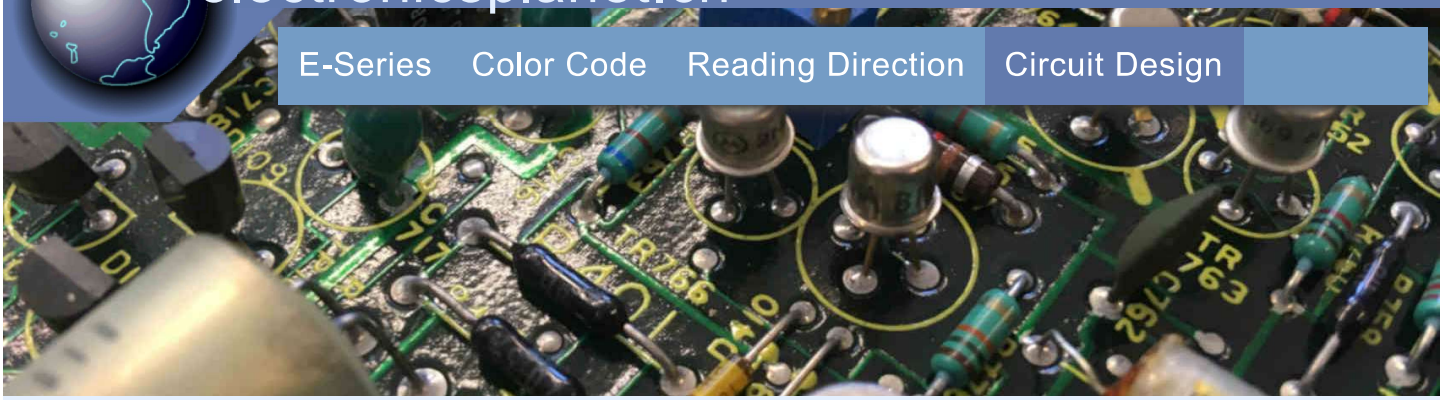


PNP transistor as a switch

Using a PNP transistor as a switch, a small component can switch a large load with a few milliampere

Why use a PNP transistor as a switch?

Logic gates and microcontrollers can only drive small loads by themselves. But sometimes a load needs to be switched that requires more current than the controlling component can supply. In this case, a transistor can be used as a switch to reach the required current and voltage amplification. can be achieved.

With a PNP transistor, the microcontroller only has to sink the base current. Depending on the switching state, the emitter-collector path of the PNP transistor becomes high impedance or conductive and can thus act as a switch for the load.

How does a transistor replace a switch and what possibilities does it give you?

If a transistor is operated as a switch, it is in an ON-OFF mode and can interrupt or close an electric circuit. Just like a mechanical switch. Instead of that it is operated by a human like a mechanical switch, it is controlled by an electrical signal.

The switching path can be controlled very precisely in time and with high frequency. Instead of an eye-visible signal change, very short pulses can be generated. Also PWM signals and any other digital signal can be generated at the load.

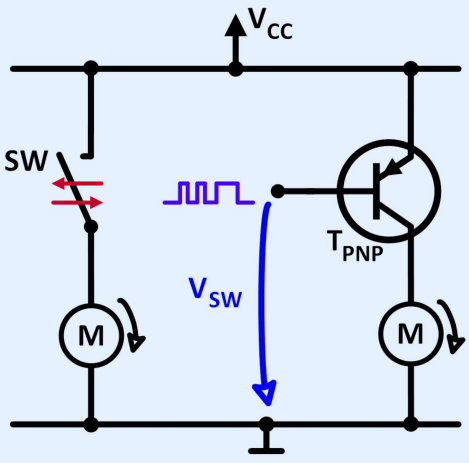


Figure 1: Mechanical switch and pnp transostor as a switch

Korrekte Polarität und Schaltung zur Last

In switch mode, a transistor is operated in a fixed bias configuration. Therefore the load is always connected to the collector of the transistor. And since the current flows out of the collector of the PNP transistor, the transistor is switched in current direction in front of the load and not behind the load.

The PNP transistor thus provides a sourcing current and not a sinking current as the NPN transistor would.

Fig. 2 shows the correct and the incorrect installation of the PNP transistor and for comparison the correct wiring of a NPN transistor as a switch.

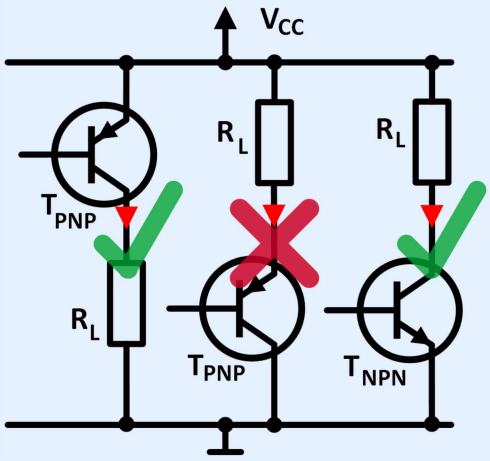


Figure 2: Valid circuits and non wirking circuits of transistors as a switch

Basic circuit of a PNP transistor as switch

In the fixed bias configuration of the PNP transistor as a switch, in addition to the transistor and the load a base resistor R_B is needed. It defines the base current.

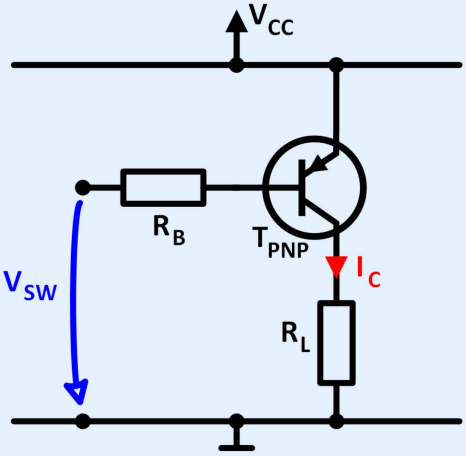


Figure 3: Basic circuit of the pnp transistor as a switch

The base must have the lower voltage potential than the emitter. The circuit works according to the following simple state table, depending on input V:$_{SW}$:

Input V_{SW}	Transistor State
V_{SW} = V_{cc} = High:	Transistor high-Z
V_{SW} = GND = Low:	Transistor conducting

Tabelle 1: State Table PNP Transistor as a switch

Basic circuit with parameters

Symbol	Parameter
R_L:	Load resistor
R_B:	Base reistor
V_{EC}:	Emitter- collector- voltage
V_{EB}:	Base diode voltage
V_{RB}:	Base resistor voltage
V_{SW}:	Control voltage
V_{cc}:	Supply voltage
GND:	Ground
I_L:	Load current
I_B:	Base current

Tabelle 2: Schaltungsparameter

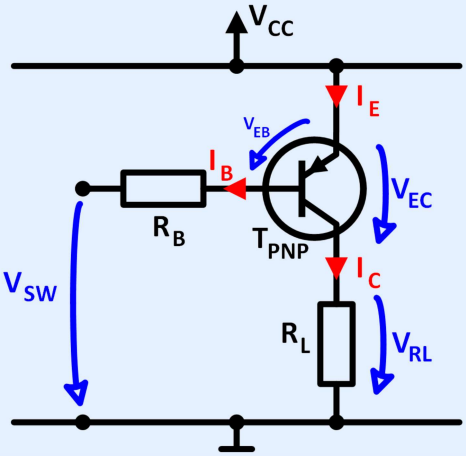


Figure 4: Basic circuit with the designation of all relevant parameters

Calculations

Calculating the component and voltage values is not very difficult. But you need from the data sheet of the transistor the following parameters:

Symbol	Parameter
V_{CEsat}	Saturation voltage
I_C max	Max collector current
h_{FE}	Current gain factor

Tabelle 3: Benötigte Parameter aus dem Datenblatt

Calculation of the voltage V_{RL}

First, the voltage V_{RL} is calculated, which drops across R_L, when the transistor is conducting. To do this, subtract the saturation voltage V_{ECSat}, which drops across the transistor, from the supply voltage V_{cc}.

$$V_{RL} = V_{CC} - V_{EC\ sat}$$

Figure 5: Formula for calculating the voltage V_L across the load

Load current I_L

Then the collector current is calculated, which flows through R_L when the transistor is switched on. To do this, divide V_{RL} by the load resistance R_L to get I_L.

$$I_{RL} = \frac{V_{RL}}{R_L} = \frac{V_{CC} - V_{EC\,sat}}{R_L}$$

Figure 6: Formula for calculating the load current I_L

Can the transistor handle the current?

Now check whether the transistor can withstand the load current. I_L must be smaller than $I_C$max and I_E max from the data sheet. If the transistor does not withstand the current, a different transistor must be must be chosen.

Base resistor R_B

To determine the base resistance R_B, first calculate the required base current I_B. Since the transistor in DC mode is a current amplifier with a fixed amplification factor h_{FE} a base current is required which is larger than I_L divided by h_{FE}. In order to get make the transistor going into a strong saturation and achieving a fast switching time, the base current should be 4 to 10 times higher than I_{FE}.

$$I_{B\,on} = \frac{I_{C\,on} \cdot 7}{h_{FE}}$$

Figure 7: Formula for calculating the base current I_B

The voltage across the base resistor of the conduction PNP transistor is V_{EB} less than the supply voltage V_{cc}. With this value and the base current, the required base resistor can be calculated.

$$R_B = \frac{V_{CC} - V_{EB}}{I_{B\,on}}$$

Figure 8: Formula for calculating the base resistor R_B

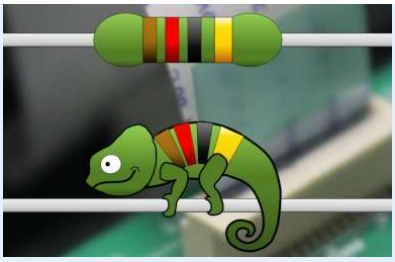
The PNP circuit in the off state

Im sperrenden Zustand wird V_{in} auf V_{cc} geschaltet. So kann kein Strom aus der Basis hinausfliessen, derTransistor sperrt und der Laststrom I_L kommt zum erliegen In the blocking state, V_{in} is pulled to V_{cc}. In this way no current can flow out of the base, the transistor blocks and the load current I_L gets zero.

Losses in the on state and in the off state

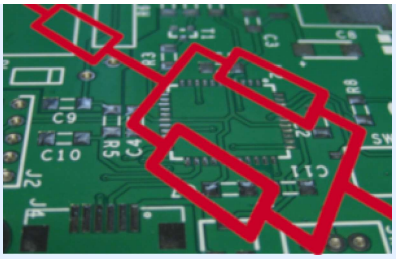
In practice, minimal leakage currents always flow into and out of the transistor in the blocking state. How large they are can be found in the data sheet of the transistor data sheet. And since the transistor remains a low resistance in the conducting state a small saturation voltage V_{ECsat} always remains between emitter and collector. Despite these losses, the bipolar transistor is a good switch which can be used for most semiconductor switching applications.

That could bore you too:



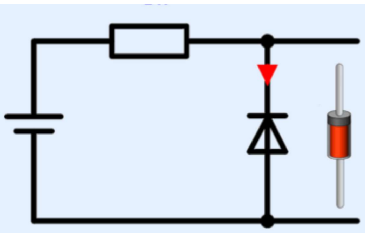
Basics for Nerds

Resistor Color Code



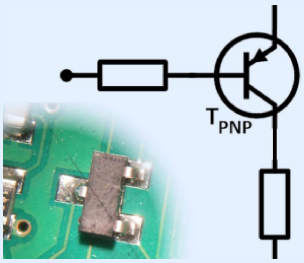
Circuit calculation

Mixed Circuits



Semiconductor basics

Diode in forward and reverse bias



Semiconductor basics

PNP transistor as a switch