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A Variable Bypass Current Source Driver Circuit Based on Reference Voltage

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Introduction

- Conventional gate drive (CGD) strategies for insulated gate bipolar transistors (IGBTs) face challenges in balancing switching losses with voltage and current spikes.
- Active gate drivers (AGD), on the other hand, can be controlled in stages to suppress these spikes and minimize switching losses.
- In this paper, we propose a new driving circuit - a variable bypass current source driver circuit based on reference voltage (VBCD), which uses the reference voltage to adjust the current magnitude of the bypass current source, thereby controlling the switching transient of the IGBT state.

Principle

- Add two voltage-controlled current sources to the CGD to achieve segmented control.
- During the turn-on transient, detect the Miller platform to control the switching on of a current source, reduce the charging speed of the gate.
- During the turn-off transient, detect the Miller platform to control the switching on of another current source, reduce the discharging speed of the gate.

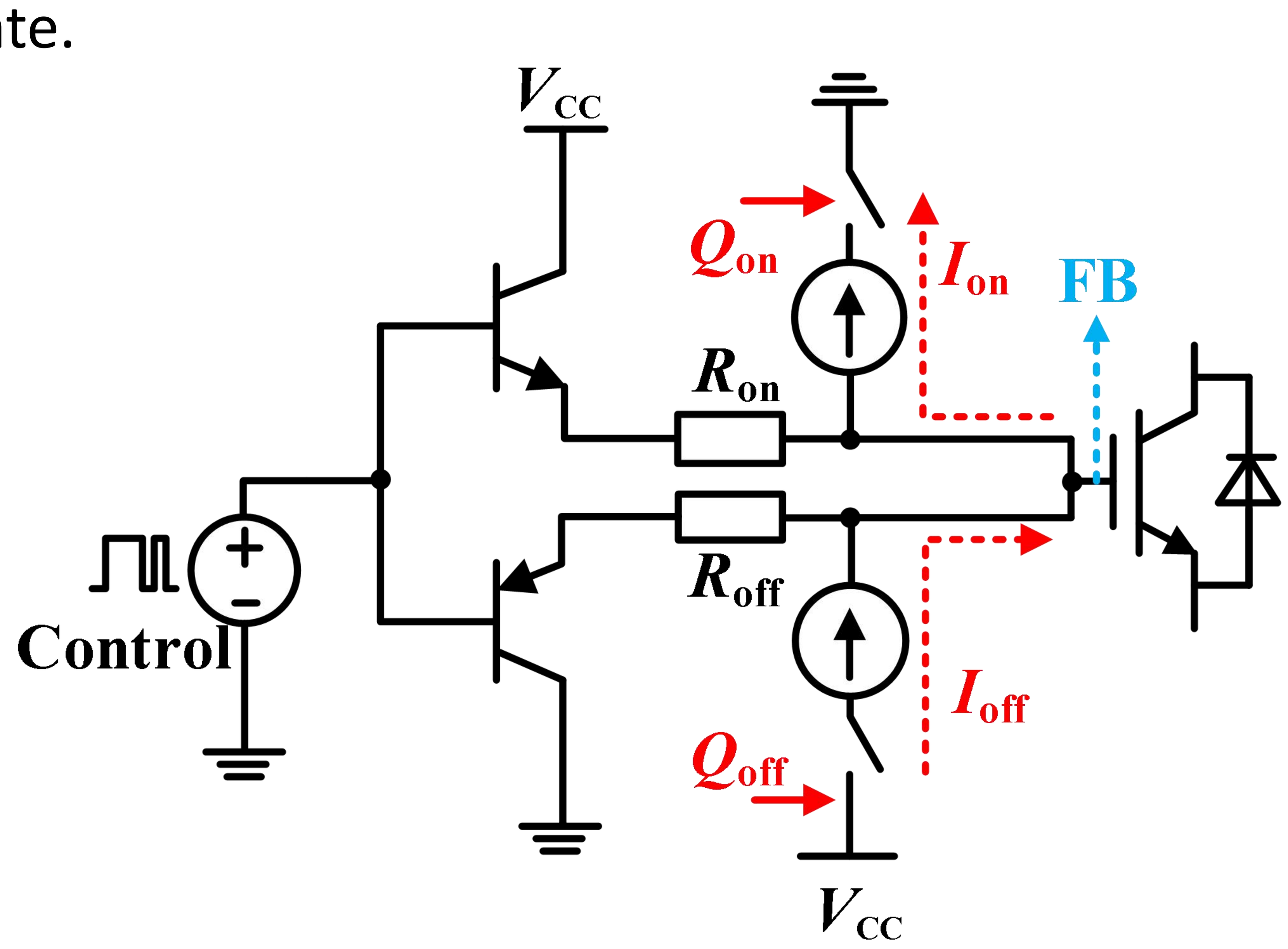

Fig. 1. Schematic diagram of VBCD

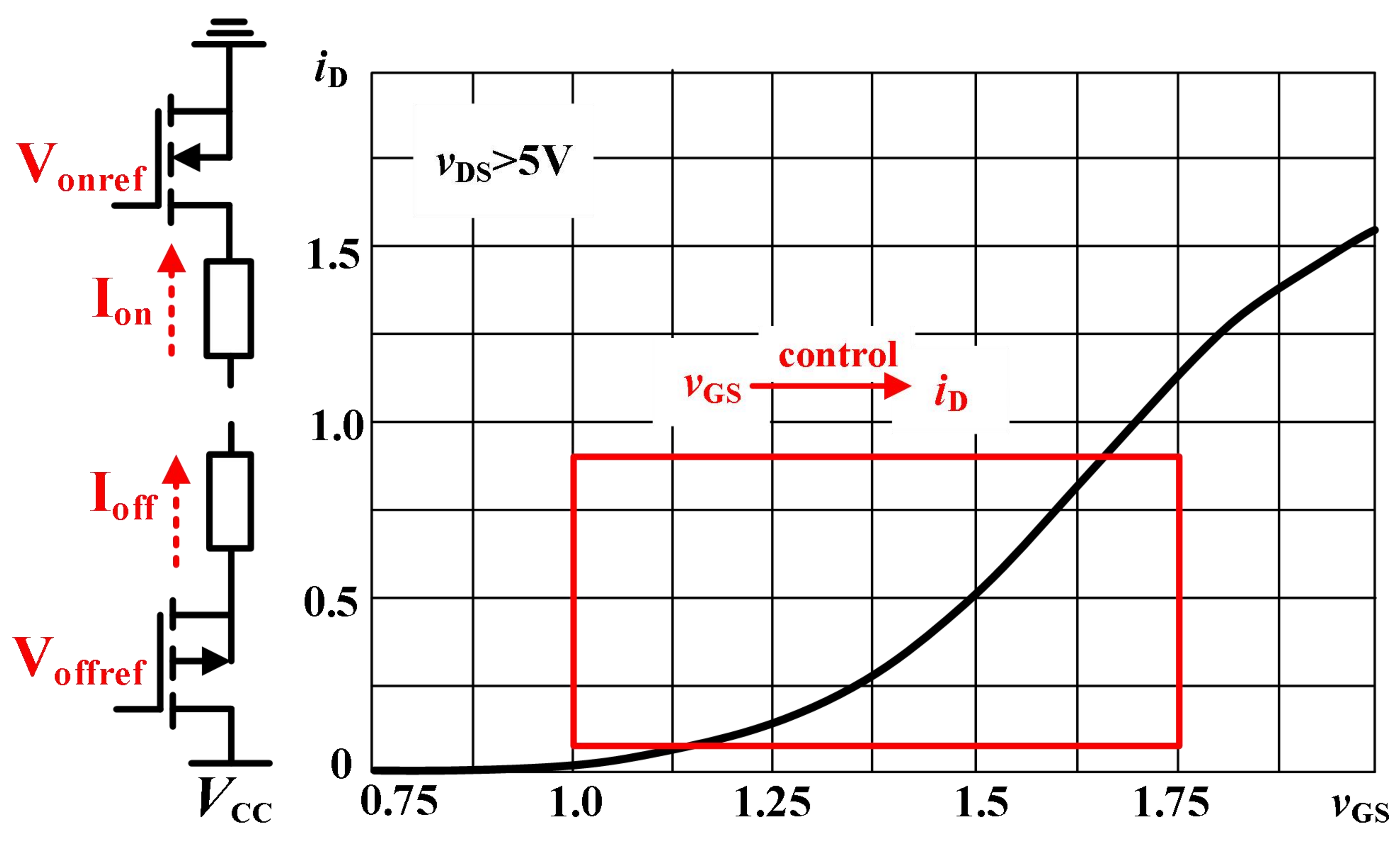

Fig. 2. Implementation of current source

Advantage

- Lower switching stress.
- Lower voltage and current spikes.
- Lower gate resistance (reduce delay).
- Adjustable driving process (by change V_{ref}).

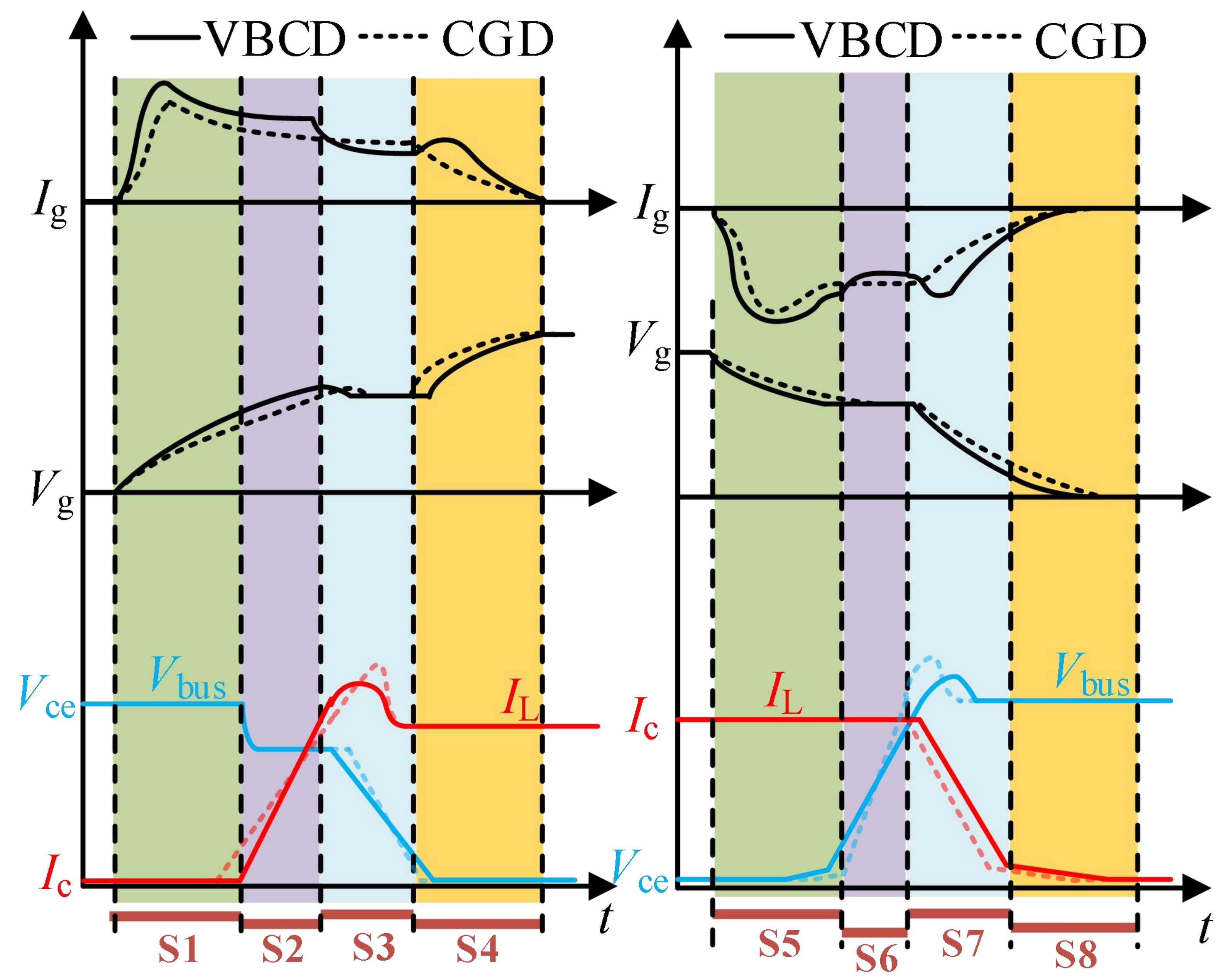

Fig. 3. Comparison between VBCD and CGD

Experimental Verification

- During the turn-off transient, the current source is controlled to be turned on and off by sampling the gate voltage.

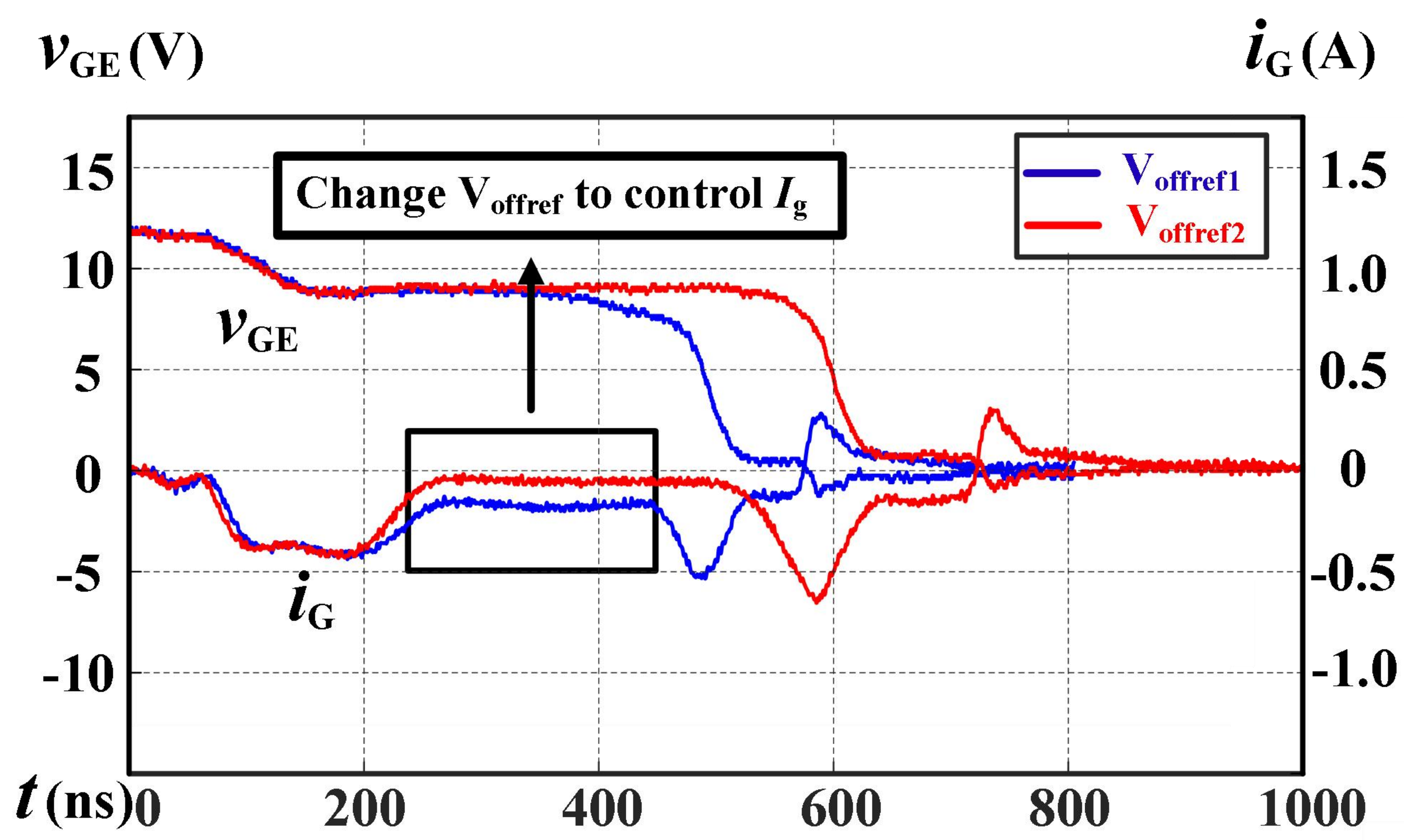

Fig. 4. Voltage-controlled current source

- Building a double pulse test circuit.

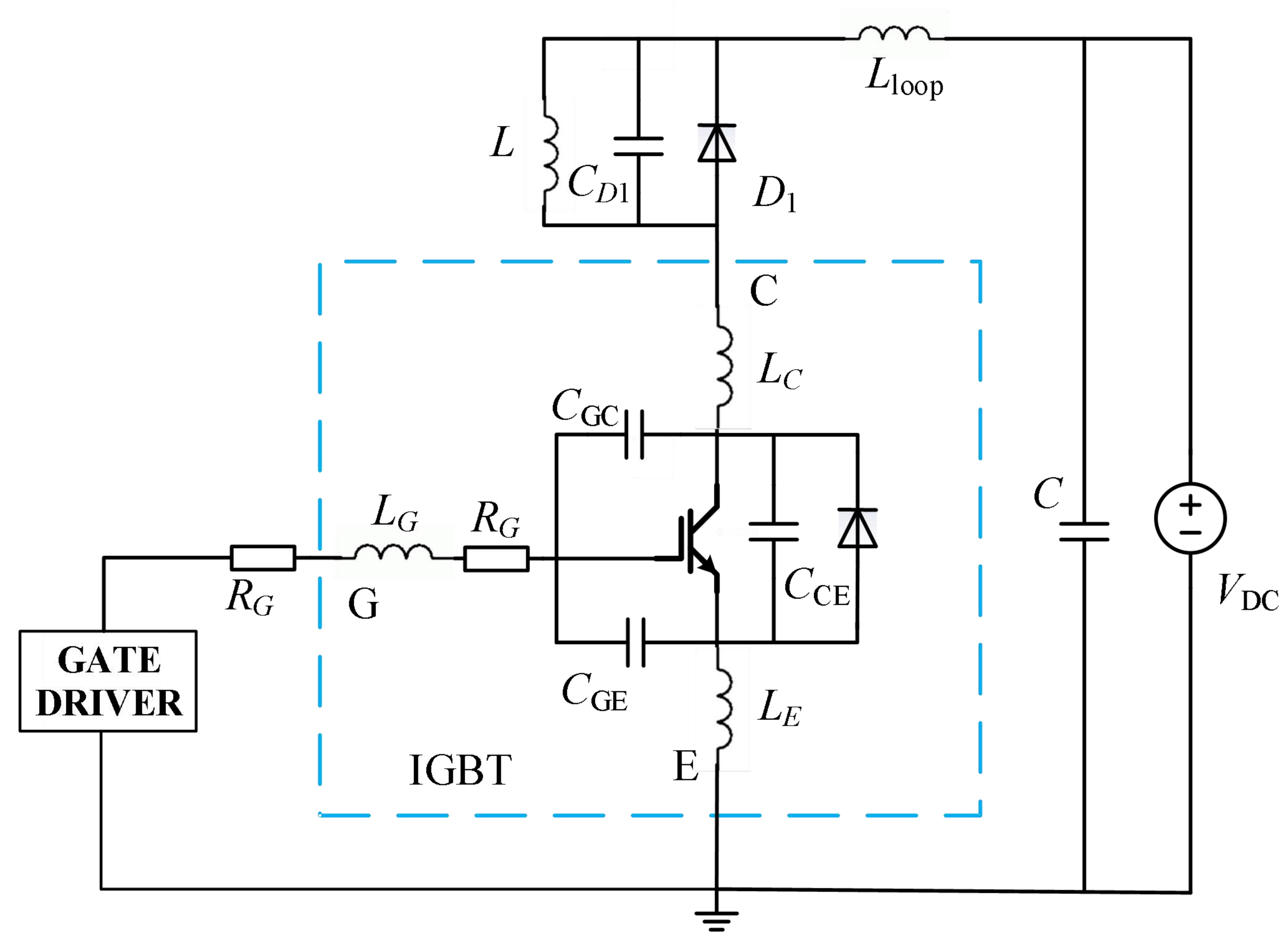

Fig. 5. Double pulse test circuit diagram

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Experimental environment

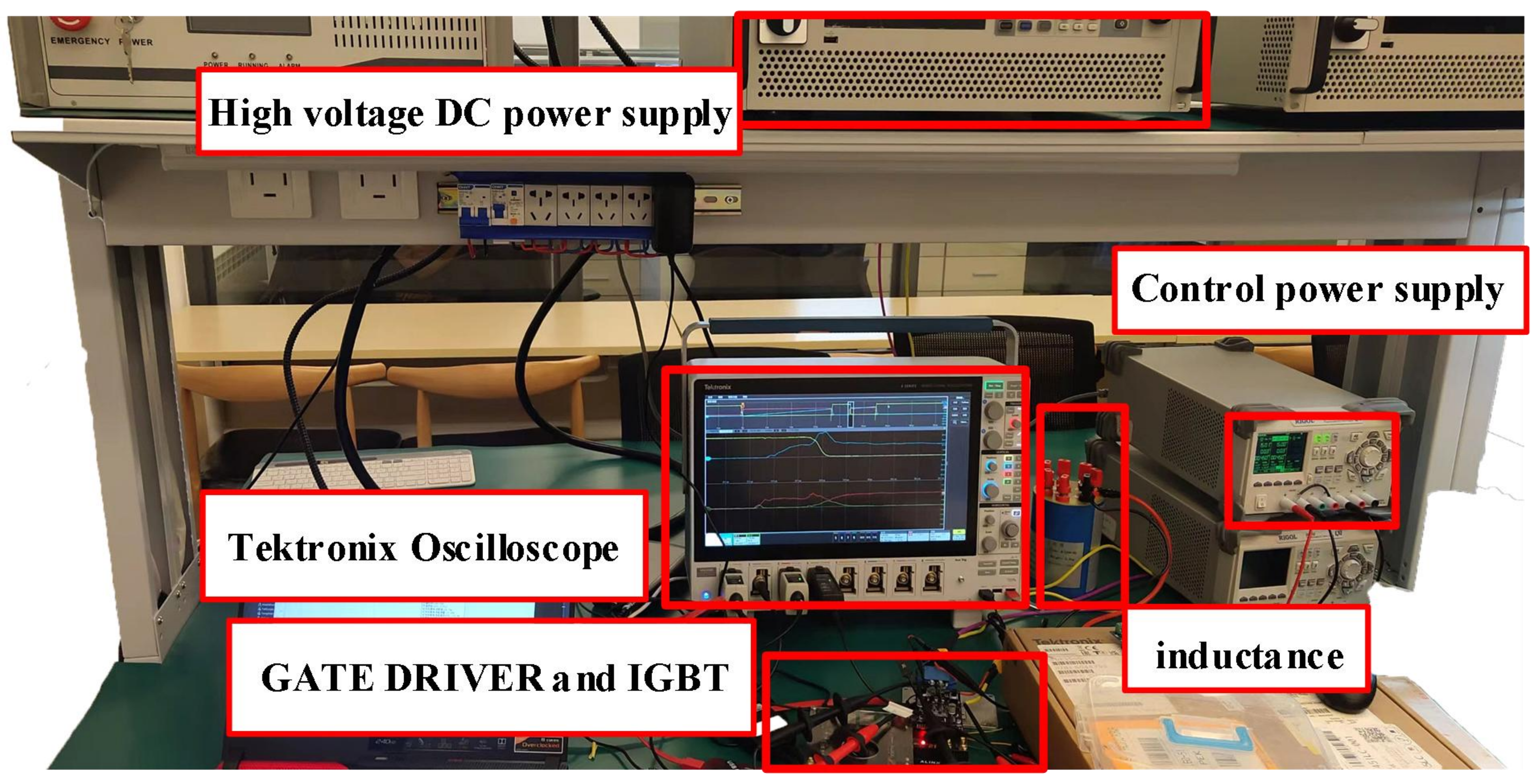

Fig. 6. Experiment platform

Equipment	Name
Oscilloscope	Tektronix 6 Series
High Voltage DC Power Supply	IT6018D-1500-40
Low voltage DC power supply	DP832
High Voltage Differential Probes	THDP0200
Low Voltage Differential Probes	TDP1000
Rogowski coil	CWTUM/03/B
FPGA	AXKU040
IGBT module	FS35R12W1T4

Double pulse test conditions: bus voltage 400V, load current 15A

CGD test result

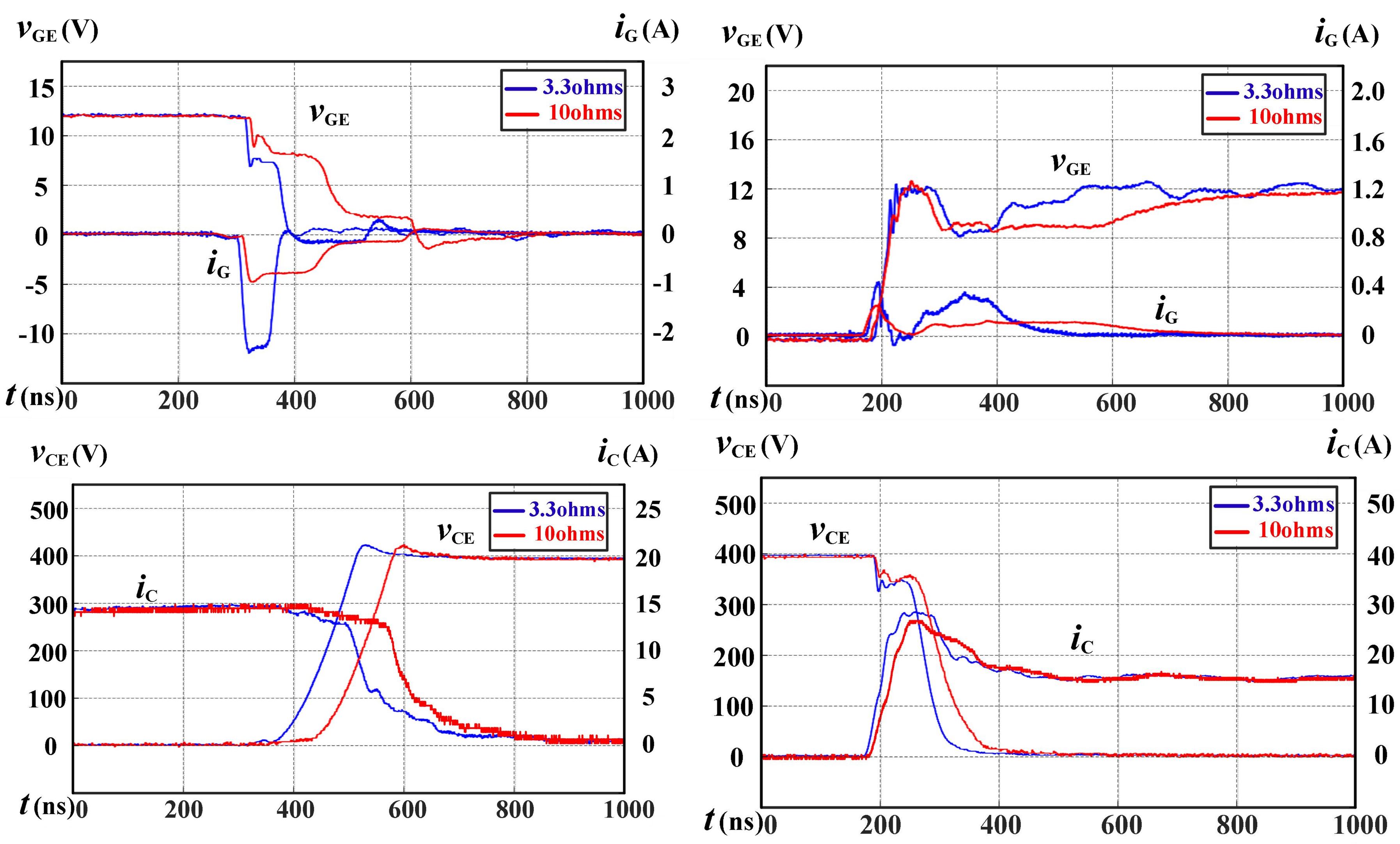

Fig. 7. Waveform of CGD

VBCD test result

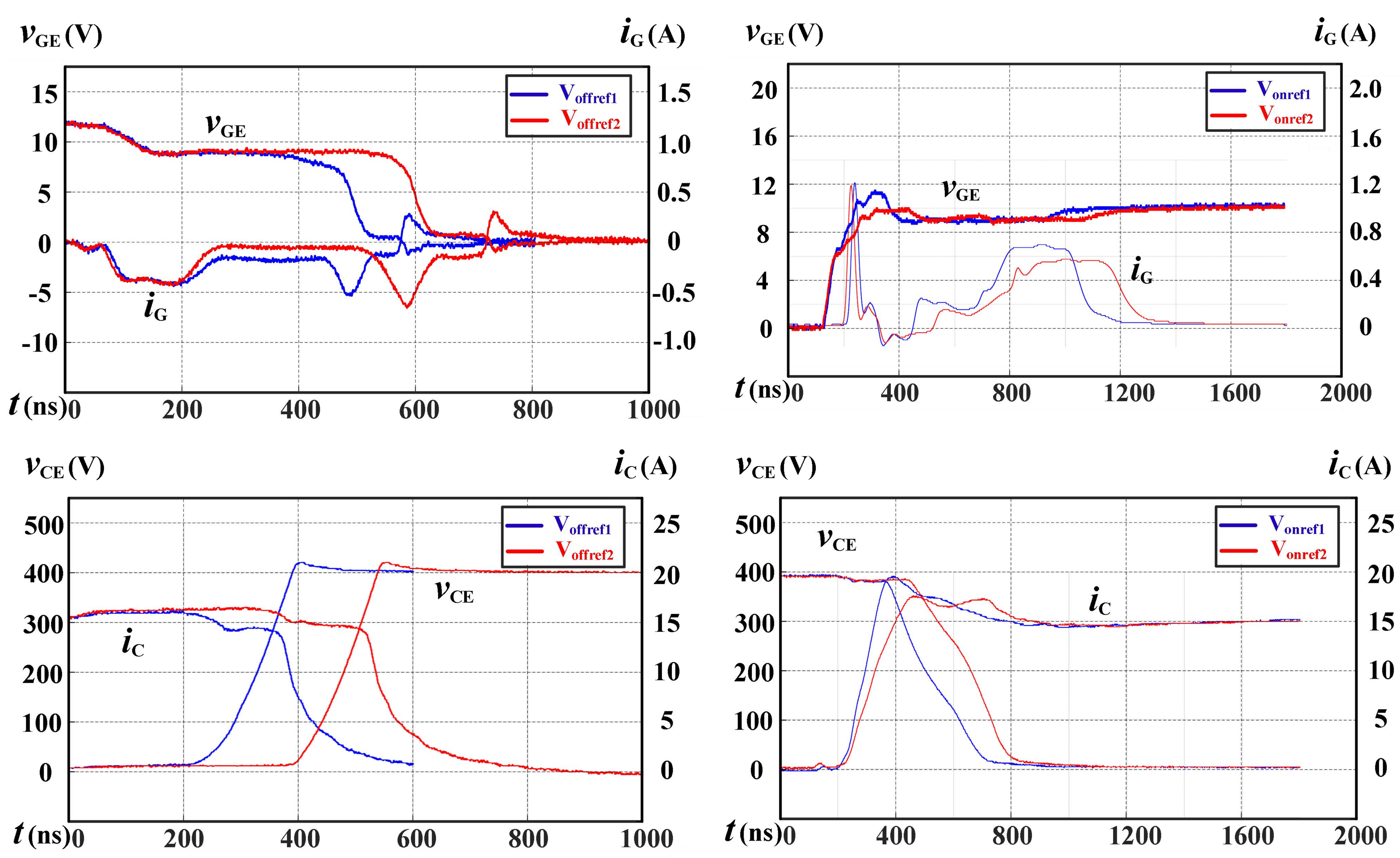

Fig. 8. Waveform of VBCD

Comparison of turn-off transients

Conditions	turn-off loss(mJ)	voltage spike(%)	di/dt(V/ns)	dv/dt(A/us)
3.3ohms	0.50	7.74	3.49	229
10ohms	0.57	6.81	3.40	210
$V_{offref1}$	0.57	4.46	3.19	251
$V_{offref2}$	0.60	3.38	3.10	254

Comparison of turn-on transients

Conditions	turn-on loss(mJ)	corrent spike(%)	di/dt(V/ns)	dv/dt(A/us)
3.3ohms	0.74	90.8	6.92	521
10ohms	0.85	82.6	4.28	388
V_{onref1}	1.65	35.9	1.20	135
V_{onref2}	2.12	21.7	0.92	85.9

Comparison between CGD and VBCD

- During the turn-off transient, VBCD can reduce the voltage spike and dv/dt as much as possible without changing the turn-off loss, and the turn-off transient parameters can be controlled by changing V_{offref}.
- During the turn-on transient, VBCD can reduce the current peak value, di/dt and dv/dt, but the turn-on loss is relatively large. As with turn-off, turn-on transient parameters can also be controlled by changing V_{onref}.

Conclusion

- Compared with CGD, VBCD suppresses spikes at a relatively low cost.
- Compared with other AGDs, VBCD is relatively simple to implement, has fast response speed and good control effect.

Future

- More precise and controllable current source.
- Add feedback from the high-voltage side.

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