CAIRO UNIVERSITY ECO-RACING TEAM

# TASK 1

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# QUESTION 1
# ( POWER TRANSISTORS )

How to specify resistors, capacitors, and diodes?

Resistors

- Resistance value (in Ω)
- Tolerance (in %)
- Power dissipation (in W)
- Temperature range
- Thermal coefficient (in ppm/K or ppm/C)

Capacitors

- Capacitance value
- Rated voltage
- Tolerance
- Temperature range

Diodes

- Breakdown & Forward voltage
- Reverse & Forward current
- Operating temperature range

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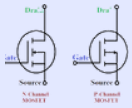
# QUESTION 1
# (POWER TRANSISTORS)

Compare between different types of power transistors (operation, applications, and how to control each type)

| | Bipolar junction transistors (BJTs) | Metal-oxide-semiconductor field-effect transistors (MOSFETs) | Insulated gate bipolar transistors (IGBTs) | Static induction transistors (SITs) |
|---|---|---|---|---|
| OPERATION | It is a current controlled device that passes current between the collector and the emitter when providing sufficient base current. | It is a voltage controlled device that passes voltage between the source and the drain when providing sufficient gate voltage. | It is a combination of BJTs and MOSFETs to produce highly efficient fast switching. | It is similar to a MOSFEt in terms of construction but can handle high voltage and current with low noise. |
| APPLICATIONS | • Switch<br>• Inverter<br>• PWM signals | | | |
| CONTROL | Base current | Gate voltage | Gate voltage | Gate voltage |
| SYMBOL |  |  |  |  |

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# QUESTION 1
# (POWER TRANSISTORS)

How to specify a MOSFET, which parameters should be considered when selecting a MOSFET?

- Drain-source breakdown voltage (V(BR)DSS)
- Gate-source threshold voltage (VGS(th))
- Continuous drain current (Id)
- Junction temperature (Tj)
- Drain-source on-state resistance (RDSon)
- Drain leakage current (Idss)
- Peak drain current (Idm)
- Source-drain voltage (Vsd)(Vsd)
- Thermal resistance (RthJC)

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# QUESTION 1
# (POWER TRANSISTORS)

For the MOSFET with part number (IRFP90N20D), get its data sheet and determine values of the selected parameters above in the previous question?

- Drain-source breakdown voltage (V(BR)DSS)=200V
- Gate-source threshold voltage (VGS(th))=+/-30V
- Continuous drain current (Id)=94A
- Junction temperature (Tj)=-55-175°C
- Drain-source on-state resistance (RDSon)=0.023Ω
- Drain leakage current (Idss)(@VDS = 200V, VGS = 0V)=25 µA
- Drain leakage current (Idss)(@VDS = 160V, VGS = 0V,Tj=150°C)=250 µA
- Peak drain current (Idm)=380A
- Source-drain voltage (Vsd)=1.5V
- Thermal resistance - Junction-to-Case (RthJC)= 0.26°C/W
- Thermal resistance - Junction-to-Ambient (RthJA)= 40°C/W

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# QUESTION 1
# (POWER TRANSISTORS)

Explain what do we mean by High-Side MOSFET and Low-Side MOSFET?

High-Side MOSFET

Case 1 (P Channel MOSFET): we connect the source to the power supply and the drain to the load.

Case 2 (N Channel MOSFET): we connect the drain to the power supply and the source to the load.

Low-Side MOSFET

Case 1 (P Channel MOSFET): we connect the source to the load and the drain to the ground.

Case 2 (N Channel MOSFET): we connect the drain to the load and the source to the ground.

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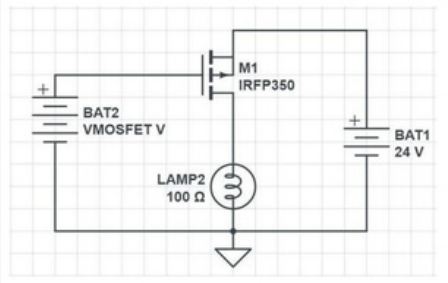
# QUESTION 1
# (POWER TRANSISTORS)




In this circuit we have a light pulp that needs 24V, if battery 2 has a value of 4v do you expect that the light pulp will perfectly work?

From the datasheet of the IRFP350 MOSFET we understand that the gate-to-source threshold voltage is at 2 to 4V. In our example, the gate-to-source voltage=24-4=20V. Hence, it will turn on.

Explain your answer in the case of N-channel and P-channel MOSFET.

P-channel MOSFET: The P-channel MOSFET will turn on provided that: we exceed the gate-to-source threshold voltage, and we connected the source to the power supply and the drain to the load (i.e. High sided switching).

N-channel MOSFET: The N-channel MOSFET will not turn on. However, we could use either of these two techniques:

1-Using at least 26V battery BAT2

2-Using a gate driver

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# QUESTION 1
# (POWER TRANSISTORS)

What are the MOSFET gate drivers?
A MOSFET gate driver is a circuit/IC designed to provide sufficient gate-to-source voltage for NMOSFETs.
Why we need them?
We need them because they are designed to charge the input gate capacitance of the MOSFET faster than without them.
What are their types?

- Isolated Drivers
- Non-isolated Drivers

State names for drivers (in Egyptian market) for each type
Isolated Drivers

- TLP250,251,350,351
- HCPL 3120
- L6386 SMD
- 4N25

Non-isolated Drivers

- IR44272LPBF
- IR213(6,62,63,65,66,67,68)

SOURCE 1:https://uge-one.com/
SOURCE 2:https://www.gs.com.eg/
SOURCE 3:https://ram-e-shop.com/

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# QUESTION 1
# (POWER TRANSISTORS)

What do you know about (TLP250), Explain How to use it with a MOSFET?

It is an isolated gate driver that uses optocoupling technology for IGBT and MOSFETs. It mainly consists of a LED and a photodetector.

It can be used to drive a power MOSFET or an IGBT (e.g. using bootstrap technique).


IMAGE :shorturl.at/lrz49

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# QUESTION 1
# (POWER TRANSISTORS)

Explain the driving bootstrap circuit in detail.

It is a driving technique used with N-MOSFETs and N-IGBTs that allows to charge the gate-to-source capacitor in the MOSFET without the need to use a higher power supply than that connected to the drain or if an independent power source could not be provided to Vgs to open the gate.

We use a series diode to the driver power supply and a parallel capacitor connected between the MOSFET source and drain. The importance of these two components is to charge the gate driver IC during the OFF period of the MOSFET switching cycle. This provides the required gate-to-source voltage threshold to the MOSFET to move it from OFF state to ON state.

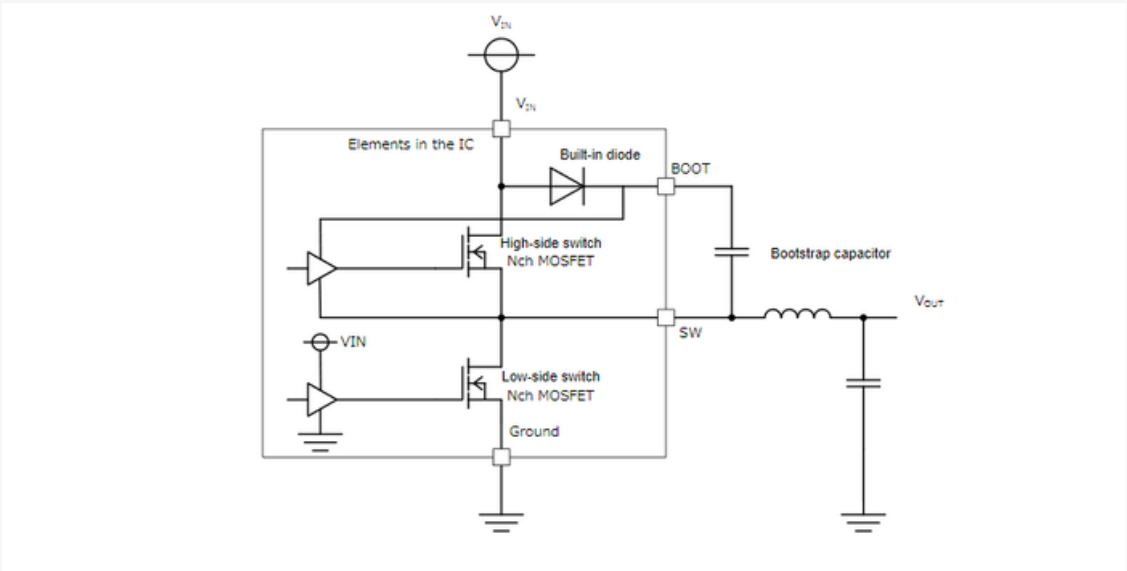


**IMAGE :shorturl.at/JLNT3**

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# QUESTION 1
# (POWER TRANSISTORS)

What do you know about flyback DC-DC converter and its advantage over the ordinary buck-boost converter?

A flyback DC-DC converter is used to convert a DC voltage to another greater or smaller DC voltage.

Its advantage over ordinary buck-boost converters is that it uses two separate inductors that are electrically isolated from each other but magnetically coupled.

It can operate at several voltages and isolate the primary side from the secondary side.

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# QUESTION 1
# (POWER TRANSISTORS)

In the circuit shown in the next figure we have a HIGH SIDE MOSFET that works as a switch to control a load.

A- what is the importance of C1 and D1?

High pass filter for the gate circuit and bootstrap power source; to filter any noise and stabilize the gate voltage.

B- what is the importance of the RC circuit parallel to the MOSFET (R5 and C5)?

Snubber circuit; used for stabilizing the voltage across the drain-source, as during high switching frequency, back induced EMF can occur across the MOSFET.

C- what is the importance of R3?

Current limiting resistor for gate; to protect against high currents to the MOSFET gate.

D- what is the importance of R4?

To protect both against large current spikes while switching

E- what is the importance of D2?

Freewheeling (Flyback) Diode; it protects against sudden drop in voltage across the gate circuit due to the self-inductance of the current limiting resistor.

F- what is the importance of R1 and R2?

Current limiting resistors for LEDs; to provide protection for the LED in the optocoupler gate drivers by consuming the extra voltage from the supply.

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# QUESTION 2
# (BLDC MOTOR)

State the differences between DC motors and BLDC motors (construction and theory of operation)

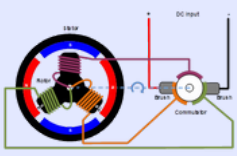
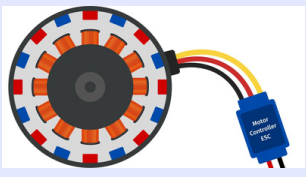
| | BRUSHED MOTOR | BRUSHLESS MOTOR |
|---|---|---|
| **CONSTRUCTION** | • Stator (stationary)<br>• Rotor (moving)<br>• Commutator<br>• Carbon brushes | • Stator (moving)<br>• Rotor (stationary)<br>• controller<br>• 3-phase connections |
| **THEORY OF OPERATION** | The stator field windings are excited through a DC power source. In addition to that, the rotor windings receive power from the carbon brushes which in turn creates a electromagenetic force inside the rotor coils to rotate. | A separately controlled microcontroller passes current in each of the 3-phase connections with a defined order so that they produce sufficient torque on the rotor permanent magnet to rotate. |
| **IMAGE** |  |  |

IMAGE 1:shorturl.at/ABPT3
IMAGE 2:shorturl.at/ceFI3

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# QUESTION 2
# (BLDC MOTOR)

Explain the six-step commutation method used with BLDC motor and what is the main function of the hall sensors in this method also explain how can we control the speed of the BLDC motor when using this method to drive the motor.

The BLDC motor is controlled by a microcontroller (MC) which in turn sends ON and OFF signals to the half H-bridge of the motor with a predefined order. The order is defined according to the hall effect sensors.

These sensors are designed to determine the position of the rotor permanent magnet so that the MC can decide which phases need to be turned on to generate the required torque to rotate the rotor.

In order to change the speed of the BLDC motor, we can modify the PWM duty cycle sent by the MC to the BLDC motor through the half H-bridge. There are 3 coomonly used techniques to control the half H-bridge of the BLDC motor:

- Hard switching
- Soft switching
- Complimentary switching

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# QUESTION 2
# (BLDC MOTOR)

In six step commutation method what is the MAX number of MOSFETS in the inverter can be on at the same time? If we turned on number of MOSFETS less than the answer you'll write, do you expect that the motor will rotate? explain your answer

The max number is 4 MOSFETs. If less, the BLDC motor may rotate. This is because the current will be able to pass through the motor as there will be at least one or two closed circuit(s) between the motor and ground as well as the motor and source.

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# QUESTION 3

## LTSPICE & PCB

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