Semiconductor Technology from A to Z

Devices

Field-Effect Transistor Families: An Overview

Shared Operating Principle

All field-effect transistors (FETs) control a conductive channel between two terminals (source and drain) via an electric field generated by a third electrode (gate). Unlike the bipolar transistor, where a base current controls the collector current, a FET draws practically no steady-state gate current – control is purely voltage-driven, through the gate-source voltage V_{GS}. The three main FET families differ mainly in how the gate is electrically isolated from the channel:

- MOSFET (Metal-Oxide-Semiconductor FET): gate separated from the channel by a thin oxide layer (insulator, e.g. SiO_2 or a high-k dielectric)
- JFET (Junction FET): gate separated from the channel by a reverse-biased pn junction
- MESFET (Metal-Semiconductor FET): gate separated from the channel by a Schottky contact (a direct metal-semiconductor junction with no intermediate layer)

The classic MOSFET structure is described in detail in Construction of a Field-Effect Transistor; the other two families are covered in the following chapters.

Depletion-Mode vs. Enhancement-Mode

A second important distinction is the operating mode. Depletion-mode FETs ("normally-on") already have a conductive channel at $V_{GS} = 0\,V$; an applied gate voltage progressively pinches this channel off. Enhancement-mode FETs ("normally-off") have no channel at $V_{GS} = 0\,V$ – one must first be induced by a gate voltage. While MOSFETs can be built in either mode (enhancement-mode dominates in digital logic), JFETs operate exclusively in depletion mode by design. MESFETs are predominantly fabricated as depletion-mode devices (D-MESFETs), though enhancement-mode variants (E-MESFETs) also exist for digital GaAs logic.

Comparison Table

The table below compares the three FET families directly:

Feature	MOSFET	JFET	MESFET
Isolation mechanism	Oxide (SiO_2/high-k)	pn junction (depletion layer)	Schottky contact

Feature	MOSFET	JFET	MESFET
Available operating modes	Enhancement & depletion	Depletion only	Predominantly depletion, some enhancement
Gate drive	Isolated gate, practically no gate current	Gate reverse-biased, small saturation leakage current	Gate reverse-biased, small Schottky leakage current
Input impedance	Extremely high	High	High
Typical material	Si (also high-k/metal-gate)	Si, GaAs	GaAs, InP (III-V)
Cutoff frequency / noise	Good, but oxide-related 1/f noise	Very low noise	Very high cutoff frequency
Main application	Digital/analog circuits, power electronics	Low-noise analog amplifiers, current sources	RF/microwave technology

Context and Outlook

Historically, the JFET was among the first practically realized field-effect transistors, but it was quickly displaced in digital logic by the MOSFET, whose oxide isolation allows far greater scaling. The MESFET, in turn, arose from the need to realize FET principles in III-V semiconductors lacking a stable native oxide, and long dominated GaAs RF technology – though in many of these applications it is increasingly being replaced today by the more capable HEMT (High-Electron-Mobility Transistor).