**Device Parameters Research & Simulation**

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1. Diode Parameters

# Define the 5 important power diode characteristics with their symbol and meanings.

1. Forward Voltage Drop (VF): Power diodes have a voltage drop across them when they are subjected voltage in forward direction. The voltage drop is around 0.7 to 1.5 volts for Silicon Diodes, 2 to 4 volts for Germanium Diodes.
2. Reverse Breakdown Voltage (VR): The reverse breakdown voltage is the maximum reverse voltage that the diode withstand before it breaks down and start the conducting in the reverse direction.
3. Forward Current Rating (IF): The forward current rating is the maximum current value in forward direction that the diodes can safely handle without damaging it.
4. Reverse Current Rating (IR): The reverse current rating is the maximum reverse current value that the diodes can safely handle without damaging it.
5. Reverse Recovery Time (tRR): The reverse recovery time of a power diode is the time it takes for the diode to stop conducting current in the reverse direction after it has been switched off. This is an important parameter to consider when designing circuits that use power diodes, as it can affect the overall performance of the circuit.

# Losses in Power Diodes

1. Conduction Losses: They are the losses that relates with the current. Conduction losses increase with the current value.
2. Switching Losses: They are the losses that relates to the switching frequency and turn-on, turn-off time. If the frequency gets higher, switching losses are increased proportionally.

# Select diodes with around 5A, 20A, and 100A current ratings. (at most 5 different types/samples for each current rating, considering different speed, different voltage rating, different material type, i.e., Si, SiC, etc.). Put them into a table to compare the change in most important parameters.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Diode Name & Package** | **V & I Ratings** | **Forward Voltage Drop (VF)** | **Type/Speed** | **TRR (Reverse Recovery Time)** | **Mounting Type** | **Temp. Range (**°C) |
| RFN5BM6SFHTL / TO252 | 600V / 5A | 1.55V @ 5A | Fast Recovery / =< 500 ns, 200mA (IO) | 50 ns | Surface mount | -45 to 150 |
| 1N3899R / DO-5 | 50V / 20A | Not Specified | Fast Recovery / | Not Specified | Standard | -65 to 150 |
| 1N3140 / DO-8 | 100V / 100A | 1.2V @ 200A | Standard Recovery / > 500 ns | Not Specified | Stud Mount | -65 to 200 |
| SK56C / DO-214AB | 60V / 5A | 0.75V @5A | Not Specified | Not Specified | Surface mount | - 55 to 150 |
| STTH100W04C / TO-247 | 400V / 100A | 0.98V | Ultrafast | 35 ns | Not Specified | -65 to 175 |

# Select diodes with around 10V, 100V, and 500V voltage ratings. (at most 5 different types/samples for each voltage rating, considering different speed, different current rating, different material type, i.e., Si, SiC, etc.). Put them into a table to compare the change in most important parameters.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Diode Name & Package** | **V & I Ratings** | **Forward Voltage Drop (VF)** | **Type/Speed** | **TRR (Reverse Recovery Time)** | **Mounting Type** | **Temp Range. (**°C) |
| ES1H / DO-214AC | 500V / 1A | 1.3 to 1.7 | Fast/Ultrafast | 35 ns | Surface mount | -55 to 150 |
| BYC20X-600 / TO-220F | 500V / 20A | 2.9 | Fast/Ultrafast | 35 ns | Through Hole | -40 to 150 |
| BY448TAP / SOD-57 | 100V / 100A | 1.6 | Slow | 2000 ns | Any | -55 to 175 |
| ES2B / DO-214AA | 100V / 2A | 0.75V @5A | Fast/Ultrafast | 20 ns | Surface mount | - 55 to 150 |
| MBRM110LT3G / CASE 457-04 | 10V / 1A | 0.325 | Not Specified | Not Specified | Surface mount | -55 to 125 |

# By referencing the selected MOSFETs in part 2.c and 2.d, comment on the trade-offs of the MOSFET parameters in detail. How does other parameters change when voltage and current ratings are increased? What may be the advantages and/or disadvantages of choosing an overdesign MOSFET? Explain in detail.

In general, if voltage ratings get higher, switching time visibly increase. Furthermore, the current ratings increase with the voltage ratings.

1. MOSFET Parameters

# Define the 5 most important power MOSFET characteristics with their symbol and meanings.

* 1. Drain-Source Voltage (VDS): This is the maximum voltage that can be applied between the drain and source of the MOSFET. It is typically denoted by the symbol "VDS" and is usually specified in volts (V).
  2. Drain Current (ID): This is the maximum current that can be safely conducted through the drain terminal of the MOSFET. It is typically denoted by the symbol "ID" and is usually specified in amperes (A).
  3. Gate-Source Voltage (VGS): This is the voltage applied between the gate and source of the MOSFET. It is typically denoted by the symbol "VGS" and is usually specified in volts (V).
  4. Drain-Source On-Resistance (RDS(ON)): This is the resistance between the drain and source of the MOSFET when it is in the on state. It is typically denoted by the symbol "RDS(ON)" and is usually specified in ohms (Ω).
  5. Maximum Drain-Source On-State Current (IDM): This is the maximum drain-source current that the MOSFET can safely handle in the on state. It is typically denoted by the symbol "IDM" and is usually specified in amperes (A).

# Explain the losses of MOSFETs. Which parameters affect the losses?

There are several types of losses that can occur in MOSFETs, including conduction losses, switching losses, and gate drive losses:

***Conduction losses*** occur when the MOSFET is in the on state and a current is flowing through it. These losses are caused by the resistance of the MOSFET (RDS(ON)) and are proportional to the square of the drain current (ID). The power dissipated due to conduction losses can be calculated using the following equation:

***Switching losses*** occur when the MOSFET is transitioning between the on and off states. These losses are caused by the internal capacitances of the MOSFET (CGS, CGD, and CSS) and the rate at which the MOSFET is switching (dI/dt). The power dissipated due to switching losses can be calculated using the following equation:

where f is the switching frequency.

***Gate drive losses*** occur when the MOSFET is being driven by a gate driver. These losses are caused by the resistance of the gate driver and the gate-source capacitance of the MOSFET (CGS). The power dissipated due to gate drive losses can be calculated using the following equation:

where RG is the resistance of the gate driver.

In summary, the main factors that affect the losses in MOSFETs are the drain current (ID), the drain-source voltage (VDS), the gate-source voltage (VGS), the switching frequency (f), and the gate driver resistance (RG).

# Select MOSFETs with around 5A, 20A, and 100A current ratings. (at most 5 different types/samples for each current rating, different voltage rating, different material type, i.e., Si, SiC, etc.). Put them into a table to compare the change in most important parameters.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **MOSFET Name & Package** | **Channel Type** | **VDS & ID Ratings** | **On-Resistance (RDS) (**Ω) | **Gate Source Voltage (VGs) / Max Value** | **Pulsed Drain Current** | **Temp Range. (**°C) |
| AO3415A/  SOT-23-3 | p-channel | -20V / -5A | 65mΩ | ± 1.8V / 8V | -30A | -55 to 150 |
| RUQ050N02HZGTR/TSMT6 (SC-95) | n-channel | 20V / 5A | 30mΩ | 1V | ±10A | -55 to 150 |
| AO4576 / 8-SOIC | n-channel | 30V / 20A | 7.6mΩ | ±20V | 144A | -55 to 175 |
| CSD19502Q5BT/ 8-VSON-CLIP (5x6) | n-channel | 80V / 100A | 3.8 mΩ | ±20V | 400A | - 55 to 150 |
| MBRM110LT3G / CASE 457-04 | p-channel | -60V /  -100A | 5mΩ | ±20V | -400A | -55 to 125 |

# Select MOSFETs with around 10V, 100V, and 500V voltage ratings. (at most 5 different types/samples for each voltage rating, considering different current rating, different material type, i.e., Si, SiC, etc.). Put them into a table to compare the change in most important parameters.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **MOSFET Name & Package** | **Channel Type** | **VDS & ID Ratings** | **On-Resistance (RDS) (Ω)** / **Admittance (S)** | **Gate Source Voltage (VGs) / Max Value** | **Pulsed Drain Current** | **Temp Range. (**°C) |
| EPC2037 / Die | n-channel | 100V / 1.7A | 550mΩ | 6V | 2.4A | -40 to 150 |
| 2SK209-Y(TE85L,F)/ SC-59 | n-channel | 10V / 0.5mA | 15mS | 0V | 14mA | -55 to 125 |
| STD15N50M2AG / TO-252 | n-channel | 500V / 10A | 0.380Ω | ±30V | 40A | -55 to 175 |

1. Simulation

Select two different diodes and MOSFETs from the devices selected for above questions. Simulate the semiconductor devices with their parameters. Show the losses of semiconductors and compare the results. (Hint: You can use below circuit to examine losses. To compare losses of diodes, keep the MOSFET same for two different diode selection and vice versa. Non-idealities can be modelled in LTspice or in Simulink with Simscape Electrical blue components.)

Results: The simulation is created in Simulink with Simscape and tested. RDS(ON) is directly proportional to the loss of the MOSFET. Also, VGS is affecting the loss because we use MOSFET in saturation region and ID (Drain Current) of the MOSFET in saturation will be:

As the VGS is increased, ID will be larger than before. Therefore, the MOSFET loss which is:

will increase.

Simulation design can be found in the same repository in Github.