MOSFET

Alex Eagles

Contents

MOSFET Key Parameters:

Saturation Drain-Source Current (IDSS)

The saturated drain-source current is the **maximum** current at the drain of the **FET** when the gate-source voltage **VGS** is zero. **IDSS** is a basic parameter, which is very important for the use of equipment, because it indicates the limiting current capacity of the equipment. If the current exceeds this value, the performance of the **FET** will be **severely** affected and may cause damage to the device.

Transfer guide (gm)

The transfer conductance is the conduction slope of the circuit on the output pole of the **FET**, which is measured by the ratio of the current change to the gate-source voltage change. The **larger** the value of gm, the **better** the amplification capability of the **FET**.

Negative Temperature Coefficient of Gain (TCAG)

Negative gain temperature coefficient is a **FET** parameter that is the proportional change in negative gain as temperature changes. This parameter is important because at high temperatures, the performance of the **FET** is easily compromised. At low temperatures, however, the negative gain coefficient of the **FET** is greatly reduced, which can be detrimental for some applications.

Forward capacitance (Cgs)

The forward capacitance is the capacitance between the gate and source of the **FET**, and it is an important indicator in the **FET** parameters. The smaller the forward capacitance, the better the **frequency response** of the **FET**.

Blocking capacitance (Cgd)

Field effect transistor is a very important semiconductor device, which has been widely used in modern electronic equipment. It is very important to understand the different parameters of **FET**s, as this helps to optimize the device performance, leading to better design results.

MOSFET Operating Regions

Cutoff Region (Off State):

- **Condition:** VGS < Vth
- **Description:** In this region, the gate-source voltage (**VGS**) is less than the threshold voltage (**Vth**). The **MOSFET** is turned off, and there is no conduction between the drain and source. The drain current (**ID**) is approximately zero.

Ohmic or Linear Region (Triode Region):

- **Condition: VGS >Vth** and **VDS < VGS − Vth**
- **Description:** When **VGS** is greater than **Vth** and **VDS** (drain-source voltage) is small, the **MOSFET** operates in the linear or ohmic region. In this region, the **MOSFET** behaves like a variable resistor, and the current **ID** through the device is proportional to **VDS**. This region is typically used when the **MOSFET** is acting as an amplifier or a switch in the "on" state but with some voltage drop across the drain and source.

Saturation Region (Active Region):

- **Condition: VGS > Vth** and **VDS ≥ VGS − Vth**
- **Description:** In this region, the **MOSFET** operates as a current source. The current **ID** is almost **independent** of **VDS** and is primarily controlled by **VGS**. The **MOSFET** is fully on, and this region is used when the device is intended to act as an amplifier or when it needs to provide a steady current.

Subthreshold Region:

- **Condition: VGS** is slightly below **Vth**

- **Description:** In this region, a small current flows through the **MOSFET** even when **VGS** is below the threshold voltage. The current **ID** in this region is exponentially related to **VGS**. This region is important in low-power and analog applications, such as in subthreshold logic circuits.

Breakdown Region:

- **Condition: VDS** exceeds the breakdown voltage.
- **Description:** If the drain-source voltage **VDS** is increased beyond a certain point (breakdown voltage), the **MOSFET** enters the breakdown region. In this region, the device can conduct a large current due to avalanche breakdown, which can potentially damage the **MOSFET** if the current is not limited.

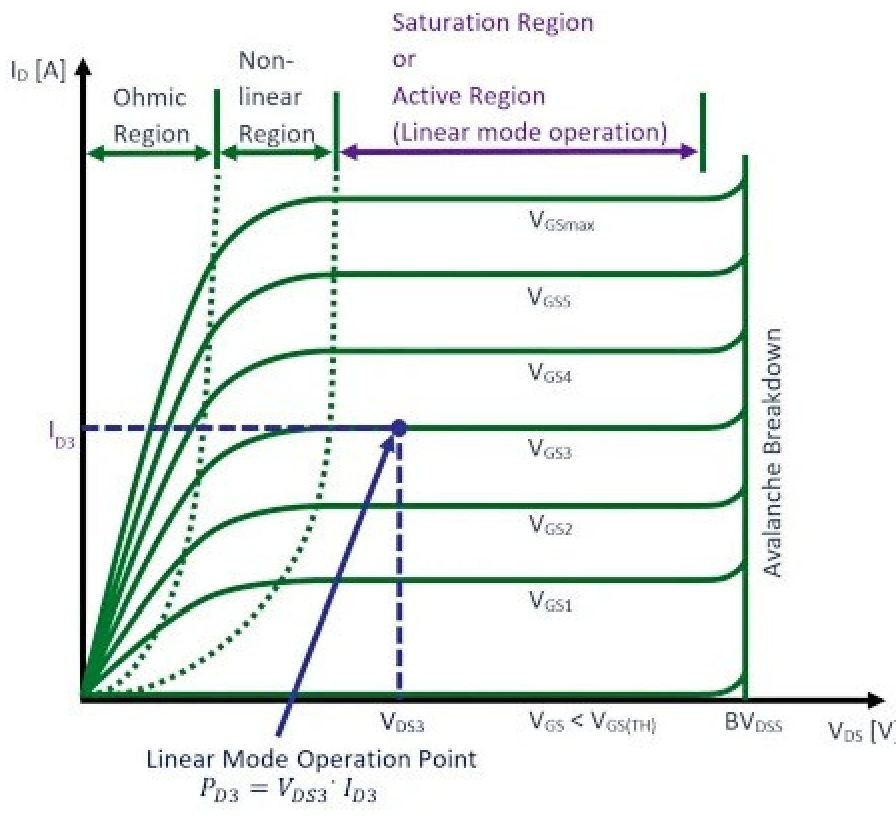

Figure 1 MOSFET Operating Regions

MOSFET Guidelines

Determine the Application Type:

- **Switching Applications (e.g., Power Supplies, Motor Drives):**
  - Choose a MOSFET with a low on-resistance **RDS(on)** to minimize conduction losses.
  - Look for a **MOSFET** with a **fast-switching** speed to reduce switching losses.
  - Ensure the **MOSFET** can handle the required voltage and current levels.
- **Linear Applications (e.g., Amplifiers, Voltage Regulators):**
  - Select a **MOSFET** with a suitable drain current (**ID**) rating that can operate efficiently in the linear region.
  - Consider the thermal characteristics, as linear applications may result in significant power dissipation.
- **Analog Applications (e.g., Signal Processing):**
  - Choose a **MOSFET** with low input capacitance (**Ciss**) and low gate charge (**Qg**) for better **high-frequency** performance.
  - Look for a **MOSFET** with good linearity and low noise characteristics.

Voltage Ratings:

- **Drain-Source Voltage (VDS) Rating:**
  - Ensure the **VDS** rating of the **MOSFET** is higher than the maximum voltage expected in the circuit. A typical guideline is to select a **MOSFET** with a **VDS** rating 20-30% higher than the maximum voltage to ensure reliability.

- **Gate-Source Voltage (VGS) Rating:**
  - Verify that the gate-source voltage rating is sufficient for your application. Most **MOSFET**s have a **VGS** rating of ±**20V**, but some applications may require more.

Current Ratings:

- **Drain Current (ID) Rating:**
  - Ensure the **MOSFET**'s **ID** rating exceeds the maximum current the circuit will demand. Consider both continuous and peak current ratings.
- **Pulsed Drain Current (ID) Rating:**
  - If the application involves short-duration high current pulses (e.g., in switching power supplies), check the **MOSFET**'s **ID** rating.

On-Resistance RDS(on)

- Select a **MOSFET** with a low **RDS(on)** to minimize power loss in the on-state, especially in high-current applications. Lower **RDS(on)** typically results in better efficiency and less heat generation.

Switching Speed:

- **Gate Charge (Qg) and Input Capacitance (Ciss):**
  - For high-speed switching applications, select a MOSFET with low **Qg** and **Ciss**. These parameters affect how quickly the **MOSFET** can turn on and off.
- **Rise and Fall Times:**
  - Check the rise and fall times specified in the datasheet to ensure they meet your application's speed requirements.

Thermal Considerations:

- **Power Dissipation:**
  - Calculate the expected power dissipation based on **RDS(on)** and **ID**. Ensure the **MOSFET** can handle this power without exceeding its maximum junction temperature.
- Thermal Resistance (RΩJA, RΩJC):
  - Choose a MOSFET with a low thermal resistance to efficiently transfer heat away from the junction. Consider the use of heatsinks or cooling if necessary.

Package Type:

- **Surface Mount vs. Through-Hole:**
  - Select the package type based on your **PCB** design. Surface-mount devices (**SMD**) are preferred for compact designs, while through-hole components may be better for applications requiring higher power dissipation.
- **Thermal Performance:**
  - Consider packages with enhanced thermal performance, such as DPAK, D2PAK, or TO-220, if high power dissipation is expected.

Special Features:

- **Logic-Level MOSFETs:**
  - For low-voltage control applications (e.g., microcontroller outputs), choose a logic-level **MOSFET** that can fully turn on with low **VGS** (e.g., 3.3V or 5V).
- **Integrated Protection Features:**

    - Some **MOSFET**s come with built-in protection features like **ESD** protection, avalanche ruggedness, or integrated diodes. These can add reliability to your design.
- **P-Channel vs. N-Channel:**
    - Choose **N-channel MOSFET**s for better performance in most cases. **P-channel MOSFET**s are often used when a simple **high-side** switch is needed, but they typically have higher **RDS(on)** and lower efficiency compared to **N-channel** counterparts.

Manufacturer and Quality:

- **Reliability:**
    - Choose **MOSFET**s from reputable manufacturers to ensure reliability and access to detailed datasheets and application notes.
- **Availability and Cost:**
    - Consider the availability and cost of the **MOSFET**. Ensure the **MOSFET** you choose is readily available and cost-effective for your application.

Environmental Considerations:

- **Operating Temperature Range:**
    - Ensure the **MOSFET** can operate within the temperature range expected in your application.
- **Humidity and Contaminants:**
    - For harsh environments, consider **MOSFET**s with protective coatings or those designed for high-reliability applications.