Transistors Cheat Sheet

A comprehensive guide to understanding and using transistors, covering their types, characteristics, and common applications.

Transistor Basics

Transistor Types

Bipolar Junction Transistor (BJT)	Current-controlled current source. Two types: NPN and PNP. • **NPN**: Current flows from collector to emitter when a small current is applied to the base. • **PNP**: Current flows from emitter to collector when a small current is drawn from the base.
Field-Effect Transistor (FET)	Voltage-controlled current source. Two main types: JFET and MOSFET. • **JFET**: Junction Field-Effect Transistor. Depletion mode device. • **MOSFET**: Metal-Oxide-Semiconductor Field-Effect Transistor. Enhancement or depletion mode. Includes N-channel and P-channel types.

Key Parameters

`V_CE` (Collector-Emitter Voltage)	Voltage between collector and emitter terminals (BJT).
`I_C` (Collector Current)	Current flowing through the collector terminal (BJT).
`h_FE` or `β` (Current Gain)	Ratio of collector current to base current (BJT). Indicates amplification capability.
`V_GS` (Gate-Source Voltage)	Voltage between gate and source terminals (FET).
`I_D` (Drain Current)	Current flowing through the drain terminal (FET).
`V_th` (Threshold Voltage)	Gate voltage required to turn on the MOSFET.

Operating Regions (BJT)

Cut-off Region: Transistor is OFF. No current flows from collector to emitter.
Both junctions are reverse biased.

Active Region: Transistor acts as an amplifier. Collector current is proportional to base current. Base-emitter junction is forward biased, base-collector is reverse biased.

Saturation Region: Transistor is fully ON. Maximum current flows from collector to emitter. Both junctions are forward biased.

BJT Configurations and Biasing

BJT Configurations

Common Emitter (CE)	Emitter is common to both input and output. Provides high voltage and current gain. Most common configuration.
Common Collector (CC) / Emitter Follower	Collector is common to both input and output. Provides high input impedance and low output impedance. Used as a buffer.
Common Base (CB)	Base is common to both input and output. Provides high voltage gain and low current gain. Used in high-frequency applications.

Biasing Techniques

Fixed Bias: Simple but unstable. Highly dependent on transistor β.

```
I_B = (V_CC - V_BE) / R_B
I_C = β * I_B
```

Emitter Bias: More stable than fixed bias due to the emitter resistor providing negative feedback.

```
I_E ≈ V_EE / R_E
I_C ≈ I_E
```

Voltage Divider Bias: Most stable biasing technique. Sets the base voltage using a voltage divider network.

```
V_B = V_CC * (R_2 / (R_1 + R_2))
I_C ≈ V_E / R_E = (V_B - V_BE) / R_E
```

Small Signal Model

The small-signal model is used to analyze the AC behavior of transistor circuits. It replaces the transistor with an equivalent circuit composed of resistors and dependent sources.

Key parameters:

- `r_e`: dynamic emitter resistance
- `r_π`: dynamic base resistance
- `g_m`: transconductance

FET Characteristics and Applications

FET Types

JFET (Junction Field-Effect Transistor)	Operates in the depletion mode. The channel is initially open and is pinched off by applying a reverse voltage to the gate-source junction.
MOSFET (Metal-Oxide-Semiconductor FET)	Can operate in enhancement or depletion mode. • **Enhancement Mode**: Channel is initially closed and is opened by applying a voltage to the gate. • **Depletion Mode**: Channel is initially open and is pinched off by applying a voltage to the gate.
N-channel vs. P-channel	Similar to NPN and PNP for BJTs, N-channel uses electrons as charge carriers, while P-channel uses holes.

FET Biasing

Self-Bias (JFET): Achieved by using a resistor between the source and ground. The drain current creates a voltage drop across the resistor, which biases the gate-source junction.

```
V_GS = -I_D * R_S
```

Voltage Divider Bias (MOSFET): Similar to BJT voltage divider bias. Sets the gate voltage using a voltage divider network.

```
V_G = V_DD * (R_2 / (R_1 + R_2))
```

FET Applications

Amplifiers	FETs are used as amplifiers in various circuits due to their high input impedance.
Switches	MOSFETs are commonly used as electronic switches due to their low ON-resistance and high OFF-resistance.
Current Sources	FETs can be configured as constant current sources.

Advanced Transistor Concepts

Transistor Packages

Transistors come in various packages, including:

- **TO-92**: Common through-hole package for small signal transistors.
- **TO-220**: Larger package for power transistors.
- **SMD (Surface Mount Devices)**: For high-density PCB designs (e.g., SOT-23, SOT-223).

Thermal Considerations

Transistors generate heat when conducting current. It's essential to consider thermal management to prevent overheating and damage.

- **Heat Sinks**: Used to dissipate heat from power transistors.
- **Thermal Resistance**: Parameter that indicates how effectively a component dissipates heat.

SPICE Modeling

SPICE (Simulation Program with Integrated Circuit Emphasis) is a powerful tool for simulating electronic circuits, including transistor circuits. Transistor models are used to accurately represent the behavior of transistors in simulations.

```
.MODEL Q2N2222 NPN (BF=200 IS=1E-14
VAF=100)
```