

# Circuits Theory and Electronic Fundamentals

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## Lab 2: RC Circuit Analysis

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## 1 Introduction

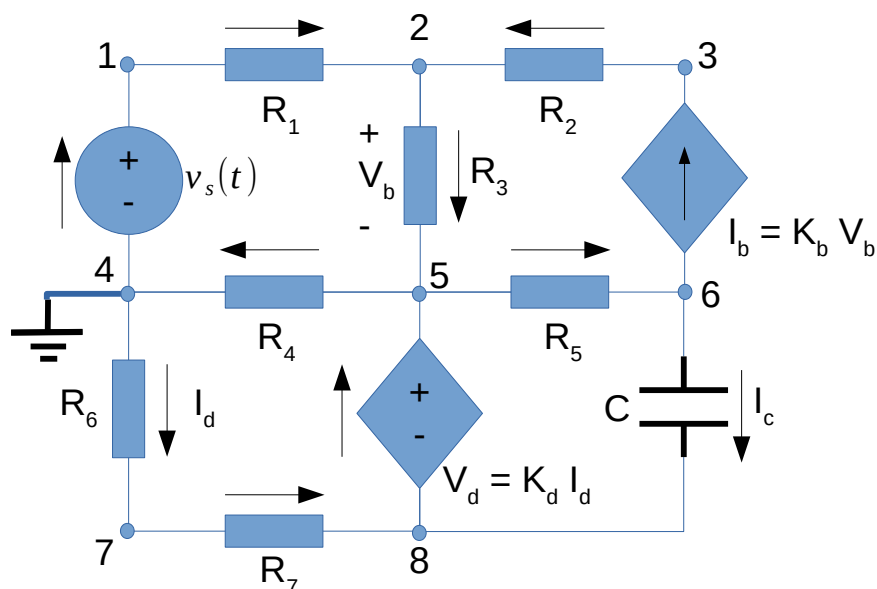


Figure 1: Circuit to be analysed in this laboratory assignment.

Designation	Value [V, kΩ, mS or μF]
$R_1$	1.04053890347
$R_2$	2.00185929606
$R_3$	3.06593231919
$R_4$	4.15163583349
$R_5$	3.03409481751
$R_6$	2.05654586148
$R_7$	1.00587575204
$V_s$	5.16821048288
$C$	1.0127707267
$K_b$	7.29055867767
$K_d$	8.22649929708

Table 1: Values obtained by running the file t2\_datagen.py. Resistances  $R_i$  and constant  $K_d$  are in kΩ, voltage  $V_s$  is in volts, capacitance  $C$  is in microfarads and constant  $K_b$  is in milisiemens.

## 2 Theoretical Analysis

### 2.1 Exercise 1

In this section, the circuit shown in Figure 1 is analysed theoretically, by using the node method. The Kirchhoff Current Law (KCL) states that the sum of the currents converging or diverging in a node is null. The nodes considered for the following equations are those represented in Figure 1. Using KCL and Ohm's Law (which can also be written as  $I = VG$ ) in nodes not connected to voltage sources and additional equations for nodes related by voltage sources, it is possible to obtain a linear system from which the voltages at nodes  $V_1$  to  $V_8$  and currents in resistances  $R_1$  to  $R_7$  can be determined.

The following linear system is obtained:

$$\begin{pmatrix}
 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\
 -\frac{1}{R_1} & \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} & -\frac{1}{R_2} & 0 & -\frac{1}{R_3} & 0 & 0 & 0 \\
 0 & -K_b - \frac{1}{R_2} & \frac{1}{R_2} & 0 & K_b & 0 & 0 & 0 \\
 0 & 0 & 0 & 1 & 0 & 0 & 0 & 0 \\
 0 & -\frac{1}{R_3} & 0 & -\frac{1}{R_4} & \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5} & -\frac{1}{R_5} & -\frac{1}{R_7} & \frac{1}{R_7} \\
 0 & K_b & 0 & 0 & -\frac{1}{R_5} - K_b & \frac{1}{R_5} & 0 & 0 \\
 0 & 0 & 0 & 0 & 0 & 0 & \frac{1}{R_6} + \frac{1}{R_7} & -\frac{1}{R_7} \\
 0 & 0 & 0 & -\frac{K_d}{R_6} & 1 & 0 & \frac{K_d}{R_6} & -1
 \end{pmatrix}
 \begin{pmatrix}
 V_1 \\
 V_2 \\
 V_3 \\
 V_4 \\
 V_5 \\
 V_6 \\
 V_7 \\
 V_8
 \end{pmatrix}
 =
 \begin{pmatrix}
 V_s \\
 0 \\
 0 \\
 0 \\
 0 \\
 0 \\
 0 \\
 0
 \end{pmatrix}
 \quad (1)$$

By solving the linear system 1, the following values for node voltages and branch currents (calculated by using Ohm's Law) are obtained:

Designation	Value [A or V]
$I_1$	2.341433E-04
$I_2$	-2.451090E-04
$I_3$	-1.096569E-05
$I_4$	1.194275E-03
$I_5$	-2.451090E-04
$I_6$	9.601318E-04
$I_7$	9.601318E-04
$I_b$	-2.451090E-04
$I_c$	4.336809E-19
$I_{V_s}$	2.341433E-04
$I_{V_d}$	9.601318E-04
$V_1$	5.168210E+00
$V_2$	4.924575E+00
$V_3$	4.433902E+00
$V_5$	4.958195E+00
$V_6$	5.701879E+00
$V_7$	-1.974555E+00
$V_8$	-2.940328E+00

Table 2: Values of node voltages (in volts) and branch currents (in amperes). Current  $I_i$  corresponds to the current passing through resistance  $R_i$ .

### 3 Simulation Analysis

#### 3.1 Exercise 1

Table 3 shows the simulated operating point results for the circuit presented in Figure 1. Again, currents designated below as  $I_i$  refer to the currents passing through the respective resistances,  $R_i$ .

Designation	Value [A or V]
$I_1$	2.341433e-04
$I_2$	-2.45109e-04
$I_3$	-1.09657e-05
$I_4$	1.194275e-03
$I_5$	-2.45109e-04
$I_6$	9.601318e-04
$I_7$	9.601318e-04
$I_b$	-2.45109e-04
$I_c$	0.000000e+00
$I_{V_s}$	-2.34143e-04
$I_{V_d}$	-9.60132e-04
$V_1$	5.168210e+00
$V_2$	4.924575e+00
$V_3$	4.433902e+00
$V_5$	4.958195e+00
$V_6$	5.701879e+00
$V_7$	-1.97456e+00
$V_8$	-2.94033e+00

Table 3: Operating point analysis table. Currents  $I_i$  are in amperes; voltages  $V_i$  are in volts.

Comparing the theoretical analysis results presented in Table 2 and the results in Table 3, we can notice almost no differences. This was to be expected, since the circuit has no time dependency - meaning it's equal at any point in time. The biggest differences are in the values of  $I_{V_s}$  and  $I_{V_d}$ , which are symmetrical to those presented in Table 2. This is because Ngspice considers the current direction of voltage sources going from  $+$  to  $-$ , which is exactly the opposite direction which was chosen for each voltage source, as seen in Figure 1. There is only a small difference between the two values of  $I_c$ , although it is negligible.

## 4 Conclusion