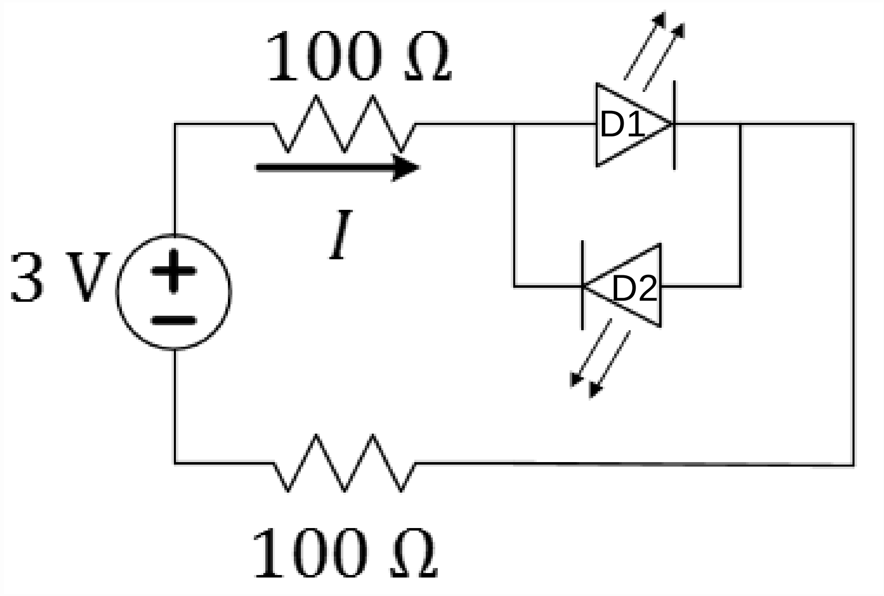
Lecture 17: Diode Circuits

- Guess-and-check for diode circuits
- Current-limiting resistors and power dissipation
- Voltage-limiting (clipping) diode circuits

Guess-and-check example



Assume OIM with V_{ON} = 2 V (red LED)

L17Q1: What is the current supplied by the voltage source?

L17Q2: What is the power dissipated in each diode?

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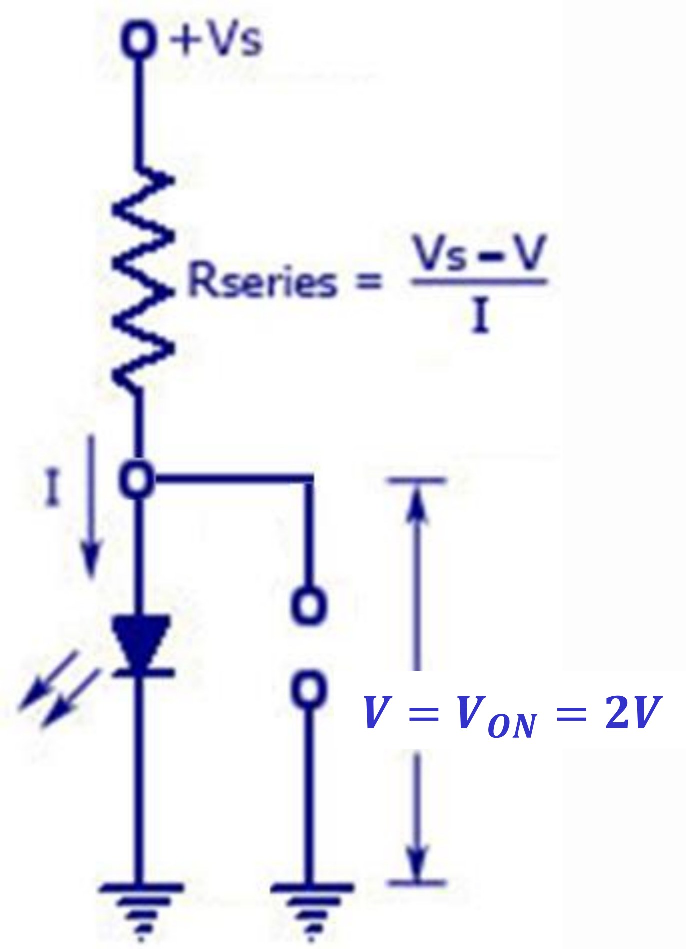
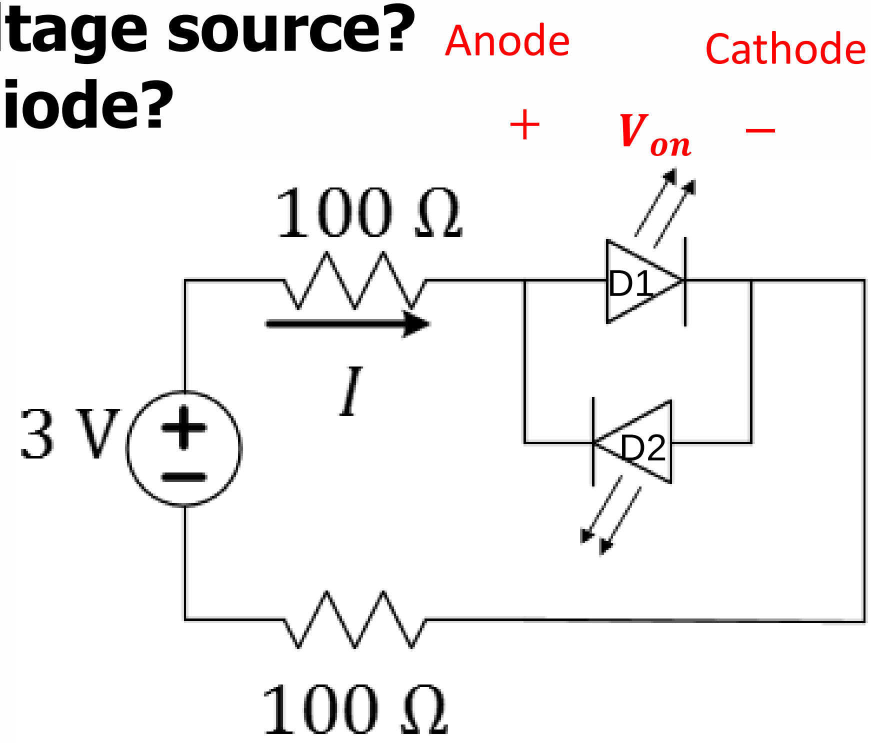
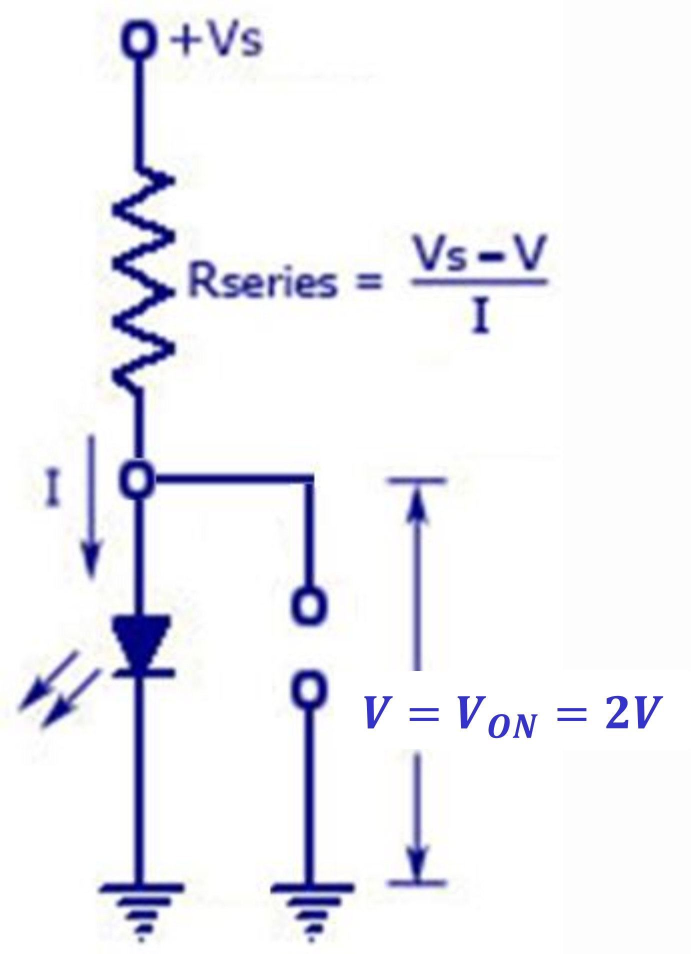


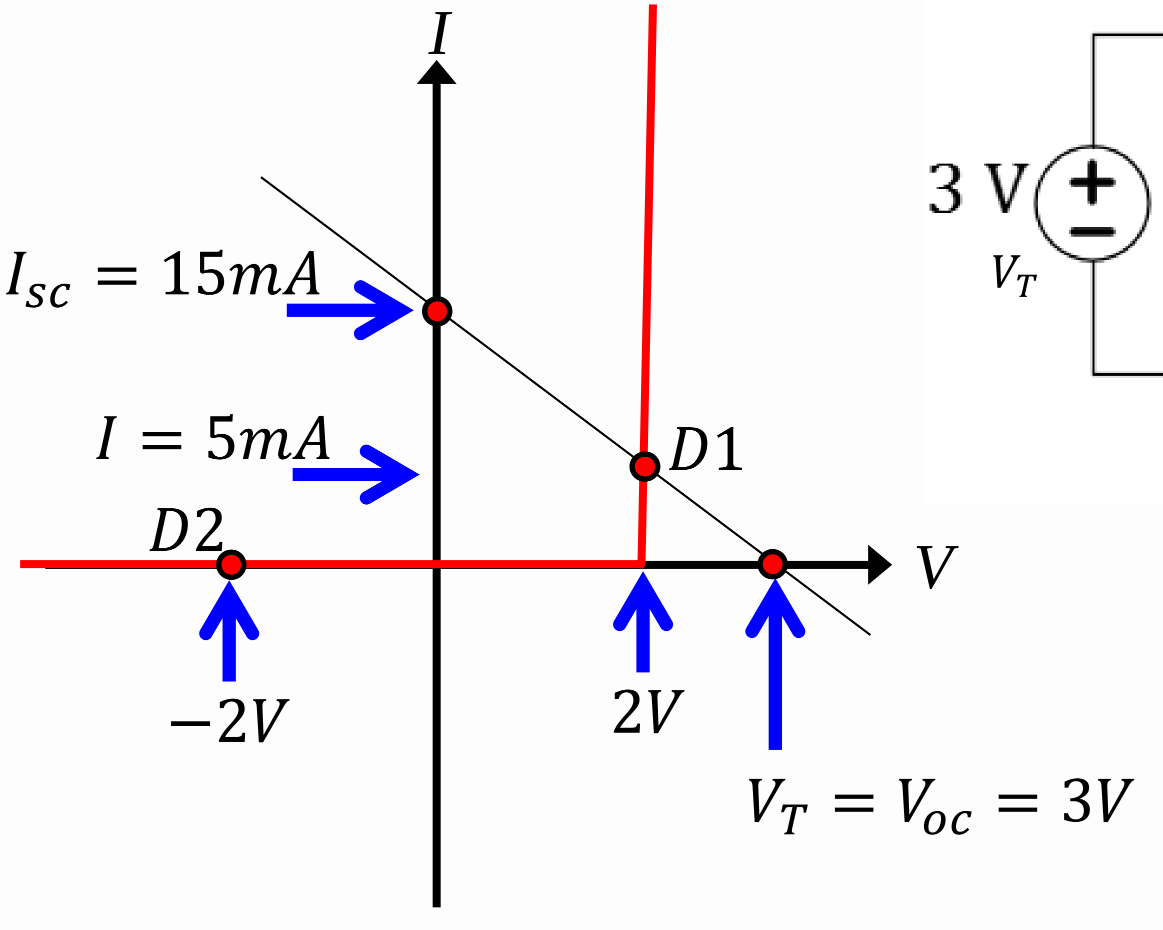
$$I = \frac{V_s - V_{ON}}{R_{tot}}$$
$$= \frac{3-2}{100+100}$$
$$= 5mA$$

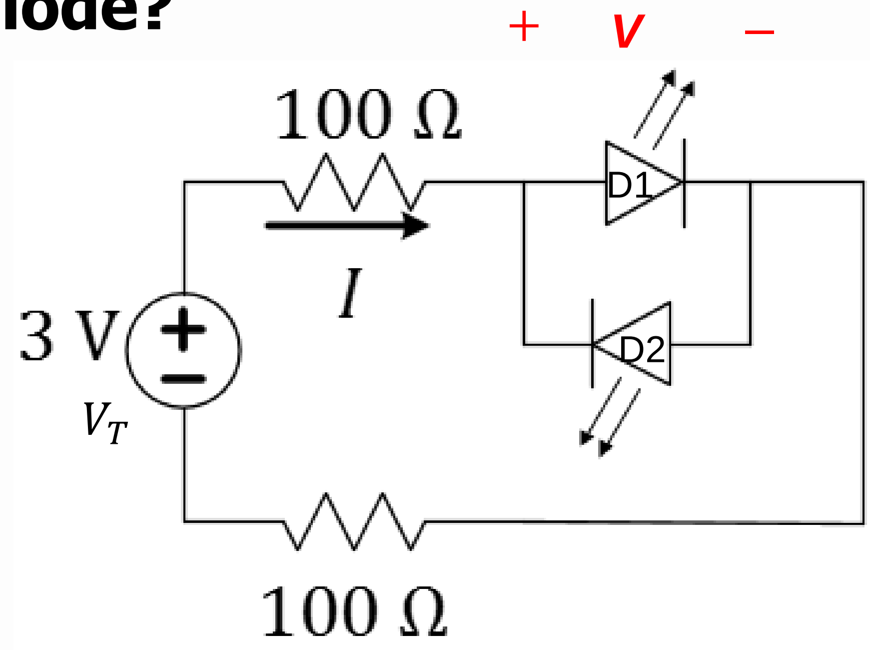


$$P_{D1} = V_{ON} \times I = 10mW$$
$P_{D2} = 0W$ (reverse bias)

L17Q1: What is the current supplied by the voltage source?
L17Q2: What is the power dissipated in each diode?





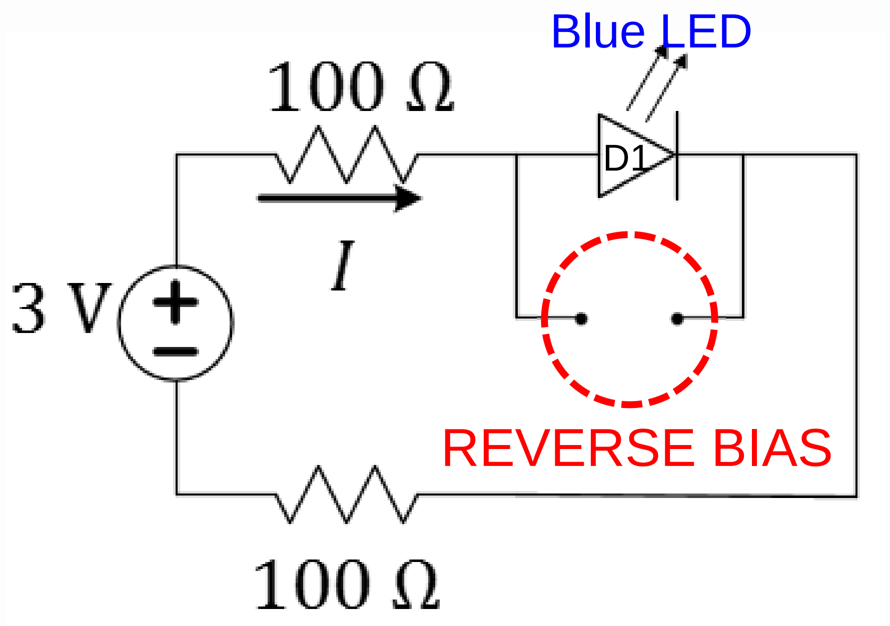


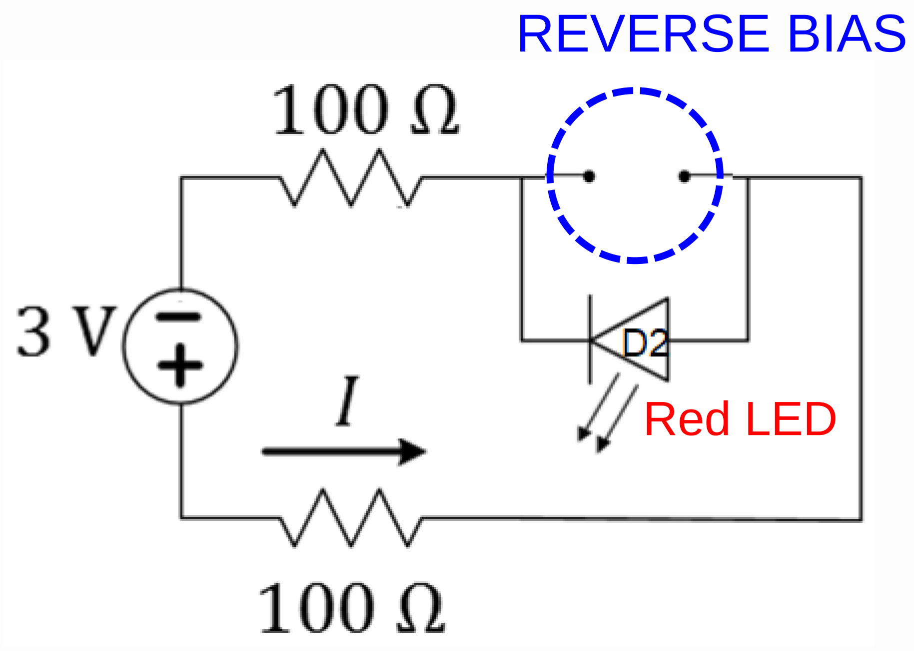
$$I = \frac{V_T - V}{R_T} = \frac{V_T}{R_T} - \frac{V}{R_T}$$

$$I = \frac{3}{200} - \frac{V}{200}$$

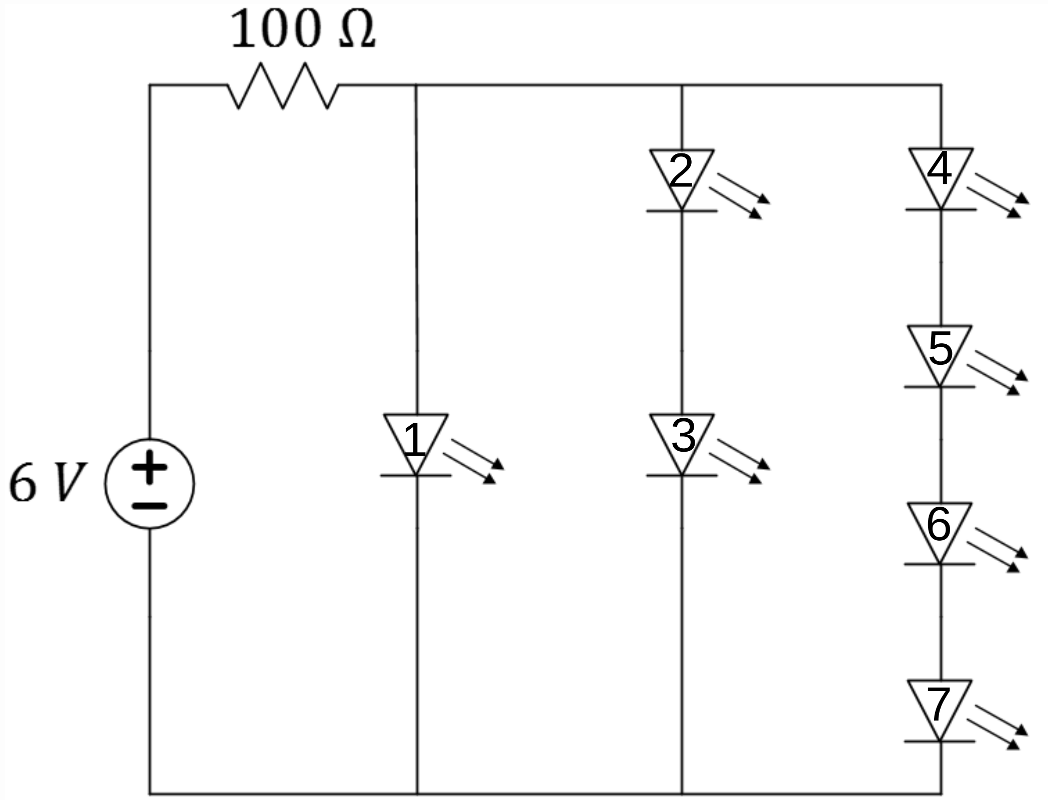
$D1$ is an operating point

NOTE - This is a typical device configuration used for two-color display. One device is always on, the other off. Flip the bias to change the color





Another guess-and-check example

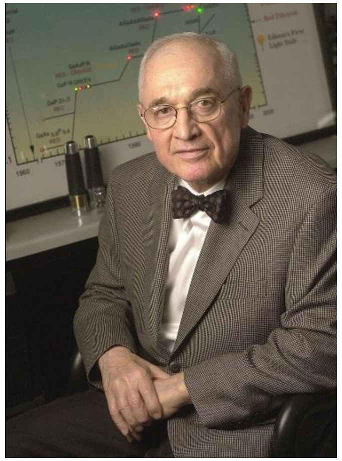


$$V_{on} = 2\ V$$

Q3:
A. 1
B. 3
C. 4
D. 7
E. *other*

ECE Spotlight…

The first visible-light LED was developed by University of Illinois alumnus (and, later, professor) Nick Holonyak, Jr., while working at General Electric in 1962 with unconventional semiconductor materials.
He immediately predicted the widespread application of LED lighting in use today.



L17Q3: How many red LEDs are turned on in the circuit above? (Use OIM)

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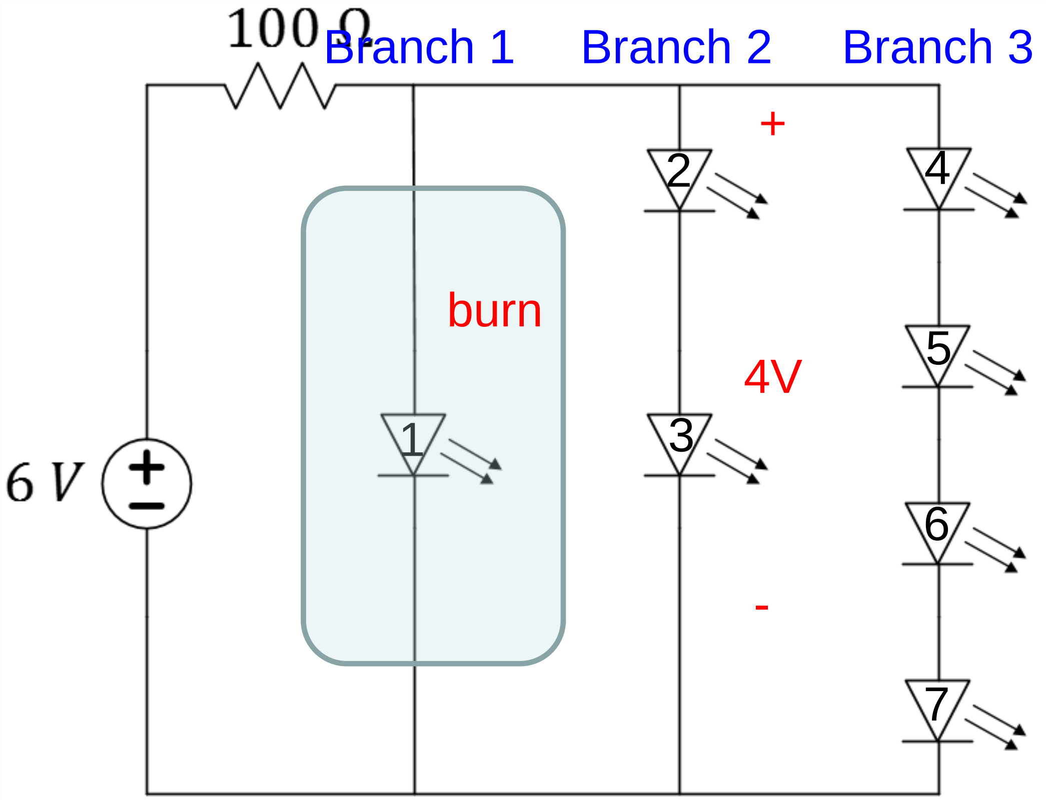


$$V_{on} = 2\,V$$

For branch 1, turn-on voltage is V_{on} = 2V

For branch 2, turn-on voltage is $2V_{on}$= 4V

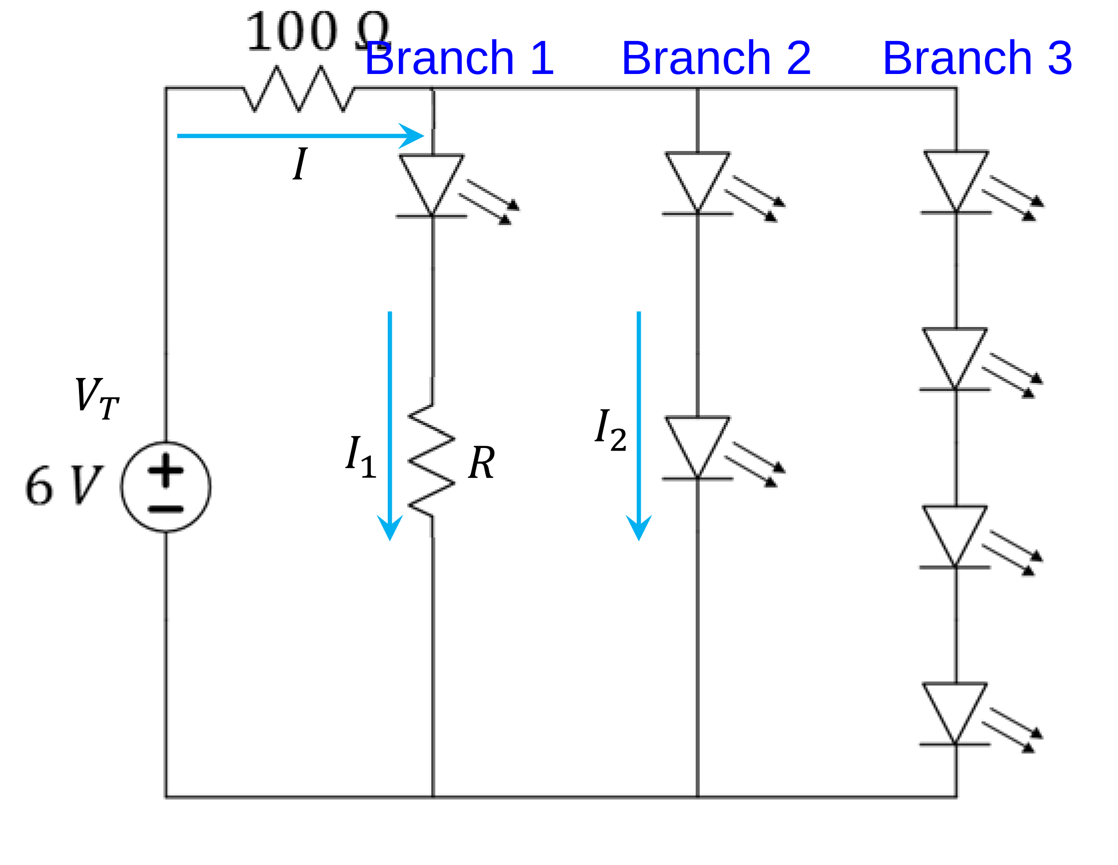
For branch 3, turn-on voltage is $4V_{on}$ = 8V

Q3:

A. 1
B. 3
C. 4
D. 7
E. *other*

The only condition to make the circuit work normally is the voltage between branch 1 is no more than V_{on}

Add a resistor to make the second branch glow



$$V_{on} = 2\ V$$

Question: solving if any limitation on R

Condition 1: the voltage in branches 1 &2 are equal

$$I_1 = \frac{2V_{on} - V_{on}}{R} = \frac{2}{R}$$

Condition 2: $I_1 + I_2 = I$

Condition 3: $I = \frac{V_T - 2\times V_{on}}{R_T} = \frac{6-4}{100} = 0.02A$

$$I > I_1 \Rightarrow I > \frac{2}{R}$$

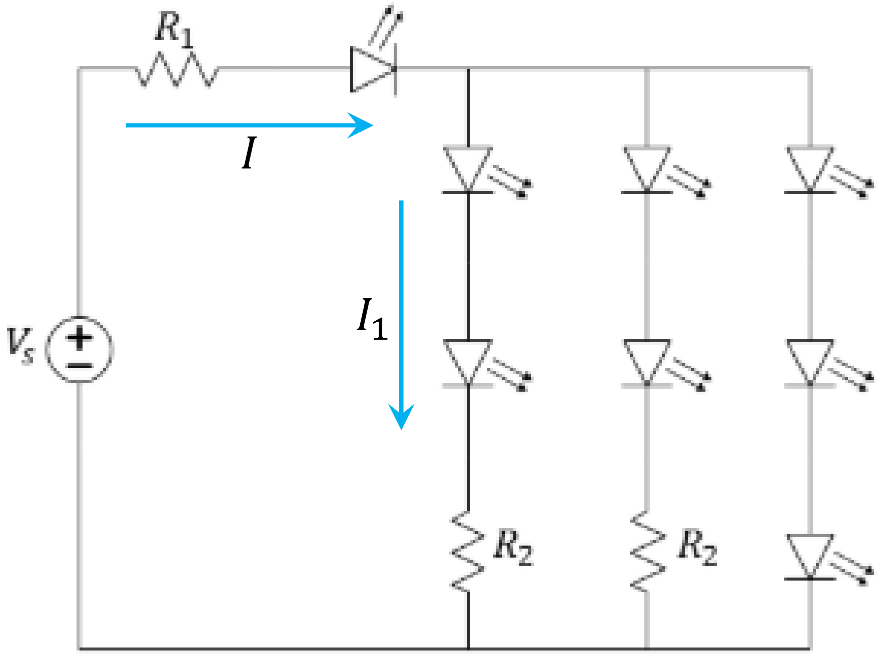
$$R > 100\Omega$$

Note: the block content is supplemented by myself

How many red LEDs are turned on in the circuit?

Assume an ideal-offset model with $V_{ON} = 3\ V$ for the LEDs. If $V_S = 13\ V$, $R_1 = 100\ \Omega$, and $R_2 = 10\ \Omega$,

How many of the LEDs are illuminated (drawing current)?



$n =$ ☐ $LEDs$

(enter an integer value)

Case 1: Assume all LEDs glow

$$I_1 = \frac{3V_{on} - 2V_{on}}{R_2} = \frac{3}{10} = 0.3A$$

$$I = \frac{V_S - 3 \times V_{on} - V_{on}}{R_1} = 0.01A$$

$$I < I_1$$

Contradictory!!!

A. 1
B. 2
C. 3
D. 5
E. 8

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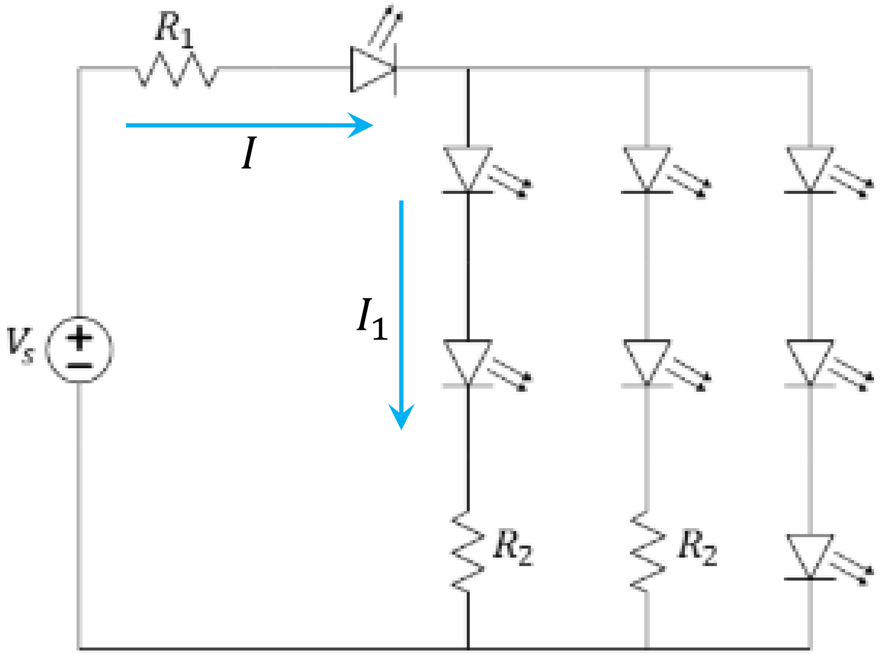

$n =$ $LEDs$

(enter an integer value)

Case 2: Assume the first and second branch glow

$$\begin{cases} V_s = (V_{on} + V_{on} + R_2 \times I_1) + V_{on} + R_1 \times I \\ I = 2 \times I_1 \end{cases}$$

$$13 - (3 + 3 + 10 \times I_1) - 3 = 100 \times 2 \times I_1$$

$$I_1 = \frac{4}{210} = 19.05\ mA$$

$$I = 38.1\ mA$$

$$I > I_1$$

Correct!!

And the voltage in the first branch $2V_{on} + I_1 \times R_2 < 3V_{on}$

A. 1
B. 2
C. 3
D. 5
E. 8

How many red LEDs are turned on in the circuit?

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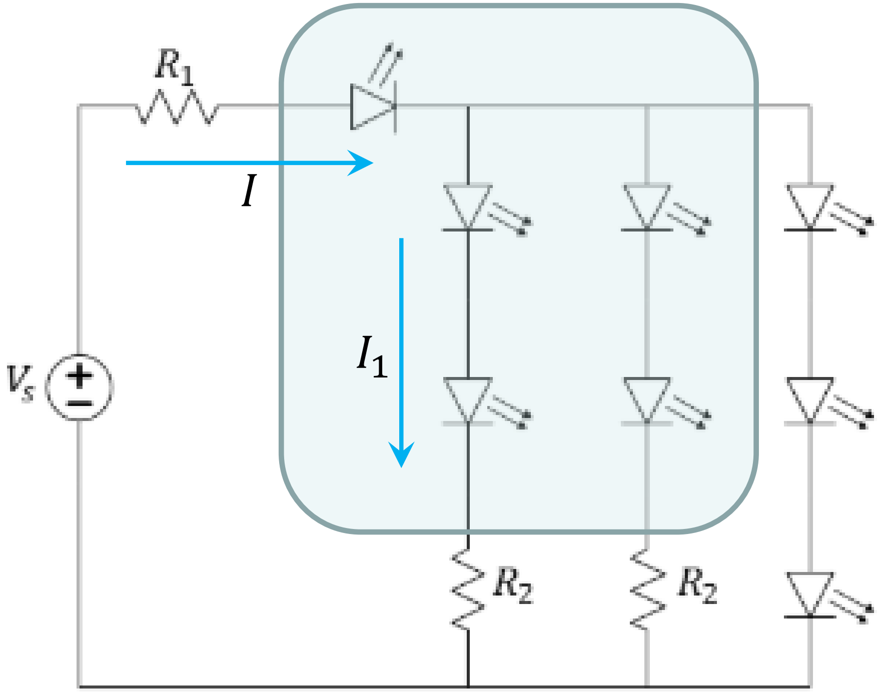


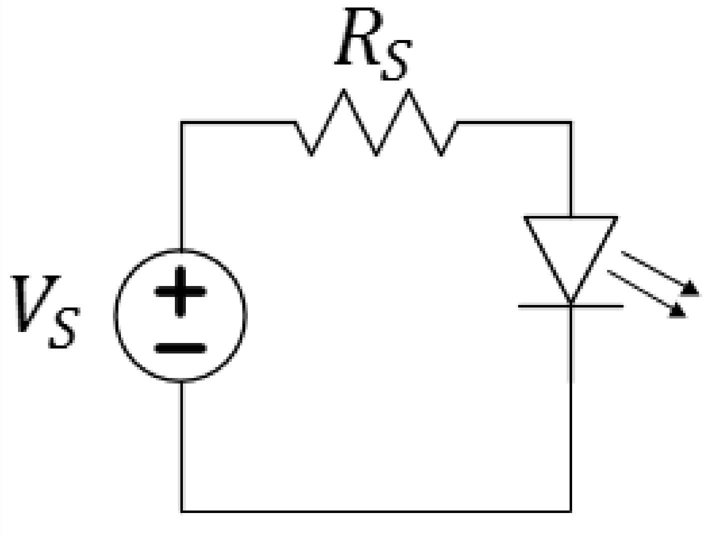
$n =$ 5 $LEDs$

(enter an integer value)

A. 1
B. 2
C. 3
D. 5
E. 8

Current-limiting resistors for LEDs

Assume OIM with V_{ON} = 3.3 V (blue LED)



L17Q4: How many 1.5 V batteries are needed to turn on the LED?
L17Q5: What is the series resistance needed to get 16 mA through the LED?
L17Q6: What is the resulting power dissipation in the diode?

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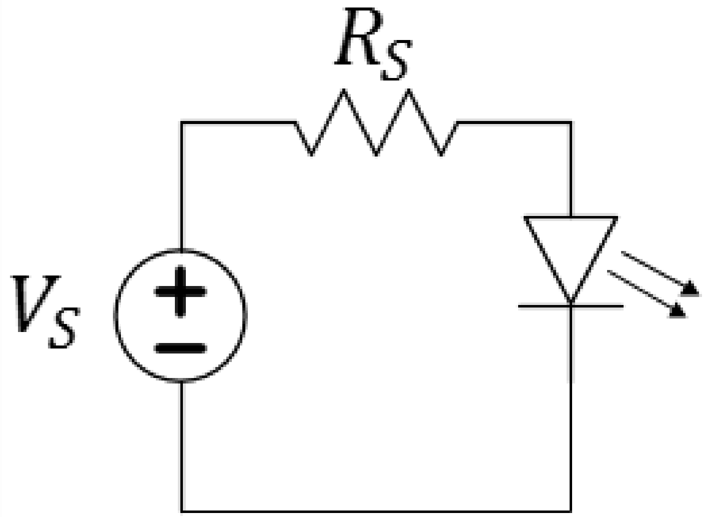


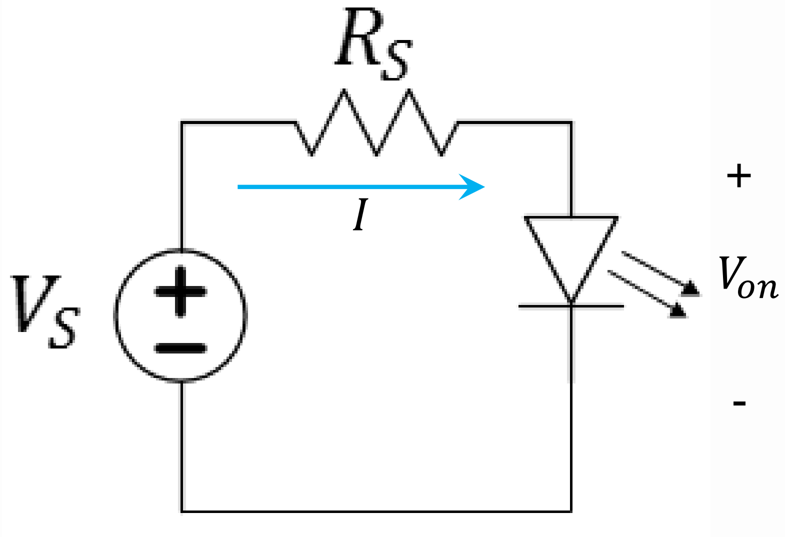
2 Batteries: 3V < 3.3V

3 Batteries: 4.5V > 3.3V

(In reality, LED will glow a little with 3V, because some current may flow when close to V_{ON})

L17Q5: What is the series resistance needed to get 16 mA through the LED?
L17Q6: What is the resulting power dissipation in the diode?

Assume OIM with V_{ON} = 3.3 V (blue LED)



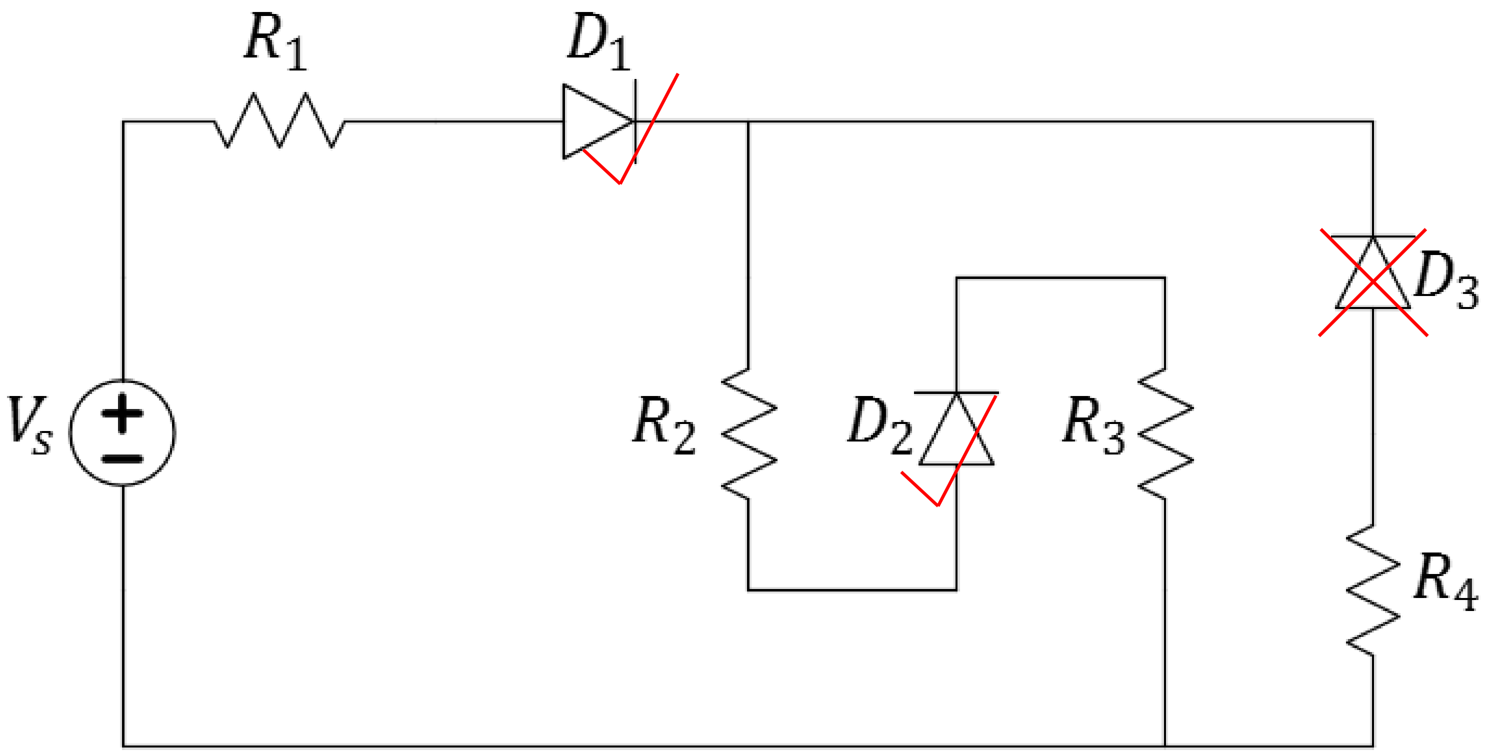
$$I = \frac{V_s - V_{ON}}{R_s} = \frac{4.5 - 3.3}{R_s} = 16mA$$

$$R_s = \frac{1.2}{16m} = 75\Omega$$

$$P_{D1} = V_{ON} \times I = 3.3 \times 16m$$
$$= 52.8mW$$

Extra practice

When a diode is forward biased above its nominal turn-on voltage, it is said to be on. When biased below the turn-on voltage, it is said to be off. Help John Genius make an educated initial assumption about the operating region of each diode in the circuit below. He knows that $V_s = 10V$ and all the resistors are 330 Ohms. For each diode, $V_{ON} < 1V$. Select all diodes that are on.



$V_s = 10V$

All the resistors are 330 Ohms

For each diode, $V_{on} < 1$

$2V_{on} < V_s$

- ☐ (a) Diode D2
- ☐ (b) Diode D1
- ☐ (c) Diode D3

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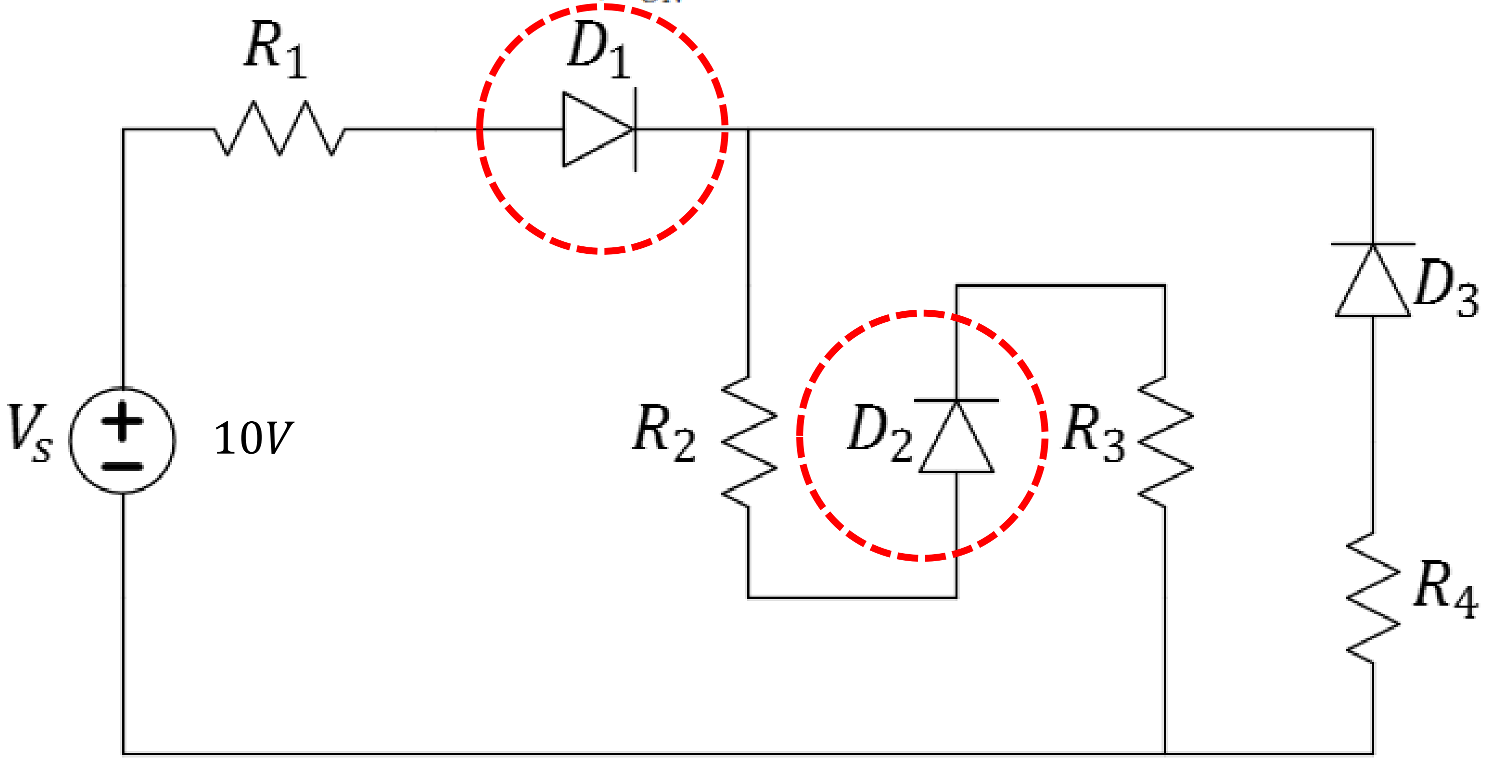
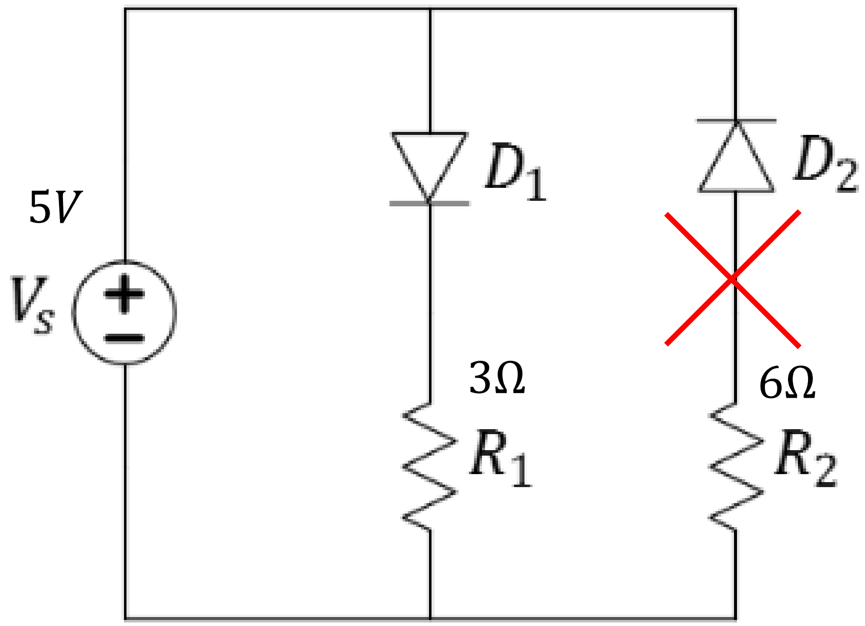


- (a) Diode D2
- (b) Diode D1
- (c) Diode D3

Extra practice

$V_S = 5\ V$, $R_1 = 3\ \Omega$ and $R_2 = 6\ \Omega$. Treat both diodes with the offset-ideal model having a V_{on} of 1.0 Volts.



$$V_{on} = 1.0\ Volts$$

Which of the two diodes is ON?

- D1
- D2

What is the current in the ON diode?

$I_{ON} =$ ______ A

(within three significant digits)

$$\boxed{I_{on} = \frac{V_s - V_{on}}{R_1} = \frac{5-1}{3} = 1.333A}$$

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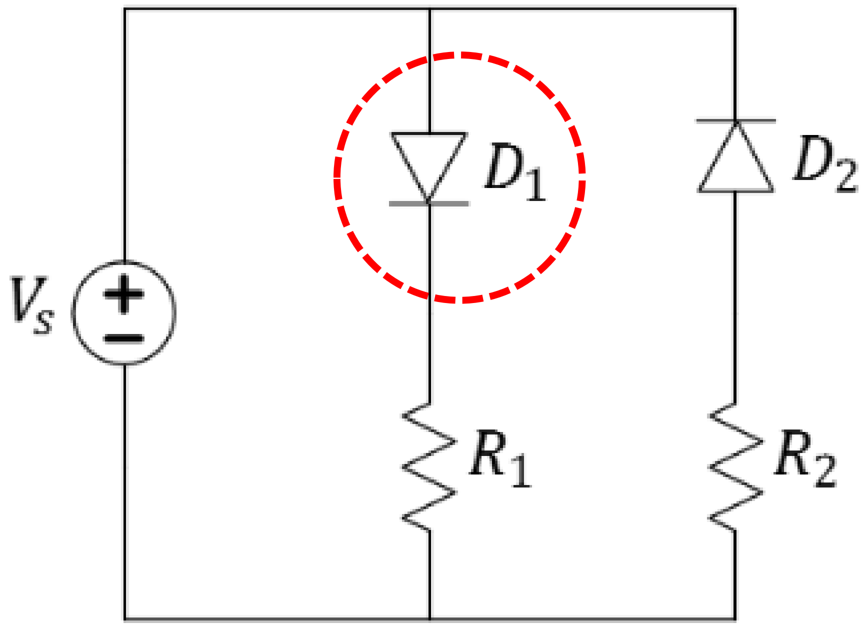


Which of the two diodes is ON?

- D1
- D2

What is the current in the ON diode?

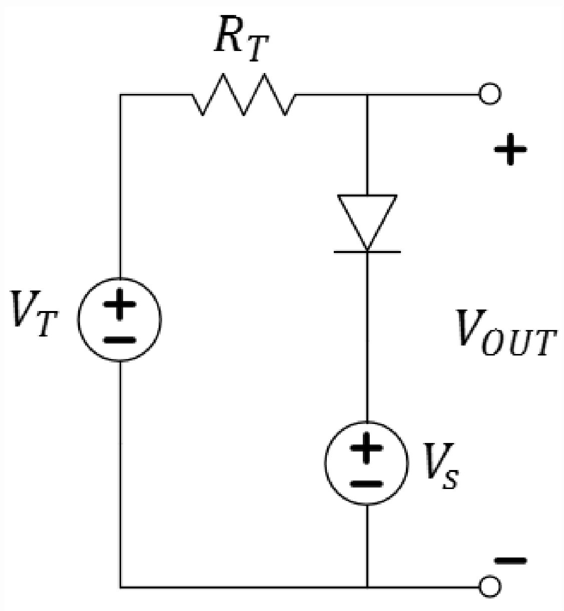
$I_{ON} =$ ______ A

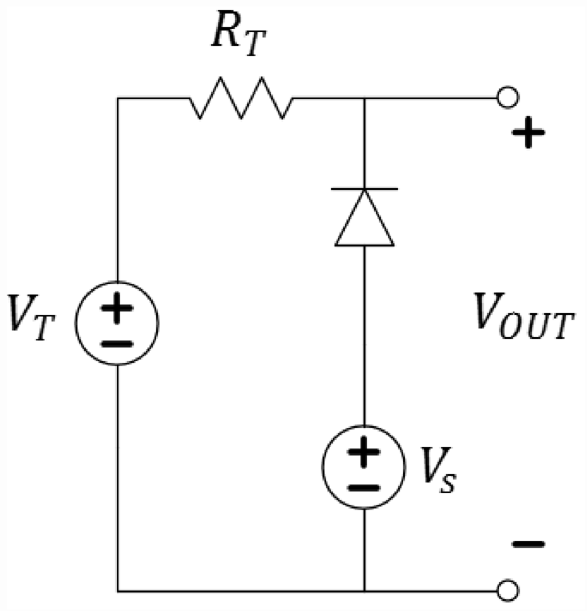
(within three significant digits)

$$I_{ON} = 1.33333\ A$$

Setting voltage limits with diodes

Assume OIM model with V_{ON} = 0.3 V (Ge diode)

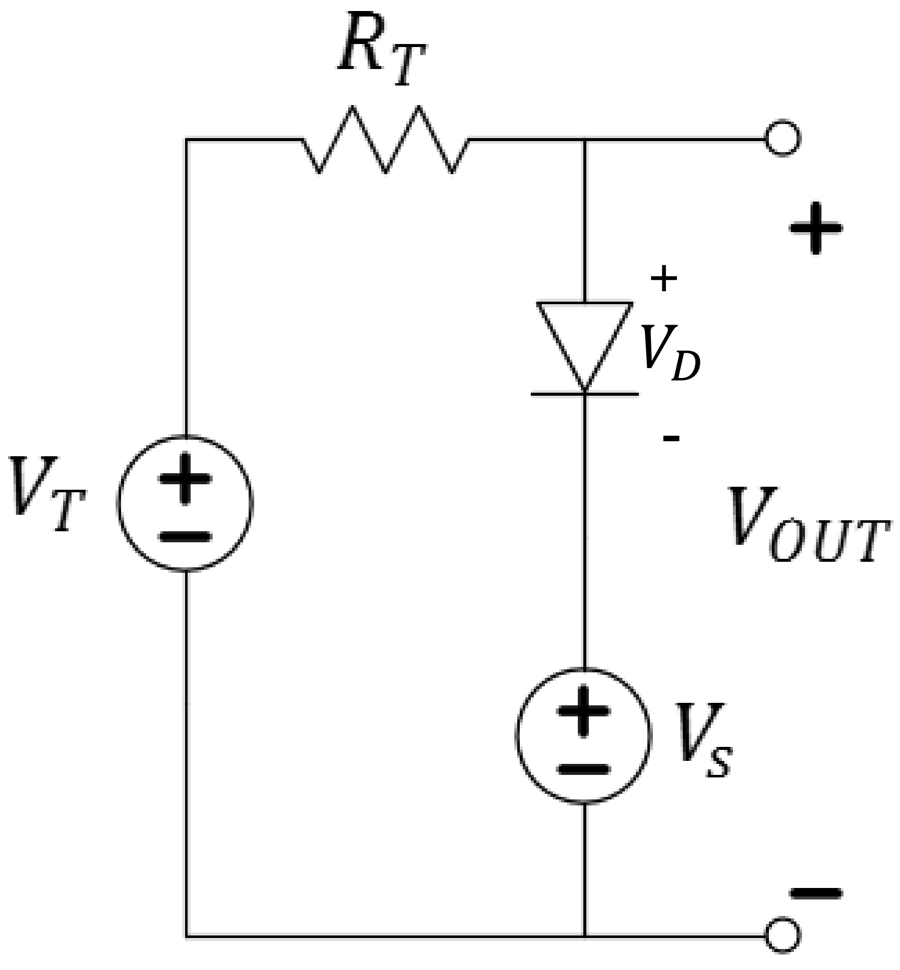




L17Q7: What is the possible range of the output voltages in the left circuit?
L17Q8: What is the possible range of the output voltages in the right circuit?

L17Q7: What is the possible range of the output voltages ?

Assume OIM model with V_{ON} = 0.3 V (Ge diode)



$$V_{out} = V_D + V_s$$

$$V_D \leq V_{on} \Rightarrow V_D \leq 0.3$$

$$V_{out} \leq V_s + 0.3$$

$$V_{out} \in [-\infty, V_S + 0.3]$$

L17Q8: What is the possible range of the output voltages?

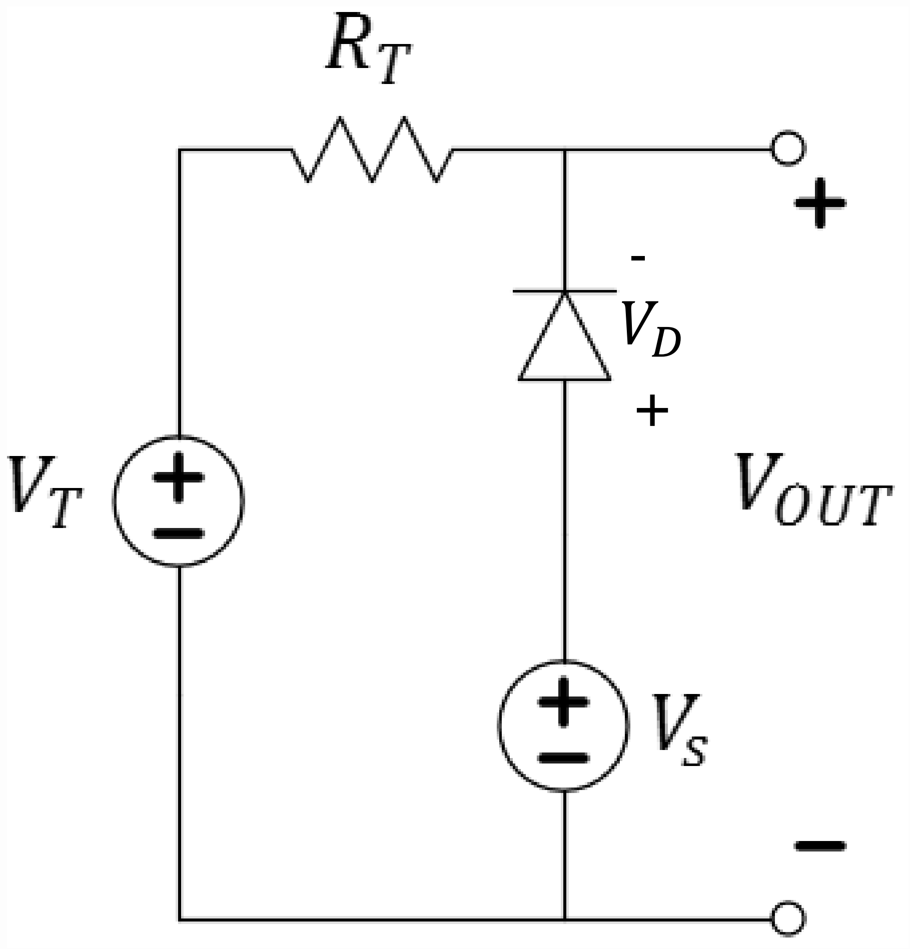
Assume OIM model with V_{ON} = 0.3 V (Ge diode)

$$V_{out} = V_s - V_D$$

$$V_D \leq V_{on} \Rightarrow V_D \leq 0.3$$

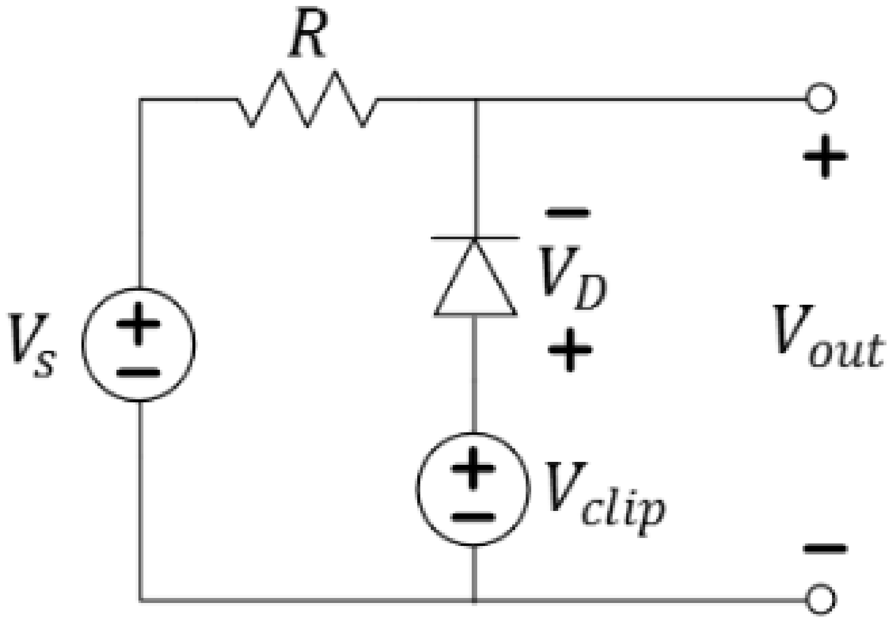
$$V_{out} \geq V_s - 0.3$$

$$V_{out} \in [V_S - 0.3, \infty]$$



Extra — Voltage clipping problem

$V_{clip} = 2.9\ V$, $R = 38\ \Omega$, and $V_{on} = 0.7\ V$ for the diode (assume offset-ideal model).
Suppose V_s can take any value from -16 to $16\ V$.
What are the maximum and minimum values that V_{out} might take on?



$Maximum\ V_{out} =$ ______ V

$Minimum\ V_{out} =$ 2.2 V

(within three significant digits)

Let's see in which situation, Vout is minimum

Parameter list

$V_{clip} = 2.9\ V$

$R = 38\ \Omega$

$V_{on} = 0.7\ V$

$V_s \in [-16,16]$

When $V_{clip} - V_s > V_{on}$

$V_{clip} - V_{on} > V_s$

$2.2 > V_s$

$V_{out} = minimum\ value$
$= V_{clip} - 0.7 = 2.2$

$$V_{out} = V_{clip} - V_D \quad \boldsymbol{V_D \leq V_{on} = 0.7}$$

$$V_{out} \in [V_{clip} - 0.7, \infty]$$

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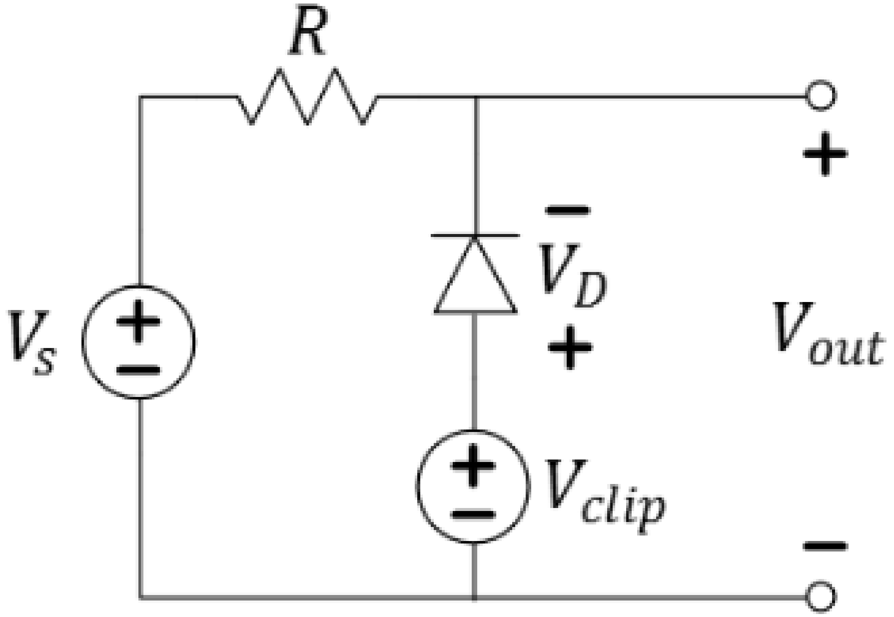

When Vs = 16 V, the diode is off.
and Vout = maximum value = 16 V

$Maximum\ V_{out} =$ 16 V

$Minimum\ V_{out} =$ V

(within three significant digits)