Effects of high switching speed on driving semiconductors and on Insulation Lifetime
Advantages of fast switching

- Smaller formfactor
- Less ressources
- Higher efficency

2”x 4”
≈1KW/dm³

6,3” x 4”
≈250W/dm³
Actual switching speed (600 V Class)

- GaN HEMT > 100Mhz (Datasheet)
- SIC Mosfet several kA/µs
- Superjunction Mosfet >100V/ns
- Trench IGBTs >20V/ns
Transistor basics

With a low Voltage VGS in the range of 5-20V you switch high Voltage VDS
Transistor basics

\[-V = L \frac{di}{dt}\]

10A/ns is possible with GaN (Datasheet)

\[L_{\text{emitter}} = 15 \text{ nH (approx. 2.5 cm route on PCB)}\]

\[-V = 15\text{nH} \times 10\text{A/ns} = \textbf{150V}\]

Via Inductivity ≈1.2 nH

\[-V = 1,2\text{nH} \times 10\text{A/ns} = \textbf{12V}\]
Transistor basics

Additional influences of other bridge legs
Transistor basics

Eliminating the influence of layout inductivity with isolated gate drivers and isolated power supplies.
Transistor basics

Eliminating the influence of layout inductivity with isolated gate drivers and isolated power supplies and Kelvin contacts
Transistor basics

Negative gate source voltage helps to avoid unwanted turn on due to Miller capacitance. Further benefits only possible with driver integration.
GaN on CMOS

www.ganoncmos.eu
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Meaning</th>
<th>Typical values</th>
</tr>
</thead>
<tbody>
<tr>
<td>DTI</td>
<td>Distance through Isolation</td>
<td>sometimes &lt; 10µm</td>
</tr>
<tr>
<td>Cr</td>
<td>Creepage</td>
<td>several mm</td>
</tr>
<tr>
<td>Cl</td>
<td>Clearance</td>
<td>several mm</td>
</tr>
<tr>
<td>V IORM</td>
<td>Maximum working insulation Voltage</td>
<td>600-2500 Vpeak</td>
</tr>
<tr>
<td>V PR</td>
<td>Production Test Voltage (1 sec)</td>
<td>VIORM x 1,875</td>
</tr>
<tr>
<td>V IOTM</td>
<td>Sinusoidal overvoltage for 60 seconds</td>
<td>several kV</td>
</tr>
<tr>
<td>V Surge</td>
<td>1,2µs/50µs Surge Voltage</td>
<td>several kV</td>
</tr>
<tr>
<td>CMTI</td>
<td>Common Mode Transient Immunity</td>
<td>Up to 400kV/µs</td>
</tr>
</tbody>
</table>
Isolated Gate Driver

Common mode transient immunity describes the maximum $dv/dt$ between isolated circuits, where no bit failure occurs. Mostly only single pulse measurement. This has nothing to do with reliability!
Isolated Gate Driver

VIORM/VIOWM/VIOTM/VPR

Test methods are defined in
IEC60747-5-5
VDE 0884-10
UL1755

All test methods refer to 50/60 Hz ,DC or peak values
Gate transformer

Not well defined maximum allowed voltage
Not standardized

Example:

Isolation Voltage : 1000VRMS

The isolation test voltage represents a measure of immunity to transient voltages and the part should never be used as an element of a safety isolation system. The part could be expected to function correctly with several hundred volts offset applied continuously across the isolation barrier.
Gate Transformer

construction
Gate Drive Power supplies

Similar situation as with gate transformers
Not standardized

CMTI mostly missing

Continuous working voltage value is missing
Aging due to partial discharge

Partial Discharge is a formation of plasma within a void.

Partial discharge occurs on organic and inorganic insulation materials.

With organic material, partial discharge leads to a carbonizing of the surface within the void.
Aging due to partial discharge

Paschen curve

Breakdown Voltage vs frequency in air at atmospheric pressure IEC 60664-4
Additional effects

Breakdown voltage of solid isolation IEC 60664-4

Some ICs have a DTI < 10µm!!!
Other effects

Influence of higher resonance frequencies
von Prof. Dr. –Ing. Alexander Stadler
ECPE Tutorial: Wide Bandgap User Training
Other effects

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Insulation equivalent circuit

Losses increase with frequency
R-Ref01-HB

Half bridge reference design for fast switching

Suitable for different Gate Source Voltages
+6V, +15V/-3V, +15V/-9V, +20V/-5V …..

Suitable for TO-247 3 and 4 Pin

Available through distribution
Barrier Insulation Evaluation Research

Priv.-Doz. Dipl.-Ing. Dr.techn. Christof Sumereder/TU Graz, FH Johanneum
Recom Team
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>Test duration:</td>
<td>1464h</td>
</tr>
<tr>
<td>Test voltage:</td>
<td>1000V</td>
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<tr>
<td>Ambient temperature:</td>
<td>70°C</td>
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<tr>
<td>R12P22005D</td>
<td>93°C</td>
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<tr>
<td>C2M1000170D-NC</td>
<td>116°C</td>
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<tr>
<td>Switching frequency</td>
<td>50kHz</td>
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<tr>
<td>dv/dt</td>
<td>65kV/µs</td>
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</table>
BIER
Partial discharge measurements

VPD Peak [KV] before Test

VPD Peak [kV] after Test
DC/DC Converters for GaN Gate Drivers

January 2017

Designing Robust Transistor Circuits with IGBTs and SiC MOSFETs

August 2016
summary

• Isolated gate drives have advantages at high switching speed
• High switching speed has an influence on insulation characteristics
• Isolation voltages are often based on low frequencies.
• Partial discharge measurement gives more information about the insulation than high potential testing
• The voltage on the insulation can be higher than the bus voltage
• Dielectric losses have a bigger impact at higher frequencies
• BIER Test proves: RECOM DC-DC power supplies are suitable for high switching speed
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