Power MOSFETs Selection (CSD18540Q5B)

In [ ]:
```
from engineering_notation import EngNumber
import numpy as np
import json
```

Setup Parameters:

In [ ]:
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#Transistor Data:
L = 15e-6
L_dcr = 33e-3

#EVM
#L = 10e-6
#L_dcr = 12e-3

Tamb = 25   #[°C] - Ambient Temperature
V_in = 20   #[V] - Input Voltage
V_out = 40  #[V] - Output Voltage
I_out = 2   #[A] - Output Current
Fs = 250e3  #[Hz] - Switching Frequency
D = 1-V_in/V_out #[-] - Duty Cycle
I_in = I_out / (1 - D) #[A] - Input Current
IL_DC = I_in    #[A] - Mean Inductor Current
I_ripple = (D*V_in)/(Fs*L)  #[A] - Ripple Inductor Current
V_REGN = 5 # [v] - Reg Voltage to power up the FETs

rac_sns = 5e-3  #[ohm] - Serial Resistor to measure the Input Current
rbat_sns = 5e-3 #[ohm] - Serial Resistor to measure the Battery Current
Esr_cap = 1/((5/16.9e-3)+(2/306e-3)) #[Ohm] - Asociated ESR from the capaci
RDS_on_charge_fet = 3.3e-3  #[ohm] - RDS from charge FET (used by BMS)
RDS_on_dischg_fet = 3.3e-3  #[ohm] - RDS from discharge FET (used by BMS)
RDS_on_bypass_fet = 3.3e-3  #[ohm] - RDS from pass transistor from the buck

#List of transistors:
#CSD18540Q5B 3.45W current desing mosfets
#SQJA84EP EVM alternative
#SiR680LDP EVM second alternative
#CSD18532NQ5B
#CSD18532Q5B
#CSD19502Q5B
#CSD19532Q5B
#CSD19534Q5A
#CSD19533Q5A
#CSD19531Q5A
#CSD18563Q5A
#CSD18537NQ5A
#CSD18534Q5A
#CSD18533Q5A
#CSD18531Q5A

with open('mosfets_parameters.json', 'r') as file:
    data = json.load(file)

selected_PN = "CSD18540Q5B"

Q_Gd = data["MOSFETS"][selected_PN]["Q_Gd"] #[nC] - Gate charge gate-to-dra
Q_Gs = data["MOSFETS"][selected_PN]["Q_Gs"] #[nC] - Gate charge gate-to-sou
Q_oss = data["MOSFETS"][selected_PN]["Q_oss"] #[nC] - Output charge
Q_Gate_top = data["MOSFETS"][selected_PN]["Q_Gate_top"] #[nC] - Gate charge
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Q_Gate_bottom = data["MOSFETS"][selected_PN]["Q_Gate_bottom"] #[nC] - Gate
Q_rr = data["MOSFETS"][selected_PN]["Q_rr"] #[nC] - Reverse recovery charge
V_plt = data["MOSFETS"][selected_PN]["V_plt"] #[V] - Threshold Voltage
R_on = data["MOSFETS"][selected_PN]["R_on"] #[Ohm] - Turn On resistance fro
R_off = data["MOSFETS"][selected_PN]["R_off"] #[Ohm] - Turn Off resistance
RDS_on_top = data["MOSFETS"][selected_PN]["RDS_on_top"] #[mOhm] - Drain-to-
RDS_on_bottom = data["MOSFETS"][selected_PN]["RDS_on_bottom"] #[mOhm] - Dra
t_dead_rise = data["MOSFETS"][selected_PN]["t_dead_rise"] #[nS] - Specified
t_dead_fall = data["MOSFETS"][selected_PN]["t_dead_fall"] #[nS] - Specified
Gfs = data["MOSFETS"][selected_PN]["Gfs"] #[S] - Transconductance
VF =  data["MOSFETS"][selected_PN]["VF"] #[V] - Diode forward voltage
Rja = data["MOSFETS"][selected_PN]["RJA"] #[W/°C] - Junction-to-ambient the
Rjc = data["MOSFETS"][selected_PN]["RJC"] #[W/°C] - Junction-to-case therma


print("Switching Transistor Parameters:")
print(f"-Selected Part Number: {selected_PN}")
print(f"-Q_Gd: {EngNumber(Q_Gd)}C".format("%f"))
print(f"-Q_Gs: {EngNumber(Q_Gs)}C".format("%f"))
print(f"-Q_oss: {EngNumber(Q_oss)}C".format("%f"))
print(f"-Q_Gate_top: {EngNumber(Q_Gate_top)}C".format("%f"))
print(f"-Q_Gate_bottom: {EngNumber(Q_Gate_bottom)}C".format("%f"))
print(f"-Q_rr: {EngNumber(Q_rr)}C".format("%f"))
print(f"-V_plt: {EngNumber(V_plt)}V".format("%f"))
print(f"-R_on: {EngNumber(R_on)}Ohm".format("%f"))
print(f"-R_off: {EngNumber(R_off)}Ohm".format("%f"))
print(f"-RDS_on_top: {EngNumber(RDS_on_top)}Ohm".format("%f"))
print(f"-RDS_on_bottom: {EngNumber(RDS_on_bottom)}Ohm".format("%f"))
print(f"-t_dead_rise: {EngNumber(t_dead_rise)}Sec".format("%f"))
print(f"-t_dead_fall: {EngNumber(t_dead_fall)}Sec".format("%f"))
print(f"-Gfs: {EngNumber(Gfs)}S".format("%f"))
print(f"-VF: {EngNumber(VF)}V".format("%f"))
print(f"-Rja: {EngNumber(Rja)}W/°C".format("%f"))
print(f"-Rjc: {EngNumber(Rjc)}W/°C".format("%f"))

print("\nFunctional Parameters")
print(f"-Input Current {IL_DC}A".format("%f"))
print(f"-Duty Cicle: {D}".format("%f"))
print(f"-Inductor Ripple Current: {EngNumber(I_ripple)}A".format("%f"))
```

```
Switching Transistor Parameters:
-Selected Part Number: CSD18540Q5B
-Q_Gd: 6.70nC
-Q_Gs: 8.80nC
-Q_oss: 83nC
-Q_Gate_top: 26nC
-Q_Gate_bottom: 26nC
-Q_rr: 145nC
-V_plt: 1.90V
-R_on: 3.40Ohm
-R_off: 1Ohm
-RDS_on_top: 3.30mOhm
-RDS_on_bottom: 3.30mOhm
-t_dead_rise: 45nSec
-t_dead_fall: 45nSec
-Gfs: 116S
-VF: 1V
-Rja: 50W/°C
-Rjc: 800mW/°C

Functional Parameters
-Input Current 4.0A
-Duty Cicle: 0.5
-Inductor Ripple Current: 2.67A
```

Power Loss:

In [ ]:

```
# Power On Top
print("Power Loss On Top Mosfet:")

P_Gate_top = V_in*Q_Gate_top*Fs # (30)
print(f"Top MOSFET gate drive loss: {EngNumber(P_Gate_top)}W".format("%f"))

P_Qoss_top = 0.5*V_out*Q_oss*Fs # (29)
print(f"MOSFET parasitic output capacitance loss: {EngNumber(P_Qoss_top)}W"

I_on = (V_REGN-(V_plt+IL_DC/Gfs))/R_on # (28.1)
print(f"Turn-on gate driving current: {EngNumber(I_on)}A".format("%f"))

I_off = (V_plt+IL_DC/Gfs)/R_off # (28.2)
print(f"Turn-off gate driving current: {EngNumber(I_off)}A".format("%f"))

Q_sw=Q_Gd+Q_Gs # (27)
print(f"Switching Charge: {EngNumber(Q_sw)}C".format("%f"))

t_off = Q_sw/I_off # (26.1)
print(f"MOSFET turn-off time: {EngNumber(t_off)}S".format("%f"))

t_on = Q_sw/I_on # (26.2)
print(f"MOSFET turn-on time: {EngNumber(t_on)}S".format("%f"))

I_peak = IL_DC+0.5*I_ripple # (25)
print(f"Inductor current peak value: {EngNumber(I_peak)}A".format("%f"))

I_valley = IL_DC-0.5*I_ripple # (24)
print(f"Inductor current valley value: {EngNumber(I_valley)}A".format("%f")

P_IV_top = 0.5*V_out*I_valley*t_on*Fs+0.5*V_out*I_peak*t_off*Fs # (23)
print(f"Voltage and Current Overlap Power Losses: {EngNumber(P_IV_top)}W".f

IL_RMS = np.sqrt( IL_DC**2 + (I_ripple**2)/12) # (21)
print(f"Inductor IRMS: {EngNumber(IL_RMS)}A".format("%f"))

P_sw_top = P_IV_top + P_Qoss_top + P_Gate_top # (22)
print(f"Multiple switching loss items in top MOSFET: {EngNumber(P_sw_top)}W

P_con_top = D*(IL_RMS**2)*RDS_on_top # (20)
print(f"Conduction Power Loss: {EngNumber(P_con_top)}W".format("%f"))

P_top = P_con_top + P_sw_top # (19)
print(f"Power Loss @ Top = P_con_top + P_sw_top : {EngNumber(P_top)}W".form
```

```
Power Loss On Top Mosfet:
Top MOSFET gate drive loss: 130mW
MOSFET parasitic output capacitance loss: 415mW
Turn-on gate driving current: 901.62mA
Turn-off gate driving current: 1.93A
Switching Charge: 15.50nC
MOSFET turn-off time: 8.01nS
MOSFET turn-on time: 17.19nS
Inductor current peak value: 5.33A
Inductor current valley value: 2.67A
Voltage and Current Overlap Power Losses: 442.88mW
Inductor IRMS: 4.07A
Multiple switching loss items in top MOSFET: 987.88mW
Conduction Power Loss: 27.38mW
Power Loss @ Top = P_con_top + P_sw_top : 1.02W
```

In [ ]:
```
# Power On Bottom
print("Power Loss On Bottom Mosfet:")

P_Dead_bottom = VF * I_valley * Fs * t_dead_rise + VF * I_peak * Fs * t_dea
print(f"Dead time body diode conduction loss: {EngNumber(P_Dead_bottom)}W".

P_RR_bottom = V_out * Q_rr * Fs # (34)
print(f"Reverse recovery losses: {EngNumber(P_RR_bottom)}W".format("%f"))

P_Gate_bottom = V_in*Q_Gate_bottom*Fs # (Copy of 30)
print(f"Gate drive loss: {EngNumber(P_Gate_bottom)}W".format("%f"))

P_con_bottom = (1-D) *(IL_RMS**2)*(RDS_on_bottom) # (32)
print(f"Conduction loss: {EngNumber(P_con_bottom)}W".format("%f"))

P_sw_bottom = P_RR_bottom + P_Dead_bottom + P_Gate_bottom # (33)
print(f"Multiple switching loss items in bottom MOSFET: {EngNumber(P_sw_bot

P_bottom = P_con_bottom + P_sw_bottom # (31)
print(f"Power Loss @ Bottom = P_con_bottom + P_sw_bottom : {EngNumber(P_bot
```

```
Power Loss On Bottom Mosfet:
Dead time body diode conduction loss: 90mW
Reverse recovery losses: 1.45W
Gate drive loss: 130mW
Conduction loss: 27.38mW
Multiple switching loss items in bottom MOSFET: 1.67W
Power Loss @ Bottom = P_con_bottom + P_sw_bottom : 1.70W
```

In [ ]:
```
Power_switching_mosfet = P_bottom + P_top

Top_mosfet_junction_temperature = Tamb + P_top * Rja
Bottom_mosfet_junction_temperature = Tamb + P_bottom * Rja

print(f"Total Mosfets Power Loss : {EngNumber(Power_switching_mosfet)}W".fo
print(f"Top Mosfet Junction Temperature {Top_mosfet_junction_temperature}°C
print(f"Bottom Mosfet Junction Temperature {Bottom_mosfet_junction_temperat
```

```
Total Mosfets Power Loss : 2.71W
Top Mosfet Junction Temperature 75.76300991119426°C
Bottom Mosfet Junction Temperature 109.86888888888888°C
```

In [ ]:
```
#Passive Component Loss

P_iac_sns = 1
P_ibat_sns = 1
P_l_dcr = 1

P_l_dcr = L_dcr * IL_RMS**2
P_iac_sns = rac_sns * IL_DC**2
P_ibat_sns = rbat_sns * I_out**2
P_cout_loss = Esr_cap * (I_out*np.sqrt((V_out/V_in) -1 ))**2

print(f"Inductor Power Loss : {EngNumber(P_l_dcr)}W".format("%f"))
print(f"Rac Power Loss : {EngNumber(P_iac_sns)}W".format("%f"))
print(f"Rbat Power Loss : {EngNumber(P_ibat_sns)}W".format("%f"))
print(f"Output Capacitor Power Loss:  {EngNumber(P_cout_loss)}W".format("%f
```

```
Inductor Power Loss : 547.56mW
Rac Power Loss : 80mW
Rbat Power Loss : 20mW
Output Capacitor Power Loss:  13.23mW
```

In [ ]:
```
#Active Component Loss

P_charge_discharge = (RDS_on_charge_fet + RDS_on_dischg_fet) * I_out**2
print(f"Charge and Discharge power loss : {EngNumber(P_charge_discharge)}W"

P_bypass_mosfet = (RDS_on_bypass_fet) * IL_DC**2
# P_bypass_mosfet= 0
print(f"Bypass mosfet power loss : {EngNumber(P_bypass_mosfet)}W".format("%
```

```
Charge and Discharge power loss : 26.40mW
Bypass mosfet power loss : 52.80mW
```

In [ ]:
```
#Total Power Loss

total_power_loss = P_iac_sns+P_ibat_sns+P_l_dcr+Power_switching_mosfet+P_co
efficiency = ((V_out*I_out - total_power_loss)/(V_in*I_in))*100
print(f"Entire Power Loss: {EngNumber(total_power_loss)}W")
print(f"Efficiency: {round(efficiency,2)}%")
```

```
Entire Power Loss: 3.45W
Efficiency: 95.68%
```