650V IGBT4

the optimized device for large current modules with 10µs short-circuit withstand time

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Outline

- Motivation
- Design and technology of the 650V IGBT4
- Static and dynamic characteristics
- Softness
- Short-circuit behavior

Motivation

- 600V IGBT3
  - still a benchmarking device
  - but: optimized for smaller power application and very low stray inductance applications (high dI/dt)
  - overvoltage $V_{CE,max} = L \cdot dI/dt$

→ provide additional degrees of freedom for applications with larger currents / larger stray inductance

- 650V IGBT4
  - higher blocking voltage capability
  - lower overshoot voltage $V_{CE,max}$
  - lower turn-off current slope dI/dt
  - enhanced short circuit withstand time

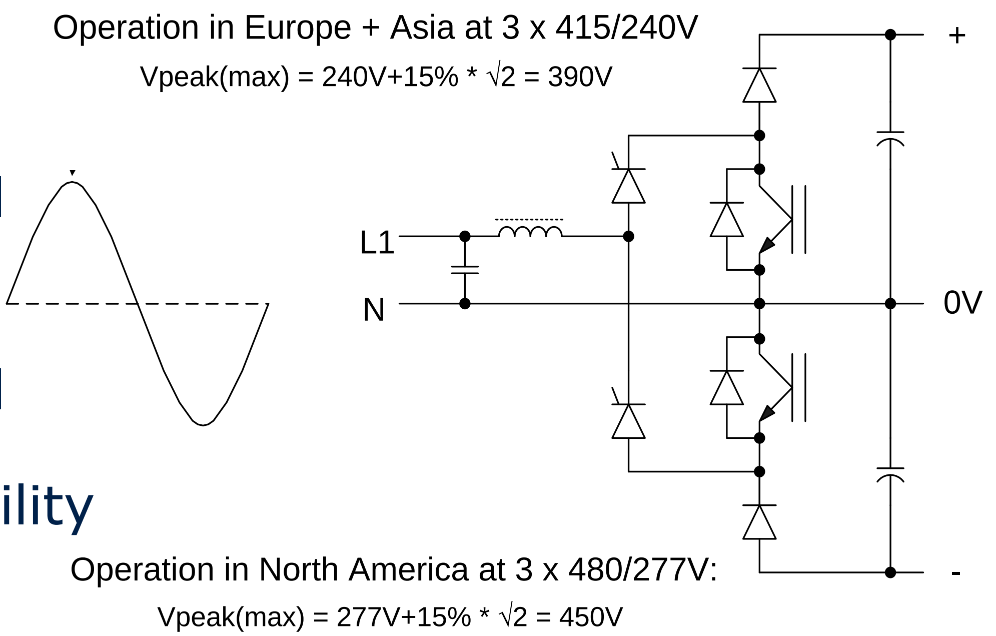
Why 650V blocking voltage capability?

3-level topology:

- Europe typical: 3x 400 V_{AC}
  - 240V phase-neutral nominal
- North America: 3x 480V_{AC}
  - 277V phase-neutral nominal
- UPS: 15% over-voltage capability
- DC bus voltage: +/- 450V
- load steps in UPS effect DC voltage variations

→ standard 600V IGBT and Diodes

not recommendable for 3-Level UPS



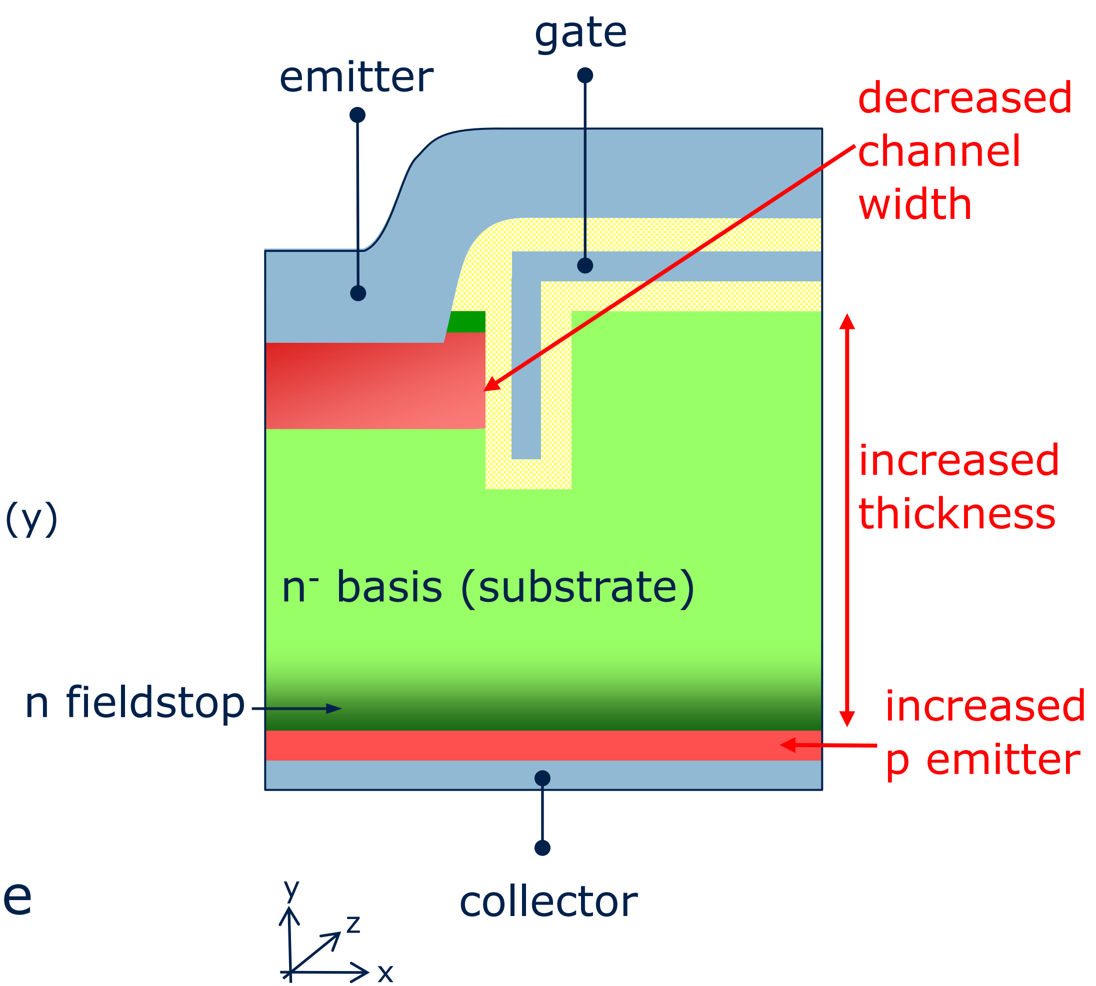
Dr. Andreas Härtl, IMM INP DC T PM

Design and technology of the 650V IGBT4

- trench MOS-top-cell
- thin wafer technology
- field-stop concept

difference to 600V IGBT3:

- increased chip thickness (y) ~+15%
- reduced MOS channel width (z) ~-20%
- increased efficiency of the back side p-emitter



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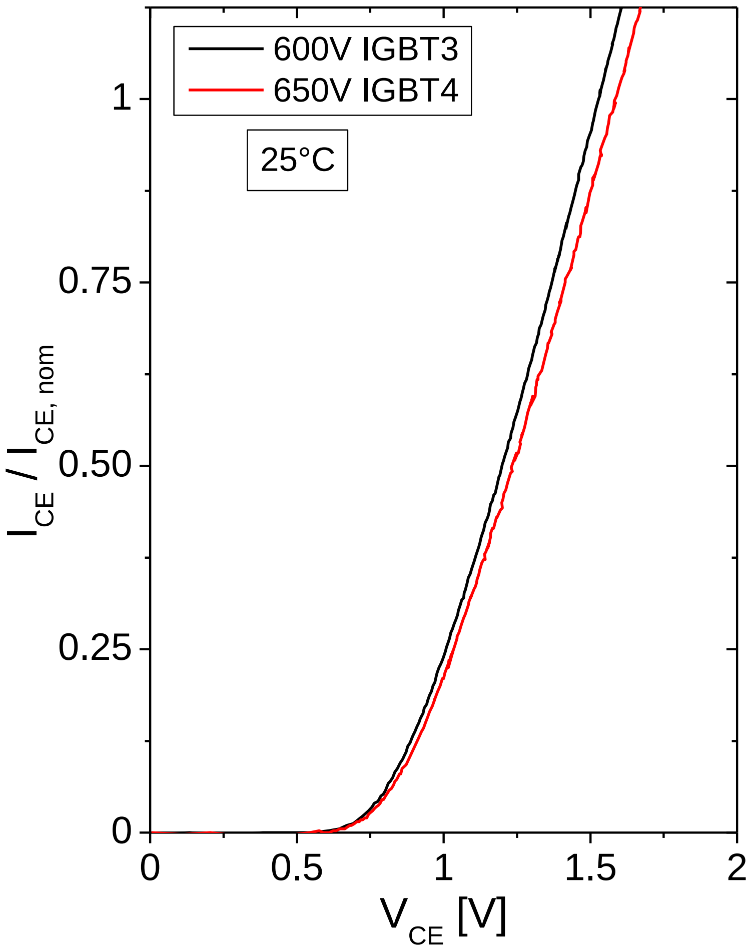
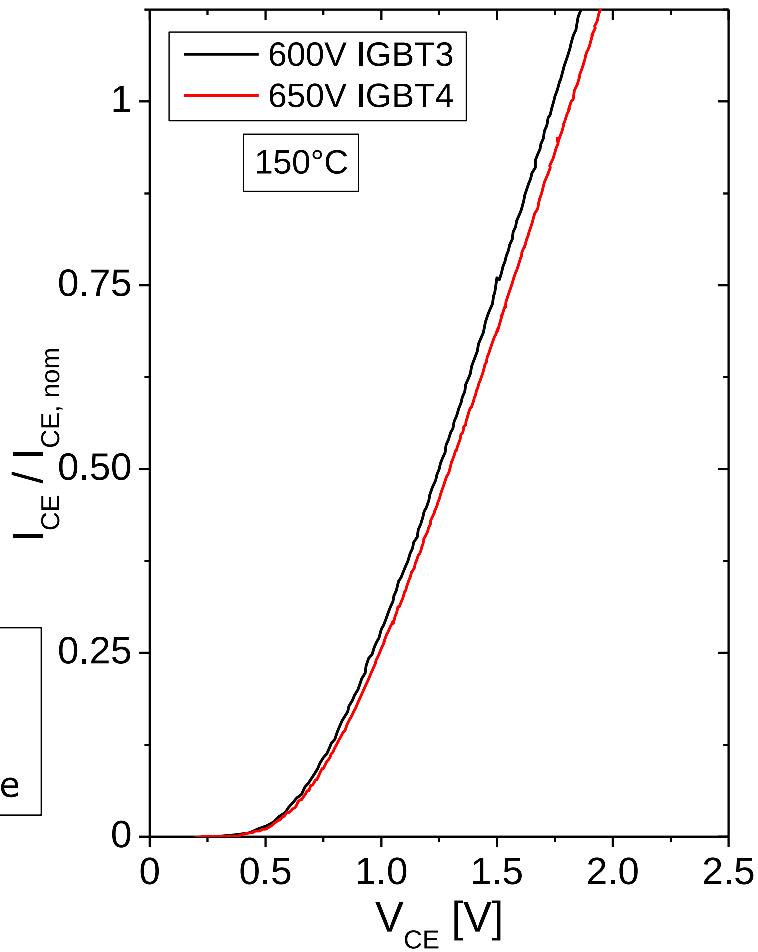
Static characteristics

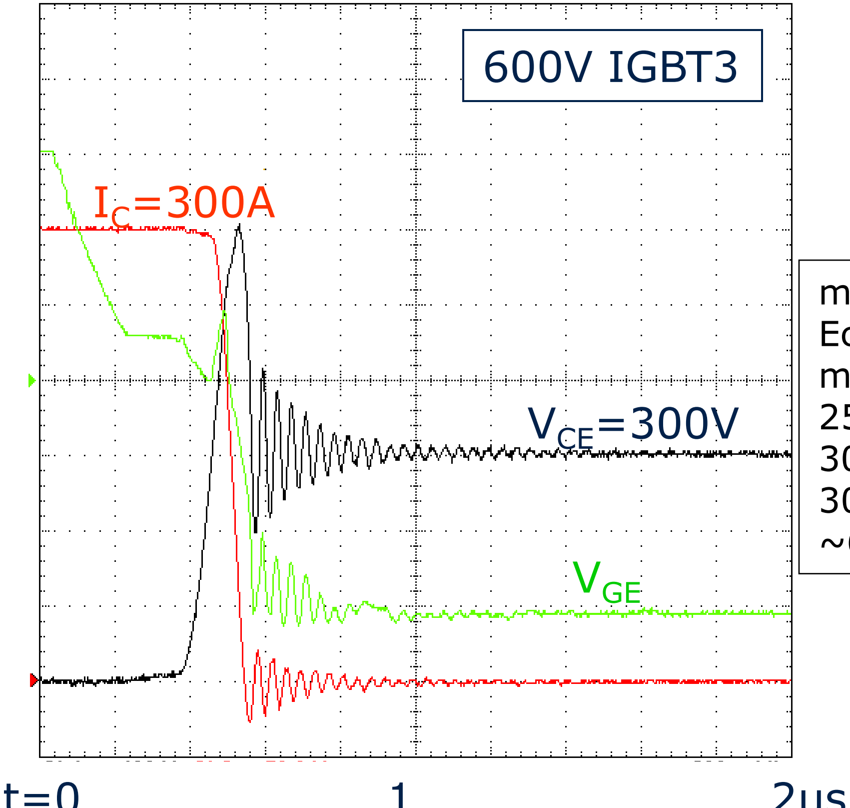
- higher blocking voltage capability: 650V
- $V_{CE,sat}$ increase compared to 600V IGBT3: ~50mV at 150°C on module level



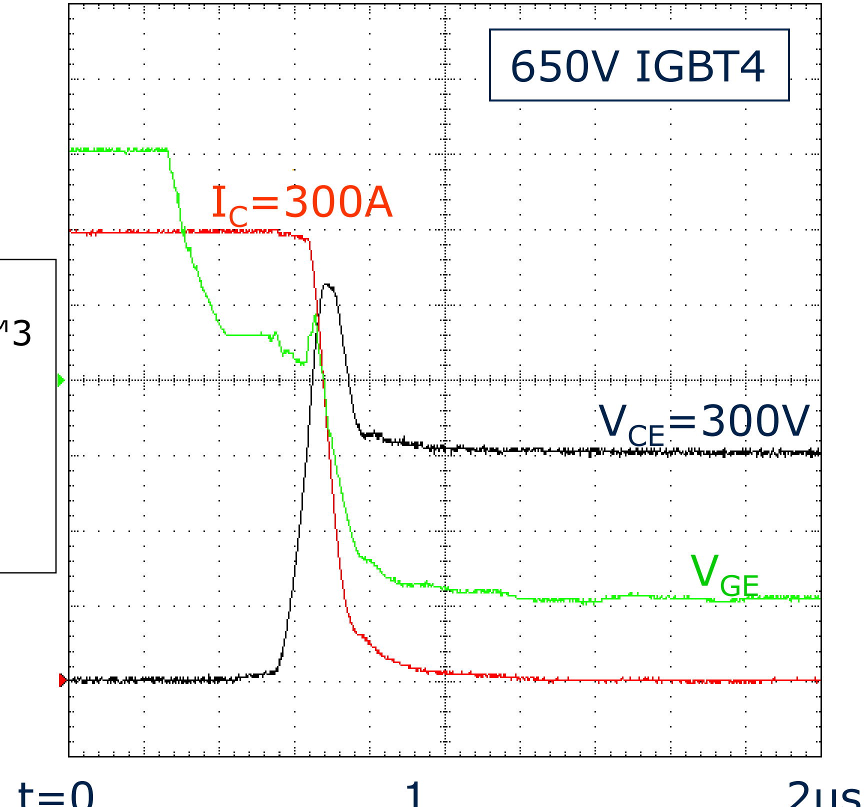
measured on DBC level for a 200A device



Dynamic characteristics



measured in EconoDUAL™3 modules at
25°C
300V
300A
~60nH



- softer switch-off behavior
  - reduced turn-off current slope dI/dt → no oscillations at 25°C, less EMI efforts
  - lower overshoot voltage
- still comparatively low on-state losses and turn-off losses

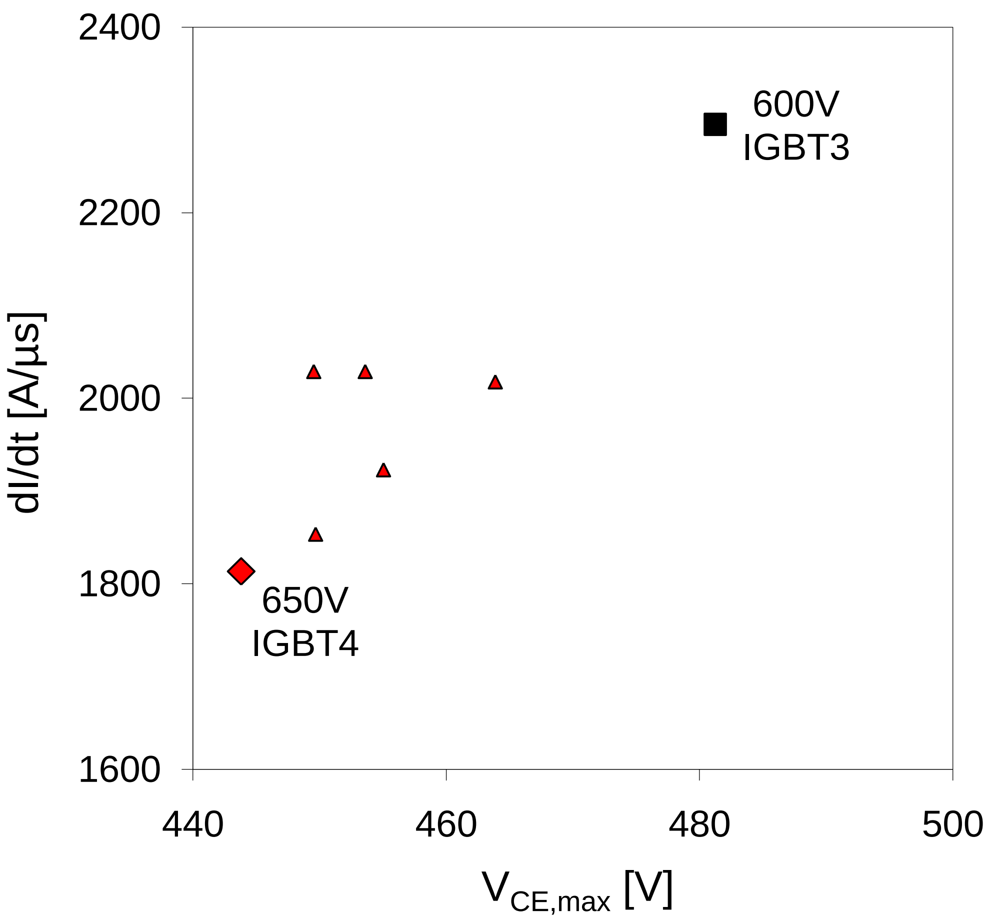
Softness: 600V IGBT3 vs. 650V IGBT4

- reduction of turn-off current slope dI/dt

  (on module level by >20%)

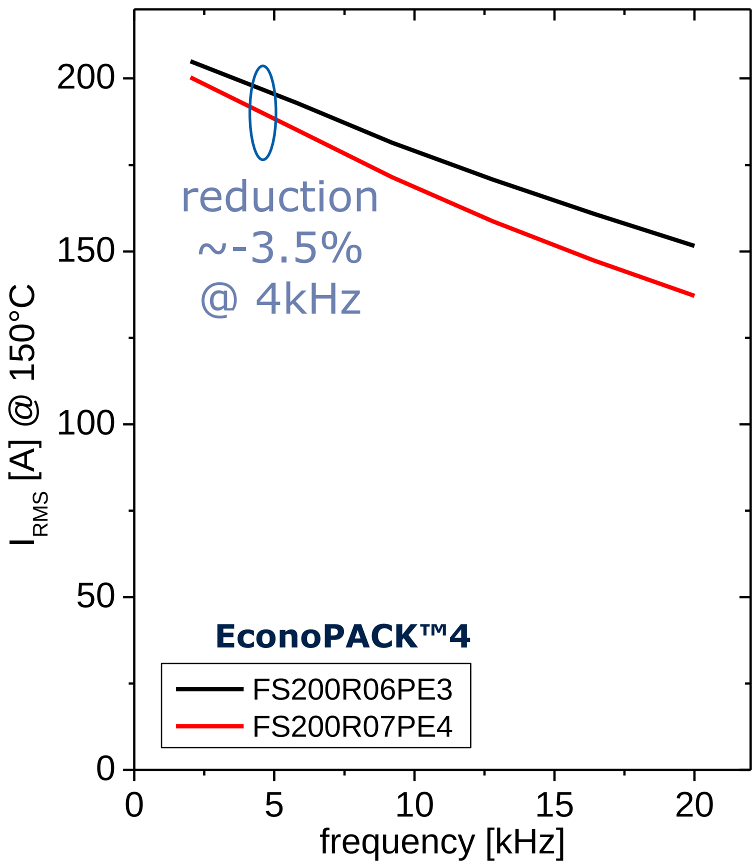
- reduction of maximum overshoot voltage $V_{CE,max}$

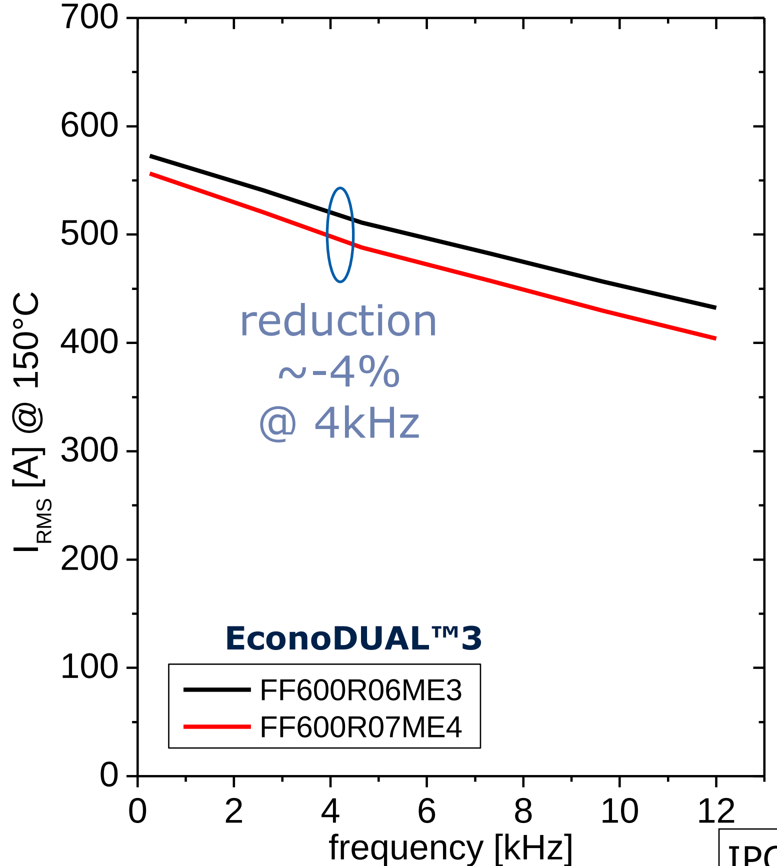
  (on module level up to 100V)



measured at 25°C on DBC level for a 200A device

IPOSIM: RMS module current





IPOSIM sim. conditions:
R_{th}(hs)=0.09K/W
T(ambient)=35°C
$T_{vj,op}$=150°C
cos(φ)=0.85

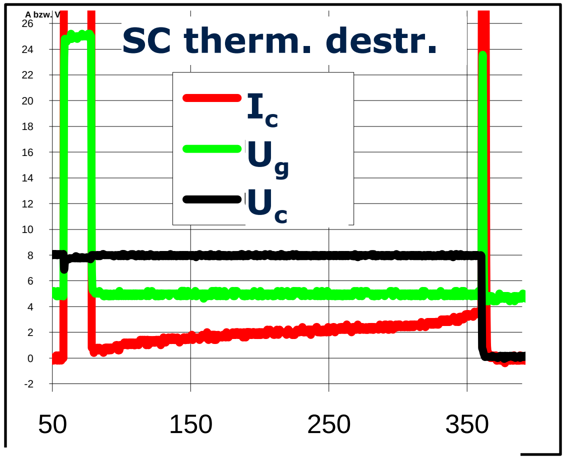
- reduction of the RMS module current:

~-2 ... -10% for frequencies 2 to 20kHz

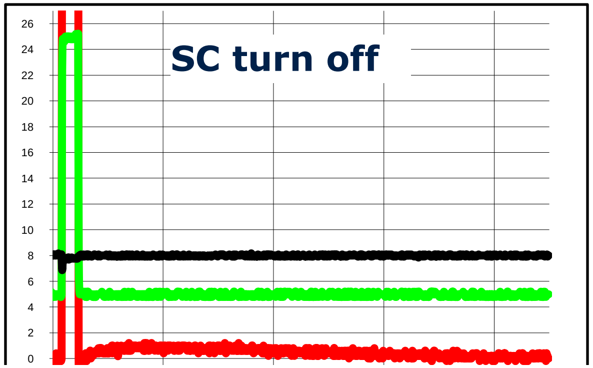
~-3 ... -7% for frequencies 0.25 to 12kHz

Mechanism of thermal short-circuit destruction

- heat generation in the chip center during the short circuit pulse
- temperature maximum at the end of the short-circuit pulse
- heat diffusion to the back side of the chip
  → temperature increase at the backside p-emitter → hole current
- heat diffusion to the front side of the chip
  → temperature increase at n-source → electron leakage current
  → pnp-amplification → hole current from the backside p-emitter
- hot leakage current → increasing chip temperature
- latch-up and destruction of the IGBT

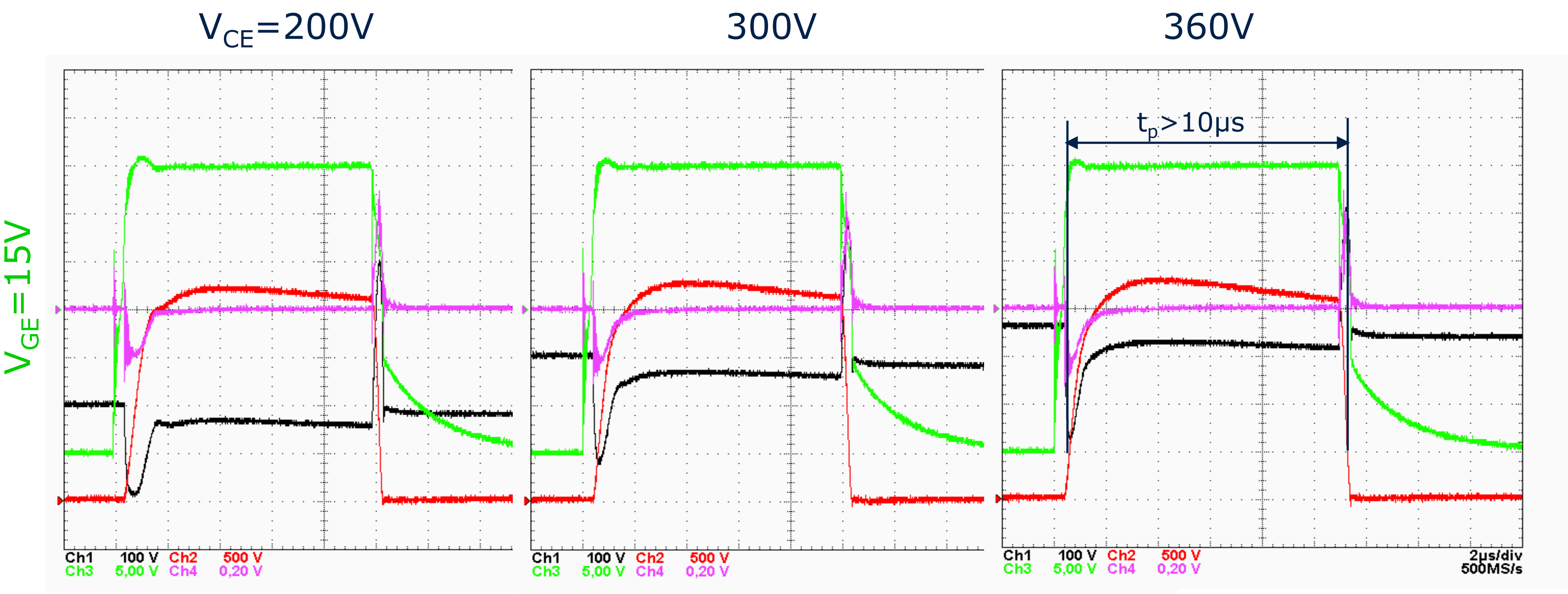


> → F. Hille et al., ISPSD 2010:
>
> „Failure mechanism and improvement potential of IGBT's short circuit operation"



- 650V IGBT4:
  - increased thermal budget (increased chip thickness)
  - reduced short-circuit current (decreased MOS channel width)

Short-circuit behavior



- short-circuit pulse withstand time t_p>10µs
- short-circuit current about 4.5 I_{nom}

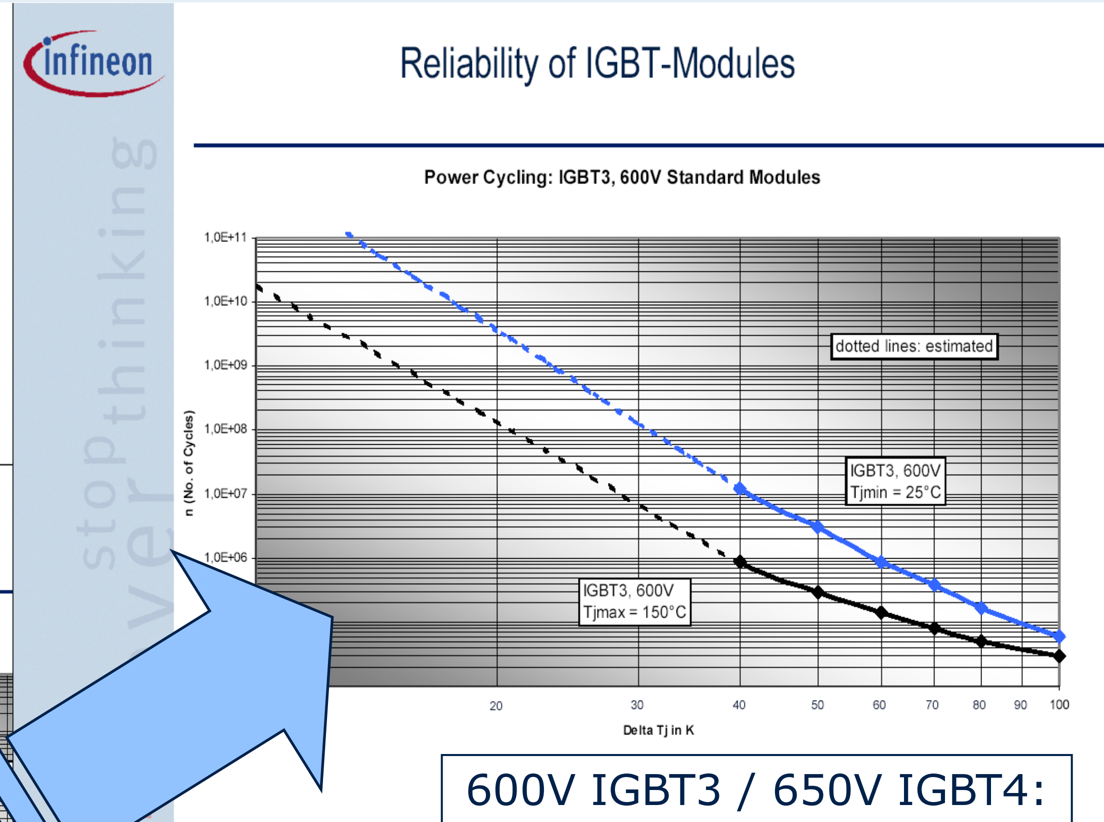
→ enhanced short-circuit withstand time

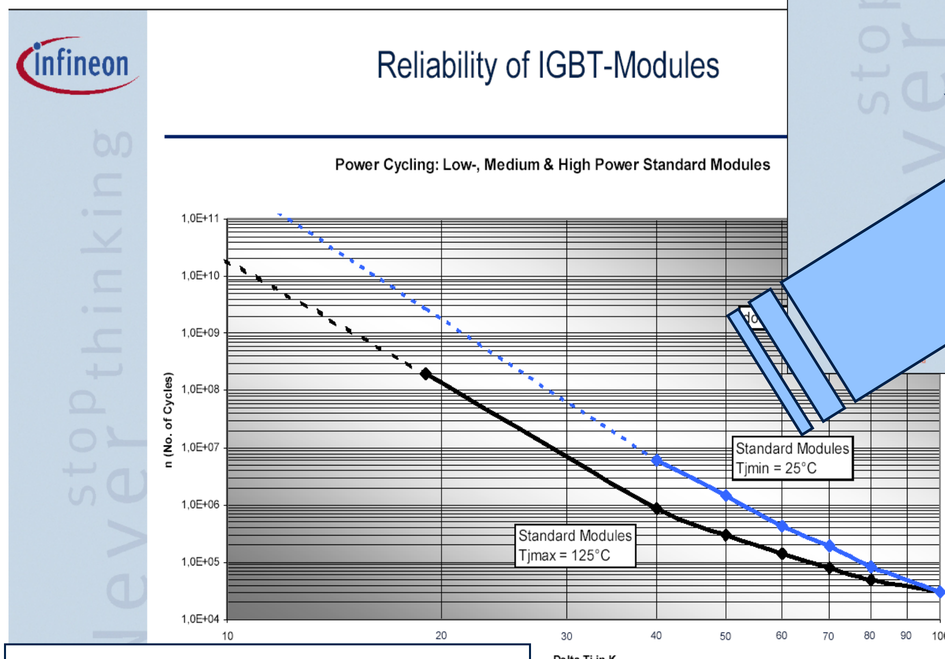
→ different detection mechanisms possible

Power cycling capability

- high power cycling capability with the 650V IGBT4
- example:

  T_{vj}=25°C, ΔT=40K





600V IGBT3 / 650V IGBT4:
~15 Mio cycles

600V IGBT2:
~6 Mio cycles

Medium Power target product portfolio 650V IGBT4

A

600

400

300

200

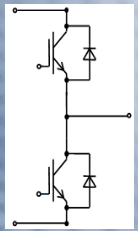
150

100

75

62mm

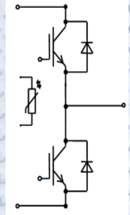
600A*
400A
300A
Half Bridge



*under investigation

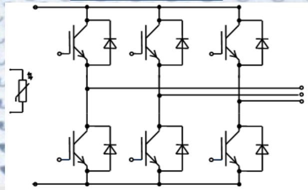
EconoDUAL™3

600A
450A
300A
Half Bridge



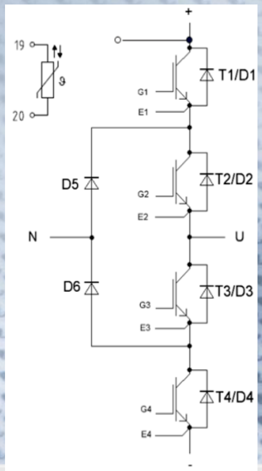
EconoPACK™4

200A
150A
100A
SixPACK



3 level one phase modules

300A
200A



Conclusion

- 650V IGBT4:
  - increased chip thickness
  - reduced MOS channel width
  - increased efficiency of the back side p-emitter
- softer switch-off behavior:
  - lower overshoot voltage
  - reduced turn-off current slope dI/dt
  - reduced EMI efforts
- good trade-off: comparatively low on-state and turn-off losses
- enhanced short-circuit behavior: withstand time >10µs

→ optimized device for larger current applications

→ use of larger DC link voltages and/or higher inductances possible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We create value.

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