Study on Current-Driven IGBT Driver Circuit

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OUTLINE

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

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Research Background

IGBTs have advantages of both MOSFETs and bipolar transistors

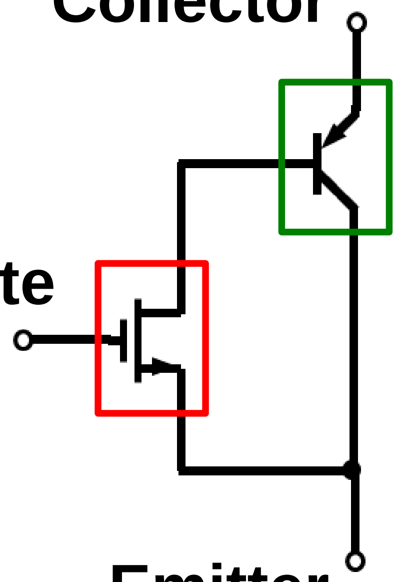
Used in wide range of applications as power semiconductor devices

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 → Switching loss

Parasitic inductance → Excessive overshoot

Change drive resistance during switching → Complex control

Objective

Current Drive →

- Reduction of Switching loss and Excessive overshoot
- Simplification of control design

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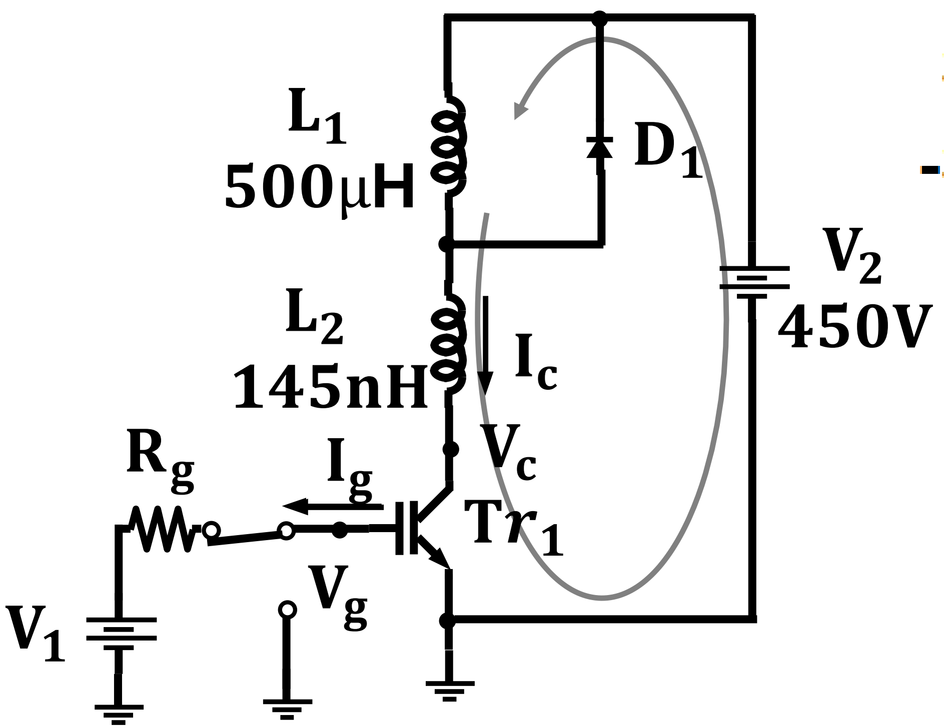
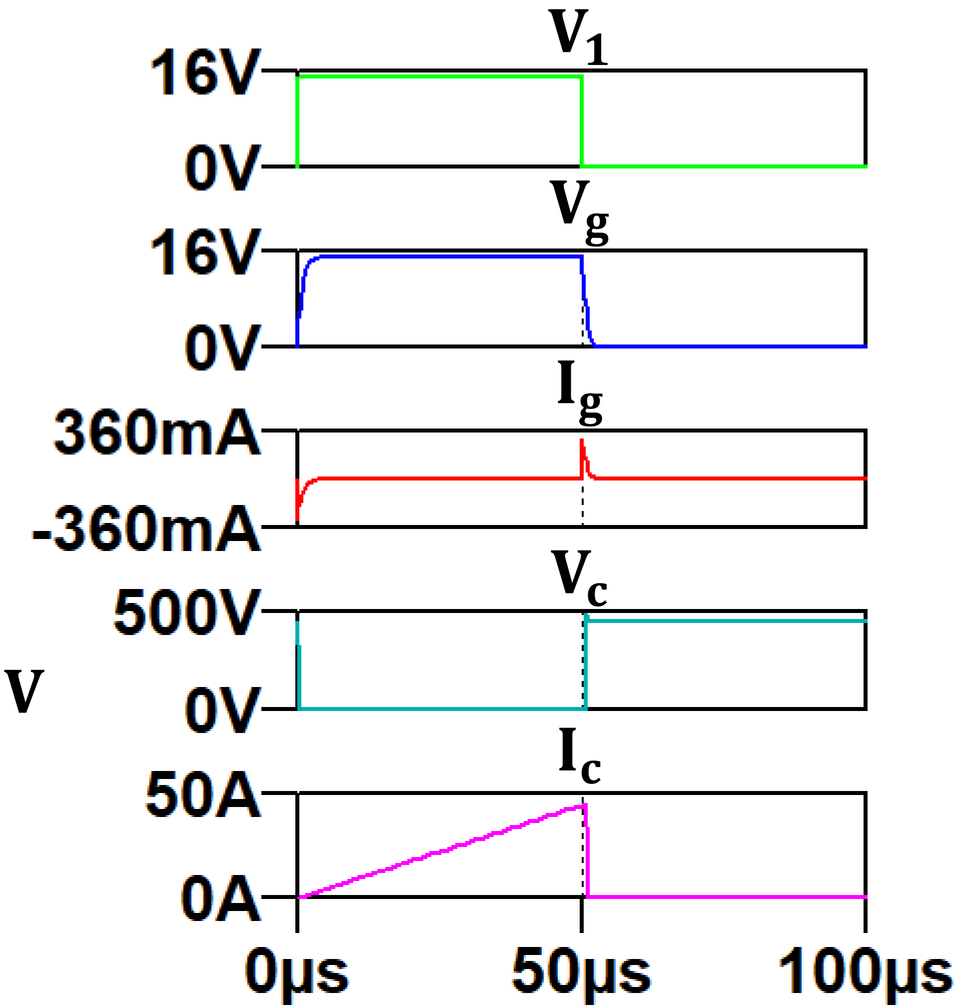
Voltage-Driven IGBT Evaluation Circuit (1/2)

Input voltage V_1

V_g turns on IGBT
I_c gradually flows



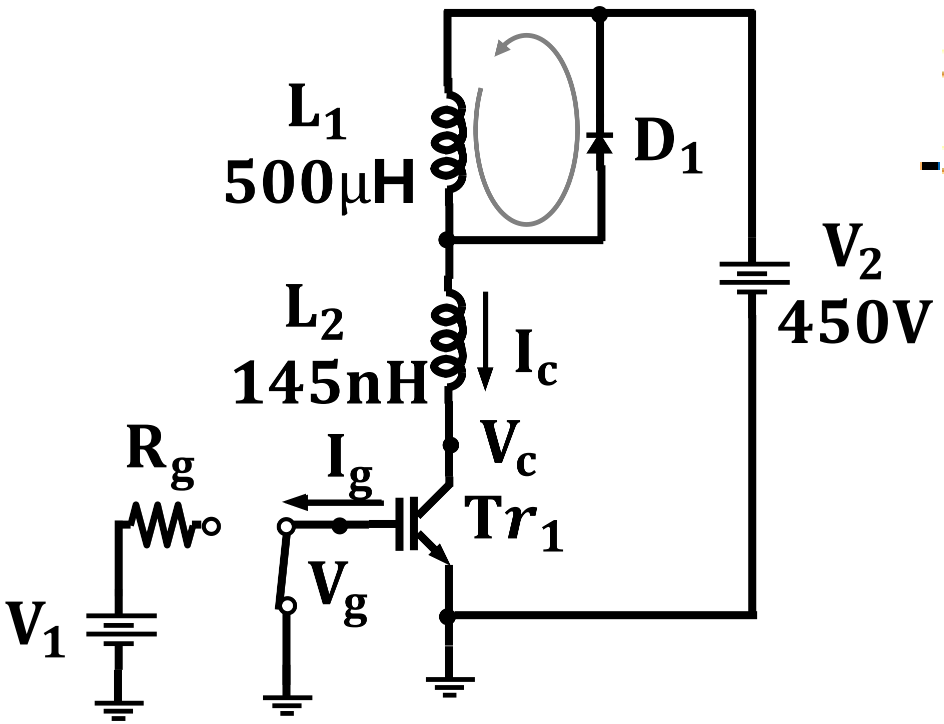


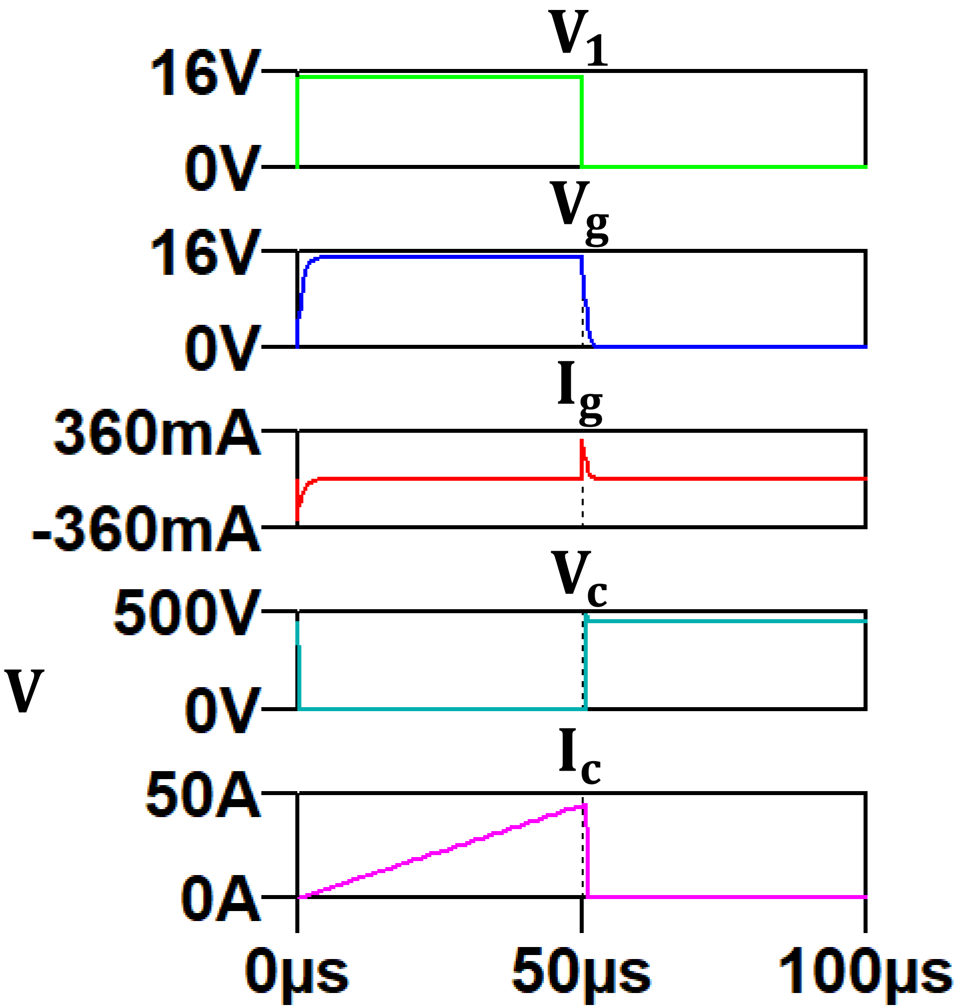
Voltage-Driven IGBT Evaluation Circuit (2/2)

V_1 becomes 0

V_g turns off IGBT

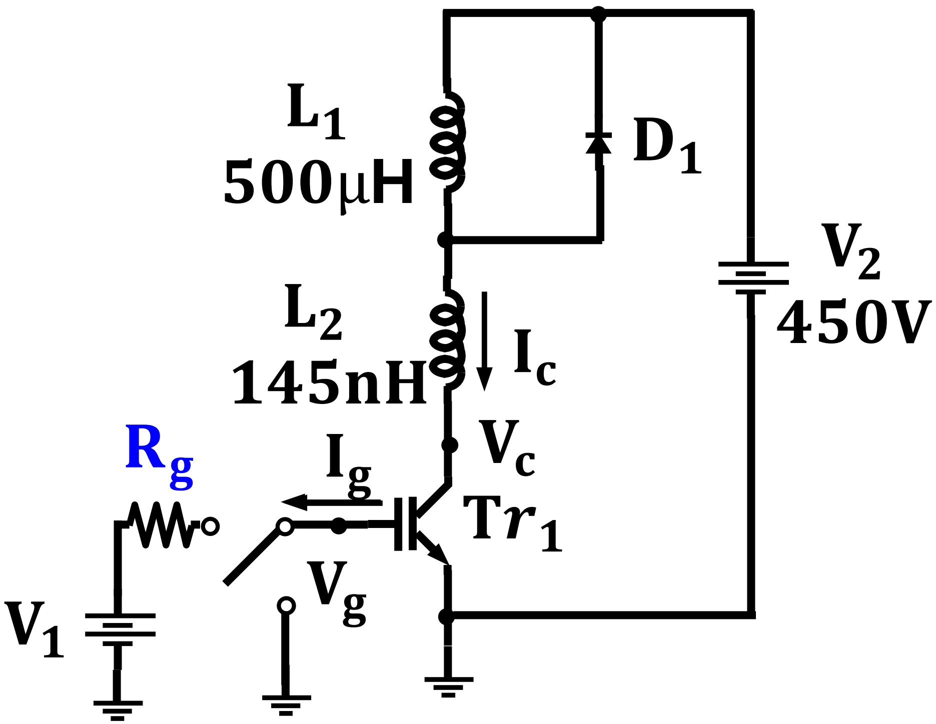
I_c gradually decreases

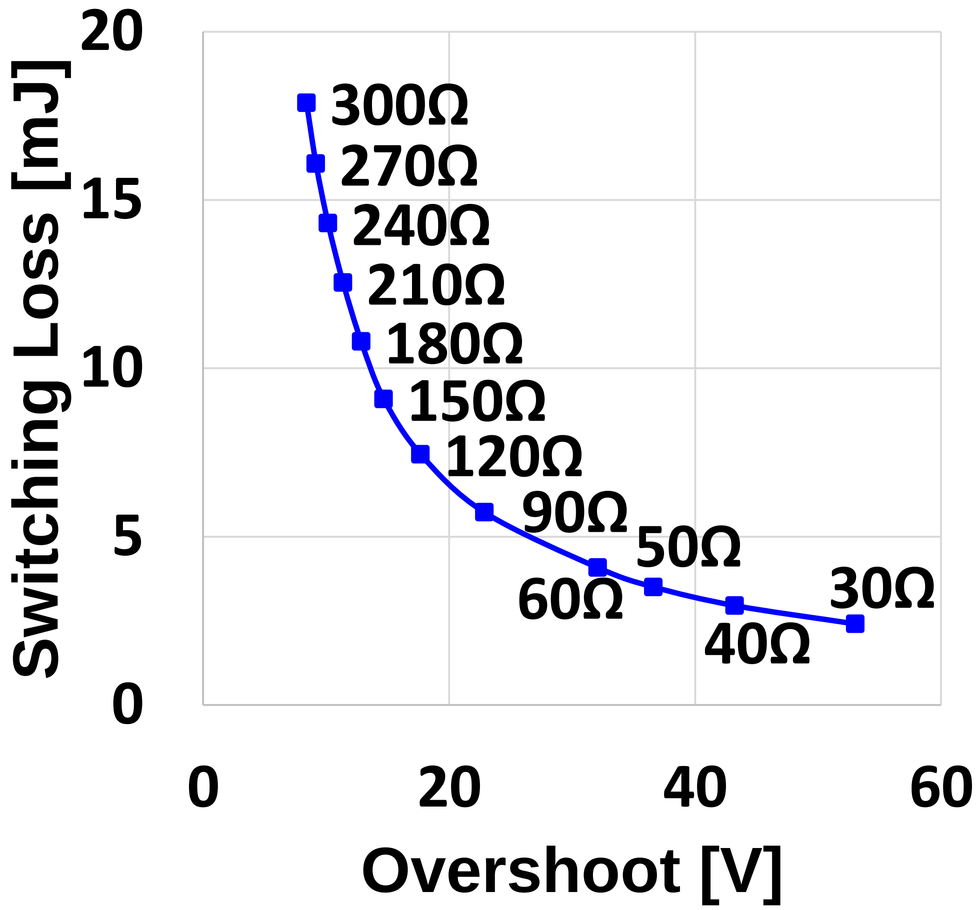




Overshoot and Switching Loss during Turn-off

Change gate resistance R_g from 30Ω to 300Ω





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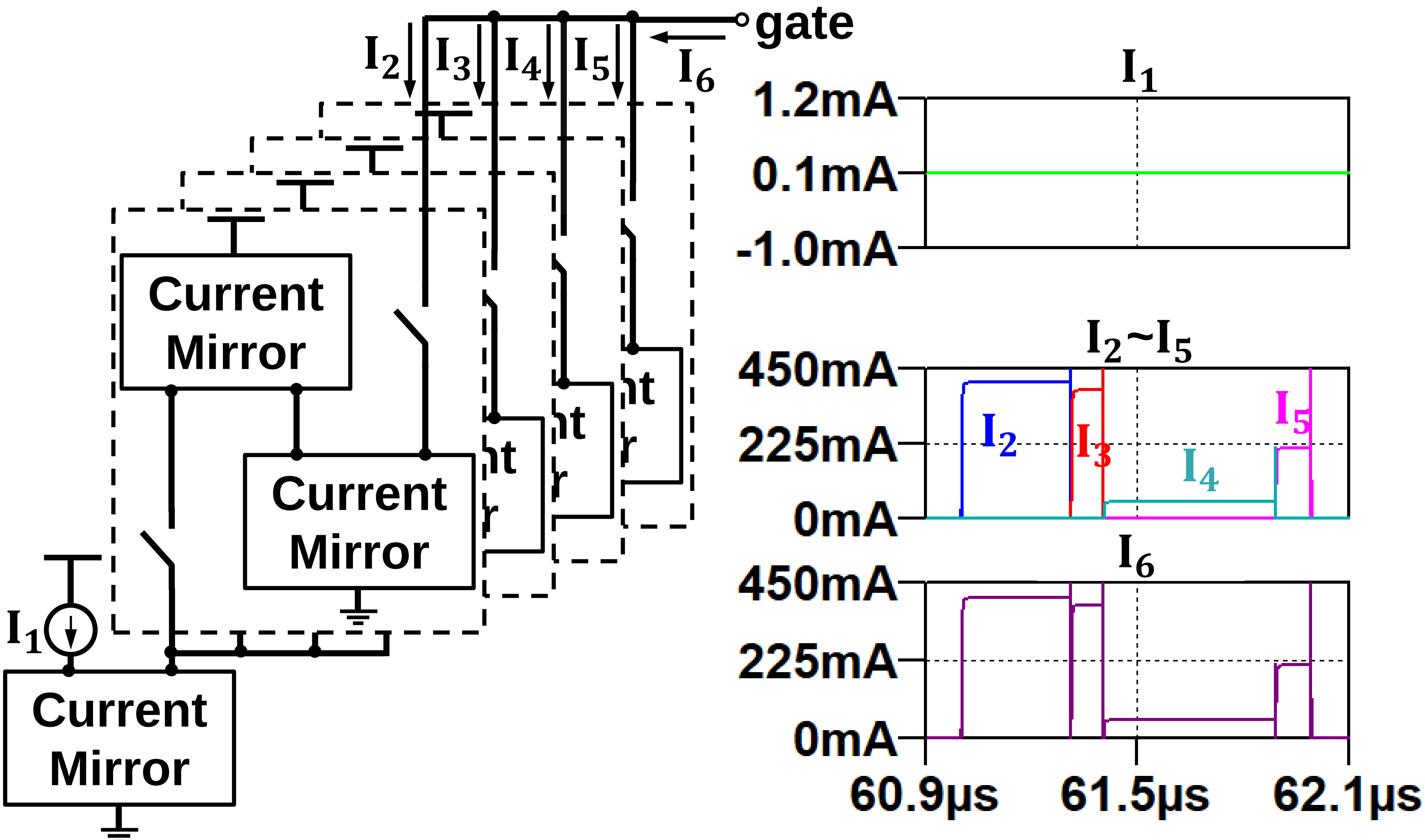
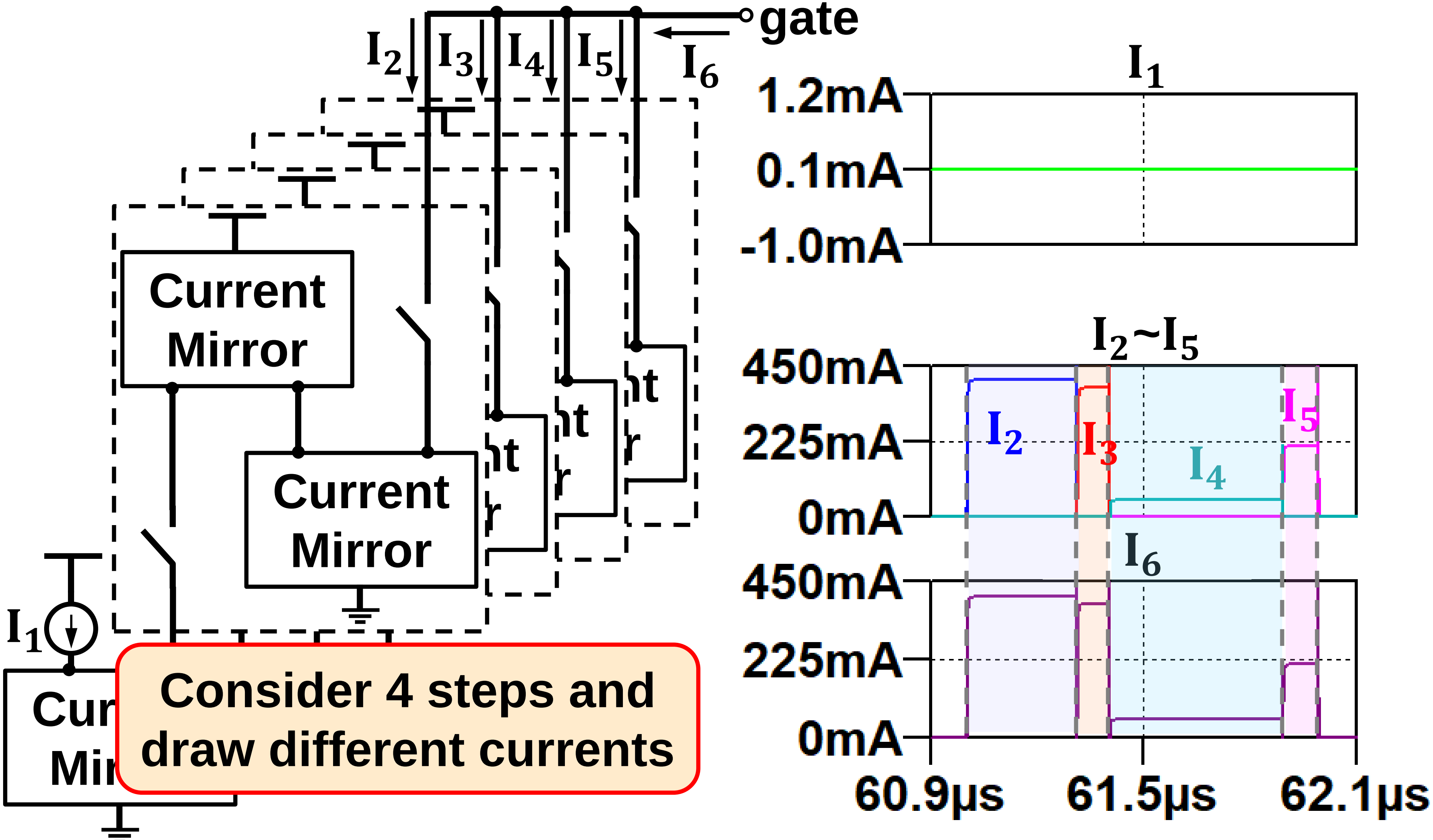
Current Gate Driver Circuit（1/2）



Current Gate Driver Circuit（2/2）



Consider 4 steps and draw different currents

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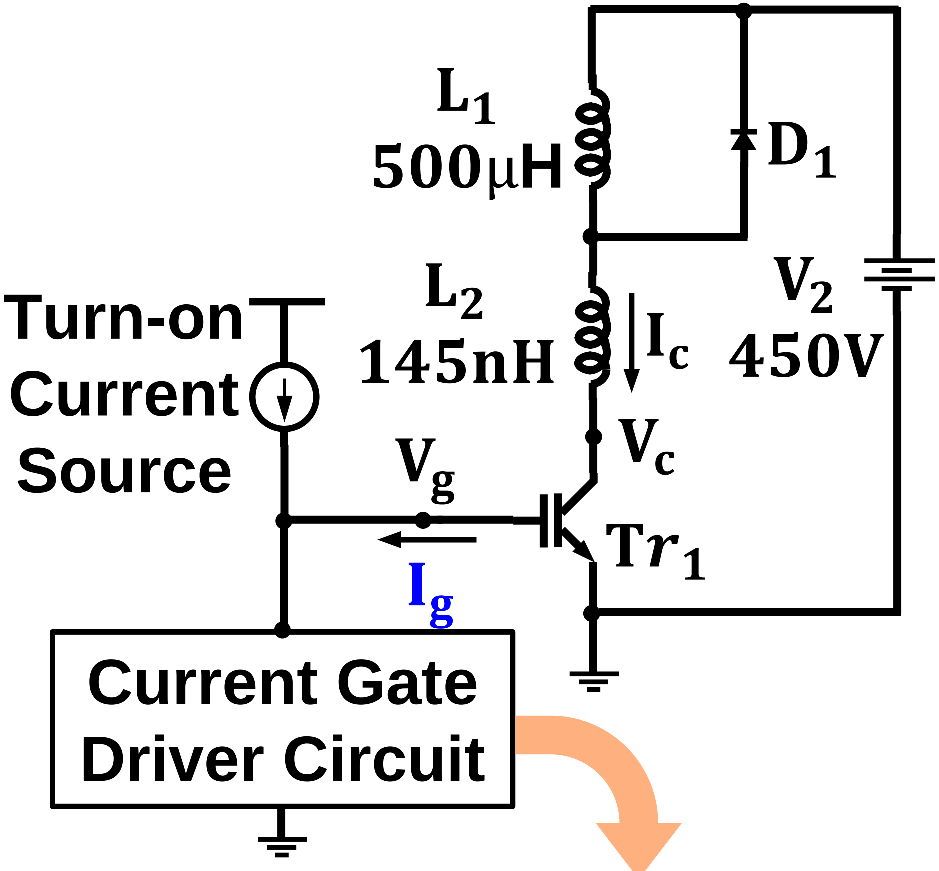
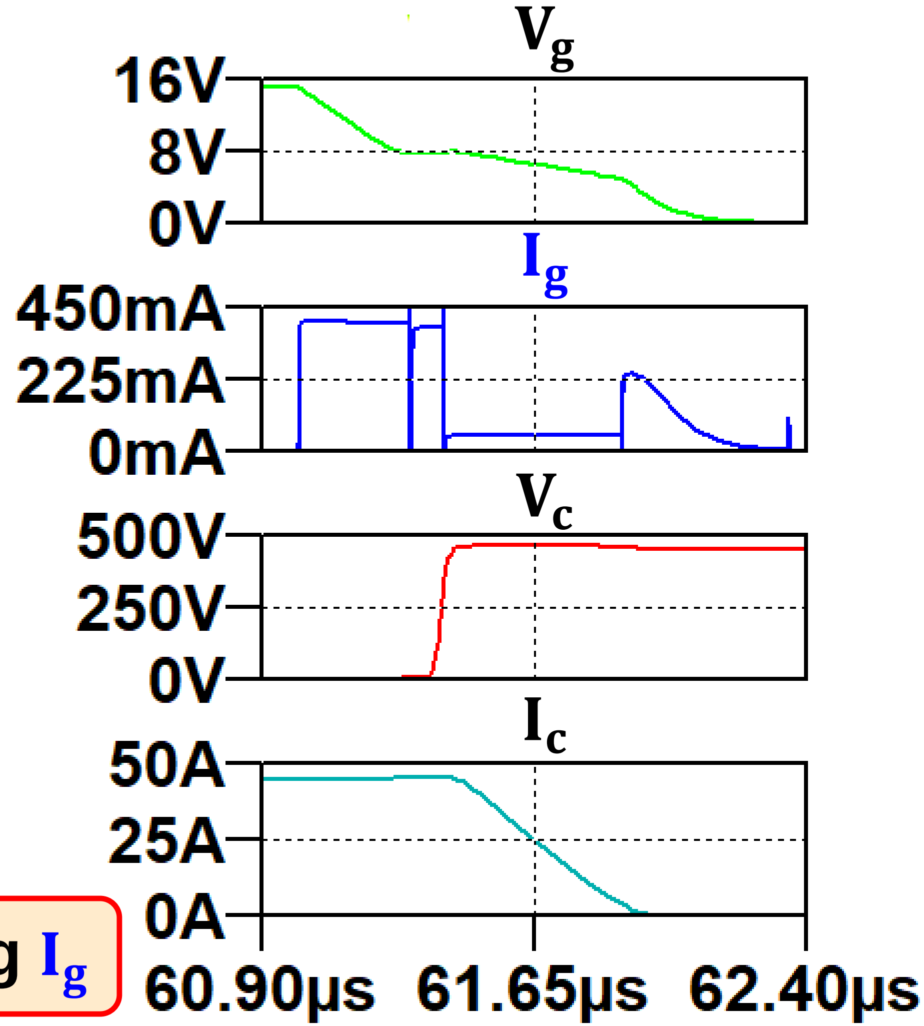
IGBT Turn-off Characteristics





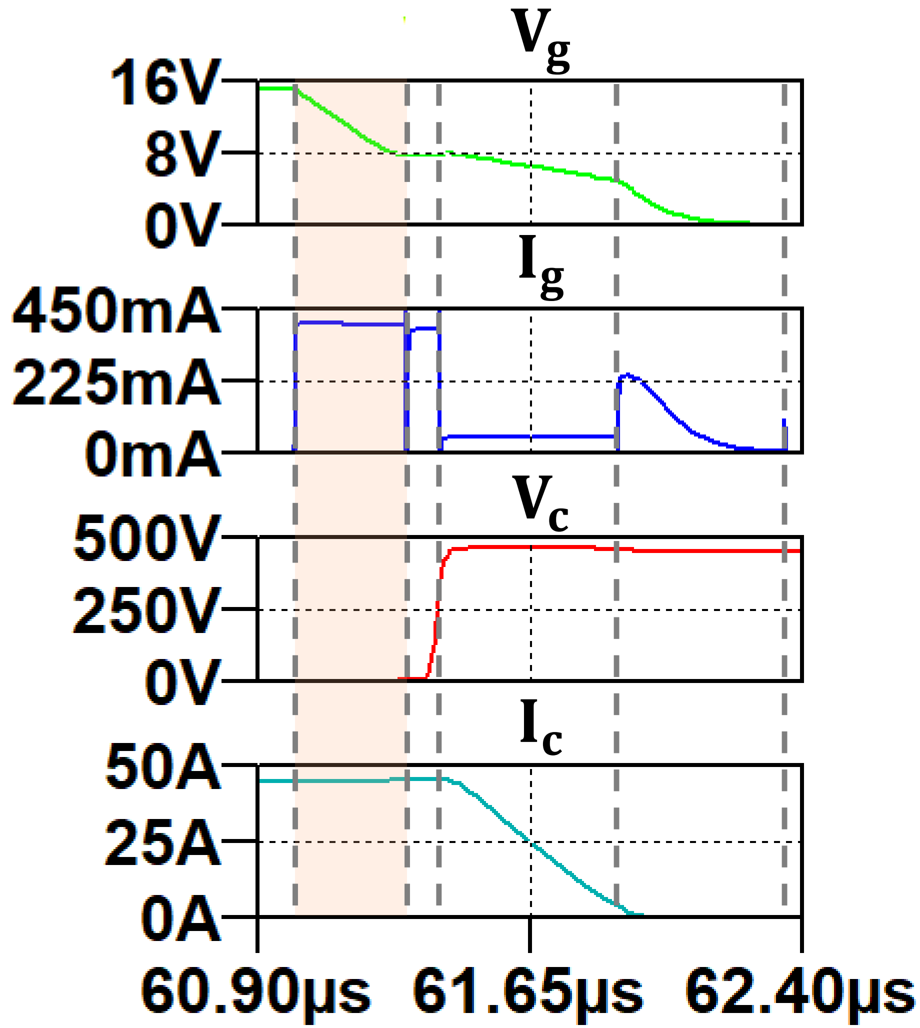
Control gate voltage by flowing I_g

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)

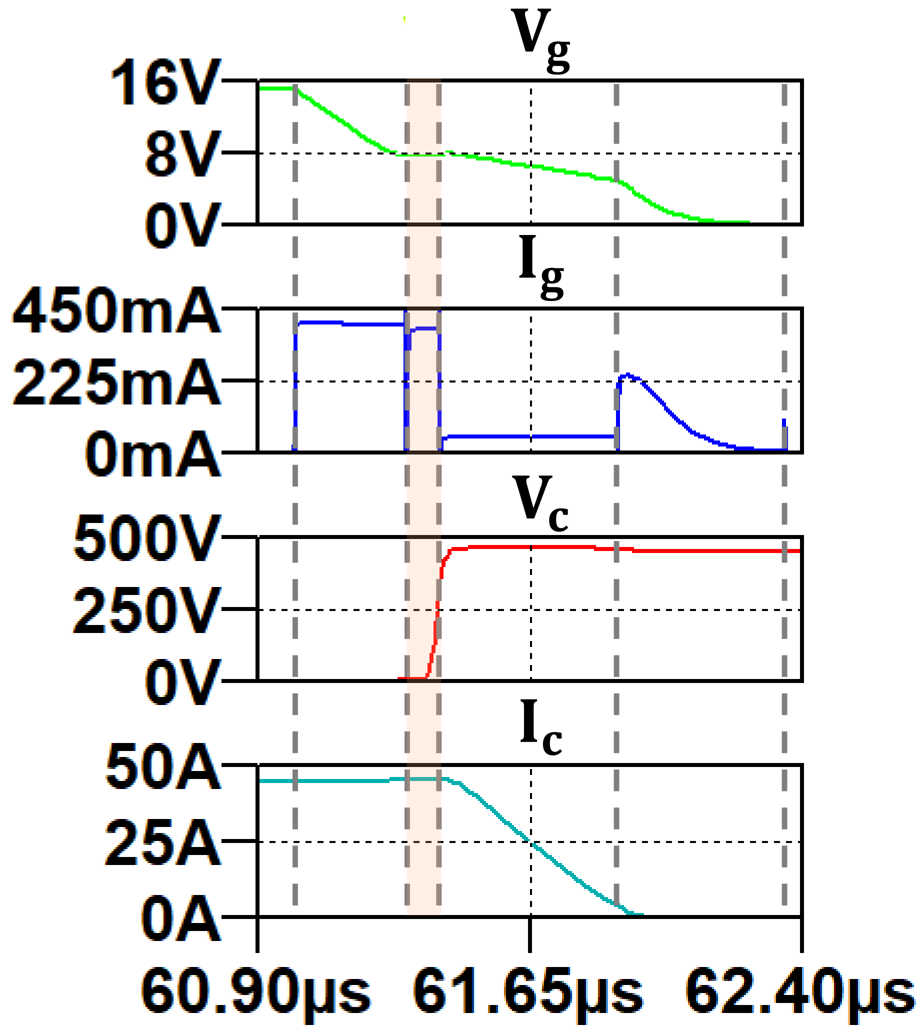
Step2

V_g : Miller period of IGBT

Trade-off between switching loss and slew rate

⬇

Switching loss can be reduced



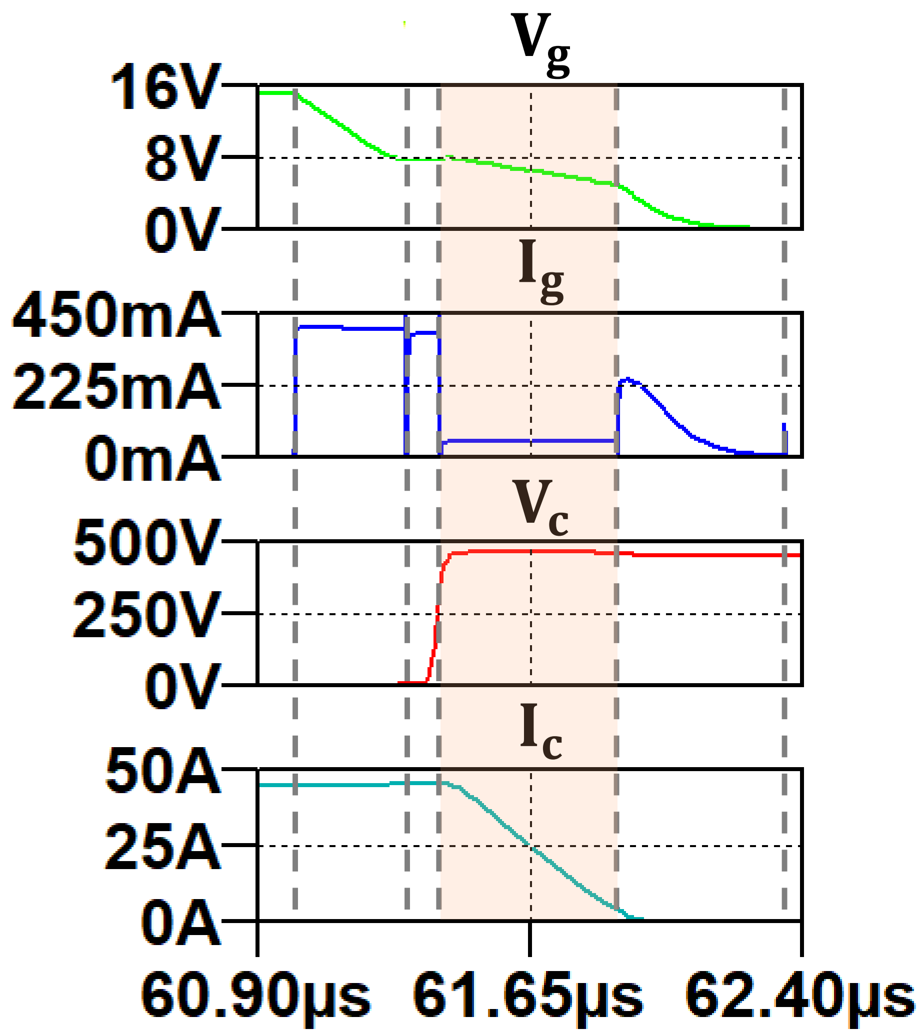
Control of Gate Voltage by Gate Current (Step3)

Step3

V_g : Miller voltage to threshold voltage

Trade-off between switching loss and overshoot

Overshoot can be reduced



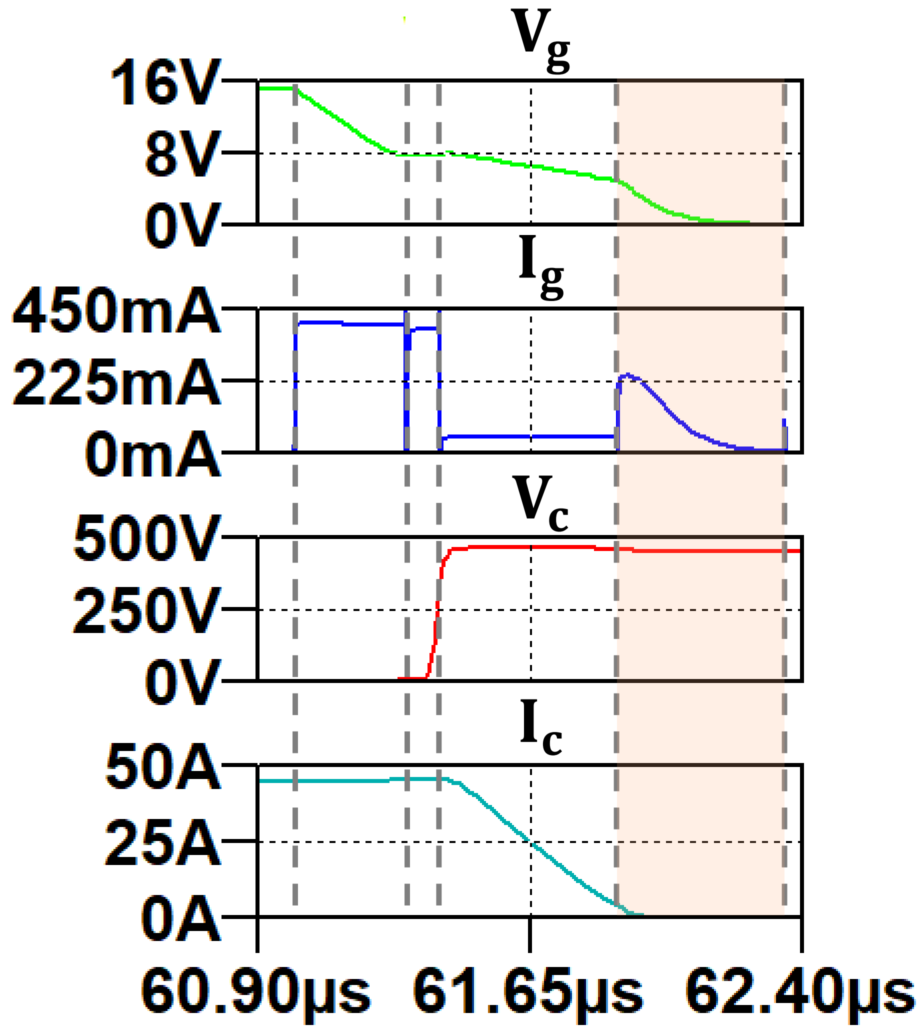
Control of Gate Voltage by Gate Current (Step4)

Step4

V_g : Threshold voltage to 0

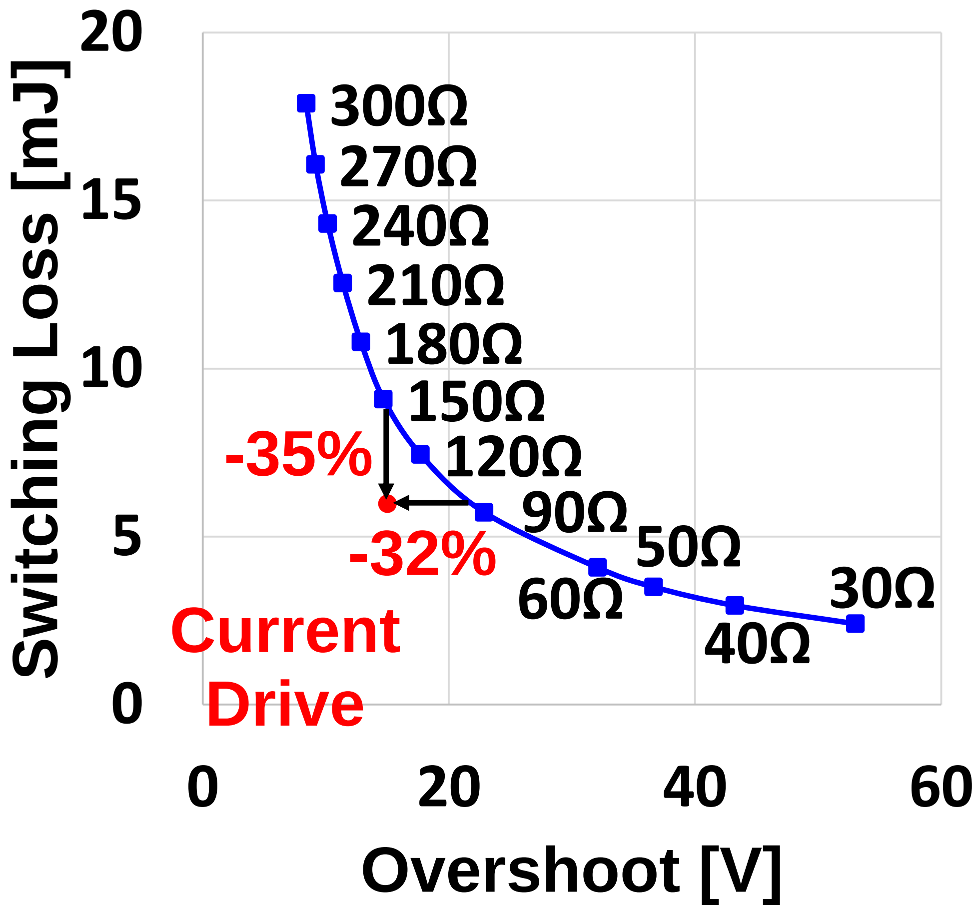
I_g : Uncontrollable due to I-V characteristics of MOSFETs

No effects on switching loss and overshoot



Comparison with Voltage Drive

Switching Loss : -35%, Overshoot : -32%



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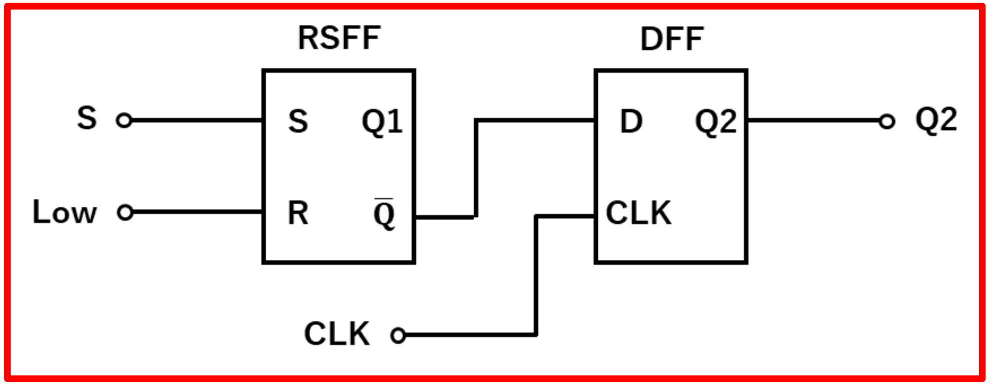
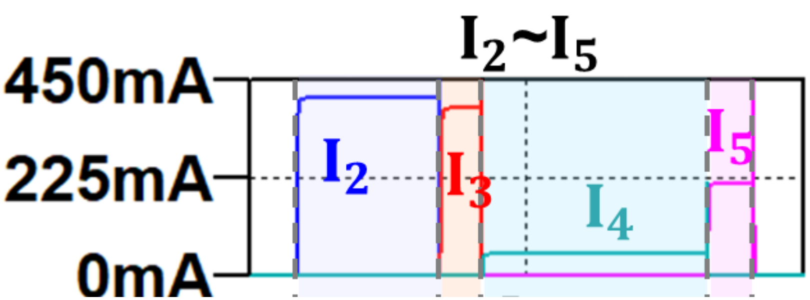
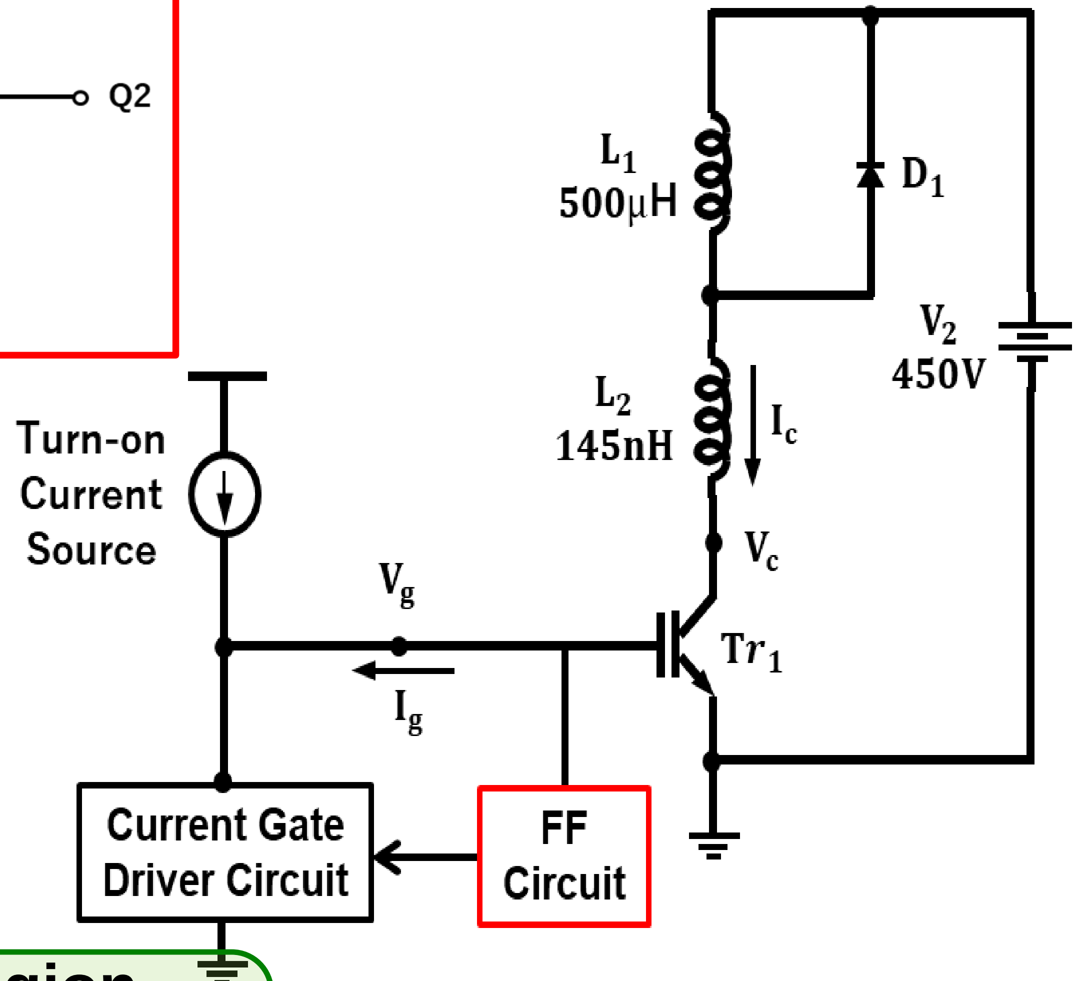
Gate Current Automatic Control



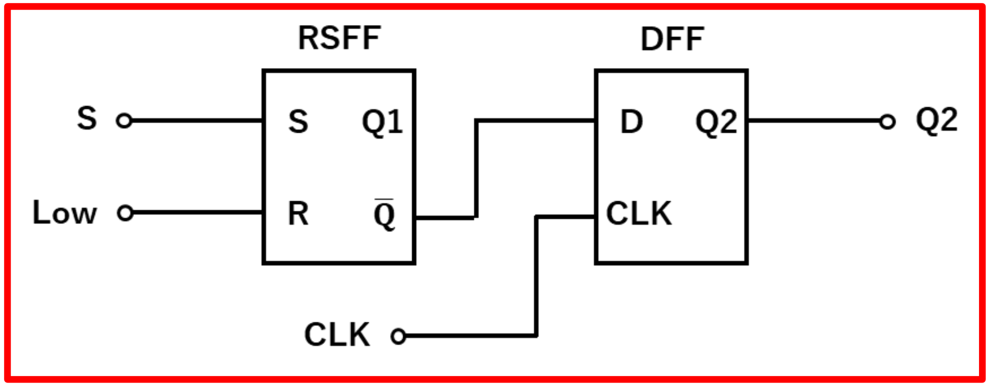


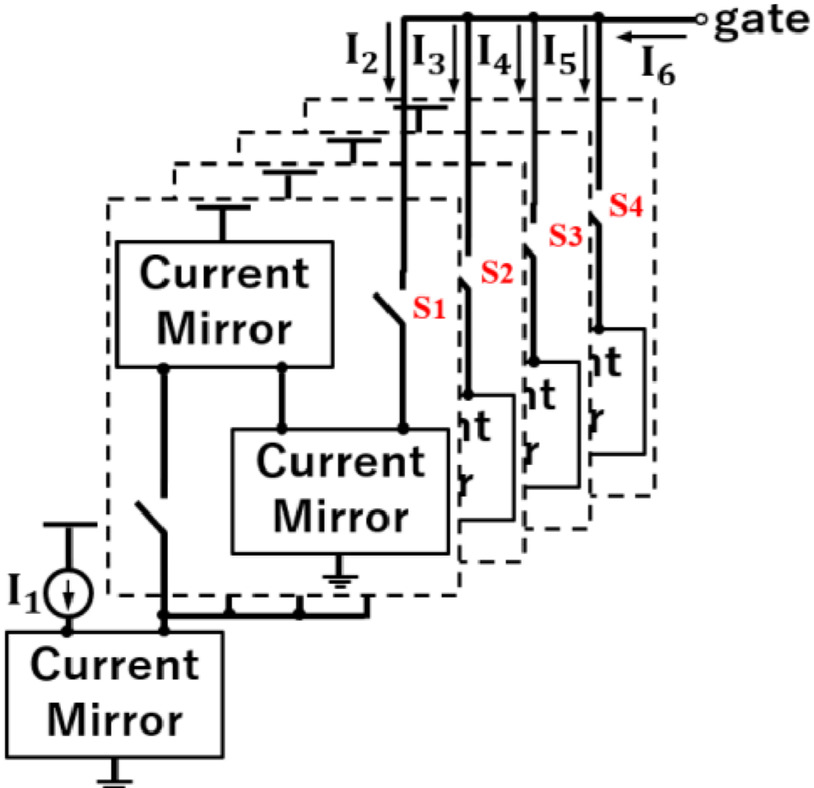
4 regions



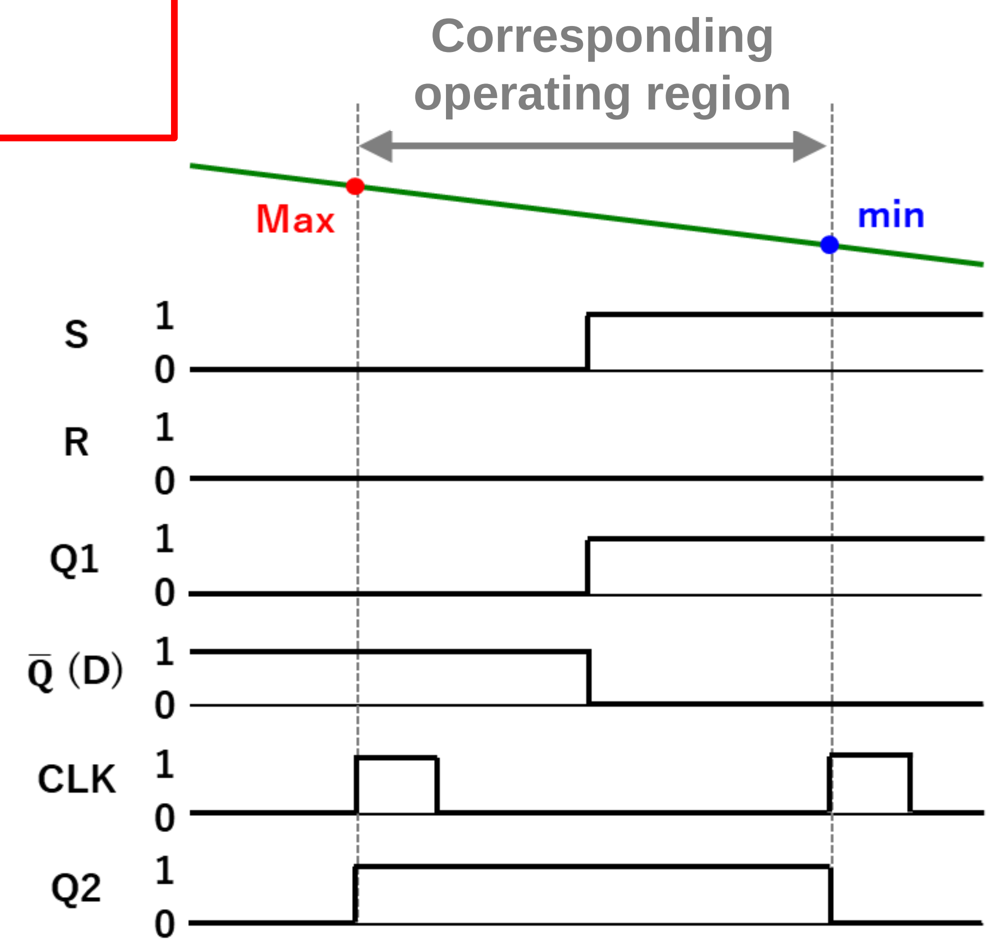
Judge the operating region from the voltage value of the gate, and determine the control current

FF circuit time chart



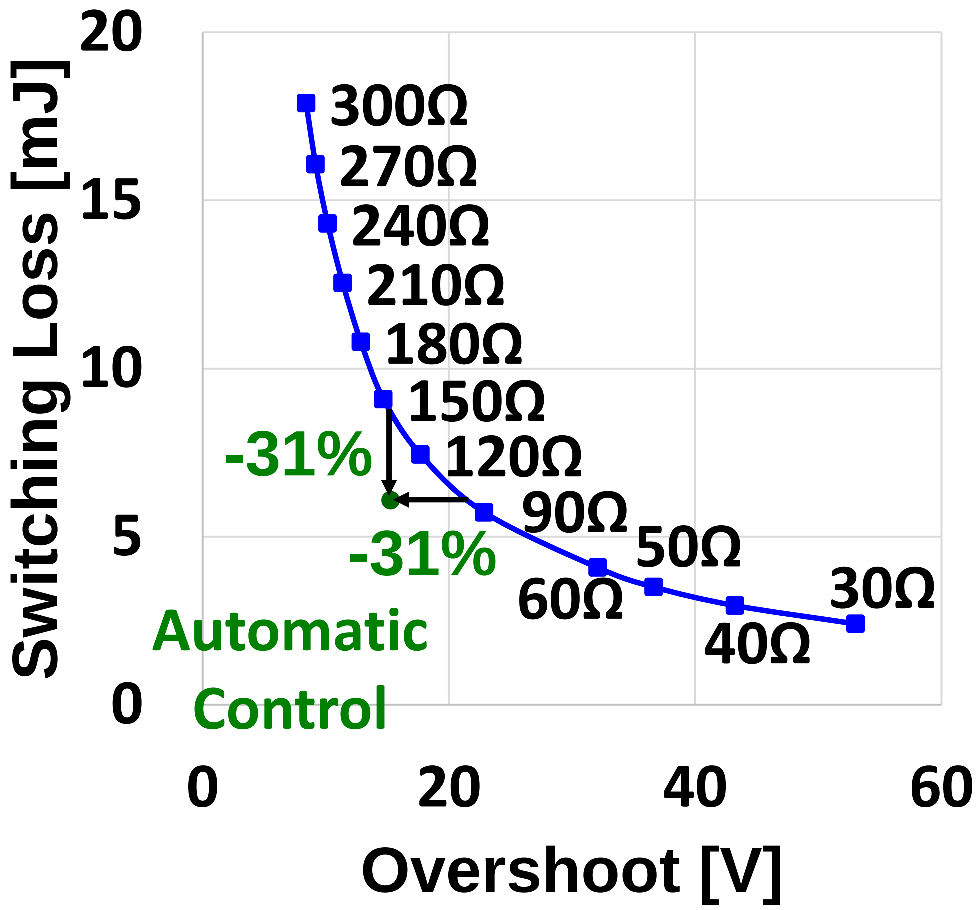


Automatic control only for the time in each operating region



Comparison of Voltage Drive and Automatic Control Current Drive

Switching Loss : -31%, Overshoot : -31%



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Conclusion and Challenges

Conclusion

- **Proposal of current drive circuit to control gate voltage of IGBT**

- **During turn-off, when compared to conventional voltage drive :**

Current Drive → switching loss (-35%), overshoot (-32%)
Automatic Control → switching loss (-31%), overshoot (-31%)

Challenges

- **Automatic control of current value in each operating region**