

Part A calculations

5b)

* $F_{osc} = 4 \text{ MHz (default)}$ ← Internal clock rate
 $F_{clk} = 1 \text{ MHz } (\frac{1}{4} \text{ of } F_{osc})$ ← Instruction clock

(1 instruction takes 4 internal clock cycles)

Time to complete 1 instruction cycle \rightarrow 1 instruction cycle $= \frac{1}{4 \text{ MHz}} \times 4 = 1 \mu\text{s}$
 \uparrow
 (F_{osc})

* Each loop will iterate 254 times
 (counter1 = 255 (0xFF)) / (counter2 = 255 (0xFF))

Calculating delay

* $\text{if } \emptyset$, takes 2 instruction cycles $\rightarrow 2 \times 1 \mu\text{s} = 2 \mu\text{s}$
 $\text{if } !\emptyset$, takes 1 instruction cycles $\rightarrow 1 \times 1 \mu\text{s} = 1 \mu\text{s}$

* goto \rightarrow takes 2 instruction cycles $\rightarrow 2 \times 1 \mu\text{s} = 2 \mu\text{s}$

LED delay ON or OFF $= ((254 \times 1 \mu\text{s}) + (254 \times 2 \mu\text{s})) + 1 \times 2 \mu\text{s} = 764 \mu\text{s}$
 (LED will be ON for 764 μs and OFF for 764 μs because of 50% duty cycle)

Calculating LED Frequency

$$\text{Frequency} = \frac{1}{T}$$

$$= \frac{1}{1.528 \text{ ms}}$$

$$\text{Period} = 764 \mu\text{s} \times 2$$

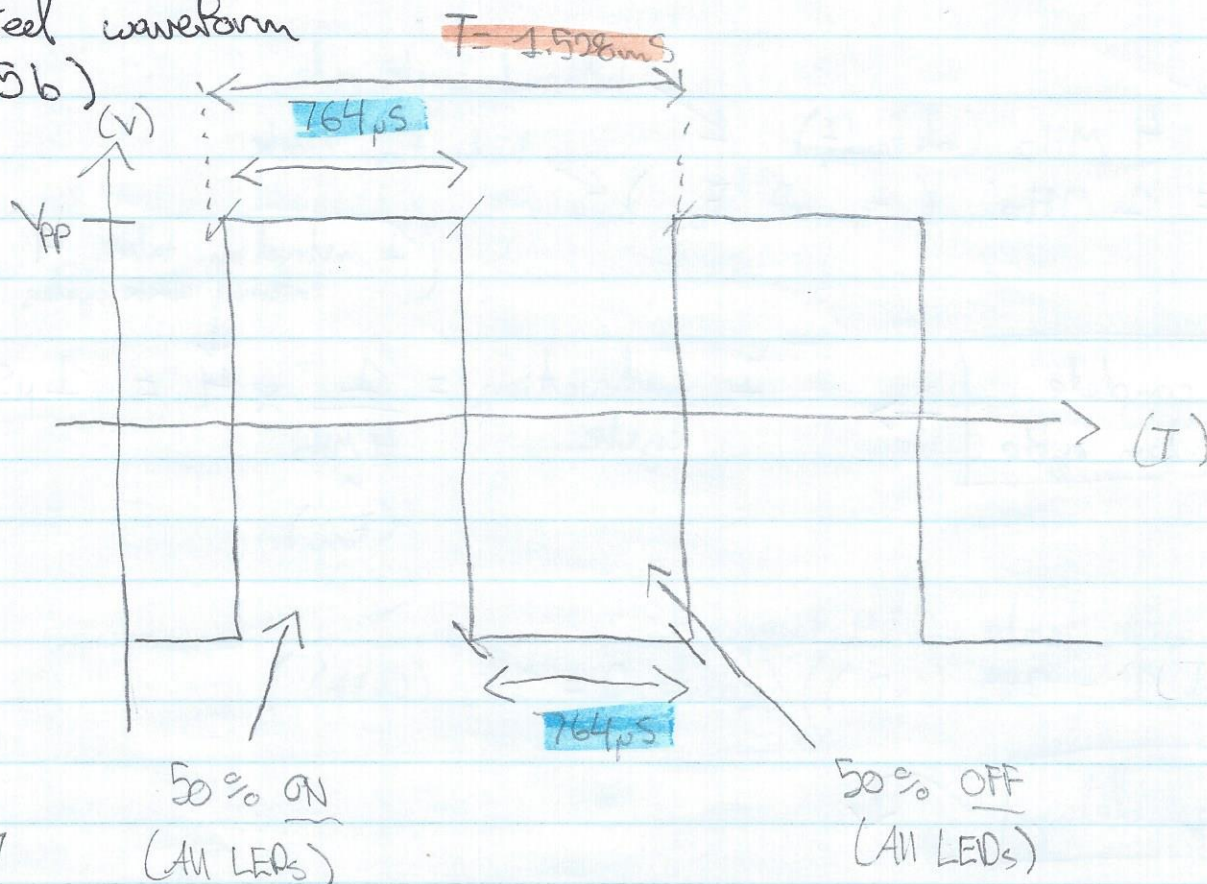
$$\text{Period} = 1.528 \text{ ms}$$

$$\text{Frequency} \approx 654.45 \text{ Hz}$$

LED Flashing Frequency for Part A

Part A calculations (cont.)

Expected waveform
for 5b)



$$F = 654.45\text{ Hz}$$

Observation (img)

Scope :

Time = 0.5ms/div.

Volts = 1V/div.

$$\text{CLKOUT} \approx 1\text{ MHz}$$

$$F = \frac{1}{1\mu\text{s}} \leftarrow (0.5\mu\text{s} \times 2)$$

$$V_{pp} \approx 4.5\text{ V}$$

LED Flashing Frequency

$$V_{pp} \approx 4.5\text{ V}$$

$$F = \frac{1}{1.5\text{ms}} \leftarrow (0.5\text{ms} \times 3)$$

$$F \approx 665\text{ Hz}$$

Time = $.5\mu\text{s/div.}$

Volts = 1V/div.

Part B (I) calculations

8b)

$$* F_{osc} = 31 \text{ kHz}$$

$$F_{cy} = 7.750 \text{ kHz}$$

$$\boxed{\text{Time to complete 1 instruction cycle}} \rightarrow 1 \text{ instruction cycle} = \frac{1}{31 \text{ kHz}} \times 4 = 129.032 \mu\text{s}$$

* Each loop will iterate 254 times
(Counter1 = 255 (0xFF)) / (Counter2 = 2 (0x02))

Calculating delay \rightarrow

$$\begin{aligned} * 1 \text{ } \text{decrs2} & \rightarrow \text{if } \emptyset, \text{ takes 2 instruction cycles} \rightarrow 2 \times 129.032 \mu\text{s} = 258.064 \mu\text{s} \\ & \rightarrow \text{if } !\emptyset, \text{ takes 1 instruction cycles} \rightarrow 1 \times 129.032 \mu\text{s} = 129.032 \mu\text{s} \\ 2 \text{ } \text{goto} & \rightarrow \text{takes 2 instruction cycles} \rightarrow 2 \times 129.032 \mu\text{s} = 258.064 \mu\text{s} \end{aligned}$$

$$\text{LED delay ON or OFF} = ((254 \times 129.032 \mu\text{s}) + (254 \times 258.064 \mu\text{s})) + 1 \times 258.064 \mu\text{s} \approx 98.98 \text{ ms}$$

(LEDs will be ON for 98.98 ms and OFF for 98.98 ms because of 50% duty cycle)

Calculating LED Frequency \rightarrow

$$\text{Frequency} = \frac{1}{T}$$

$$\text{Period} = 98.98 \text{ ms} \times 2$$

$$\text{Period} = 197.16 \text{ ms}$$

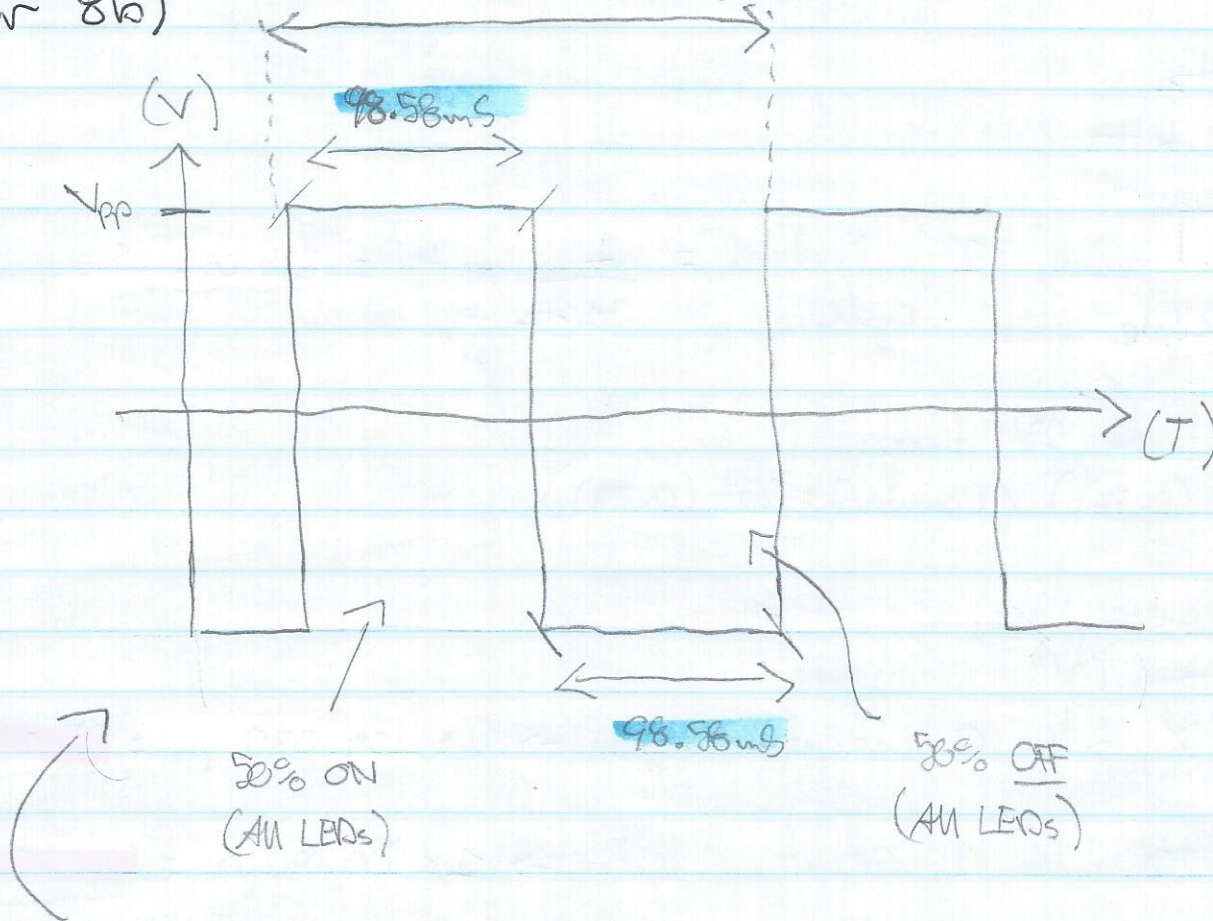
$$= \frac{1}{197.16 \text{ ms}}$$

$$\boxed{\text{Frequency} \approx 5.07 \text{ Hz}}$$

(LED Flashing Frequency for Part B Q7-9)

Part B (I) calculations (cont.)Expected waveform
for 8b)

$$T = 197.16 \mu s$$



$$F = 5.07 \text{ Hz}$$

Observation (my)

Scope:Time = $100 \mu s / \text{div.}$ Volts = $1 \text{ V} / \text{div.}$

$$\text{CLKOUT} \approx 6.7 \text{ kHz}$$

$$F = \frac{1}{150 \mu s} \leftarrow (50 \mu s \times 3)$$

LED Flashing Frequency

$$V_{pp} \approx 4.5 \text{ V}$$

$$F = \frac{1}{200 \mu s}$$

$$F = 5 \text{ Hz}$$

Time = $50 \mu s / \text{div.}$ Volts = $1 \text{ V} / \text{div.}$

$$V_{pp} \approx 4.5 \text{ V}$$

(4)

Part B (II) calculations

10)

Calculating delay

2 x 254 loop iterations because of nested loop technique

For inner loop

$$\begin{aligned}
 \text{LED delay ON or OFF} &= 2(254 \times 129.032 \mu\text{s} + 1 \times 258.064 \mu\text{s}) + (1 \times 129.032 \mu\text{s} + 1 \times 258.064 \mu\text{s}) \\
 &= 197.80 \text{ ms}
 \end{aligned}$$

for outer loop

(LEDs will be ON for 197.80ms and OFF for 197.80ms)
because of 50% duty cycle

Calculating LED
Flash frequency

$$\begin{aligned}
 \text{Period} &= 197.80 \text{ ms} \times 2 \\
 \text{Period} &= 395.6 \text{ ms}
 \end{aligned}$$

$$\text{Frequency} = \frac{1}{T}$$

$$= \frac{1}{395.6 \text{ ms}}$$

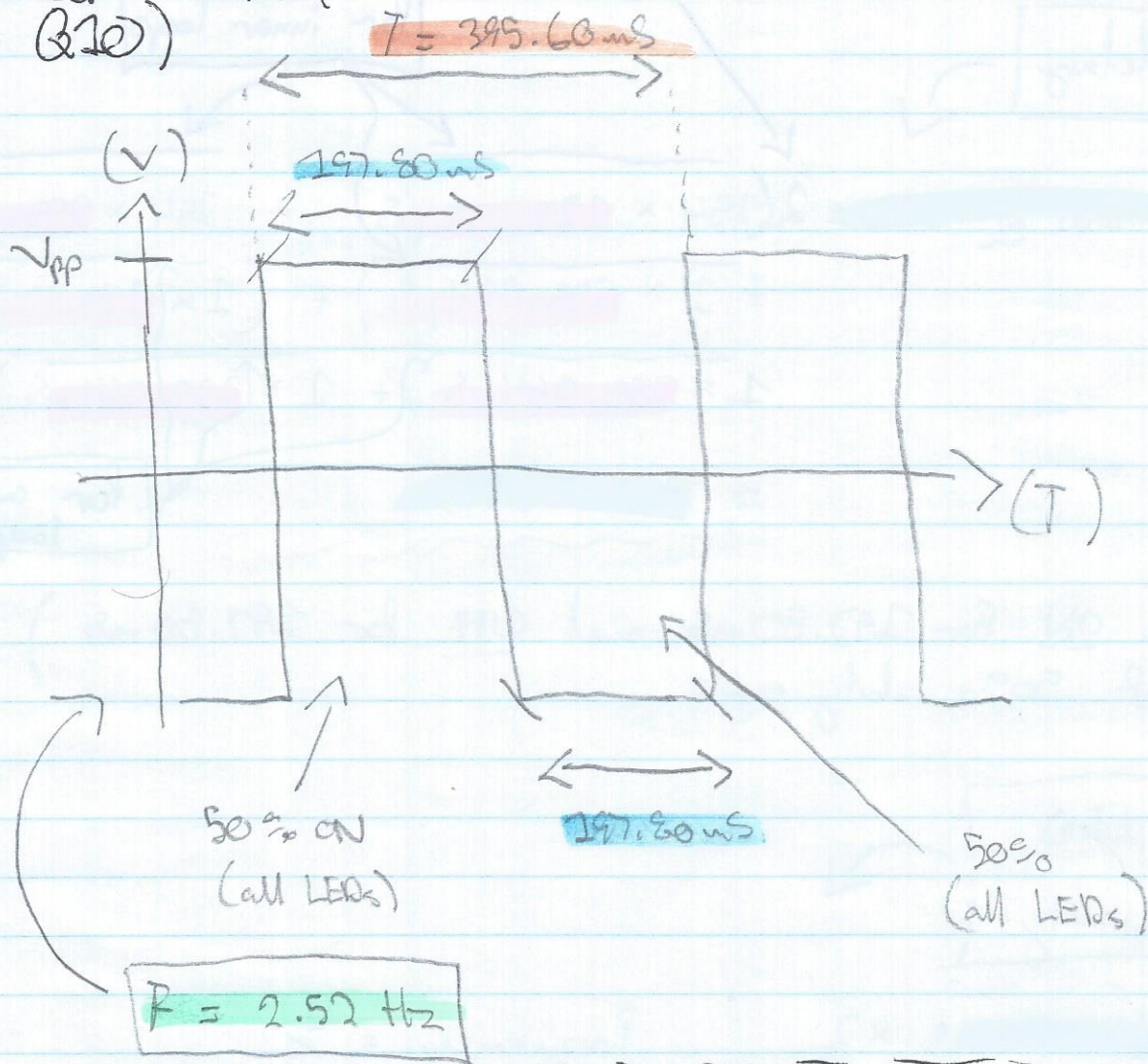
$$\text{Frequency} \approx 2.52 \text{ Hz}$$

$$\frac{5.07 \text{ Hz}}{2.52 \text{ Hz}} = 2 \times \text{slower with nested loops!}$$

LED flashing
frequency for
Part B Q10 with
nested loops

Part B (II) calculations (cont.)

Expected waveform
for Q10)



Observation (img)

Scope:

Time = 100 ns / div.

Volts = 1 V / div.

$CLKOUT \approx 6.7 \text{ kHz}$

$$F = \frac{1}{150 \mu s} \leftarrow (50 \mu s \times 3)$$

LED Flashing frequency

$V_{pp} \approx 4.5 \text{ V}$

$$F = \frac{1}{400 \mu s} \leftarrow (4 \times 100 \mu s)$$

$F = 2.5 \text{ Hz}$

$V_{pp} \approx 4.5 \text{ V}$

Time = 50 ns / div.
Volts = 1 V / div.

⑥