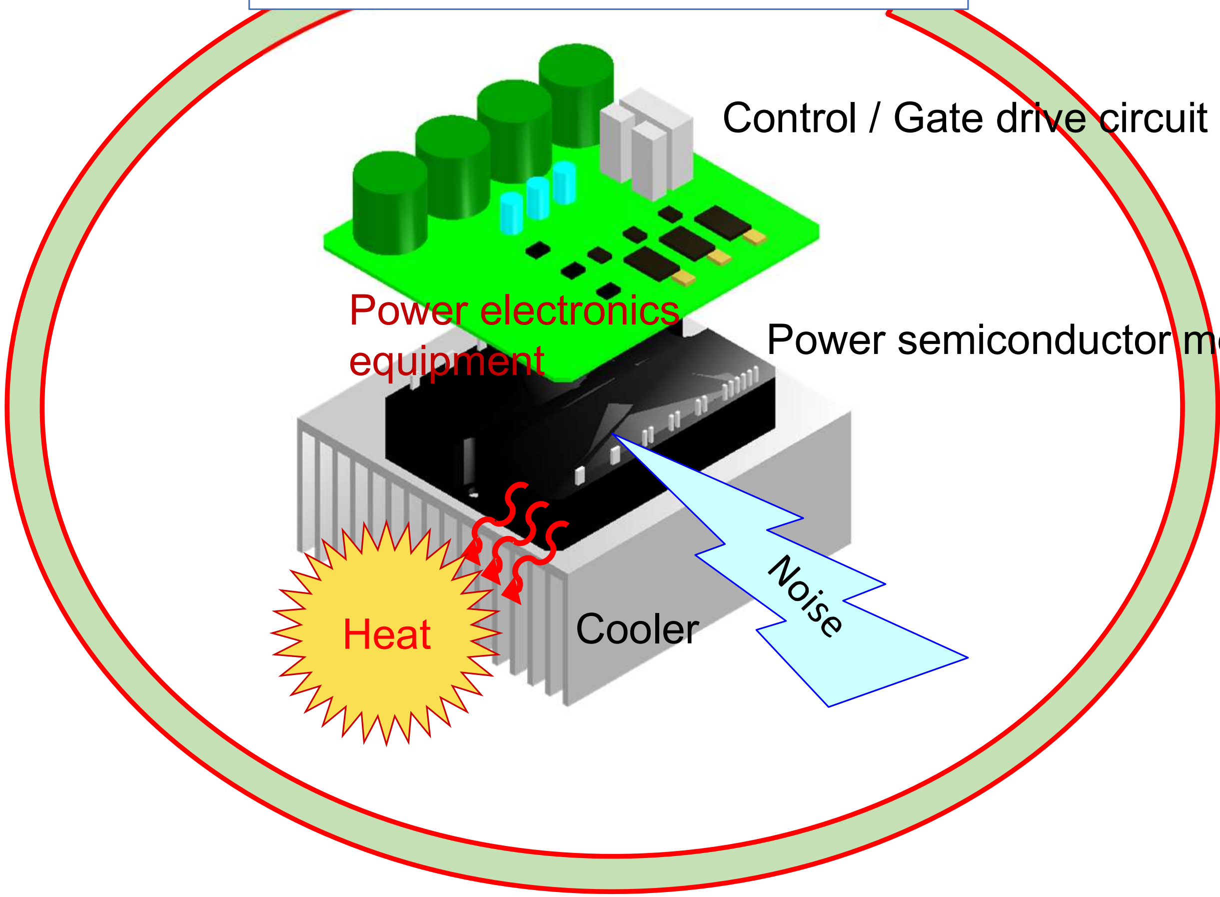
Purpose: Construction of an accurate and easy-to-use power semiconductor model for virtual production and verification of power electronics equipment utilizing simulation technology

Simulation（Analysis）



1. Building an I_D-V_{DS} model for power semiconductor devices

Modeling method（@MATLAB）

Step.1
Import the actual measurement data (I_D vs. V_{DS}).
Extract the values of the variables Func1, Func2, and Func3 in the basic model formula for each V_{GS} data.

↓

Step.2
Model the extracted Func1, Func2, Func3 data with a Gaussian function as a function of V_{GS}.

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Step.3
Replace Func1 ~ 3 model with basic model formula.

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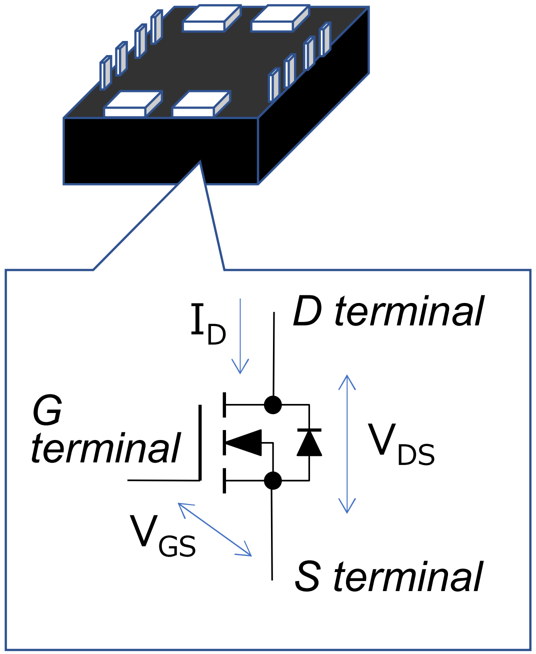
Power semiconductor model is completed

Target : 1.2kV-Full SiC module

Power semiconductor module



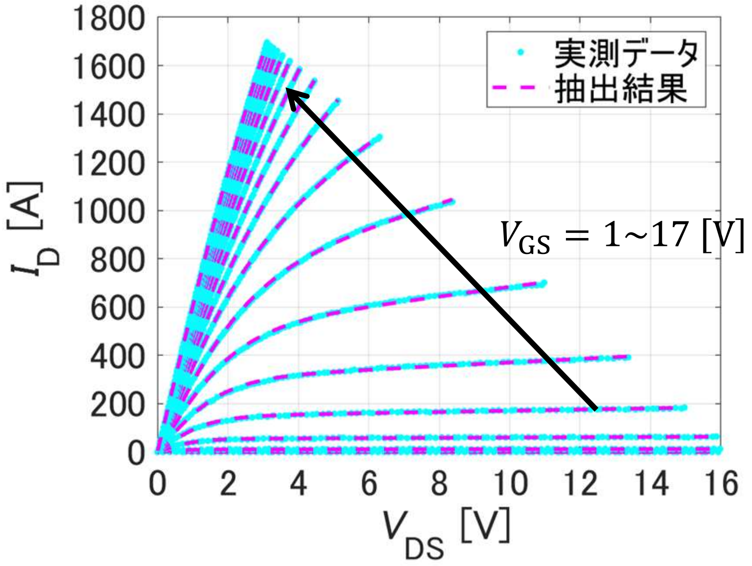
Power semiconductor device

Step.1
Import the actual measurement data (I_D vs. V_{DS}). Extract the values of the variables Func1, Func2, and Func3 in the basic model formula for each V_{GS} data.

＊Fitting measured data with Func1,2,3.

Basic model formula :

$$I_{D(V_{DS})} = f_{(\mathbf{Func1},\mathbf{Func2},\mathbf{Func3},V_{DS})}$$
$$= \mathbf{Func1} \times tanh(\mathbf{Func2} \times V_{DS} \cdots) + \cdots$$



Target : 1.2kV-Full SiC module

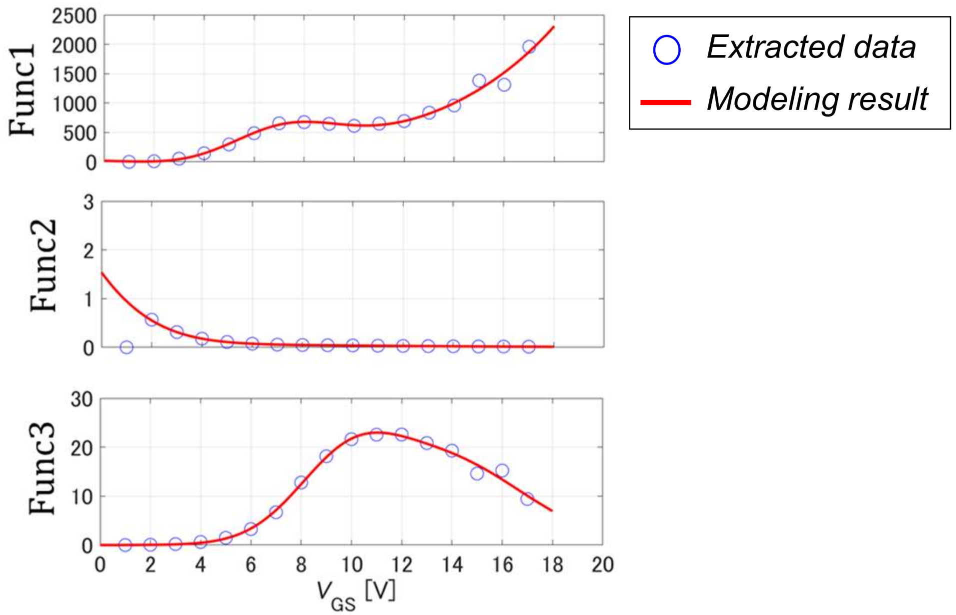
Step.2
Model the extracted Func1, Func2, Func3 data with a Gaussian function as a function of V_{GS} .

$$\mathrm{Func1}_{(V_{GS})} = \sum_{i=1}^{n} \mathbf{A1}_i \times e^{-\left(\frac{V_{GS}-\mathbf{B1}_i}{\mathbf{C1}_i}\right)^2}$$

$$\mathrm{Func2}_{(V_{GS})} = \sum_{i=1}^{n} \mathbf{A2}_i \times e^{-\left(\frac{V_{GS}-\mathbf{B2}_i}{\mathbf{C2}_i}\right)^2}$$

$$\mathrm{Func3}_{(V_{GS})} = \sum_{i=1}^{n} \mathbf{A3}_i \times e^{-\left(\frac{V_{GS}-\mathbf{B3}_i}{\mathbf{C3}_i}\right)^2}$$

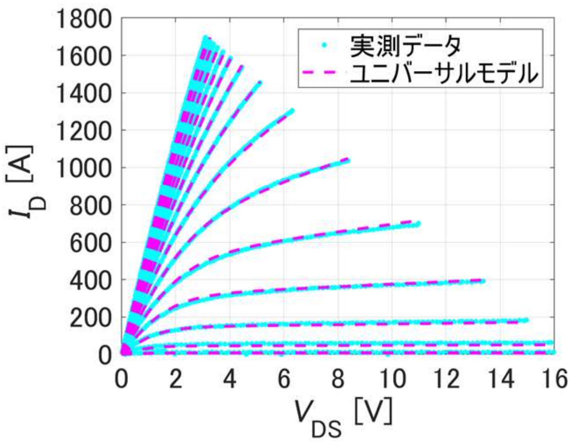
$\mathbf{A1}_i \sim \mathbf{C3}_i$
: Constant parameter



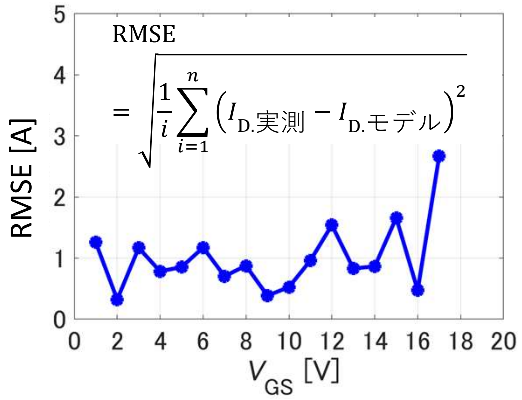
__Step.3__
Replace Func1 ~ 3 model with basic model formula.

＊Power semiconductor model is completed

$$I_{\mathrm{D}(V_{\mathrm{DS}},V_{\mathrm{GS}})} = f_{\left(\mathrm{Func1}_{(V_{\mathrm{GS}})},\mathrm{Func}_{(V_{\mathrm{GS}})},\mathrm{Func}_{(V_{\mathrm{GS}})},V_{\mathrm{DS}}\right)}$$



__Compare the measured data with the model__

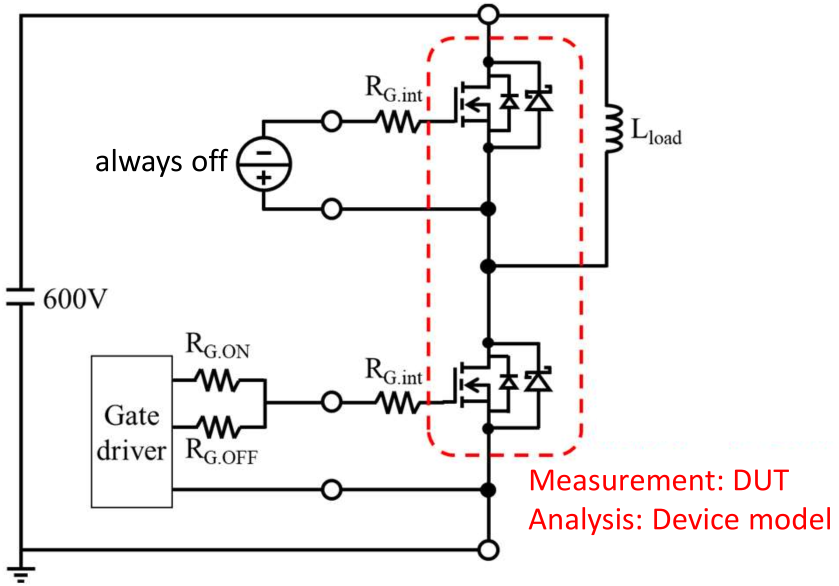


__Mean square error between measured data and model__

__Target : 1.2kV-Full SiC module__

2. Matching the switching characteristics of the model with those of the semiconductor device

①Measuring switching waveforms using a test circuit



Configuration of the test circuit

②Add tuning parameters to the model

Add tuning parameters to I_D-V_{DS} models, C_{GS} models, C_{DG} models

③Set objective function for tuning

Calculating the difference between the measured waveform and the analysis waveform for the following items under each current

RMSE I_G: Error between measurement and analysis I_G
RMSE V_G: Error between measurement and analysis V_G
RMSE dI_D/dt: Error between measurement and analysis dI_D/dt
RMSE dV_{DS}/dt: Error between measurement and analysis dV_{DS}/dt

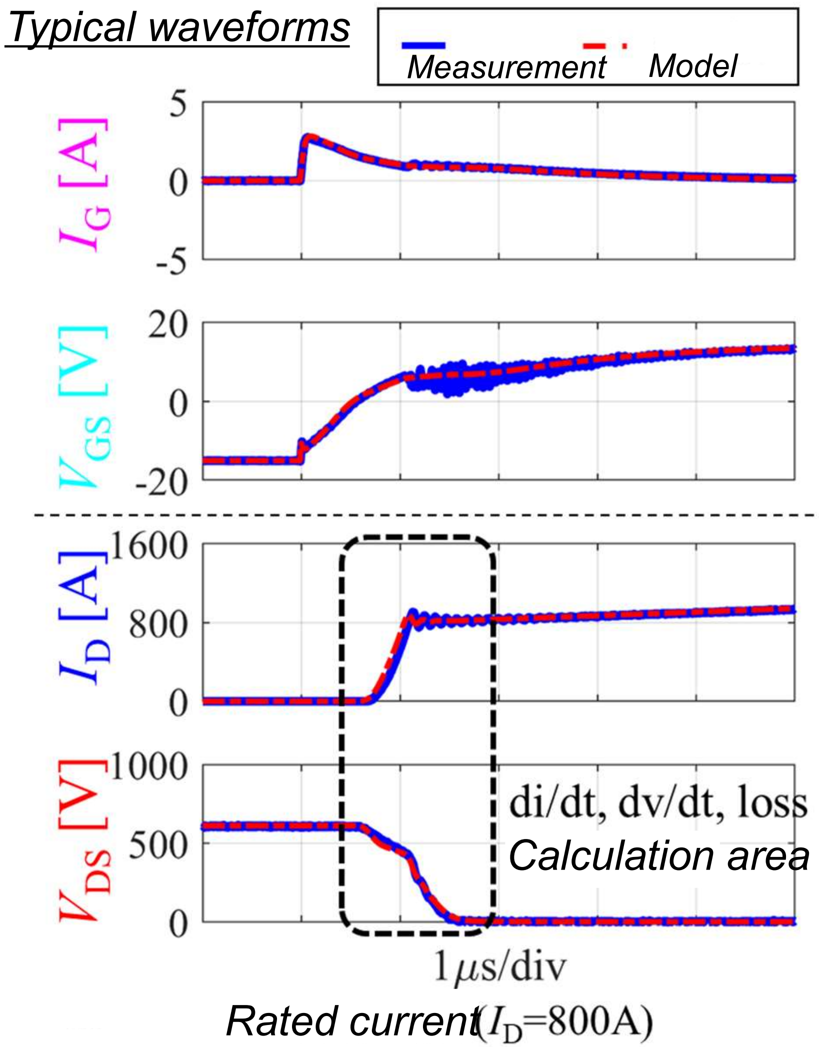
$$I_{G.ON.RMSE} = \sqrt{\frac{1}{16}\sum_{i=1}^{16}\left\{\left(\Delta I_{G.ON(@I_D=i\times100[A])}\right)^2\right\}}$$

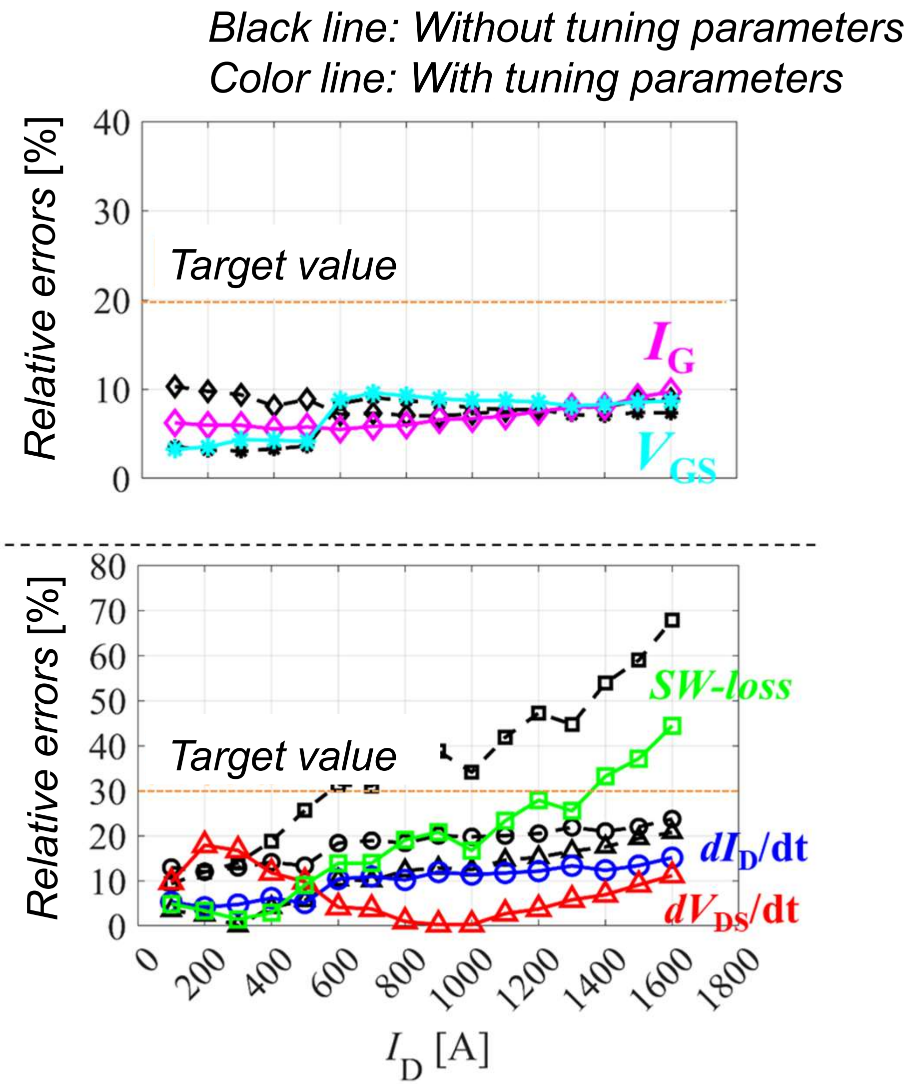
The objective function consists of a total of eight factors that take into account turn-on and turn-off.

$$f_{obj} = I_{G.ON.RMSE} + I_{G.OFF.RMSE} + V_{GS.ON.RMSE} + V_{GS.OFF.RMSE} + \frac{dI_{D.ON}}{dt}_{RMSE} + \frac{dI_{D.OFF}}{dt}_{RMSE} + \frac{dV_{DS.ON}}{dt}_{RMSE} + \frac{dV_{DS.OFF}}{dt}_{RMSE}$$

④The objective function is minimized by simulated annealing.

Comparison of measurement and analysis (turn-on)





Comparison of measurement and analysis (turn-off)