Lecture Overview

- Input devices
  - Input switches
    - Basics of switches
  - Keypads
- Output devices
  - LCD
Input Switches

- Most basic binary input devices
- The switch output is high or low, depending on the switch position.
- Pull-up resistors are necessary in each switch to provide a high logic level when the switch is open.
- Problem with switches:
  - Switch bounce.
    - When a switch makes contact, its mechanical springiness will cause the contact to bounce, or contact and break, for a few milliseconds (typically 5 to 10 ms).
Input Switches (cont.)

(a) Single-pole, single-throw (SPST) logic switch Data Bus

(b) Multiple pole switch.

$\frac{1}{2}$ 74LS244 Octal Buffer
NAND Latch Debouncer

Logic high with switch up
Logic low with switch down

Vcc
Software Debouncing

- Basic idea: wait until the switch is stable
- For example:
  - Wait and see:
    - If the software detects a low logic level, indicating that switch has closed, it simply waits for some time, say 20 to 100ms, and then test if the switch is still low.
  - Counter-based approach:
    - Initialize a counter to 10.
    - Poll the switch every millisecond until the counter is either 0 or 20. If the switch output is low, decrease the counter; otherwise, increment the counter.
    - If the counter is 0, we know that switch output has been low (closed) for at least 10 ms. If, on the other hand, the counter reaches 20, we know that the switch has been open for at least 10 ms.
One-Dimensional Array of Switches

Selected Input From Output Port

I0 74LS151 8 to 1 Multiplexer
I1
I2
I3
I4
I5
I6
I7

Scanned Switch Data To Input Port

Selected Input From Output Port
One-Dimensional Array of Switches

- Switch bouncing problem must be solved
  - Either using software or hardware
- The array of switches must be scanned to find out which switches are closed or open.
  - Software is required to scan the array. As the software outputs a 3-bit sequence from 000 to 111, the multiplexer selects each of the switch inputs.
  - The output of switch array could be interfaced directly to an eight-bit port at point A.
Keyboard Matrix of Switches

74LS138 3-of-8 Decoder

Scan Input From Output Port

74LS151 8-to-1 Input Multiplexer

Scanned Switch Data To Input Port

Select Input From Output Port

Vcc

E3 E2 E1 A2 A1 A0

O0 O1 O2 O3 O4 O5 O6 O7

I0 I1 I2 I3 I4 I5 I6 I7

00 01 02 06 07 10 11 12 17

B

70 71 77

A

Z
A keyboard is an array of switches arranged in a two-dimensional matrix.

A switch is connected at each intersection of vertical and horizontal lines.

Closing the switch connects the horizontal line to the vertical line.

8*8 keyboard can be interfaced directly into 8-bit output and input ports at point A and B.
Software can scan the keyboard by outputting a three-bit code to the decoder and then scanning the multiplexer to find the closed switch or switches.

- The combination of the two 3-bit scan codes (A2A1A0 and S2S1S0) identifies which switch is closed. For example, the code 0000000 scan switch 00 in the upper left-hand corner.

- The diode prevents a problem called ghosting.
Ghosting

Row 0 (Pulled low, error)
Row 1 (Pulled low, OK)
Row 2 (High, OK)

Low
(Scanned column)
Ghosting (cont.)

- Ghosting occurs when several keys are pushed at once.
- Consider the case shown in the figure where three switches 01, 10 and 11 are all closed. Column 0 is selected with a logic low and assume that the circuit does not contain the diodes. As the rows are scanned, a low is sensed on Row 1, which is acceptable because switch 10 is closed. In addition, Row 0 is seen to be low, indicating switch 00 is closed, which is NOT true. The diodes in the switches eliminate this problem by preventing current flow from R1 through switches 01 and 11. Thus Row 0 will not be low when it is scanned.
Example

- Get the input from 4*4 keypad
Example (solution)

● Algorithm

Scan columns from left to right
  for each column, scan rows from top to bottom
    for each key being scanned
      if it is pressed
        display
        wait
      endif
    endfor
  endfor
endfor
Repeat the scan process

● A column is selected, its related Cx value is set to 0.
● A mask is used to read one row at a time.
Code Implementation

; The program gets input from keypad and displays its ascii value on the
; LED bar

.include "m2560def.inc"

.def row = r16 ; current row number
.def col = r17 ; current column number
.def rmask = r18 ; mask for current row during scan
.def cmask = r19 ; mask for current column during scan
.def temp1 = r20
.def temp2 = r21

.equ PORTADIR = 0xF0 ; PD7-4: output, PD3-0, input
.equ INITCOLMASK = 0xEF ; scan from the rightmost column,
.equ INITROWMASK = 0x01 ; scan from the top row
.equ ROWMASK = 0x0F ; for obtaining input from Port D
RESET:

```assembly
ldi temp1, low(RAMEND) ; initialize the stack
out SPL, temp1
ldi temp1, high(RAMEND)
out SPH, temp1

ldi temp1, PORTADIR ; PA7:4/PA3:0, out/in
out DDRA, temp1
ser temp1 ; PORTC is output
out DDRC, temp1
out PORTC, temp1
```

main:

```assembly
ldi cmask, INITCOLMASK ; initial column mask
clr col ; initial column
```
colloop:
cpi col, 4
breq main ; If all keys are scanned, repeat.
out PORTA, cmask ; Otherwise, scan a column.

ldi temp1, 0xFF ; Slow down the scan operation.
delay:
dec temp1
brne delay

in temp1, PINA ; Read PORTA
andi temp1, ROWMASK ; Get the keypad output value
cpi temp1, 0xF ; Check if any row is low
breq nextcol

ldi rmask, INITROWMASK ; If yes, find which row is low
clr row ; Initialize for row check
Code Implementation

rowloop:
  cpi row, 4
  breq nextcol ; the row scan is over.
  mov temp2, temp1
  and temp2, rmask ; check un-masked bit
  breq convert ; if bit is clear, the key is pressed
  inc row ; else move to the next row
  lsl rmask
  jmp rowloop

nextcol:
  lsl cmask ; if row scan is over
  inc col ; increase column value
  jmp colloop ; go to the next column
convert:
cpi    col, 3      ; If the pressed key is in col.3
breq   letters    ; we have a letter

; If the key is not in col.3 and

cpi    row, 3      ; If the key is in row3,
breq   symbols    ; we have a symbol or 0

mov    temp1, row  ; Otherwise we have a number in 1-9
lsl    temp1
add    temp1, row
add    temp1, col  ; temp1 = row*3 + col
subi   temp1, -'1' ; Add the value of character ‘1’
jmp    convert_end
Code Implementation

letters:
  ldi temp1, 'A'
  add temp1, row ; Get the ASCII value for the key
  jmp convert_end

symbols:
  cpi col, 0 ; Check if we have a star
  breq star
  cpi col, 1 ; or if we have zero
  breq zero
  ldi temp1, '#' ; if not we have hash
  jmp convert_end

star:
  ldi temp1, '*' ; Set to star
  jmp convert_end

zero:
  ldi temp1, '0' ; Set to zero
  jmp convert_end

convert_end:
  out PORTC, temp1 ; Write value to PORTC
  jmp main ; Restart main loop
LCD

- Liquid Crystal Display
- Programmable output device
Dot Matrix LCD

- Characters are displayed using a dot matrix.
  - 5x7, 5x8, and 5x11
- A controller is used for communication between the LCD and other devices, e.g. MPU
- The controller has an internal character generator ROM. All display functions are controllable by instructions.
## Pin Assignments

<table>
<thead>
<tr>
<th>Pin Number</th>
<th>Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$V_{ss}$</td>
</tr>
<tr>
<td>2</td>
<td>$V_{cc}$</td>
</tr>
<tr>
<td>3</td>
<td>$V_{ee}$</td>
</tr>
<tr>
<td>4</td>
<td>RS</td>
</tr>
<tr>
<td>5</td>
<td>R/W</td>
</tr>
<tr>
<td>6</td>
<td>E</td>
</tr>
<tr>
<td>7</td>
<td>DB0</td>
</tr>
<tr>
<td>8</td>
<td>DB1</td>
</tr>
<tr>
<td>9</td>
<td>DB2</td>
</tr>
<tr>
<td>10</td>
<td>DB3</td>
</tr>
<tr>
<td>11</td>
<td>DB4</td>
</tr>
<tr>
<td>12</td>
<td>DB5</td>
</tr>
<tr>
<td>13</td>
<td>DB6</td>
</tr>
<tr>
<td>14</td>
<td>DB7</td>
</tr>
</tbody>
</table>
# Pin Descriptions

<table>
<thead>
<tr>
<th>Signal name</th>
<th>No. of Lines</th>
<th>Input/Output</th>
<th>Connected to</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>DB4 ~ DB7</td>
<td>4</td>
<td>Input/Output</td>
<td>MPU</td>
<td>4 lines of high order data bus. Bi-directional transfer of data between MPU and module is done through these lines. Also DB7 can be used as a busy flag. These lines are used as data in 4 bit operation.</td>
</tr>
<tr>
<td>DB0 ~ DB3</td>
<td>4</td>
<td>Input/Output</td>
<td>MPU</td>
<td>4 lines of low order data bus. Bi-directional transfer of data between MPU and module is done through these lines. In 4 bit operation, these are not used and should be grounded.</td>
</tr>
<tr>
<td>E</td>
<td>1</td>
<td>Input</td>
<td>MPU</td>
<td>Enable - Operation start signal for data read/write.</td>
</tr>
<tr>
<td>R/W</td>
<td>1</td>
<td>Input</td>
<td>MPU</td>
<td>Signal to select Read or Write</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>“0”: Write</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>“1”: Read</td>
</tr>
<tr>
<td>RS</td>
<td>1</td>
<td>Input</td>
<td>MPU</td>
<td>Register Select</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>“0”: Instruction register (Write)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>: Busy flag; Address counter (Read)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>“1”: Data register (Write, Read)</td>
</tr>
<tr>
<td>Vee</td>
<td>1</td>
<td>Power Supply</td>
<td></td>
<td>Terminal for LCD drive power source.</td>
</tr>
<tr>
<td>Vcc</td>
<td>1</td>
<td>Power Supply</td>
<td></td>
<td>+5V</td>
</tr>
<tr>
<td>Vss</td>
<td>1</td>
<td>Power Supply</td>
<td></td>
<td>0V (GND)</td>
</tr>
</tbody>
</table>
Dot Matrix LCD Diagram
Operations

- MPU communicates with LCD through two registers
  - Instruction Register (IR)
    - To store instruction codes like Display clear or Cursor Shift as well as addresses for the Display Data RAM (DD RAM) or the Character Generator RAM (CG RAM)
  - Data Register (DR)
    - To temporarily store data to be read/written to/from the DD RAM of the display controller.
Operations (cont.)

- The register select (RS) signal determines which of these two register is selected.

<table>
<thead>
<tr>
<th>RS</th>
<th>R/W</th>
<th>Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>IR write, internal operation (Display Clear etc.)</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
<td>Busy flag (DB₇) and Address Counter (DB₀ ~ DB₆) read</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
<td>DR Write, Internal Operation (DR ~ DD RAM or CG RAM)</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>DR Read, Internal Operation (DD RAM or CG RAM)</td>
</tr>
</tbody>
</table>
Operations (cont.)

- When the busy flag is high or ‘1’, the LCD module is busy with internal operation.
- The next instruction must not be written until the busy flag is low or ‘0’.
- For details, refer to the LCD USER’S MANUAL.
LCD Instructions

- A list of binary instructions are available for LCD operations
- Some typical ones are explained in the next slides.
**Instructions**

- Clear Display

<table>
<thead>
<tr>
<th>RS</th>
<th>R/W</th>
<th>DB7</th>
<th>DB6</th>
<th>DB5</th>
<th>BD4</th>
<th>DB3</th>
<th>DB2</th>
<th>DB1</th>
<th>DB0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Code</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

- The display clears and the cursor or blink moves to the upper left edge of the display.
- The execution of clear display instruction sets entry mode to increment mode.
Instructions

- Return Home

<table>
<thead>
<tr>
<th>Code</th>
<th>RS</th>
<th>R/W</th>
<th>DB7</th>
<th>DB6</th>
<th>DB5</th>
<th>BD4</th>
<th>DB3</th>
<th>DB2</th>
<th>DB1</th>
<th>DB0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

- The cursor or the blink moves to the upper left edge of the display. Text on the display remains unchanged.
Instructions

- **Entry Mode Set**

<table>
<thead>
<tr>
<th>RS</th>
<th>R/W</th>
<th>DB7</th>
<th>DB6</th>
<th>DB5</th>
<th>BD4</th>
<th>DB3</th>
<th>DB2</th>
<th>DB1</th>
<th>DB0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

- Sets the Increment/Decrement and Shift modes to the desired settings.
  - **I/D**: Increments (I/D = 1) or decrements (ID = 0) the DD RAM address by 1 when a character code is written into or read from the DD RAM.
  - The cursor or blink moves to the right when incremented by +1.
  - The same applies to writing and reading the CG RAM.
  - **S**: Shifts the entire display either to the right or to the left when S = 1; shift to the left when I/D = 1 and to the right when I/D = 0.
Instructions

- Display ON/OFF Control

Controls the display ON/OFF status, Cursor ON/OFF and Cursor Blink function.

- D: The display is ON when D = 1 and OFF when D = 0.
- C: The cursor displays when C = 1 and does not display when C = 0.
- B: The character indicated by the cursor blinks when B = 1.

<table>
<thead>
<tr>
<th>RS</th>
<th>R/W</th>
<th>DB7</th>
<th>DB6</th>
<th>DB5</th>
<th>BD4</th>
<th>DB3</th>
<th>DB2</th>
<th>DB1</th>
<th>DB0</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>D</td>
</tr>
<tr>
<td>Code</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Instructions

- Cursor or Display Shift

<table>
<thead>
<tr>
<th>RS</th>
<th>R/W</th>
<th>DB7</th>
<th>DB6</th>
<th>DB5</th>
<th>BD4</th>
<th>DB3</th>
<th>DB2</th>
<th>DB1</th>
<th>DB0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Code</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>S/C</td>
<td>R/L</td>
</tr>
</tbody>
</table>

- Shifts the cursor position or display to the right or left without writing or reading display data.

<table>
<thead>
<tr>
<th>S/C</th>
<th>R/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>
**Instructions**

- **Function Set**

<table>
<thead>
<tr>
<th>RS</th>
<th>R/W</th>
<th>DB7</th>
<th>DB6</th>
<th>DB5</th>
<th>BD4</th>
<th>DB3</th>
<th>DB2</th>
<th>DB1</th>
<th>DB0</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>DL</td>
<td>N</td>
<td>F</td>
<td>x</td>
</tr>
</tbody>
</table>

- Sets the interface data length, the number of lines, and character font.
  - DL = 1, 8 -bits; otherwise 4 bits
  - N: Sets the number of lines
    - N = 0 : 1 line display
    - N = 1 : 2 line display
  - F: Sets character font.
    - F = 1 : 5 x 10 dots
    - F = 0 : 5 x 7 dots
Instructions

- Read Busy Flag and Address

<table>
<thead>
<tr>
<th>RS R/W</th>
<th>DB7</th>
<th>DB6</th>
<th>DB5</th>
<th>BD4</th>
<th>DB3</th>
<th>DB2</th>
<th>DB1</th>
<th>DB0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Code</td>
<td>0</td>
<td>1</td>
<td>BF</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
</tbody>
</table>

Reads the busy flag (BF) and value of the address counter (AC). BF = 1 indicates that an internal operation is in progress and the next instruction will not be accepted until BF is set to ‘0’. If the display is written while BF = 1, abnormal operation will occur.
Instructions

- **Write Data to CG or DD RAM**

<table>
<thead>
<tr>
<th>RS R/W DB7 DB6 DB5 BD4 DB3 DB2 DB1 DB0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Code</td>
</tr>
</tbody>
</table>

- Writes binary 8-bit data DDDDDDDDDD to the CG or DD RAM.

- The previous designation determines whether the CG or DD RAM is to be written (CG RAM address set or DD RAM address set). After a write the entry mode will automatically increase or decrease the address by 1. Display shift will also follow the entry mode.
Timing Characteristics

- For write operation
Timing Characteristics

- For read operation

- RS (LS)
  - 2.0V
  - 0.8V
  - $t_{AS}$

- R/W
  - 2.0V
  - $P_{W_{EH}}$
  - $t_{AH}$
  - $t_{ER}$

- E
  - 0.8V
  - $t_{E_1}$
  - $t_{DDR}$

- $DB_0 \sim DB_7$
  - 2.4V
  - 0.4V
  - Effective data
  - tcycle
Examples

- Send a command to LCD

; Register data stores value to be written to the LCD
; Port D is output and connects to LCD; Port A controls the LCD.
; Assume all other labels are pre-defined.

.macro_lcd_write_com
    out PORTD, data ; set the data port's value up
    clr temp
    out PORTA, temp ; RS = 0, RW = 0 for a command write
    nop ; delay to meet timing (Set up time)
    sbi PORTA, LCD_E ; turn on the enable pin
    nop ; delay to meet timing (Enable pulse width)
    nop
    nop
    nop
    cbi PORTA, LCD_E ; turn off the enable pin
    nop ; delay to meet timing (Enable cycle time)
    nop
    nop
    nop
.endmacro
Examples

- Send data to display

```assembly
; comments are same as in previous slide.

.macro lcd_write_data
  out PORTD, data
  ldi temp, 1 << LCD_RS
  out PORTA, temp
  nop
  sbi PORTA, LCD_E
  nop
  nop
  nop
  cbi PORTA, LCD_E
  nop
  nop
  nop
.endmacro
```
Examples

- Check LCD and wait until LCD is not busy

```assembly
; comments are same as in the previous slide
.macro lcd_wait_busy
  clr temp
  out DDRD, temp ; Make PORTD be an input port for now
  out PORTD, temp
  ldi temp, 1 << LCD_RW
  out PORTA, temp ; RS = 0, RW = 1 for a command port read
busi_loop:
  nop ; delay to meet set-up time)
  sbi PORTA, LCD_E ; turn on the enable pin
  nop ; delay to meet timing (Data delay time)
  nop
  nop
  in temp, PIND ; read value from LCD
  cbi PORTA, LCD_E ; turn off the enable pin
  sbrc temp, LCD_BF ; if the busy flag is set
  rjmp busy_loop ; repeat command read
  clr temp ; else
  out PORTA, temp ; turn off read mode,
  ser temp ;
  out DDRD, temp ; make PORTD an output port again
.endmacro
```
LCD Initialization

- LCD should be initialized before use
- Internal Reset Circuit can be used, but it is related to power supply loading, may not work properly.
- Therefore, software initialization is recommended.
Software Initialization

8-Bit Initialization:

Power ON

Wait more than 15ms after Vcc = 4.5V

No data should be transferred to or from the display during this time.

RS R/W DB7 DB6 DB5 DB4 DB3 DB2 DB1 DB0
0 0 0 0 1 1 x x x x

Function Set Command: (8-Bit interface)
BF cannot be checked before this command.

Wait more than 4.1ms

No data should be transferred to or from the display during this time.

RS R/W DB7 DB6 DB5 DB4 DB3 DB2 DB1 DB0
0 0 0 0 1 1 x x x x

Function Set Command: (8-Bit interface)
BF cannot be checked before this command.

Wait more than 100μs

No data should be transferred to or from the display during this time.
Software Initialization

Wait more than 100μs

No data should be transferred to or from the display during this time.

Function Set Command: (8-Bit interface)
After this command is written, BF can be checked.

Function Set (Interface = 8 bits, Set No. of lines and display font)
Display OFF
Clear Display
Entry Mode Set:
Display ON (Set C and B for cursor/Blink options.)

Note: BF should be checked before each of the instructions starting with Display OFF.
Example of Initialization Code

.include “m2560def.inc”

; The del_hi:del_lo register pair store the loop counts
; each loop generates about 1 us delay
.macro delay
loop:  subi del_lo, 1
       sbci del_hi, 0
       nop
       nop
       nop
       nop
       nop
       brne loop ; taken branch takes two cycles.
       ; one loop time is 8 cycles = ~1.08us
.endmacro

; continued
Example of Initialization Code

ldi del_lo, low(15000) ; delay (>15ms)
ldi del_hi, high(15000)
delay

; Function set command with N = 1 and F = 0
; for 2 line display and 5*7 font. The 1st command
ldi data, LCD_FUNC_SET | (1 << LCD_N)
lcd_write_com

ldi del_lo, low(4100) ; delay (>4.1 ms)
ldi del_hi, high(4100)
delay

lcd_write_com ; 2nd Function set command

; continued
Example of Initialization Code

```assembly
ldi del_lo, low(100) ; delay (>100 ns)
ldi del_hi, high(100)
delay

lcd_write_com ; 3rd Function set command
lcd_write_com ; Final Function set command

lcd_wait_busy ; Wait until the LCD is ready
ldi data, LCD_DISP_OFF
lcd_write_com ; Turn Display off

lcd_wait_busy ; Wait until the LCD is ready
ldi data, LCD_DISP_CLR
lcd_write_com ; Clear Display

; continued```
Example of Initialization Code

```c
lcd_wait_busy ; Wait until the LCD is ready
; Entry set command with I/D = 1 and S = 0
; Set Entry mode: Increment = yes and Shift = no
ldi data, LCD_ENTRY_SET | (1 << LCD_ID)
lcd_write_com

lcd_wait_busy ; Wait until the LCD is ready
; Display On command with C = 1 and B = 0
ldi data, LCD_DISP_ON | (1 << LCD_C)
lcd_write_com
```
Reading Material

- Chapter 7: Computer Buses and Parallel Input and Output. Microcontrollers and Microcomputers by Fredrick M. Cady.
  - Simple I/O Devices
- DOT Matrix LCD User’s Manual
  - Available on the course website.
1. The circuit shown in the next slide is a switch array input circuit. Is there any switch bounce issue with this circuit? Can the CLK frequency have any impact on this problem? How to solve it in hardware?
Selected Input From Output Port

74LS151 8 to 1 Multiplexer

Vcc

D

CLK
Homework

2. Write an assembly program to initialize LCD panel to display characters in one line with 5x7 font.