Analog Circuits 1

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Low Power Loss IGBT Driver Circuit Using Current Drive

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Outline

- Research Background and Objective
- IGBT Evaluation Circuit
- IGBT Current Drive Simulation
  - — Current Gate Driver Circuit
  - — Simulation Results
- Conclusion and Challenges

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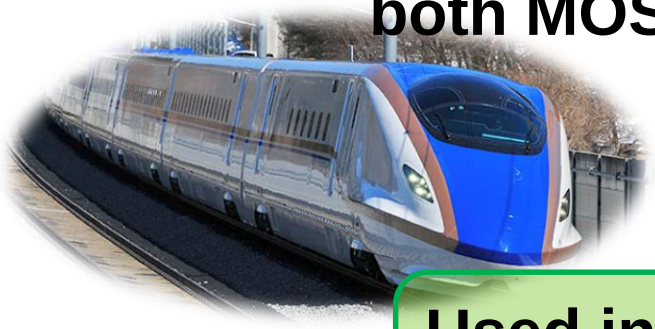
Research Background

IGBTs have advantages of both MOSFETs and bipolar transistors

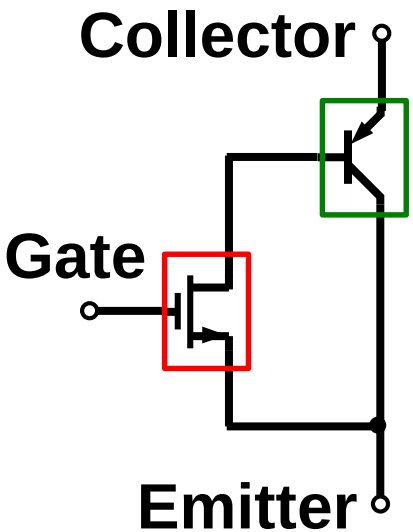


Used in wide range of applications as power semiconductor devices

Development of IGBT and its driver circuit is important

IGBT and Driver Circuit

IGBT
(Insulated Gate Bipolar Transistor)



Input part is MOSFET
Output part is bipolar transistor

Advantages

- **Fast operating speed**
- **Large current amplification factor (~1.2kA)**
- **High withstand voltage (~3.3kV)**

Large gate capacitance ➡ Driver circuit is difficult

Objective

IGBT circuit

- **Parasitic capacitance and tail current cause switching loss**

- **Parasitic inductance causes excessive overshoot**

Reduction of switching loss and excessive overshoot by current drive control of IGBT

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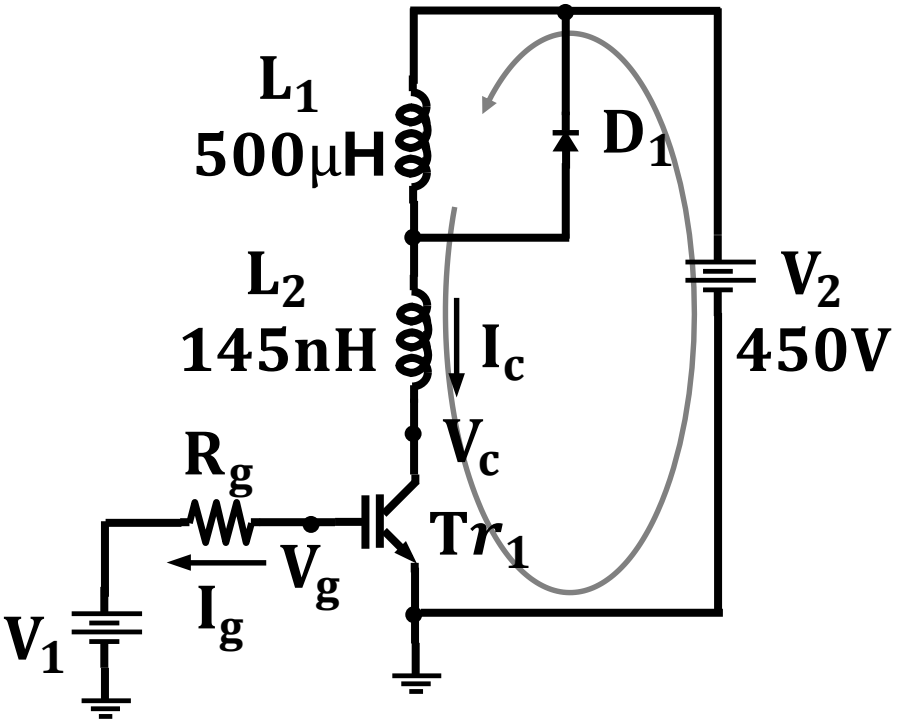
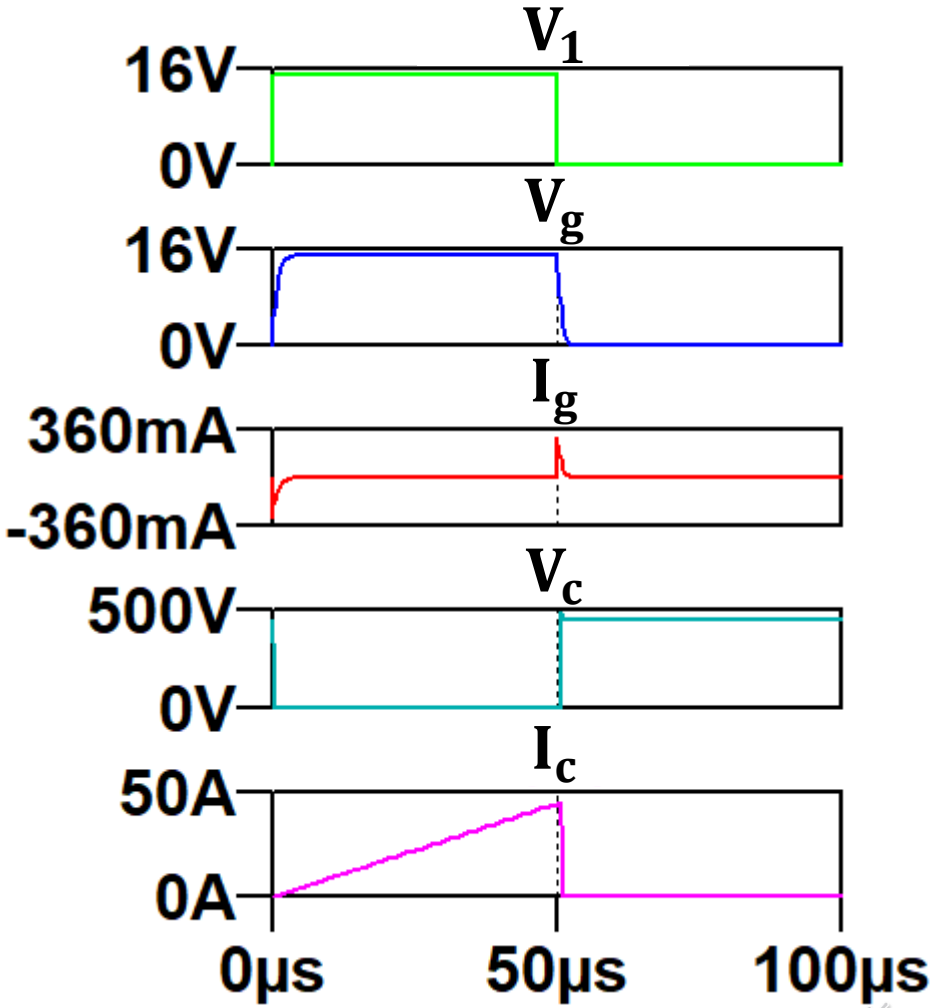
Voltage-Driven IGBT Evaluation Circuit (1/2)

Input voltage V_1

V_g turns on IGBT

I_c gradually flows



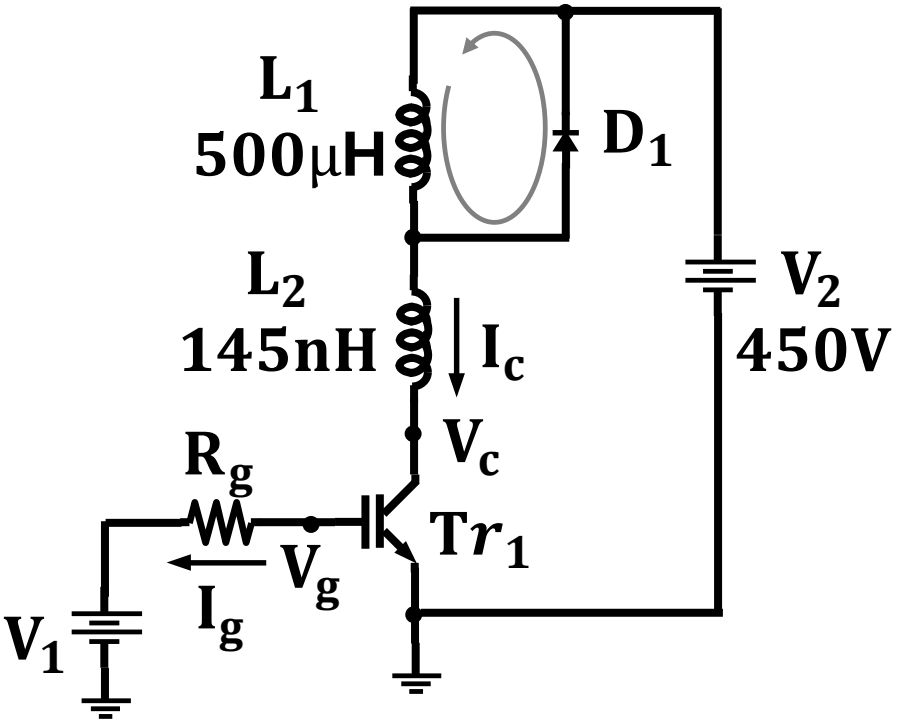


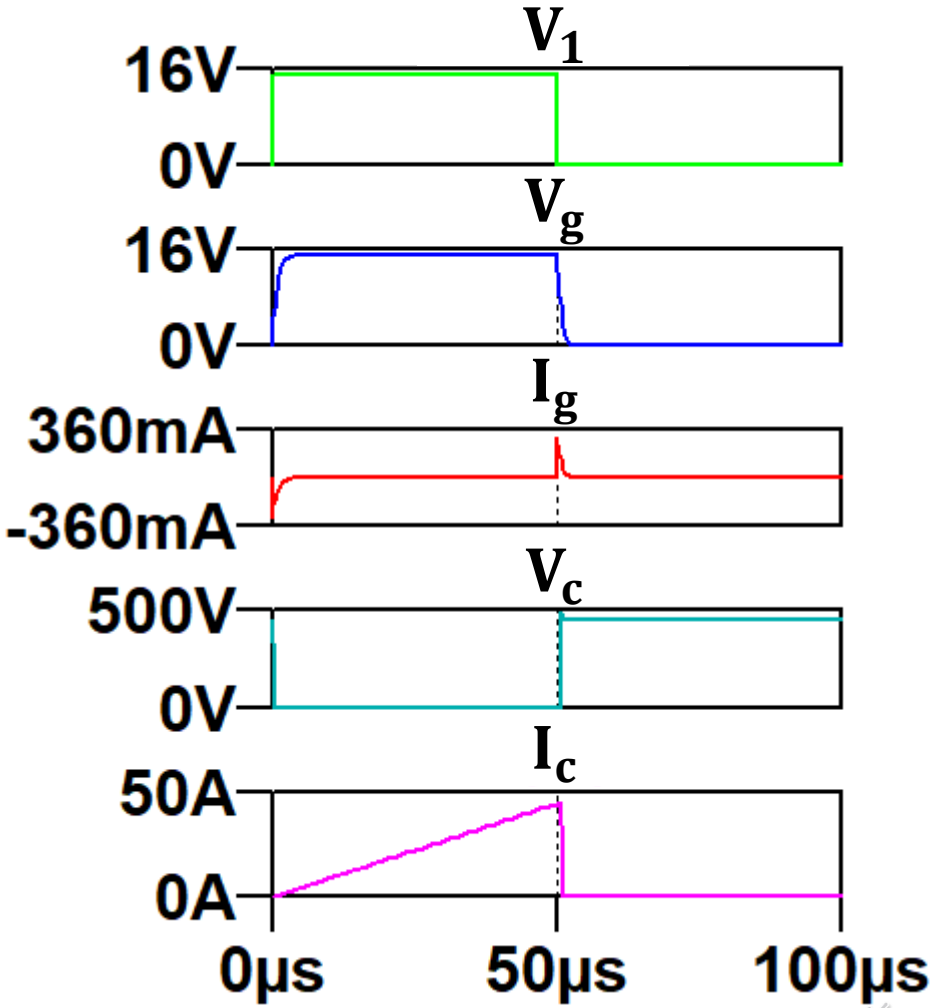
Voltage-Driven IGBT Evaluation Circuit (2/2)

V_1 becomes 0

V_g turns off IGBT

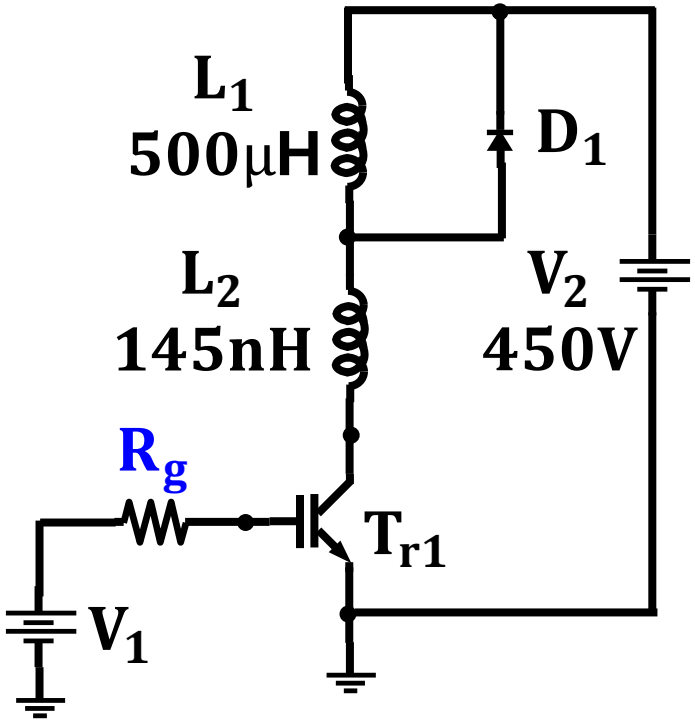
I_c gradually decreases

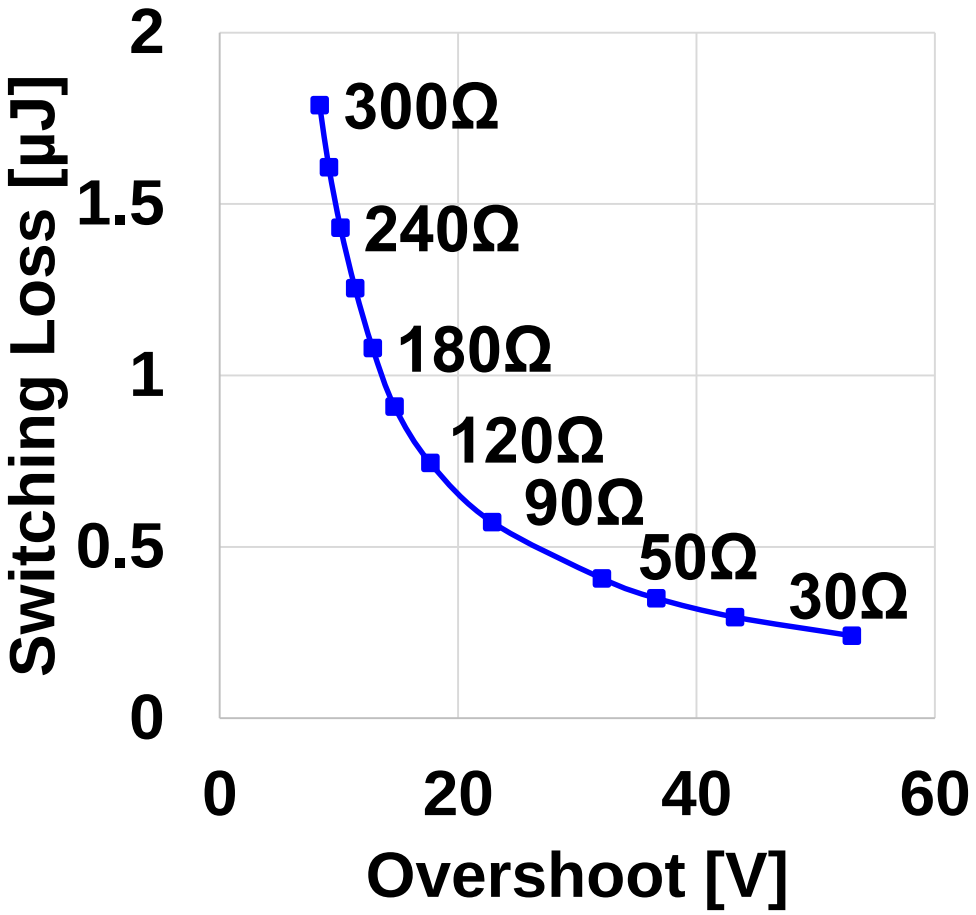




Overshoot and Switching Loss during Turn-off

Change gate resistance R_g from 30Ω to 300Ω





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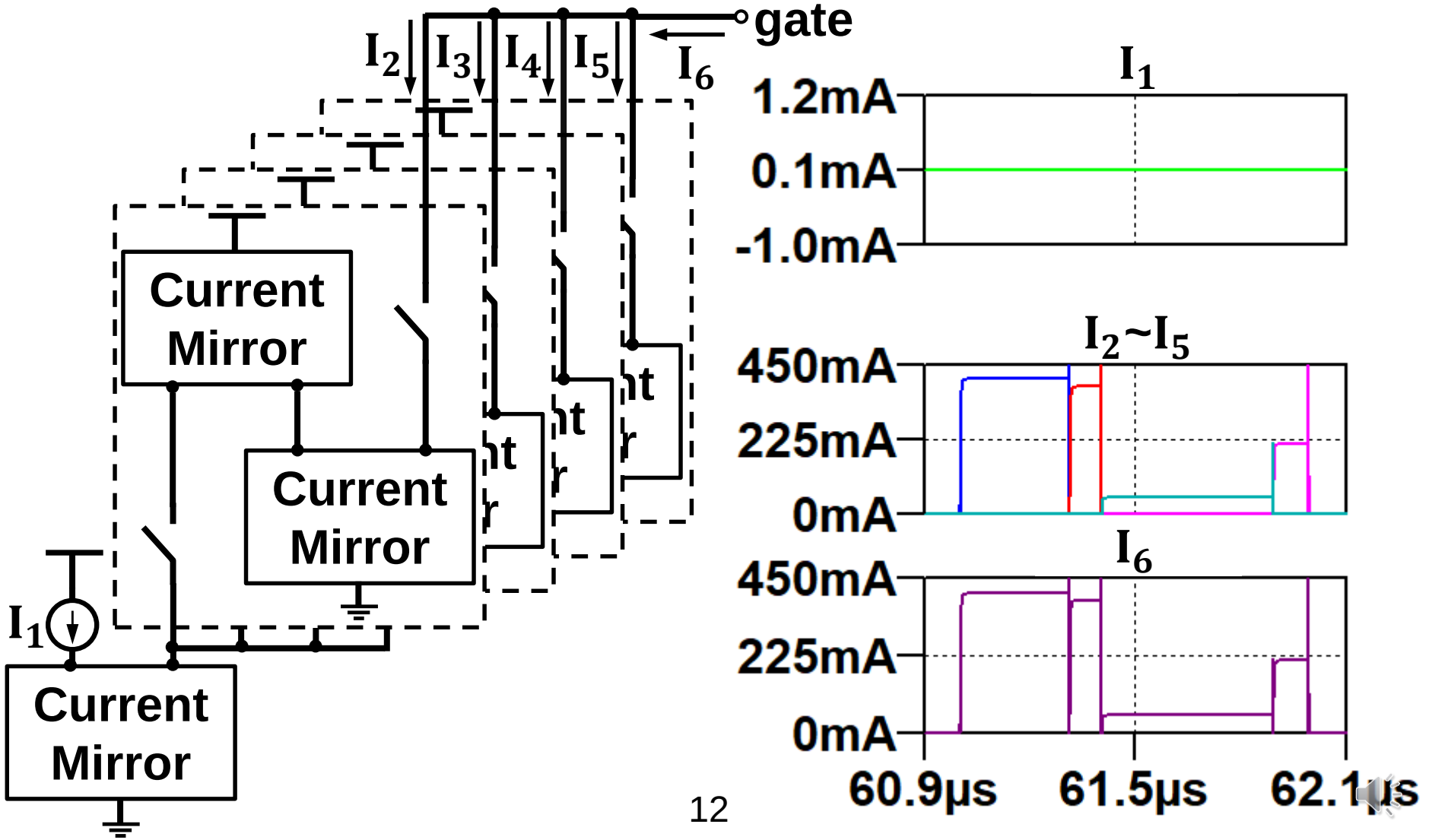
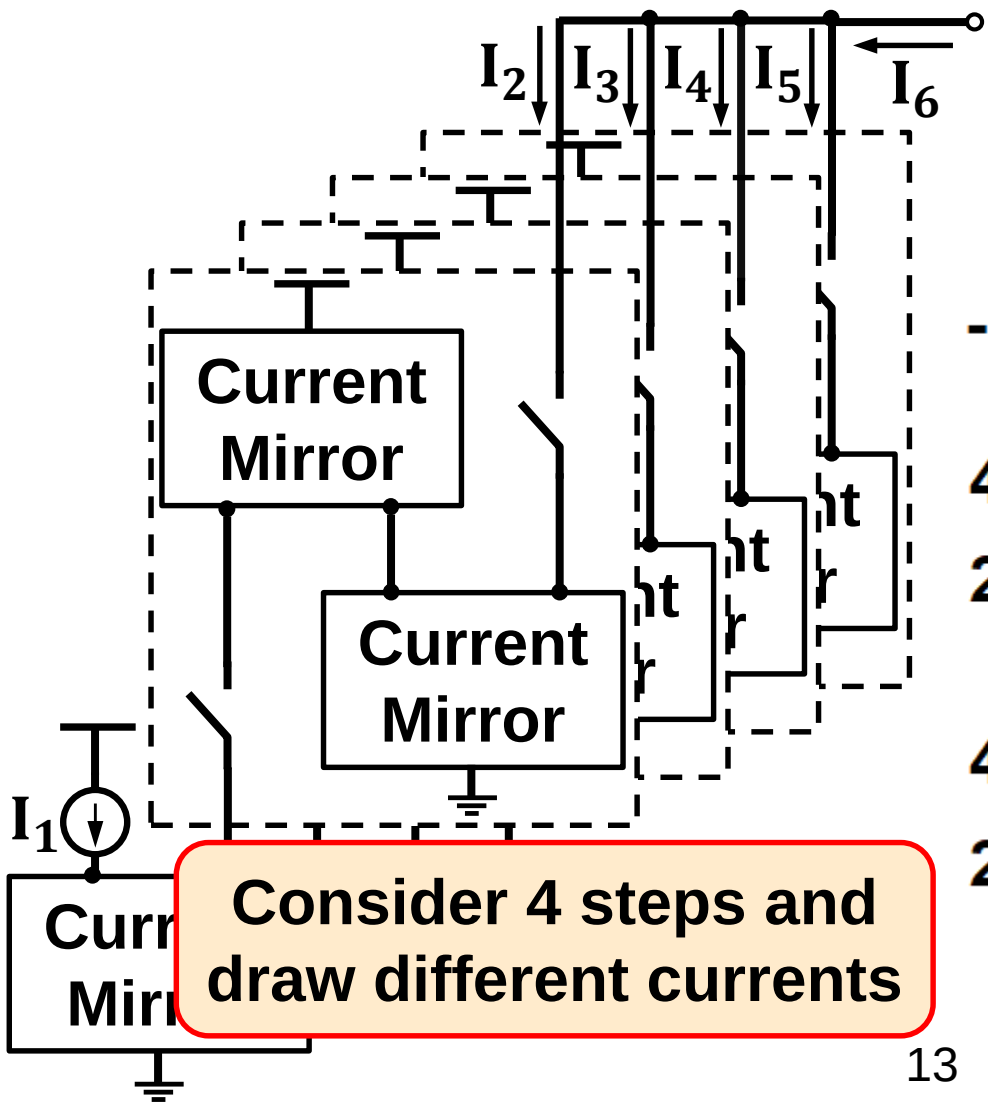
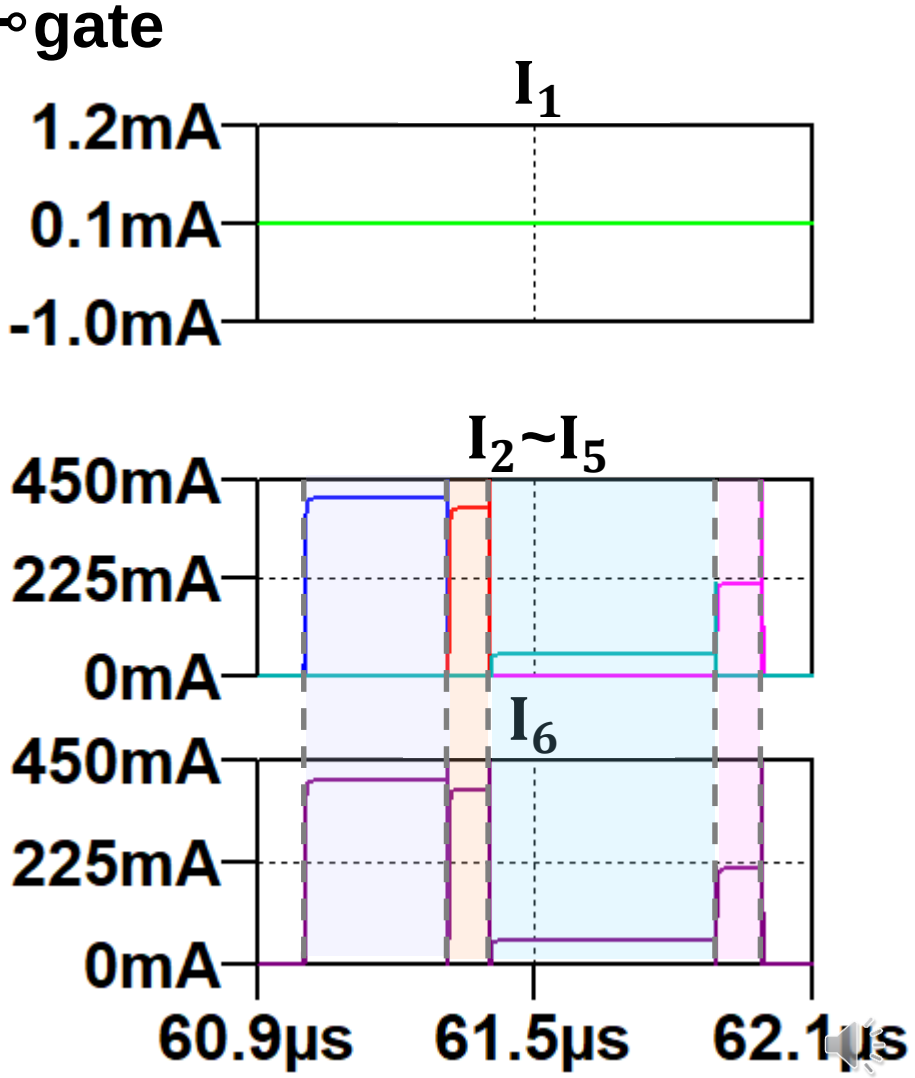
Current Gate Driver Circuit (1/2)



Current Gate Driver Circuit (2/2)



Consider 4 steps and draw different currents



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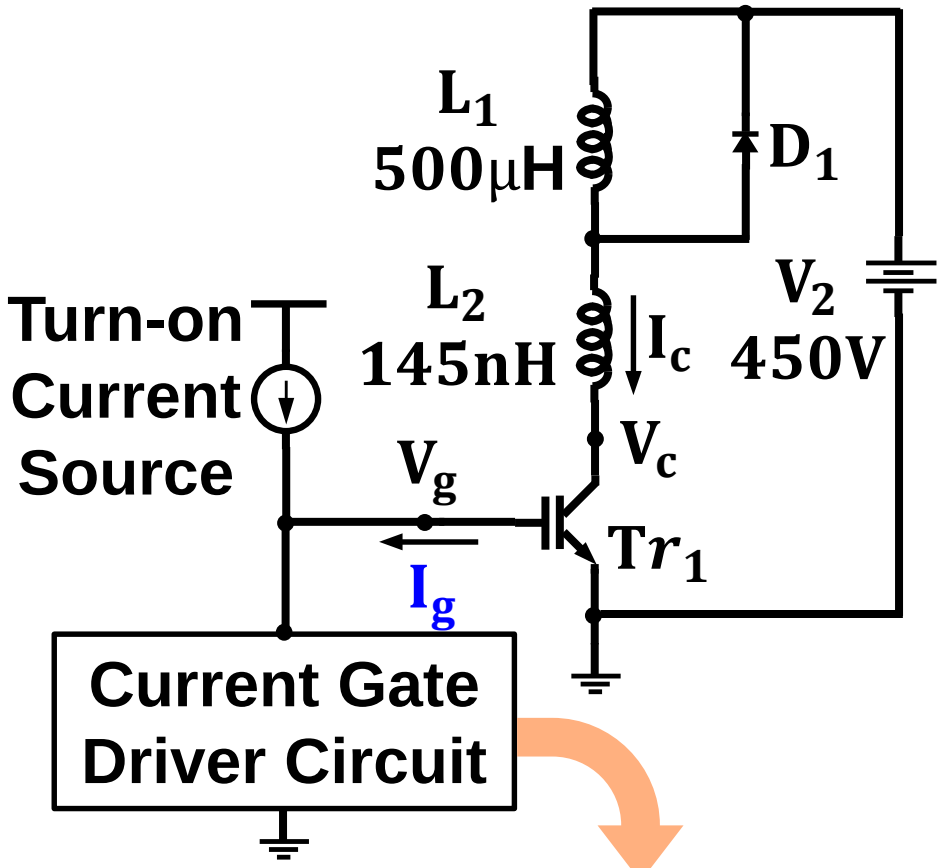
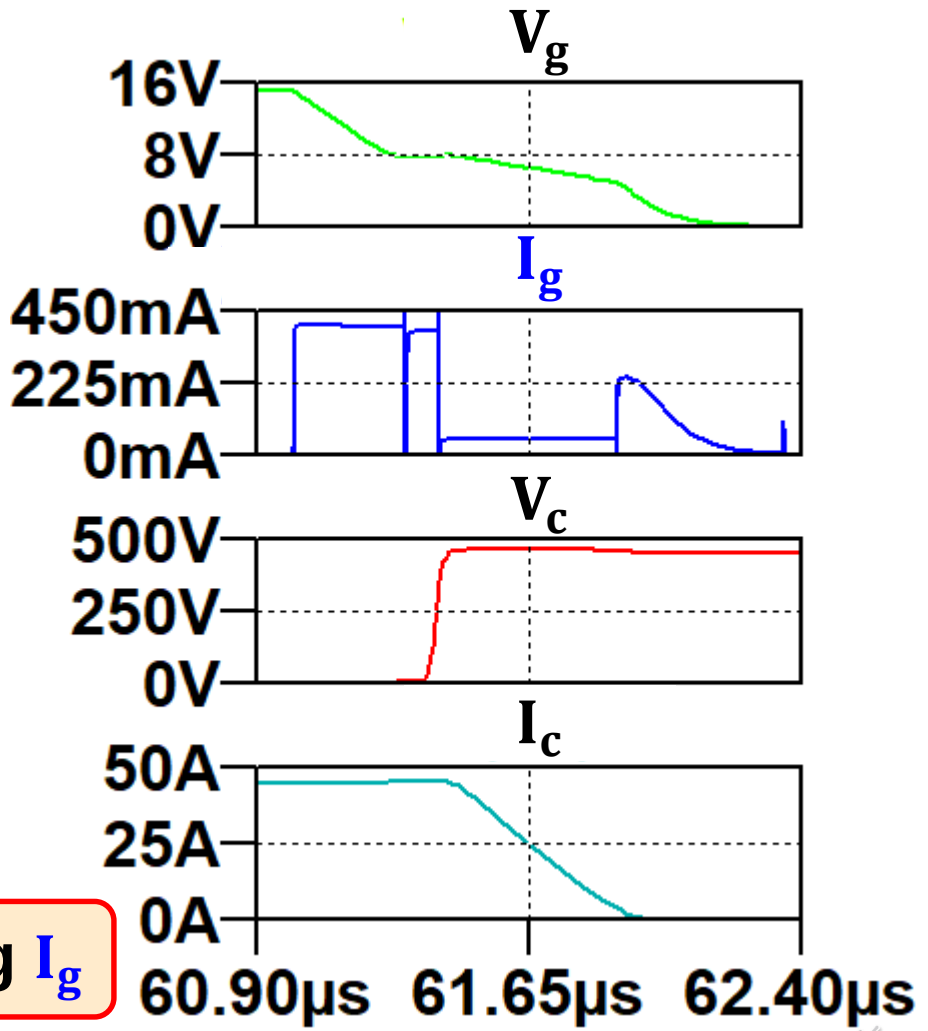
IGBT Turn-off Characteristics





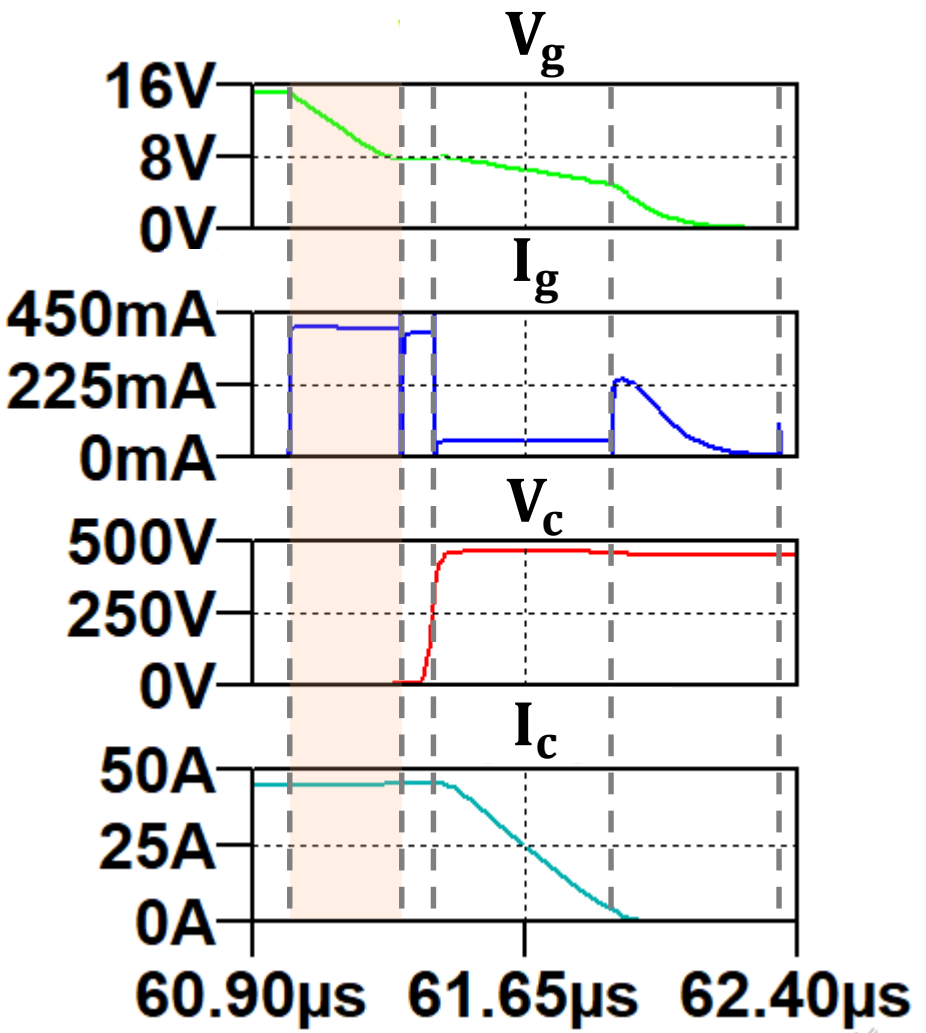
Control gate voltage by flowing I_g

Control of Gate Voltage by Gate Current (Step1)

Step1

V_g : Saturation voltage to Miller voltage

No effects on switching loss and overshoot



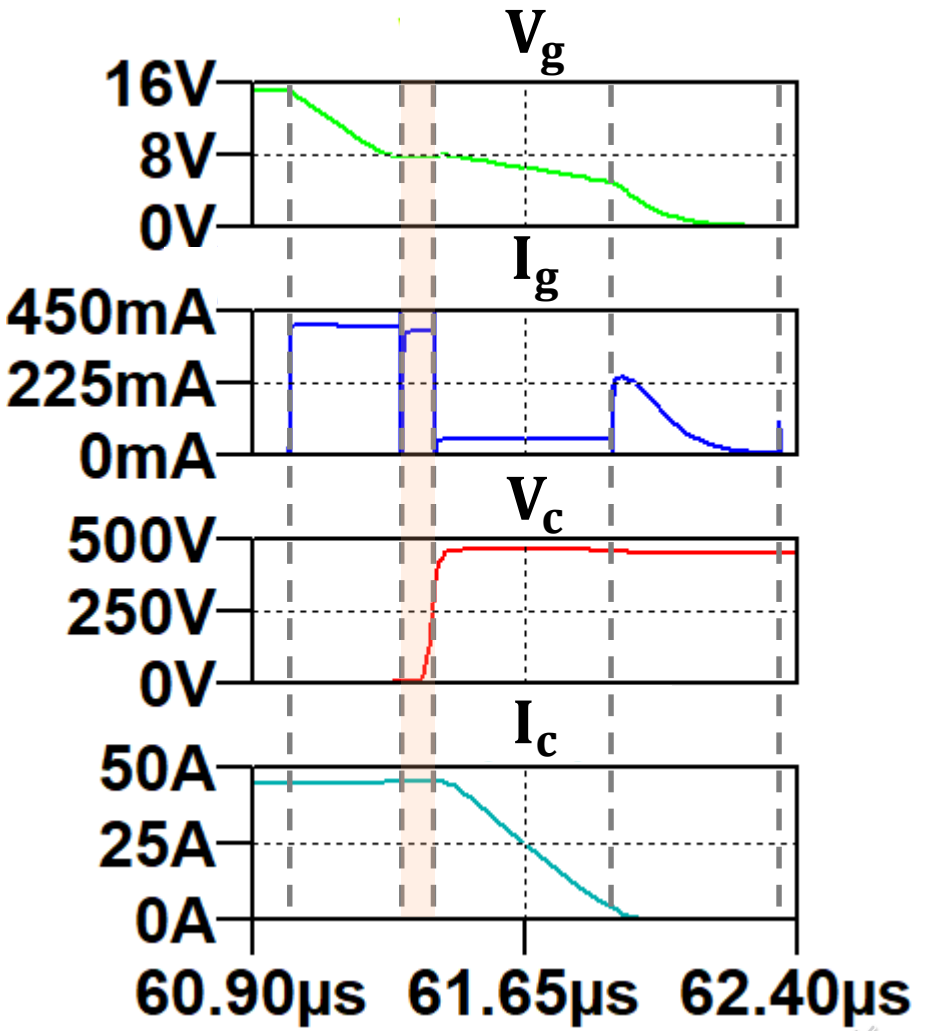
Control of Gate Voltage by Gate Current (Step2)

Step2

V_g : Miller period of IGBT

Trade-off between switching loss and slew rate

Switching loss can be reduced



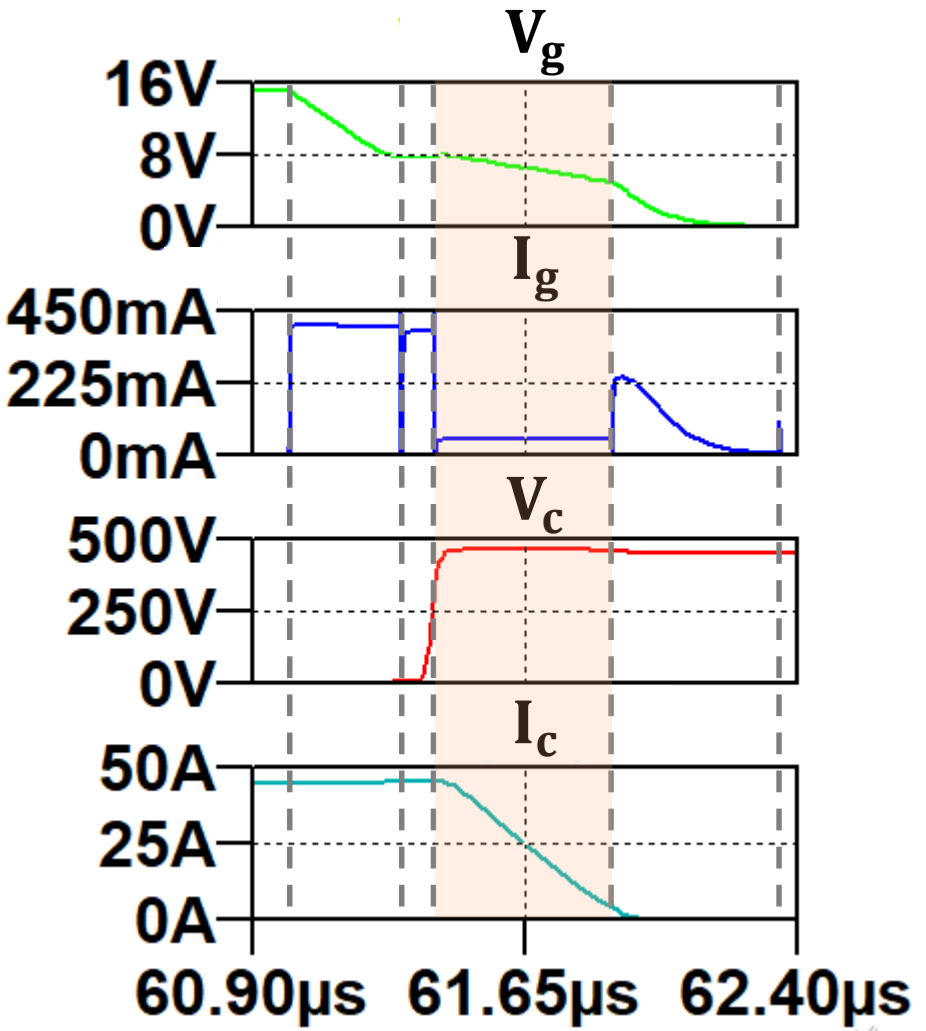
Control of Gate Voltage by Gate Current (Step3)

Step3

V_g : Miller voltage to threshold voltage

Trade-off between switching loss and overshoot

Overshoot can be reduced



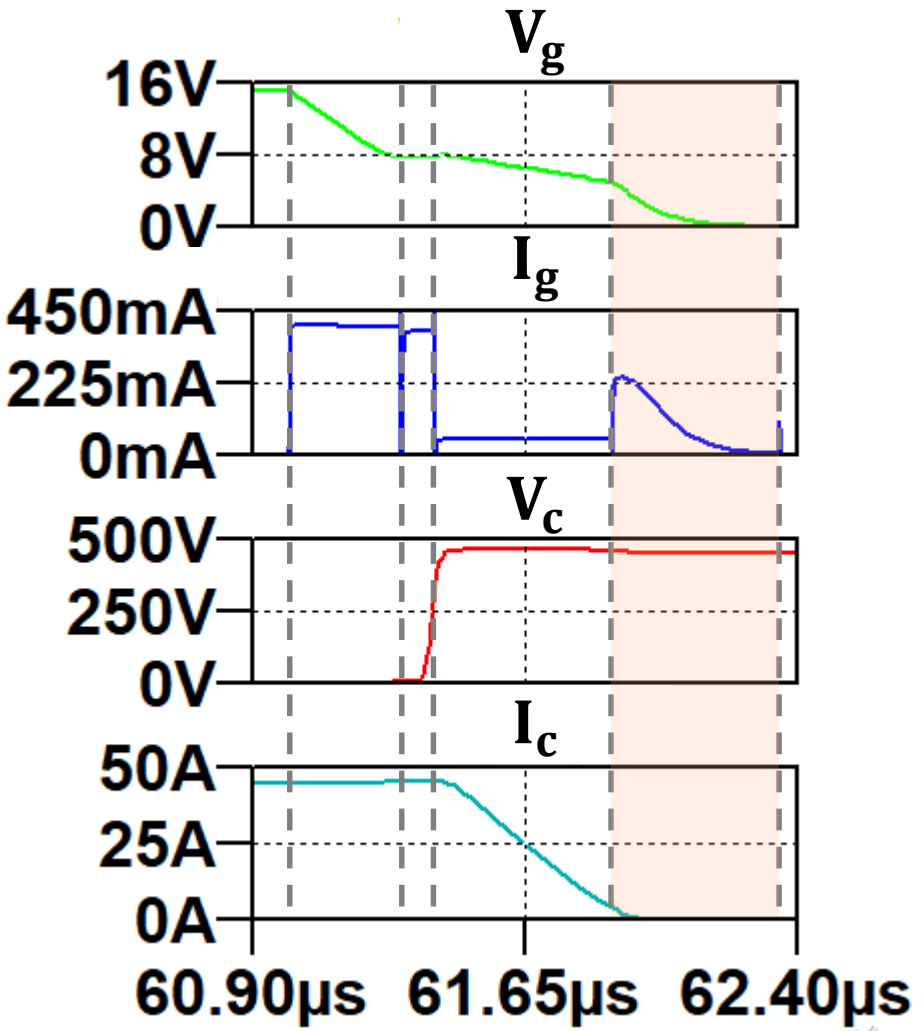
Control of Gate Voltage by Gate Current (Step4)

Step4

V_g : Threshold voltage to 0

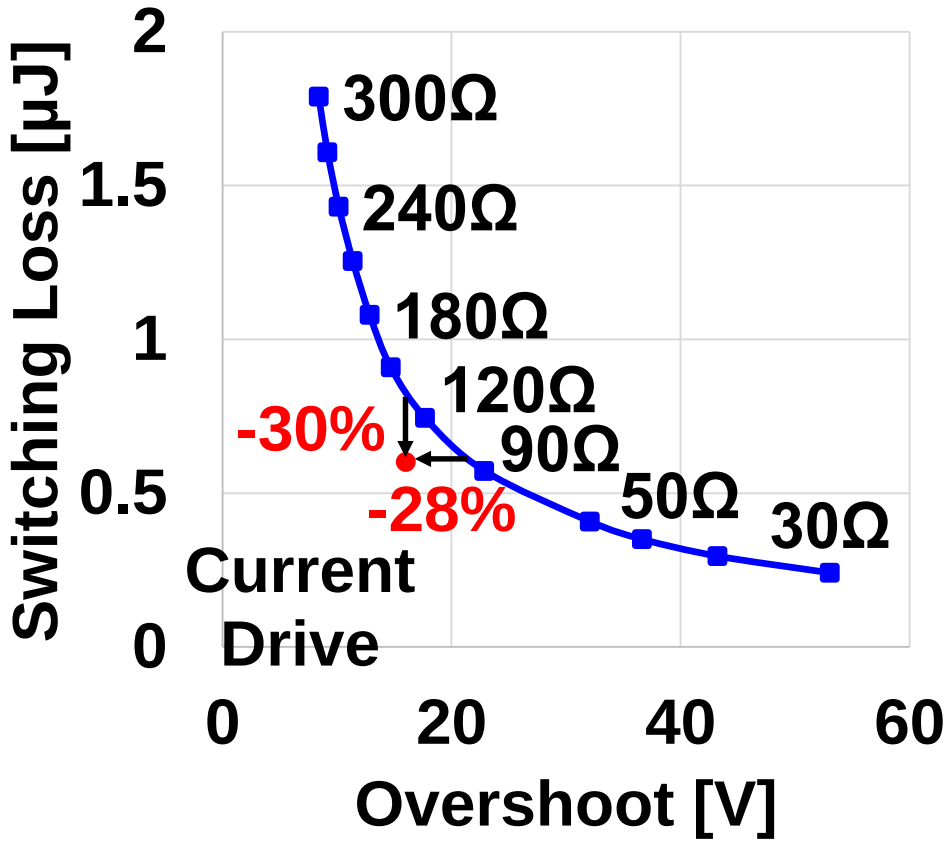
I_g : Uncontrollable due to I-V characteristics of MOSFETs

No effects on switching loss and overshoot



Comparison with Voltage Drive

Switching Loss : -30%, Overshoot : -28%



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Conclusion

- **Proposal of current drive circuit to control gate voltage of IGBT**
- **Current drive circuit draws different value of current at each 4-step operating region**
- **Simulation verification: During turn-off, reduction of switching loss (-30%), overshoot (-28%) compared to conventional voltage drive**

Challenges

- **Improve the current drive circuit**
  - Adapt to change in supply voltage during turn-off and supply charge during turn-on

Current drive will simplify the circuit to adapt to various changes

Thank you for your attention