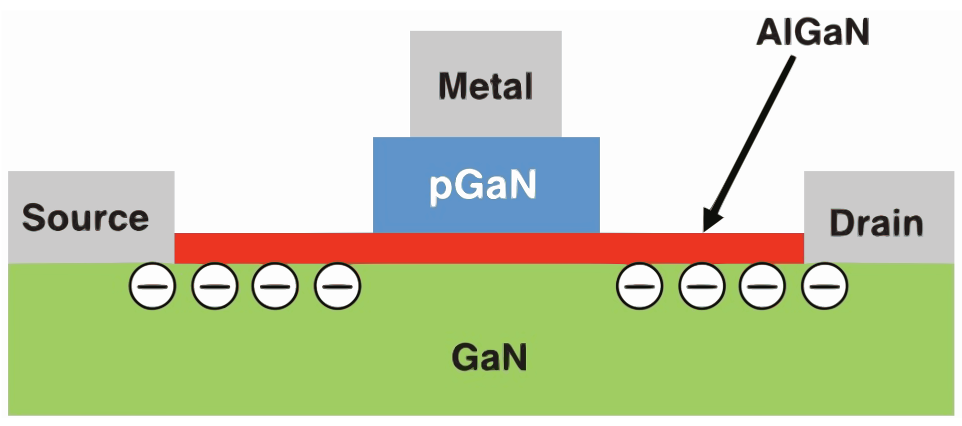
## Abstract

Wide band-gap semiconductor devices such as Silicon Carbide (SiC) and Gallium Nitride (GaN) become widespread in power applications due to their higher efficiency and higher transient speed comparison to Silicon (Si) based semiconductors. The fast transient speed of the wide band-gap semiconductors leads to potentially harmful oscillations in circuitry which makes the characterization of the wide band-gap semiconductors essential. Also, the unique reverse conduction behavior of the GaN Field Effect Transistors (GaNFETs) requires to understand how the device channel is activated when reverse bias is applied. In this study, characterization of a 650V enhancement-mode GaN power transistor is investigated.

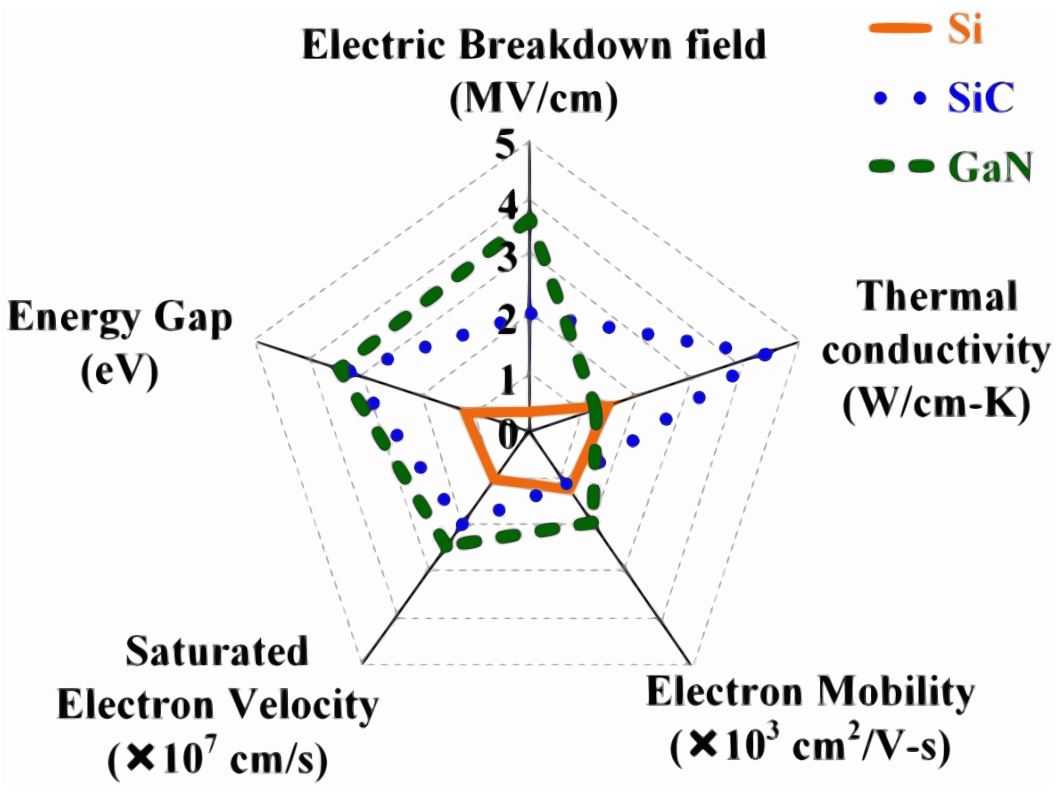

## GaNFET Structure




When GaN/AlGaN contact is created, a 2 dimensional electron gas (2DEG) cloud emerges in GaN layer due to piezoelectricity caused by crystal structure.

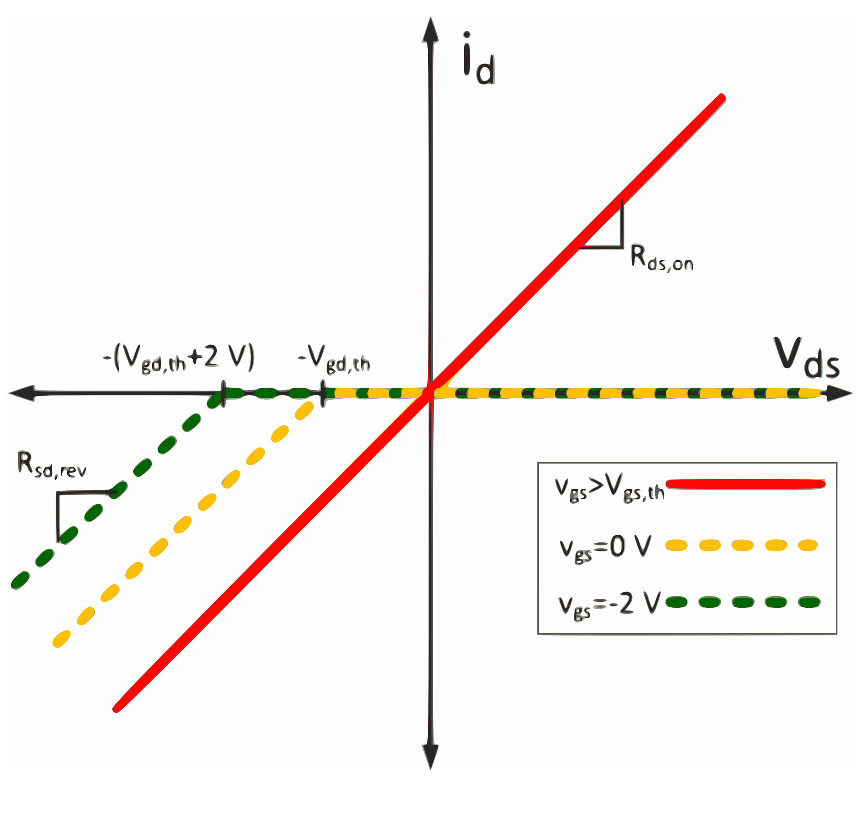
## Advantages of GaNFETs

650V / 30A GaN Transistor

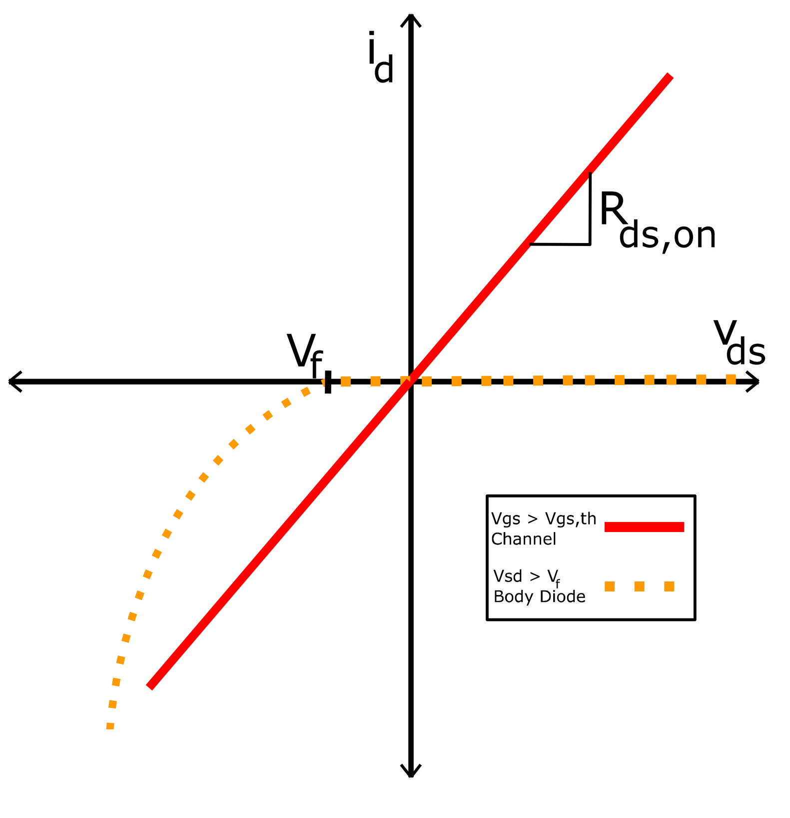



- ✓ Smaller package size leading to lower parasitics
- ✓ Increased power density
- ✓ Faster switching transition
- ✓ Lower conduction loss

## Unique Reverse Conduction Characteristic



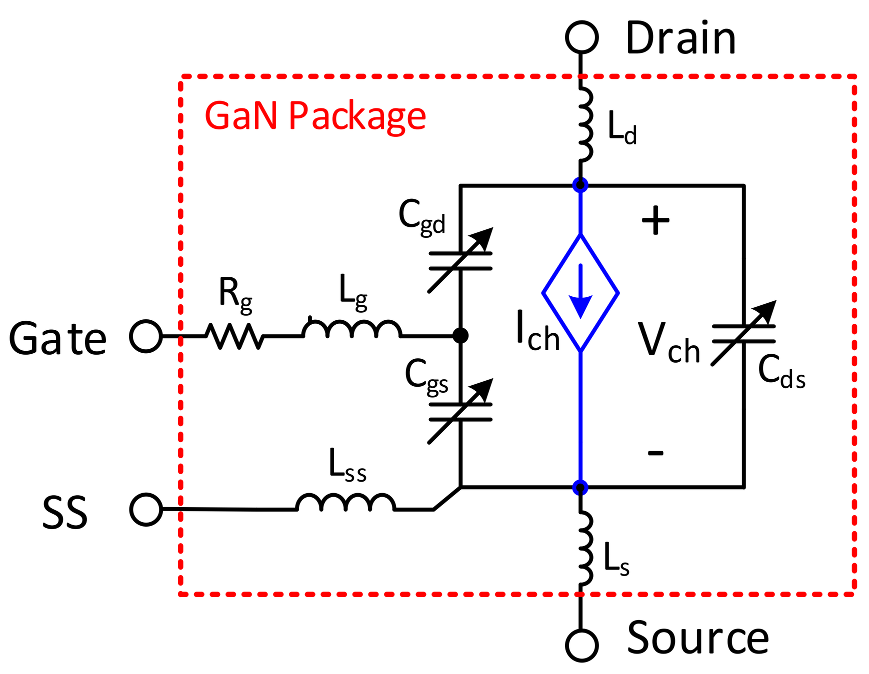
GaNFET Characteristic



Power MOSFET Characteristic

A GaNFET conducts in forward direction if and only if the gate-source bias is positive. However, for any level of gate-source bias voltage, the channel is activated if a reverse bias is applied through the drain-source terminals. Moreover, if the applied gate-source bias voltage is reduced further, the reverse conduction losses increase significantly for dead time bands resulting efficiency for high-frequency switching applications.

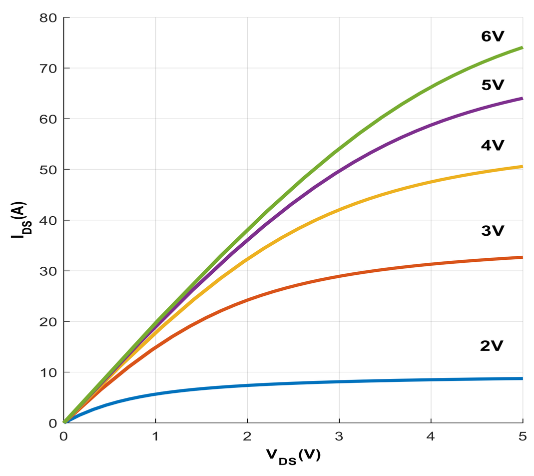
## Behavioral GaNFET Model



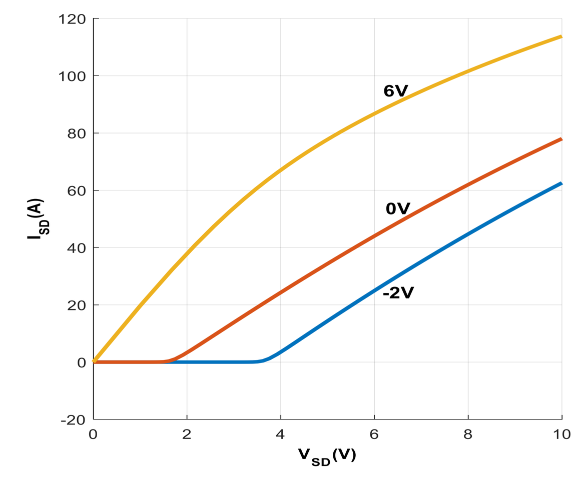

Behavioral model involves both static and dynamic states of GaNFET.

The **static state** means the channel current is constant as a result of constant gate-source & drain-source biases. On the contrary, the **dynamic state** is experienced when gate-source or drain-source bias voltages are changed, so a turn-on or turn-off process is going on.

### Static Model Results



Forward Conduction



Reverse Conduction

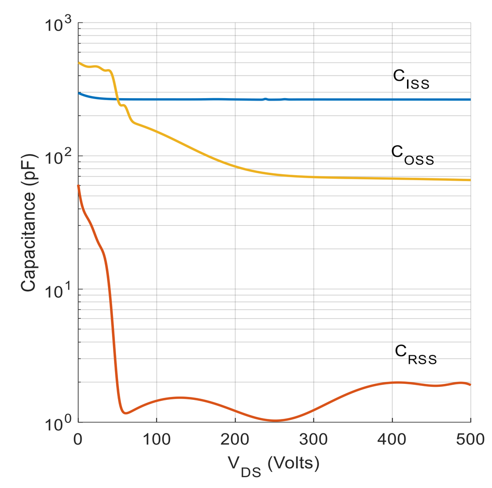
<u>Forward Conduction Equation</u>

$$I_{ds} = K_1(T) * \ln\left[1 + e^{\left(\frac{V_{gs}-V_{th}}{K_2}\right)}\right] * \frac{V_{ds}}{1 + \max\left(K_4 + K_5 * (V_{gs} + K_6), K_7\right) * V_{ds}}, K_i \text{ are constant}$$

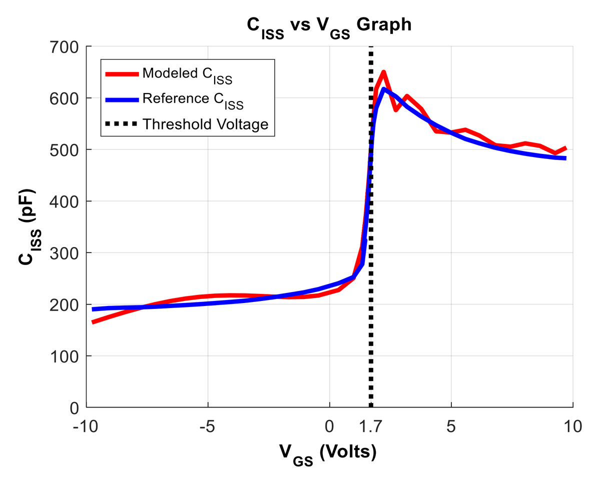
<u>Reverse Conduction Equation</u>

$$I_{ds} = -K_1(T) * \ln\left[1 + e^{\left(\frac{V_{gd}-V_{th}}{K_8}\right)}\right] * \frac{V_{sd}}{1 + \max\left(K_4 + K_5 * (V_{gd} + K_9), K_7\right) * V_{sd}}, K_i \text{ are constant}$$

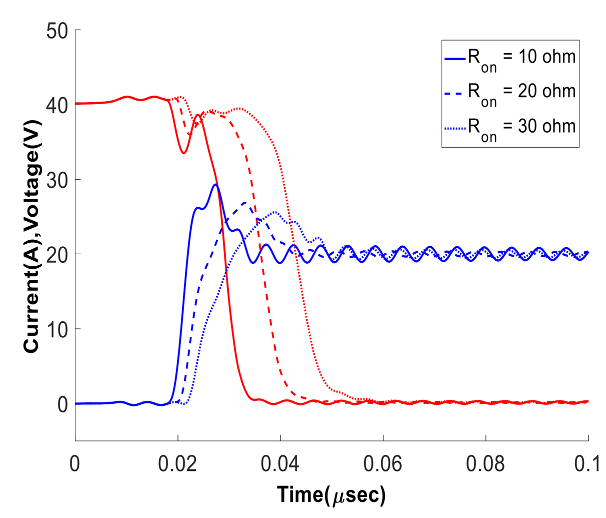
### Dynamic Model Results



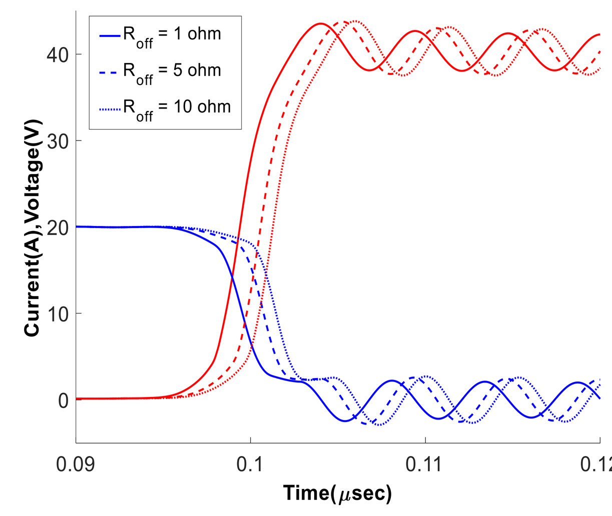
Capacitances vs VDS



CISS vs VGS



Turn-On Waveform



Turn-off Waveform

## Conclusion

In this study, the general structure of an enhancement mode GaN transistor is shared. Since the GaN transistors are wide bandgap transistors it is possible to manufacture them in small package sizes which reduces parasitics components significantly and also device losses. A model is created in Simulink® platform to analyse the switching performances of GaNFETs. The static and dynamic results of the model clearly show the capabilities of GaN transistors.


## References

[1] GaN Transistors for Efficient Power Conversion. (2014).
[2] Jones, E. A., Wang, F. F., & Costinett, D. (2016). Review of Commercial GaN Power Devices and GaN-Based Converter Design Challenges. IEEE Journal of Emerging and Selected Topics in Power Electronics, 4(3), 707–719.
[3] GaN Systems, "GS66508B Bottom-side cooled 650 V E-mode GaN transistor Preliminary Datasheet," pp. 1–16, 2018.