What are MODFETs? - MOSFET Threshold Values,I_D-V_{GS} Characteristics, and Temperature Characteristics

Si Transistors

In succession to the preceding discussion of MOSFET switching characteristics, here we explain the gate threshold voltage, which is a crucial characteristic of MOSFETs, as well as the I_D-V_{GS} characteristics, and the temperature characteristics of each of these.

MOSFET $V_{GS(th)}$：　Gate Threshold Voltage

The MOSFET $V_{GS(th)}$ or gate threshold voltage is the voltage between the gate and source that is needed to turn on the MOSFET. In other words, if V_{GS} is at least as high as the threshold voltage, the MOSFET turns on.

Some persons may be wondering just how much of a current I_D can be passed on this "MOSFET on" state. And it is true that I_D changes depending on V_{GS}. Speaking from the standpoint of the $V_{GS(th)}$ specification, if the conditions are not determined, a value for $V_{GS(th)}$ cannot be guaranteed; the datasheet for the MOSFET stipulates these conditions. This table is excerpted from the datasheet for the N-ch, 600 V, 4 A power MOSFET R6004KNX.

● **Electrical characteristics** (T_a = 25°C)

Parameter	Symbol	Conditions	Values			Unit
			Min.	Typ.	Max.	
Drain - Source breakdown voltage	$V_{(BR)DSS}$	V_{GS} = 0V, I_D = 1mA	600	-	-	V
Zero gate voltage drain current	I_{DSS}	V_{DS} = 600V, V_{GS} = 0V				μA
		T_j = 25°C	-	-	100	
		T_j = 125°C	-	-	1000	
Gate - Source leakage current	I_{GSS}	V_{GS} = ±20V, V_{DS} = 0V	-	-	±100	nA
Gate threshold voltage	$V_{GS(th)}$	V_{DS} = 10V, I_D = 1mA	3	-	5	V
Static drain - source on - state resistance	$R_{DS(on)}$ *5	V_{GS} = 10V, I_D = 1.5A				Ω
		T_j = 25°C	-	0.90	0.98	
		T_j = 125°C	-	1.36	-	
Gate resistance	R_G	f = 1MHz, open drain	-	3.3	-	Ω

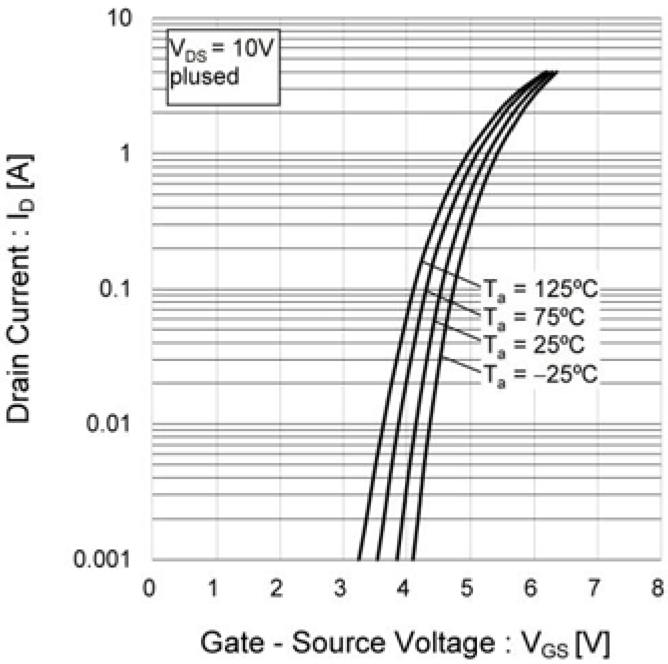
The blue line surrounds information on $V_{GS(th)}$, and the conditions column indicates that conditions are V_{DS} = 10 V and I_D = 1 mA. Under these conditions, and at Ta = 25℃, $V_{GS(th)}$ is guaranteed to have minimum and maximum values of 3 V and 5 V.

In other words, as V_{GS} is raised, the MOSFET begins to turn on (I_D begins to flow), and when I_D is 1 mA, the value of V_{GS} is between 3 V and 5 V inclusive; this value is $V_{GS(th)}$. Various methods of expression are possible, but we can say that the MOSFET on state is defined as being when I_D = 1 mA at V_{DS} = 10 V, and the V_{GS} at this time is taken to be $V_{GS(th)}$, the value of which is between 3 V and 5 V.

It should also be noted that voltages and currents that change according to some state, such as an input or output or a turning on or off of some function, are commonly called threshold values, and are not limited to MOSFETs.

Temperature Characteristics of $V_{GS(th)}$ and I_D-V_{GS}

From the initial graph showing the I_D-V_{GS} characteristic, the $V_{GS(th)}$ for the MOSFET can be read off. The condition V_{DS} = 10 V matches the stipulated condition. When I_D is 1 mA, V_{GS} is equal to $V_{GS(th)}$, and so the V_{GS} when the curve for Ta = 25℃ intersects the 1 mA (0.001 A) line is approx. 3.8 V. The datasheet does not indicate a representative or typical value (indicated by "Typ"), and we see from the graph that the Typ value for $V_{GS(th)}$ is about 3.8 V. The graph value can in essence be regarded as the Typ value.



Next, we consider the I_D-V_{GS} characteristic. As the specification value for $V_{GS(th)}$, the value when I_D = 1 mA is used, but in actual use, a 4 A MOSFET is unlikely to be used with I_D at only 1 mA. For example, when an I_D of 1 A at Ta = 25℃ is required, we see from the graph that the V_{GS} is about 5.3 V.

From the graph of the I_D-V_{GS} temperature characteristic, at high temperatures there is a tendency for I_D to increase if V_{GS} is constant. Taking as an example the previous condition that I_D = 1 A at Ta = 25℃, at Ta = 75℃, an I_D of about 1.5 A can be passed, and so the conditions of use must be considered carefully.

Returning to the gate threshold voltage, the temperature characteristic of $V_{GS(th)}$ is shown in a graph. As was seen from the I_D-V_{GS} graph, we see that at 25℃, $V_{GS(th)}$ is approx. 3.8 V. The temperature in this graph is Tj, but as indicated by the term "pulsed", the data was obtained in pulsed tests, and it is permissible to assume that Tj ≈ Ta ≈ 25℃.

It is seen that the temperature characteristic is such that at high temperatures, $V_{GS(th)}$ tends to decline. This indicates that as the temperature rises, because $V_{GS(th)}$ declines, a larger I_D can flow at a lower V_{GS}. In other words, and as would be expected, this matches the I_D-V_{GS} temperature characteristic.

$V_{GS(th)}$ can be used to estimate Tj. The $V_{GS(th)}$ temperature characteristic is linear, and so a proportionality coefficient can be calculated, and the increase in temperature can be calculated from the amount of change in $V_{GS(th)}$.