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Task 1

First, we need to understand what an H-Bridge motor is. An H-Bridge motor is a 4 switch topology that allows DC current to flow in both directions, using MOSFET as the switches improves efficiency and allows for PWM speed control.

Components Used and Justification

1. **MOSFETs:** Four N-channel enhancement mode MOSFETs are used as the main switching devices. As highlighted in the slides, MOSFETs are voltage-controlled devices with very low conduction losses when ON, which makes them more efficient than BJTs in switching applications.

2. **Flyback Diodes:** Since the motor is an inductive load, it generates back-EMF when switching occurs. To prevent damage to the MOSFETs, diodes are placed across each switch. They provide a safe path for the current when polarity changes or during PWM OFF cycles.

3. **Resistors:** These limit the inrush current when charging or discharging the MOSFET gate capacitance, ensuring smooth transitions and preventing oscillations. Pull-down resistors (10 kΩ) are also added to ensure MOSFETs stay OFF when no signal is applied.

4. **Capacitor:** Acts as a decoupling capacitor, stabilizing the supply voltage and absorbing voltage spikes caused by sudden motor current changes.

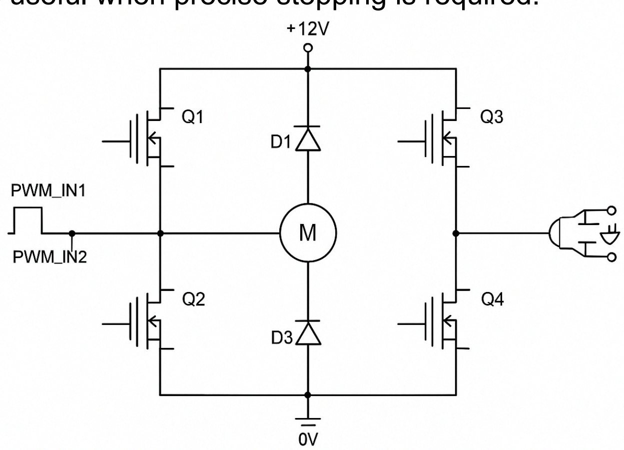
5. **Driver/Input Signals:** The MOSFETs are driven by logic-level control signals (PWM and direction inputs). In hardware, a driver IC like the IR2110 could be used to provide proper gate voltages for the high-side MOSFETs, but in simulation we can directly drive the gates.

How the Circuit Works

The H-Bridge arranges the four MOSFETs in a configuration that resembles the letter "H". The motor is placed in the middle of the bridge, connected between the midpoints of the two legs. By selectively switching the MOSFETs ON and OFF in complementary pairs, the current through the motor can be reversed, stopped, or controlled in magnitude using PWM.

Modes of Operation

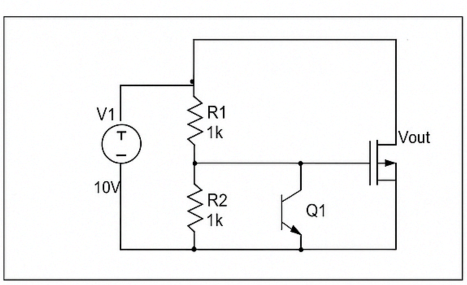
- ➔ **Forward Mode:**
    - ◆ Q1 (high-side left) and Q4 (low-side right) are turned ON.
    - ◆ Current flows from the supply → through Q1 → motor → Q4 → ground.
    - ◆ The motor rotates forward.
- ➔ **Reverse Mode:**
    - ◆ Q3 (high-side right) and Q2 (low-side left) are turned ON.
    - ◆ Current flows from the supply → through Q3 → motor (opposite direction) → Q2 → ground.
    - ◆ The motor rotates in reverse.
- ➔ **Coasting (Freewheel):**
    - ◆ All MOSFETs are OFF.
    - ◆ The motor terminals are left floating, and the motor continues to spin freely due to inertia.
    - ◆ Energy is dissipated through the body diodes or external flyback diodes.
- ➔ **Braking (Dynamic Braking):**
    - ◆ Both low-side MOSFETs (Q2 and Q4) are turned ON.
    - ◆ The motor terminals are shorted to ground, which causes the motor to stop quickly as its kinetic energy is dissipated as heat in the winding resistance.
    - ◆ This is useful when precise stopping is required.



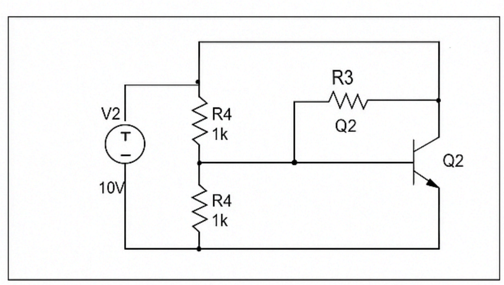
Task 2

Measure of Comparison	NPN BJT	PNP BJT
Working Principle	The Zener diode is connected in reverse bias at the transistor base. Below the Zener breakdown voltage (safe condition), the transistor stays OFF, and current flows normally to the load. When the input exceeds the Zener threshold, the diode conducts, turning the NPN transistor ON. The transistor then shorts the excess voltage to ground, protecting the load.	The Zener diode again defines the threshold. Below the Zener breakdown, the PNP transistor remains ON, allowing current to flow to the load. When input voltage exceeds the Zener voltage, the diode conducts and turns the PNP transistor OFF, cutting power to the load and preventing damage.
Response to Overvoltage	Shunts excess current to ground	Disconnects load from supply
Load Behavior	Load may still see some stress if clamping isn't perfect	Load is fully disconnected
Complexity	Slightly simpler	Slightly more complex
Use Cases	Good for transient spike suppression	Better for protecting sensitive loads

In both circuits, increasing the input voltage above the Zener threshold (e.g., >5.6 V) triggered the protection mechanism. The NPN circuit diverted current to ground, keeping the load safe. The PNP circuit disconnected the load entirely, preventing exposure to high voltage.
So, in conclusion, The NPN solution is better suited for shunting sudden spikes, while the PNP solution offers stronger protection by fully cutting off the load supply when unsafe conditions are detected.



NPN BJT Overvoltage Protection Circuit



PNP BJT Overvoltage Protection Circuit