4.1

MOSFET

Metal Oxide Semi-conducter Field Effect Transistor (Mosfet) is a voltage controlled power switch. It has three leg as Gate (G), Drain (D) and Source (S).

As depicted picture, Although Drain and Sourced are directedly connected with n-type region to constitue a channel for current flow, Gate leg is isolated with SiO_2 and SiN. This isolation layer is thin, so Mosfet is highly susceptible to static electric. It requires a special attention to touch it. Also Its breakdown voltage is lower to the ones with conventional transistors. For this reason Mosfets must be protected at high security level.

Parasitic Capacitances

Since Mosfet comprises some layers, the parasitic capacitances are present among the legs.

C_{iss}, Input capacitance = $C_{gd} + C_{gs}$

C_{oss}, Output capacitance = $C_{ds} + C_{gd}$

C_{rss}, Reverse transfer capacitance = C_{gd}.

These capacitances are not included in mathematical model of mosfet but they have a substantial impact over its switching characteristic.

Ciss is charged from gate for turn-on state. The time duration for charging and discharging is dependent on its size. If C_{oss} is large, a current arising due to C_{oss} starts to flow even if Mosfet is turned off. So it is needed extra time for the output to turn off completely. If C_{rss} is large, the rise and fall of i_D, drain current are delayed during turn on/off states. The parasitic capacitances are highly important for the switching speed and frequency as a component of dynamic characteristic.

Turn on/off conditions

$V_{GS(th)}$ theshold voltage is the voltage between the gate and source legs. V_{GS} voltage must be as high as $V_{GS(th)}$ at least to turn on. V_{GSth} value is affected from temprature value shown in figure. Also i_D, drain source value changes depending on $V_{GS(th)}$.

Turn-on state starts to supply voltage V_{GS}. If V_{GS} is under $V_{GS(th)}$, i_D will be zero. The parasitic capacitances are charged with this voltage. After reaching $V_{GS(th)}$, i_D drain current starts to flow with lower V_{DS}, drain and source voltage. If V_{DS} is increased, channel structure at source side is distorted by narrowing and so i_D rise reduces and this region is called as active (saturation) region.

MOSFET

$t_{ON} = t_{d(on)} + t_r$

$t_{d\,ON}$ = The time taken for the gate source voltage rises over 10% of V_{GS} until the drain-source voltage reaches 90% of V_{DS}

t_r = Rise time: The time taken for the drain-source to fall from 90% to 10% of V_{DS}.

$t_{off} = t_{d(off)} + t_f$

$t_{d(off)}$ = The time from when the gate-source voltage drops below 90% V_{GS} until the drain-source voltage reaches 10% of V_{DS}

t_f = Fall time. Time the taken for the drain-source voltage to rise from 10% to 90% of V_{DS}.

Turn-off state begins with removing V_{GS}. t_{off} value is lower than the one in BJT and t_{ON} value is shorter than the one in Thyristor. All in all, Mosfet is the fastest power switch. It presents the most suitable solutions for high frequency circuits.

4.4

Mosfet is a power switch having the highest conduction loss and the lowest switching loss among other power switches.

Major drawbacks of Mosfet are higher $R_{DS_{ON}}$ resistance, susceptible Gate leg, lower breakdown voltage. For this reason, it must be protected firmly. It is a unipolar device

INSULATED GATE BIPOLAR TRANSISTOR (IGBT)

IGBT is a three leg (terminal) power switch having high input impedance like Mosfet and low on state power loss as in BJT. In other words, IGBT is a combined form of best qualities of BJT and mosfet. The control side from mosfet but current capacity is originated from BJT.

Its internal resistance is small. So the conduction losses are low. IGBT is made of four layers of semiconducter to form PNPN structure. IGBT is a voltage controlled device requiring a small voltage at its gate to control I_C collector-emitter current. But V_{GE} gate-emitter voltage must be grater than V_{GET} gate-emitter threshold voltage like mosfet.

TURN on/off States of IGBT

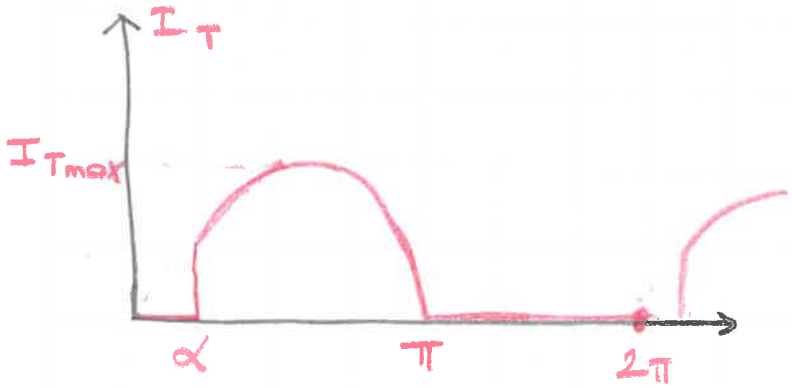
As depicted figure, when V_{GE} is zero, there is no I_c current flow and power switch remains off-state. If V_{GE} is slighly increased but below threshold, there will be a small leakage current. When the V_{GE} exceeds the threshold limit, I_c start to flow and the device is on-state anymore. Since it is a unidirectional device, the current only flows in one direction.

When the V_{GE} is greater than V_{GET}, the IGBT operates in the active region. As the V_{GE} increases I_c increases as well.

The collector emitter voltage V_{CE} decreases for a given load resistance R_L. For a spesific I_c current, when V_{CE} is lower than V_{GE}, this region is called as saturation region.

IGBT has higher voltage and current handling capacities like 3300 V and 1200 A. It has very low on-state resistance. It means that the conduction loss is lower. But the switching loss is a bit higher than mosfet and also it is slightly expensive from BJT and mosfet. It is unidirectional so, it can not conduct in reverse direction.

4.6



A tyristor is supplied wit the current shown in the picture. The temperature of the ambient is 40°C.

a) While α, triggering angle is 30°, the temperature of Junction is known as 104 °C. Find the max value of current?

b) If 50 A dc current is supplied to thyristor, find the junction temprature?

c) What is the max dc current value to be supplied.

$U_{TT} = 1.2\ V$ (anod - cathode threshold voltage)
$r_T = 10\ m\Omega$ (internal tyristor resistance)
$R_{Thjc} = 0.20\ °C/W$
$R_{ThCA} = 0.20\ °C/W$
Operation temprature −55 °C and 125 °C

a) $\alpha = 30°$

$$I_{TAV} = \frac{1}{2\pi}\int_{\alpha}^{\pi} I_m \cdot \operatorname{Sin} t \cdot dt = \frac{I_m}{2\pi}(1+\operatorname{Cos}\alpha)$$

$$I_{Trms}^2 = \frac{1}{2\pi} \cdot \int_{\alpha}^{\pi} I_m^2 \cdot \operatorname{Sin}^2 t \cdot dt = \frac{I_m^2}{4\pi}\left(\pi - \alpha + \frac{1}{2}\operatorname{Sin}2\alpha\right.$$

$$\underset{\text{total loss}}{P} = U_{TT} \cdot I_{TAV} + r_T \cdot I_{Trms}^2$$ for tyristor

4.7

$$\theta_{vj} = \theta_A + P\,(R_{ThCA} + R_{Thjc}) \Rightarrow$$

$$104 = 40 + P \cdot (0{,}2 + 0{,}2) \Rightarrow \quad P = 160\ W$$

$$160 = U_{TT} \cdot \frac{I_m}{2\pi}\,(1 + \cos 30^\circ) + r_T \cdot \frac{I_m^2}{4\pi}\,\left(\pi - 30 + \frac{1}{2}\sin 2 \cdot 30^\circ\right.$$

$$I_{max_1} = 193\ A \qquad I_{max_2} = -340\ A$$

$$I_{max} = 193\ A$$

b) for 50A dc.

$$P = U_{TT} \cdot 50 + r_T \cdot 50^2 = 85\ W.$$

$$\theta_{vj} = \theta_A + P\,(R_{ThCA} + R_{Thjc})$$

$$= 40 + 85\,(0{,}2 + 0{,}2) = 74\ ^\circ C$$

c) Max operation tempreture is 125°

$$125^\circ = P_{max} \cdot (0{,}2 + 0{,}2) + 40$$

$$P_{max} = 212.5\ W.$$

$$212.5 = U_{TT} \cdot I_m + r_T \cdot I_m^2$$

$$I_{max_1} = 97.5\ A$$

$$I_{max\,2} = -217.5\ A.$$

$$I_m = 97.5\ A$$

$t_q \leq t_N = 20\ \mu s$

$\swarrow$ t_{off} $\searrow$ time for negative voltage supplied

$(dV/dt)_{critic} > \frac{3000-0}{50-20}\ \mu s$

$// \quad > 100\ V/\mu s$

$V_{BO} > 3000\ V.$

2. a) For a diode, threshold voltage is 0.6 V. conductance resistor is 10 mΩ. A continuous current is supplied to this diode as 40 A. Find the voltage drop and power loss for the diode?

b) A diode is used to conduct the positive half wave of sinusoidal current with 100π A. Find the average and rms value of current for this diode?

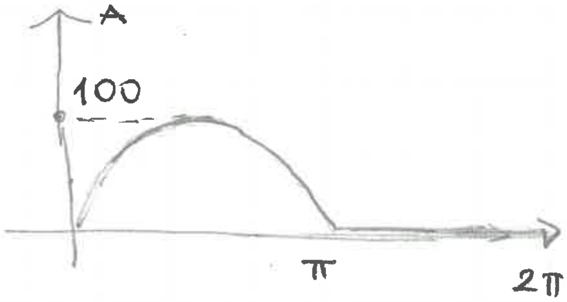
a) $V_F = V_{FT} + r_F \cdot i_F$

$= 0.6 \quad 10 \cdot 10^{-3} \cdot 40 = 1\ V$

$P = V_F \cdot i_F = 1 \cdot 40 = 40\ W$

b) $I_{TAV} = \frac{1}{2\pi} \int_0^{\pi} I_m \cdot \sin(\omega t) \cdot d(\omega t)$

$= \frac{1}{2\pi} \cdot I_m \cdot -\cos \omega t \Big|_0^{\pi} = \frac{1}{\pi} \cdot I_m$



$I_{rms} = \sqrt{\frac{1}{2\pi} \cdot \int_0^{\pi} I_m^2 \cdot \sin^2(\omega t)}$