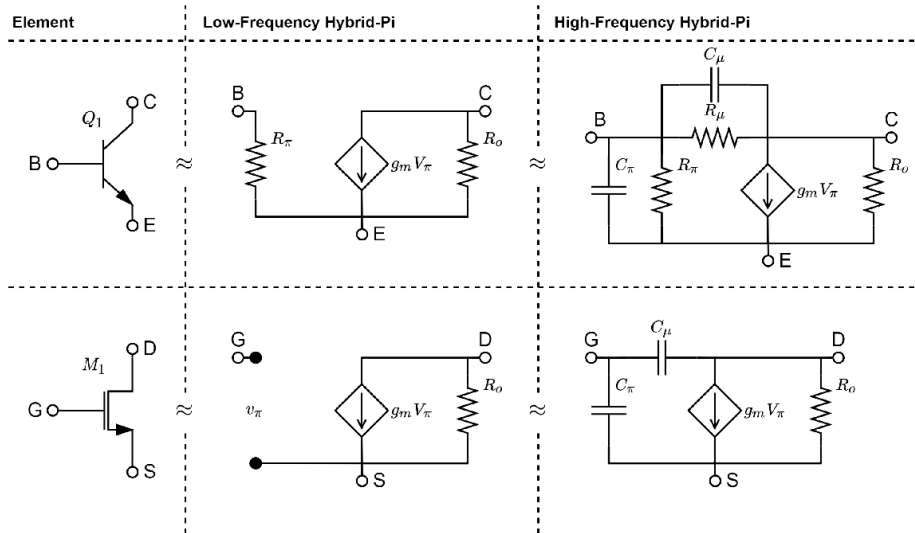


# Transistor circuits

ELABorate can handle transistors by modelling them using an appropriate set of linear elements.

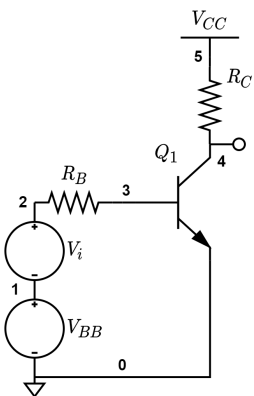


## 1. BJTs

We start by loading in a circuit containing a BJT. In this case, it's a simple common-source amplifier with biasing.

```
circuit = Circuit('circuits/bjt_cs_amp.txt');
circuit.list
```

```
ans =
'VBB 0 1 DC VBB
VCC 5 0 DC VCC
Vi 1 2 AC Vi
RB 2 3 RB
RC 4 5 RC
Q1 3 4 0 beta_Q1
'
```

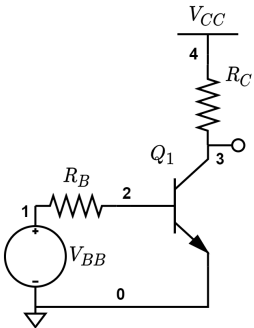


Typically, when analyzing such circuits, we split up the analysis into a DC-part and an AC-part. To find the DC-equivalent of the circuit above, one can simply call the `dc_eq` function (short for *direct-current-equivalent*).

This function uses lower-level functions such as `short`, `open` and `clean` to modify the given circuit into its DC-equivalent.

```
ELAB.dc_eq(circuit);
circuit.list
```

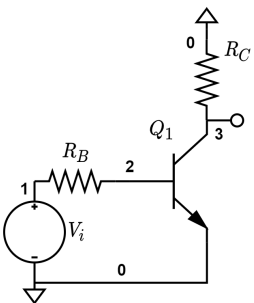
```
ans =
    'VBB 0 1 DC VBB
    VCC 4 0 DC VCC
    RB 1 2 RB
    RC 3 4 RC
    Q1 2 3 0 beta_Q1
    '
```



Similarly, the program can convert the given circuit into its AC-equivalent.

```
circuit = Circuit('circuits/bjt_cs_amp.txt');
ELAB.ac_eq(circuit);
circuit.list
```

```
ans =
    'Vi 0 1 AC Vi
    RB 1 2 RB
    RC 3 0 RC
    Q1 2 3 0 beta_Q1
    '
```

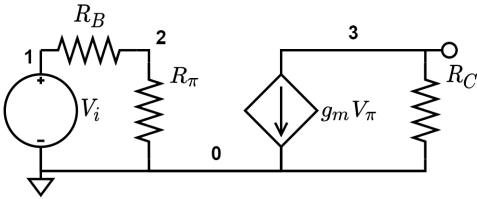


From the AC-equivalent, you can model the transistor as linear elements, using the `hpi` (hybrid-pi) function, which can either assume the circuit will operate in low-frequency "lf" or high-frequency "hf". We can use the `clone` function to preserve the AC-equivalent.

```
lf_circuit = circuit.clone;
ELAB.hybrid_pi(lf_circuit, 'lf');
```

```
lf_circuit.list
```

```
ans =  
'Vi 0 1 AC Vi  
RB 1 2 RB  
RC 3 0 RC  
R_pi_Q1 2 0 R_pi_Q1  
R_o_Q1 3 0 R_o_Q1  
G_m_Q1 3 0 0 2 G_m_Q1  
,
```



```
hf_circuit = circuit.clone;  
ELAB.hybrid_pi(hf_circuit, 'hf');  
hf_circuit.list
```

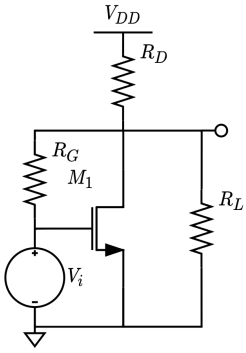
```
ans =  
'Vi 0 1 AC Vi  
RB 1 2 RB  
RC 3 0 RC  
R_pi_Q1 2 0 R_pi_Q1  
R_o_Q1 3 0 R_o_Q1  
R_mu_Q1 2 3 R_mu_Q1  
C_pi_Q1 2 0 C_pi_Q1  
C_mu_Q1 2 3 C_mu_Q1  
G_m_Q1 3 0 0 2 G_m_Q1  
,
```

## 2. MOSFETs

All the same functionality exists for circuits containing MOSFET transistors. To illustrate this, we load in this circuit.

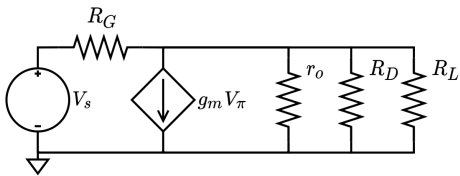
```
circuit = Circuit('circuits/mos_cs_amp.txt');  
circuit.list
```

```
ans =  
'Vi 1 0 AC Vi  
VDD 3 0 DC VDD  
RD 2 3 RD  
RG 1 2 RG  
RL 2 0 RL  
M1 1 2 0 100  
,
```



```
ELAB.hybrid_pi(circuit, 'lf');
circuit.list
```

```
ans =
'Vi 1 0 AC Vi
RD 2 0 RD
RG 1 2 RG
RL 2 0 RL
R_o_M1 2 0 R_o_M1
G_m_M1 2 0 0 1 G_m_M1
'
```



As this circuit contains three resistors in parallel, we may want to simplify the circuit for further analysis.

```
ELAB.simplify(circuit);
circuit.list
```

```
ans =
'Vi 1 0 AC Vi
RG 1 2 RG
Req1 2 0 (RD*RL*R_o_M1)/(RD*RL+RD*R_o_M1+RL*R_o_M1)
G_m_M1 2 0 0 1 G_m_M1
'
```