Outline

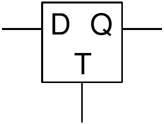
1. Digital Systems
   - flip-flops
   - registers
2. Intrinsic Operations
   - sorting words
   - values of numbers given in words
3. queues and stacks
   - using Python lists
   - towers of Hanoi
4. Summary + Assignments

MCS 260 Lecture 10
Introduction to Computer Science
Jan Verschelde, 3 February 2016

flip-flops and registers
queues and stacks

Flip-Flops
one bit memory

Flip-Flops (and latches) are the simplest circuits to store one bit.



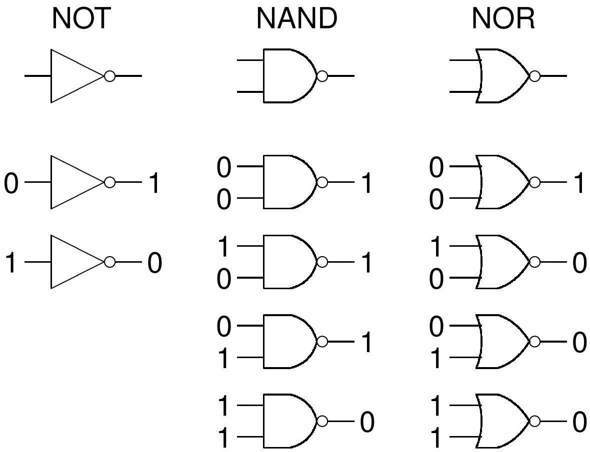
D: input line
T: clock line
Q: output line

Its behavior is as follows:

1. When one arrives on the clock line, the output line is set to the value present on the input line.
2. The value at the output line is stored at the flip-flop, until a new one arrives on the clock line.

Logic Gates

A flip-flop is realized with NOT, NAND, and NOR gates:

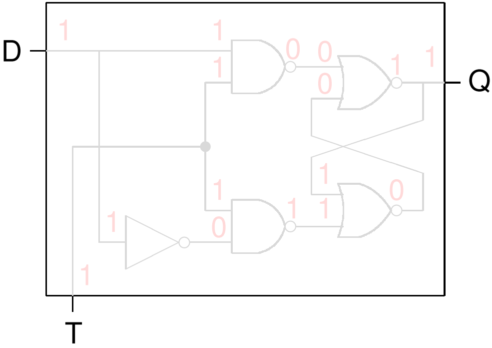


Exercise: represent `NOT ( x NOR ( NOT y ) )`.

Realization of a Flip-Flop

one NOT, two NANDs, and two NORs

We simulate the *latching* of a 1 at D to Q, with 1 at Q.



Exercise: verify the effect is the same for 0 at Q.

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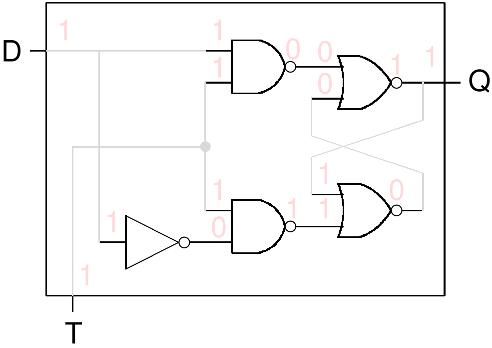

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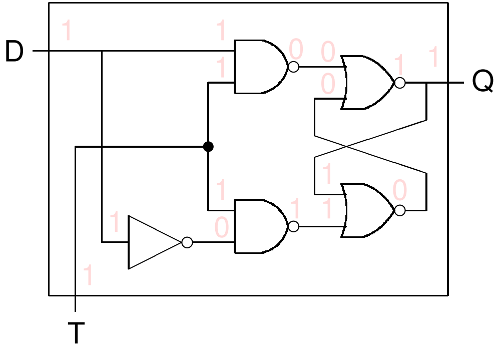

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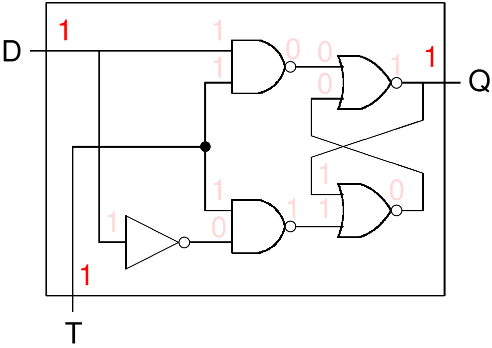

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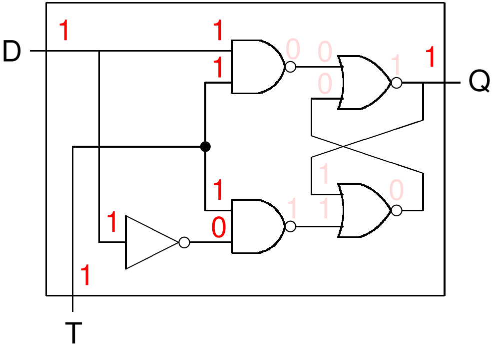

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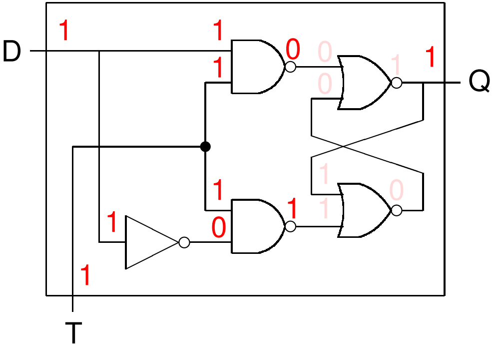

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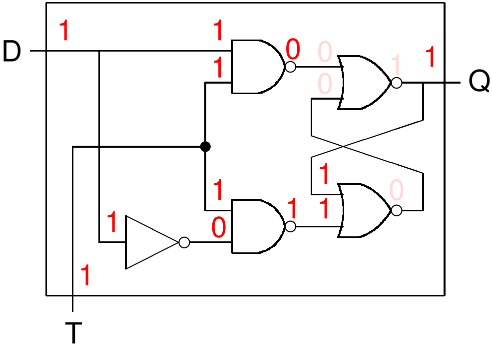

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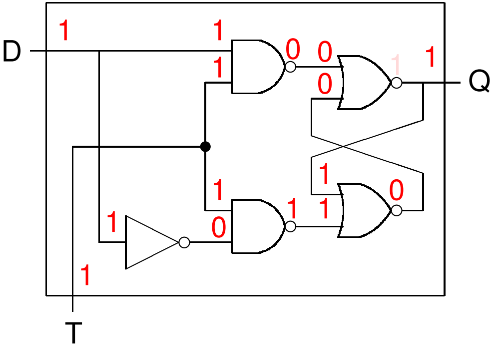

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Realization of a Flip-Flop

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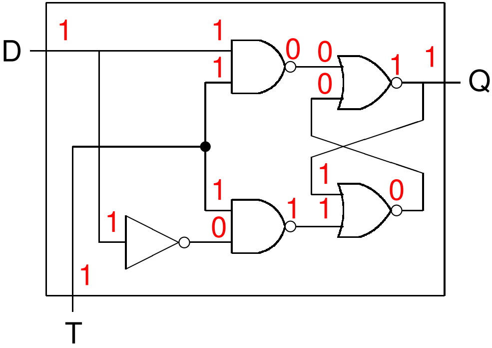
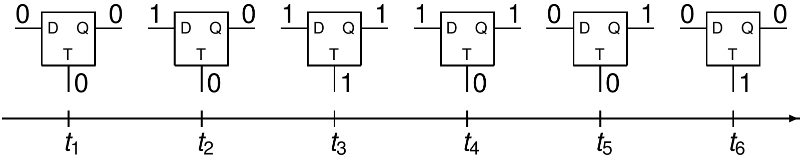


Exercise: verify the effect is the same for 0 at Q.

Behavior in Time

how latching of bits works

The evolution in time is



At t_1: 0 at D, 0 at T, and 0 at Q

At t_2: 1 at D, but 0 at T and nothing happens

At t_3: 1 at T $\Rightarrow$ 1 at D copied to 1 at Q

At t_4: 0 at T and nothing happens

At t_5: 0 at D, but 0 at T and nothing happens

At t_6: 1 at T $\Rightarrow$ 0 at D copied to 0 at Q

flip-flops and registers
queues and stacks

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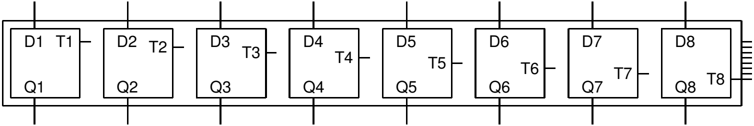
Registers

An 8-bit register is realized with 8 flip-flops.

eight input lines and eight clock lines

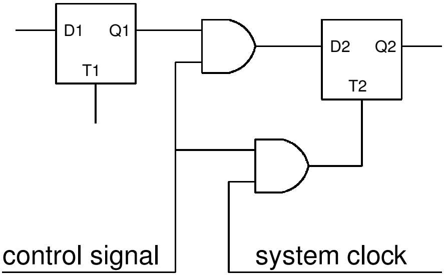


eight output lines

Copy Bits

using 2 AND gates

We want to copy a bit from one latch to the other.
The bit is at the output line of the first latch, at Q1 and has to get to the output line of the second latch, at Q2.



The copy is activated by the control signal.
For synchronization, another signal from the system clock copies the bit from the input line at D2 to Q2.

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sorting words – program specification

Input/Output problem statement:

Input: string with words separated by spaces.

Output: string with alphabetically sorted words.

Running sortwords.py at the command prompt `$`:

```
$ python sortwords.py
Give words : this is my sentence
Sorted words : is my sentence this
$
```

sorting words in the Python shell

```
>>> s = 'this is my sentence'
>>> L = s.split()
>>> L
['this', 'is', 'my', 'sentence']
```

Methods are different from functions:

```
>>> max(L)
'this'
>>> min(L)
'is'
>>> L.sort()
>>> L
['is', 'my', 'sentence', 'this']
>>> ' '.join(L)
'is my sentence this'
```

operations on strings and lists: split, join, and sort

To sort a list `L`:

```
>>> L.sort()
```

A compare function can be given as argument in `()`.

To split a string `s` into a list `L` of strings:

```
>>> L = s.split()
```

The default separator is a space, another separator (like a comma or colon) can be given as string in `()`.

To join a list of strings `L` into one string `s`:

```
>>> s = ' '.join(L)
```

The separator used between the strings in `L` is the string to which the method is applied to.

sorting words – a Python program

The program sortwords.py:

```
"""
This program shows intrinsic operations
on strings and lists, to sort words,
given as a raw input string by the user.
"""
WORDS = raw_input('Give words : ')
SPLITTED = WORDS.split()     # spaces separate words
SPLITTED.sort()              # sort alphabetically
SORTED = ' '.join(SPLITTED) # join the sorted list
print('Sorted words :' , SORTED)
```

flip-flops and registers queues and stacks

value of a number given in words

Problem Statement:

Input: string with *at most* two words, separated by *exactly one* space.

Output: value of the number represented by the string.

Running the Python code `write_values.py`:

```
$ python write_values.py
give a number in words : forty seven
the value of forty seven is 47
```

Note: reverse of `write_numbers.py` of the previous lecture.

the dictionary to translate words into values

The keys are strings representing words,
the values are the corresponding numbers.

```
DIC = { \
    'zero':0, 'one':1, 'two':2, 'three':3, \
    'four':4, 'five':5, 'six':6, 'seven':7, \
    'eight':8, 'nine':9, 'ten':10, \
    'eleven':11, 'twelve':12, 'thirteen':13, \
    'fourteen':14, 'fifteen':15, 'sixteen':16, \
    'seventeen':17, 'nineteen':19, 'twenty':20, \
    'thirty':30, 'forty':40, 'fifty':50, \
    'sixty':60, 'seventy':70, 'eighty':80, \
    'ninety':90, 'hundred':100 \
}
```

The dictionary solves 28 cases.

dictionary is stored in write_values.py

```
>>> from write_values import DIC as d
>>> s = 'forty seven'
>>> s in d
False
>>> L = s.split(' ')
>>> L
['forty', 'seven']
>>> L[0] in d
True
>>> d[L[0]]
40
>>> d[L[1]]
7
>>> v = d[L[0]] + d[L[1]]
>>> v
47
```

Python script `write_values.py` continued

```
WORDS = raw_input('give a number in words : ')
OUTCOME = 'the value of ' + WORDS + ' is '
if WORDS in DIC:
    OUTCOME += str(DIC[WORDS])
else:
    SPLITTED = WORDS.split(' ')
    OUTCOME += str(DIC[SPLITTED[0]] \
                 + DIC[SPLITTED[1]])
print OUTCOME
```

Alternative: do *first* `L = s.split(' ')`
and then test on `len(L) == 1` to determine `outcome`.

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Queues and Stacks

use of Python lists
Two protocols to retrieve elements sequentially:

- **FIFO:** First In First Out, a queue
  think of a normal waiting list
- **FILO:** First in Last Out, a stack
  think of a pile of papers on a desk

Intrinsic operations on a list L:

L.append(<item>)	appends <item> to L
<item> = L.pop()	removes last item added to L
<item> = L.pop(0)	removes first item added to L
L.insert(0,<item>)	inserts <item> to front of L

All these operations modify L!

How to select from L, *without modifications*?

```
>>> L[0]
>>> L[len(L)-1]
```

Lists as Queues and Stacks

a session in the Python shell

```
>>> L = 'these are some words'.split()
>>> L
['these', 'are', 'some', 'words']
>>> L.append('and')
>>> L
['these', 'are', 'some', 'words', 'and']
>>> last = L.pop()
>>> last
'and'
>>> first = L.pop(0)
>>> first
'these'
>>> L
['are', 'some', 'words']
```

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The Towers of Hanoi

a mathematical puzzle

Input: a stack of disks, all of varying size,
no larger disk sits above a smaller disk,
and two other empty stacks.

Task: move the disks from the first stack to the second, obeying the following rules:
1. move one disk at a time,
2. never place a larger disk on a smaller one,
you may use the third stack as buffer.

How many moves does it take?

Towers of Hanoi

for three disks in Python

- three lists `A`, `B`, `C` as stacks
- disks are represented as numbers $1 < 2 < 3$

```
Towers of Hanoi with 3 disks
initially : A = [1, 2, 3] B = [] C = []

move 1 : A = [2, 3] B = [1] C = []

move 2 : A = [3] B = [1] C = [2]

move 3 : A = [3] B = [] C = [1, 2]

move 4 : A = [] B = [3] C = [1, 2]

move 5 : A = [1] B = [3] C = [2]

move 6 : A = [1] B = [2, 3] C = []

move 7 : A = [] B = [1, 2, 3] C = []
```

Towers of Hanoi for 3 disks

```
"""
To illustrate the use of stacks we solve the
towers of Hanoi problem with three disks.
"""
print 'Towers of Hanoi with 3 disks'
A = [1, 2, 3]
B = []
C = []
print('initially : A =', A, 'B =', B, 'C =', C)
```

Towers of Hanoi: the moves for 3 disks

```
B.insert(0, A.pop(0))
print('move 1 : A =', A, 'B =', B, 'C =', C)
C.insert(0, A.pop(0))
print('move 2 : A =', A, 'B =', B, 'C =', C)
C.insert(0, B.pop(0))
print('move 3 : A =', A, 'B =', B, 'C =', C)
B.insert(0, A.pop(0))
print('move 4 : A =', A, 'B =', B, 'C =', C)
A.insert(0, C.pop(0))
print('move 5 : A =', A, 'B =', B, 'C =', C)
B.insert(0, C.pop(0))
print('move 6 : A =', A, 'B =', B, 'C =', C)
B.insert(0, A.pop(0))
print('move 7 : A =', A, 'B =', B, 'C =', C)
```

Summary + Assignments

In this lecture we covered more of

- section 1 in *Computer Science: an overview*;
- pages 122-127 of *Python Programming in Context*.

Assignments:

1. Translate the realization diagram for a flip-flop into a logical expression involving the variables D, T, and Q, using NOT, NAND, and NOR.
2. Write a Python program to convert a date like `3 February 2016` into `2016-02-03`.
   Names of the month are written in full.
3. Extend `write_values.py` so it works for all strings representing numbers less than one thousand.
4. Extend the Python code for the towers of Hanoi so that it works for four disks.