Experiment 2

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Bachelor of Technology

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August 21, 2025

Objective

Determine the small-signal DC parameters of Diode, BJT, and MOSFET devices using both hand calculations and simulation.

1 Diode

Parameters and Formulae Used

- **Shockley Equation**

$$I_D = I_s \left(e^{\frac{V_D}{nV_T}} - 1 \right)$$

- **Dynamic Resistance** r_d
  - Hand Calculation: $r_d = \frac{\eta V_T}{I_D}$
  - Experimental: $r_d = \frac{\partial V_D}{\partial I_D}$ (from graph)

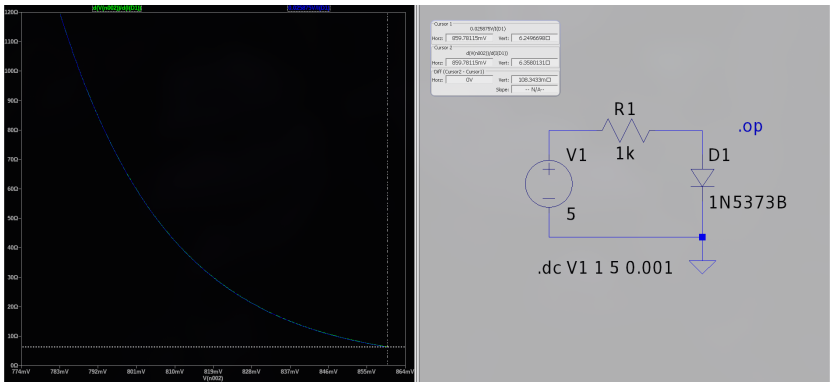
1.1 Plots

Operating Point values used,

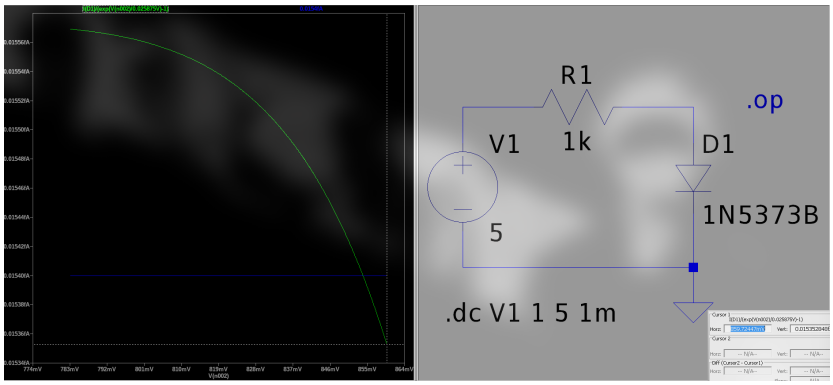
```
        --- Operating Point ---

V(n002):      0.859781      voltage
V(n001):      5             voltage
I(V1):        -0.00414022   device_current
I(R1):        -0.00414022   device_current
I(D1):        0.00414022    device_current
```

I_s of the diode chosen is $0.0154fA$

1. r_d



2. I_s



Experimental vs Theoretical Results

Parameter	Experimental	Theory	Error (%)
r_d	6.358 $k\Omega$	6.249 $k\Omega$	1.71
I_s	0.01535 fA	0.0154 fA	2.27

2 BJT

Parameters and Formulae Used

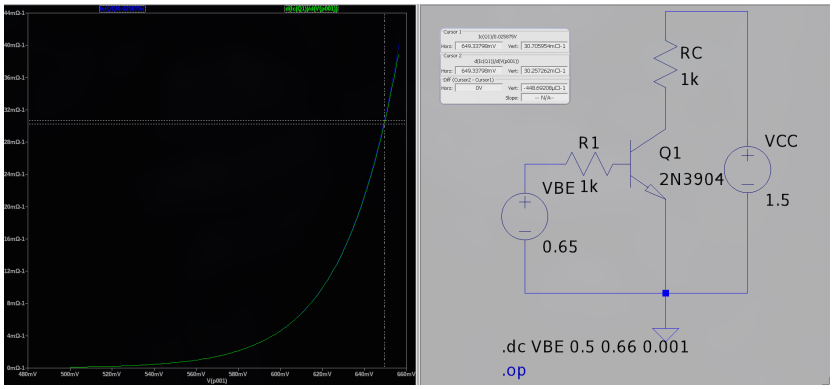
- **Transconductance** g_m
  - Hand Calculation: $g_m = \frac{I_C}{\eta V_T}$
  - Experimental: $g_m = \frac{\partial I_C}{\partial V_{BE}}$ (from graph)
- **Input Resistance** r_π
  - Hand Calculation: $r_\pi = \frac{\eta V_T}{I_B}$
  - Experimental: $r_\pi = \frac{\partial V_{BE}}{\partial I_B}$ (from graph)
- **Current Gain** β
  - Hand Calculation: $\beta = \frac{I_C}{I_B}$
  - Experimental: $\beta = \frac{\partial I_C}{\partial I_B}$
- **Output Resistance** r_o
  - Hand Calculation: $r_o = \frac{1}{\lambda I_C}$
  - Experimental: $r_o = \frac{\partial V_{CE}}{\partial I_C}$ (from graph)

2.1 Plots

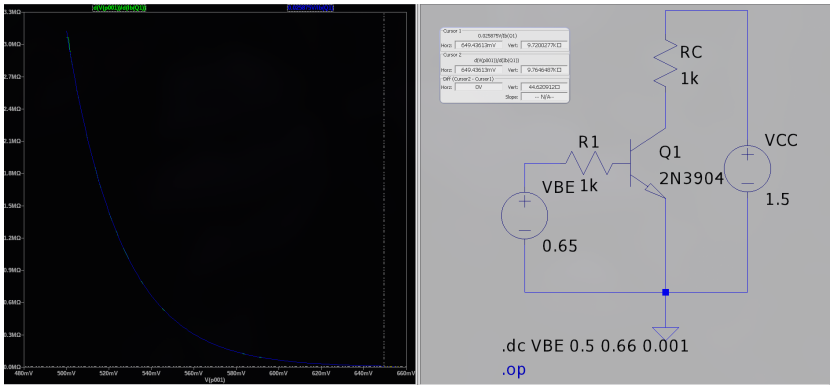
Operating Point values used, For the BJT chosen, $\eta = 1$

```
        --- Operating Point ---

V(p001):      0.647526      voltage
V(n003):      0.65          voltage
V(n002):      0.758491      voltage
V(n001):      1.5           voltage
Ic(Q1):       0.000741509   device_current
Ib(Q1):       2.47353e-06   device_current
Ie(Q1):       -0.000743983  device_current
Is(Q1):       0             device_current
I(VCC):       -0.000741509  device_current
I(R1):        -2.47353e-06  device_current
I(RC):        0.000741509   device_current
I(VBE):       -2.47353e-06  device_current
```

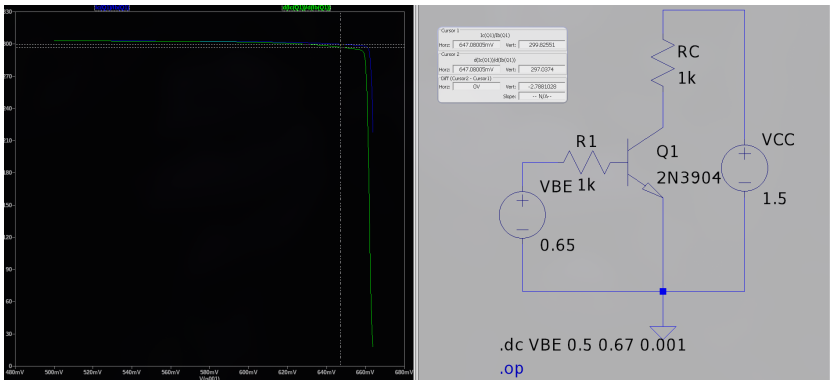
1. g_m



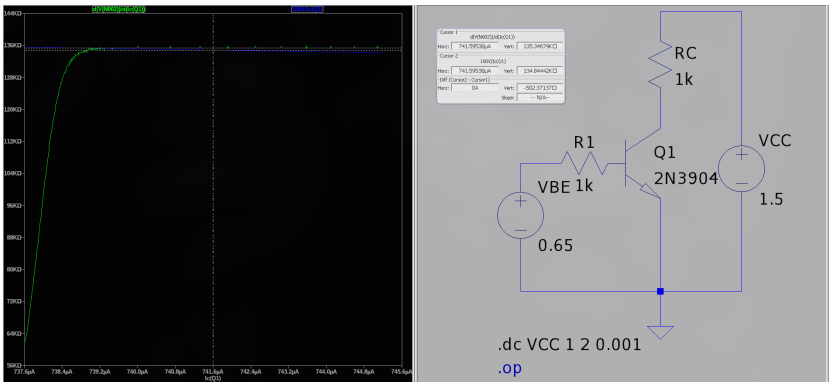
2. r_π



3. β



4. r_0



Experimental vs Theoretical Results

Parameter	Experimental	Theory	Error (%)
g_m	30.257 $m\Omega^-1$	30.705 $m\Omega^-1$	1.45
r_π	9.764 $k\Omega$	9.720 $k\Omega$	0.45
β	297.304	299.825	0.93
r_0	135.346 $k\Omega$	134.844 $k\Omega$	0.37

3 MOSFET

Parameters and Formulae Used

- **Transconductance** g_m
  - Hand Calculation: $g_m = \frac{2I_D}{V_{GS}-V_{TH}}$
  - Experimental: $g_m = \frac{\partial I_D}{\partial V_{GS}}$ (from graph)
- **Output Resistance** r_o
  - Hand Calculation: $r_o = \frac{\left(\frac{1}{\lambda}+V_{GS}\right)}{I_D} \approx \frac{1}{\lambda I_D}$
  - Experimental: $r_o = \frac{\partial V_{DS}}{\partial I_D}$ (from graph)

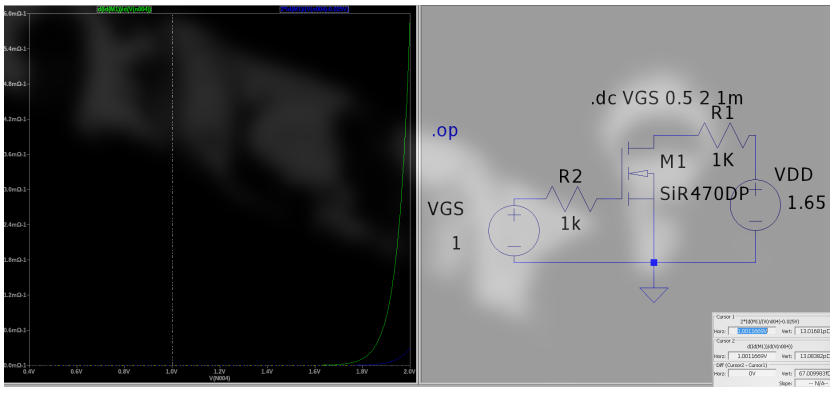
3.1 Plots

Operating Point values used, For the chosen MOSFET, $\lambda = \frac{1}{V_A} = 1000, V_{TH} =$

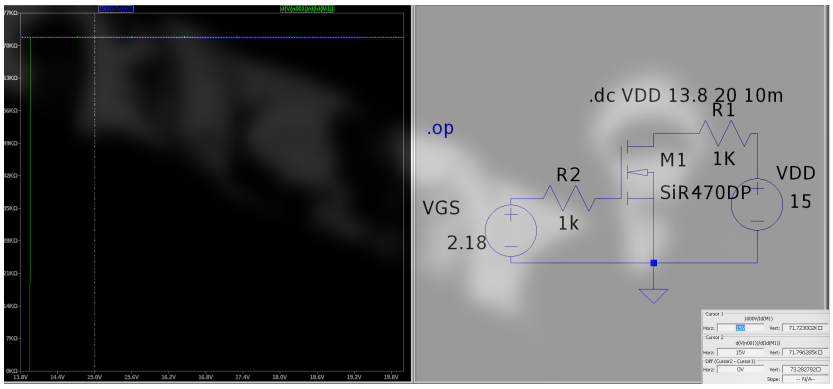
```
        --- Operating Point ---

V(n004):      1              voltage
V(n002):      1.65           voltage
V(n001):      1.65           voltage
V(n003):      1              voltage
Id(M1):       1.57289e-09    device_current
Ig(M1):       -1.54195e-09   device_current
Is(M1):       -3.09387e-11   device_current
I(VDD):       -3.54647e-11   device_current
I(R2):        1.45217e-16    device_current
I(VGS):       1.45283e-16    device_current
I(R1):        3.54647e-11    device_current
```

$0.025V$

1. g_m



2. r_0



Experimental vs Theoretical Results

Parameter	Experimental	Theory	Error (%)
g_m	13.083 $p\Omega^-1$	13.016 $p\Omega^-1$	0.51
r_0	71.796 $k\Omega$	71.723$k\Omega$	0.1

4 Conclusion

The experiment to conduct small signal analysis and verify the parameters with hand calculations was successful with a maximum error of 5%.