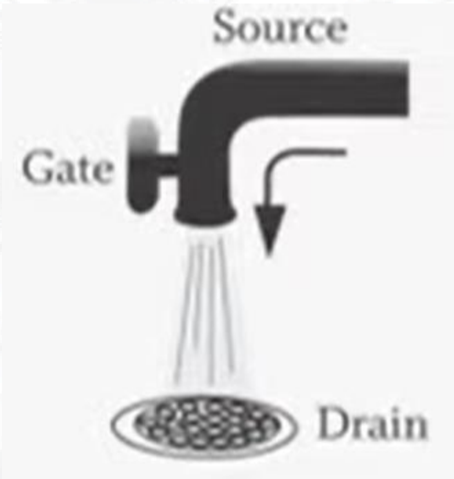
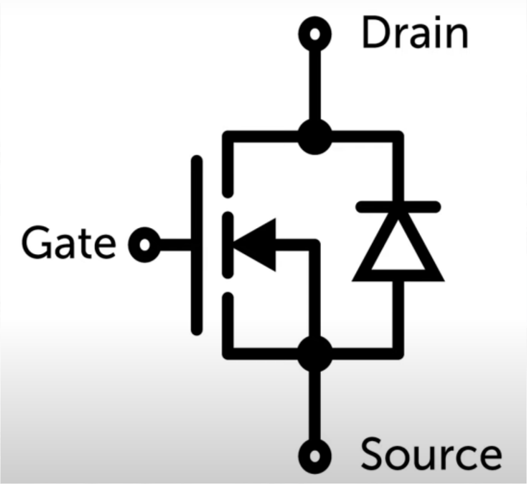
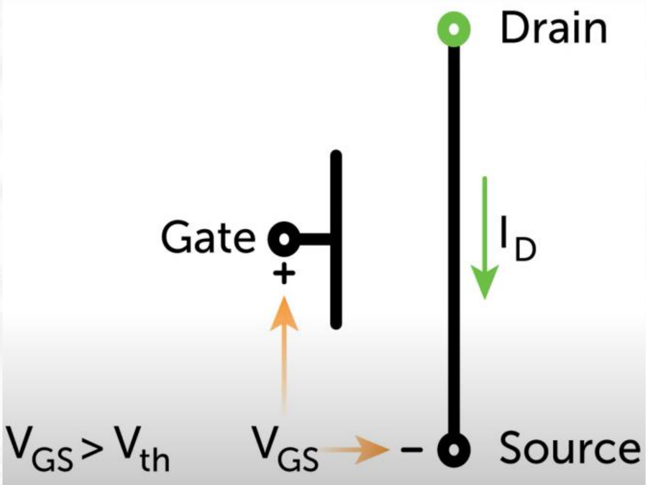
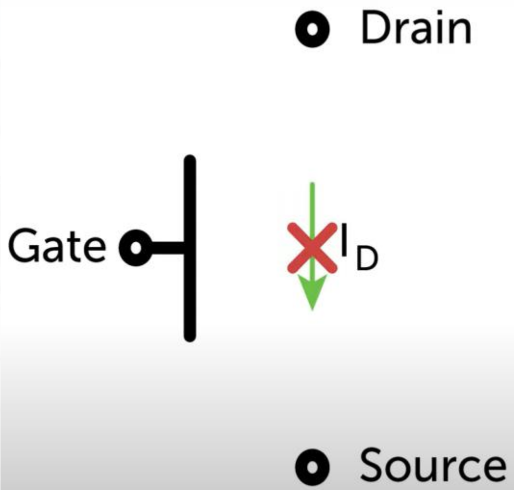
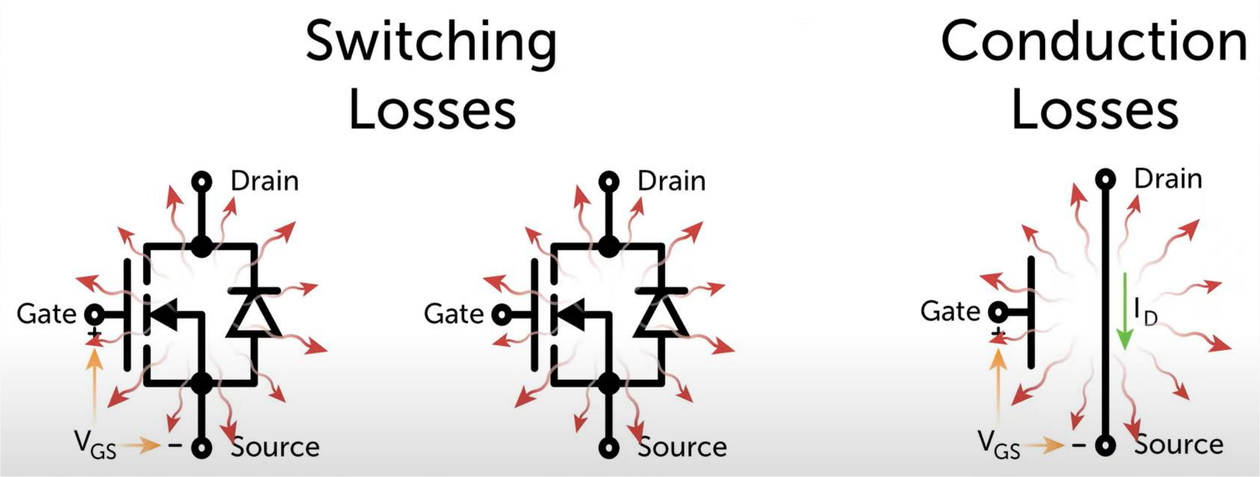
Function of a MOSFET





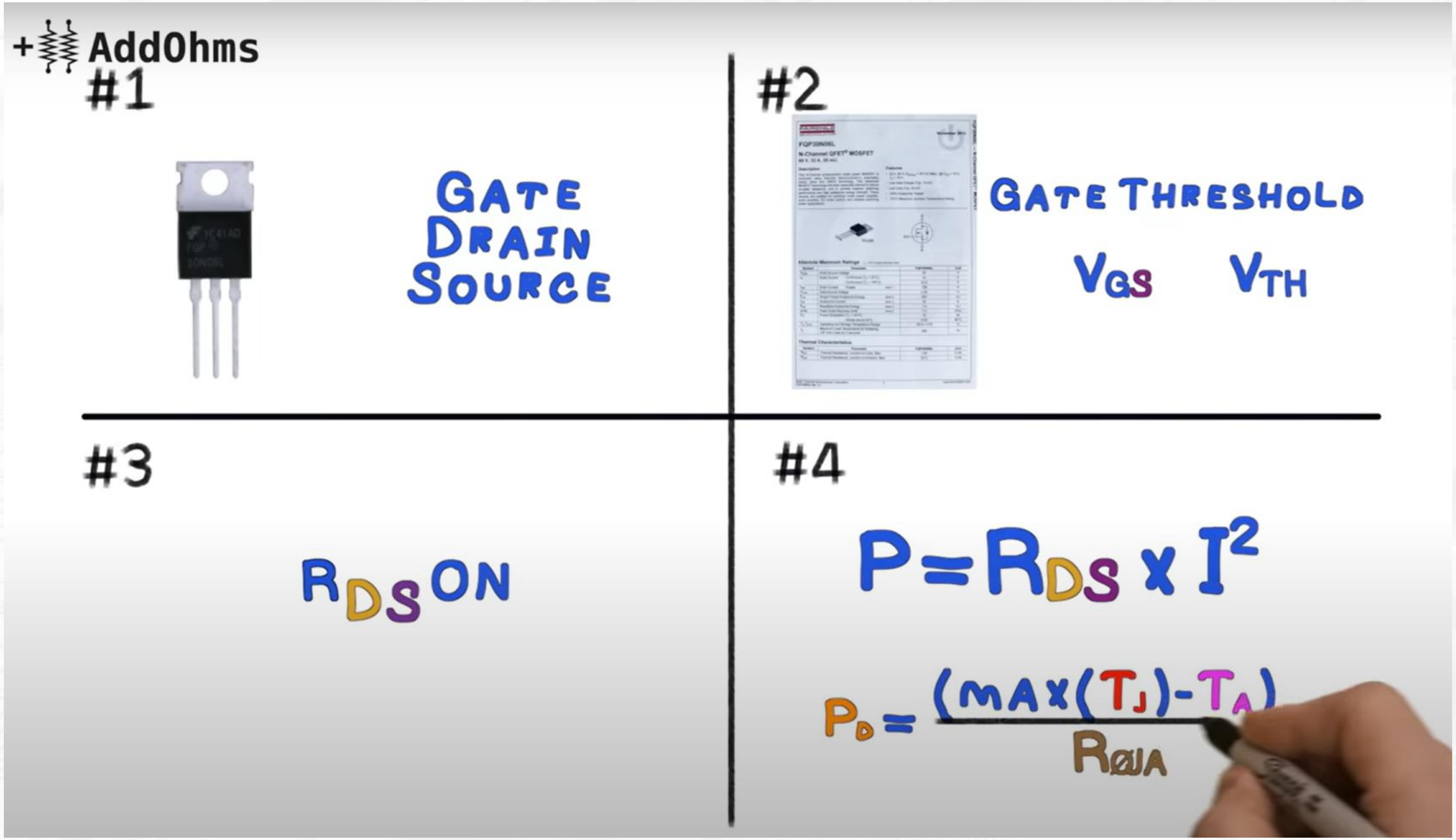






Source: https://www.youtube.com/watch?v=qkrgrBvgGpU https://www.youtube.com/watch?v=KSOHwVoxpzg

Most important MOSFET parameters



Source: https://www.youtube.com/watch?v=GrvvkYTW_0k

Understanding the datasheet of MOSFET

- What customer used MOSFET for?
  - As a switch

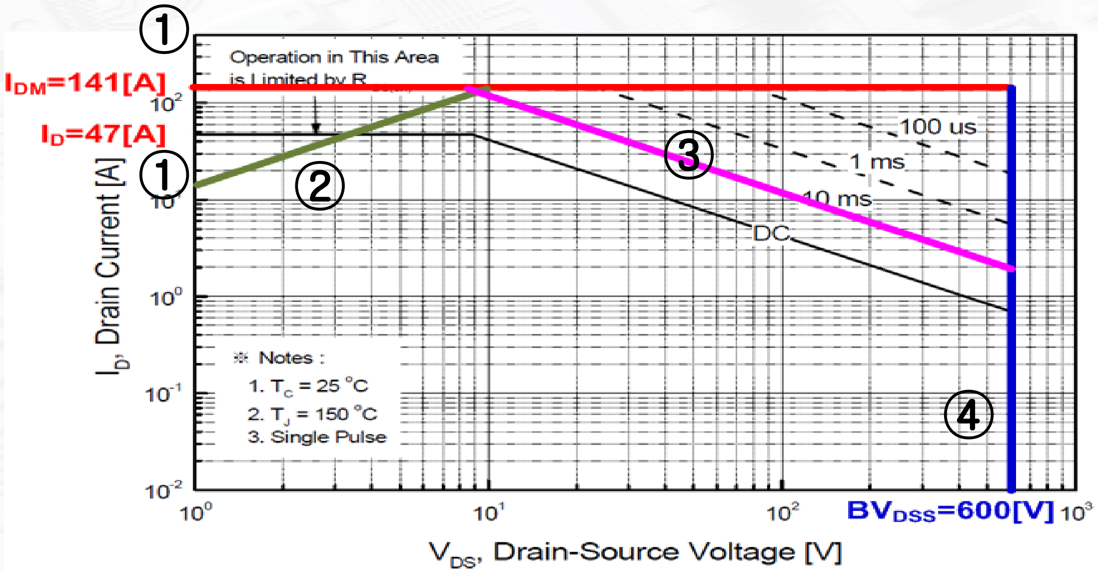
- What customer care when they use MOSFET?
  - Safety
    - Absolute Maximum Ratings
    - SOA
    - EAS (single pulse avalanche energy)
  - V_{DS}
    - N-CHANNEL
    - P-CHANNEL
  - Efficiency
    - Conduction loss
    - Switching loss

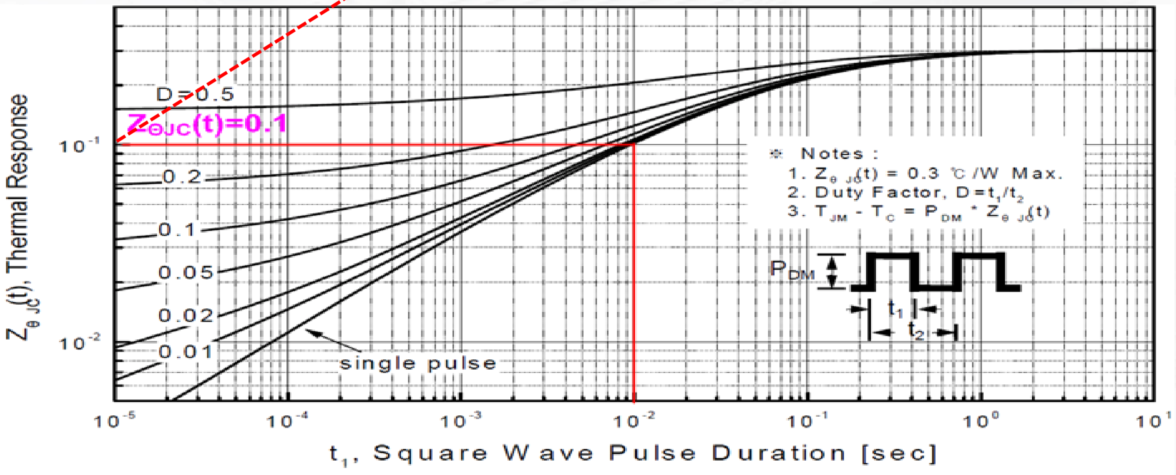
Understanding the datasheet of MOSFET

- SOA
  - Safe operating area.
  - Make sure Application is inside SOA
- Four boundaries for the SOA :
  - ① The maximum operational current : I_D, I_{DM} (current limit)
  - ② The on-resistance : $R_{DS(on)}$
  - ③ The boundary where both voltage and current become simultaneously large : Power Dissipation limit, P_D
  - ④ The maximum operational voltage : $BV_{DSS\ max}$

Rthjc=0.3ºC/W

Zthjc(10ms)=0.1ºC/W





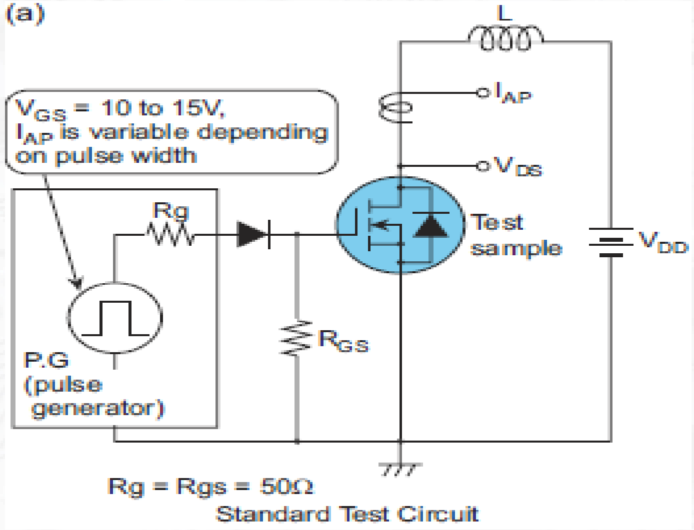
Understanding the datasheet of MOSFET

Absolute Maximum Ratings@T_j=25°C(unless otherwise specified)

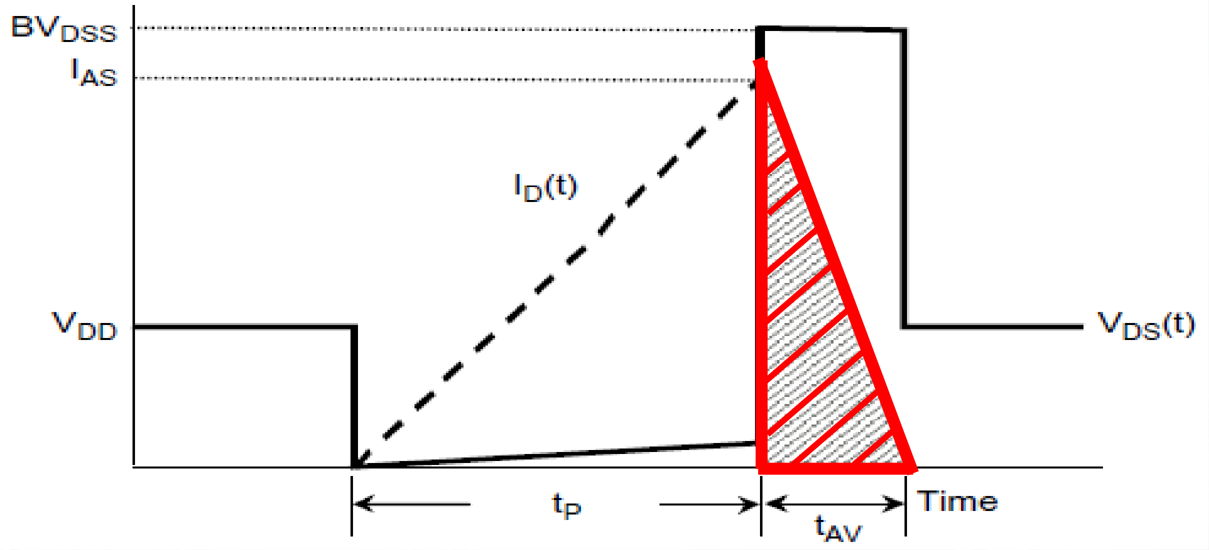
Symbol	Parameter	Rating	Units
E_{AS}	Single Pulse Avalanche Energy[5]	147	mJ
dv/dt	Peak Diode Recovery dv/dt[6]	15	V/ns
T_{STG}	Storage Temperature Range	-55 to 150	℃
T_J	Operating Junction Temperature Range	-55 to 150	℃

- Spike Voltage(L*di/dt) > BVDSS,
  - MOSFET break down
  - triangle area is the EAS.
  - Energy over EAS will damage MOSFET
- Die size ↑, EAS ↑

$$E_{AS} = \frac{1}{2} L_L I_{AS}^2 \frac{BV_{DSS}}{BV_{DSS} - V_{DD}}$$



Standard Test Circuit



Understanding the datasheet of MOSFET

Absolute Maximum Ratings

I_D@T_C=25℃	Drain Current, V_{GS} @ 10V[3,4]	13.5	A
I_D@T_C=100℃	Drain Current, V_{GS} @ 10V[3,4]	8.5	A
I_{DM}	Pulsed Drain Current[1]	39	A
dv/dt	MOSFET dv/dt Ruggedness (V_{DS} = 0 …400V)	50	V/ns
P_D@T_C=25℃	Total Power Dissipation	32	W
P_D@T_A=25℃	Total Power Dissipation	1.92	W
E_{AS}	Single Pulse Avalanche Energy[5]	147	mJ
dv/dt	Peak Diode Recovery dv/dt[6]	15	V/ns
T_{STG}	Storage Temperature Range	-55 to 150	℃
T_J	Operating Junction Temperature Range	-55 to 150	℃

Thermal Data

Symbol	Parameter	Value	Units
Rthj-c	Maximum Thermal Resistance, Junction-case	3.9	℃/W
Rthj-a	Maximum Thermal Resistance, Junction-ambient	65	℃/W

✓ $$P_D(T_C) = I_D{}^2(T_C) \cdot R_{DS(on)\_MAX} = \frac{T_{JMAX} - T_C}{R_{\theta JC}}$$

✓ $$P_D(T_A) = I_D{}^2(T_A) \cdot R_{DS(on)\_MAX} = \frac{T_{JMAX} - T_A}{R_{\theta JA}}$$

Understanding the datasheet of MOSFET

Electrical Characteristics

Electrical Characteristics@T_j=25°C(unless otherwise specified)

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Units
BV_{DSS}	Drain-Source Breakdown Voltage	V_{GS}=0V, I_D=250uA	600	-	-	V
$R_{DS(ON)}$	Static Drain-Source On-Resistance[2]	V_{GS}=10V, I_D=5.2A	-	-	0.28	Ω
$V_{GS(th)}$	Gate Threshold Voltage	V_{DS}=V_{GS}, I_D=250uA	2	-	5	V
g_{fs}	Forward Transconductance	V_{DS}=10V, I_D=5A	-	10	-	S
I_{DSS}	Drain-Source Leakage Current	V_{DS}=480V, V_{GS}=0V	-	-	100	uA
I_{GSS}	Gate-Source Leakage	V_{GS}=±20V, V_{DS}=0V	-	-	±100	nA
Q_g	Total Gate Charge	I_D=5A	-	36	57.6	nC
Q_{gs}	Gate-Source Charge	V_{DS}=480V	-	9	-	nC
Q_{gd}	Gate-Drain ("Miller") Charge	V_{GS}=10V	-	16	-	nC
$t_{d(on)}$	Turn-on Delay Time	V_{DD}=300V	-	14	-	ns
t_r	Rise Time	I_D=5A	-	11	-	ns
$t_{d(off)}$	Turn-off Delay Time	R_G=3.3Ω	-	38	-	ns
t_f	Fall Time	V_{GS}=10V	-	9	-	ns
C_{iss}	Input Capacitance	V_{GS}=0V	-	1300	2080	pF
C_{oss}	Output Capacitance	V_{DS}=100V	-	50	-	pF
C_{rss}	Reverse Transfer Capacitance	f=1.0MHz	-	5	-	pF
R_g	Gate Resistance	f=1.0MHz	-	3.8	7.6	Ω

DC characteristics
Static characteristics

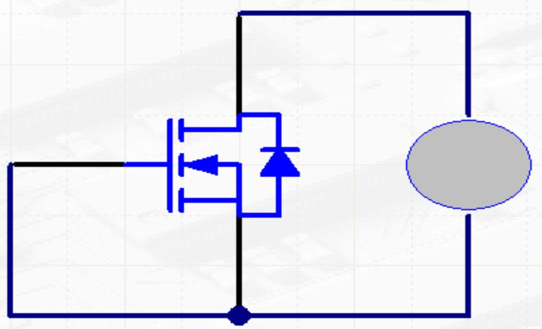
AC characteristics
Dynamic characteristics

Understanding the datasheet of MOSFET

Electrical Characteristics – BV_{DSS}, ($\Delta BV_{DSS} / \Delta T_J$)

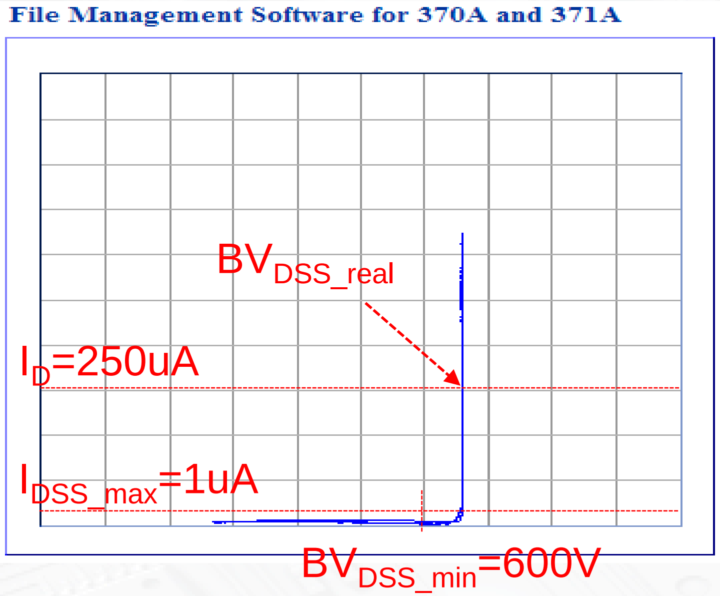
Off Characteristics

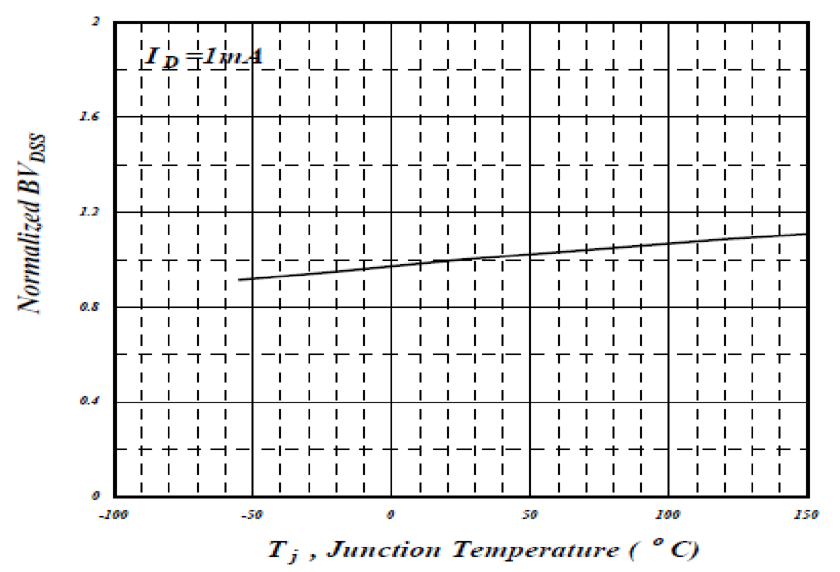
Off Characteristics						
BV_{DSS}	Drain-Source Breakdown Voltage	V_{GS} = 0V, I_D = 250μA, T_J = 25°C	600	--	--	V
		V_{GS} = 0V, I_D = 250μA, T_J = 150°C	--	650	--	V
ΔBV_{DSS} / ΔT_J	Breakdown Voltage Temperature Coefficient	I_D = 250μA, Referenced to 25°C	--	0.6	--	V/°C
BV_{DS}	Drain-Source Avalanche Breakdown Voltage	V_{GS} = 0V, I_D = 47A	--	700	--	V
I_{DSS}	Zero Gate Voltage Drain Current	V_{DS} = 600V, V_{GS} = 0V V_{DS} = 480V, T_C = 125°C	-- --	-- --	1 10	μA μA
I_{GSSF}	Gate-Body Leakage Current, Forward	V_{GS} = 30V, V_{DS} = 0V	--	--	100	nA
I_{GSSR}	Gate-Body Leakage Current, Reverse	V_{GS} = -30V, V_{DS} = 0V	--	--	-100	nA



BV_{DSS} / ($\Delta BV_{DSS} / \Delta T_J$)

- BVDSS is Positive Temperature Coefficient.
  - Temperature ↑, BVDSS ↑



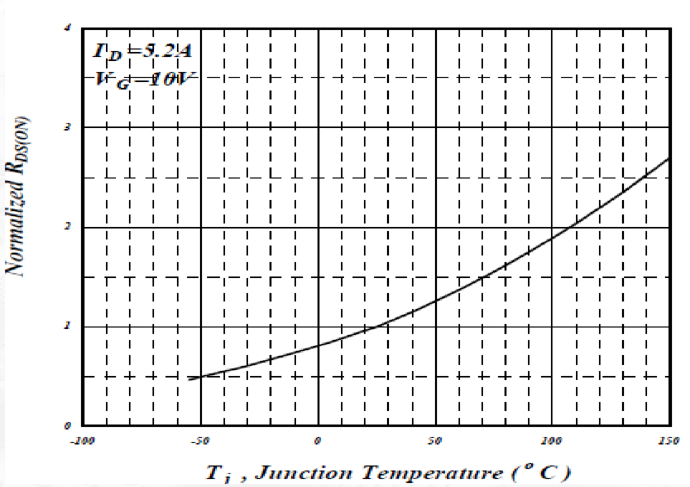


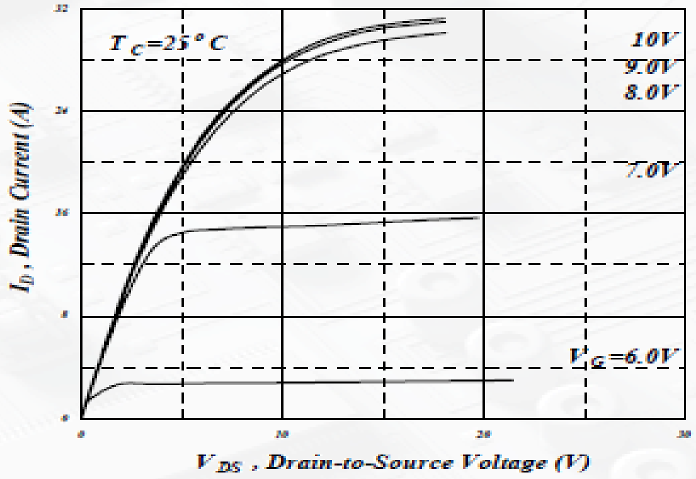
Understanding the datasheet of MOSFET

DC Electrical Characteristics

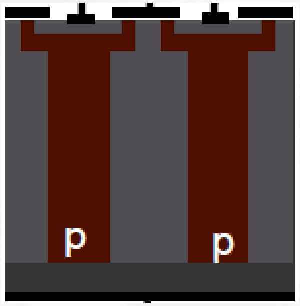
On Characteristics

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Units
BV_{DSS}	Drain-Source Breakdown Voltage	V_{GS}=0V, I_D=250uA	600	-	-	V
$R_{DS(ON)}$	Static Drain-Source On-Resistance[2]	V_{GS}=10V, I_D=5.2A	-	-	0.28	Ω





Deep Trench



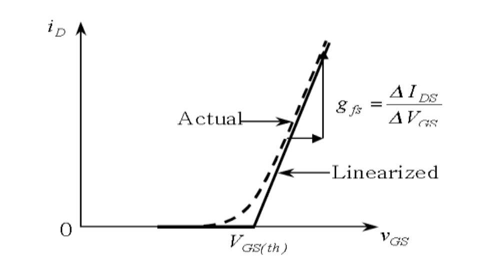
- RDS(ON) is Positive Temperature Coefficient.
  - Temperature ↑,RDS(ON) ↑

Understanding the datasheet of MOSFET

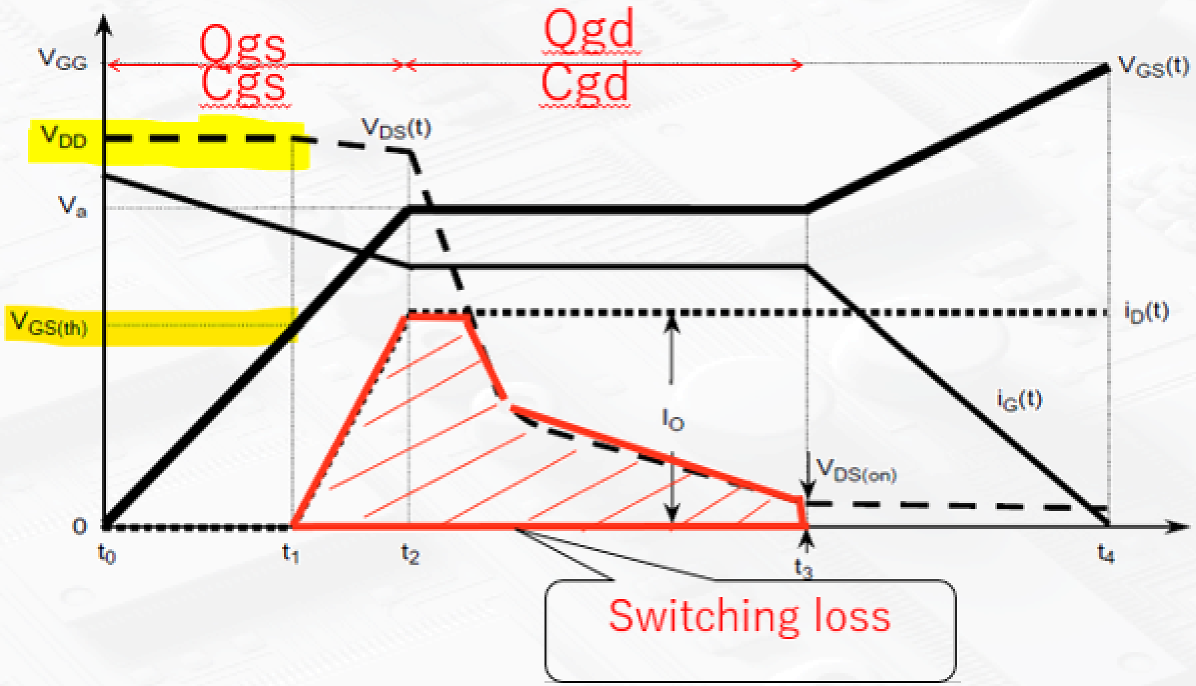
DC Electrical Characteristics

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Units	
$V_{GS(th)}$	Gate Threshold Voltage	$V_{DS}=V_{GS}$, $I_D=250uA$	2	-	5	V	1
g_{fs}	Forward Transconductance	$V_{DS}=10V$, $I_D=5A$	-	10	-	S	2
I_{DSS}	Drain-Source Leakage Current	$V_{DS}=480V$, $V_{GS}=0V$	-	-	100	uA	3
I_{GSS}	Gate-Source Leakage	$V_{GS}=\pm 20V$, $V_{DS}=0V$	-	-	$\pm$100	nA	

- VGS =VGS(TH)
  - MOSFET begins to turn on.
- VGS(TH) is NTC (negative temperature coefficient).
  - Temperature ↑ VGS(TH) ↓ .
  - The value is related to Maximum VGS rating.
- VGS ratings
  - ±8V Ultra Low Gate Drive
  - ±12V Low Gate Drive
  - ±20V Normal Gate Drive。
- gfs
  - High gfs is good in High Frequency Switching application.



$$gfs = \frac{\Delta I_D}{\Delta V_{GS}}$$

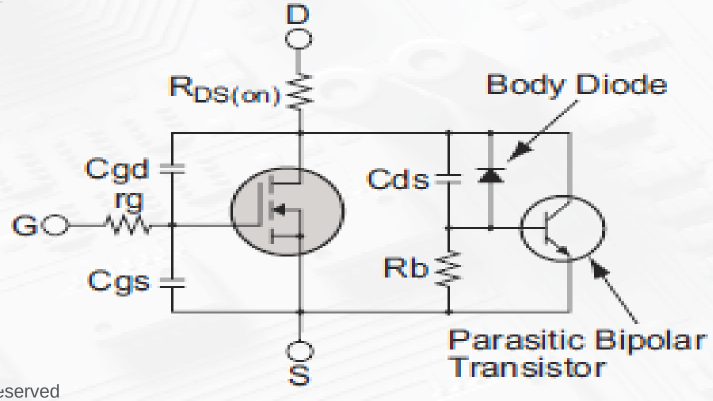


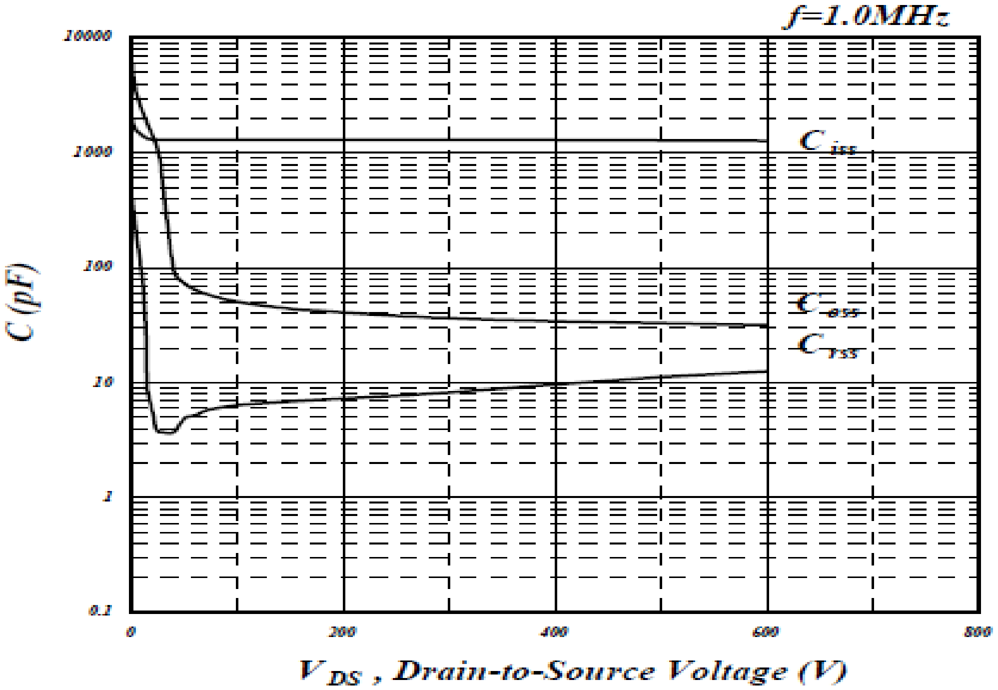
Understanding the datasheet of MOSFET

AC Electrical Characteristics

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Units	
C_{iss}	Input Capacitance	V_{GS}=0V	-	1300	2080	pF	
C_{oss}	Output Capacitance	V_{DS}=100V	-	50	-	pF	1
C_{rss}	Reverse Transfer Capacitance	f=1.0MHz	-	5	-	pF	
R_g	Gate Resistance	f=1.0MHz	-	3.8	7.6	Ω	2

- Equivalent circuit capacitances are as below
  - $C_{iss} = C_{gs} + C_{gd}$
  - $C_{oss} = C_{gd} + C_{ds}$
  - $C_{rss} = C_{gd}$ (Miller CAPacitance)
  - The value is not related to temperature
- Rg (Gate Resistance)
  - affect MOSFET turn on/turn off speed



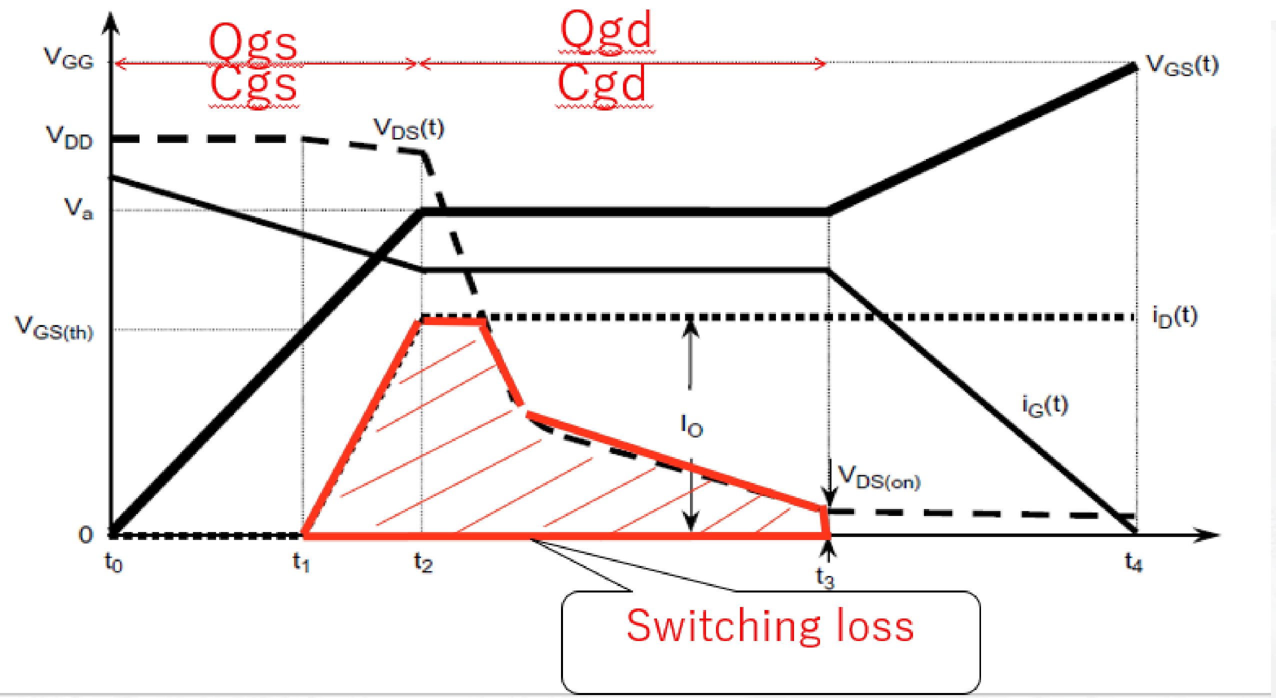


Understanding the datasheet of MOSFET

Electrical Characteristics

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Units
Q_g	Total Gate Charge	I_D=5A	-	36	57.6	nC
Q_{gs}	Gate-Source Charge	V_{DS}=480V	-	9	-	nC
Q_{gd}	Gate-Drain ("Miller") Charge	V_{GS}=10V	-	16	-	nC

Qgs: the amount of charge during t0~t2 (charge Cgs)
Qgd: the amount of charge during t2~t3 (charge Cgd)
It effected by Rg and parasitic cap.



Understanding the datasheet of MOSFET

Electrical Characteristics

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Units
$t_{d(on)}$	Turn-on Delay Time	V_{DD}=300V	-	14	-	ns
t_r	Rise Time	I_D=5A	-	11	-	ns
$t_{d(off)}$	Turn-off Delay Time	R_G=3.3Ω	-	38	-	ns
t_f	Fall Time	V_{GS}=10V	-	9	-	ns

- td(on): 10% VGS → 90% VDS. Turn on Mosfet.
- td(off): 90% VGS → 10% VDS. Turn off Mosfet
- tr: 90% VDS → 10% VDS. It affected by Rg and Crss the most.
- tf: 10% VDS → 90% VDS. It affected by Rg and Crss the most.