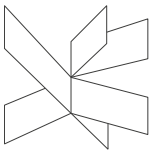
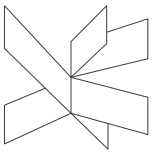


Mandatory Assignment

Table of content



1 Calculate the delays

1.1 Calculate the delay. The clock frequency is 16MHz

```
delay:
ldi r20, 86
loop1:
dec r20
brne loop1
```

Solution

$$1+86\cdot 3-1=258 \qquad \frac{258}{16\ MHz}=16.125\ \mu s$$

1.2 Calculate the delay. The clock frequency is 16MHz

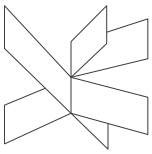
```
delay:
ldi r20, 100
loop1:
nop
dec r20
brne loop1
nop
nop
```

Solution

$$1+100\cdot 4-1+2=402 \qquad \frac{402}{16\ MHz}=25.125\ \mu s$$

1.3 Calculate the delay. The clock frequency is 16MHz

```
delay:
```



```
ldi r20, 200
loop1:
nop
dec r20
nop
nop
brne loop1
nop
nop
```

Solution

$$1+200\cdot 6-1+2=1202 \qquad \frac{1202}{16\ MHz}=75.125\ \mu s$$

1.4 Calculate the delay. The clock frequency is 16MHz

```
delay:
ldi r18, 180
loop2:
ldi r20, 199
loop1:
dec r20
brne loop1
dec r18
brne loop2
```

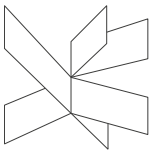
Solution

$$loop1 := 1+3\cdot 199-1=597$$

$$delay := (597+3)\cdot 180=108000 \qquad \frac{108000}{16\ MHz}=6.75\ ms$$

1.5 Calculate the delay. The clock frequency is 16MHz

```
delay:
ldi r18, 11
loop2:
nop
ldi r20, 15
```



```
loop1:
nop
nop
dec r20
nop
brne loop1
nop
nop
dec r18
brne loop2
nop
nop
nop
```

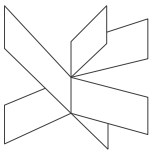
Solution

$$loop1 := 1 + 6 \cdot 15 - 1 = 90$$

$$delay := (90 + 6) \cdot 11 + 3 = 1059 \qquad \frac{1059}{16\ MHz} = 66.188\ \mu s$$

1.6 Calculate the delay. The clock frequency is 16MHz

```
delay:
ldi r16, 14
loop3:
ldi r18, 11
loop2:
ldi r20, 15
loop1:
dec r20
brne loop1
dec r18
brne loop2
dec r16
brne loop3
```



Solution

$$loop1 := 3 \cdot 15 = 45$$

$$loop2 := (45 + 3) \cdot 11 = 528$$

$$delay := (528 + 3) \cdot 14 = 7434 \qquad \frac{7434}{16\ MHz} = 464.625\ \mu s$$

1.7 Calculate the delay. The clock frequency is 16MHz

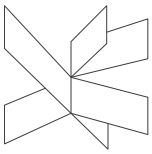
```
delay:
ldi r16, 14
loop3:
nop
ldi r18, 110
loop2:
nop
ldi r20, 150
loop1:
dec r20
brne loop1
nop
nop
dec r18
brne loop2
dec r16
nop
brne loop3
nop
nop
nop
```

Solution

$$loop1 := 3 \cdot 150 = 450$$

$$loop2 := (450 + 6) \cdot 110 = 50160$$

$$delay := (50160 + 5) \cdot 14 + 3 = 702313 \qquad \frac{702313}{16\ MHz} = 43.895\ ms$$



2 Create delays

2.1 Your microcontroller is connected to a 16MHz clock. Create a delay that is around $10\mu s$ (+- 5%):

Solution

$$clocks := 10\ \mu s \cdot 16\ MHz = 160$$

You could choose a loop of 5 clocks and run it 32 times ($32 * 5 = 160$)

```
delay:
ldi r16, 32
loop1:
nop
nop
dec r16
brne loop1
```

2.2 Your microcontroller is connected to a 16MHz clock. Create a delay that is around $168\mu s$ (+- 5%):

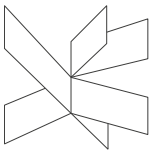
Solution

$$clocks := 168\ \mu s \cdot 16\ MHz = 2688$$

If you divide this number with 16, you get a round number: $\frac{2688}{16} = 168$

So make a loop that take 16 clocks and run it 168 times:

```
delay:
ldi r16, 168
loop1:
nop
nop
nop
nop
nop
nop
nop
nop
nop
nop
```



```
nop
nop
nop
dec r16
brne loop1
```

2.3 Your microcontroller is connected to a 16MHz clock. Create a delay that is around $1ms$ (+- 5%):

Solution

$$clocks := 1 \cdot ms \cdot 16 \cdot MHz = 16000$$

One way of doing this is to create an innerloop that takes 495 clocks. Then an outer loop that add 5 clocks, and then runs 32 times.

$$(495 + 5) * 32 = 16000$$

```
delay:
ldi r17, 32
loop2:
ldi r16, 99
loop1:
nop
nop
dec r16
brne loop1
nop
nop
dec r17
brne loop2
```