Inverse diodes/ free-wheeling diodes

Forward current I_F
Maximum forward current value of inverse or free-wheeling diodes,
Parameter: case temperature, e.g. T_{case} = 25°C, 80°C

Peak forward current I_{FM} or pulsed forward current I_{Fpuls}
Peak value of diode current during pulse operation
Parameters: pulse duration t_p, case temperature, e.g. T_{case} = 25°C, 80°C

2.2.2 Characteristics

MOSFETs/ module structure

Drain-source breakdown voltage$V_{(BR)DSS}$
Breakdown voltage between drain and source, gate-source short-circuited (V_{GS} = 0)
Parameters: Reverse drain current I_D, case temperature T_{case} = 25°C

Gate-source threshold voltage $V_{GS(th)}$
Gate-source voltage above which considerable drain current will flow,
Parameters: drain-source voltage $V_{DS} = V_{GS}$, drain current I_D, case temperature T_{case} = 25°C

Zero gate voltage drain current I_{DSS}
Blocking current between drain and source with gate-source short-circuited (V_{GS} = 0) and drain-source voltage $V_{DS} = V_{DSS}$,
Parameter: chip temperature, e.g. T_j = 25°C and 125°C

Gate-source leakage current I_{GSS}
Leakage current between gate and source with drain-source short-circuited (V_{DS} = 0) at maximum gate-source voltage V_{GS},
Parameters: gate-source voltage V_{GS}, case temperature T_{case} = 25°C

Drain-source on-resistance $R_{DS(on)}$
Quotient of changing drain-source voltageV_{DS} and drain current I_D in a thoroughly gate-controlled MOSFET at a specified gate-source voltage V_{GS} and a specified drain current I_D (at “rated current”),
In this state V_{DS} is proportional to I_D, during large-signal behaviour the forward on-state voltage $V_{DS(on)} = R_{DS(on)} * I_D$.
Parameters: gate-source voltage V_{GS}, drain current I_D (“rated current”), case temperature T_{case} = 25°C ($R_{DS(on)}$ is extremely dependent on temperature!).

Forward transconductance g_{fs}
Quotient of changing drain current and gate-source voltage at a specified drain current I_D (at “rated current”),
Parameters: drain-source voltage V_{DS}, drain current I_D (“rated current”), case temperature T_{case} = 25°C

Capacitance chip-case C_{CHC}
Capacitance between a sub-component and the case base plate or the heatsink potential,
Parameter: case temperature T_{case} = 25°C

Input capacitance C_{iss}
Capacitance between gate and source with drain-source short-circuited for AC and gate-source voltage V_{GS} = 0.
Parameters: drain-source voltage V_{DS}, measuring frequency f, case temperature T_{case} = 25°C

Output capacitance C_{oss}
Capacitance between drain and source with gate-source short-circuited (V_{GS} = 0),
Parameters: drain-source voltage V_{DS}, measuring frequency f, case temperature T_{case} = 25°C

Reverse transfer capacitance (Miller capacitance) C_{rss}, C_{mi}
Capacitance between drain and gate with drain-source short-circuited at AC and gate-source voltage V_{GS} = 0. For measuring, the source has to be connected with the protective shield of the measuring bridge.
Parameters: drain-source voltage V_{DS}, measuring frequency f, case temperature T_{case} = 25°C

Parasitic drain-source inductance L_{DS}
Inductance between drain and source

Switching times
Switching times indicated in MOSFET datasheets are determined from a measuring circuit under ohmic load according to Figure 2.1a. They refer to the gate-source characteristics during turn-on and turn-off, see Figure 2.1b.
Switching times as well as real current and voltage characteristics are determined by internal capacitances, inductances and resistances and by those of the gate and drain circuit; for this reason, all indications in the datasheets and the characteristics depicted therein may serve only as a guide.

As the current and voltage characteristics are not relevant to most applications, because they are based on the application of pure ohmic load, their importance is actually restricted to the definition of switching times.
The waveforms will deviate significantly especially if inductive or capacitive loads are involved (chapter 1.2.3) and also the measurement results may differ.

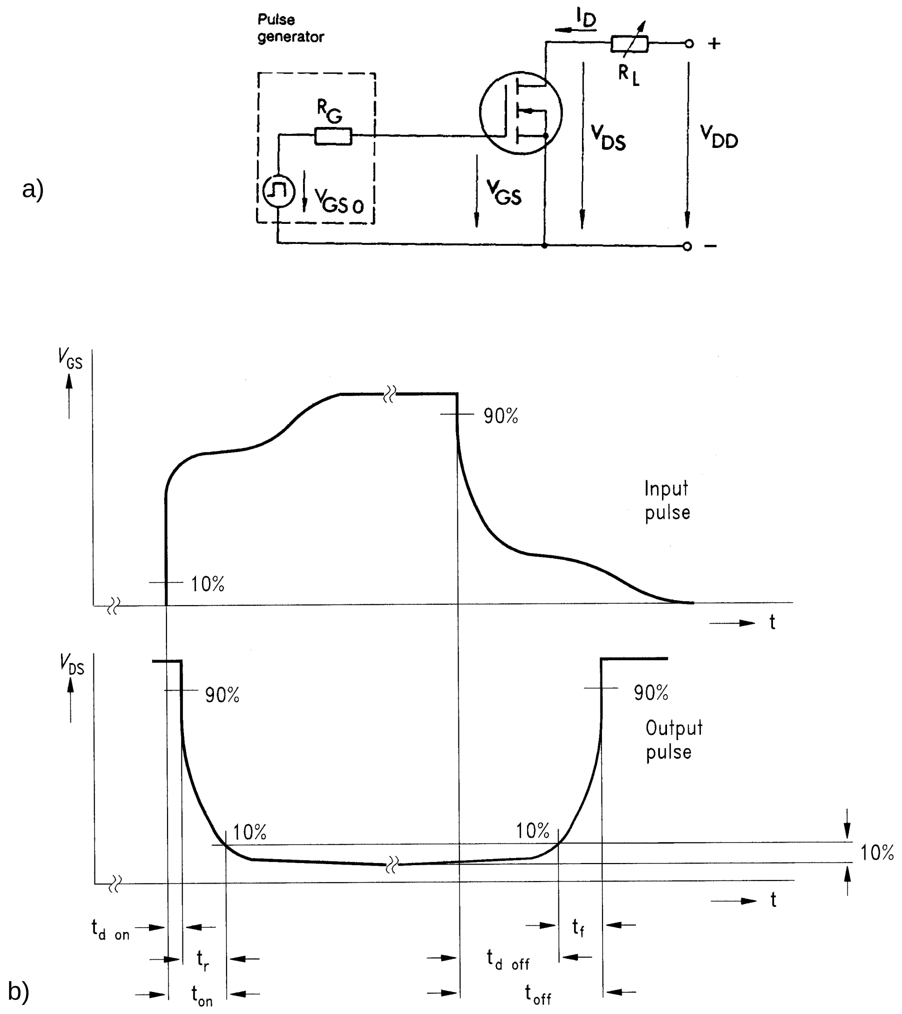

Figure 2.1 a) Measuring circuit
b) Definition of MOSFET switching times under ohmic load

The following parameters are indicated relevant to switching times:
measuring circuit, drain-source supply voltage V_{DD}, gate-source control voltage V_{GS}, drain current I_D, gate series resistance R_G (internal resistance of the control circuit), sometimes gate-source resistance R_{GS}, case temperature T_{case} = 25°C.

Turn-on delay time $t_{d(on)}$
After sudden turn-on of a positive gate-source control voltage V_{GG}, the gate-source voltage V_{GS} starts to rise with a time constant determined by input capacitance and gate resistance. As soon as the threshold voltage $V_{GS(th)}$ has been reached, the drain-source voltage V_{DS} will start to decrease and the drain current I_D will begin to rise.
The **turn-on delay time $t_{d(on)}$** is defined as the time interval between the moment when the gate-emitter voltage V_{GE} has reached 10 % of its end value (V_{GG}), and when the drain-source voltage has dropped to 90 % of its initial value (V_{DD}) .

Rise time t_r
The **rise time t_r** is defined as the time interval following the turn-on delay time, where the drain-source voltage drops from 90 % to 10 % of its initial value (V_{DD}). During this time, the drain

current will rise (therefore “rise time”), i.e. the major part of the turn-on losses is generated during this time interval.

The sum of **turn-on delay time $t_{d(on)}$** and **rise time t_r** is called **turn-on time t_{on}**.
As the drain-source voltage V_{DS} will not yet have reached its forward on-state value $V_{DS(on)} = R_{DS(on)} * I_D$ at the (defined) end of t_{on}, but still amounts to 10 % of V_{DD}, there will still be higher losses after t_{on} than the forward on-state losses.

Turn-off delay time $t_{d(off)}$
After sudden turn-off of the positive gate-source control voltage V_{GG}, the gate-source voltage V_{GS} starts to decline with a time constant determined by the input capacitance of the MOSFET and the gate-source resistance R_{GS}. The drain current which is coupled with the gate voltage in the active operating area via forward transconductance $g_{fs} = di_D/dv_{GS}$ also begins to decrease, whereas the drain-source voltage starts to rise accordingly.
The **turn-off delay time $t_{d(off)}$** is defined as the time interval between the moment when the gate-emitter voltage V_{GE} has declined to 90 % of its initial value (V_{GG}), and the drain-source voltage has risen to 10 % of the supply voltage V_{DD}.

Fall time t_f
The **fall time t_f** is defined as the time interval following the turn-off delay time, where the drain-source voltage rises from 10 % to 90 % of its end value V_{DD}. During this time, the drain current will fall accordingly (therefore “fall time”), i.e. most of the turn-off losses are generated here.

The sum of **turn-off delay time $t_{d(off)}$** and **fall time t_f** is called **turn-off time t_{off}**.
As the drain current I_D will not have dropped to cut-off current level at the defined end of t_{off}, but still amounts to 10 % of its forward on-state value, there will still be higher losses after t_{off} than the blocking losses.

Internal thermal resistance junction to case R_{thjc} per MOSFET
The thermal resistance R_{thjc} describes the passage of heat between the MOSFET chips (index j) and the module case (index c). It characterizes the static heat dissipation of a MOSFET system within a module (mostly consisting of paralleled chips) and depends on chip size and module assembly.
The temperature difference ΔT_{jc} between chip temperature T_j and case temperature T_{case} at a constant power dissipation P is defined as follows: $\Delta T_{jc} = T_j - T_{case} = P * R_{thjc}$.

Contact thermal resistance case to heatsink R_{thch} per MOSFET module
The thermal resistance R_{thch} describes the passage of heat between the module case (index c) and the heatsink (index h). It characterizes the static heat dissipation of a MOSFET module (possibly with several MOSFET switches) and depends on module size, heatsink and case surfaces, thickness and parameters of thermal layers (pastes, foils, print covers) between module and heatsink as well as on the mounting torque of the fixing screws.
The temperature difference ΔT_{ch} between case temperature T_c and heatsink temperature T_h at a constant total amount of single power dissipations P_n within the module is defined as follows: $\Delta T_{ch} = T_{case} - T_h = P_n * R_{thch}$.

Separate determination of R_{thjc} and R_{thch} is not possible for modules without base plate (e.g. SEMITOP, SKiiPPACK, MiniSKiiP). For these module, R_{thjh} is indicated per MOSFET and per module. The temperature differences may be calculated in analogy.

Mechanical data

Apart from the **case construction type,** the following mechanical data are usually indicated in the datasheets:

Mounting torque M_1 of the fixing screws (minimum and maximum value) in Nm or lb.in.;
Mounting torque M_2 of the output terminals (minimum and maximum value) in Nm or lb. in.;
Weight w of the module in g;
Permissible **acceleration under vibration a** in $m*s^{-2}$.

Free-wheeling diodes/ inverse diodes

Inverse diode forward voltage (negative source-drain voltage) V_{SD}, V_F

Negative source-drain voltage drop with gate-source short-circuited (V_{GS} = 0). V_{SD} describes the forward characteristics of the parasitic inverse diodes of the MOSFETs or the hybrid free-wheeling diodes, which are antiparallel to the MOSFETs.
Parameters: forward current I_F; case temperature T_{case} = 25°C

Threshold voltage of the inverse diode $V_{(T0)}$
Forward slope resistance of the inverse diode r_T

With the help of threshold voltage and forward slope resistance a simplified approximation of the forward characteristic may be produced. The threshold voltage indicates the point of crossover with the voltage axis, the forward slope resistance determines the rate of rise of the characteristic.

Reverse recovery time of the inverse diode t_{rr}

Reverse recovery time of the internal or hybrid MOSFET inverse diode during free-wheeling operation, i.e. when a high drain current $-I_D = I_F$ is commutated with a high di_F/dt and a high reverse voltage $V_R = V_{DD}$.
Note: t_{rr} depends very strongly on the temperature (almost doubled value between 25°C and

Parameters: forward current I_F; reverse voltage V_R, rate of fall of forward current $-di_F/dt$, chip temperature T_j = 25°C und 150°C.

Recovered charge of inverse diode Q_{rr}

Recovered charge of internal or hybrid MOSFET inverse diode during free-wheeling operation, i.e. when a high drain current $-I_D = I_F$ is commutated with a high di_F/dt and a high reverse voltage $V_R = V_{DD}$.
Note: Q_{rr} depends very strongly on the temperature (initial value may be doubled or even increased eight-fold between 25°C and 150°C).
Parameters: forward current I_F; reverse voltage V_R, rate of fall of forward current $-di_F/dt$, chip temperature T_j = 25°C and 150°C.