Chapter 8 Sense IGBT Performance

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1. Scope

This chapter is explaining about a 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 usage of the IGBT and the data are just reference of the outline of the sense IGBT.

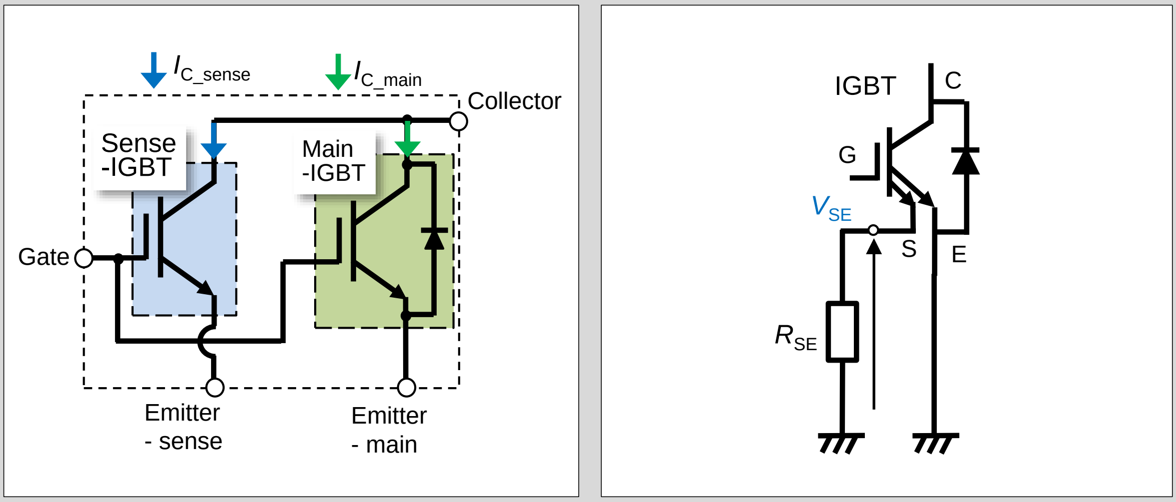
★Since the driver IC revision differs with respect to the below explanation for the sense IGBT function and the content of the explanation provided for the evaluation board in Chapter 7, there may be differences in certain values such as the threshold voltage, but please understand that these values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

$I_{C\_sense} \propto I_{C\_main}$ --- 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.



(a) Equivalent circuit of a IGBT with sense-IGBT
(b) Detecting circuit

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 15V,
   V_{SE} value should be under 15V, at least.
3) Based on above trade-off and including safety margin, 120Ω of R_{SE} is recommended for Short-circuit current detection resistance.

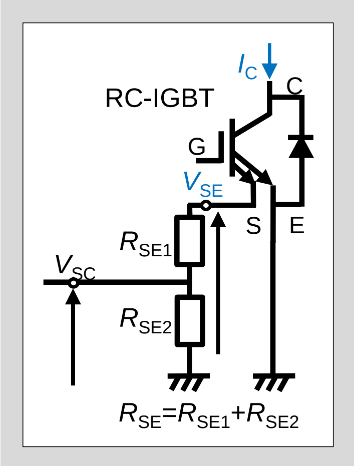
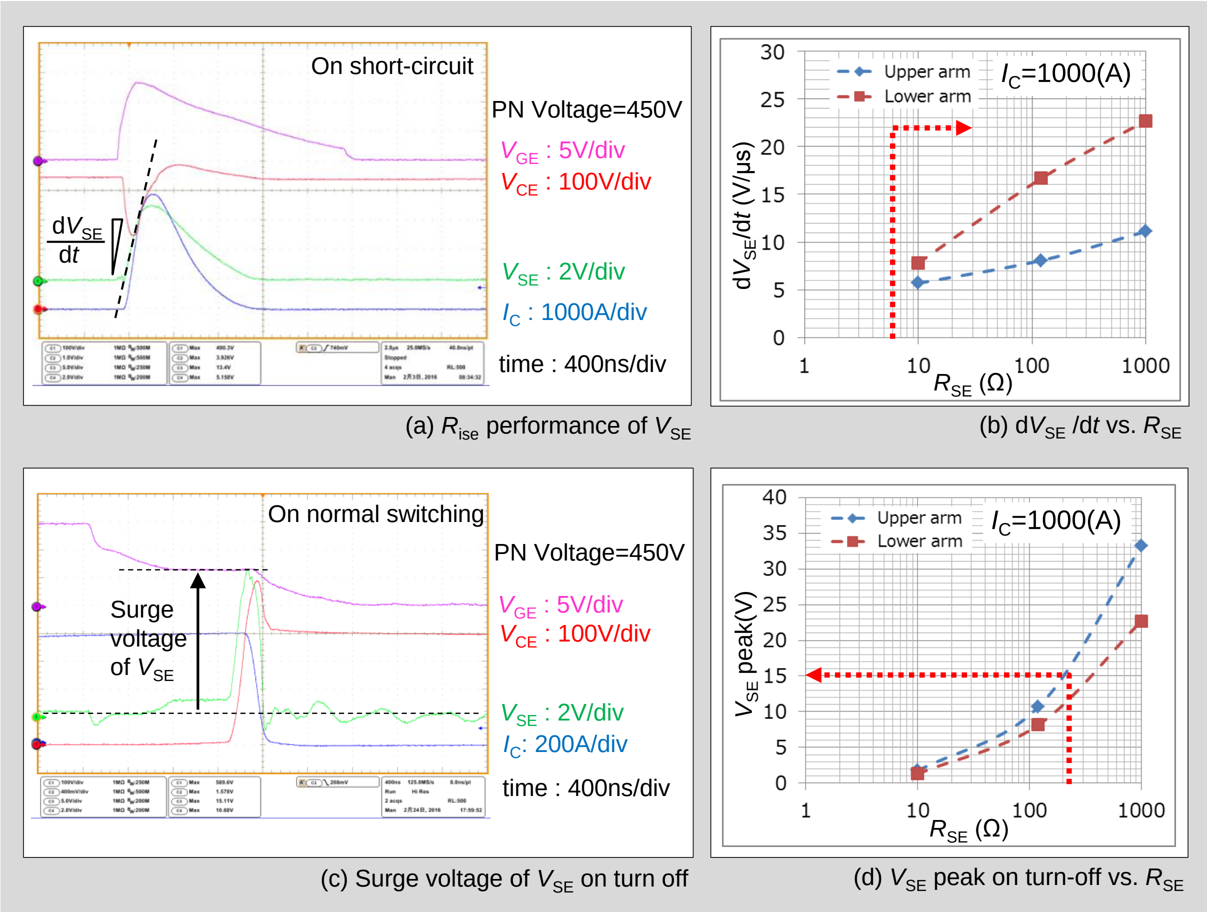


Fig. 8-2 V_{SE} and R_{SE}

*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.



(a) R_{ise} performance of V_{SE}

(b) dV_{SE}/dt vs. R_{SE}

(c) Surge voltage of V_{SE} on turn off

(d) V_{SE} peak on turn-off vs. R_{SE}

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 = 200~1000, step 200A
- T_{vj} = -40, 25, 125, 175℃
- R_{SE} = 120Ω

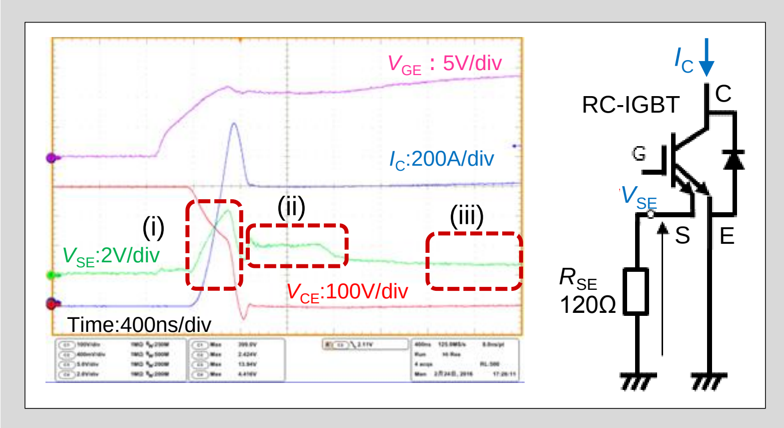
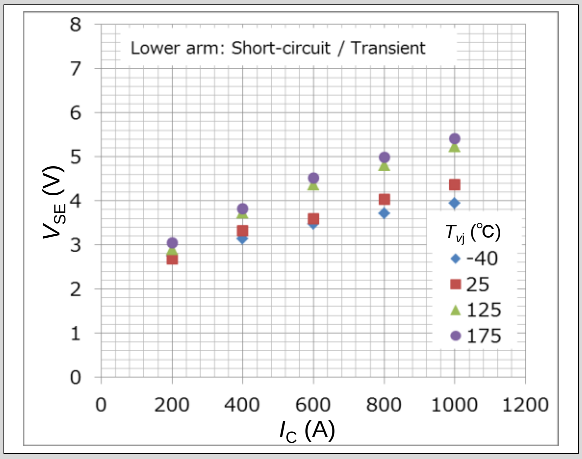
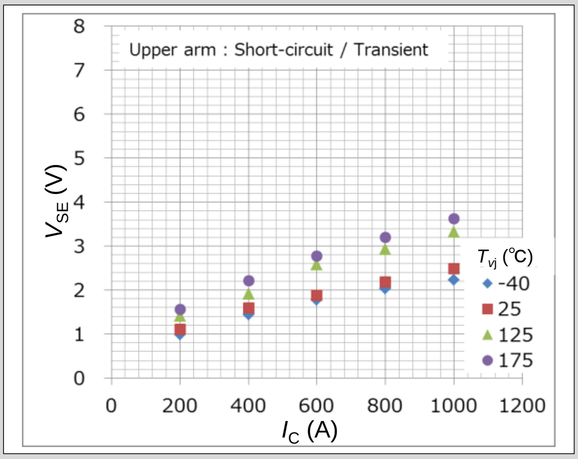


Fig. 8-4 V_{SE} on the switching waveform

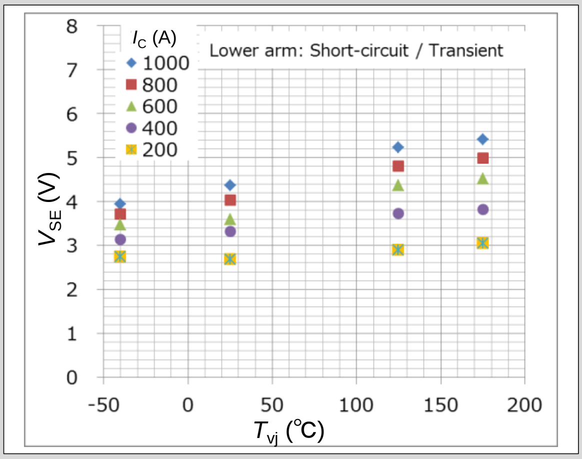
5. V_{SE} Dependence of I_C and T_{vj} : (i) Short-Circuit / Transient



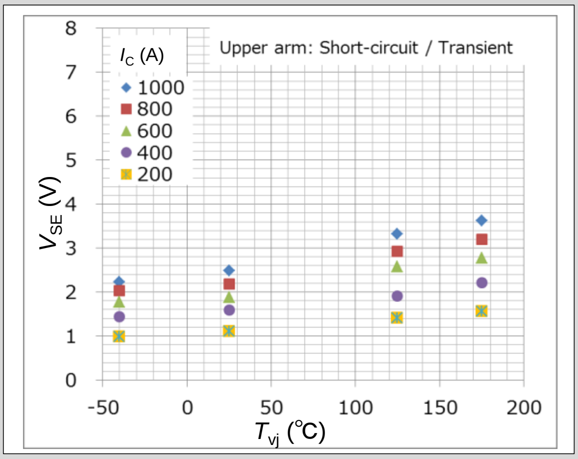
(a) V_{SE} vs. I_C: Lower arm



(b) V_{SE} vs. I_C: Upper arm



(c) V_{SE} vs. T_{vj}: Lower arm



(d) V_{SE} vs. T_{vj}: Upper arm

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

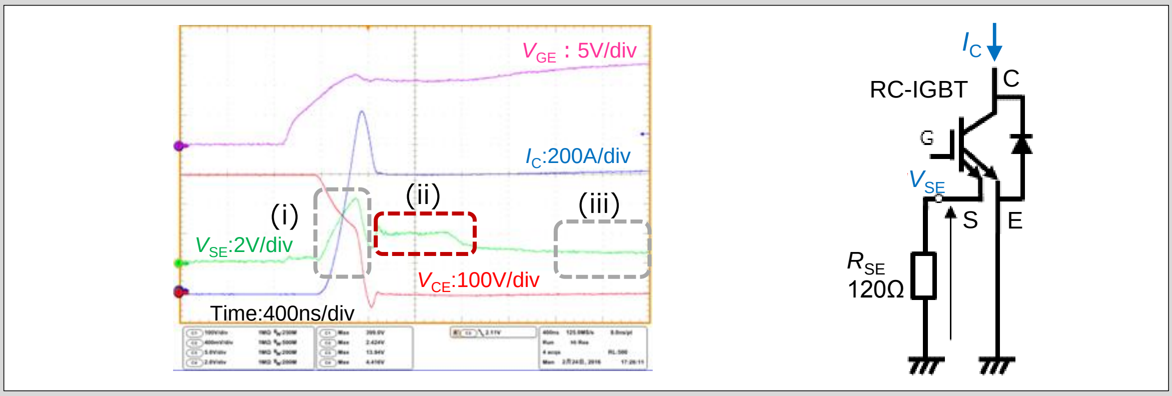
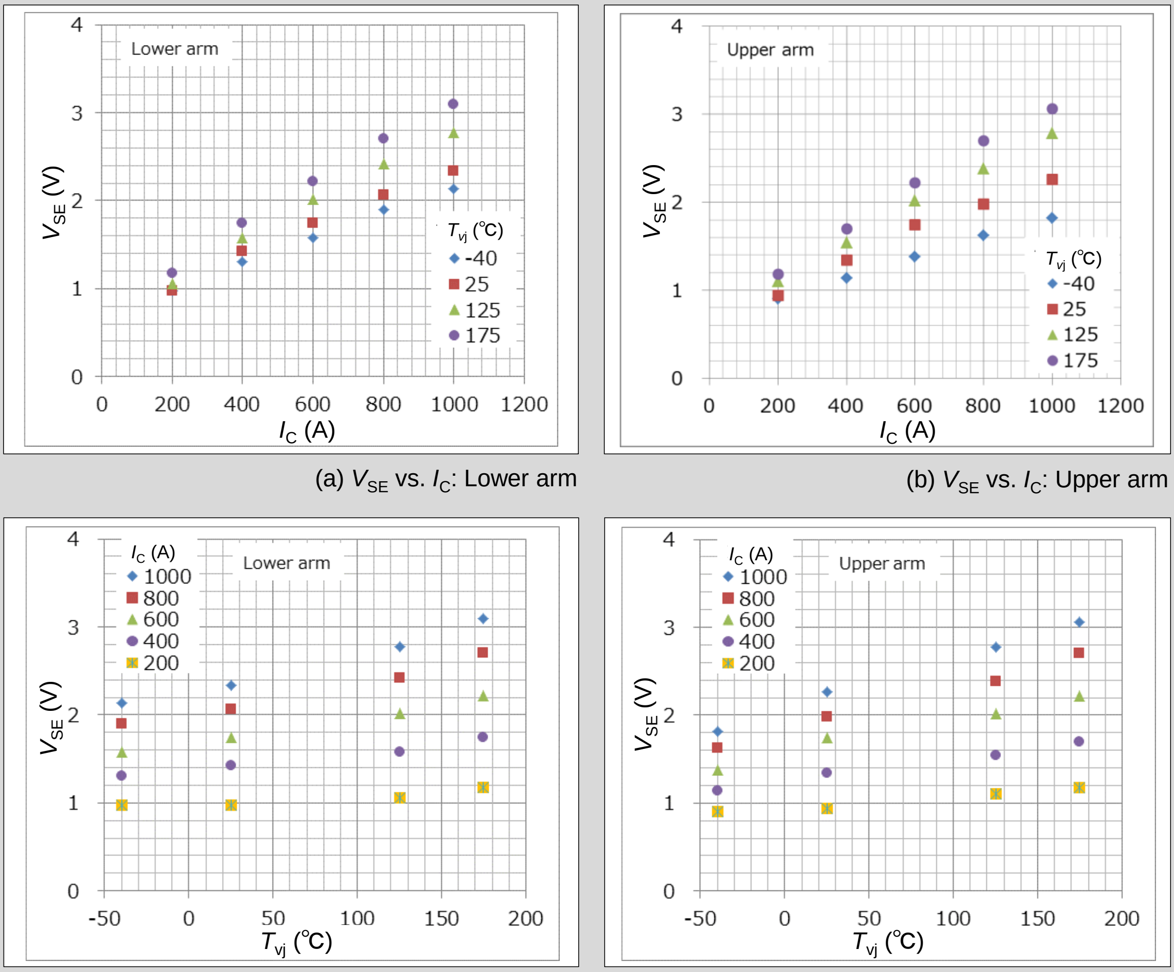


Fig. 8-6 V_{SE} on the switching waveform



(a) V_{SE} vs. I_C: Lower arm

(b) V_{SE} vs. I_C: Upper arm

(c) V_{SE} vs. T_{vj}: Lower arm

(d) V_{SE} vs. T_{vj}: Upper arm

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

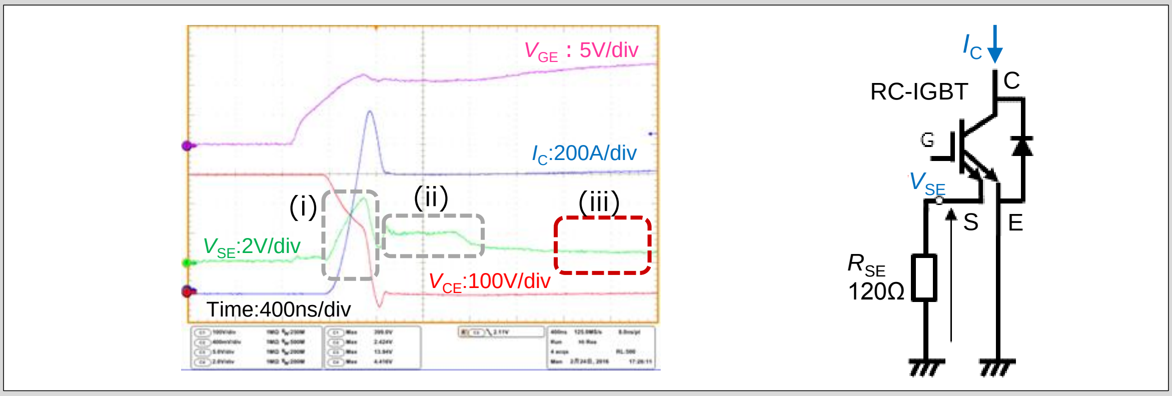
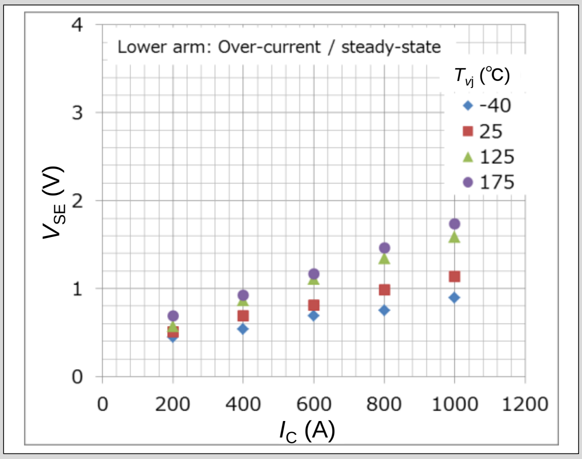
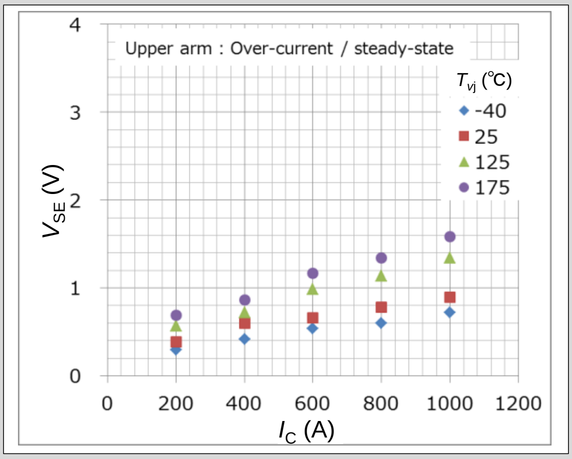


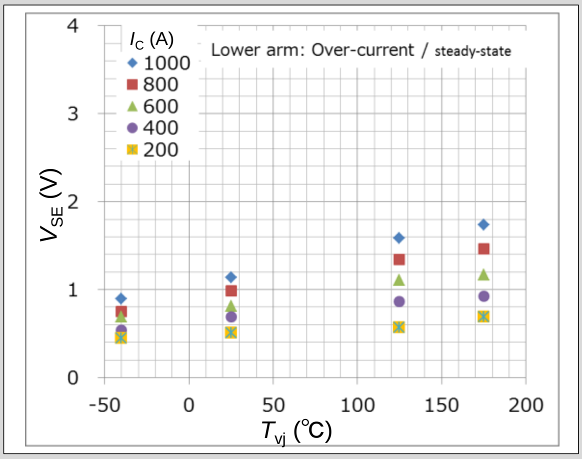
Fig. 8-8 V_{SE} on the switching waveform



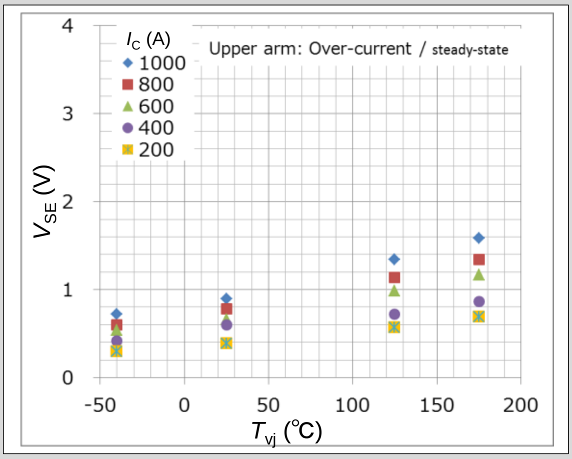
(a) V_{SE} vs. I_C: Lower arm



(b) V_{SE} vs. I_C: Upper arm



(c) V_{SE} vs. T_{vj}: Lower arm



(d) V_{SE} vs. T_{vj}: Upper arm

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, 120Ω 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 120Ω of R_{SE} and 800A of IC are used, typical example result: Line-1 is shown in Fig. 8-11.
   In this case, 25 to 175℃ 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. → V_{SE} = 2.87@175℃ --- Line-2
3) On the other hand, V_{SC} level of ADuM4138 is 2V type.
   $V_{SC} = V_{SE} * R_{SE2} /(R_{SE1} + R_{SE2})$ --- eq.-1
   $R_{SE1} + R_{SE2} = 120$ --- eq.-2
   From eq.-1, eq.-2 and constants, R_{SE1} = 34.3Ω, R_{SE2} = 85.7Ω, respectively.
   Because E24 series resistor set were used, R_{SE1} =36Ω and R_{SE2} = 82Ω 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
   This V_{SE} value is the peak value of the V_{SE} waveform at the short circuit shown in Fig. 8-3(a).
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 12V 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 12V 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 2.87V 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.

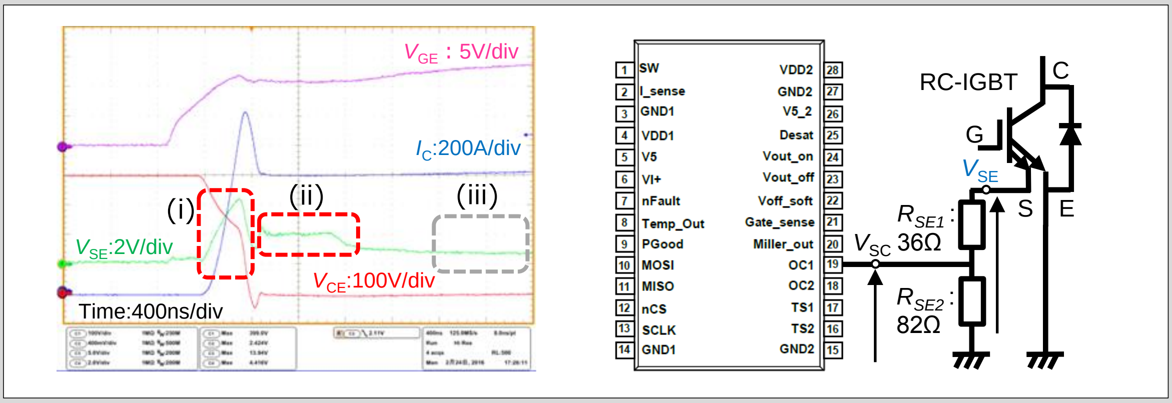


Fig. 8-10 Circuit diagram of SC protection by using ADuM1438

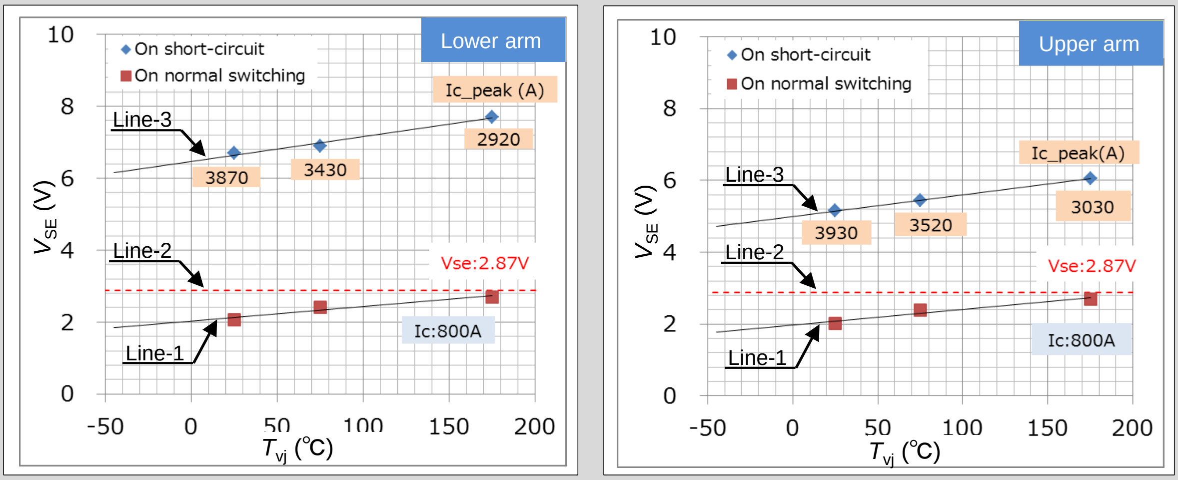


Fig. 8-11 SC protection function characteristics in terms of V_{SE}