EE341 Fall 2019 HW 2
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github.com/LewisCollum/microelectronics

Problem 4.35

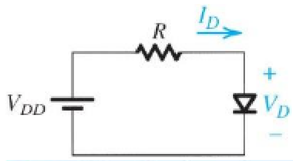


Fig. 10

4.35 Use the iterative-analysis procedure to determine the diode current and voltage in the circuit of Fig. 4.10 for $V_{DD} = 1$ V, $R = 1$ kΩ, and a diode having $I_S = 10^{-15}$ A.

Given

```
import numpy
import pint
unit = pint.UnitRegistry()

R = 1 * unit.kohm
v = {'DD': 1 * unit.V, 'D': []}
i = {'S': 10e-15 * unit.A, 'D': []}
```

Assume

$V_T = 25\text{mV}$ (thermal voltage at room temperature).

$V_{D[0]} = 0.7\text{V}$

```
v['T'] = 25 * unit.mV
v['D'].append(0.7 * unit.V)
```

Solve for $I_{D[0]}$ from diode characteristic equation

$$I_{D[0]} = I_S \cdot e^{V_{D[0]}/V_T}$$

```
i['D'].append((i['S']*numpy.exp(v['D'][0] / v['T'])).to('mA'))
print("\\noindent\\[I_{D[0]} =", f"{i['D'][0]:.3~Lx}\\]")
```

$$I_{D[0]} = 14.5\,\text{mA}$$

Solve for $I_{D[1]}$ by KVL

$$V_{DD} = I_D R + V_D$$

$$\text{So, } I_D = \frac{V_{DD} - V_D}{R}$$

```
i['D'].append(((v['DD'] - v['D'][0])/R).to('mA'))
print("\\noindent\\[I_{D[1]} =", f"{i['D'][1]:.3~Lx}\\]")
```

$$I_{D[1]} = 0.3\,\text{mA}$$

Iterative solution for V_D and I_D

$$V_{D[n]} - V_{D[n-1]} = V_T \ln \frac{I_{D[n]}}{I_{D[n-1]}}$$

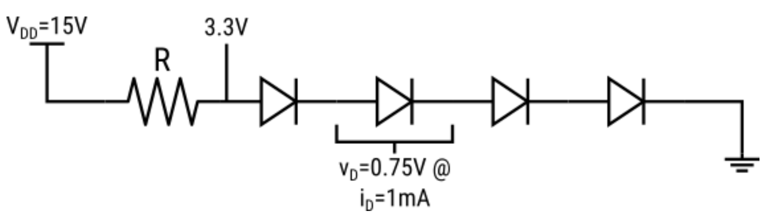
```
iterations = 7

table = [["Iteration", "$V_D$ (V)", "$I_D$ (mA)"],
         [0, f"{v['D'][0].magnitude:.6}", f"{i['D'][0].magnitude:.6}"]]

for n in range(1, iterations+1):
    v['D'].append(v['D'][n-1] + v['T']*numpy.log(i['D'][n]/i['D'][n-1]))
    table.append([n, f"{v['D'][n].magnitude:.6}", f"{i['D'][n].magnitude:.6}"])
    i['D'].append(((v['DD'] - v['D'][n])/R).to('mA'))

print(table)
```

Iteration	V_D (V)	I_D (mA)
0	0.7	14.4626
1	0.603112	0.3
2	0.610108	0.396888
3	0.609664	0.389892
4	0.609692	0.390336
5	0.60969	0.390308
6	0.609691	0.39031
7	0.609691	0.390309

PROBLEM 4.37

D 4.37 Assuming the availability of diodes for which $v_D = 0.75$ V at $i_D = 1$ mA, design a circuit that utilizes four diodes connected in series, in series with a resistor R connected to a 15-V power supply. The voltage across the string of diodes is to be 3.3 V.

Circuit Design



Given

```
import api.homework_2 as api
import pint
import math
unit = pint.UnitRegistry()

diodeCount = 4
i = {'D': [1 * unit.mA]}
v = {'DD': 15 * unit.V, 'D': [0.75 * unit.V], 'T': 25 * unit.mV, 'O': 3.3 * unit.V}
```

Solve for I_S

Finding the saturation current using the characteristic diode equation allows us to use the equation again to solve for the current of the circuit with a different voltage across the diodes.

```
i['S'] = i['D'][0]*math.exp(-v['D'][0]/v['T'])
api.printEquation("I_S", i['S'], 4)
```

$$I_S = 9.358 \times 10^{-14}\,\text{mA}$$

Solve for $V_{D[1]}$ and $I_{D[1]}$

The output voltage, V_O, must be split among the diodes in series. Once we have the voltage drop for each diode, we find the corresponding current using the characteristic diode equation.

```
v['D'].append(v['O']/diodeCount)
i['D'].append(i['S']*math.exp(v['D'][1]/v['T']))
api.printEquation("V_{D[1]}", v['D'][1], 4)
api.printEquation("I_{D[1]}", i['D'][1], 4)
```

$$V_{D[1]} = 0.825\,\mathrm{V}$$

$$I_{D[1]} = 20.09\,\mathrm{mA}$$

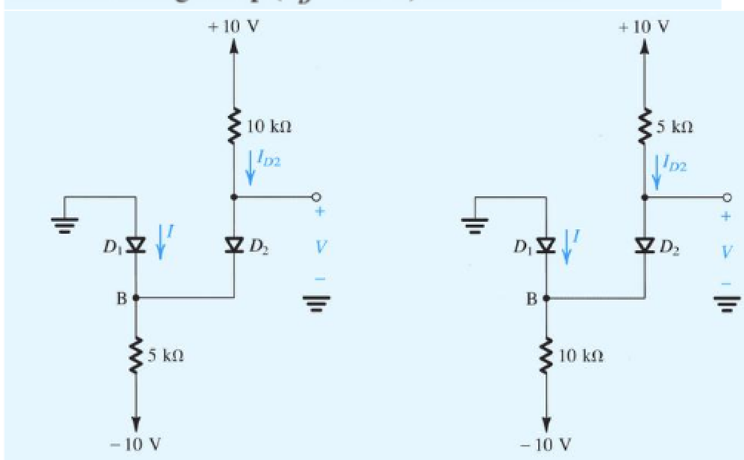
Solve for R

```
R = ((v['DD'] - v['O'])/i['D'][1]).to('ohm')
api.printBoxedEquation("R", R, 4)
```

$$\boxed{R = 582.5\,\Omega}$$

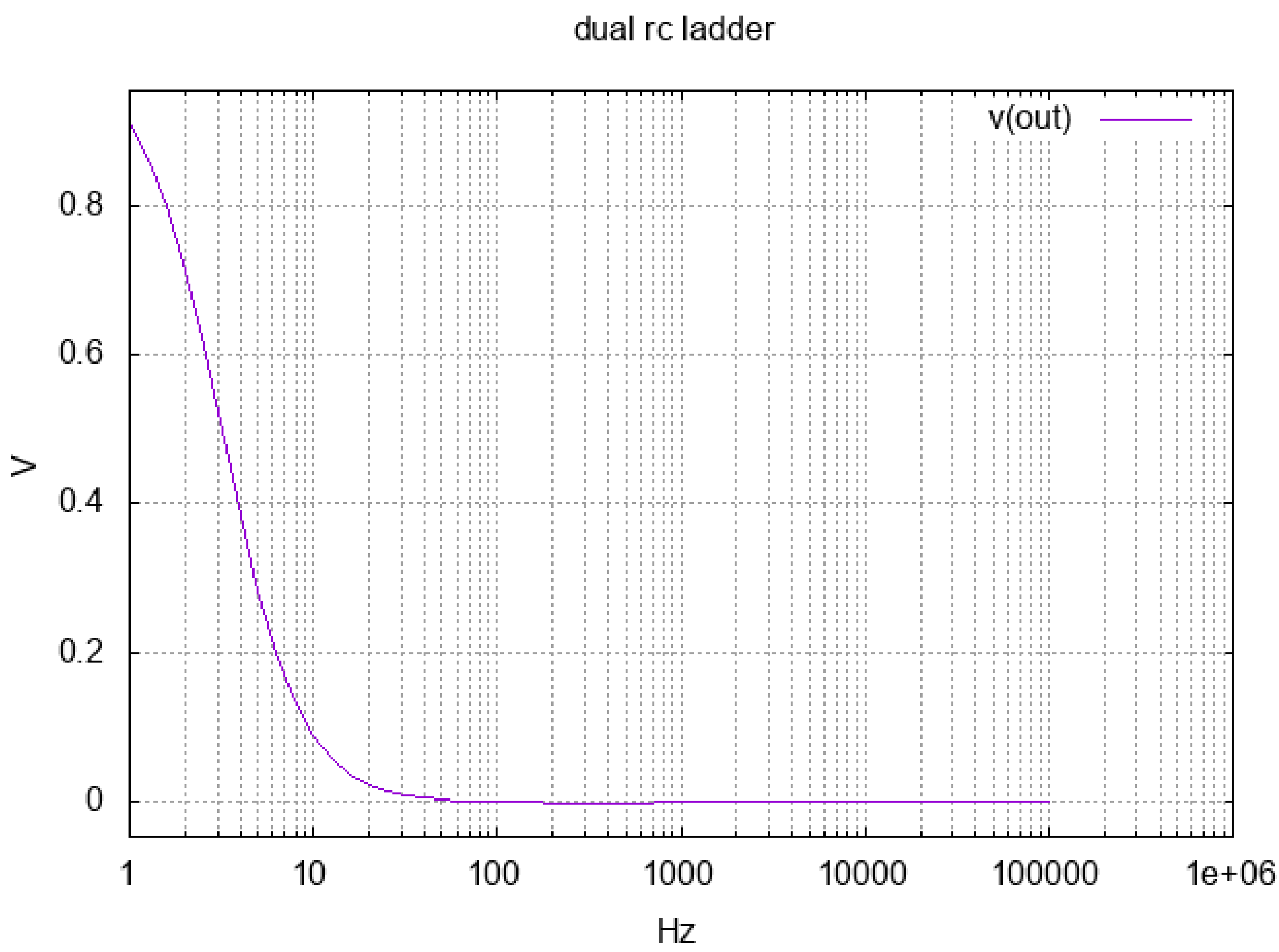
PROBLEM 4.40

4.40 Solve the problems in Example 4.2 using the constant-voltage-drop ($V_D = 0.7$ V) diode model.



PROBLEM SPICE

```
.title dual rc ladder
R1 int in 5k
V1 in 0 dc 0 ac 1 PULSE (0 10 1u 1u 1u 1 1)
R2 out int 1k
C1 int 0 10u
C2 out 0 100n
.control
ac dec 10 1 100k
set gnuplot_terminal=png/quit
gnuplot $file v(out)
.endc
.end
```



PROBLEM APPENDIX: CODE

```
import pint

a = 5

def printEquation(tag, value, digits):
    print(f"\\noindent\\[{tag} = {value:.{digits}Lx}\\]")

def printBoxedEquation(tag, value, digits):
    print("\\noindent\\[\\boxed{", f"{tag} = {value:.{digits}Lx}", "}\\]")
```