Calculator project introduction

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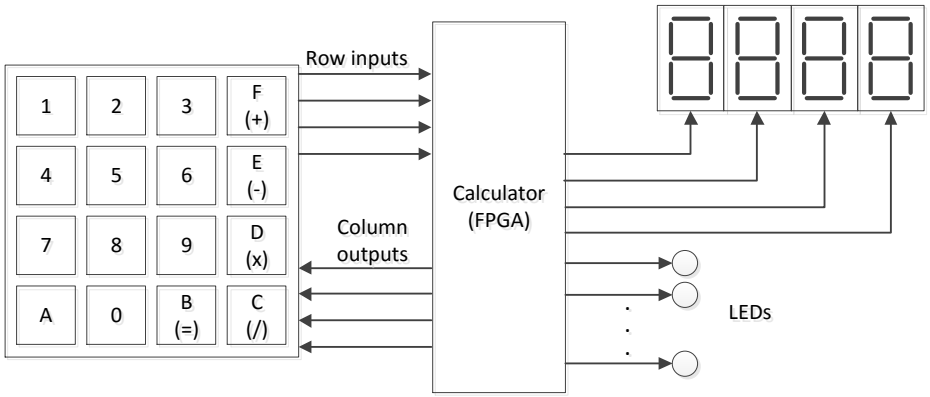
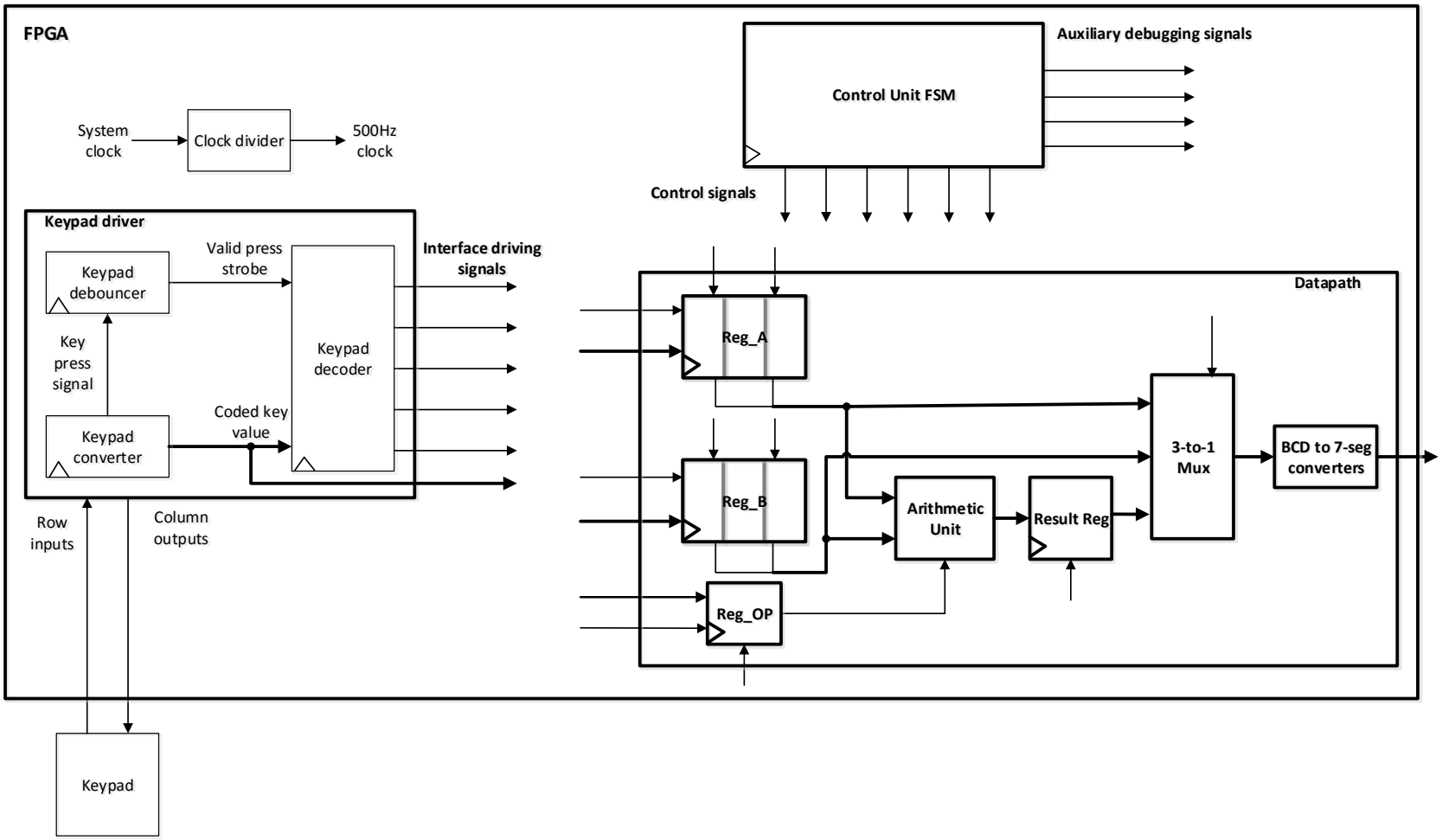
Simple calculator

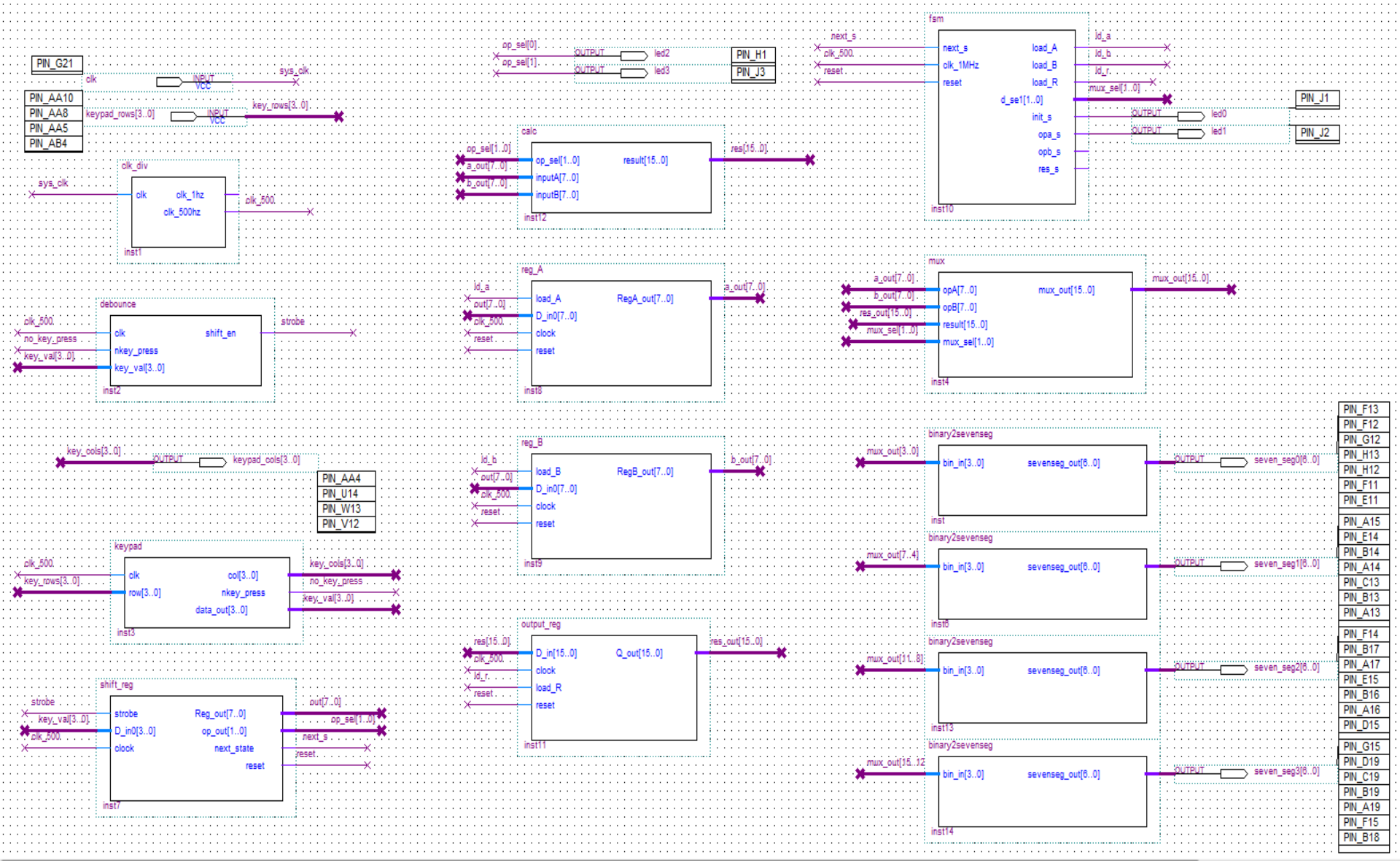
- Project summary: a simple calculator that
  - Accepts and stores up to two digits integer input (value range?) for both operands
  - Performs
    - Two operands op: addition, subtraction, multiplication, or division on the operands
    - For the result of division, display integer quotient and remainder
  - Display the entered operands and computed results as integer values on the 7-segment displays
  - Keys on the keypad are used for entering digits and operations



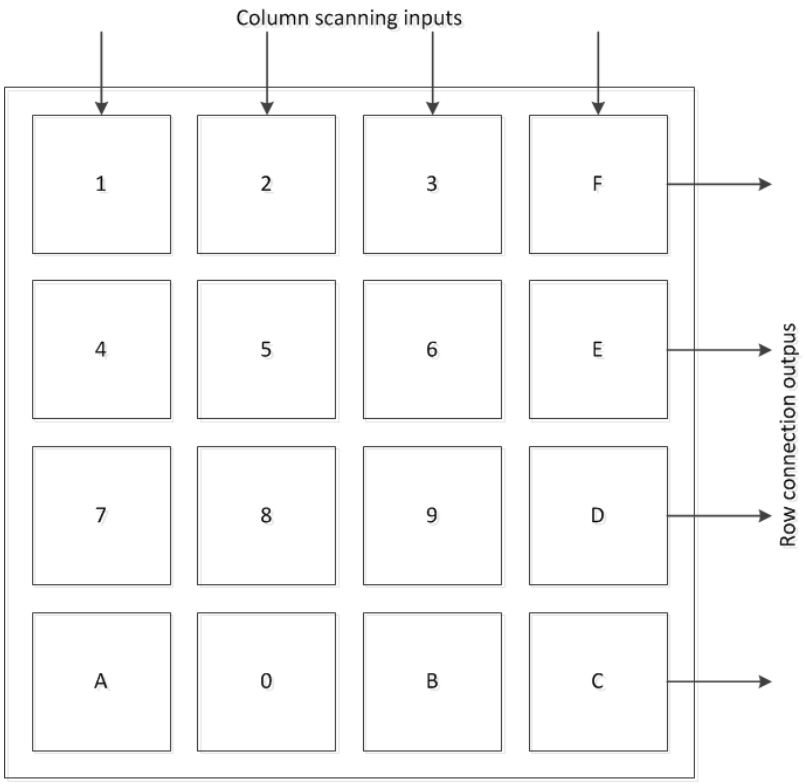
Simple calculator



Simple calculator in reality

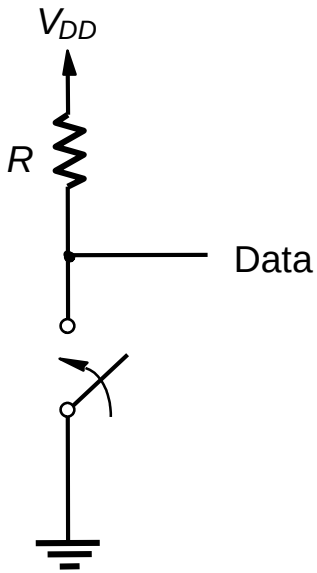


Matrix keypad



- Different to DIP switch and pushbutton, keypad provides coded inputs rather than raw on/off signal
- Assume no multiple key presses at the same time
- Questions:
  - How to handle variable numbers of input digits
  - How to differentiate numbers and operations
  - How to assign multiple roles to a single key

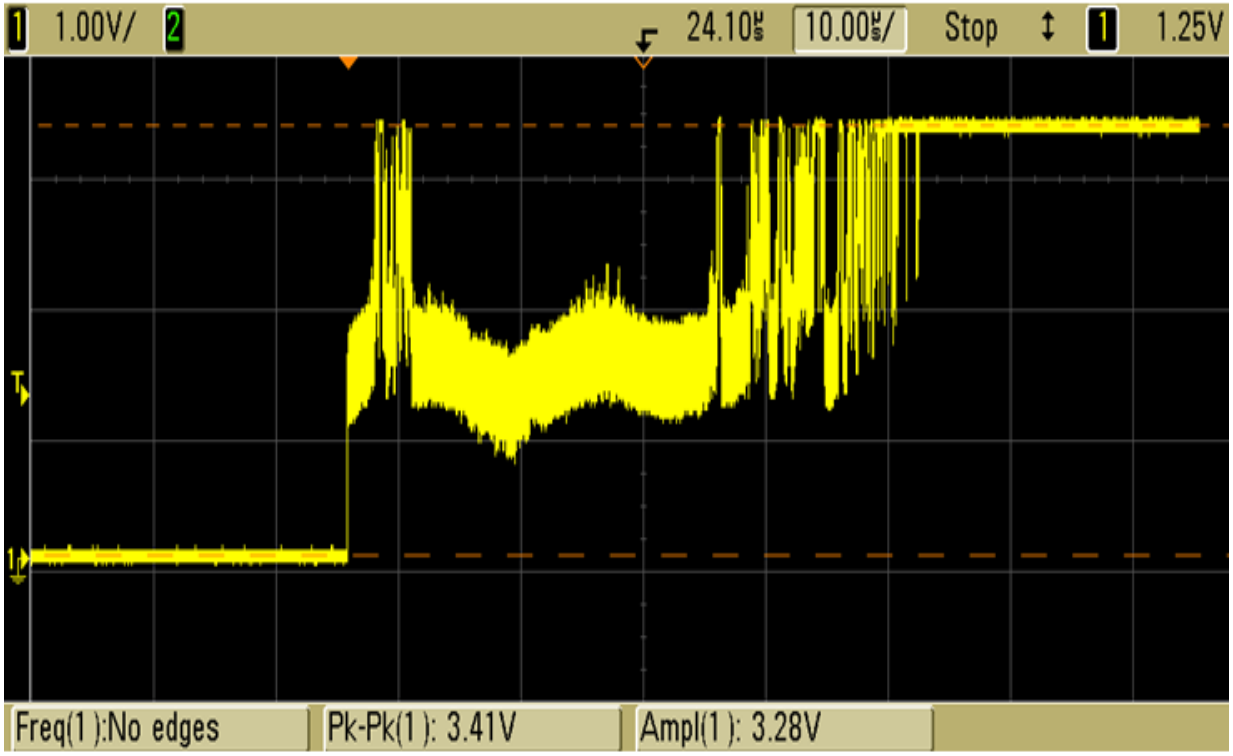
Mechanical switches



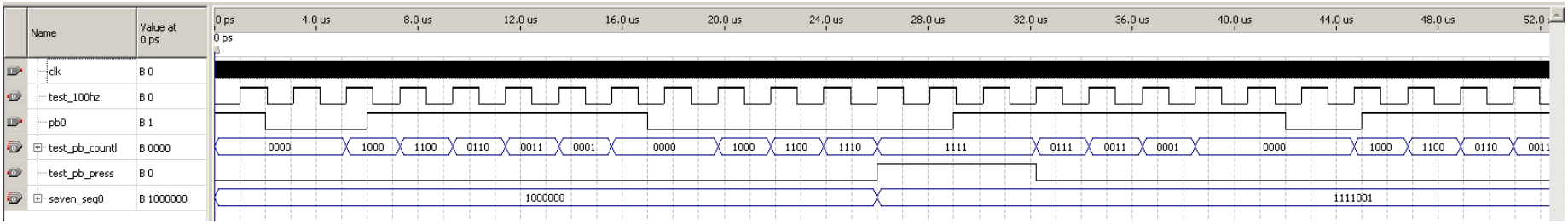
- If the switch is open, the *Data* signal = 1
- When the switch is now closed, it will bounces for some time, causing *Data* to oscillates between 1 and 0
- Bouncing persist for about 10 ms. Data alternates between 0 and 1, while you expect a clean signal
  - Lead into falsely recognised multiple presses
- Different mechanical devices may have different characteristics

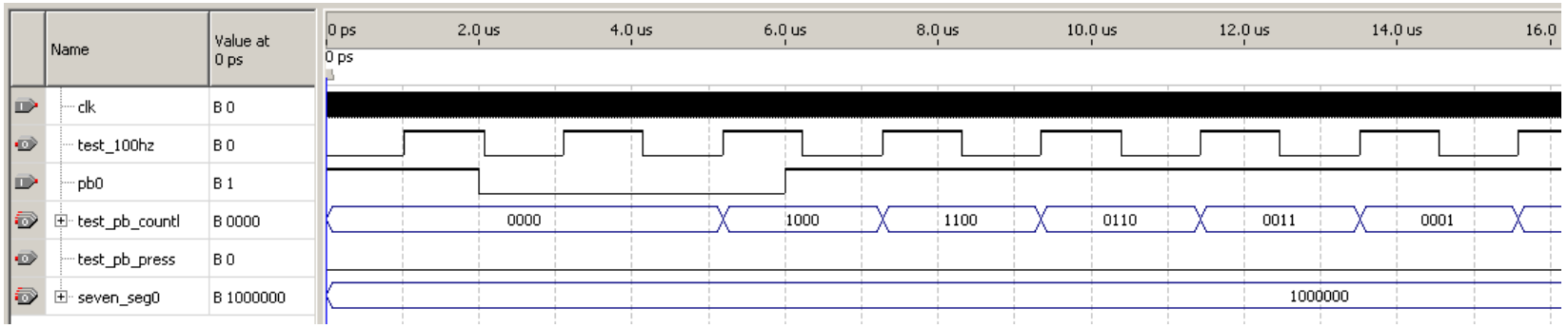
Bouncing effect for DE0 pushbutton

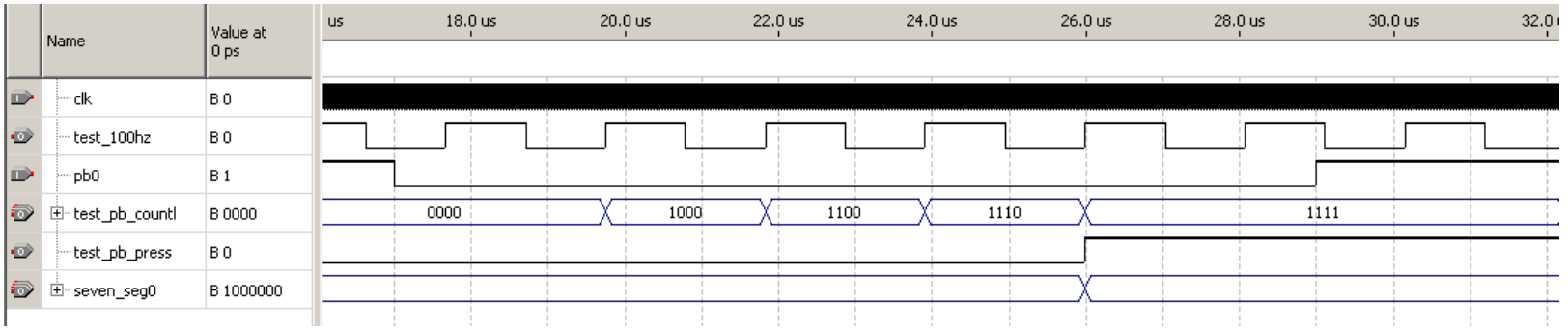
- Active low pushbutton
- Bouncing happens on the rising edge



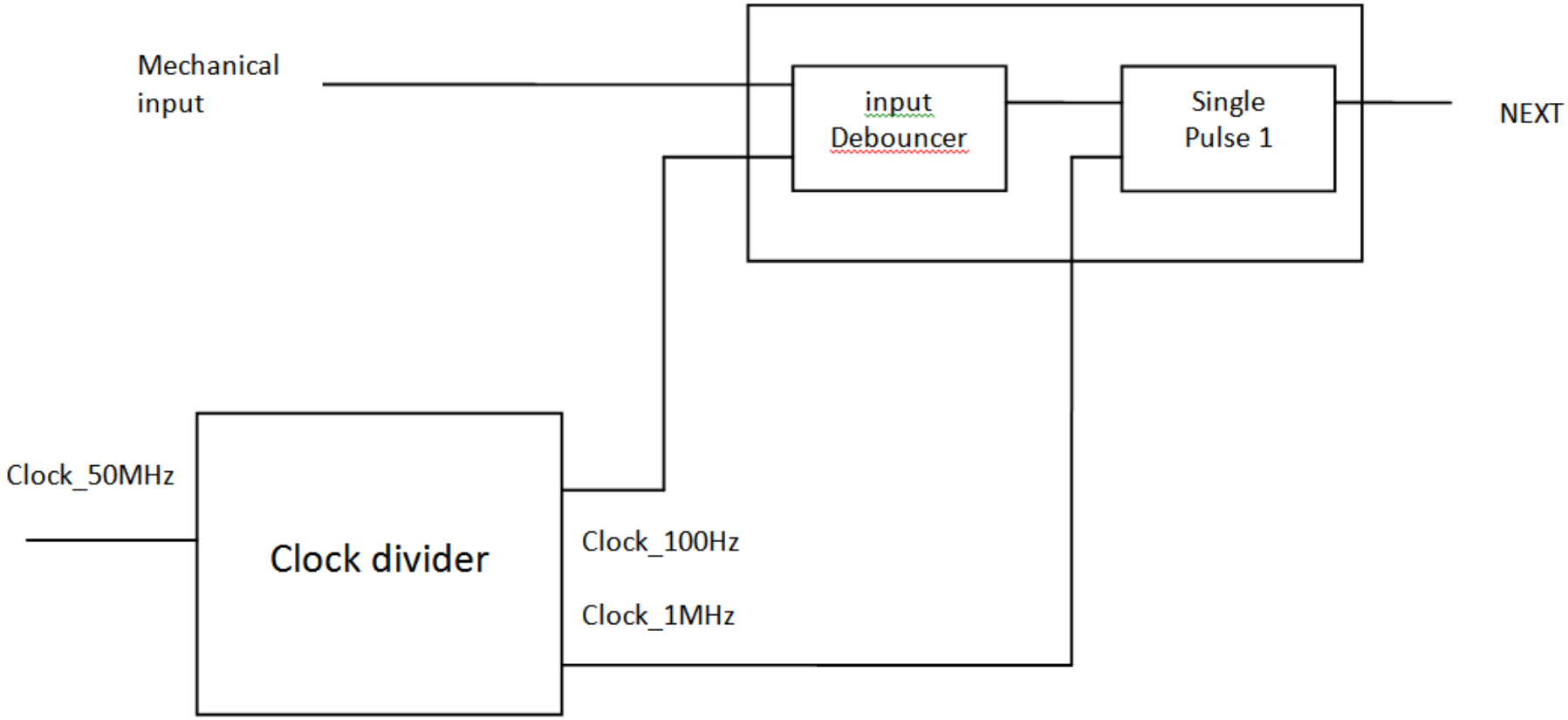
Debouncer (cont'd)





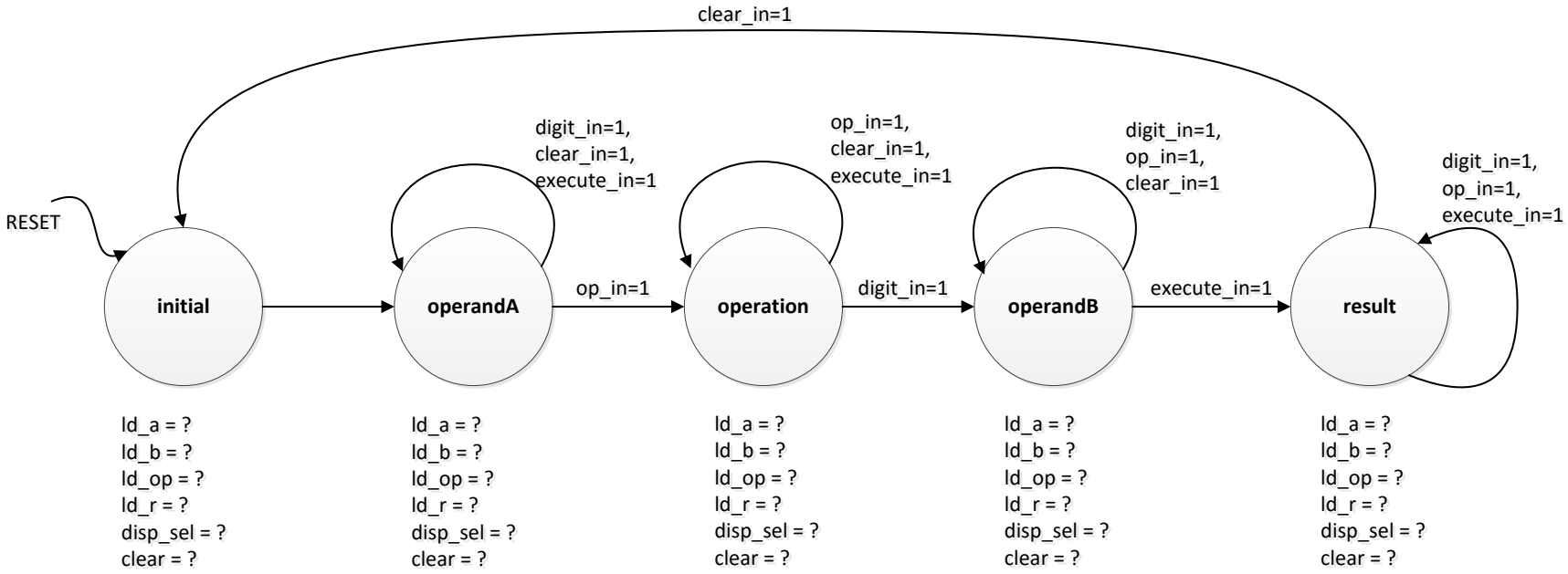


Debouncer (cont'd)



Control unit FSM

- Who commands each individual component to reach harmonic overall operations



Register transfer action

Control signal	Register transfer	Comment
clear	A←0, B←0, R←0, OP←0, STATE←INITIAL	Initialize all registers to 0 and set FSM to the first state
ld_a	A←KEY_IN	Load operand A
disp_sel=00 (A)	DISPLAY←A	Display operand A it on 7-seg
ld_b	B←KEY_IN	Load operand B
disp_sel=01 (B)	DISPLAY←B	Display operand B on 7-seg
ld_op	OP←KEY_IN	Load operation
ld_r, op_sel=op	R←A op B	Load result of selected operation
disp_sel=10 (R)	DISPLAY←R	Display result on 7-seg

- FSM Design: in order to achieve the necessary register transfer actions, what control signals need to be outputted in each state?