Written Midterm

- July 11 (Wed), 10:10-11:50am, at Rm6591

Seating plan will be post outside of exam venue on exam day

- 5 Questions
  - 25% easy, 50% medium, 25% hard
  - Hot topics:
    - Resistance, Diode, Transistor
    - Breadboard arrangement
    - Pulse, Timer, PWM, all ICs presented in Lab3
    - Logic design (Truth table & K-map)

Quantities & Units

- Can you describe the relationship between these quantities?

Quantity	Symbol	Unit
Voltage	V	Volt (V)
Energy	E	Joule (J)
Charge	Q	Coulomb (C)
Power	P	Watt (W)
Current	I	Ampere (A)
Resistance	R	Ohm (Ω)

$$E = QV$$

$$E = Pt$$

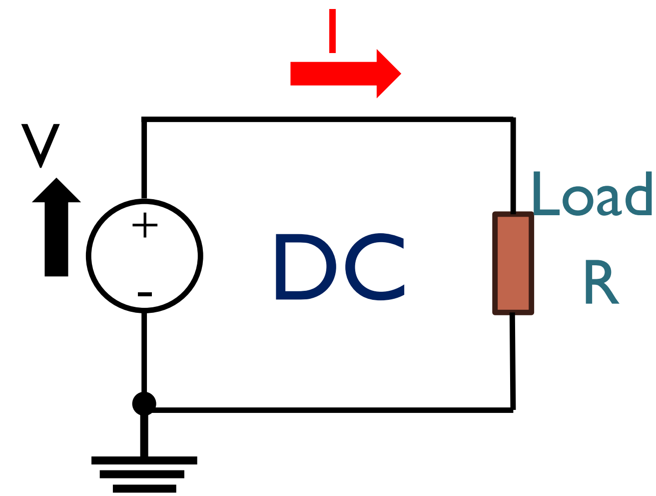
$$I = Q / t$$

$$V = IR$$

Ohm's Law

- Ohm's Law:

$$V = IR$$



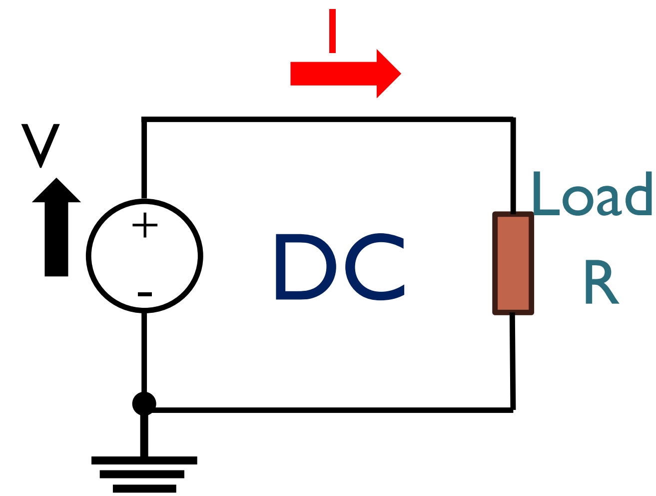
- Q: Why AA battery does not harm human?
  - Typical human electrical resistance: 10kΩ
  - AA battery: 1.5V
  - I = V/R = 1.5 / 10k = 0.15mA
  - More than 30mA is harmful

Unit	10^x	Unit	10^x
m	-3	K	3
μ	-6	M	6
n	-9	G	9
p	-12	T	12

Power Calculation

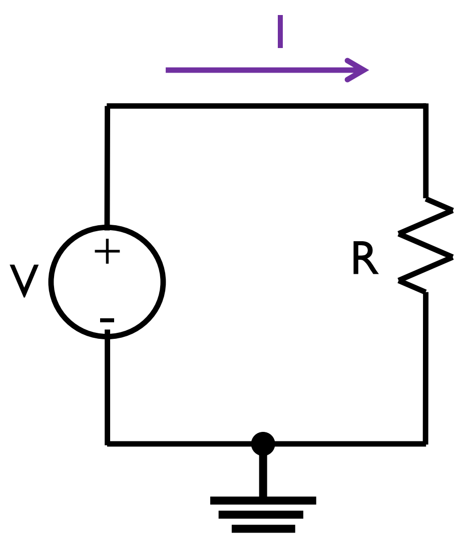
- Power = ?

$$P = I^2 R = \frac{V^2}{R}$$

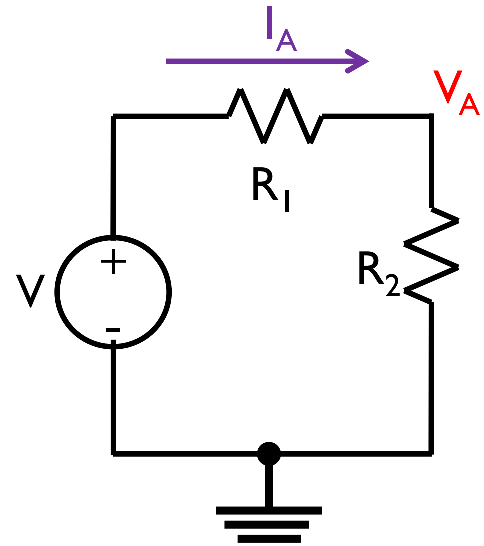


- Q: "60W, 240V" light bulb, R = ? I = ?
  - P = V^2 / R => 60 = 240^2 / R => R = 960Ω
  - I = V / R = 240 / 960 = 0.25A = 250mA
    - But if you measure the resistance of an unconnected light bulb using a multimeter, it is only ~64Ω.
    - When light bulb is on, its resistance increases ~15 times.

Resistors



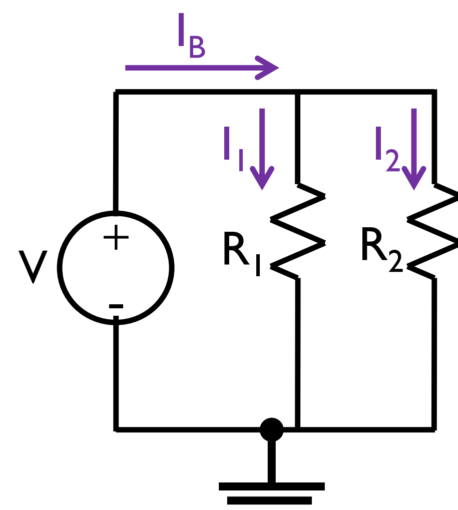
$$\boxed{V = IR}$$



Series

$$V = I_A(R_1 + R_2)$$

$$\boxed{V_A = V\frac{R_2}{R_1 + R_2}}$$



Parallel

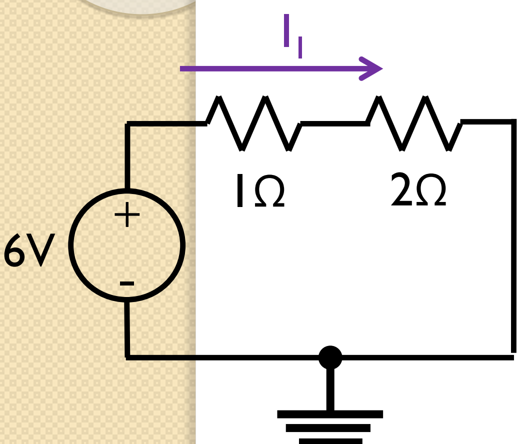
$$I_1 = \frac{V}{R_1}; I_2 = \frac{V}{R_2}$$

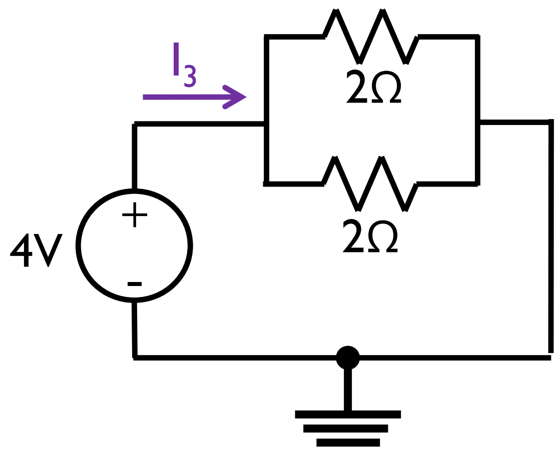
$$I_B = I_1 + I_2$$

$$\boxed{I_B = V\left(\frac{1}{R_1} + \frac{1}{R_2}\right)}$$

Exercise

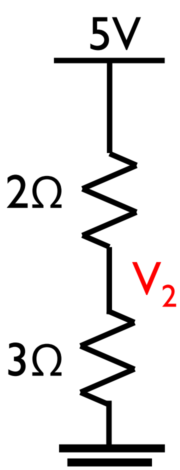
- Find the unknowns of the following circuits

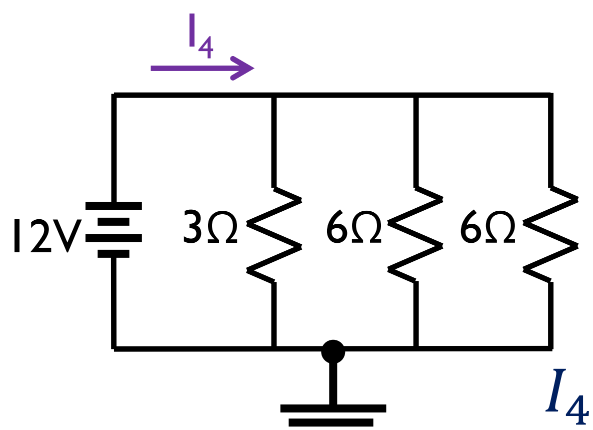




$$I_1 = \frac{6}{1+2} = 2A$$

$$V_2 = 5 \times \frac{3}{2+3} = 3V$$



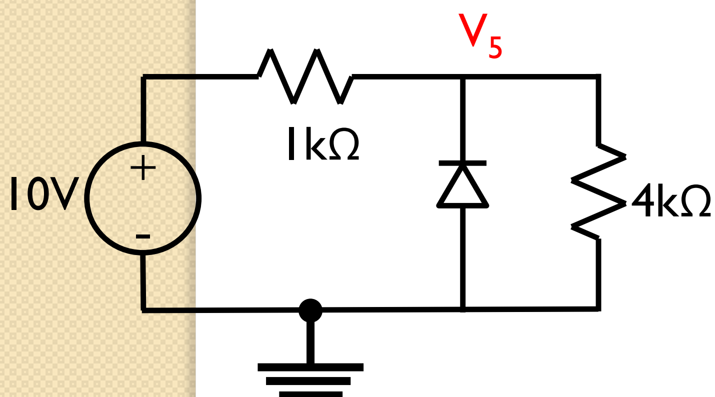


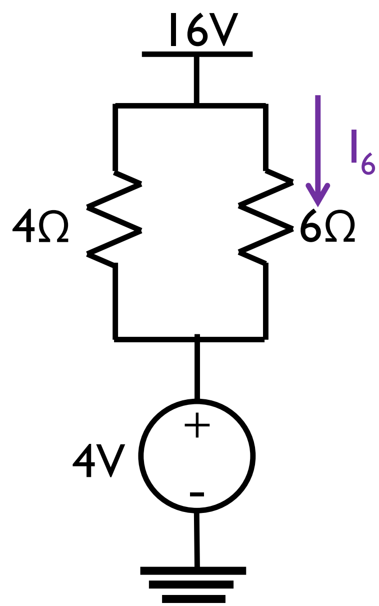
$$I_3 = \frac{4}{2} + \frac{4}{2} = 4A$$

$$I_4 = 12\left(\frac{1}{3} + \frac{1}{6} + \frac{1}{6}\right) = 8A$$

Exercise

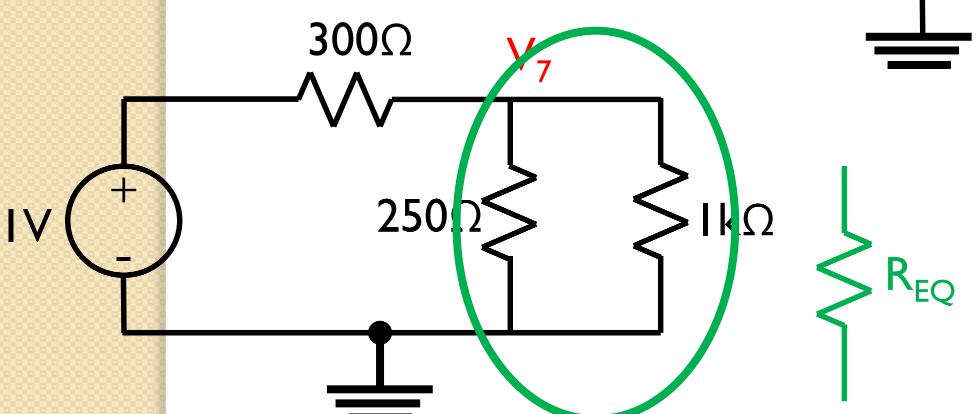
- Find the unknowns of the following circuits





$$V_5 = 10 \times \frac{4k}{1k + 4k} = 8V$$

$$I_6 = \frac{16 - 4}{6} = 2A$$

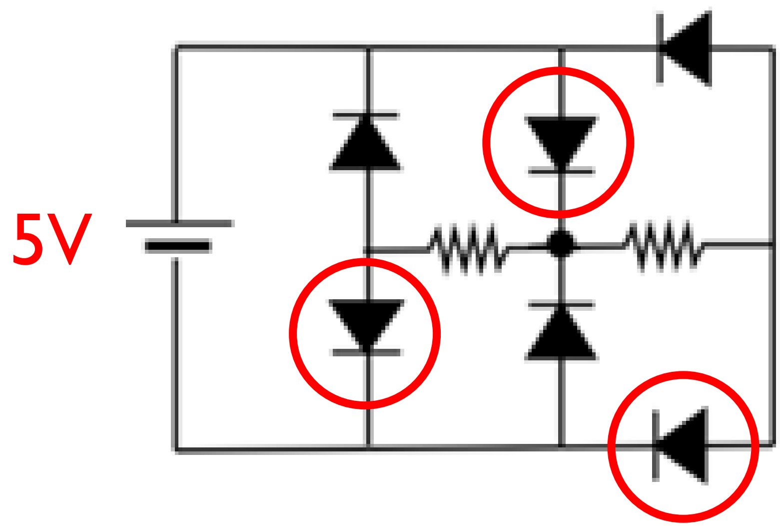


$$R_{EQ} = \frac{250 \times 1k}{250 + 1k} = 200\Omega$$

$$V_7 = 1 \times \frac{200}{300 + 200} = 0.4V$$

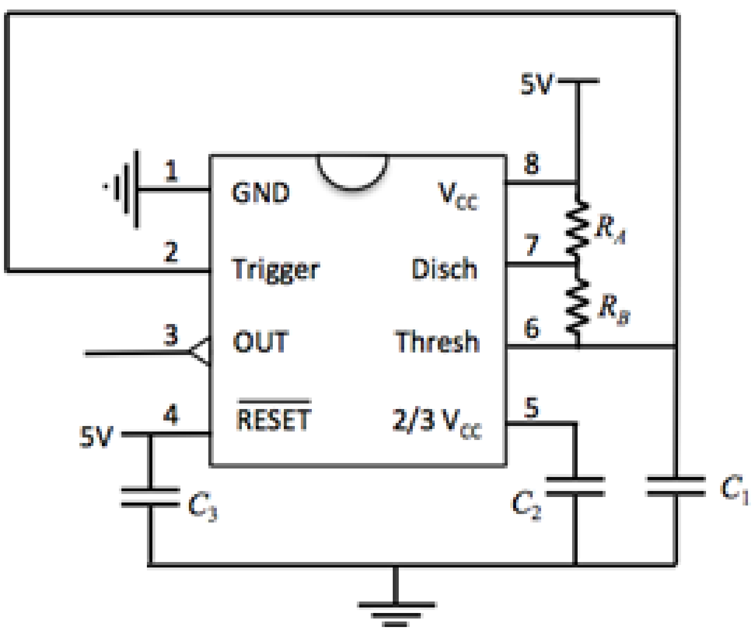
Diodes

Figure below shows a diode circuit where the turn-on voltage of the diode is 0.7V. Circle the diodes that could be turned on.



NE555 Timer

For the timer circuit shown below, the resistance ratio between the two resistors is given by RA:RB = 4:3. Determine the duty cycle of the pulse output from pin 3.



$$duty\ cycle = \frac{R_A + R_B}{R_A + 2R_B}$$

$$= \frac{4/3\, R_B + R_B}{4/3\, R_B + 2R_B}$$

$$= \frac{7/3}{10/3} = \frac{7}{10} = 0.7$$

Transistor

For the given transistor circuit, assume β = 200, VBE = 0.7V, find out the value of Vin when:

a) the transistor is off

When 0V < V_{in} <0.7V

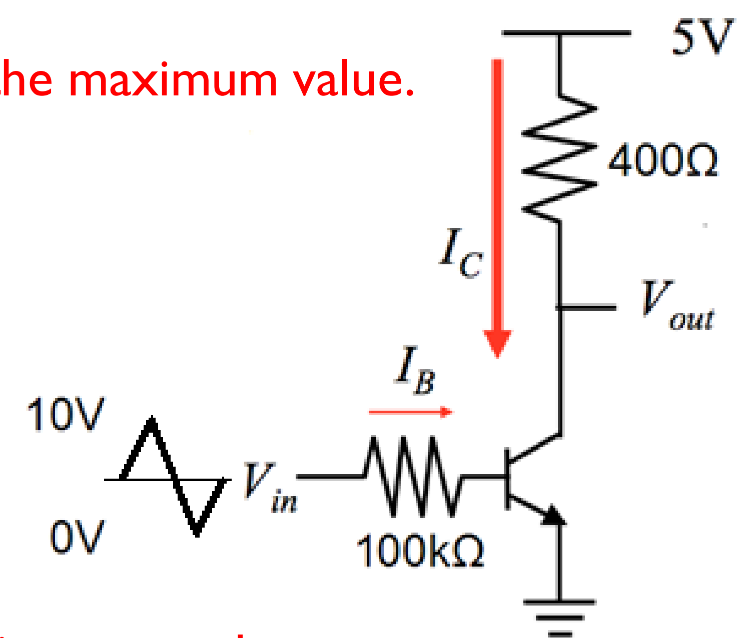
b) the transistor is saturated

When the transistor saturates, I_c attains the maximum value.

$$I_C = \frac{5}{400} = 12.5mA$$

$$\frac{V_{sat} - 0.7}{100k} \times 200 = 12.5m$$

$$V_{sat} = 6.95V$$

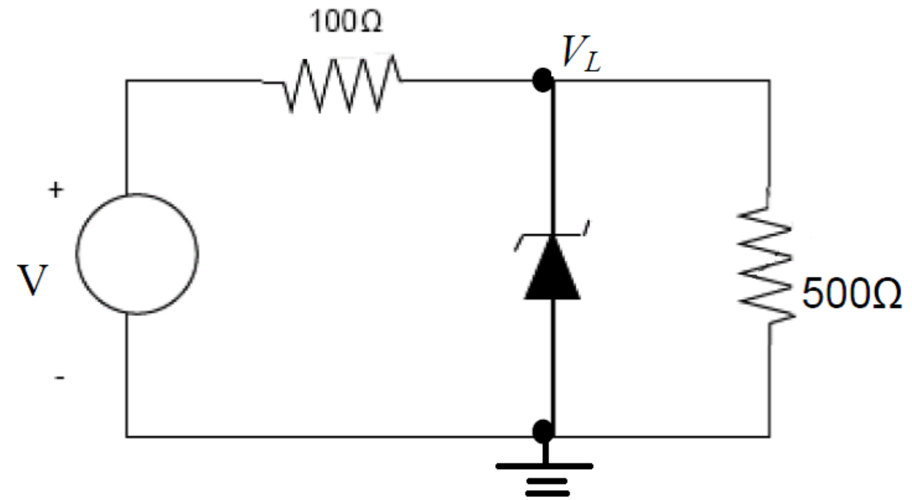


When 6.95V < V_{in} <10V, the transistor is saturated.

Voltage Regulator

The figure below shows a simple voltage regulator design. Assume that the breakdown voltage of the ideal Zener diode is 6.8V. Find out the current flowing through the Zener diode for the following cases.

a) V = 5V   b) V = 8V



a) Since V<6.8V, $i_z = 0A$

b) Assume the Zener diode is off

$$V_L = 8 \times \frac{500}{100+500} = 6.67V < 6.8V$$

$$i_z = 0A$$

The Zener diode is OFF

Logic Design

Design a circuit that has a 3-bit binary input $Q_2Q_1Q_0$ and a single output Y specified as follows:

- Y = 0, no prime number
- Y = 1, prime numbers 2, 3, 5, 7

(a) Finish the truth table for outputs.
(b) Use K-map to find out the *simplest* output expression in terms of the input bits $Q_2Q_1Q_0$.

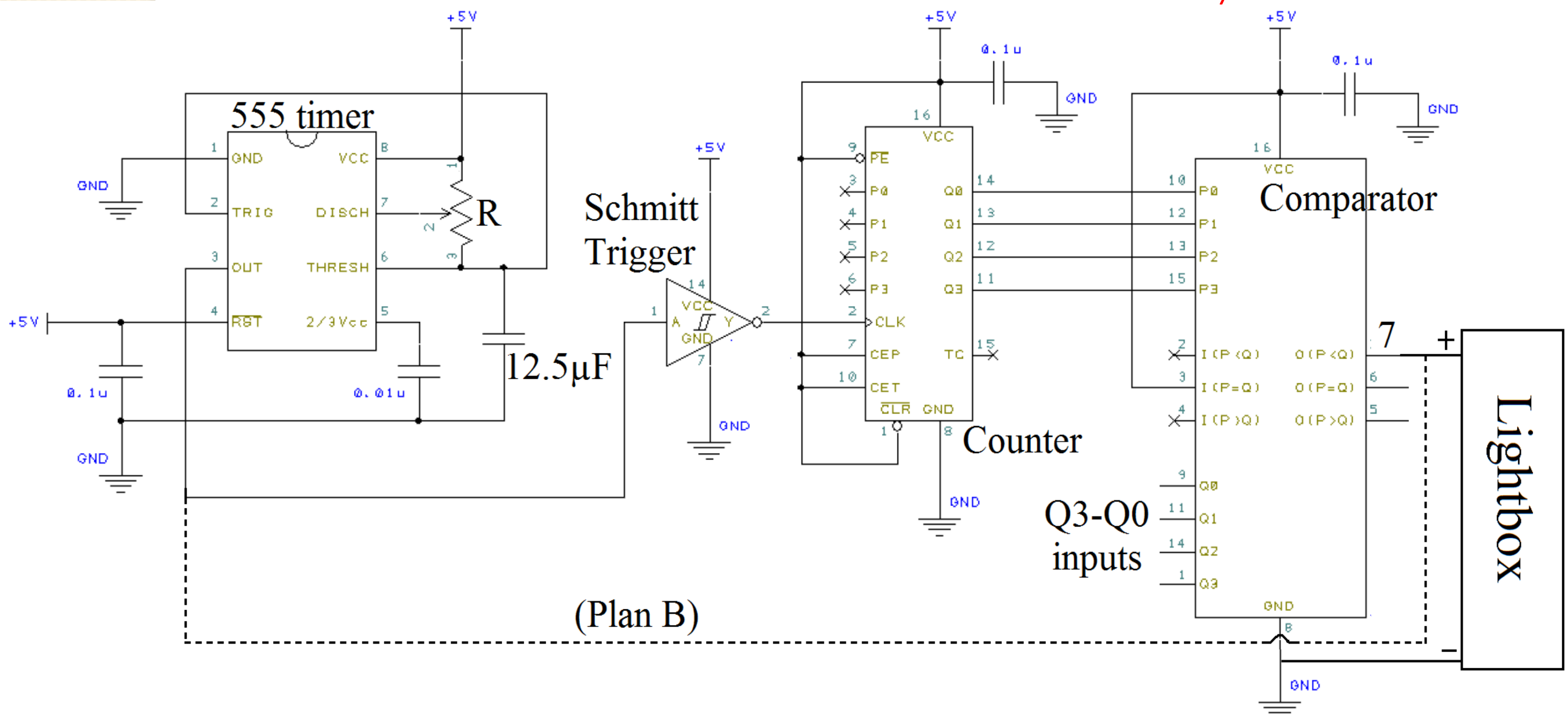
Q_2Q_1 / Q_0	00	01	11	10
0	0	1	0	0
1	0	1	1	1

$$Y = \overline{Q_2}Q_1 + Q_2Q_0$$

Q_2	Q_1	Q_0	Y
0	0	0	0
0	0	1	0
0	1	0	1
0	1	1	1
1	0	0	0
1	0	1	1
1	1	0	0
1	1	1	1

Pulse Generation & PWM

A shop wants to install an advertisement lightbox with neon lights. Figure below shows a proposal of the input voltage pulse to the lights. The total value of the variable resistor is R=RA+RB= 4kΩ with RA (across pins 8 & 7) and RB (across pins 7 & 6). The lights should flash at a frequency of $\frac{10}{7}$ Hz.



Pulse Generation & PWM

a) Determine the comparator inputs Q3-Q0 when the duty cycle at pin 7 is $\frac{5}{8}$.

Since duty cycle = $\frac{5}{8}$, Q = $\frac{5}{8} \times 16 = 10$; Q3-Q0 = 1 0 1 0

b) Using the timer equations, determine the values of RA and RB.

Frequency of comparator $= \frac{10}{7}$;

Frequency of timer $= \frac{10}{7} \times 16 = \frac{160}{7}$.

Period $T = \frac{1}{Freq} = \frac{7}{160} = 0.7(R_A + 2R_B) \times 12.5 \times 10^{-6}$

$\rightarrow R_A + 2R_B = 5k\Omega$;

with given information: $R_A + R_B = 4k\Omega$;

$\rightarrow R_B = 1k\Omega, R_A = 3k\Omega$

Pulse Generation & PWM

c) Due to some technical reason, the comparator IC is not available. The shop decides to provide the input voltage pulse directly from the timer (Plan B, dotted line in the figure). For this scheme change, three variable resistors are available: R = 4kΩ; R = 50kΩ; R = 100kΩ. Which variable resistor should you choose in order to keep the same frequency?

Frequency = 10 / 7;

Period T = 7/10 = $0.7(R_A + 2R_B)(12.5\mu) \rightarrow R_A + 2R_B = 80k\Omega$;

Analysis: R=4kΩ or 100kΩ

→ leads to unreasonable value of R_A or R_B

Conclusion: Choose R = 50kΩ → $R_A + R_B = 50k\Omega$

$\rightarrow R_B = 30k\Omega, R_A = 20k\Omega$