

Development of SSCB on the Train Auxiliary Power Supply(SIV) of Urban Railway

6th Joint University Students Workshop

Geonhui Hyeong

Chungbuk National University
Electric Machine Drive Lab



충북대학교
CHUNGBUK NATIONAL UNIVERSITY

Electric Machine Drive Lab



OUTLINE

- 1 Introduction
- 2 Short-Circuit Current Sensing
- 3 PCB Trace
- 4 Over Voltage Protection
- 5 Solid-state device

❖ Types of urban railway vehicles



K-AGT(rubber-tired system)

- Korea's first driverless operation system
- Busan Metro Line 4 (rubber-tired system), 102 cars



Incheon IAT

- Incheon Airport Railroad
- Rubber-tired light rail transit, 6 cars
- Fully automated driverless operation using ATO/ATP



Sillim Line

- Yeouido to Seoul National University Station



Smart Monorail

- Taejongdae Monorail

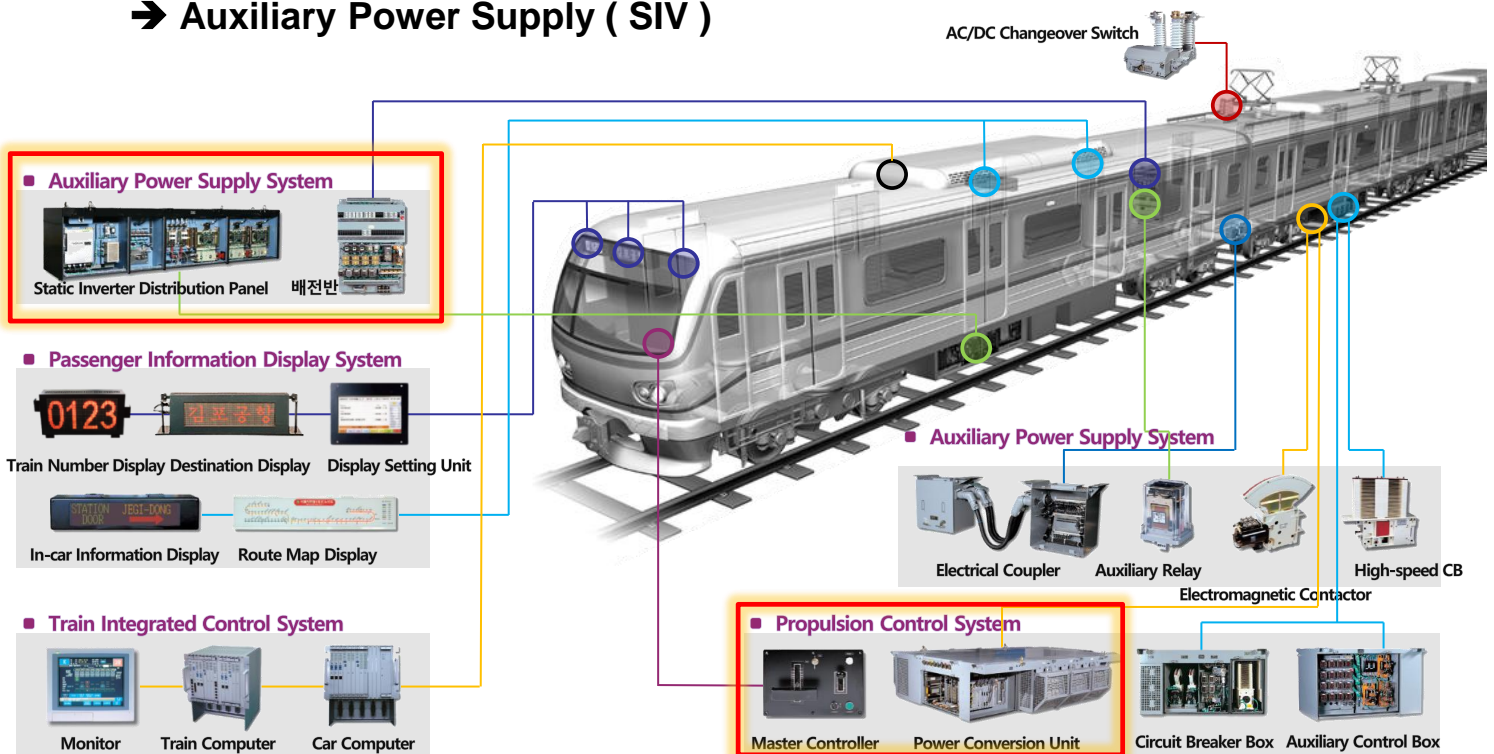


Medium-sized Monorail

- Daegu Transportation Corporation Line 3, 84 cars
- Signaling: Fully automated driverless operation using ATP/ATO

❖ Major electrical equipment for railway vehicles

- ▶ Propulsion & Service Power Converters
 - ➔ Propulsion Control Unit
 - ➔ Auxiliary Power Supply (SIV)



❖ Recent Need for SSCB Development



[*] <https://developer.nvidia.com/blog/nvidia-800-v-hvdc-architecture-will-power-the-next-generation-of-ai-factories/>
Chungbuk National University Electric Machine Drive Lab

❖ Recent Need for SSCB Development

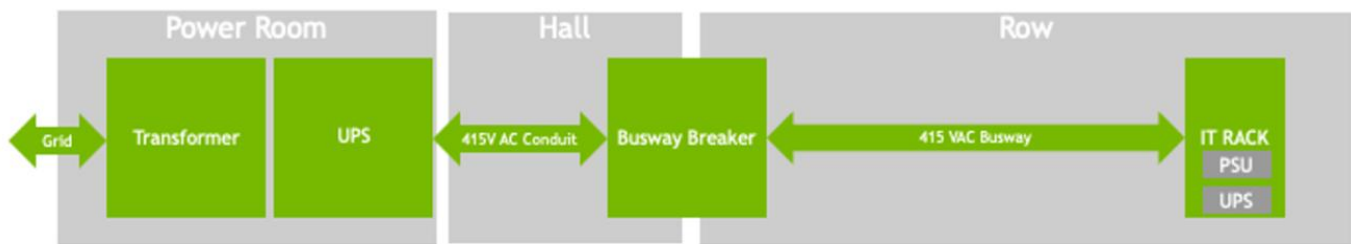


Figure 1. Current data center power architecture

The 800 VDC revolution

NVIDIA 800 VDC architecture addresses these challenges through a holistic redesign. NVIDIA is collaborating with the data center power ecosystem on the innovations and changes that will be necessary to realize this concept.



Figure 2. NVIDIA 800 VDC architecture minimizes energy conversions.

[*] <https://developer.nvidia.com/blog/nvidia-800-v-hvdc-architecture-will-power-the-next-generation-of-ai-factories/>
Chungbuk National University Electric Machine Drive Lab

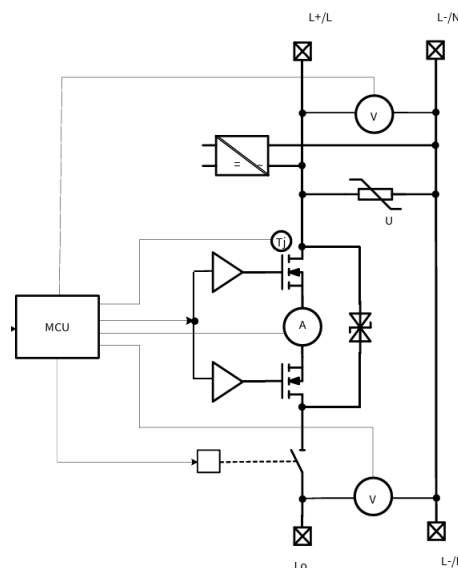
OUTLINE

1	Introduction
2	Short-Circuit Current Sensing
3	PCB Trace
4	Over Voltage Protection
5	Solid-state device

2 Short-Circuit Current Sensing

❖ Short-Circuit Current Sensing Method

- ▶ It immediately turns off the SSCB semiconductor switch when the fault current exceeds the threshold.
- ▶ Short-circuit current sensing can be implemented using the following methods.
 - ✓ Desaturation Detection, TMR Current Sensor, Hall-effect Sensor
 - ✓ Shunt Resistor sensing, Rogowski Coil

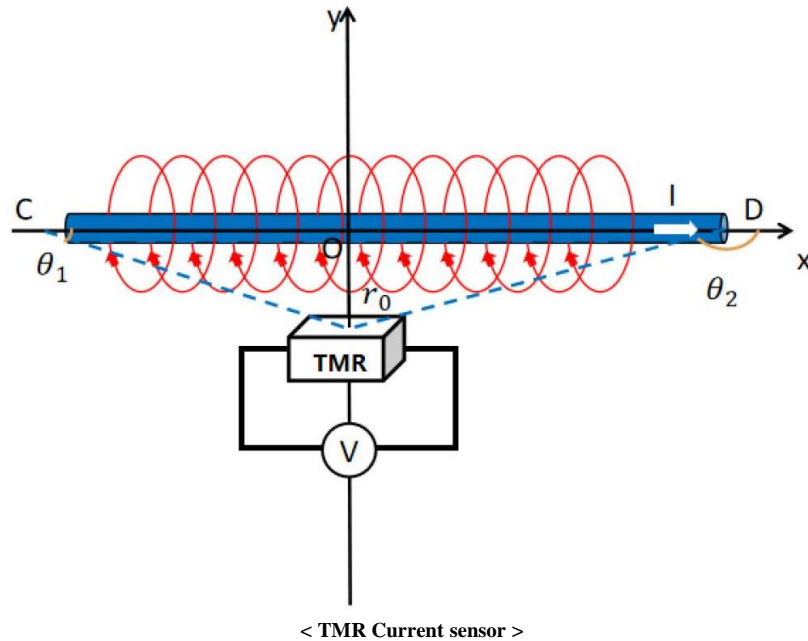


< MCU Current sensing block diagram >

[*] <https://www.infineon.com/application/solid-state-circuit-breaker>

❖ TMR Current Sensor

- ▶ TMR current sensors offer galvanic isolation and high bandwidth.
- ▶ Their performance can be affected by temperature variation, external magnetic fields, and sensor placement.
- ▶ Temperature compensation and magnetic shielding are required.



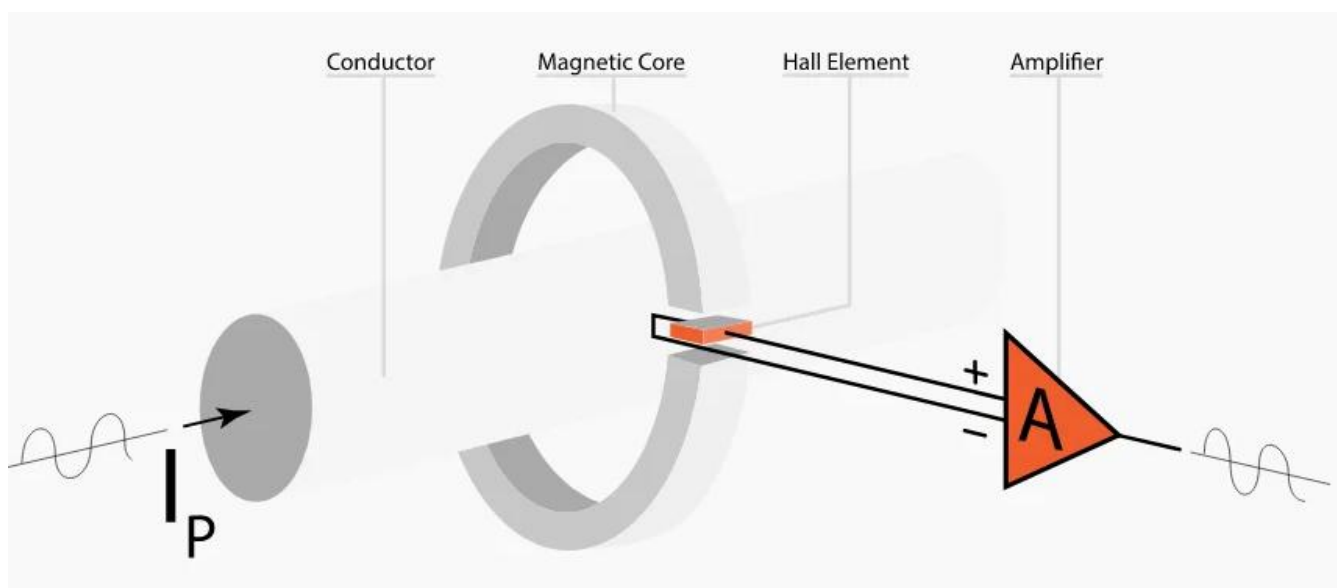
[*] <https://pmc.ncbi.nlm.nih.gov/articles/PMC11857788/>

Chungbuk National University Electric Machine Drive Lab

8/45

❖ Hall-effect Sensor

- ▶ It measures current by detecting the magnetic field generated around the current path using the Hall effect.
- ▶ Hall-effect sensors provide galvanic isolation, but magnetic saturation and limited bandwidth make them less suitable for fast SSCB fault detection.



< Hall-effect sensor >

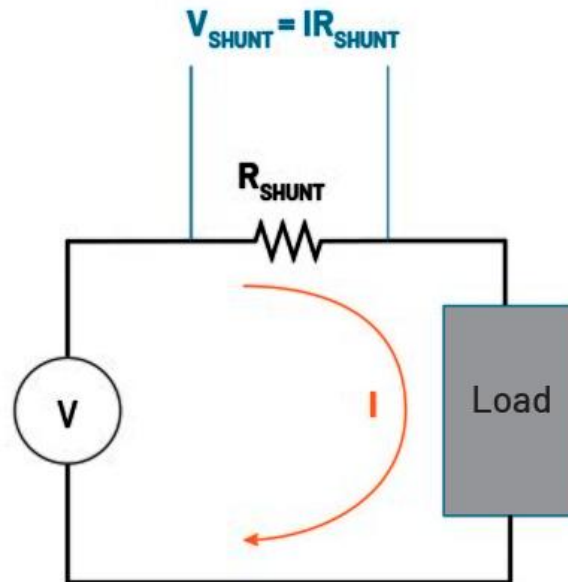
[*] <https://www.allaboutcircuits.com/technical-articles/hall-effect-current-sensing-open-loop-and-closed-loop-configurations/>

Chungbuk National University Electric Machine Drive Lab

9/45

❖ Shunt Resistor sensing

- ▶ A shunt resistor detects fault current by measuring the voltage drop across a low-value resistor inserted in the current path.
- ▶ It is simple and fast, but causes power loss, heat generation, and requires additional isolation in high-voltage SSCBs.



< Shunt resistor sensing >

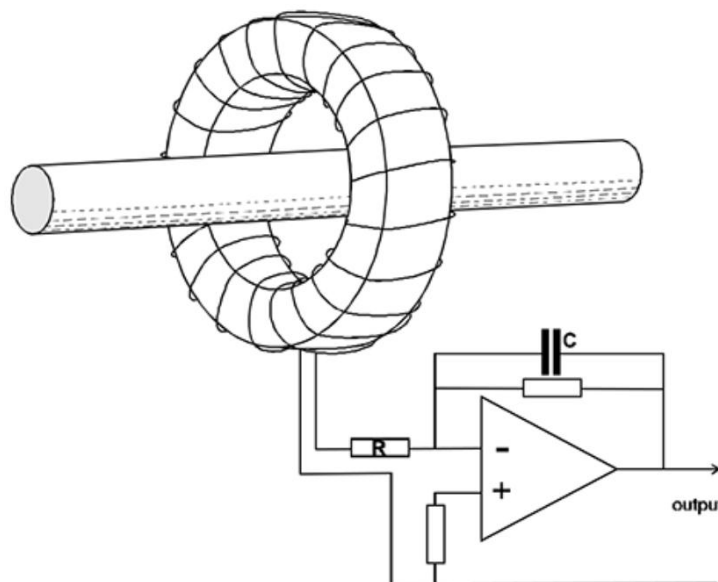
[*] <https://www.tek.com/en/blog/measuring-current-using-shunt-resistors?>

Chungbuk National University Electric Machine Drive Lab

10/45

❖ Rogowski coil

- ▶ A Rogowski coil measures the current change rate di/dt from the magnetic field around a conductor and integrates it to obtain current.
- ▶ It offers wide bandwidth and galvanic isolation, but cannot directly measure DC current and requires an integrator.



< Rogowski coil sensing >

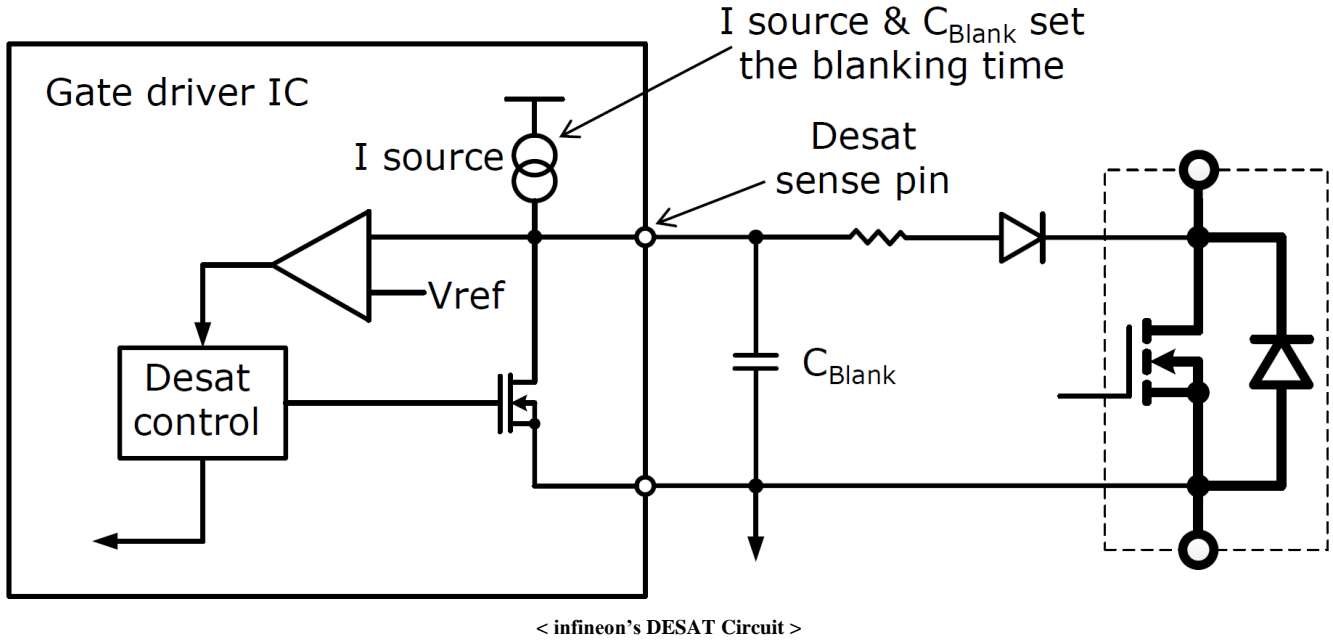
[*] <https://www.rocoil.co.uk/rogowski-coils/>

Chungbuk National University Electric Machine Drive Lab

11/45

❖ Desaturation Detection

- ▶ DESAT is a gate-driver-based protection method that detects short-circuit faults by monitoring the voltage rise across a conducting semiconductor switch.
- ▶ It is suitable for SSCB protection because it enables very fast fault detection and can be directly implemented in the gate driver circuit.



[*] <https://www.infineon.com/product-information/power/gate-driver-ics/eicedriver-enhanced>

❖ Desaturation Detection Gate IC' Time Delay

- ▶ Even after DESAT detection, soft turn-off causes a delay before complete interruption.
- ▶ Therefore, both semiconductor short-circuit withstand capability and gate-driver turn-off delay must be considered.

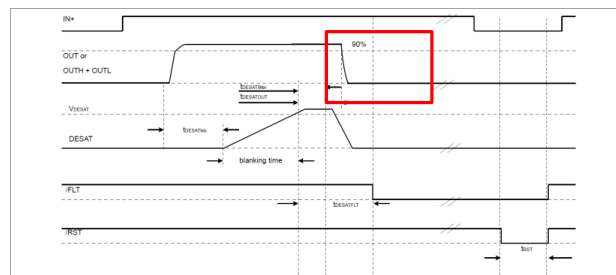


Figure 12 DESAT hard off behavior

The Figure 13 show the soft off behavior.

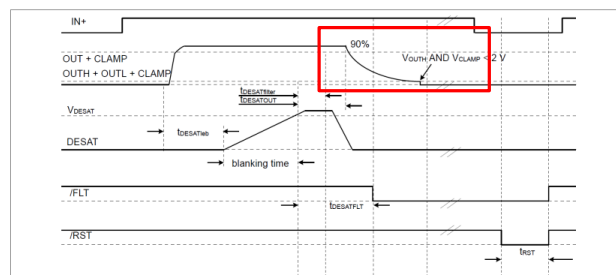


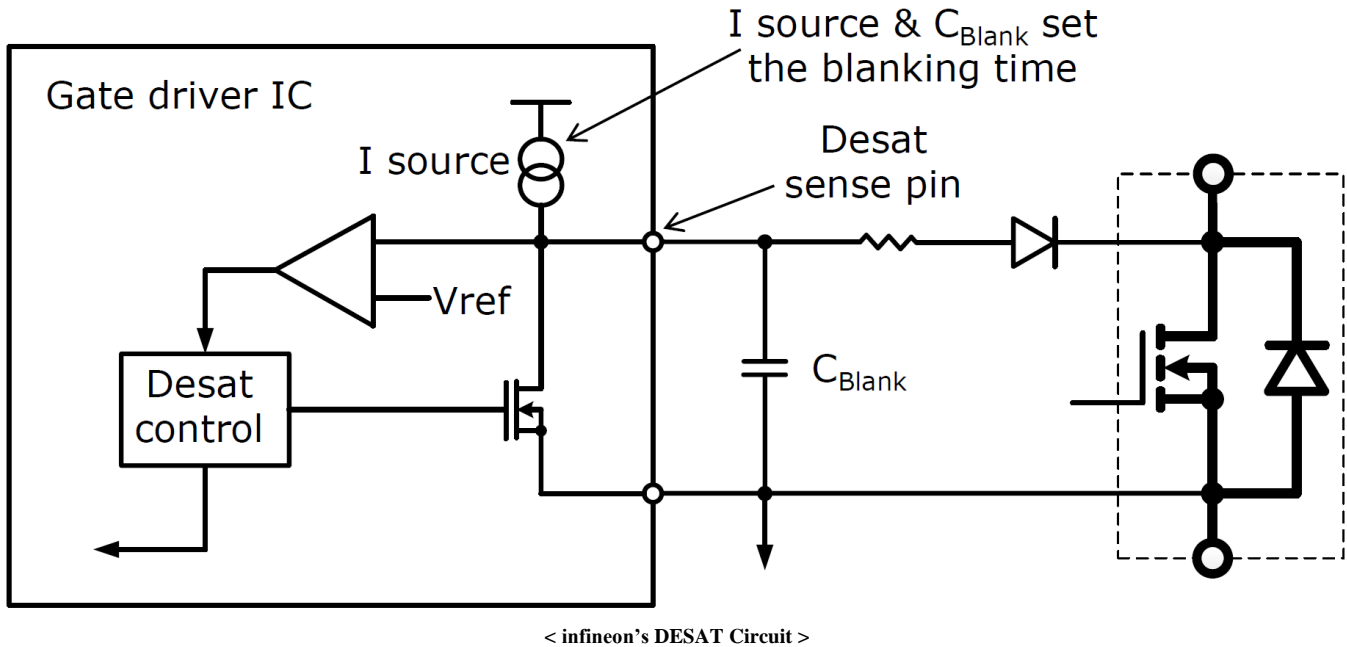
Figure 13 DESAT soft off behavior

< Differences in DESAT Behavior of Gate Driver ICs >

[*] <https://www.infineon.com/product-information/power/gate-driver-ics/eicedriver-enhanced>

❖ Desaturation Detection principle

- ▶ A DESAT circuit detects a short-circuit fault by monitoring the rise of V_{DS} or V_{CE} while the switch is ON.
- ▶ During normal conduction, the switch voltage is low, but under a short-circuit fault, high current causes the voltage to rise and triggers DESAT detection.

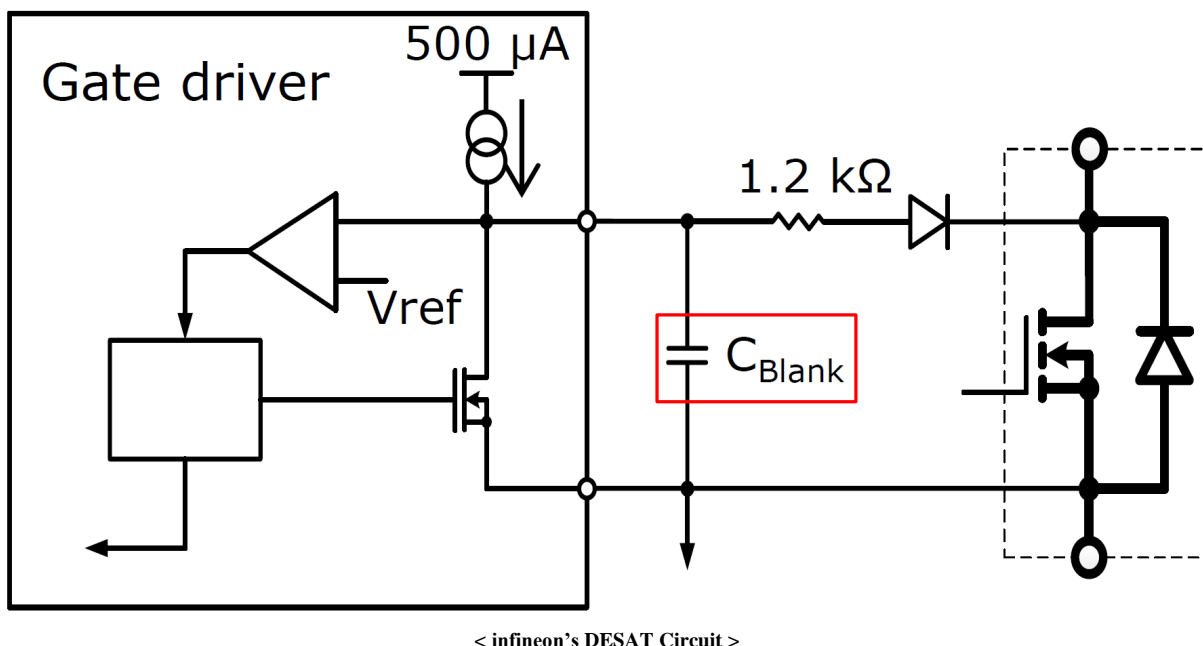


[*]

2 Short-Circuit Current Sensing

❖ Desaturation Detection principle detail

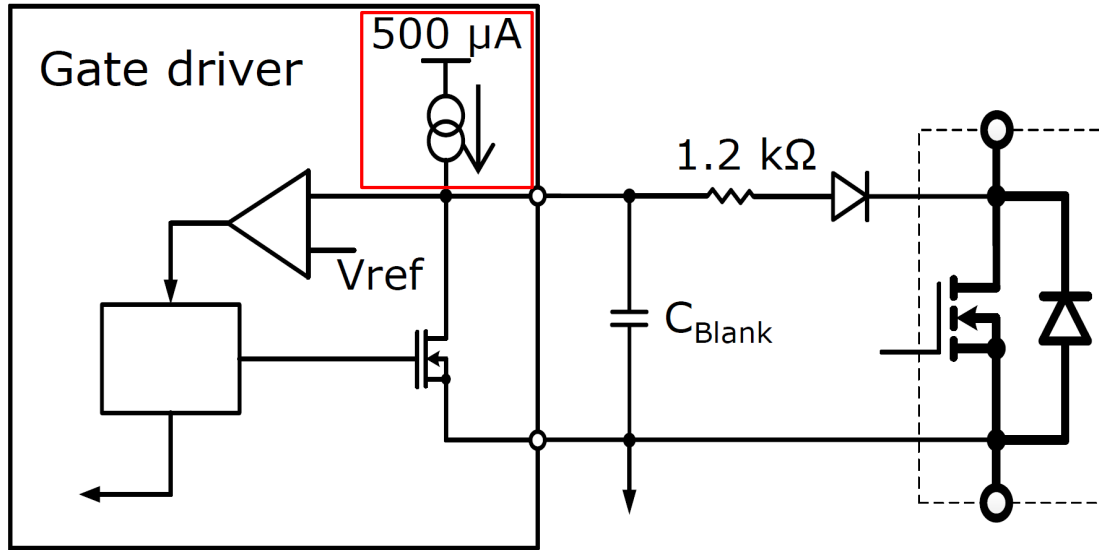
- ▶ The blanking capacitor sets the DESAT blanking time to prevent false detection right after turn-on.
- ▶ During normal turn-on, V_{DS} decreases, so C_{Blank} is not fully charged and the DESAT pin voltage stays below V_{ref} .



[*]

❖ Desaturation Detection principle detail

- ▶ During a short-circuit fault, V_{DS} remains high even when the MOSFET is ON due to the large fault current.
- ▶ The DESAT current cannot discharge toward the drain, so C_{Blank} keeps charging.
- ▶ V_{DESAT} exceeds V_{ref} , the gate driver detects fault and turns off the switch.



< infineon's DESAT Circuit >

[*]

2 Short-Circuit Current Sensing

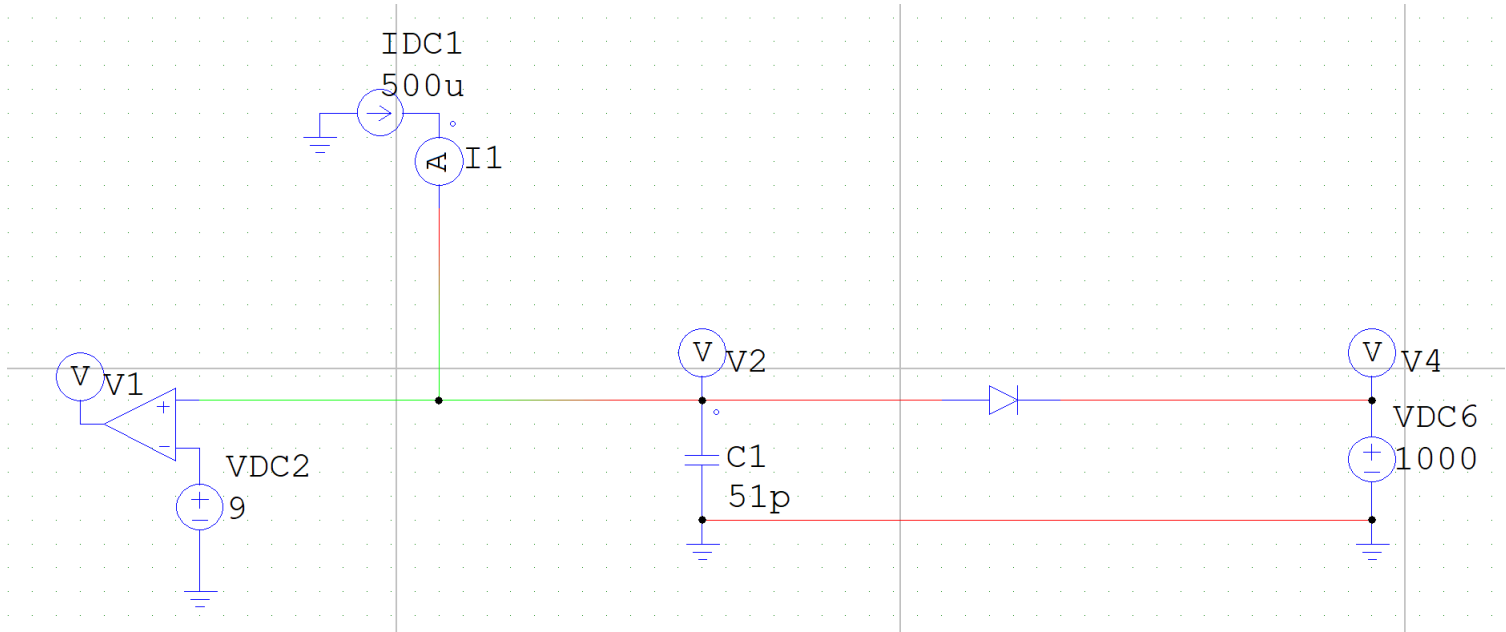
❖ SiC MOSFET Short-circuit capability

- ▶ For Infineon CoolSiC MOSFETs, the short-circuit withstand capability varies depending on the device series, but it is typically around 2 μs .
- ▶ Therefore, short-circuit protection must be completed within 2 μs .
- ▶ For the gate driver IC shown in the previous material, the internal current source is **500 μA** , and the V_{ref} of the internal comparator is **9 V**.
- ▶ The short-circuit protection operating time is calculated as follows.
 - ✓ $t_{DESATBLANK} + t_{DESATOUT} < t_{SC} = 2 [\mu\text{s}]$
 - ✓ $t_{DESATBLANK} = \frac{C_{DESAT} * V_{DESATth}}{I_{DESAT}} = \frac{51[\text{pF}] * 9[\text{V}]}{500[\mu\text{A}]} = 0.918[\mu\text{sec}]$
- ▶ $t_{DESATOUT}$ varies depending on whether **soft turn-off** or **hard turn-off** is used.

[*]

❖ DESAT Simulation circuit

- ▶ Simulation Circuit for DESAT Time Verification

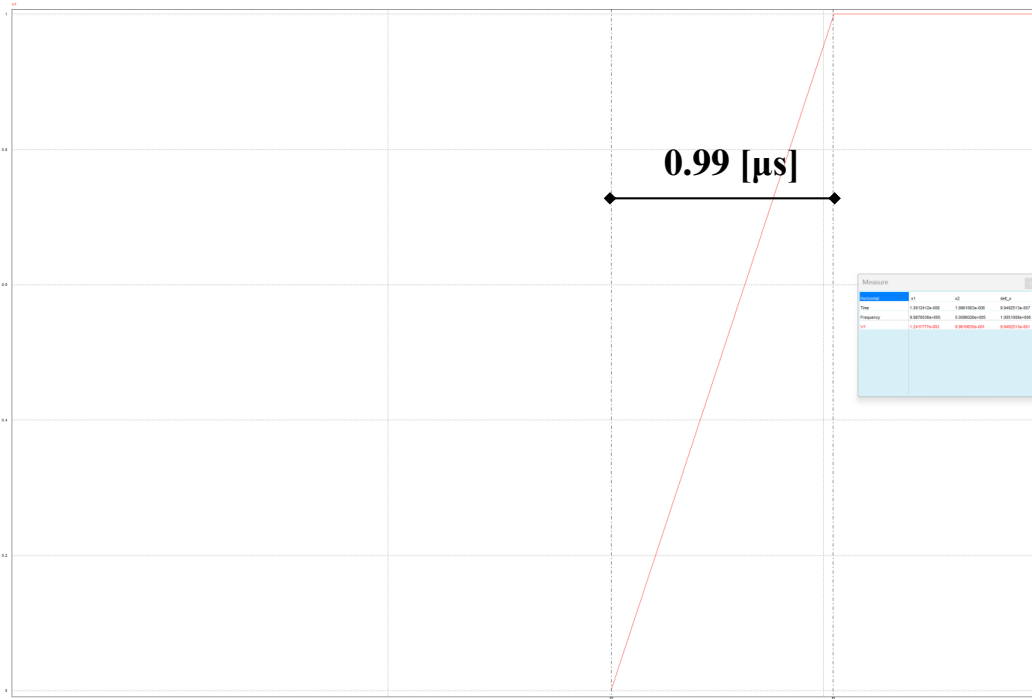


[*]

2 Short-Circuit Current Sensing

❖ DESAT Simulation result

- ▶ The signal output time is 0.99 [μs].
- ▶ Although there is a slight difference from the calculated value, the simulation shows a similar result.



[*]

❖ Hard-off behavior time delay

- ▶ For hard turn-off, only the internally set delay time of **0.918 [μs]** to prevent false triggering and the gate IC internal delay of **350 [ns]** are considered.
- ▶ Assuming the voltage falls ideally, the operating time is calculated as follows
 - ✓ $t_{\text{DESATBLANK}} + t_{\text{DESATOUT}} = 0.918[\text{us}] + 0.350[\text{us}] = 1.268 [\text{us}]$
- ▶ This satisfies the **2 [μs]** short-circuit withstand capability of the SiC MOSFET.

Parameter	Symbol	Values			Unit	Note or condition
		Min.	Typ.	Max.		
Pulse suppression filter time	$t_{\text{DESATfilter}}$		250		ns	1)
Desaturation sense to out low delay	t_{DESATOUT}		350	430	ns	$V_{\text{OUT}} = 90\%$, $C_{\text{OUT}} = 1 \text{ nF}$, $\text{OUT} = \text{OUTH} + \text{OUTL}$ shorted, 1ED3322, 1ED3323

< Hard-off behavior in datasheet >

[*]

Chungbuk National University Electric Machine Drive Lab

20/45



OUTLINE

1

Introduction

2

Short-Circuit Current Sensing

3

PCB Trace

4

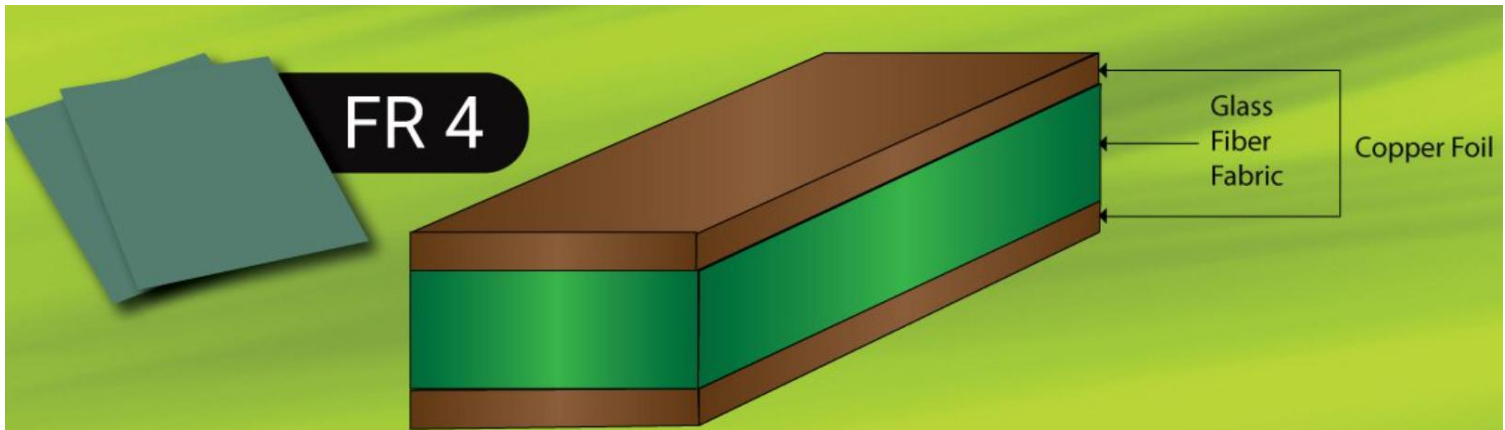
Over Voltage Protection

5

Solid-state device

❖ Considerations for PCB

- ▶ The input and output currents of the SSCB are several tens of amperes higher than those of signal lines.
- ▶ When high current flows through a PCB trace, I^2R loss occurs due to trace resistance, leading to temperature rise.
- ▶ Temperature rise in PCB traces can increase copper resistance and degrade insulation, FR-4 reliability, and solder-joint durability.



< PCB Trace structure >

[*] <https://www.globalwellpcb.com/>

3 PCB Trace

❖ PCB Trace Width

- ▶ As mentioned before, the PCB traces of the SSCB must be designed considering trace thickness and width according to the current level.
- ▶ The trace width was evaluated for a current level of 55 [A].
- ▶ The required trace width was calculated using DigiKey's Trace Width Calculator.

전류 (I)	<input type="text" value="30"/>	A
두께 (T)	<input type="text" value="3"/>	oz/ft ² ▼
온도 상승 (T _{RISG})	<input type="text" value="10"/>	°C ▼
주위 온도	<input type="text" value="25"/>	°C ▼
트레이스 길이	<input type="text" value="150"/>	mm ▼

최소 트레이스 폭	<input type="text" value="28.39105953 mm"/>
최소 트레이스 폭	<input type="text" value="10.91359450 mm"/>

내부 중 필요한 트레이스 폭 (W)	<input type="text" value="28.39105953"/>	mm ▼
외부 중(공기 중) 필요한 트레이스 폭 (W)	<input type="text" value="10.91359450"/>	mm ▼

< Digikey Trace width calculator >

[*] <https://www.digikey.kr/ko/resources/conversion-calculators/conversion-calculator-pcb-trace-width>

❖ PCB Trace Width Calculation with condition

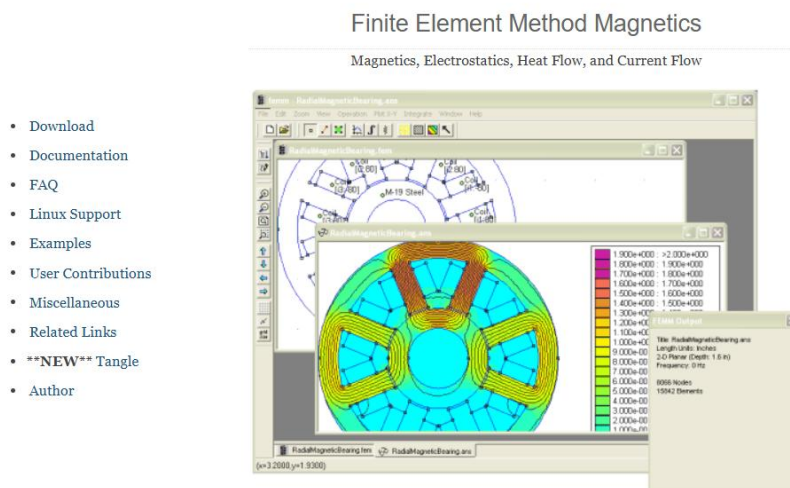
- ▶ Rated current: 55 [A]
- ▶ When 55 [A] is applied through both the top and bottom layers, the current per layer was assumed to be 30 [A] with a design margin.
- ▶ The calculation conditions are as follows:
 - ✓ Ambient temperature: 25 [°C], Temperature rise: 10 [°C], Copper thickness: 3 [oz/ft²]
- ▶ Calculated minimum trace width: 10.9 mm

< Digikey' Trace width calculator >

[*] <https://www.digikey.kr/ko/resources/conversion-calculators/conversion-calculator-pcb-trace-width>

❖ Actual Temperature Rise of the Trace Width Calculator

- ▶ For a trace width of 10.9 [mm] and a copper thickness of 3 [oz/ft²], the temperature rise was analyzed to verify whether it remains within 10 °C.
- ▶ The analysis was performed using analytical equations and FEMM thermal simulation.
- ▶ FEMM is a free 2D finite element analysis software that supports electromagnetic, heat flow, and current flow analysis.



< FEMM Website – Supported Analysis Features >

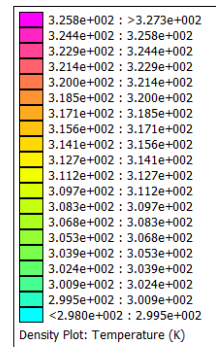
[*] <https://www.femm.info/wiki/HomePage>

❖ FEMM Thermal Analysis Result with FR4 Attached Beneath the Trace

- ▶ Trace temperature: 327.306 [K] = 54.306 [°C]
- ▶ Therefore, $\Delta T = 54.306 - 25 = 29.306$ [°C]
- ▶ This temperature rise is significantly lower than the 123.2 [°C] temperature rise obtained when FR4 was not attached.
- ▶ The FR4-based PCB acts as a heat sink.
 - ✓ Due to the thermal conductivity of FR4, the heat from the copper spreads into the PCB and is dissipated.

```

FEMM Output
Point: x=4.43, y=0.04
T = 327.306 K
[F] = 3609.21 W/m^2
[Fx] = -3606.26 W/m^2
[Fy] = -145.809 W/m^2
[G] = 9.07425 K/m
[Gx] = -9.06684 K/m
[Gy] = -0.366592 K/m
[Kx] = 397.742 W/(m^2K)
[Ky] = 397.742 W/(m^2K)
    
```



< FEMM Thermal Analysis Result with FR4 Attached Beneath the Trace >

[*] <https://www.femm.info/wiki/HomePage>

❖ PCB Board & Temperature Test

- ▶ PCB traces were fabricated considering the current level.
- ▶ A thermal camera test will be conducted to verify whether the temperature rise under current flow matches the calculated value.



[*] <https://www.femm.info/wiki/HomePage>

OUTLINE

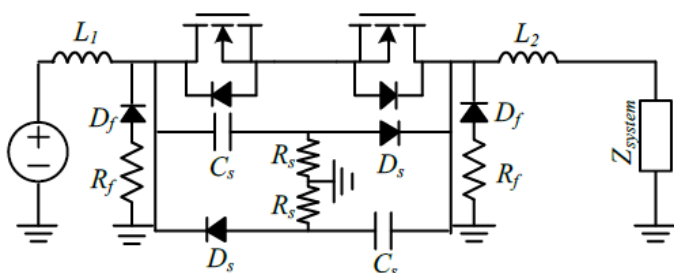
1	Introduction
2	Short-Circuit Current Sensing
3	PCB Trace
4	Over Voltage Protection
5	Solid-state device

4 Over Voltage Protection



❖ SSCB Over Voltage

- ▶ Since an SSCB interrupts fault current very rapidly, large overvoltage can be generated by the energy stored in the system inductance.
- ▶ When the current changes rapidly during interruption, the voltage across the semiconductor switch increases sharply according to $V = L \frac{di}{dt}$
- ▶ Since semiconductor devices can fail if their voltage rating is exceeded, overvoltage suppression is essential.
- ▶ OVP devices such as snubbers, MOVs, and TVS diodes absorb or dissipate the energy stored in the system inductance to protect the semiconductor device.



< RCD Snubber Example >

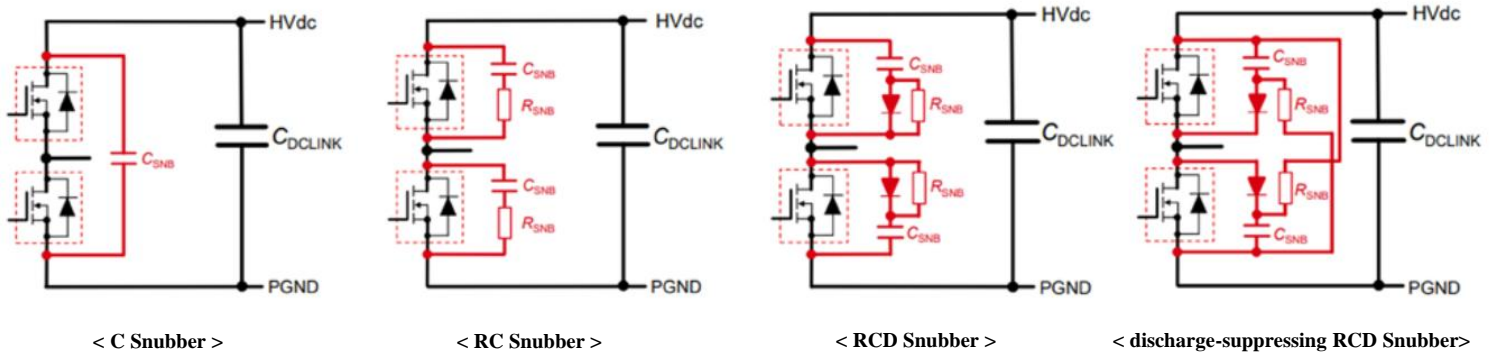


< MOV Example >

[*] 박동훈. "계통 인덕턴스에 따른 반도체 차단기 과전압 억제 회로 시정수 결정 방법 및 시지연 효과 분석." 국내석사학위논문 서울대학교 대학원, 2019. 서울

❖ Snubber – OVP

- ▶ A C snubber is the simplest snubber that uses only a capacitor to slow the voltage rise across the switch.
- ▶ An RC snubber uses a capacitor and resistor to suppress overvoltage and ringing while dissipating the stored energy in the resistor.
- ▶ An RCD snubber uses a diode to control the energy-flow direction, stores the energy in a capacitor, and discharges it through a resistor.
- ▶ A discharge-suppressing RCD snubber pre-charges the capacitor so that fault-current rise and overvoltage can be suppressed immediately after turn-off.

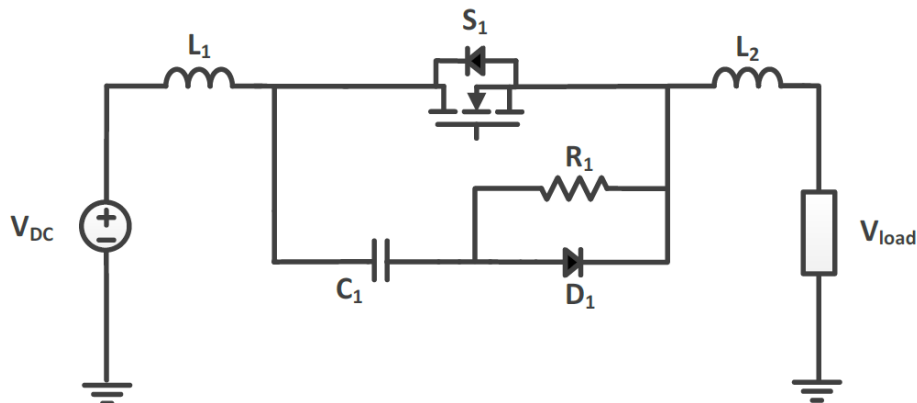


[*] <https://techweb.rohm.co.kr/product/power-device/sic/15886/>

4 Over Voltage Protection

❖ RCD Snubber

- ▶ RCD snubber is referred to as a charge-discharge type RCD snubber.
- ▶ A charge-discharge type RCD snubber is composed of a resistor R , capacitor C , and diode D . Its purpose is to suppress the overvoltage generated across the semiconductor switch during fault-current interruption.
- ▶ A charge-discharge type RCD snubber can reduce the inrush current during re-closing compared with a simple C snubber.
- ▶ However, since the capacitor is not sufficiently charged at the moment of fault occurrence, it cannot immediately suppress the fault current right after turn-off.

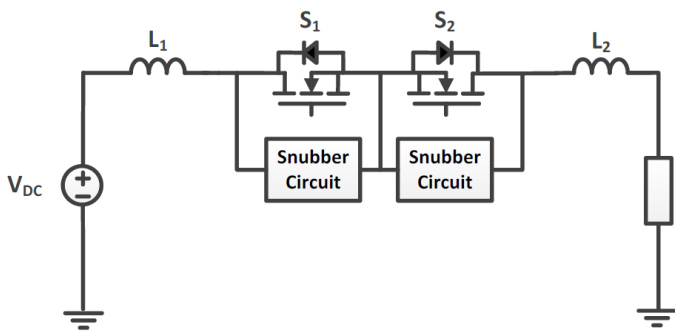


< RCD Snubber >

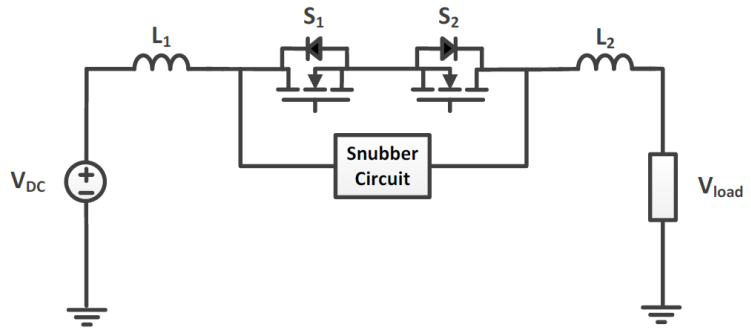
[*] 신동호. "SiC MOSFET을 사용한 DC 반도체 차단기의 비대칭 스너버 회로 연구." 국내석사학위논문 서울대학교 대학원, 2018. 서울

❖ Bidirectional SSCB Snubber

- ▶ In DC systems, fault current can flow in both directions depending on the fault location, so a bidirectional snubber circuit is required.
- ▶ In a bidirectional system, two unidirectional snubber circuits are applied to the two semiconductor switches to handle fault currents in both directions
- ▶ In a bidirectional system, one bidirectional snubber circuit is applied across the entire semiconductor breaker to handle fault currents in both directions.



< Bidirectional SSCB using two unidirectional snubber circuits >



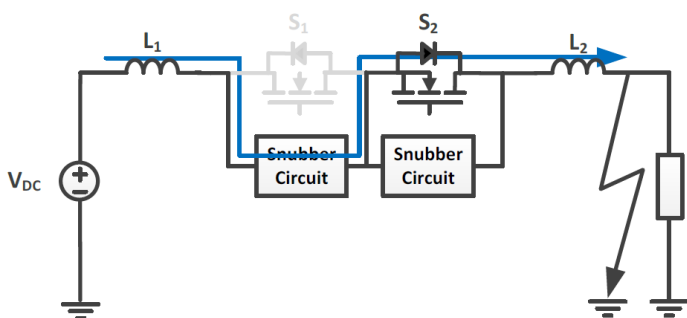
< Bidirectional SSCB using one bidirectional snubber circuit >

[*] 신동호. "SiC MOSFET을 사용한 DC 반도체 차단기의 비대칭 스너버 회로 연구." 국내석사학위논문 서울대학교 대학원, 2018. 서울

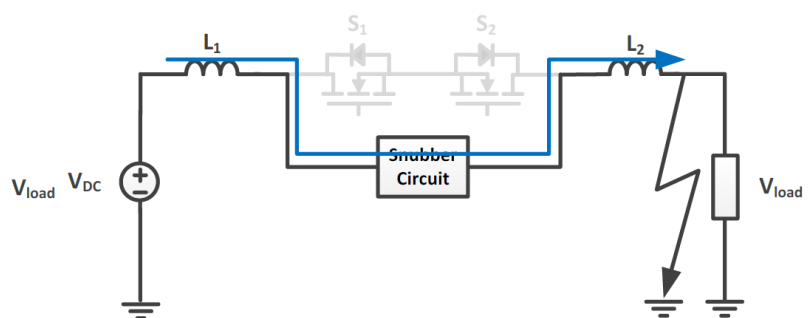
4 Over Voltage Protection

❖ Bidirectional SSCB Snubber

- ▶ With two unidirectional snubbers, part of the fault current can flow through the MOSFET body diode.
- ▶ This increases conduction loss and thermal stress due to the high forward voltage of the body diode.
- ▶ A single bidirectional snubber diverts the fault current into the snubber circuit and protects the semiconductor device.



< Case where the fault current flows through the body diode during fault-current interruption >

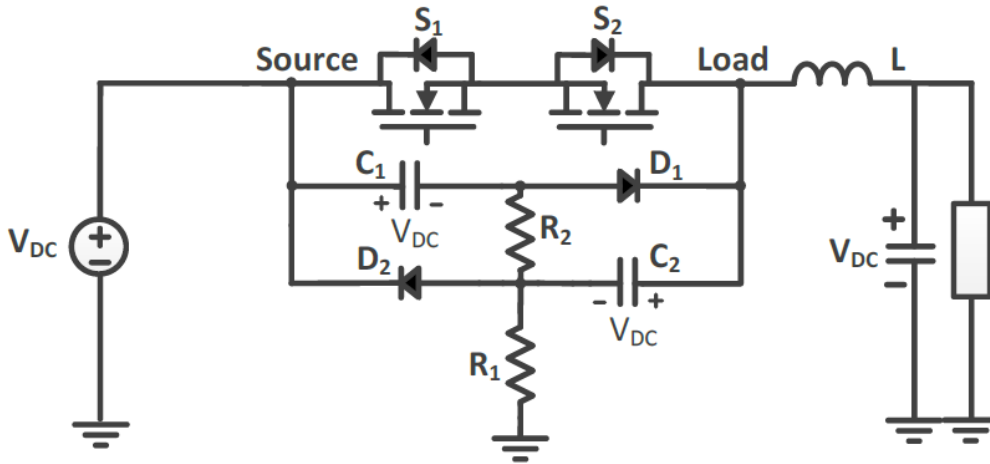


< Case where the entire fault current flows through the snubber circuit during fault-current interruption >

[*] 신동호. "SiC MOSFET을 사용한 DC 반도체 차단기의 비대칭 스너버 회로 연구." 국내석사학위논문 서울대학교 대학원, 2018. 서울

❖ Bidirectional snubber used in an SSCB

- ▶ This structure uses a snubber circuit designed to handle bidirectional fault currents in a DC system.
- ▶ The fault current is diverted through the snubber circuit instead of flowing through the body diode of the semiconductor switches, thereby reducing conduction loss and thermal stress in the body diode.
- ▶ As a result, the bidirectional semiconductor circuit breaker can improve both overvoltage protection and fault-current suppression performance.



< Bidirectional Snubber Circuit for SSCB >

[*] 신동호. "SiC MOSFET을 사용한 DC 반도체 차단기의 비대칭 스너버 회로 연구." 국내석사학위논문 서울대학교 대학원, 2018. 서울

Chungbuk National University Electric Machine Drive Lab

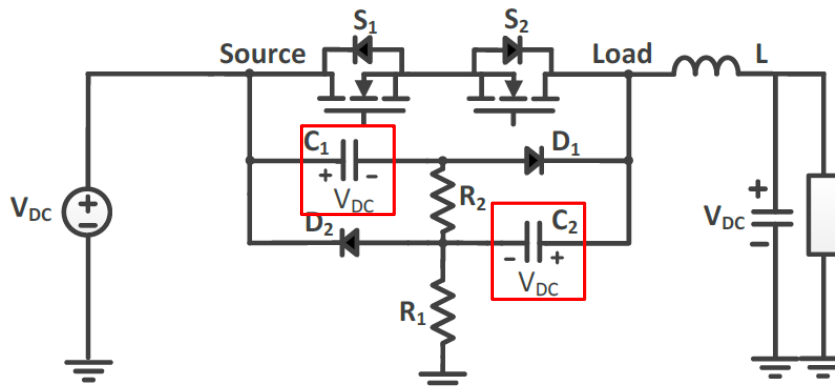
4 Over Voltage Protection

❖ Snubber Capacitor Selection

- ▶ The snubber capacitors C_1 and C_2 absorb the inductive energy during fault-current interruption and limit the semiconductor switch voltage below $V_{max,sw}$.
- ▶ Design Equation :

$$C \geq L \left(\frac{I_{fault}}{V_{max,sw} - V_{DC}} \right)^2$$

- L : Equivalent inductance to be handled by the snubber
- I_{fault} : Fault current at the moment of semiconductor turn-off
- $V_{max,sw}$: Maximum allowable switch voltage



< Bidirectional Snubber Circuit for SSCB >

[*] 신동호. "SiC MOSFET을 사용한 DC 반도체 차단기의 비대칭 스너버 회로 연구." 국내석사학위논문 서울대학교 대학원, 2018. 서울

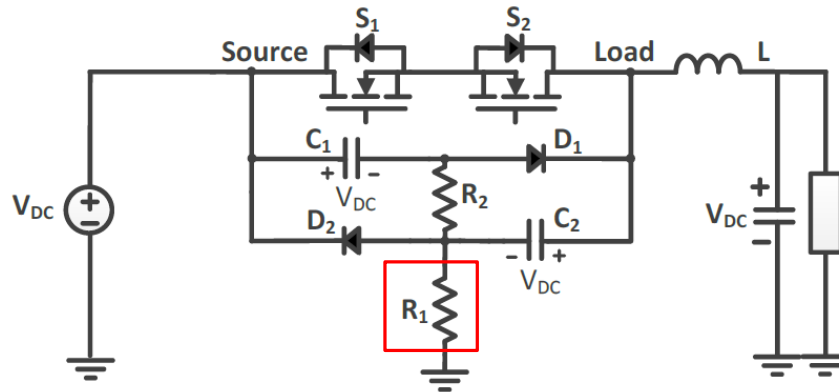
Chungbuk National University Electric Machine Drive Lab

❖ Snubber R_1 Selection

- ▶ R_1 determines the additional current flowing through the snubber during a source-side short-circuit fault.
- ▶ A smaller R_1 can improve fault detection and current suppression, but it increases the instantaneous current stress of the semiconductor switch.
- ▶ Design Equation :

$$R_1 \geq \frac{V_{DC}}{I_{max,sw} - I_{rated}}$$

- I_{rated} : Rated current under normal operation
- $I_{max,sw}$: Maximum current capability of the semiconductor switch



< Bidirectional Snubber Circuit for SSCB >

[*] 신동호. "SiC MOSFET을 사용한 DC 반도체 차단기의 비대칭 스너버 회로 연구." 국내석사학위논문 서울대학교 대학원, 2018. 서울

Chungbuk National University Electric Machine Drive Lab

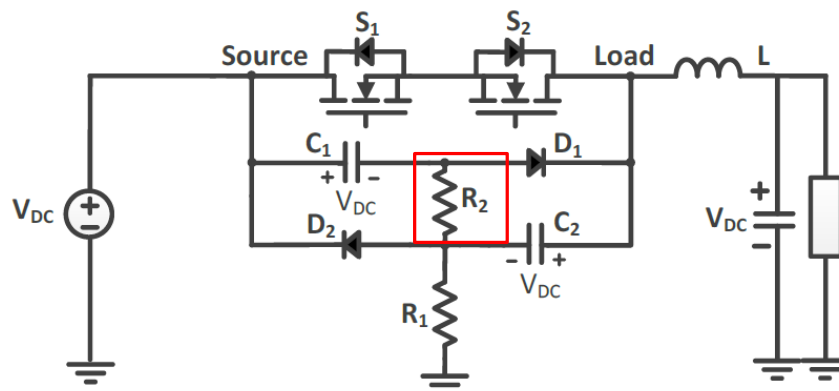
36/45

4 Over Voltage Protection

❖ Snubber R_2 Selection

- ▶ R_2 determines the initial output voltage of the snubber circuit immediately after turn-off.
- ▶ In a load-side short-circuit fault, the fault current rises up to the protection level before interruption; therefore, a low initial snubber voltage can increase the fault-current peak.

$$R_2 \geq \frac{R_1 V_{DC}}{R_1 I_{fault} - V_{DC}}$$



< Bidirectional Snubber Circuit for SSCB >

[*] 신동호. "SiC MOSFET을 사용한 DC 반도체 차단기의 비대칭 스너버 회로 연구." 국내석사학위논문 서울대학교 대학원, 2018. 서울

Chungbuk National University Electric Machine Drive Lab

37/45

❖ Design Equation-Based Component Selection

▶ Component values are selected based on the preceding design equations.

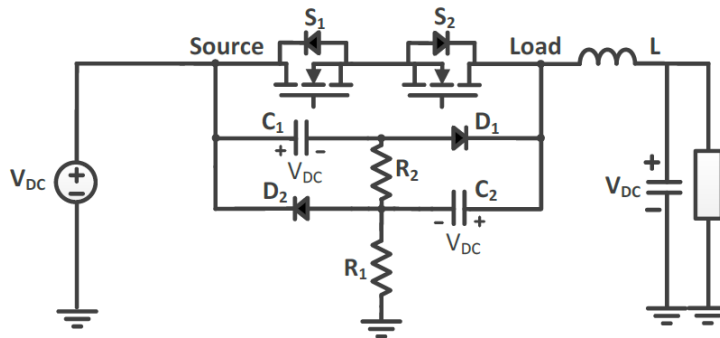
$$✓ C \geq L \left(\frac{I_{fault}}{V_{max,sw} - V_{DC}} \right)^2 = 20[\mu F] \left(\frac{250[A]}{1400[V] - 1000[V]} \right)^2 = 7.8125[\mu F] \approx 8[\mu F]$$

$$✓ R_1 \geq \frac{V_{DC}}{I_{max,sw} - I_{rated}} = \frac{1000[V]}{525[A] - 350[A]} = 5.714[\Omega]$$

$$✓ R_2 \geq \frac{R_1 V_{DC}}{R_1 I_{fault} - V_{DC}} = \frac{5.714[\Omega] \times 1000[V]}{525[A] - 350[A]} = 13.33[\Omega]$$

▶ These can be increased to limit snubber discharge current, reduce current stress, and adjust the over voltage.

▶ The final component values can be modified.



< Bidirectional Snubber Circuit for SSCB >

[*] 신동호. "SiC MOSFET을 사용한 DC 반도체 차단기의 비대칭 스너버 회로 연구." 국내석사학위논문 서울대학교 대학원, 2018. 서울

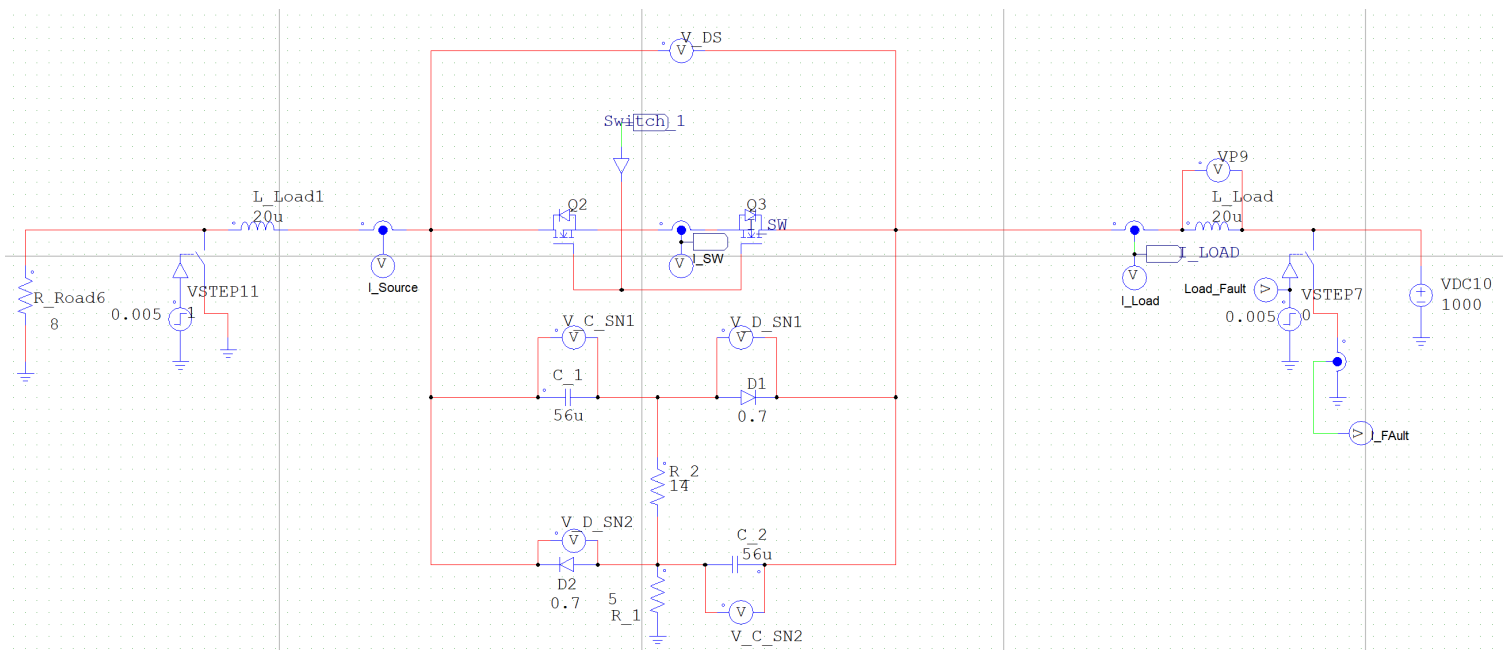
4 Over Voltage Protection

❖ OVP Snubber simulation circuit

▶ The figure below shows the snubber circuit implemented in PSIM.

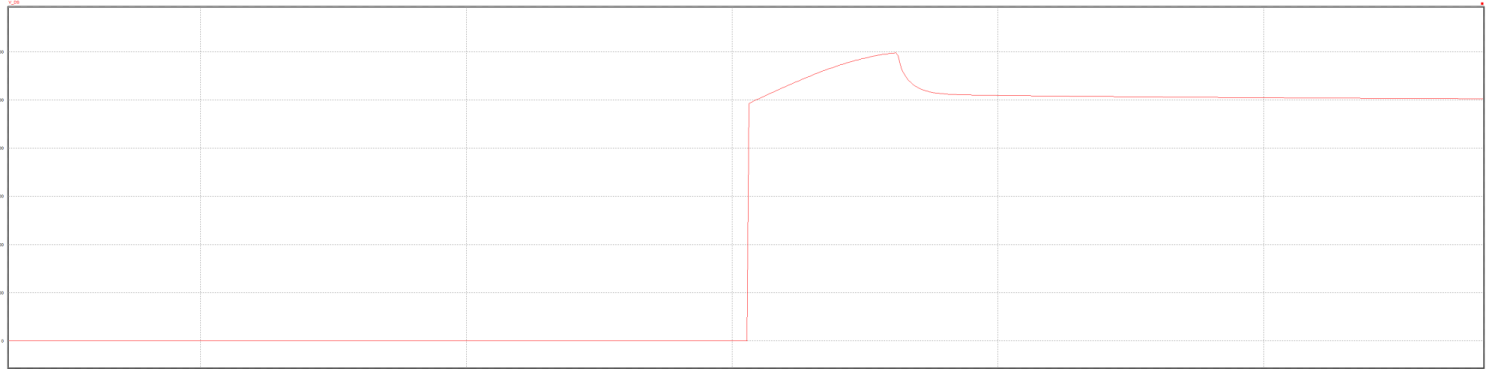
▶ The circuit includes switches used to simulate short-circuit faults.

▶ The component values selected using the previous design equations were adjusted through multiple simulations.



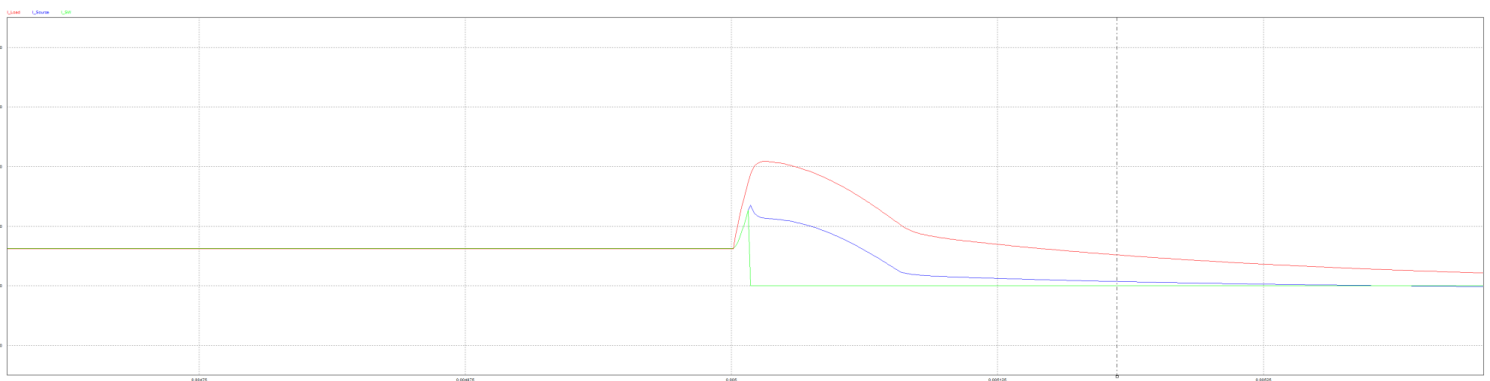
❖ OVP Snubber simulation Result

- ▶ This waveform shows the interruption behavior of the semiconductor circuit breaker and snubber circuit after a load-side short-circuit fault occurs.
- ▶ The peak voltage across the semiconductor switch, V_{DS} , is **1195.4 [V]**, which is successfully limited below the maximum voltage limit of **1400 [V]**.



❖ OVP Snubber simulation Result

- ▶ In the lower waveform, the green trace represents the semiconductor device current, which rapidly decreases to 0 A after fault detection.
- ▶ This indicates that the semiconductor switch is successfully turned off.
- ▶ The red trace represents the load current, and the blue trace represents the source current.
- ▶ After the switch is turned off, both currents do not disappear immediately but gradually decay.



❖ SSCB Non-Linear Over Voltage Protection

- ▶ SSCB Non-Linear Over Voltage Protection is a protection method that limits the overvoltage generated during semiconductor interruption using non-linear devices such as MOVs or TVS diodes.
- ▶ MOVs or TVS devices conduct only when the switch voltage exceeds a certain level, diverting the fault energy into another path and clamping the V_{DS} peak.
- ▶ Non-linear OVP works as a final voltage clamp to suppress transient overvoltage that cannot be fully handled by the snubber circuit alone, protecting the semiconductor devices in the SSCB.



< TVS Diode Example >



< MOV Example >

OUTLINE

1

Introduction

2

Short-Circuit Current Sensing

3

PCB Trace

4

Over Voltage Protection

5

Solid-state device

❖ SSCB Solid-state device

- ▶ The solid-state device in an SSCB is the main semiconductor switch that interrupts current without mechanical contacts.
- ▶ It enables fault-current interruption within tens of microseconds, but it must withstand high voltage stress
- ▶ High transient current because system inductance generates overvoltage during turn-off.
- ▶ Various power semiconductor devices can be used in SSCBs, such as IGBT, SiC MOSFET, SiC JFET.



Typical appearance

< infineon's cool SiC MOSFET >

[*] [Gate Driver Finder | Infineon Technologies](#)

❖ SSCB Solid-state device comparison

	IGBT	SiC MOSFET	SiC JFET
Voltage / Current	Suitable for high-voltage and current applications	Suitable for high-voltage and speed switching	Suitable for high-voltage, low-resistance, and fast interruption
Switching Speed	Relatively slow	Fast	Fast
Turn-off Characteristic	Has tail current	Almost no tail current	Capable of fast interruption
Conduction Loss	Can be advantageous at high current	Low $R_{DS(on)}$	Very low $R_{DS(on)}$ is possible
SSCB Suitability	Applicable, but less advantageous in terms of loss and speed	Suitable for SSCBs	Highly suitable for SSCBs, but normally-on behavior must be considered

< infineon's cool SiC JFET >

[*] <https://www.infineon.com/product-information/power/silicon-carbide-jfets>

Thank you

