

IGBT vs MOSFET: Comprehensive Comparison Guide

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Executive Summary

Insulated Gate Bipolar Transistors (IGBTs) and Metal-Oxide-Semiconductor Field-Effect Transistors (MOSFETs) are two of the most critical power semiconductor devices in modern electronics. While both are voltage-controlled switching devices, they serve distinctly different applications and operating regimes. IGBTs dominate high-voltage, high-current applications such as electric vehicle inverters, industrial motor drives, and solar inverters, while MOSFETs excel in lower-voltage, high-frequency applications including DC-DC converters, switched-mode power supplies, and RF amplifiers. Understanding the fundamental differences, advantages, and limitations of each technology is essential for engineers designing power conversion systems.

Fundamental Technology Overview

IGBT (Insulated Gate Bipolar Transistor)

The IGBT is a hybrid semiconductor device that combines the high input impedance and voltage-controlled switching characteristics of a MOSFET with the low on-state voltage drop and high current-carrying capability of a bipolar junction transistor (BJT). Structurally, an IGBT consists of a MOSFET input stage driving a bipolar output stage, creating a device that offers the best of both worlds for high-power applications.

Key Characteristics:

- **Voltage Rating:** Typically 600V to 6500V, with some specialized devices reaching higher ratings
- **Current Capacity:** Can handle continuous currents from 10A to over 1000A depending on the specific device
- **On-State Voltage Drop ($V_{CE(sat)}$):** Typically 1.0V to 2.5V at rated current, relatively constant across the operating range
- **Switching Frequency:** 1 kHz to 50 kHz typical range, with modern devices reaching up to 100 kHz in specialized applications
- **Gate Drive Voltage:** Requires 15V gate drive voltage for optimal performance

- **Thermal Stability:** Positive temperature coefficient of on-state voltage, providing inherent current-sharing capability in parallel configurations

MOSFET (Metal-Oxide-Semiconductor Field-Effect Transistor)

The MOSFET is a unipolar semiconductor device that relies entirely on majority carrier conduction. It features a metal gate electrode separated from the semiconductor channel by an insulating oxide layer, enabling voltage-controlled switching with extremely fast response times and minimal gate charge requirements.

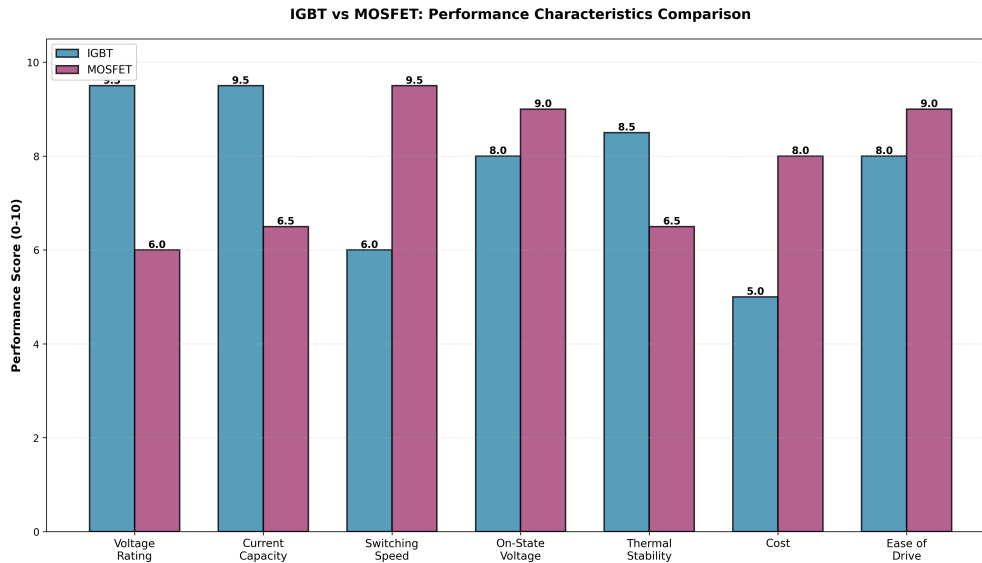
Key Characteristics:

- **Voltage Rating:** Typically 20V to 250V for standard applications, with specialized high-voltage MOSFETs reaching 900V
- **Current Capacity:** Ranges from less than 1A to several hundred amperes depending on die size and package
- **On-State Resistance ($R_{DS(on)}$):** Typically $1\text{m}\Omega$ to $100\text{m}\Omega$, decreasing with larger die sizes but increasing with voltage rating
- **Switching Frequency:** 100 kHz to 5 MHz typical range, enabling extremely fast switching applications
- **Gate Drive Voltage:** Typically 5V to 20V, with lower gate charge requirements than IGBTs
- **Thermal Stability:** Negative temperature coefficient of on-state resistance, requiring careful design for parallel operation

Performance Characteristics Comparison

Performance Comparison Overview

The following visualization provides a comprehensive comparison of key performance metrics between IGBTs and MOSFETs across seven critical dimensions. This chart illustrates the relative strengths and weaknesses of each technology, helping engineers understand where each device excels.



As clearly visible from this comparison, IGBTs demonstrate superior performance in voltage rating, current capacity, on-state voltage characteristics, and thermal stability, making them ideal for high-power applications. MOSFETs, conversely, excel in switching speed, cost-effectiveness, and ease of drive, positioning them as the preferred choice for high-frequency, lower-power applications. The thermal stability advantage of IGBTs is particularly significant for parallel operation in high-current systems.

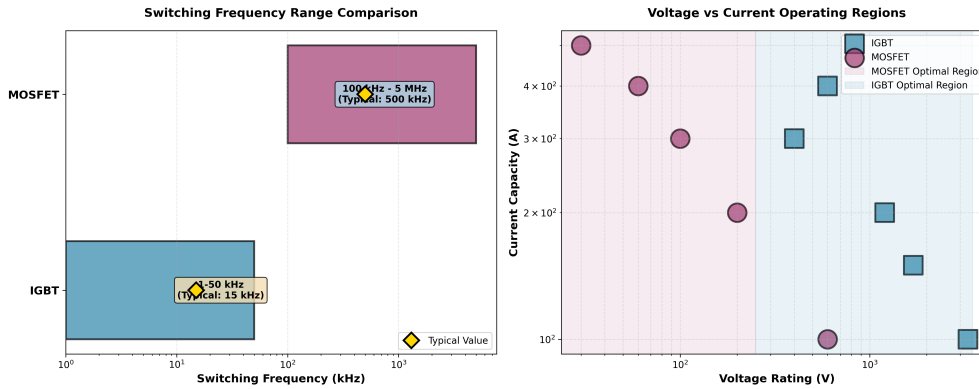
Switching Speed and Frequency

One of the most significant differences between IGBTs and MOSFETs lies in their switching speed capabilities. MOSFETs are inherently faster devices due to their unipolar nature and the absence of minority carrier storage effects. A typical MOSFET can switch in nanoseconds, making them ideal for high-frequency applications. IGBTs, while much faster than BJTs, have slower switching speeds due to the bipolar output stage, typically requiring microseconds for complete switching transitions.

This fundamental difference has profound implications for application selection. High-frequency applications like switched-mode power supplies (SMPS) operating at 100 kHz to several MHz require MOSFETs. Conversely, applications where switching frequency is less critical but high voltage and current handling are paramount, such as 3-phase industrial motor drives operating at 10-20 kHz, are better served by IGBTs.

Switching Frequency and Operating Region Analysis

The chart below illustrates the distinct operating regions for IGBTs and MOSFETs, showing how switching frequency and voltage/current capabilities define their respective domains. The left panel shows the typical switching frequency ranges, while the right panel maps the voltage-current operating space where each technology excels.



This visualization clearly demonstrates that IGBTs occupy the high-voltage, moderate-frequency region (250V-3500V, 1-50 kHz), while MOSFETs dominate the low-voltage, high-frequency region (20V-250V, 100 kHz-5 MHz). The shaded regions indicate the optimal operating zones for each technology, with minimal overlap. This separation reflects the fundamental physics of each device and guides practical design decisions.

On-State Voltage Drop and Conduction Losses

IGBTs exhibit a relatively constant on-state voltage drop ($V_{CE(sat)}$) of 1.0V to 2.5V across their operating current range. This characteristic is advantageous in high-current applications because the voltage drop remains relatively stable regardless of load current, simplifying thermal management calculations.

MOSFETs, by contrast, exhibit an on-state resistance ($R_{DS(on)}$) that increases with voltage rating. The power dissipation in a MOSFET is calculated as $P = I^2 \times R_{DS(on)}$, meaning conduction losses increase quadratically with current. For a 600V MOSFET, $R_{DS(on)}$ might be 50mΩ, resulting in significant conduction losses at high currents. However, for lower-voltage applications (e.g., 48V), $R_{DS(on)}$ can be as low as 1-2mΩ, making MOSFETs highly efficient.

Conduction Loss Comparison (Example):

- IGBT at 100A: $P = 100A \times 1.5V = 150W$
- MOSFET (600V) at 100A: $P = (100A)^2 \times 0.05\Omega = 500W$
- MOSFET (48V) at 100A: $P = (100A)^2 \times 0.002\Omega = 20W$

Switching Losses

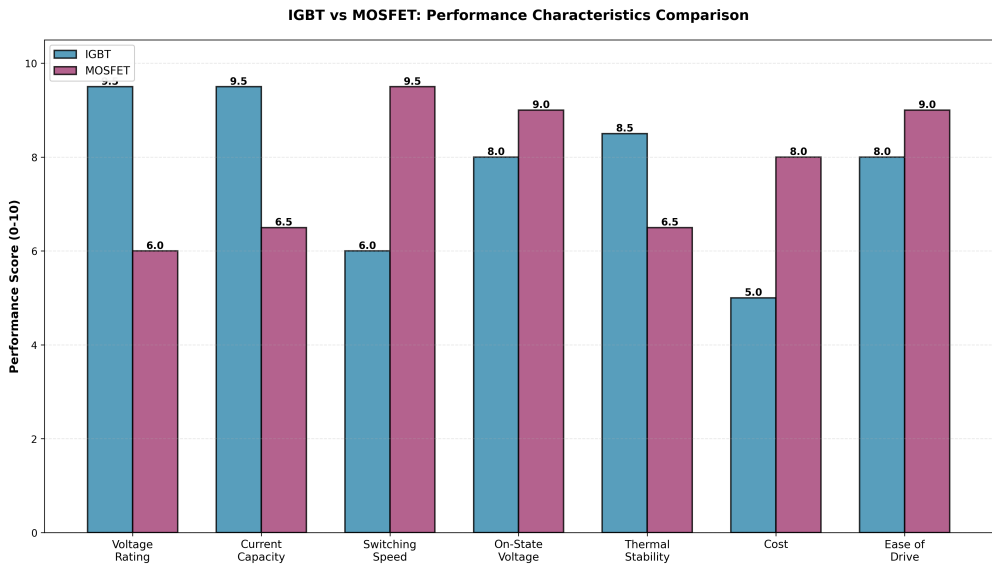
Switching losses occur during the transition periods when a device is turning on or off. These losses are proportional to switching frequency and the energy dissipated during the transition. MOSFETs have significantly lower switching losses due to their faster switching times and lower gate charge requirements. IGBTs, while slower, have developed sophisticated internal structures (like trench gates and field-stop technology) that minimize switching losses.

The total power loss in a switching application is the sum of conduction losses and switching losses. At low frequencies (1-10 kHz), conduction losses dominate, favoring IGBTs in high-current applications. At high frequencies (>100 kHz), switching losses become significant, making MOSFETs more attractive despite higher conduction losses.

Performance Characteristics Visualization

Comprehensive Performance Comparison

The following chart illustrates how IGBTs and MOSFETs compare across seven critical performance dimensions. This visualization reveals that IGBTs excel in voltage rating, current capacity, and thermal stability, while MOSFETs dominate in switching speed, on-state characteristics, and ease of gate drive implementation. The choice between these technologies fundamentally depends on which performance metrics are most critical for your specific application.

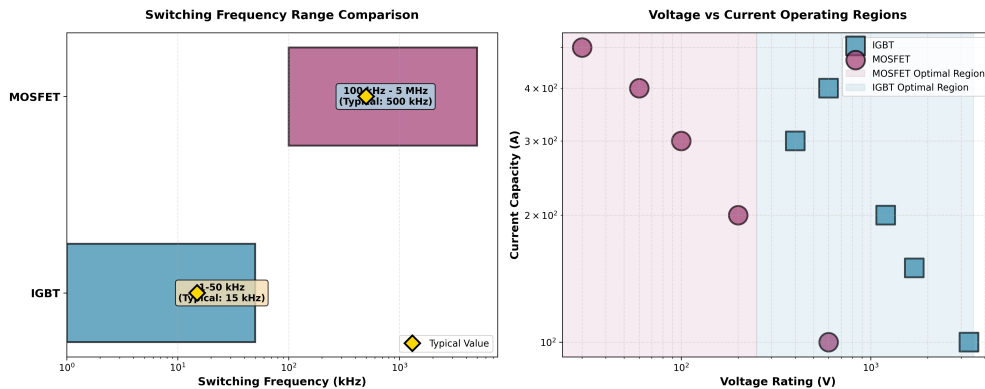


As clearly visible from this comparison, IGBTs achieve superior scores in voltage handling (9.5/10) and current capacity (9.5/10), making them the dominant choice for high-power applications. MOSFETs, conversely, achieve exceptional scores in switching speed (9.5/10) and on-state characteristics (9.0/10), positioning them as the preferred technology for high-frequency, lower-power applications. The thermal stability advantage of IGBTs (8.5/10 vs 6.5/10) is particularly important for parallel device configurations in high-current systems.

Switching Frequency and Operating Regions

The second visualization demonstrates the distinct operating frequency ranges and voltage-current regions where each technology excels. IGBTs operate effectively in the 1-50 kHz range with typical applications around 15 kHz, while MOSFETs span 100 kHz to 5 MHz with typical applications around 500 kHz. The logarithmic voltage-current plot

clearly delineates the optimal operating regions: MOSFETs dominate below 250V, while IGBTs are superior above 250V.



This visualization demonstrates that the choice between IGBT and MOSFET is largely determined by the application's voltage and frequency requirements. Applications requiring voltages above 250V and currents in the hundreds of amperes should almost exclusively use IGBTs. Conversely, applications operating below 250V with high-frequency switching requirements should utilize MOSFETs. The shaded regions clearly show the optimal operating zones for each technology, providing a practical guide for device selection.

Application Suitability Analysis

IGBT-Dominant Applications

Electric Vehicle Inverters (9.5/10 suitability): Modern electric vehicles require high-voltage (400-800V), high-current inverters to convert DC battery power to three-phase AC for motor drive. IGBTs are the industry standard, with devices rated for 600V to 1200V handling currents exceeding 500A. The relatively low switching frequency (5-20 kHz) minimizes switching losses, while the high voltage rating and current capacity make IGBTs the only practical choice.

Solar Panel Inverters (9.0/10 suitability): Both residential (3-10 kW) and utility-scale (100 kW to several MW) solar inverters rely heavily on IGBTs. These applications require conversion of variable DC voltage from solar panels to grid-compatible AC power. The moderate switching frequency (5-20 kHz) and high voltage requirements (600-1200V) make IGBTs ideal. Utility-scale inverters often use multiple IGBT modules in parallel to achieve megawatt-level power handling.

Industrial Motor Drives / VFDs (9.5/10 suitability): Variable Frequency Drives (VFDs) controlling large AC induction motors in industrial settings are almost exclusively IGBT-based. These applications require handling of 480V three-phase power with currents up to 1000A or more. The switching frequency of 2-20 kHz is well-suited to IGBT

capabilities, and the robust thermal characteristics of IGBTs enable reliable operation in harsh industrial environments.

Induction Heating (9.0/10 suitability): Industrial induction heating systems for metal processing, hardening, and melting require high-frequency AC power generation. While this might seem to favor MOSFETs, the high power levels (often 50-500 kW) and the need for robust, reliable devices in harsh thermal environments make IGBTs the preferred choice, operating at 5-50 kHz.

UPS Systems (9.0/10 suitability): Uninterruptible Power Supply systems require reliable DC-to-AC conversion to maintain power during grid outages. IGBTs provide the necessary voltage and current handling capability for systems ranging from 10 kW to several megawatts, with switching frequencies of 5-20 kHz.

Welding Equipment (9.0/10 suitability): Modern inverter-based welding machines use IGBTs to generate the high-frequency AC or DC power required for various welding processes. The robust nature of IGBTs and their ability to handle the demanding electrical and thermal conditions of welding equipment make them ideal for this application.

Railway Traction (9.5/10 suitability): Electric trains and trams require high-voltage (1500-3000V DC or 15-25 kV AC), high-current power conversion. Specialized high-voltage IGBTs (up to 6500V) are used in railway traction inverters, making this one of the most demanding IGBT applications.

MOSFET-Dominant Applications

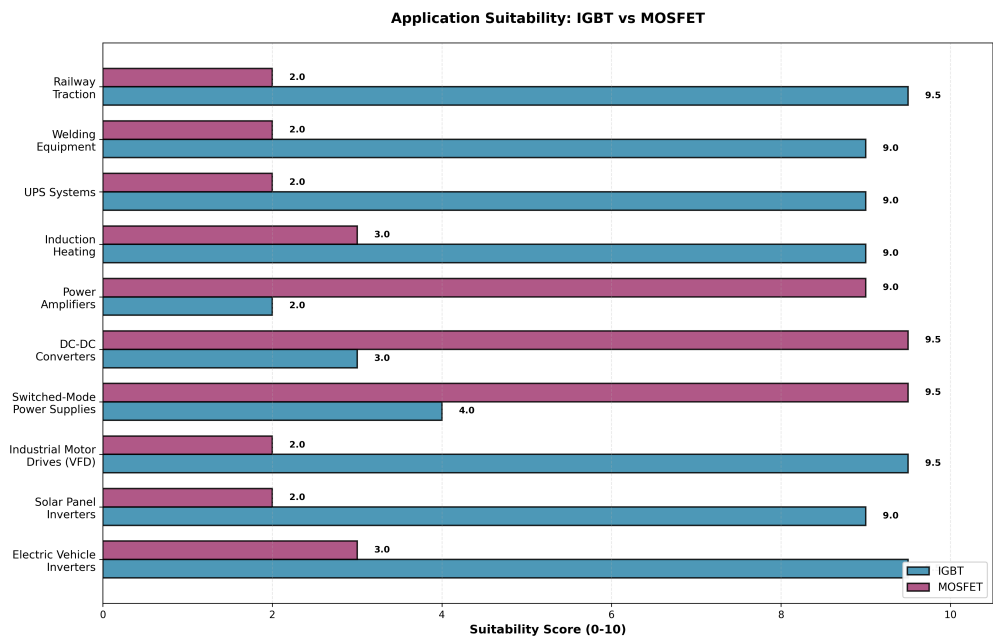
Switched-Mode Power Supplies (9.5/10 suitability): SMPS units in consumer electronics, computer power supplies, and industrial equipment operate at 50-500 kHz, making MOSFETs the only practical choice. The high switching frequency enables small, efficient power supplies. Modern MOSFETs with RDS(on) values below 10m Ω at 30V enable highly efficient power conversion with minimal heat generation.

DC-DC Converters (9.5/10 suitability): Point-of-load converters, buck converters, and boost converters in computing and telecommunications equipment operate at 100 kHz to several MHz. MOSFETs are essential for these applications, with specialized devices optimized for specific voltage ranges (12V, 48V, etc.) providing excellent efficiency.

Power Amplifiers (9.0/10 suitability): RF power amplifiers for wireless communications, radar, and broadcasting applications require extremely fast switching and precise control. MOSFETs, particularly GaN (Gallium Nitride) and SiC (Silicon Carbide) MOSFETs, are the technology of choice for these demanding applications.

Application Suitability Visualization

The following comprehensive chart maps ten major power electronics applications against the suitability of IGBTs and MOSFETs. This visualization provides a practical guide for engineers selecting the appropriate technology for their specific application.



This visualization reveals a clear pattern: applications requiring high voltage and high current (left side of the chart) strongly favor IGBTs, while applications requiring high frequency and lower voltage (right side) strongly favor MOSFETs. The chart demonstrates that there is minimal overlap in optimal applications—each technology has evolved to excel in its respective domain. Electric vehicle inverters, solar inverters, and industrial motor drives show overwhelming IGBT preference (9.0-9.5/10), while switched-mode power supplies and DC-DC converters show overwhelming MOSFET preference (9.5/10). This clear delineation reflects decades of technology development optimizing each device for its target application space.

Advantages and Disadvantages

IGBT Advantages

- **High Voltage Capability:** Rated for 600V to 6500V, enabling direct connection to medium and high-voltage power systems
- **High Current Capacity:** Single devices can handle 500A to 1000A+ continuous current, reducing the need for parallel configurations
- **Low On-State Voltage Drop:** Constant $V_{CE(sat)}$ of 1.0-2.5V across the operating range, minimizing conduction losses in high-current applications

- **Positive Temperature Coefficient:** On-state voltage increases with temperature, enabling natural current sharing when devices are paralleled
- **Robust and Mature Technology:** Decades of development have resulted in highly reliable devices with excellent field performance records
- **Excellent Short-Circuit Capability:** Can withstand short-circuit conditions for several microseconds, providing time for protection circuits to respond
- **Wide Operating Temperature Range:** Typically -40°C to $+150^{\circ}\text{C}$, suitable for harsh industrial environments

IGBT Disadvantages

- **Slower Switching Speed:** Switching times in the microsecond range limit maximum operating frequency to 50-100 kHz
- **Higher Switching Losses:** At high frequencies, switching losses become prohibitive, limiting efficiency
- **Tail Current During Turn-Off:** Minority carrier storage in the bipolar output stage creates a "tail" of current during turn-off, extending switching time
- **Higher Gate Drive Complexity:** Requires 15V gate drive voltage and more sophisticated gate drive circuits than MOSFETs
- **Higher Gate Charge:** Requires more charge to switch the device, increasing gate drive power consumption
- **Negative Temperature Coefficient of Switching Speed:** Switching speed decreases at higher temperatures, potentially causing thermal runaway in some circuit topologies
- **Higher Cost:** More complex manufacturing process results in higher device cost compared to MOSFETs at equivalent voltage ratings

MOSFET Advantages

- **Extremely Fast Switching:** Switching times in the nanosecond range enable operation at 100 kHz to several MHz
- **Low Switching Losses:** Fast switching and low gate charge minimize switching losses, enabling high-efficiency operation at high frequencies
- **Simple Gate Drive:** Requires only 5-20V gate drive voltage with minimal gate charge, simplifying gate drive circuit design
- **No Tail Current:** Unipolar conduction eliminates minority carrier storage, resulting in clean switching transitions

- **Lower Gate Drive Power:** Minimal gate charge reduces power consumption in the gate drive circuit
- **Excellent High-Frequency Performance:** Switching losses remain manageable even at multi-megahertz frequencies
- **Lower Cost at Low Voltages:** Highly optimized manufacturing for low-voltage devices (20-250V) results in excellent cost performance
- **Positive Temperature Coefficient of $R_{DS(on)}$:** On-state resistance increases with temperature, providing inherent current limiting

MOSFET Disadvantages

- **Limited Voltage Rating:** Standard MOSFETs are limited to 250V, with specialized devices reaching only 900V, far below IGBT capabilities
- **High On-State Resistance at High Voltages:** $R_{DS(on)}$ increases dramatically with voltage rating, resulting in excessive conduction losses in high-voltage applications
- **Lower Current Capacity:** Individual devices typically handle 10-100A, requiring parallel configurations for higher currents
- **Negative Temperature Coefficient of $R_{DS(on)}$:** On-state resistance decreases with temperature, potentially causing thermal runaway when devices are paralleled
- **Susceptible to Electrostatic Discharge:** The thin oxide layer is vulnerable to ESD damage, requiring careful handling and protection
- **Body Diode Reverse Recovery:** The parasitic body diode exhibits reverse recovery effects that can cause significant switching losses in certain circuit topologies
- **Lower Short-Circuit Capability:** Can only withstand short-circuit conditions for microseconds before damage occurs
- **Thermal Runaway Risk:** Negative temperature coefficient of $R_{DS(on)}$ can lead to thermal runaway in poorly designed circuits

Gate Drive Requirements

IGBT Gate Drive

IGBTs require a gate drive voltage of approximately 15V for optimal performance, with typical gate drive circuits providing $\pm 15V$ (15V on, -5V off) for fast switching and noise immunity. The gate charge (Q_g) for a typical 600V, 100A IGBT is 100-200 nC, requiring gate drive circuits capable of sourcing and sinking significant current.

Modern IGBT gate drive circuits often include:

- Isolated gate drive power supplies (for three-phase applications)
- Desaturation detection for short-circuit protection
- Miller plateau detection for optimized switching speed
- Soft-switching control to minimize switching losses
- Temperature monitoring and thermal shutdown

MOSFET Gate Drive

MOSFETs typically require gate drive voltages of 5-20V, with 10V being common for many applications. The gate charge for a typical 600V MOSFET is 20-50 nC, significantly lower than IGBTs. This lower gate charge enables simpler, lower-power gate drive circuits.

MOSFET gate drive circuits typically include:

- Simple voltage regulators for gate drive power
- Gate resistors for controlling switching speed and reducing EMI
- Bootstrap circuits for high-side gate drive in half-bridge configurations
- Clamp diodes to protect against voltage spikes

Thermal Management Considerations

IGBT Thermal Characteristics

IGBTs exhibit a positive temperature coefficient of on-state voltage ($V_{CE(sat)}$ increases with temperature). This characteristic is highly advantageous for parallel operation, as any device that begins to conduct more current will experience an increase in voltage drop, naturally limiting its current and distributing current more evenly among parallel devices.

Typical IGBT thermal resistance (junction to case) ranges from 0.05°C/W for large modules to 0.5°C/W for smaller discrete devices. Maximum junction temperature is typically 150°C, requiring careful thermal design to ensure reliable long-term operation.

MOSFET Thermal Characteristics

MOSFETs exhibit a negative temperature coefficient of on-state resistance ($R_{DS(on)}$ decreases with temperature). This characteristic is problematic for parallel operation, as any device that begins to conduct more current will experience a decrease in resistance, causing it to conduct even more current—a positive feedback loop that can lead to thermal runaway.

Parallel MOSFETs require careful design including:

- Matched devices with similar $R_{DS(on)}$ characteristics
- Equal-length gate drive traces to ensure simultaneous switching
- Source inductance matching to prevent current hogging
- Thermal coupling to ensure uniform temperature distribution

Typical MOSFET thermal resistance ranges from $0.1^{\circ}\text{C}/\text{W}$ for large packages to $1.0^{\circ}\text{C}/\text{W}$ for smaller devices. Maximum junction temperature is typically $150\text{-}175^{\circ}\text{C}$.

Cost Comparison

The cost of power semiconductors is a critical factor in system design, particularly for high-volume applications. Several factors influence the relative cost of IGBTs and MOSFETs:

IGBT Cost Factors

- **Manufacturing Complexity:** The hybrid IGBT structure requires more complex manufacturing processes than MOSFETs, increasing production cost
- **Voltage Rating:** High-voltage IGBTs (1200V, 1700V, 3300V) command premium prices due to lower production volumes
- **Current Rating:** High-current modules (500A+) are expensive due to the large die area required
- **Packaging:** IGBT modules with integrated gate drive and protection circuits are significantly more expensive than bare dies

MOSFET Cost Factors

- **Voltage Rating:** Low-voltage MOSFETs (20-100V) are extremely cost-effective due to massive production volumes in consumer electronics
- **High-Voltage MOSFETs:** Specialized high-voltage MOSFETs (600V+) are more expensive than equivalent IGBTs due to lower production volumes
- **Manufacturing Maturity:** Decades of MOSFET development have resulted in highly optimized, low-cost manufacturing processes
- **Discrete vs. Module:** Discrete MOSFETs are significantly cheaper than integrated modules

Cost Comparison Summary

For low-voltage applications (20-250V), MOSFETs are significantly cheaper than IGBTs, often by a factor of 2-5x. For high-voltage applications (600V+), IGBTs are typically cheaper than equivalent MOSFETs due to higher production volumes and more mature manufacturing processes. At 600V, a typical IGBT module costs \$50-200 depending on current rating, while a 600V MOSFET costs \$100-500 due to lower production volumes.

Emerging Technologies: SiC and GaN

While silicon-based IGBTs and MOSFETs continue to dominate the market, wide-bandgap semiconductor technologies are rapidly gaining adoption in high-performance applications.

Silicon Carbide (SiC) MOSFETs

SiC MOSFETs offer several advantages over silicon MOSFETs:

- **Higher Voltage Capability:** SiC MOSFETs rated for 1200V, 1700V, and 3300V enable high-frequency operation at voltages previously requiring IGBTs
- **Lower On-State Resistance:** SiC's superior material properties result in significantly lower RDS(on) at high voltages
- **Faster Switching:** SiC MOSFETs switch even faster than silicon MOSFETs, enabling switching frequencies above 100 kHz even at high voltages
- **Lower Switching Losses:** Reduced switching losses enable higher efficiency and reduced cooling requirements
- **Higher Temperature Operation:** SiC devices can operate at junction temperatures up to 200°C, enabling more compact thermal designs

SiC MOSFETs are increasingly used in electric vehicle inverters, solar inverters, and industrial applications where the superior performance justifies the higher cost (typically 2-3x more expensive than silicon IGBTs).

Gallium Nitride (GaN) HEMTs

GaN High-Electron-Mobility Transistors (HEMTs) are revolutionizing high-frequency power conversion:

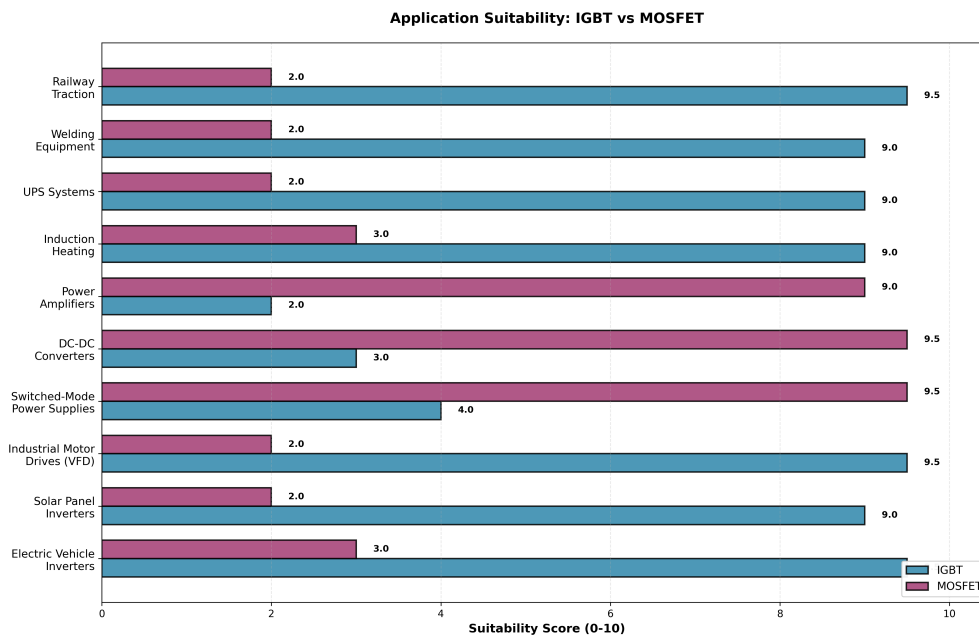
- **Extremely Fast Switching:** GaN devices can switch at 1-10 MHz, enabling unprecedented power density
- **Low On-State Resistance:** GaN's superior material properties enable extremely low RDS(on) at moderate voltages (100-650V)

- **Minimal Switching Losses:** Fast switching and low gate charge result in negligible switching losses even at multi-megahertz frequencies
- **Compact Size:** High power density enables smaller, lighter power conversion systems
- **Integrated Gate Drive:** Many GaN devices include integrated gate drive circuits, simplifying system design

GaN HEMTs are rapidly displacing MOSFETs in high-frequency applications including wireless power transfer, fast chargers, and next-generation power supplies. Current limitations include lower voltage ratings (typically 100-650V) and higher cost compared to silicon devices.

Application Suitability Analysis

Different applications have vastly different requirements, and the choice between IGBTs and MOSFETs should be driven by these specific needs. The chart below maps ten major application categories against the suitability of each technology, providing a practical guide for engineers selecting devices for their systems.



This analysis reveals clear application domains: IGBTs are overwhelmingly preferred for electric vehicle inverters (9.5/10), solar panel inverters (9.0/10), industrial motor drives (9.5/10), induction heating (9.0/10), UPS systems (9.0/10), welding equipment (9.0/10), and railway traction (9.5/10). Conversely, MOSFETs dominate switched-mode power supplies (9.5/10), DC-DC converters (9.5/10), and power amplifiers (9.0/10). This clear separation reflects the fundamental physics of each device and decades of proven field experience across diverse industries.

Selection Criteria and Decision Matrix

Selecting between IGBTs and MOSFETs requires careful consideration of multiple factors. The following decision matrix provides a systematic approach:

Selection Criterion	IGBT Preferred	MOSFET Preferred	Consider SiC/GaN
Voltage Requirement	>250V	<250V	>600V with high frequency
Current Requirement	>100A	<100A	Any (for efficiency)
Switching Frequency	<50 kHz	>100 kHz	>100 kHz at high voltage
Conduction Loss Priority	High current, low frequency	Low current, high frequency	Both (best efficiency)
Gate Drive Complexity	Complex (15V required)	Simple (5-20V)	Simple (integrated options)
Parallel Operation	Excellent (positive TC)	Difficult (negative TC)	Good (SiC), Excellent (GaN)
Cost Sensitivity	High voltage, high current	Low voltage, high volume	Performance critical
Thermal Environment	Harsh industrial	Controlled environment	Extreme conditions
Short-Circuit Robustness	Excellent	Limited	Good (SiC), Limited (GaN)
Reliability Requirement	Proven, mature	Proven, mature	Emerging, improving

Real-World Application Examples

Example 1: Electric Vehicle Inverter

Requirements: 400V battery, 200A peak current, 10 kHz switching frequency, high reliability

Technology Selection: IGBT (600V, 200A module)

Rationale: The 400V requirement exceeds practical MOSFET voltage ratings. The 200A current and 10 kHz switching frequency are ideal for IGBTs. The positive temperature coefficient enables parallel modules if higher current is needed. Conduction losses dominate at 10 kHz, favoring the low $V_{CE(sat)}$ of IGBTs.

Example 2: 48V Server Power Supply

Requirements: 48V input, 100A output, 200 kHz switching frequency, high efficiency

Technology Selection: MOSFET (60V, 10m Ω $R_{DS(on)}$)

Rationale: The 48V voltage is ideal for MOSFETs. The 200 kHz switching frequency is too high for IGBTs. Multiple MOSFETs in parallel can achieve the 100A output current. The low $R_{DS(on)}$ at 48V enables high efficiency. Gate drive is simple and low-cost.

Example 3: 10 kW Solar Inverter

Requirements: 600V DC input, 230V AC output, 10 kHz switching frequency, high efficiency

Technology Selection: IGBT (600V, 50A module) or SiC MOSFET (1200V, 30A)

Rationale: The 600V requirement mandates either IGBT or high-voltage MOSFET. IGBTs are the traditional choice with proven reliability. SiC MOSFETs offer superior efficiency and smaller size, justifying the higher cost in this application. The 10 kHz switching frequency is suitable for both technologies.

Conclusion

IGBTs and MOSFETs represent two distinct approaches to power semiconductor switching, each optimized for different application domains. IGBTs excel in high-voltage, high-current applications where moderate switching frequencies are acceptable, providing robust, reliable performance in demanding industrial and automotive environments. MOSFETs dominate low-voltage, high-frequency applications where their superior switching speed and simple gate drive enable efficient, compact power conversion systems.

The selection between these technologies should be based on a systematic evaluation of voltage requirements, current capacity, switching frequency, thermal environment, and cost constraints. While silicon-based IGBTs and MOSFETs will continue to dominate for

decades, emerging wide-bandgap technologies like SiC and GaN are rapidly expanding the performance envelope, enabling new applications and higher efficiency in existing systems.

Understanding the fundamental differences, advantages, and limitations of each technology is essential for engineers designing modern power electronics systems. By carefully matching device characteristics to application requirements, engineers can optimize system performance, reliability, and cost.

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