**Transistors**

**1. When would you choose a BJT over a MOSFET, and vice versa?**

* **BJT Preferred When:**
  + High current drive is needed (BJTs have lower on-resistance in saturation).
  + Low-cost solutions are required (BJTs are often cheaper for low-power applications).
  + Linear amplification (BJTs have better linearity in analog circuits).
  + Low-voltage drop in saturation (e.g., in low-side switches).
  + High-temperature stability (BJTs are less prone to thermal runaway than MOSFETs in some cases).
* **MOSFET Preferred When:**
  + High-frequency switching (faster switching due to no minority carrier storage delay).
  + High input impedance (MOSFETs are voltage-controlled, requiring negligible gate current).
  + Power efficiency (lower conduction losses in high-power applications).
  + Parallel operation (MOSFETs share current better due to positive temperature coefficient).
  + Low-power digital circuits (CMOS logic leverages MOSFETs for minimal static power).

**2. Advantages and disadvantages of NPN vs PNP**

| **Parameter** | **NPN Advantages** | **PNP Advantages** | **NPN Disadvantages** | **PNP Disadvantages** |
| --- | --- | --- | --- | --- |
| Availability | More common, cheaper | Available, but fewer options | – | Higher cost, fewer variants |
| Current Flow | Sinks current (easier for low-side switching) | Sources current (useful for high-side switching) | Requires a pull-down for turn-off | Requires a pull-up for turn-off |
| Speed | Faster (electron mobility > hole mobility) | Slower (hole mobility lower) | – | Slower switching |
| Voltage Levels | Works well with positive supplies | Needed for negative rails/complementary use | – | Less efficient in positive supplies |

**3. Advantages and disadvantages of N-channel vs P-channel.**

| **Parameter** | **N-Channel Advantages** | **P-Channel Advantages** | **N-Channel Disadvantages** | **P-Channel Disadvantages** |
| --- | --- | --- | --- | --- |
| Conduction Loss | Lower R<sub>DS(on)</sub> (better efficiency) | Higher R<sub>DS(on)</sub> (less efficient) | – | Higher power dissipation |
| Cost | Cheaper, more options | More expensive, fewer choices | – | Limited high-power options |
| Switching Speed | Faster (electron mobility) | Slower (hole mobility) | – | Slower switching |
| Drive Complexity | Requires  gate voltage > source (bootstrapping may be needed for high-side) | Easier high-side drive  (gate < source) | Needs charge pump/bootstrapping | Higher gate drive voltage required |

**4. What are the most important parameters for choosing a BJT and MOSFET?**

* **BJT Key Parameters:**
  + Current Gain (h<sub>FE</sub> or β): Determines base current needed for saturation.
  + Collector-Emitter Saturation Voltage (V<sub>CE(sat)</sub>): Lower = better efficiency.
  + Maximum Collector Current (I<sub>C</sub>): Must handle load current.
  + Breakdown Voltage (V<sub>CEO</sub>): Must exceed supply voltage.
  + Switching Speed (t<sub>on</sub>/t<sub>off</sub>): Critical for high-frequency apps.
* **MOSFET Key Parameters:**
  + Gate-Source Threshold Voltage (V<sub>GS(th)</sub>): Determines drive voltage needed.
  + Drain-Source On-Resistance (R<sub>DS(on)</sub>): Lower = less conduction loss.
  + Maximum Drain Current (I<sub>D</sub>): Must support load current.
  + Breakdown Voltage (V<sub>DSS</sub>): Must exceed supply voltage.
  + Gate Charge (Q<sub>g</sub>): Lower = faster switching, less drive power.
  + Body Diode Characteristics: Important for inductive load handling.

**5. What is the bootstrapping circuit? Why is it used?**

* **What is Bootstrapping?**
  + A technique to generate a voltage higher than the supply rail to fully enhance a high-side N-channel MOSFET (or NPN BJT in some cases).
* **Why Used?**
  + N-MOSFET High-Side Drive: An N-MOSFET needs V<sub>GS</sub> > V<sub>th</sub>, but if the source is floating (e.g., in a half-bridge), the gate must be driven above the supply rail.
  + Avoids P-Channel Downsides: P-MOSFETs have higher R<sub>DS(on)</sub>, so bootstrapping lets designers use efficient N-MOSFETs for high-side switching.
* **How It Works:**
  + A capacitor charges to V<sub>CC</sub> when the MOSFET is off.
  + When the MOSFET turns on, the capacitor voltage "floats" with the source, providing V<sub>CC</sub> + V<sub>Gate</sub> to ensure full enhancement.
* **Applications**:
  + Half-bridge motor drivers (e.g., in H-bridges).
  + Switching regulators with high-side N-MOSFETs.