VIDEO#22: Electronic Basics #22: Transistor (BJT) as a Switch

Introduction to BJTs

Bipolar Junction Transistors (BJTs) are essential components in electronic circuits, functioning primarily as switches or amplifiers. They come in two types: NPN and PNP. NPN transistors are commonly used to control high-power devices, while PNP transistors are used in circuits where the ground potential is applied to the base resistor to switch on the load .

Basic Operation of NPN Transistors

An NPN transistor, such as the BC 637, has three terminals: emitter, collector, and base. In a simple switching circuit, the emitter is connected to ground, and the load is placed between the supply voltage and the collector. The transistor operates by allowing current to flow from the collector to the emitter when a sufficient base current is applied .

The datasheet for BC 637 transistor is given as a pdf :  BC635.PDF

The applied voltage in a transistor cannot exceed the rated **collector-emitter voltage** because exceeding this limit can cause **breakdown** and permanent damage to the transistor. Here's why:

1. Breakdown Mechanisms

- **Avalanche Breakdown (Bipolar Junction Transistors - BJTs)**:
  If VCEV_{CE}VCE exceeds its maximum rated value, the reverse-biased collector-base junction can enter avalanche breakdown, causing excessive current flow and potential thermal damage.

- **Punch-through Effect**:
  In some cases, excessive VCEV_{CE}VCE can deplete the base region entirely, leading to loss of control over the transistor and high leakage currents.
- **Gate Oxide Breakdown (MOSFETs)**:
  In MOSFETs, exceeding the **Drain-Source voltage** (VDS(max)V_{DS(max)}VDS(max)) can damage the thin gate oxide, leading to permanent failure.

2. Thermal Runaway

- Higher voltage can increase power dissipation (P=VCE×ICP = V_{CE} \times I_CP=VCE×IC), raising the temperature and possibly leading to **thermal runaway**, where increased temperature leads to more current, which further increases temperature.

3. Manufacturing Limitations

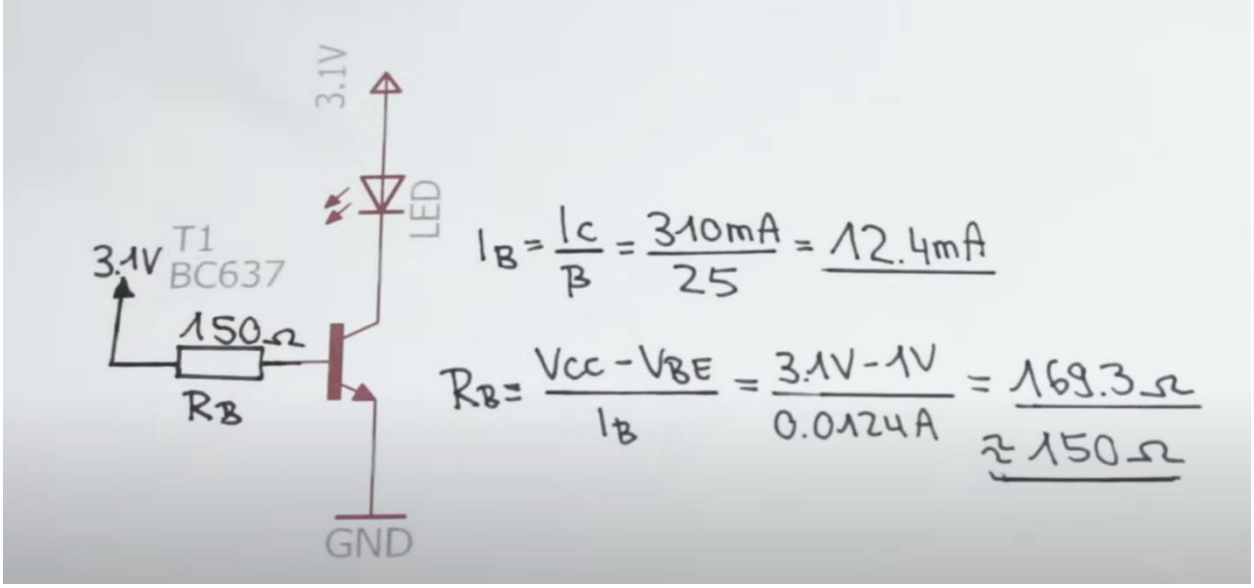
- Transistors are designed with specific **semiconductor junction doping and thickness**, limiting their voltage-handling capability.

4. Reliability and Safety

- Exceeding VCE(max)V_{CE(max)}VCE(max) can cause permanent degradation or destruction of the transistor, leading to circuit failure or even **fire hazards** in extreme cases.

Calculating Base Current and Resistor

To ensure proper operation without damaging the transistor, a current-limiting resistor is necessary. The base current can be calculated using the transistor's current gain (β), which is specified in the datasheet. This helps in determining the appropriate base resistor value to control the collector current effectively .



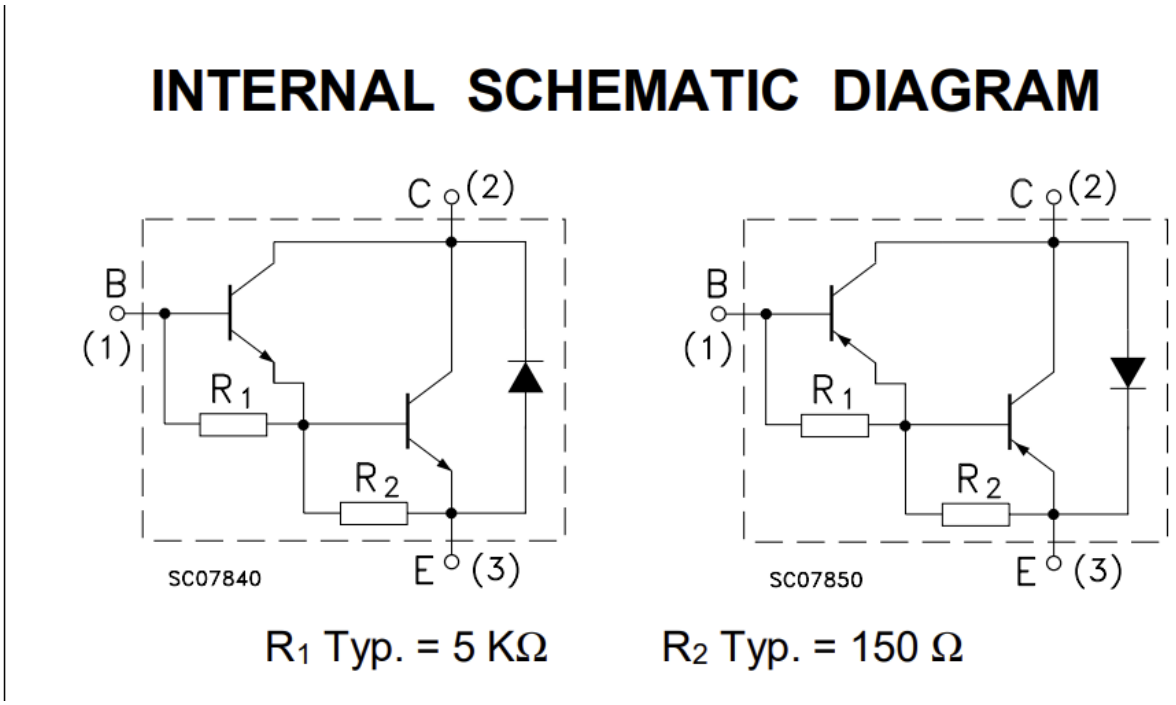
Limitations and Power Loss

One significant drawback of BJTs is the power loss due to high base current requirements, especially when handling larger loads. For instance, when using a BD 535 transistor for a 6V, 21W light bulb, the power loss can reach around 6 watts, leading to high temperatures during operation .(72 degrees in this case for the experiment within the seconds)

Using Darlington Transistors

To mitigate the high base current requirement, Darlington transistors, which consist of two BJTs, can be employed. They provide a higher current gain, allowing for smaller base currents to control larger loads. For example, a Darlington transistor can switch on a load with only 8.5 milliamps of base current, making it suitable for direct control from microcontrollers like Arduino . In this case TIP142 is used which mainly consists of two bipolar transistors.

Schematic diagram of TIP142:



BJTs are versatile components in electronic circuits, but their efficiency can be limited by power loss and current requirements. Understanding their operation, limitations, and alternatives like Darlington transistors is crucial for effective circuit design