Task 2 — BJT Overvoltage Protection

1 Circuit Overview

Two LTspice protectors with distinct behaviors:

- **NPN series pass (emitter follower):** sharp clamp near 11.3 V using a 12 V zener reference.
- **PNP shunt clamp (with input series resistor $R_{\mathbf{SER}} = 100\,\Omega$):** gradual limitation near 12.7 V by sinking excess current.

2 Components

- 2N2222 / 2N2907 transistor models ($\beta_F \approx 100$).
- 12 V zener diode (breakdown voltage $BV \approx 12\,\text{V}$, $R_S \approx 10\,\Omega$).
- Load resistor $R_{\text{LOAD}} = 1\,\text{k}\Omega$.
- Bias resistor $\approx 10\,\text{k}\Omega$.
- For PNP shunt: input series resistor $R_{\text{SER}} = 100\,\Omega$.

3 Operation & Expected Results

3.1 NPN Series Pass

- For $V_{IN} < 12\,\text{V}$:
$$V_{OUT} \approx V_{IN} - V_{CE(sat)}$$
- For $V_{IN} \gtrsim 12\,\text{V}$: zener conducts, fixing base $\Rightarrow$
$$V_{OUT} \approx V_Z - V_{BE} \approx 11.2\text{–}11.4\ \text{V}$$
- Load current:
$$I_{LOAD} \approx \frac{V_{OUT}}{R_{LOAD}} \approx 11\text{–}11.4\ \text{mA}$$
- Pass BJT dissipation:
$$P \approx (V_{IN} - V_{OUT}) \cdot I_{LOAD}$$

3.2 PNP Shunt Clamp (with R_{SER})

- For V_{IN} below knee: $V_{OUT} \approx V_{IN}$ (little shunt action).
- For V_{IN} above knee:

$$V_{OUT} \approx 12.6\text{–}13.0 \text{ V}$$

- Excess current diverted by Q_{SHUNT}:

$$I_{SHUNT} \approx \frac{V_{IN} - V_{OUT}}{R_{SER}} - \frac{V_{OUT}}{R_{LOAD}}$$

4 Key Figures to Plot

4.1 NPN File

- $V(VIN)$, $V(VOUT\_M)$ (output).
- $V(N1)$ (zener/base node).
- $I(VIM\_OUT)$ (load current).
- Optional: $V(VIN, VOUT\_M)$ (voltage drop across pass BJT).

4.2 PNP File

- $V(VIN)$, $V(VOUT)$.
- $V(NB)$ (zener/base node).
- $I(VPROBE)$ (load current).
- $I(QSHUNT)$ (or `Ic(QSHUNT)`).
- $V(VPRE)$ (pre-R_{SER} node).

5 Comparison

Aspect	**NPN Series Pass**	**PNP Shunt Clamp**
Behavior	Sharp clamp	Gradual clamp
Setpoint	11.3 V ($\approx V_Z - V_{BE}$)	12.6 –-13.0 V ($\approx V_Z + V_{EB}$)
Heat location	Pass BJT	Shunt BJT + R_{SER}
Best use	Precise protection	Soft limiting / current sharing