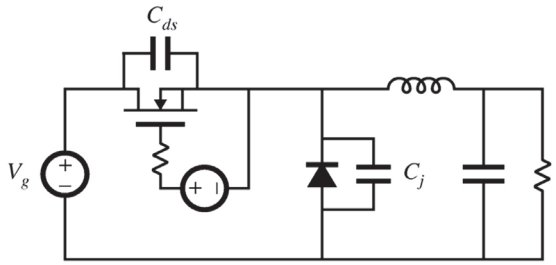
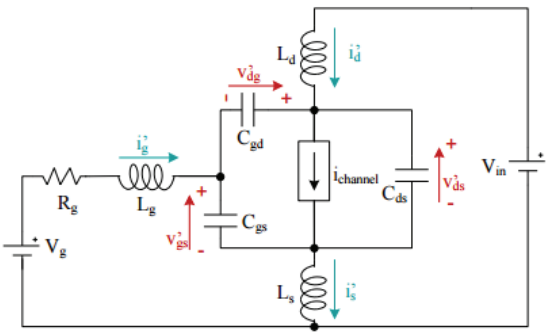
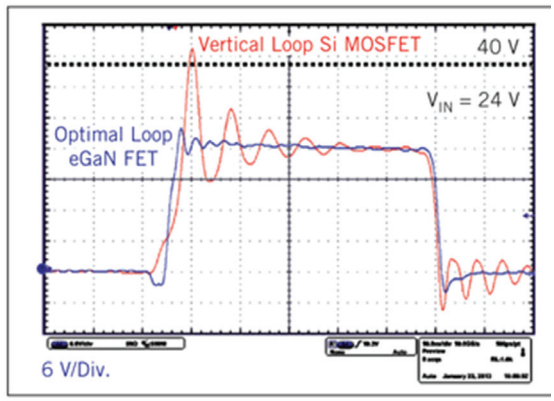
Switching Losses: Output Capacitance



Ideal Switching

Experimental Switching Waveforms





D Reusch, "eGaN® FET-Silicon Power Shoot-Out Vol. 13, Part 2: Optimal PCB Layout"
M Rodriguez et al, "Analysis of the switching process of power MOSFETs using a new analytical losses model"

The Double Pulse Test

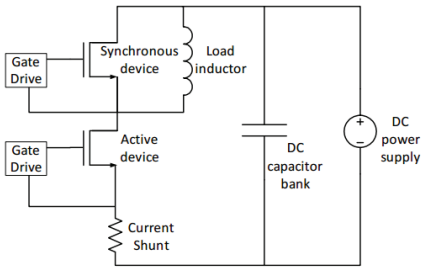


Fig. 7. Double pulse test circuit schematic.

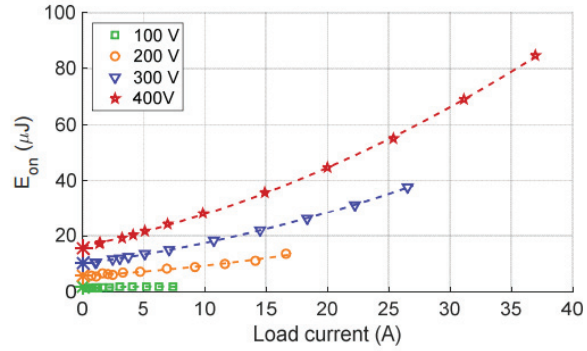
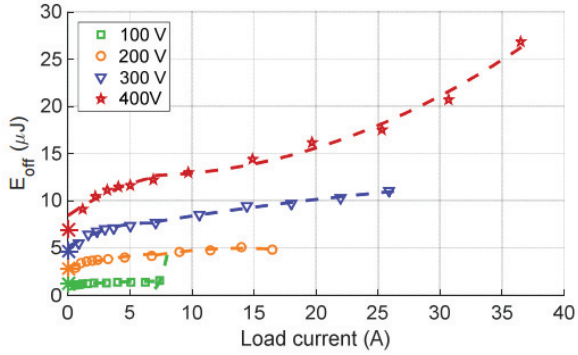
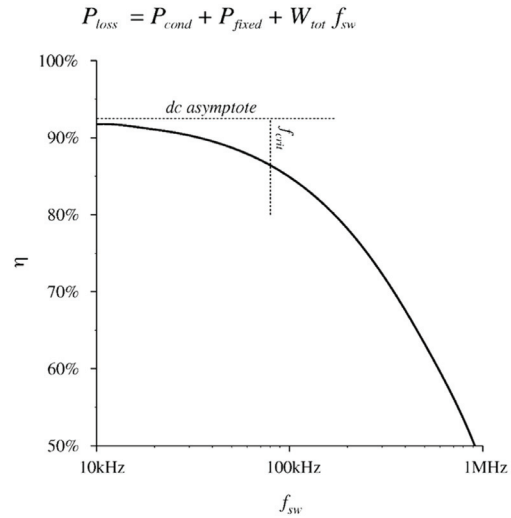


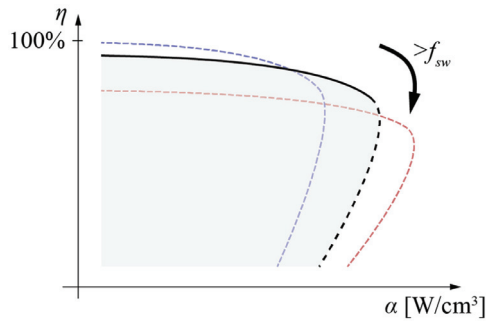
Fig. 16. Turn-on energy E_{on} at 25 °C.



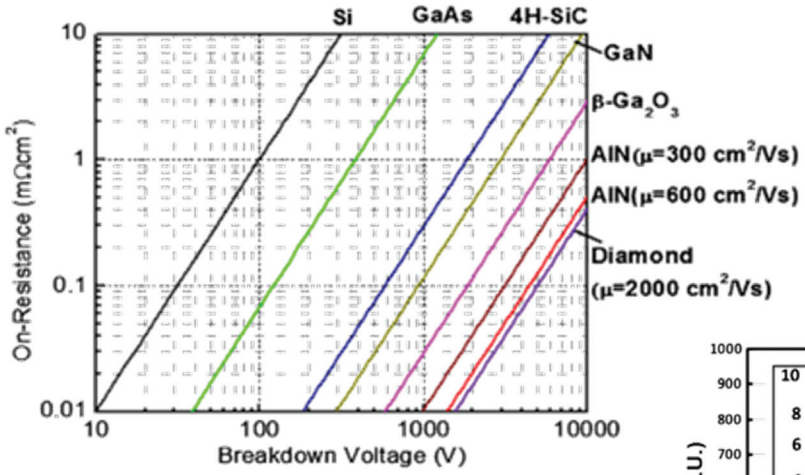
Converter Efficiency Vs. f_s

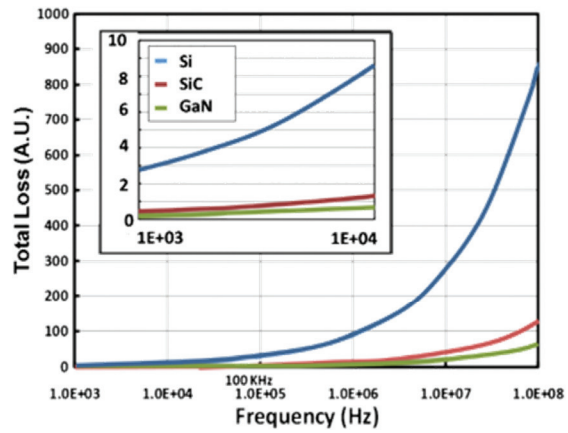


Converter Optimization



Wide Bandgap Materials



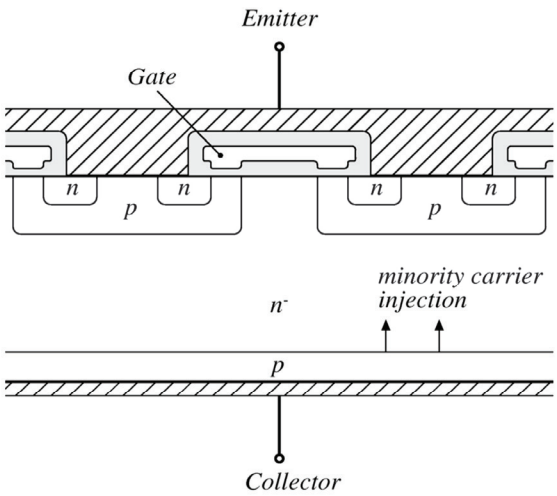


Srabanti Chowdhury *et al* "Current status and scope of gallium nitride-based vertical transistors for high-power electronics application" 2013 *Semicond. Sci. Technol.* 28, 074014

Power MOSFET: Conclusions

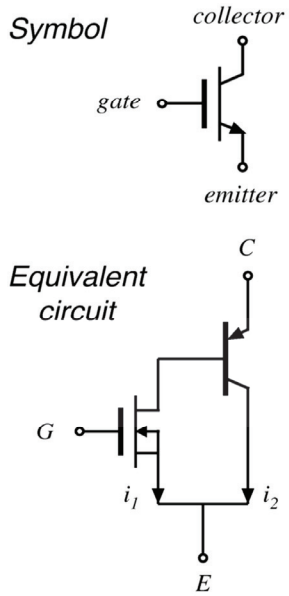
- A majority-carrier device: fast switching speed
- Typical switching frequencies: tens and hundreds of kHz
- On-resistance increases rapidly with rated blocking voltage
- Easy to drive
- The device of choice for blocking voltages less than 500V
- 1000V devices are available, but are useful only at low power levels (100W)
- Part number is selected on the basis of on-resistance rather than current rating

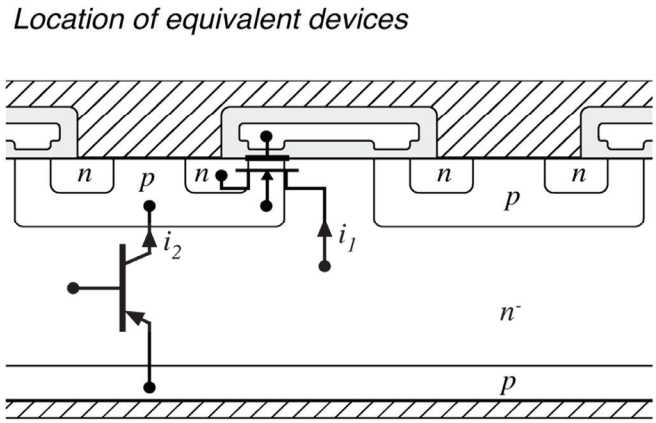
Insulated Gate Bipolar Junction Transistor



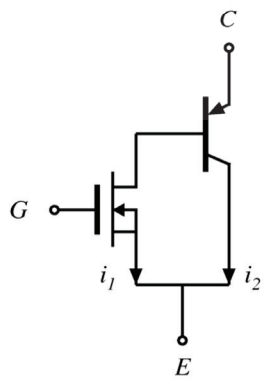
- A four-layer device
- Similar in construction to MOSFET, except extra p region
- On-state: minority carriers are injected into n^- region, leading to conductivity modulation
- compared with MOSFET: slower switching times, lower on-resistance, useful at higher voltages (up to 1700V)

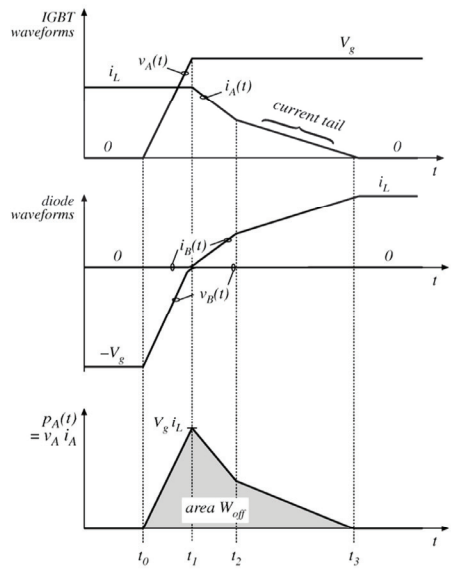
The IGBT





IGBT: Current Tailing





Conclusions: IGBT

- Becoming the device of choice in 500 to 1700V+ applications, at power levels of 1-1000kW
- Positive temperature coefficient at high current —easy to parallel and construct modules
- Forward voltage drop: diode in series with on-resistance. 2-4V typical
- Easy to drive —similar to MOSFET
- Slower than MOSFET, but faster than Darlington, GTO, SCR
- Typical switching frequencies: 3-30kHz
- IGBT technology is rapidly advancing:
  - 3300 V devices: HVIGBTs
  - 150 kHz switching frequencies in 600 V devices