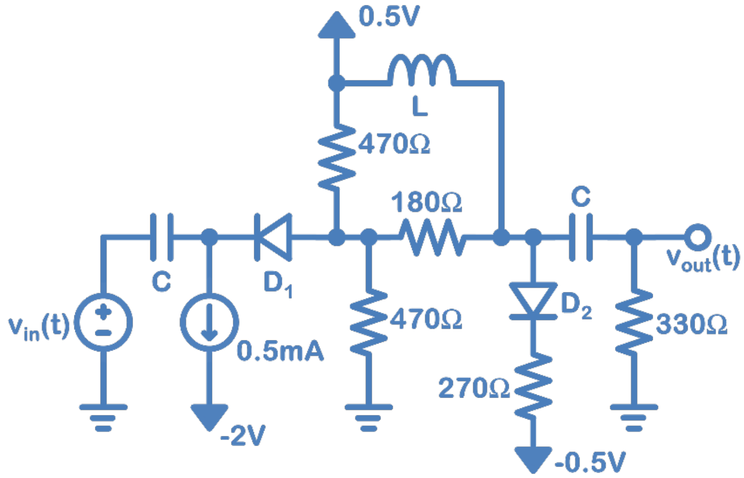
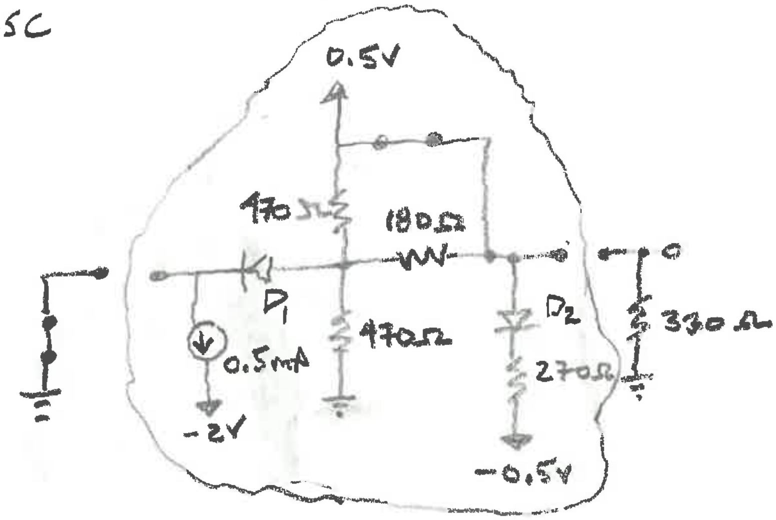
EECS312
Homework 6

Small Signal Analysis

For the circuit below, using n=2.
1) Draw the large signal circuit (do not solve).
2) Draw the small signal circuit and find v_{out}/v_{in}.
Assume large signal diode currents of I_{D1} = 0.5 mA and I_{D2} = 1.0 mA.



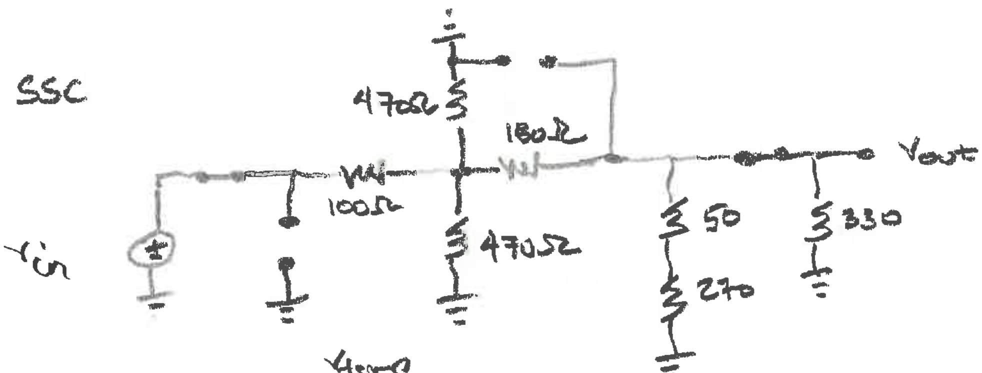
LSC



$$r_{d1} = \frac{2 \cdot 0.025}{0.0005} = 100\,\Omega$$

$$r_{d2} = \frac{2 \cdot 0.025}{0.001} = 50\,\Omega$$

SSC

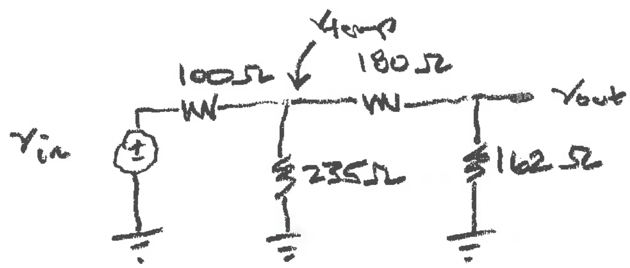


$50 + 270 = 320\,\Omega$

$330 \| 320 = 162\,\Omega$

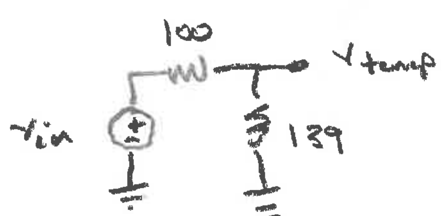
$162 + 180 = 342$

$342 \| 235 = 139$



$$\frac{V_{temp}}{V_{in}} = \frac{139}{100 + 139} = 0.58$$

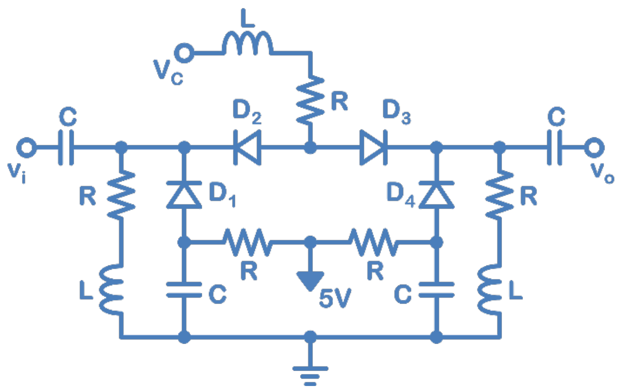
$$\frac{V_{out}}{V_{temp}} = \frac{162}{162 + 180} = 0.47$$



$$\frac{V_{out}}{V_{in}} = \frac{V_{out}}{V_{temp}} \cdot \frac{V_{temp}}{V_{in}} = \underline{0.273}$$

The figure below shows a circuit for an improved Waugh Voltage Controlled Attenuator, where V_C and V_+(5V) are the large-signal voltage sources.

Reference: https://www.microwaves101.com/encyclopedias/waugh-attenuator



Large-Signal Sources.

V_C is the “constant” control voltage.

5V is a constant voltage.

Small-Signal Source.

The small signal input v_i is on the left.

Small-Signal probe.

The small signal output v_o is on the right.

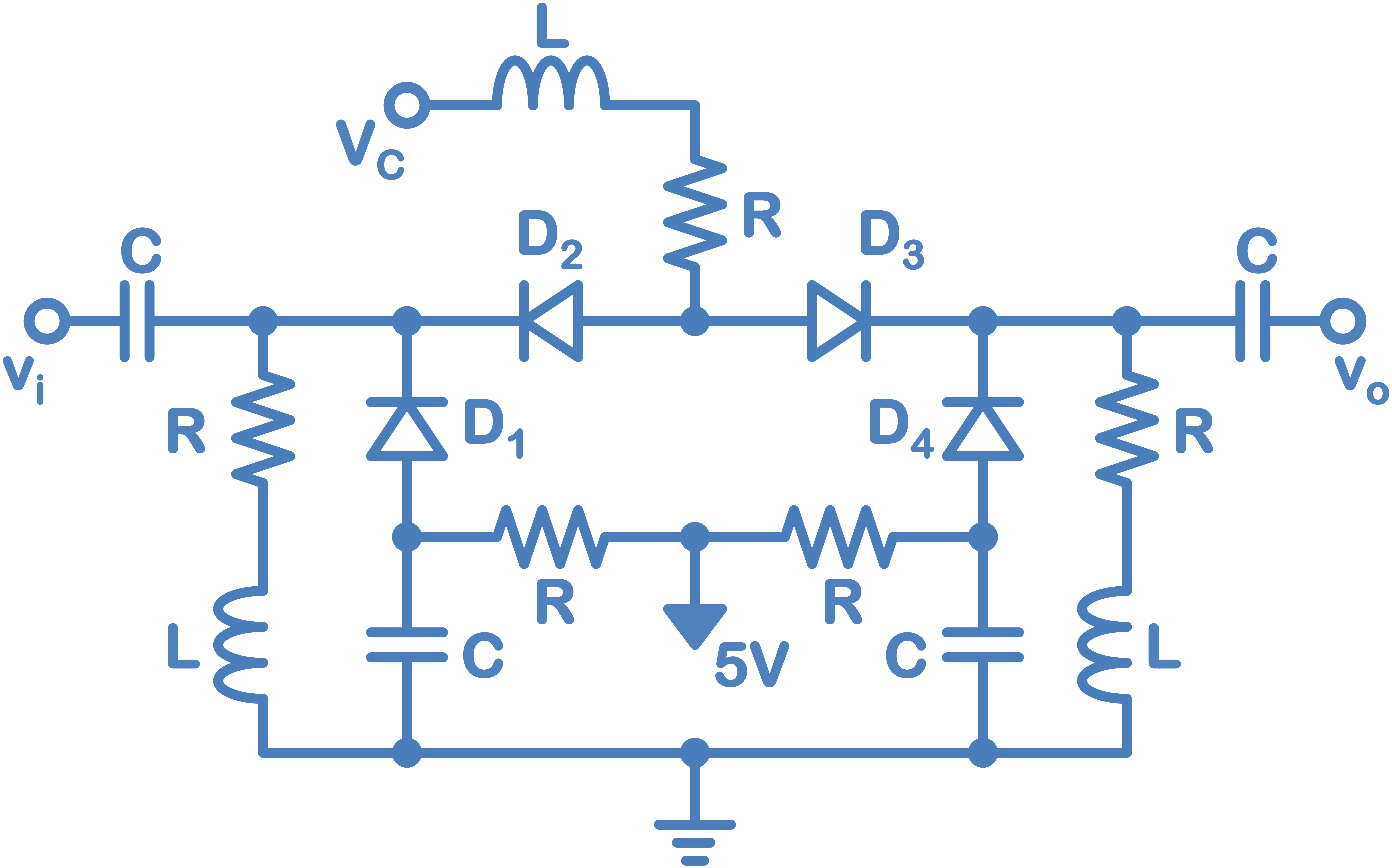
Assume all capacitors and inductors are very large, R=500Ω, and n=1 for all diodes.

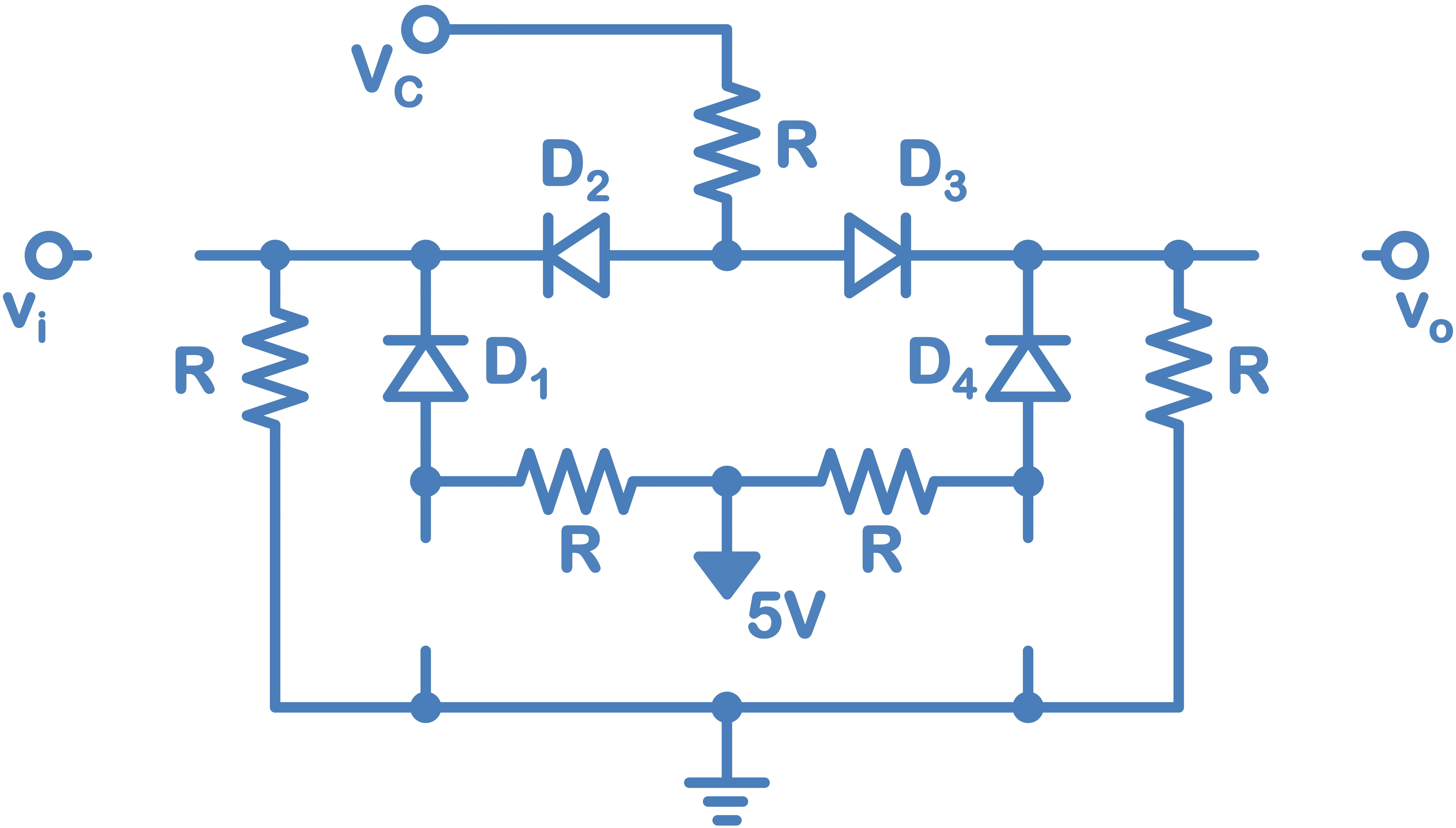
1. Draw the large-signal circuit.
2. Using the 0.7V CVD model, find the large signal diode currents for large signal control voltages:

VC = 3V, 5V, 7V, 9V, 11V, 13V

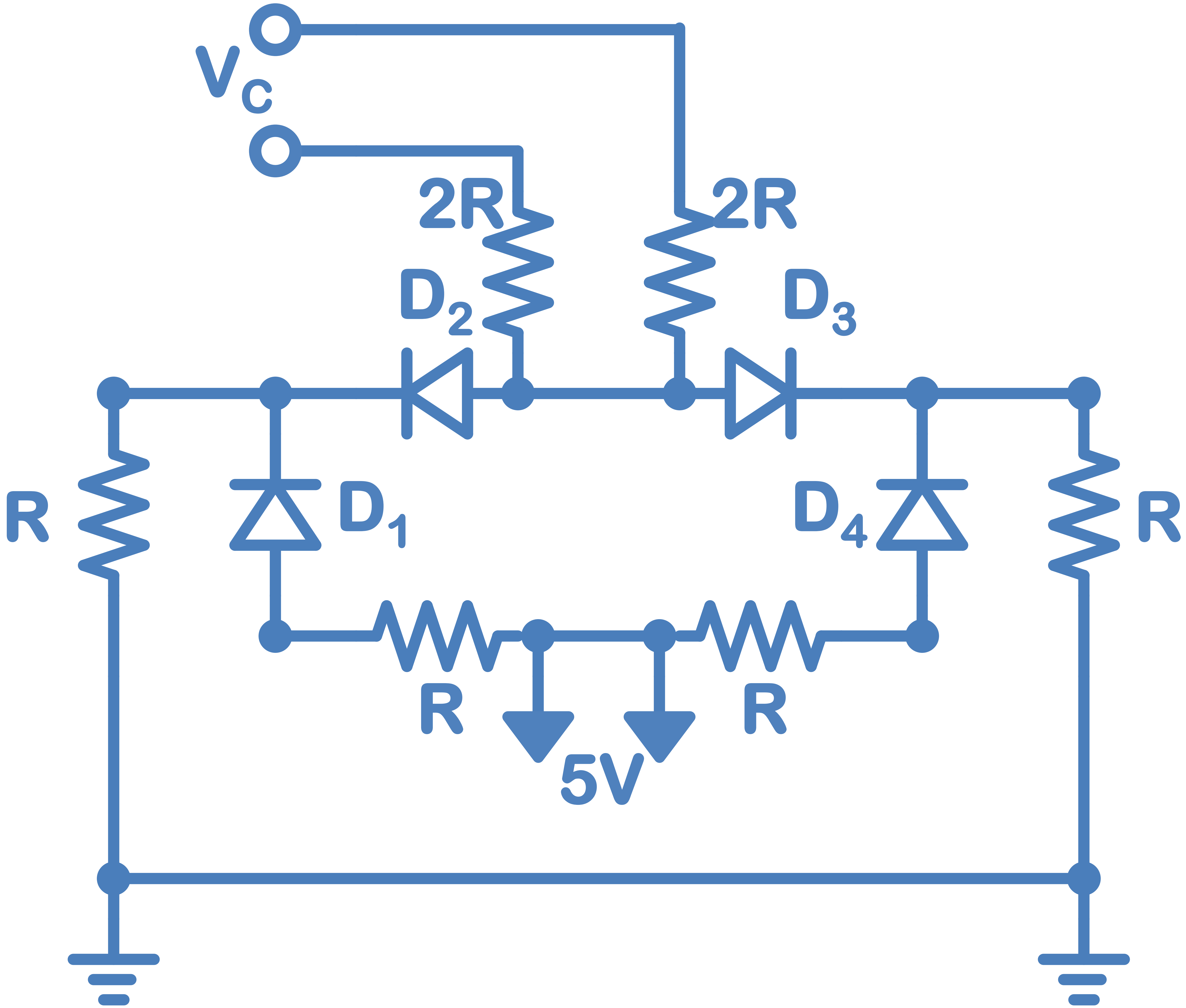
hint: The circuit is symmetrical, so you can just analyze half.
Split the top resistor into two parallel resistors with values 2R=1kΩ.
ID1=ID4, and ID2=ID3

3. Calculate the small signal resistances for the diodes for each control voltage.
4. Draw the small-signal circuit.
5. Find the small signal ratio, vo/vi, for each control voltage.
6. Generate a plot of the small signal ratio in terms of VC using your points.

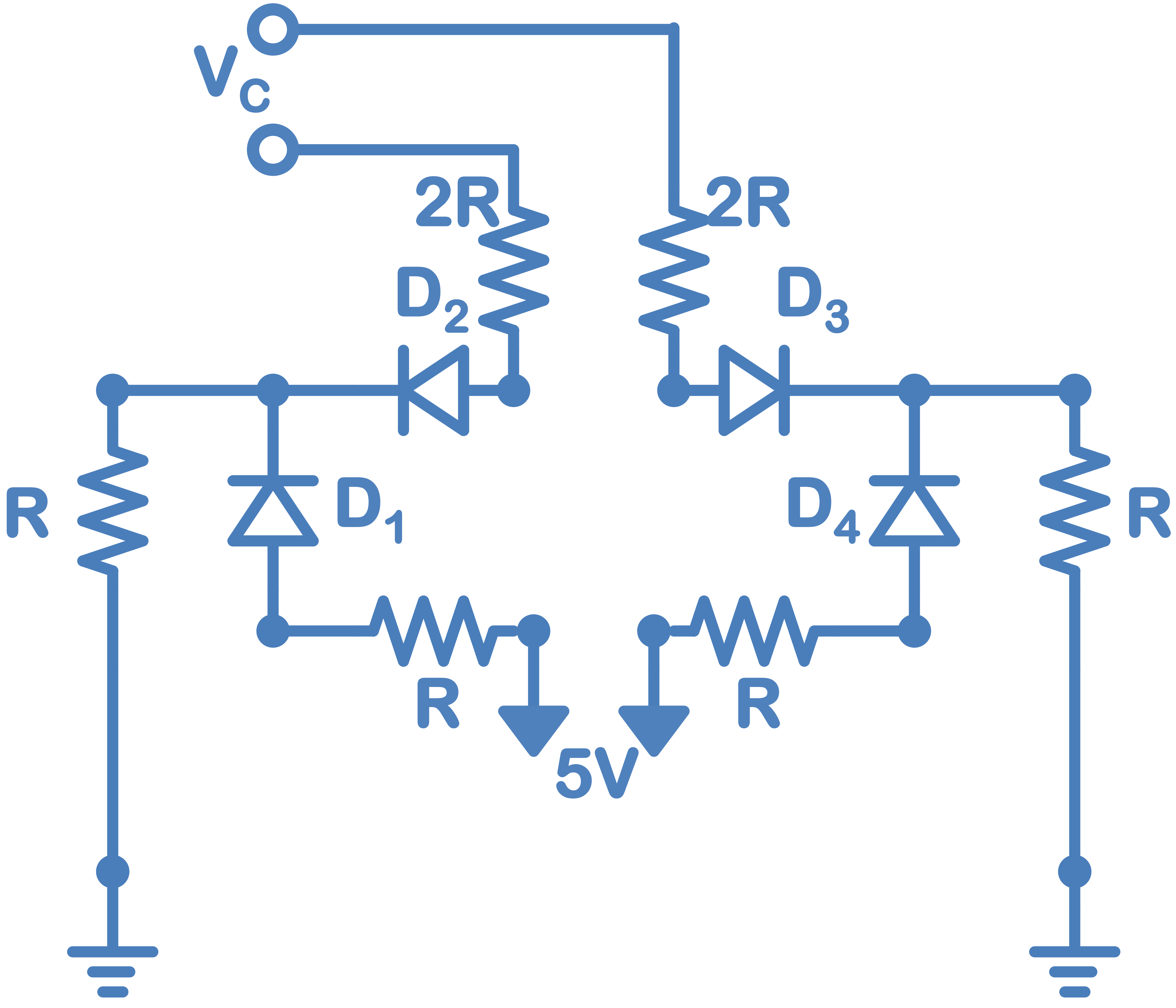

L
V_C
R
D_2
D_3
C
C
v_i
v_o
R
D_1
D_4
R
R
R
L
C
5V
C
L



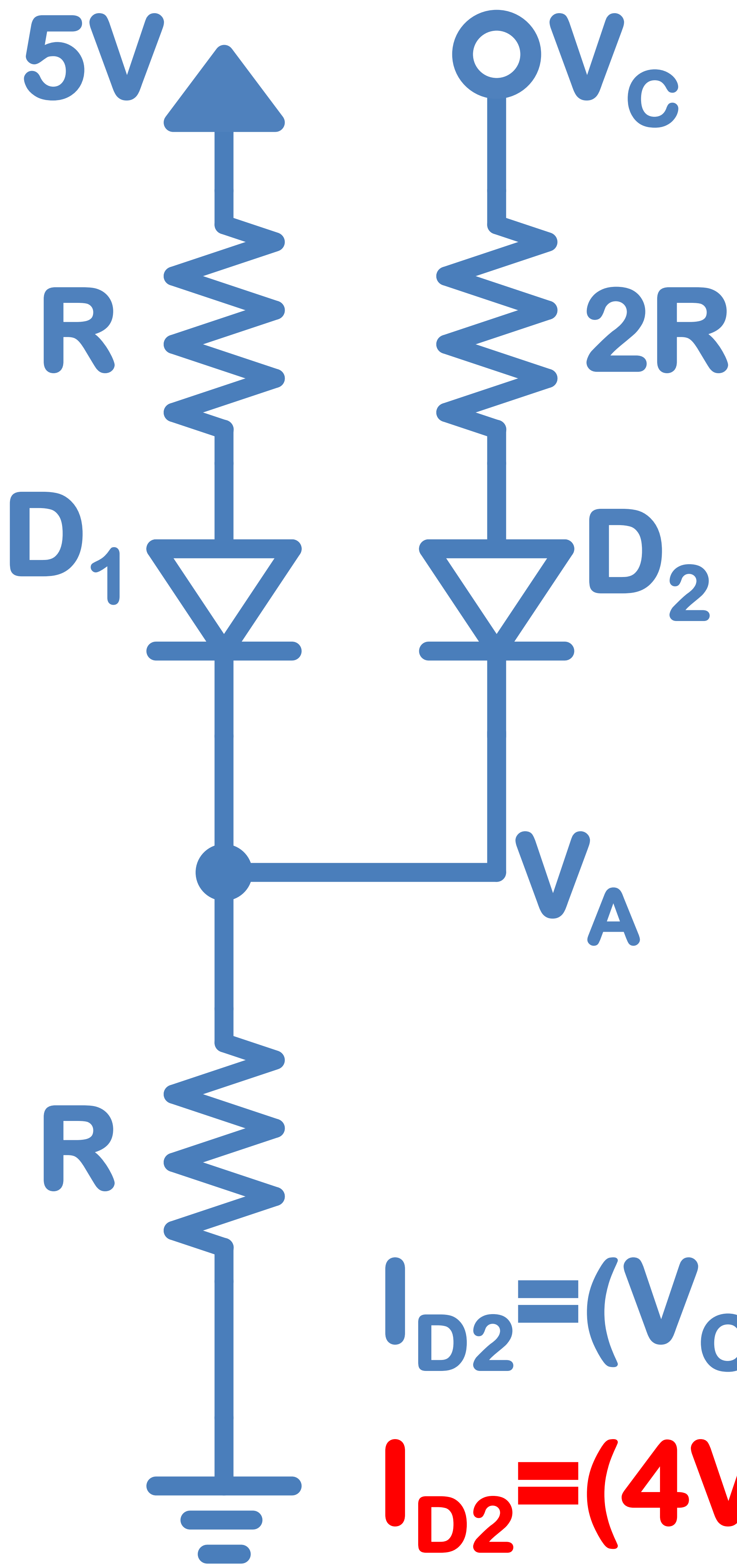
V_C
R
D_2
D_3
v_i
v_o
R
D_1
D_4
R
R
R
5V



V_C
2R
2R
D_2
D_3
R
D_1
D_4
R
R
R
5V



V
C
2R
2R
D
2
D
3
R
D
1
D
4
R
R
R
5V



KCL

$$(5-0.7-V_A)/R+(V_C-0.7-V_A)/2R=V_A/R$$

$$(10-1.4-2V_A)+(V_C-0.7-V_A)=2V_A$$

$$5V_A=10+V_C-2.1$$

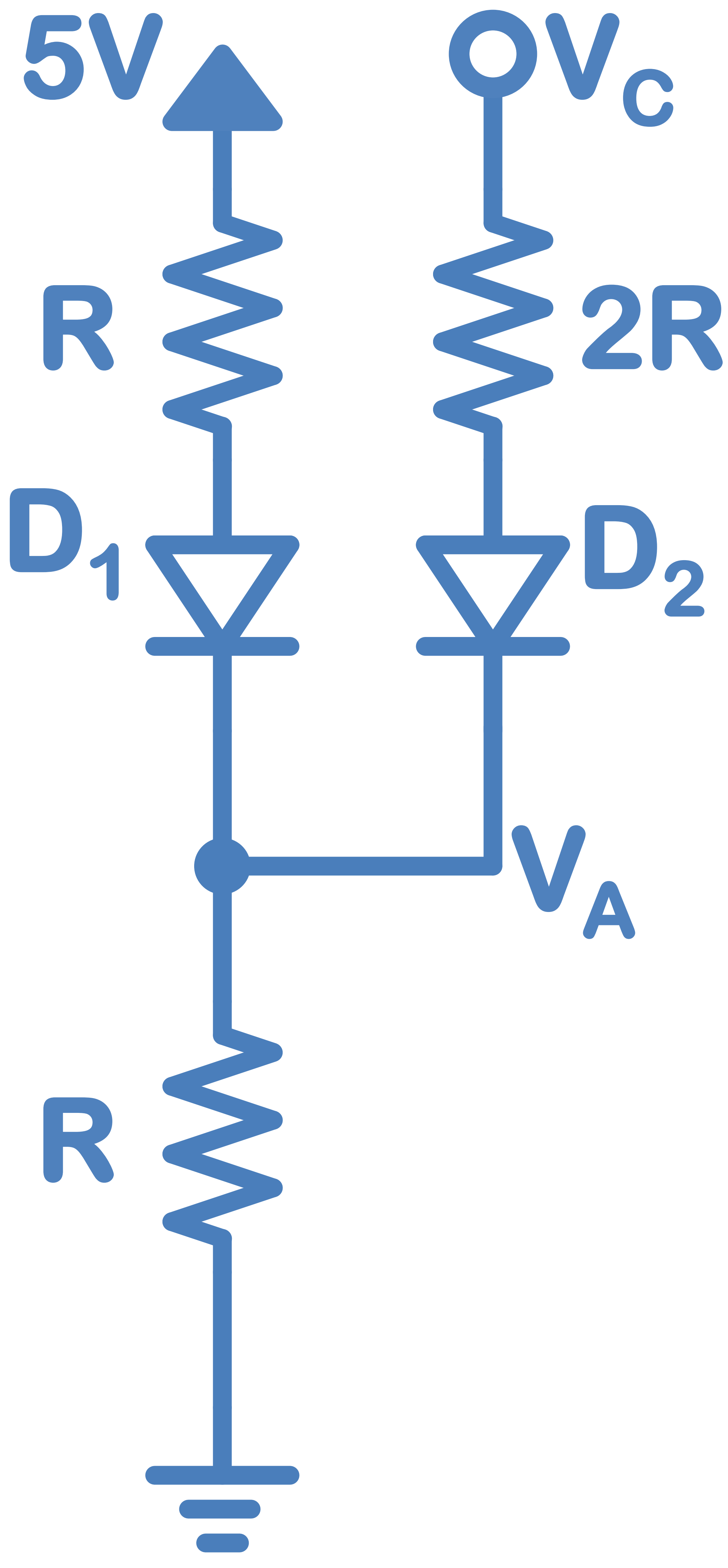
$$V_A=(7.9+V_C)/5$$

$$I_{D1}=(4.3-V_A)/R=(4.3-(7.9+V_C)/5)/R$$

$$I_{D1}=(13.6-V_C)/2.5k$$

$$I_{D2}=(V_C-0.7-V_A)/2R=(V_C-0.7-(7.9+V_C)/5)/2R$$

$$I_{D2}=(4V_C-11.4)/5k$$

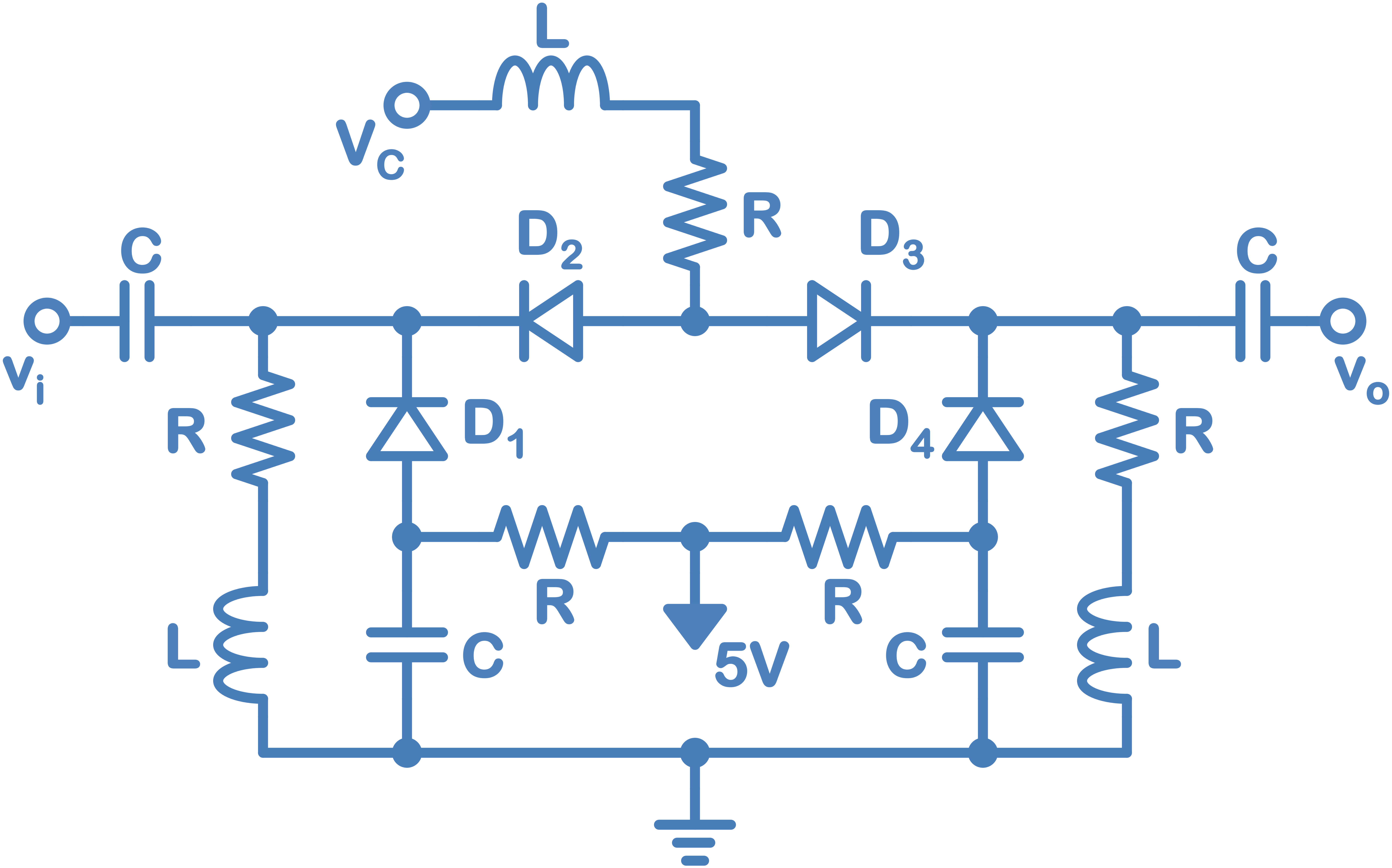


$I_{D1}=(13.6-V_C)/2.5k$

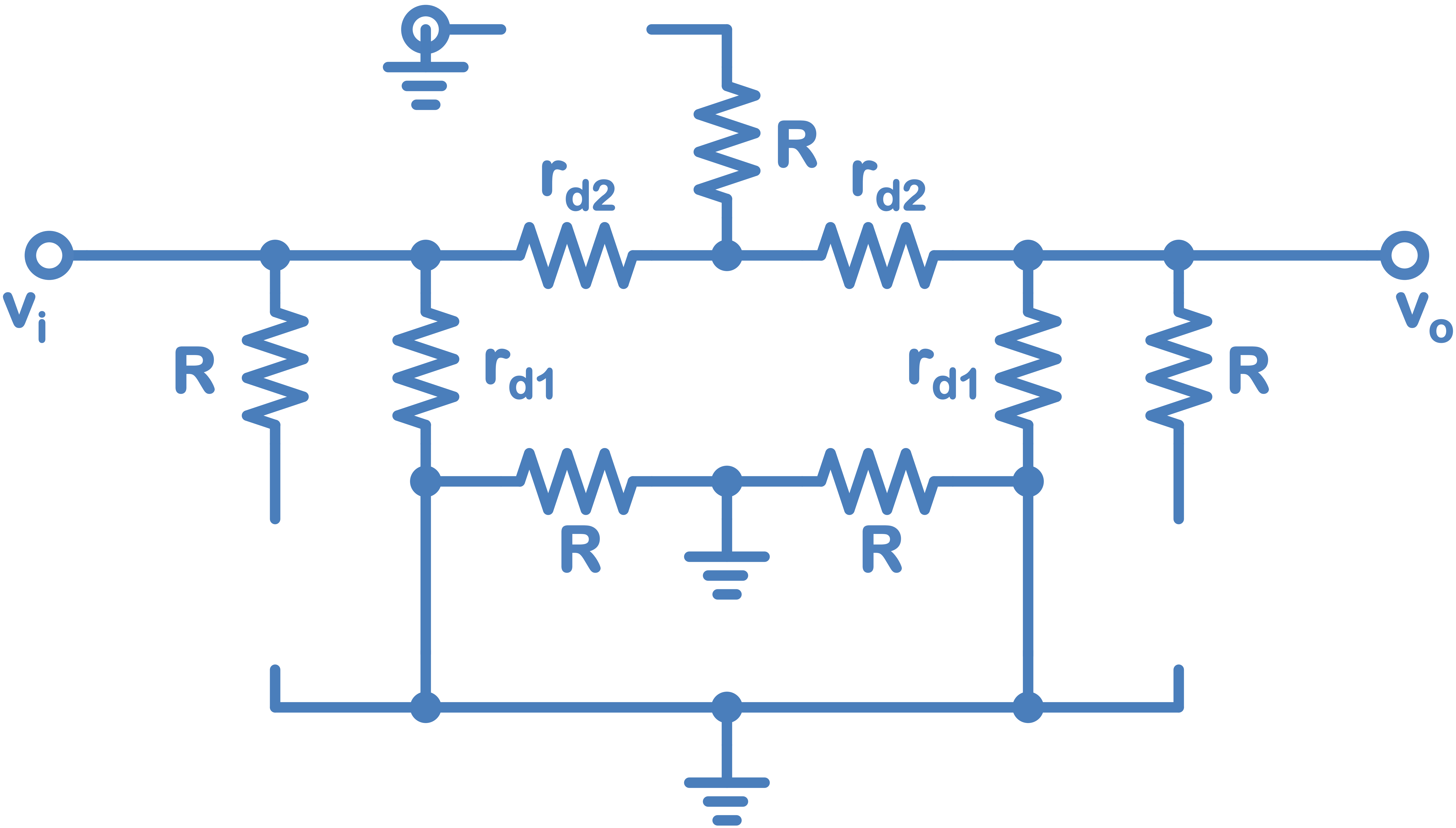
$r_{d1}=62.5/(13.6-V_C)$

$I_{D2}=(4V_C-11.4)/5k$

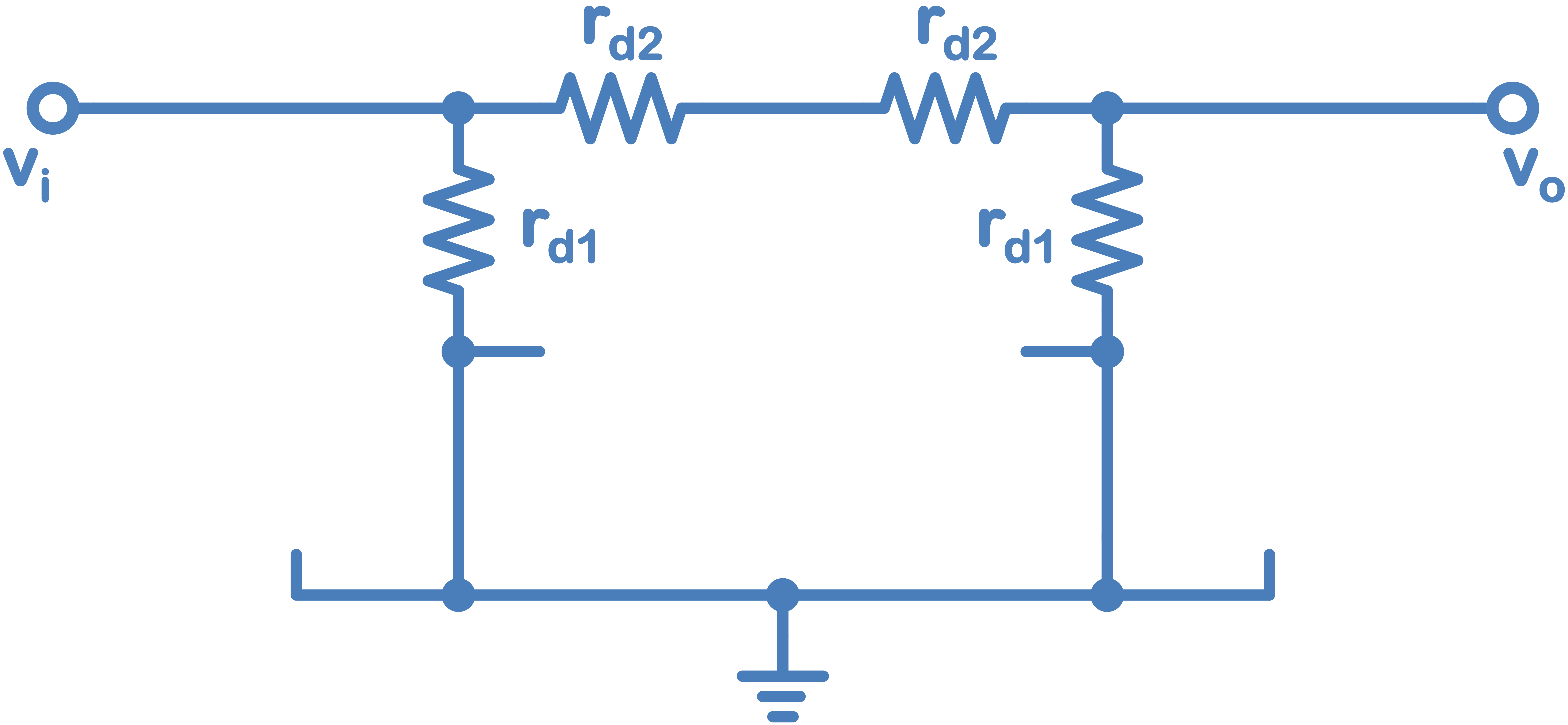
$r_{d2}=125/(4V_C-11.4)$

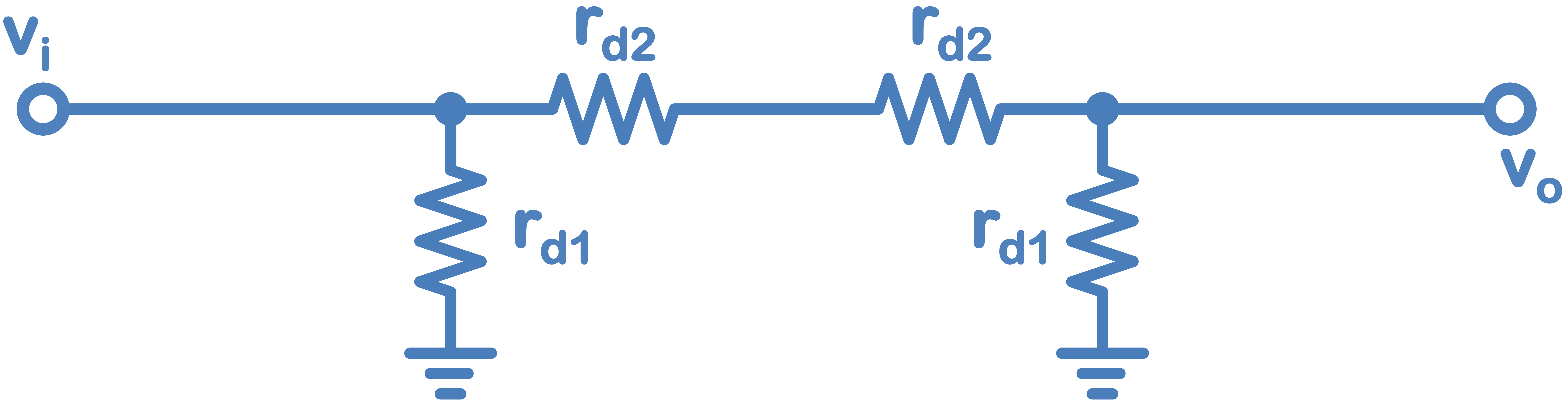


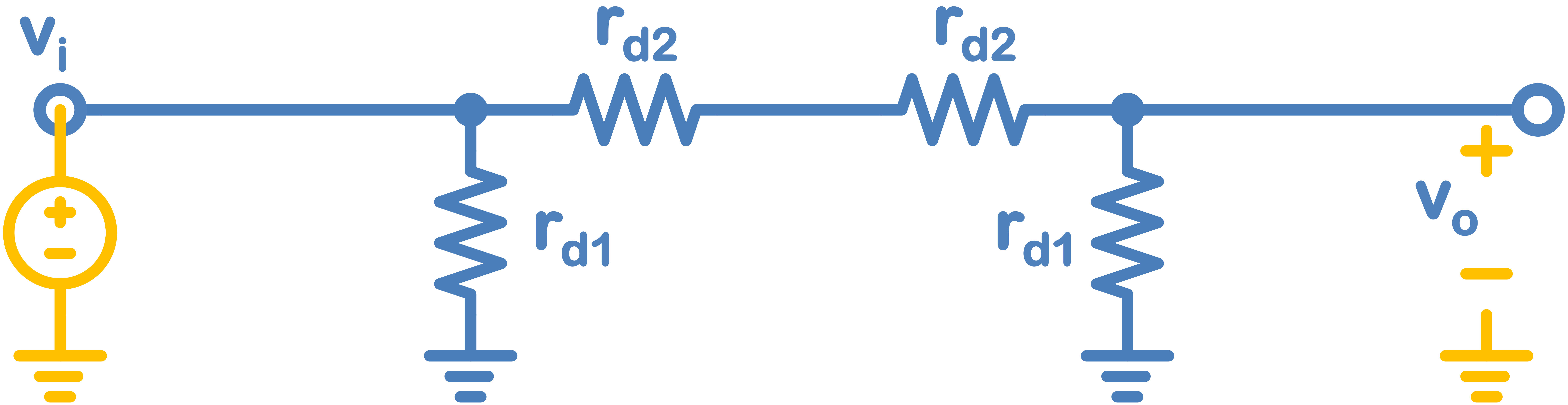
L
V_C
R
D_2
D_3
C
C
v_i
v_o
R
D_1
D_4
R
R
R
L
C
5V
C
L



R
r_{d2}
r_{d2}
v_i
v_o
R
r_{d1}
r_{d1}
R
R
R


r_{d2}
r_{d2}
v_i
v_o
r_{d1}
r_{d1}


v_i
r_d2
r_d2
r_d1
r_d1
v_o



$$v_o/v_i = r_{d1}/(2r_{d2}+r_{d1})$$

$$v_o/v_i = 62.5/(13.6-V_C)/(250/(4V_C-11.4)+62.5/(13.6-V_C))$$

$$v_o/v_i = 62.5(4V_C-11.4) / (250(13.6-V_C)+62.5(4V_C-11.4))$$

$$v_o/v_i = (250V_C-712.5) / (3400-250V_C+250V_C-712.5)$$

$$v_o/v_i = (250V_C-712.5) / (2687.5)$$

$$v_o/v_i = 0.093V_C - 0.2651$$

$$I_{D1}=(13.6-V_C)/2.5k$$

$$r_{d1}=62.5/(13.6-V_C)$$

$$I_{D2}=(4V_C-11.4)/5k$$

$$r_{d2}=125/(4V_C-11.4)$$

$$v_o/v_i = 0.093V_C - 0.2651$$

VC	ID1 (mA)	ID2 (mA)	rd1	rd2	vo/vi
3	4.24	0.12	5.896226	208.3333	0.0139
4	3.84	0.92	6.510417	27.17391	0.1069
5	3.44	1.72	7.267442	14.53488	0.1999
6	3.04	2.52	8.223684	9.920635	0.2929
7	2.64	3.32	9.469697	7.53012	0.3859
8	2.24	4.12	11.16071	6.067961	0.4789
9	1.84	4.92	13.58696	5.081301	0.5719
10	1.44	5.72	17.36111	4.370629	0.6649
11	1.04	6.52	24.03846	3.834356	0.7579
12	0.64	7.32	39.0625	3.415301	0.8509
13	0.24	8.12	104.1667	3.078818	0.9439