

## Chapter 8 Sense IGBT Performance

1. Scope	8-2
2. Function	8-2
3. Recommended $R_{SE}$ : Sense Resistor	8-3
4. Typical Characteristics of $V_{SE}$	8-4
5. $V_{SE}$ Dependence of $I_C$ and $T_{vj}$ : (i) short- circuit / Transient	8-4
6. $V_{SE}$ Dependence of $I_C$ and $T_{vj}$ : (ii) Over-current / Transient	8-5
7. $V_{SE}$ Dependence of $I_C$ and $T_{vj}$ : (iii) Over-circuit / Transient	8-6
8. Application for SC Protection Function by Using ADI-ADuM4138	8-7

## 1. Scope

This appendix is explaining about the sense IGBT (Insulated Gate Bipolar Transistor) performance. Shown typical value and the tendency in this material have been obtained by certain IGBT and test setup.

So the data in this material does not limit the usage of the IGBT and the data are just reference of the outline of the sense IGBT.

- ★ Since the driver IC revision differs with respect to the below explanation for the sense IGBT function and the content of the explanation provided for the evaluation board in Chapter 7, there may be differences in certain values such as the threshold voltage, but please understand that these values are only given as references to explain product operation.

## 2. Function

The function of the sense-IGBT is to detect overcurrent like Short-Circuit (SC) in the IGBT.

As showing in the Fig. 8-1, the sense IGBT is included in the same IGBT chip.

$I_{C\_sense}$  value is following  $I_{C\_main}$  and flows at a certain split flow ratio.

$$I_{C\_sense} \propto I_{C\_main} \text{ --- eq.-1}$$

To detect the overcurrent as a voltage, a sense resistor  $R_{SE}$  is recommended.

How to design the  $R_{SE}$  is shown in the following pages.

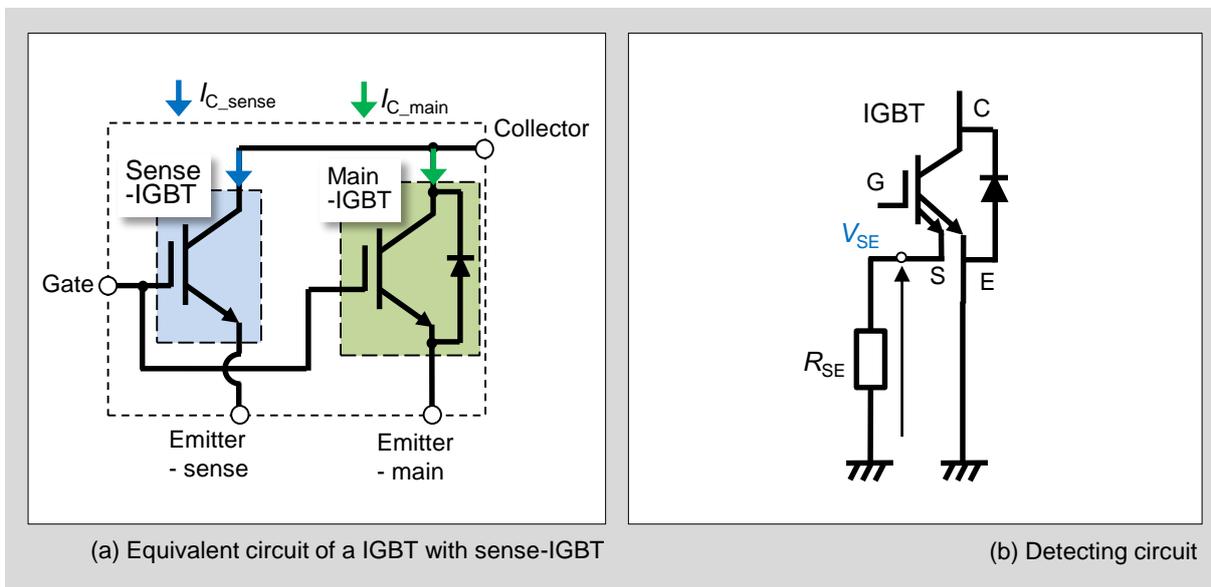


Fig. 8-1 Function of the sense-IGBT and the usage

### 3. Recommended $R_{SE}$ : Sense Resistor

Using 2 pair of resistors,  $R_{SE1}$  and  $R_{SE2}$ , is recommended as shown in Fig. 8-2, for taking account of easy design for a Short-circuit detecting voltage:  $V_{SC}$ .

Total value of  $R_{SE}$ ,  $R_{SE1} + R_{SE2}$ , is designed by following  $V_{SE}$  characteristics.

- 1) Higher  $R_{SE}$  is needed for higher SC detection speed.  
As shown in Fig. 8-3(a), steeper  $dV_{SE}/dt$  is needed for high speed SC protection, and  $dV_{SE}/dt$  tends to increase as  $R_{SE}$  value increasing shown in Fig. 8-3(b).
- 2) On the other hand, when  $R_{SE}$  is much higher value, the SC protection circuit and/or IC might be broken down due to turn-off surge voltage of  $V_{SE}$ , Fig. 8-3(c).  
The  $V_{SE}$  on turn-off depends on  $R_{SE}$ , Fig. 8-3(d)  
If SC protection circuit is driven by around 15(V),  $V_{SE}$  value should be under 15(V), at least.
- 3) Based on above trade-off and including safety margin, 120Ω of  $R_{SE}$  is recommended for Short-circuit current detection resistance.

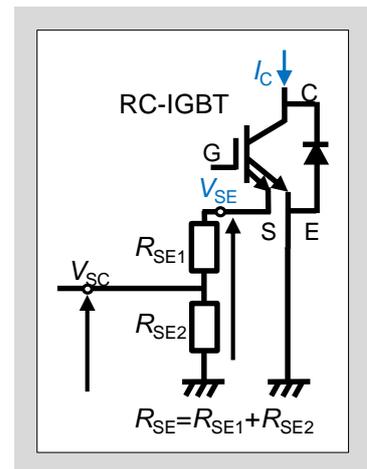


Fig. 8-2  $V_{SE}$  and  $R_{SE}$

\*Relating  $V_{SE}$  data is taken by typical circuit constant as shown in main manual.

So detail parameter designing should be confirmed under required system setting.

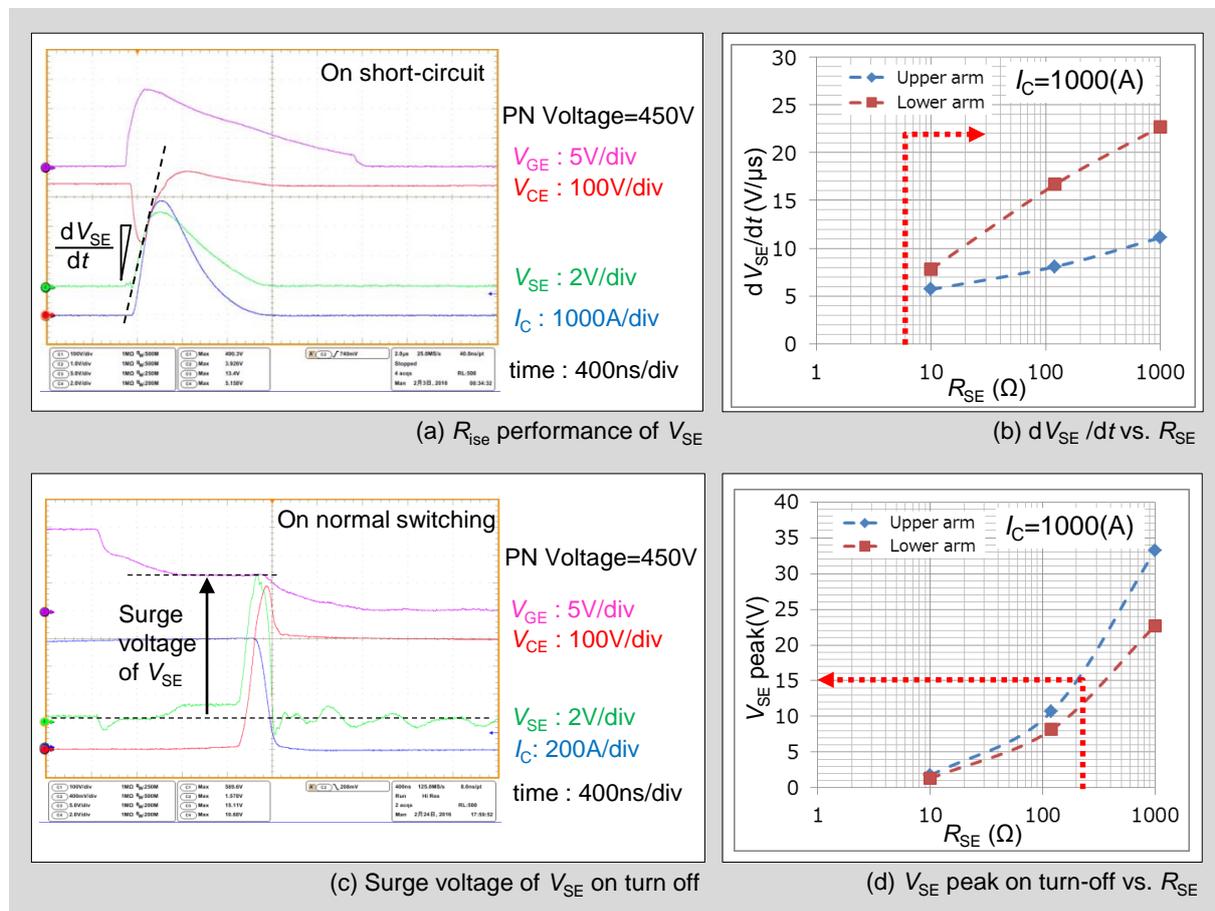


Fig. 8-3  $V_{SE}$  performance

## 4. Typical Characteristics of $V_{SE}$

$V_{SE}$  is defined as 3 parts on a switching waveform showing in Fig. 8-4.

- (i) Short-circuit: transient
- (ii) Over-current: transient
- (iii) Over-current: steady state

$V_{SE}$  characteristics on each part are illustrated in followings.

Measurement parameters:

- $I_C = 200 \sim 1000$ , step 200 (A)
- $T_{vj} = -40, 25, 125, 175$  ( $^{\circ}\text{C}$ )
- $R_{SE} = 120$  ( $\Omega$ )

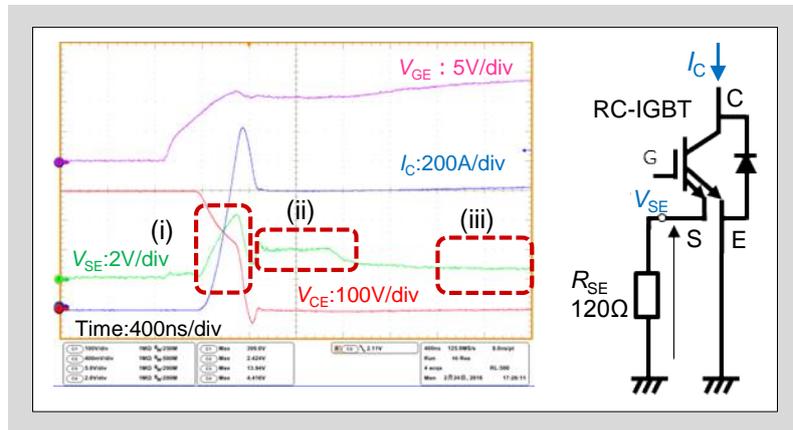


Fig. 8-4  $V_{SE}$  on the switching waveform

## 5. $V_{SE}$ Dependence of $I_C$ and $T_{vj}$ : (i) Short-circuit / Transient

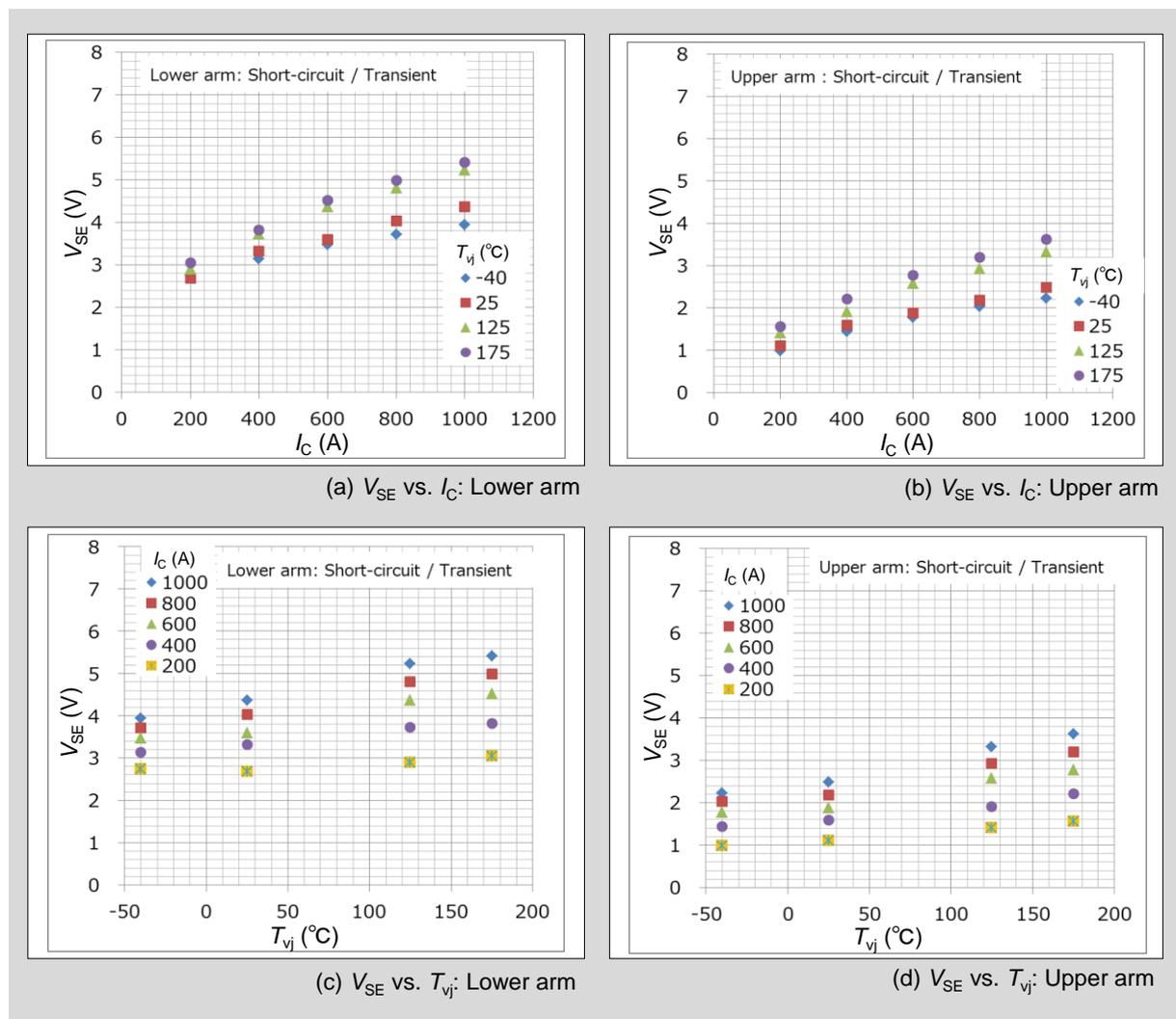


Fig. 8-5 Typical data example of  $V_{SE}$  characteristics on  $I_C$  and  $T_{vj}$  at station-(i)

## 6. $V_{SE}$ Dependence of $I_C$ and $T_{vj}$ : (ii) Over-current / Transient

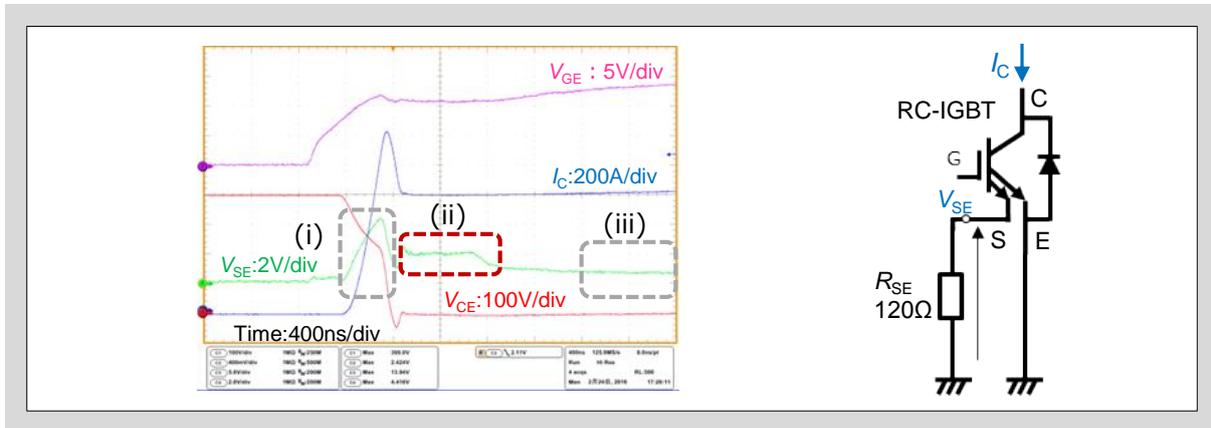


Fig. 8-6  $V_{SE}$  on the switching waveform

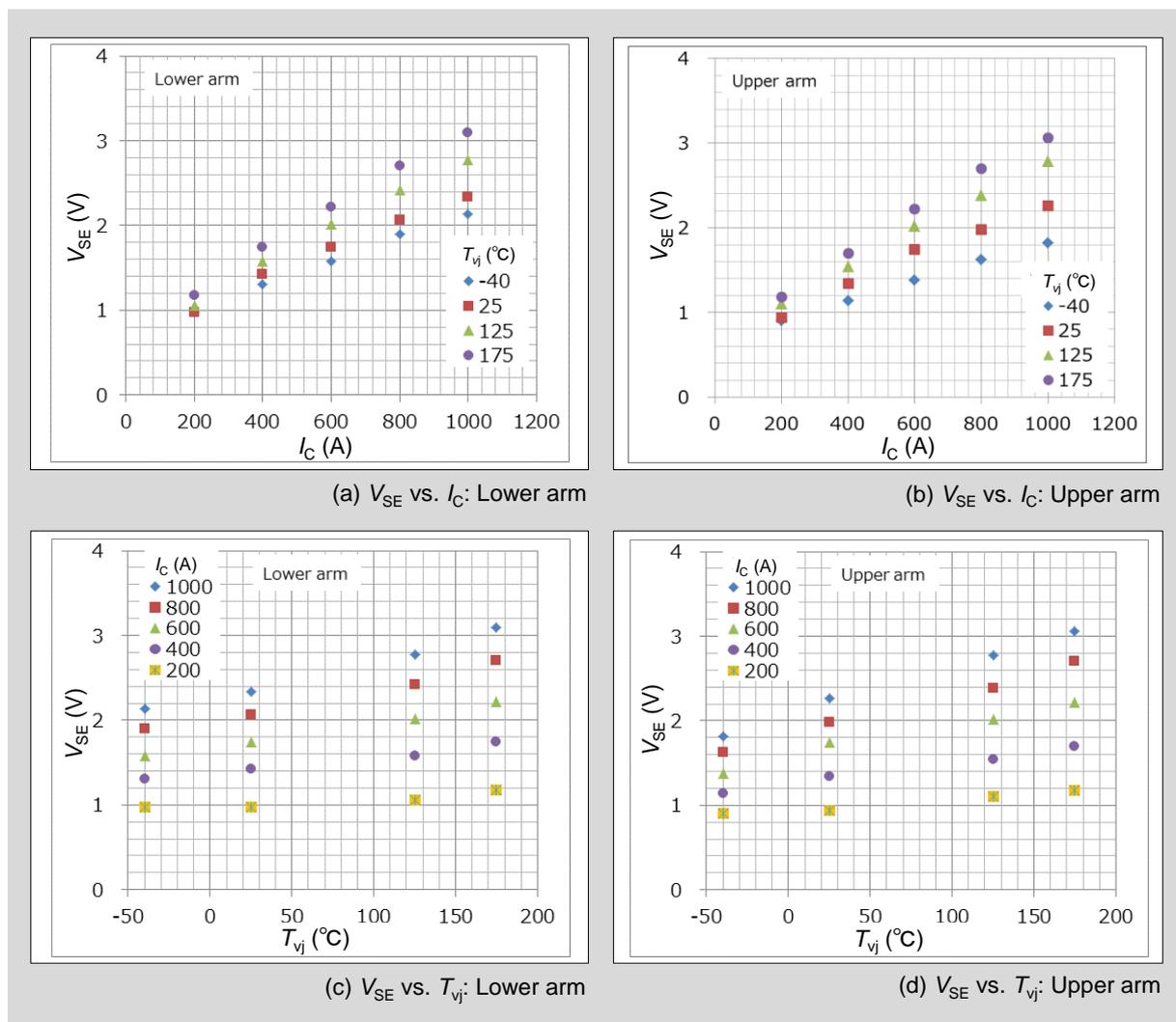


Fig. 8-7 Typical data example of  $V_{SE}$  characteristics on  $I_C$  and  $T_{vj}$  at station-(ii)

## 7. $V_{SE}$ Dependence of $I_C$ and $T_{vj}$ : (iii) Over-current / Steady state

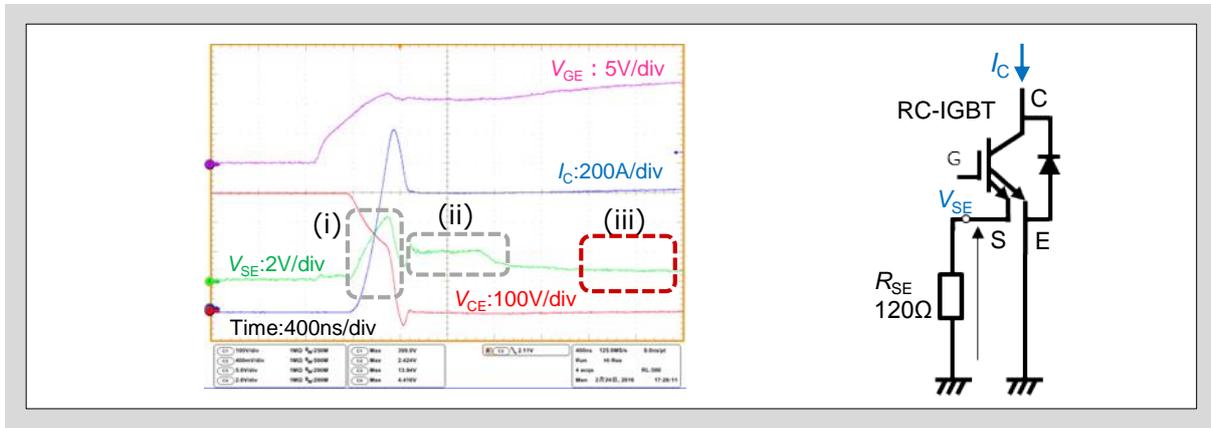


Fig. 8-8  $V_{SE}$  on the switching waveform

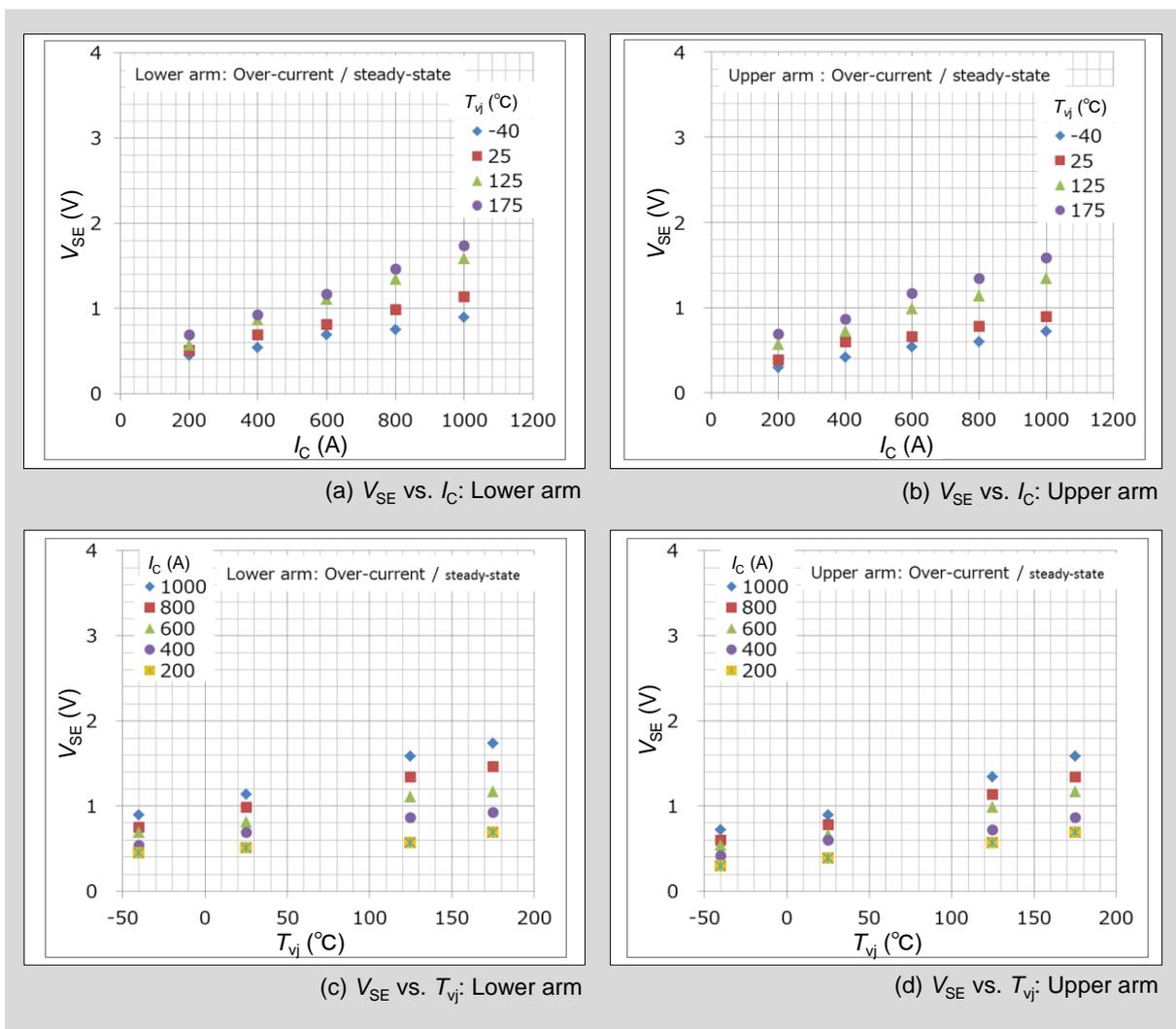


Fig. 8-9 Typical data example of  $V_{SE}$  characteristics on  $I_C$  and  $T_{vj}$  at station-(iii)

## 8. Application for SC Protection Function by Using ADI- ADuM4138\*1).

Procedure of dividing resistor design.

1) Take  $V_{SE}$  dependence of  $T_{vj}$  operation temperature by certain  $R_{SE}$  and  $I_C$  conditions.

Where, 120( $\Omega$ ) of  $R_{SE}$  is recommended as explained in front page.

For ADI driver IC,  $V_{SE}$  characteristics on the over-current / transient state showing in P8-4 is recommended. Please see (ii) part in Fig. 8-10.

When 120( $\Omega$ ) of  $R_{SE}$  and 800(A) of IC are used, typical example result: Line-1 is shown in Fig. 8-11.

In this case, 25 to 175( $^{\circ}$ C) of  $T_{vj}$  operation range are assumed.

2) Because  $V_{SE}$  value is proportional to  $T_{vj}$ , threshold level of  $V_{SE}$  is set by maximum operational temperature.  $\rightarrow V_{SE} = 2.87@175(^{\circ}$ C) --- Line-2

3) On the other hand,  $V_{SC}$  level of ADuM4138 is 2(V) type.

$$V_{CE} = V_{SE} * R_{SE2} / (R_{SE1} + R_{SE2}) \text{ --- eq.-1}$$

$$R_{SE1} + R_{SE2} = 120 \text{ --- eq.-2}$$

From eq.-1, eq.-2 and constants,  $R_{SE1} = 34.3(\Omega)$ ,  $R_{SE2} = 85.7(\Omega)$ , respectively.

Because E24 series resistor set were used,  $R_{SE1} = 36(\Omega)$  and  $R_{SE2} = 82(\Omega)$  were selected, respectively.

4) After  $R_{SE1}$  and  $R_{SE2}$  are replaced by certain resistor's value, the short-circuit protection function on RT of  $T_{vj}$  shall be checked.

5) Then, the  $V_{SE}$  at SC on  $T_{vj}$  operation range are taken. --- Line-3

Where  $V_{SE}$  value is peak value of the waveform which is part (ii) in Fig. 8-10.

6) Line-2 never cross Line-3 on  $T_{vj}$  operation range is required condition in this setting.

\*In the case of short-circuit protection function by using ADI driver IC, even if 12(V) clamp function is activated during mirror term on gate driving, there is no concern on dissipation.

The gate voltage is still increased in this term that is why influence of 12(V) clamp function to the gate voltage fluctuation is negligible.

During normal switching operation which is less than maximum current ratings, even if a  $V_{SE}$  value exceeds the threshold level of 2.87(V) on the part-(i), the soft turn-off function is not activated because the peak width is less than 800ns of delay time.

\*1) ADI: Analog Devices, Inc.

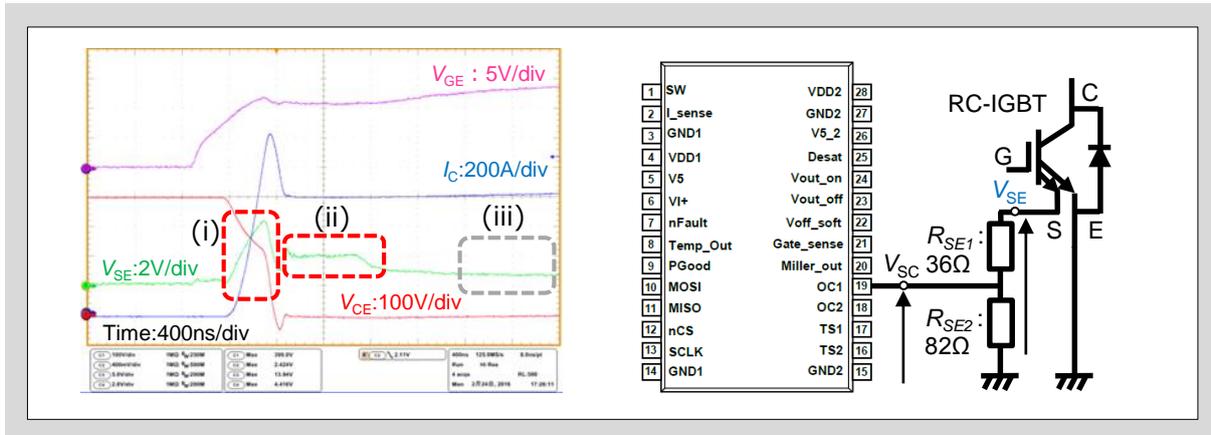


Fig. 8-10 Circuit diagram of SC protection by using ADuM1438

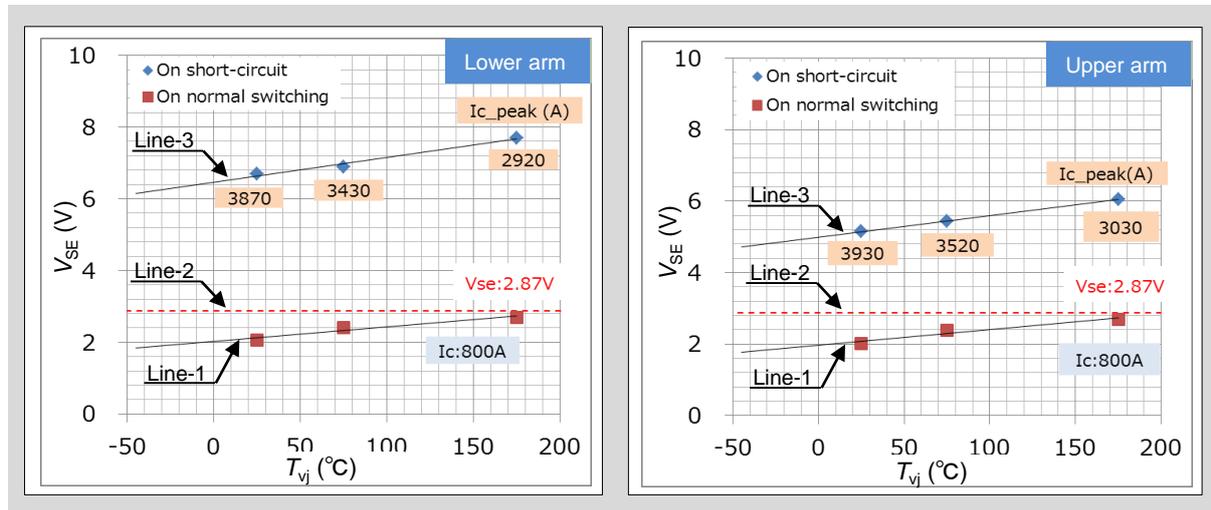


Fig. 8-11 SC protection function characteristics in terms of  $V_{SE}$