NEC 304

STLD

Lecture 33

Arithmetic Logic Unit (ALU)

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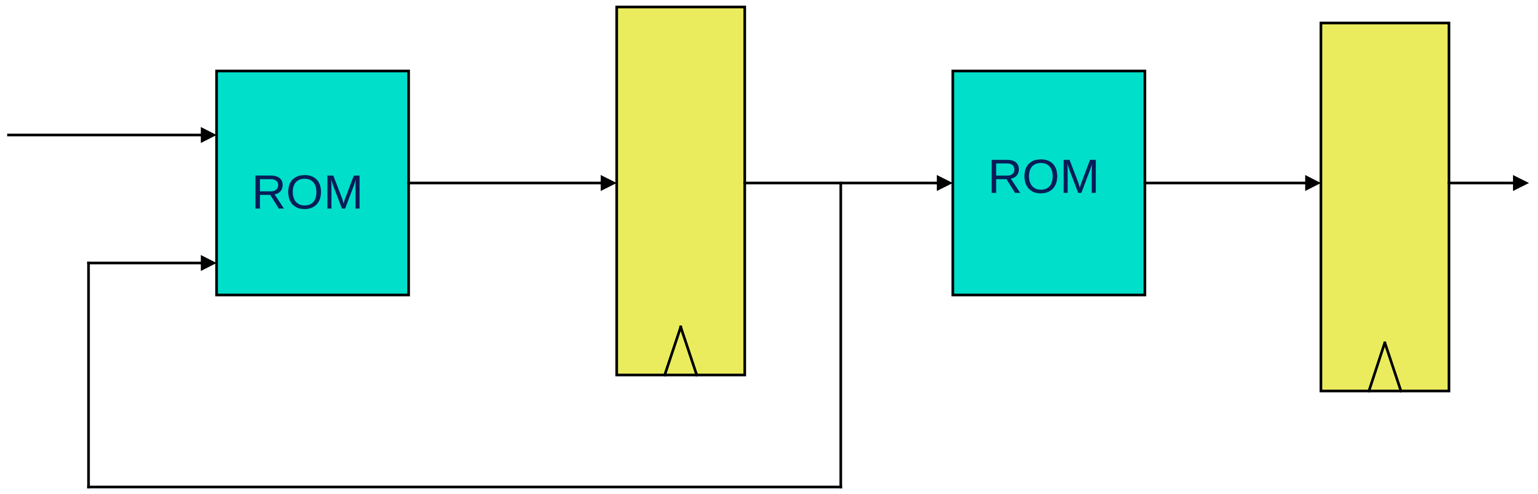
Overview

- Main computation unit in most computer systems
- ALUs perform a vaiety of different functions
  - Add, subtract, OR, AND…
- Example: ALU chip (74LS382)
  - Has data and control inputs
- Individual chips can be chained together to make larger ALUs
- ALUs are important parts of datapaths
  - ROMs often are usd in the control path
- Build a data and control path

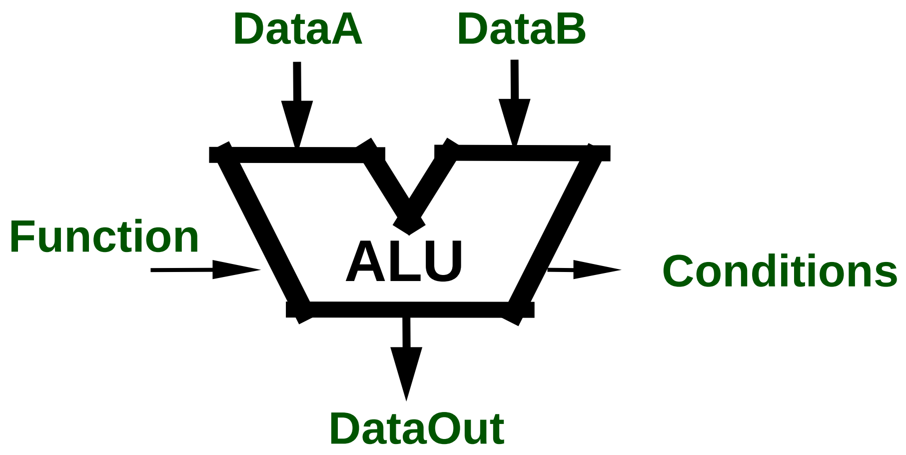
ROM-based Moore Machine Timing

- What is the maximum clock frequency of this circuit?
- Does this circuit satisfy hold time constraints?

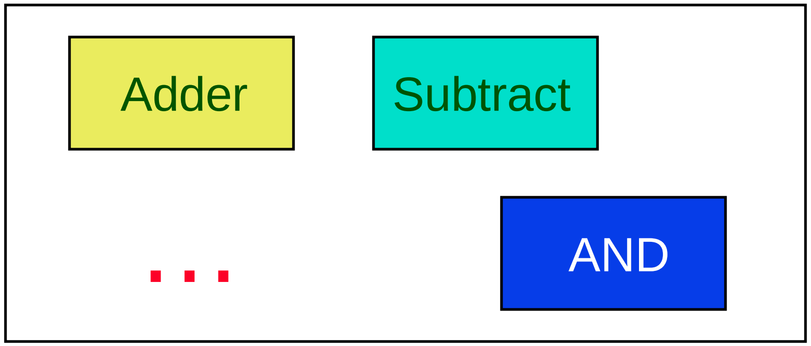


Arithmetic Logic Unit

- Arithmetic logic unit functions
  - Two multi-bit data inputs
  - Function indicates action (e.g. add, subtract, OR…)
- DataOut is same bit width as multi-bit inputs (DataA and DataB)
- ALU is combinational
- Conditions indicate special conditions of arithmetic activity (e.g. overflow).

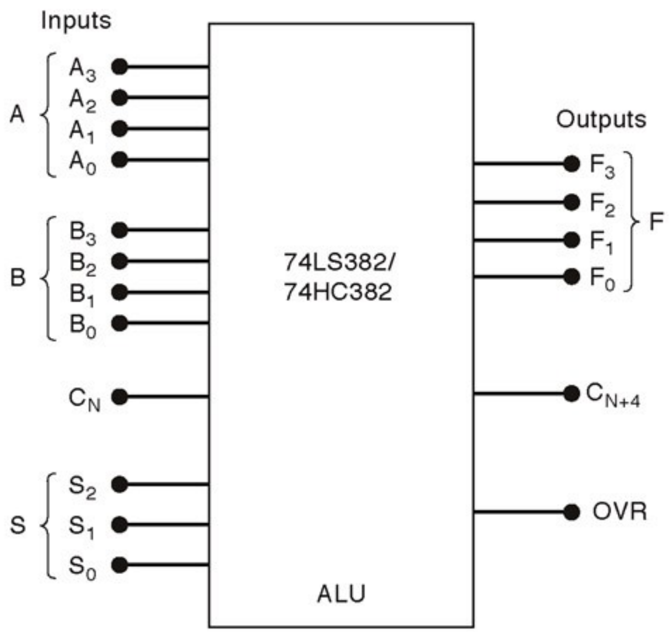


Think of ALU as a number of other arithmetic and logic blocks in a single box! Function selects the block



ALU Integrated Circuit

- Integrated circuit – off-the-shelf components
- Examine the functionality of this ALU chip



A = 4-bit input number
B = 4-bit input number
C_N = carry into LSB position
S = 3-bit operation select inputs

F = 4-bit output number
C_{N+4} = carry out of MSB position
OVR = overflow indicator

(a)

Function Table

S_2	S_1	S_0	Operation	Comments
0	0	0	CLEAR	$F_3F_2F_1F_0 = 0000$
0	0	1	B minus A	Needs $C_N = 1$
0	1	0	A minus B	
0	1	1	A plus B	Needs $C_N = 0$
1	0	0	$A \oplus B$	Exclusive-OR
1	0	1	A + B	OR
1	1	0	AB	AND
1	1	1	PRESET	$F_3F_2F_1F_0 = 1111$

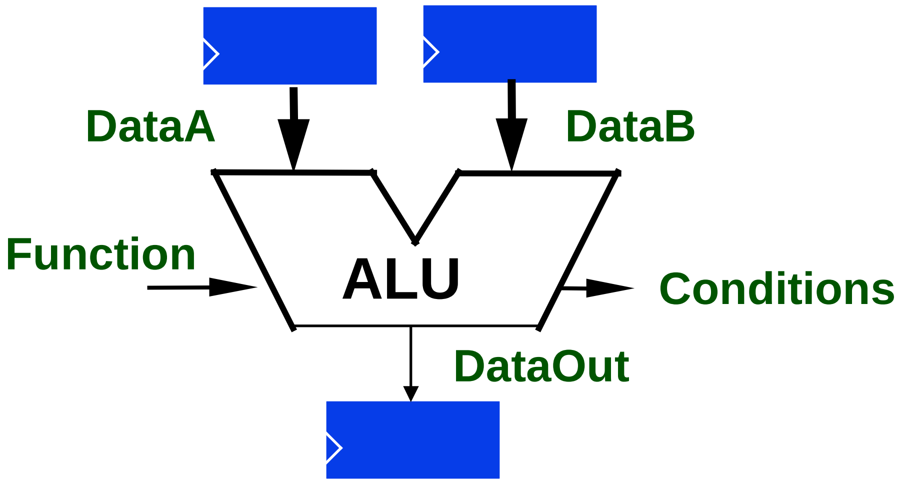
Notes: S inputs select operation.
OVR = 1 for signed-number overflow.

(b)

Performs 8 functions

Example

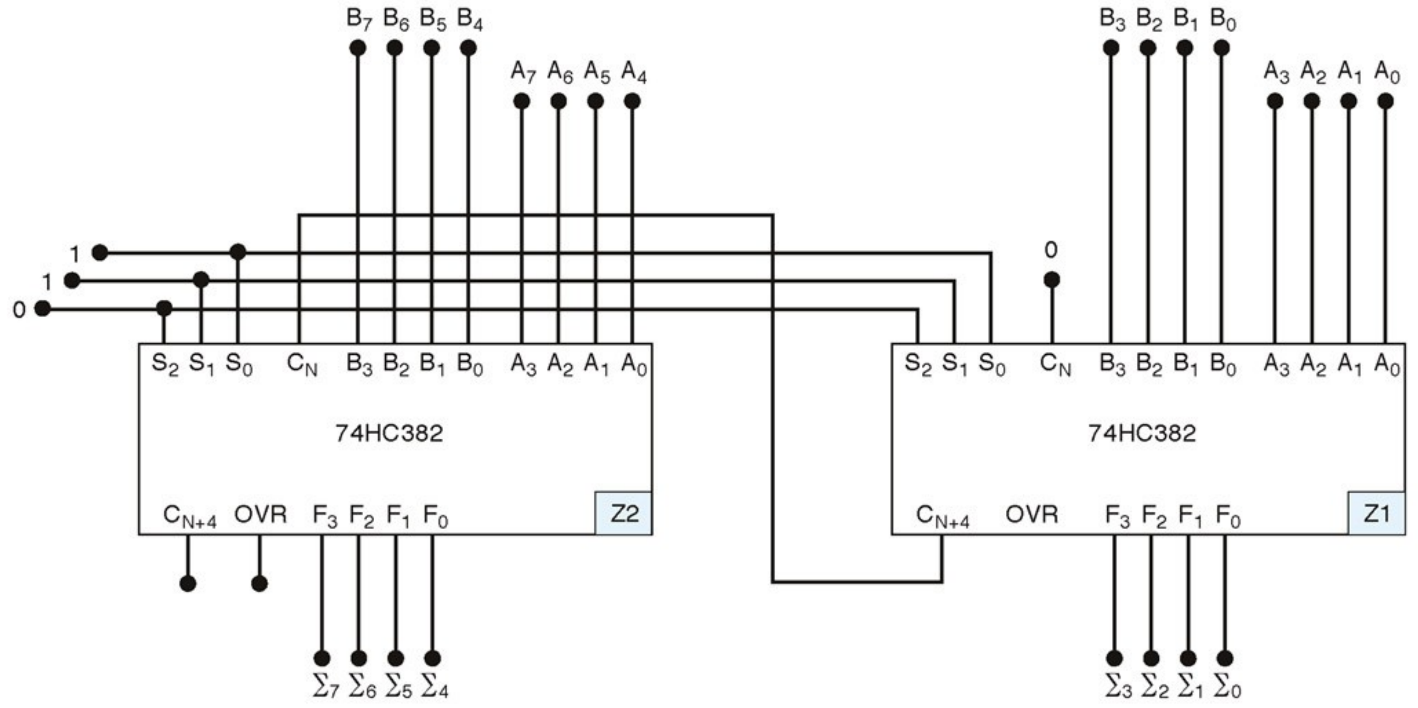
- Determine the 74HC382 ALU outputs for the following inputs: $S_2S_1S_0$=010, $A_3A_2A_1A_0$=0100, $B_3B_2B_1B_0$=0001, and C_N=1.
  - Function code indicates subtract
  - 0100 – 0001 = 0011
- Change the select code to 101 and repeat.
  - Function code indicates OR
  - 0100 OR 0001 = 0101



Synchronize ALU with a clock

Expanding the ALU

- **Multi-bit ALU created by connecting carry output of low-order chip to carry in of high order**

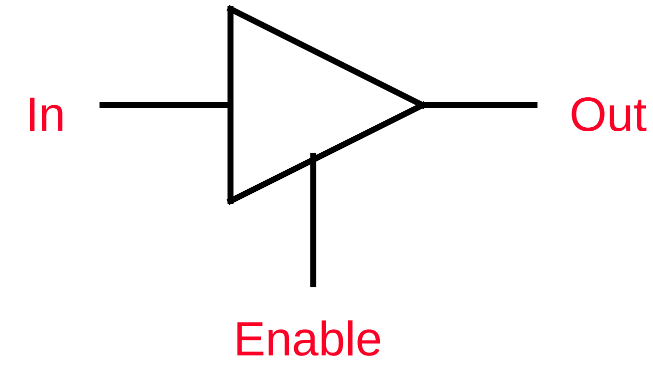


Notes: Z1 adds lower-order bits.
Z2 adds higher-order bits.
Σ_7–Σ_0 = 8-bit sum.
OVR of Z2 is 8-bit overflow indicator.

Eight-bit ALU formed from 2 four-bit ALUs

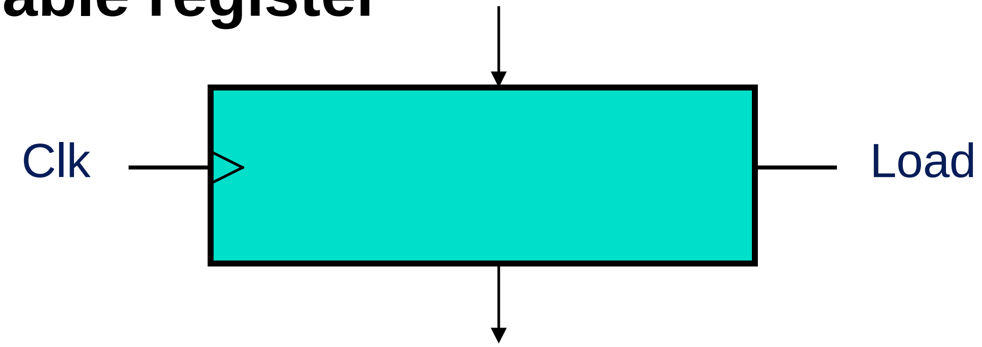
Datapath components

- **Tri-state buffer**



If Enable asserted,
  Out = In
Otherwise
  Out open-circuit

- **Loadable register**



Data stored on rising edge if Load is asserted (e.g. Load = 1)

Computation in a Typical Computer

- **Control logic often implemented as a finite state machine (including ROMs)**
- **Datapath contains blocks such as ALUs, registers, tri-state buffers, and RAMs**
- **In a processor chip often a 5 to 1 ratio of datapath to control logic**

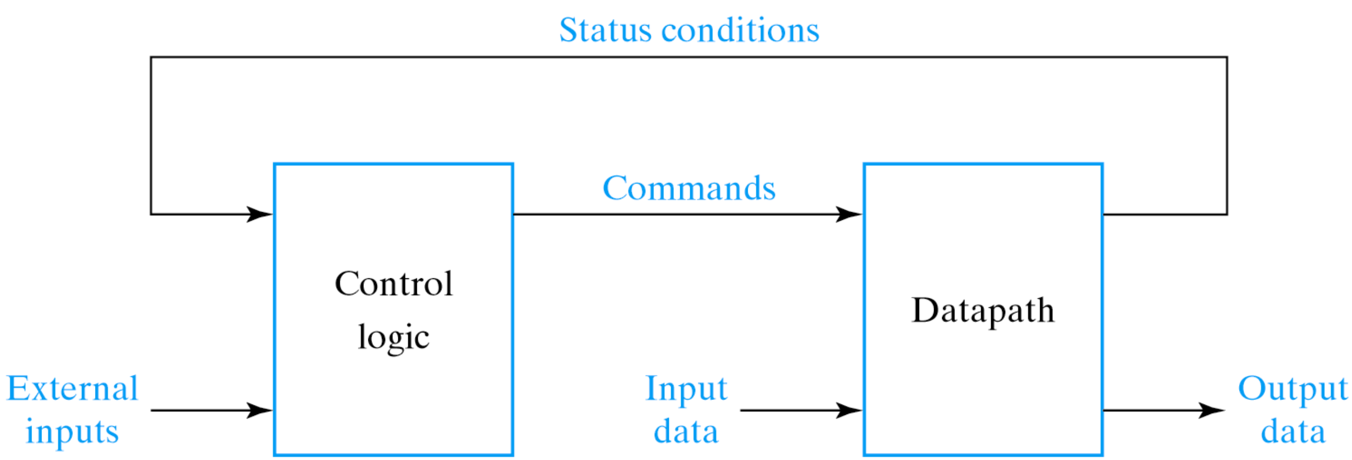
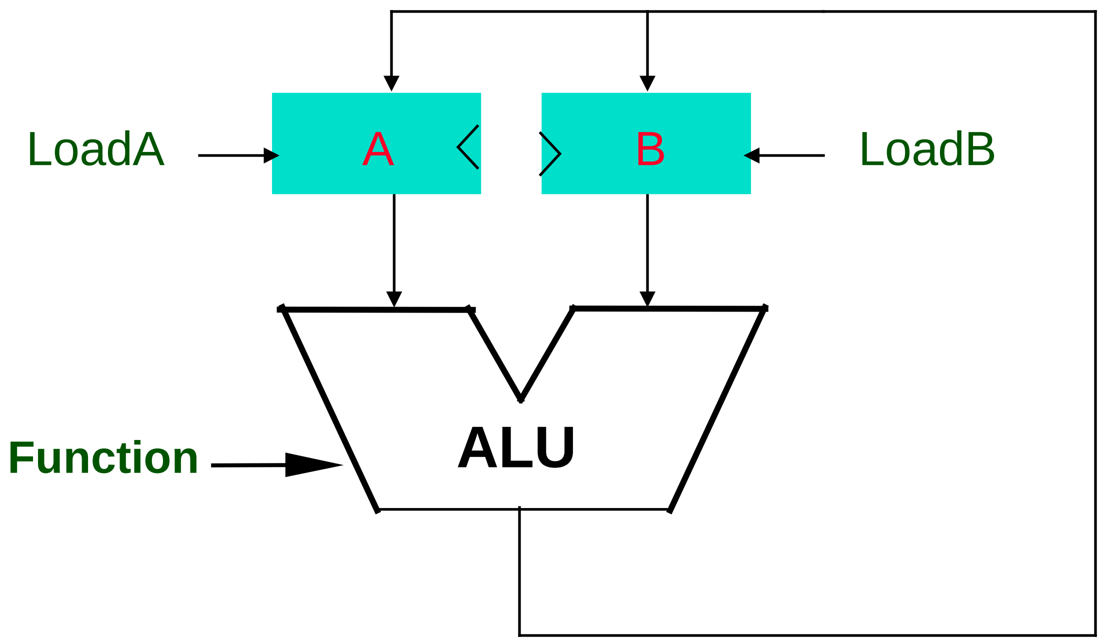


Fig. 8-2 Control and Datapath Interaction

Using a Datapath

- **Consider the following computation steps**
  1. **ADD A, B and put result in A**
  2. **Subtract A, B and put result in B**
  3. **OR A, B put result in A**
  - **Repeat starting from step 1**

Determine values
for Function, LoadA, LoadB



Modeling Control as a State Machine

- **Consider the following computation steps**
  1. **ADD A, B and put result in A**
  2. **Subtract A, B and put result in B**
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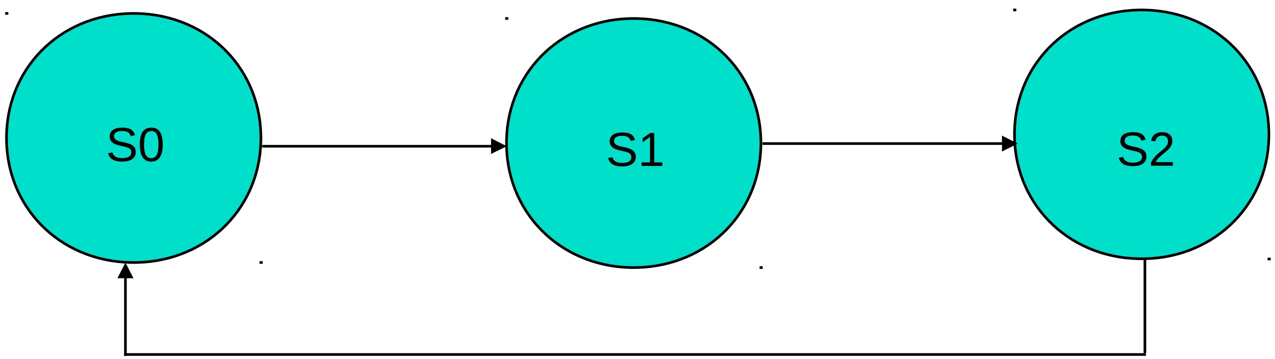
  - **Repeat starting from step 1**

Determine values
for Function, LoadA, LoadB

Model control as a state machine.
Determine control outputs for each state



Modeling Control as a State Machine

- **Consider the following computation steps**
  1. **ADD A, B and put result in A**
  2. **Subtract A, B and put result in B**
  3. **OR A, B put result in A**
  - **Repeat starting from step 1**

States
S0 = 00
S1 = 01
S2 = 10

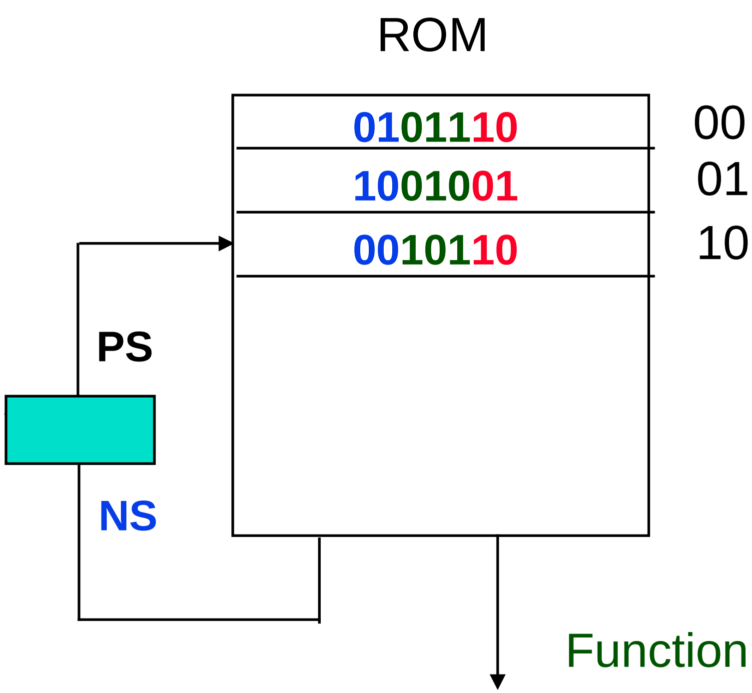
Present State	Next State	Function	LoadA	LoadB
00	01	011	1	0
01	10	010	0	1
10	00	101	1	0

We know how to implement this using an SOP.
Can we use a ROM?

ROM Implementation of State Machine

Present State	Next State	Function	LoadA	LoadB
00	01	011	1	0
01	10	010	0	1
10	00	101	1	0

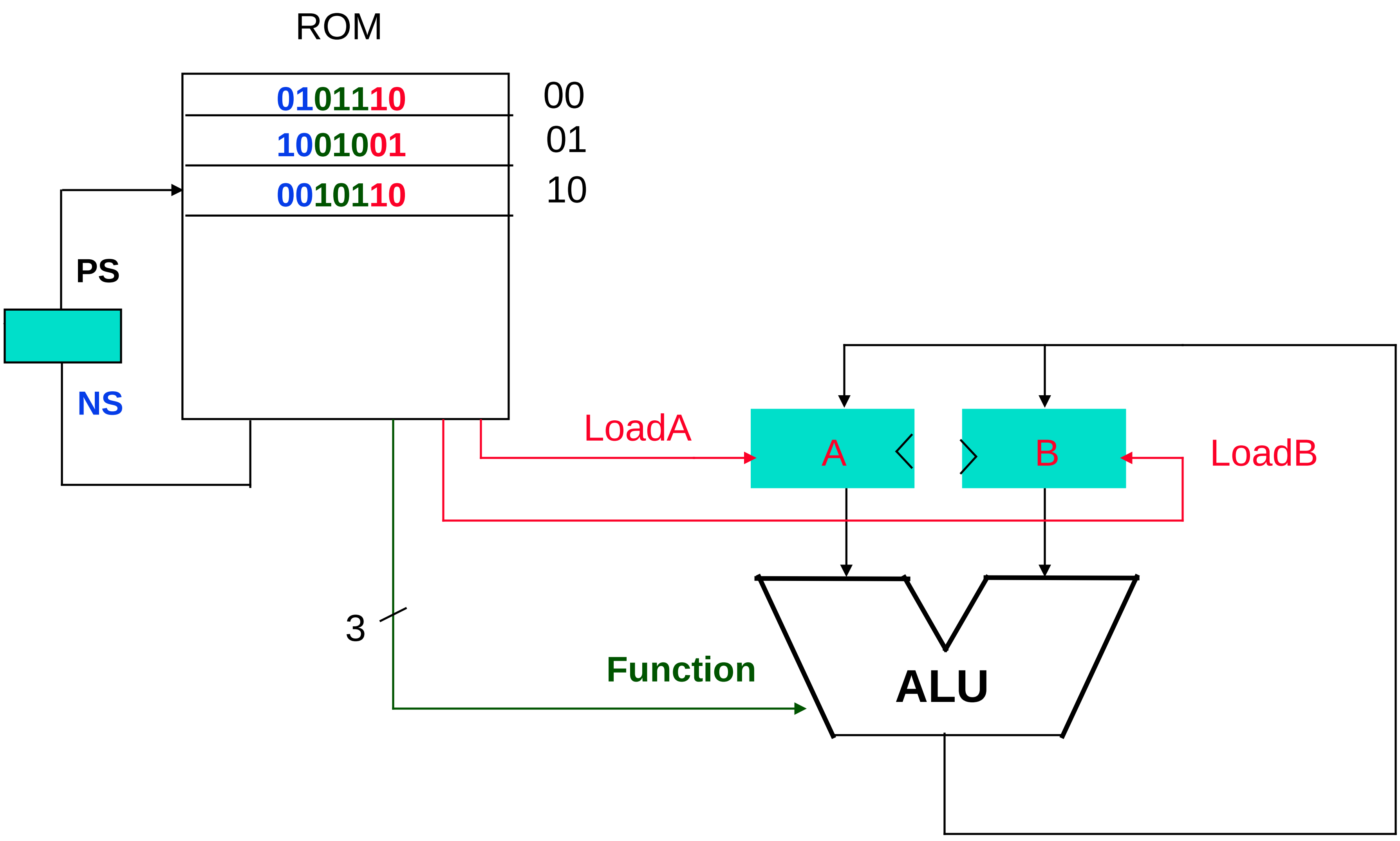
States
S0 = 00
S1 = 01
S2 = 10



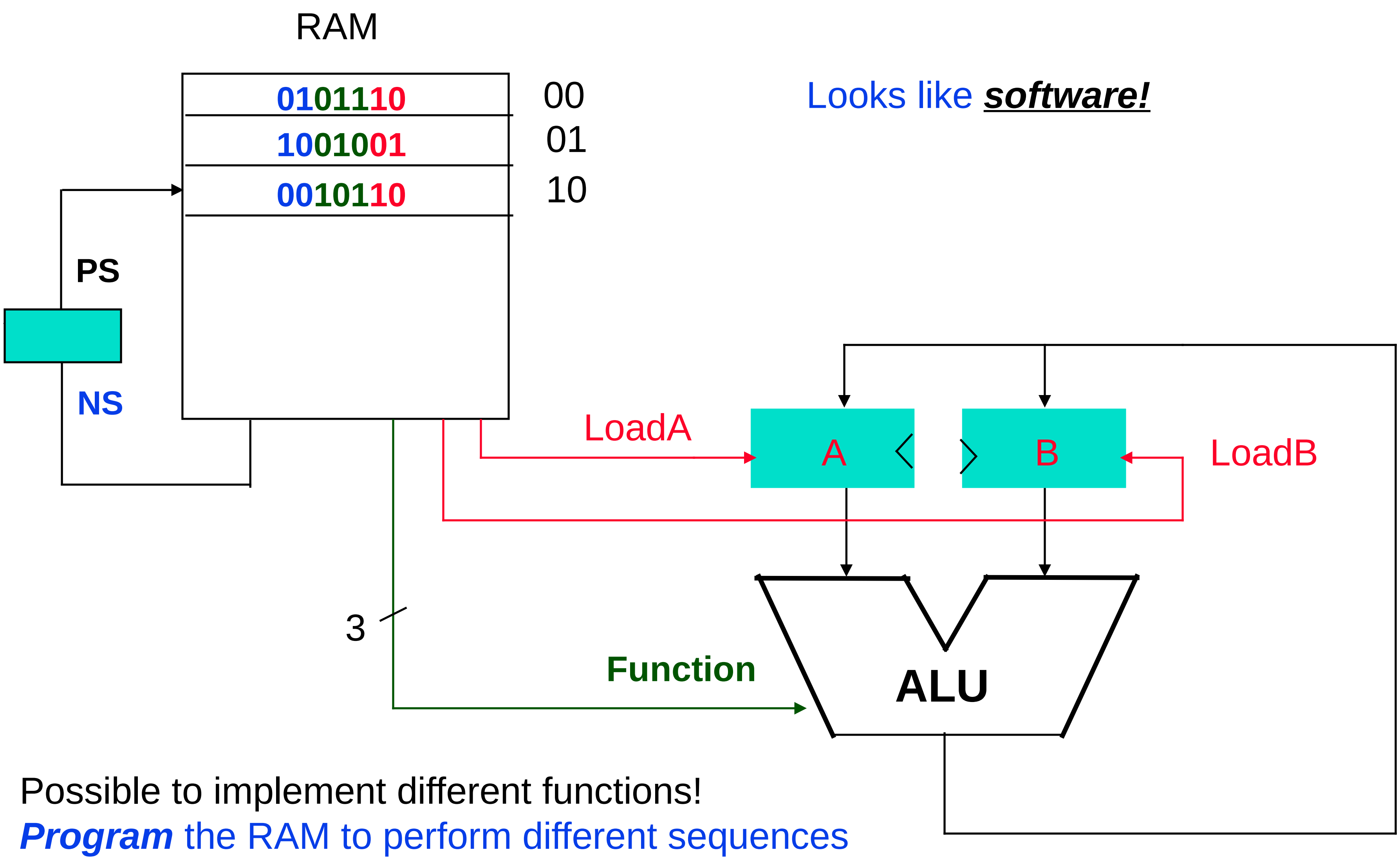
Note: No minimization!
One line in ROM for each state

Function, LoadA, LoadB

Putting the Control and Datapath Together



What if we replaced the ROM with RAM?



Possible to implement different functions!

Program the RAM to perform different sequences

Summary

- ALU circuit can perform many functions
  - Combinational circuit
- ALU chips can be combined together to form larger ALU chips
  - Remember to connect carry out to carry in
- ALUs form the basis of datapaths
- ROMs can form the basis of control paths
- Combine the two together to build a computing circuit
- Next time: more data and control paths