Displays

Networks and Embedded Software

Module 4.3.8

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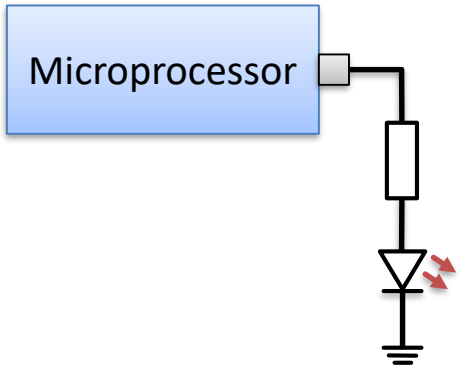
Indicator Lamps (1)

- Active High Lamps

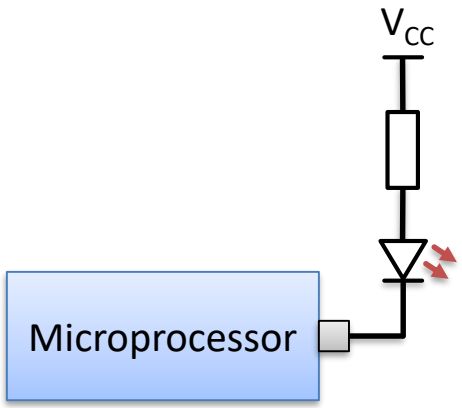
```
void led_init(void)
{
   LED_PORT.OUT &= ~LED_PIN_bm; // Turn LED off
   LED_PORT.DIR |= LED_PIN_bm;  // LED pin is output
}
void led_on(void)
{
 LED_PORT.OUT |= LED_PIN_bm;
}
void led_off(void)
{
 LED_PORT.OUT &= ~LED_PIN_bm;
}
```



Indicator Lamps (2)

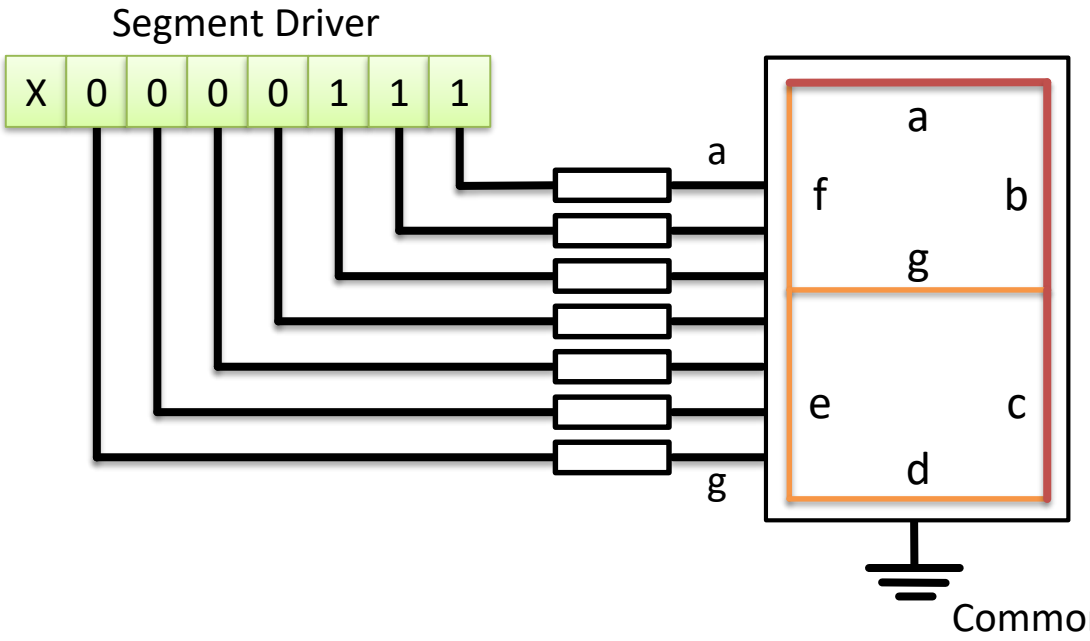
- Active Low Lamps

```
– void led_init(void)
– {
–   LED_PORT.OUT |= LED_PIN_bm;  // Turn LED off
–   LED_PORT.DIR |= LED_PIN_bm;  // LED pin is output
– }
– void led_on(void)
– {
–  LED_PORT.OUT &|= ~ LED_PIN_bm;
– }
– void led_off(void)
– {
–  LED_PORT.OUT |= LED_PIN_bm;
– }
```



Seven-Segment Displays (1)

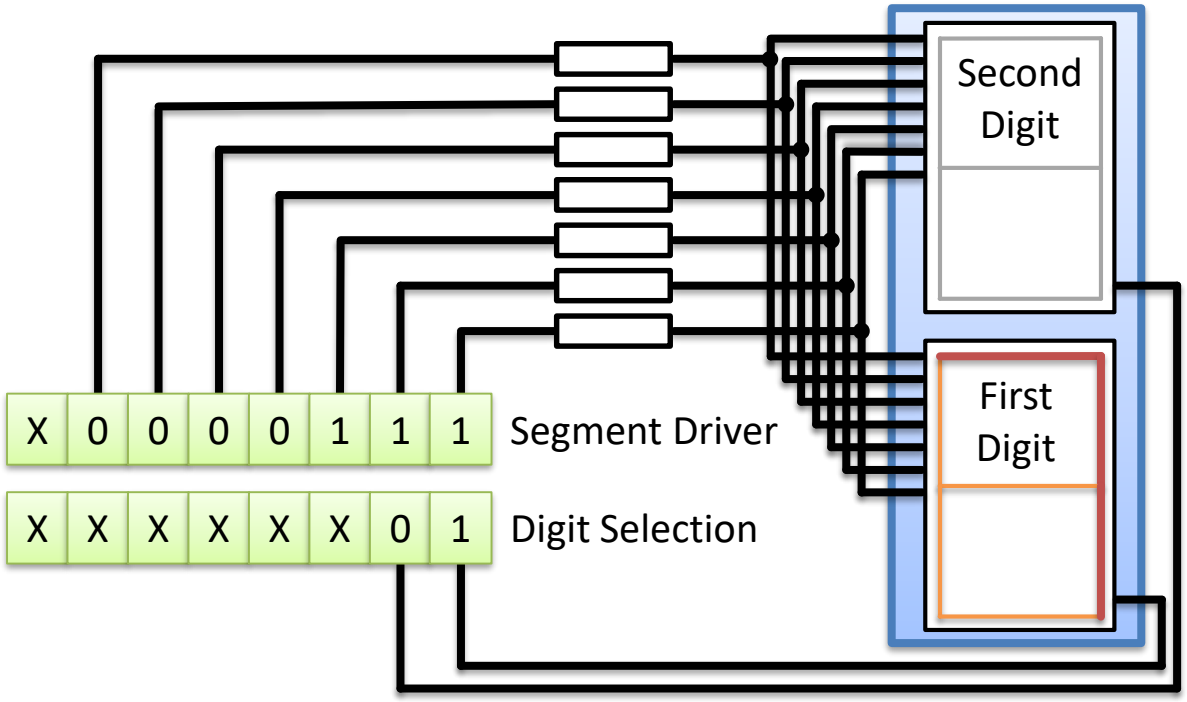
- Single Digit Display (Common Cathode)



0: 0x3F (0011 1111)
1: 0x06 (0000 0110)
2: 0x5B (0101 1011)
3: 0x4F (0100 1111)
4: 0x66 (0110 0110)
5: 0x6D (0110 1101)
6: 0x7D (0111 1101)
7: 0x07 (0000 0111)
8: 0x7F (0111 1111)
9: 0x6F (0110 1111)

Seven-Segment Displays (2)

- Multi Digit Display (Common Cathode)



Seven-Segment Displays (3)

- Programming Example (multi digit display)

```
#define DIGITS_gm 0x03
#define DIG1_PIN_bm 0x01
#define DIG2_PIN_bm 0x02
uint8_t seg[10] = { 0x3F, 0x06, …};
void display_off(void)
{
  DIG_PORT.OUT |= DIGITS_gm; // Turn active low digits off
}
void display_show_number(uint8_t n)
{
  SEG_PORT.OUT = seg[n];     // Write segment pattern
}
```

Seven-Segment Displays (4)

- Programming Example (continued)

```
void display_select_new_digit(uint8_t n)
{
  // Display must be turned off before
  switch (n) {
    case 1:
      DIG_PORT.OUT &= ~DIG1_PIN_bm;
      break;
    case 2:
      DIG_PORT.OUT &= ~DIG2_PIN_bm;
      break;
  }
}
```

Seven-Segment Displays (5)

- Programming Example (finished)

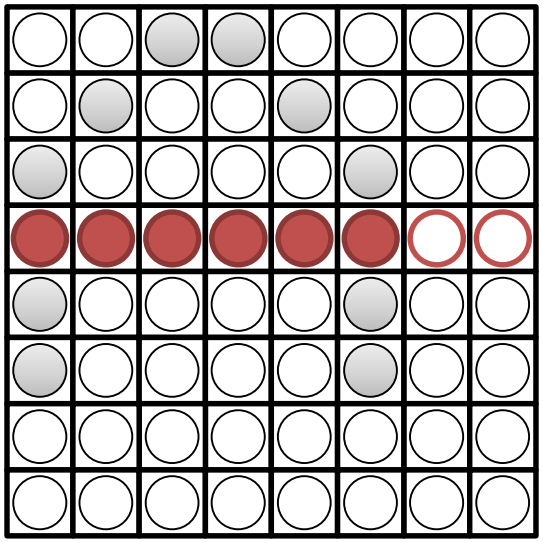
```
uint8_t digits[2] = { 2, 1 };
void display_drive(void)
{
  static n = 0;
  display_off();
  display_show_number(digit[n]);
  display_select_new_digit(n);
  n = n+1;
  if (n==2) n = 0;
}
```

Dot-Matrix Displays (1)

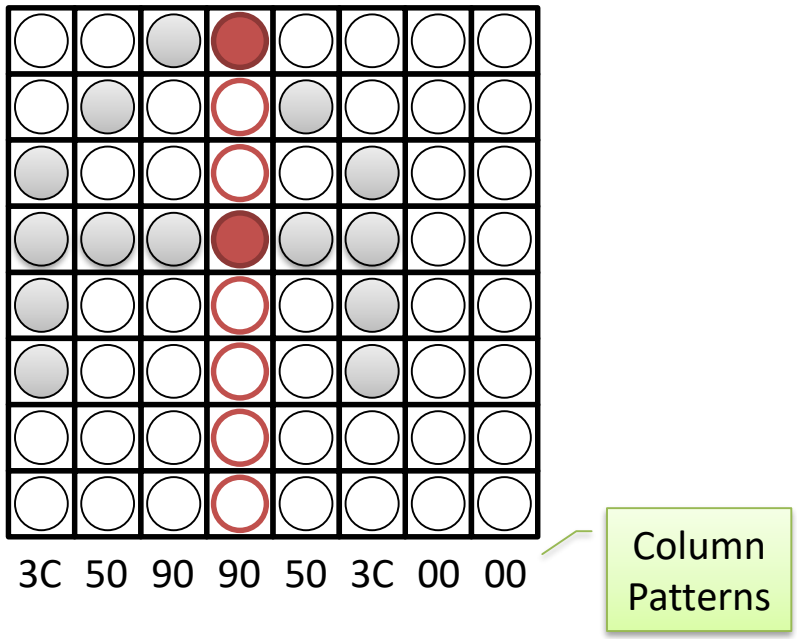
- Operation Mode (row anode)

Rows are Active High
Cols are Active Low

Row by Row

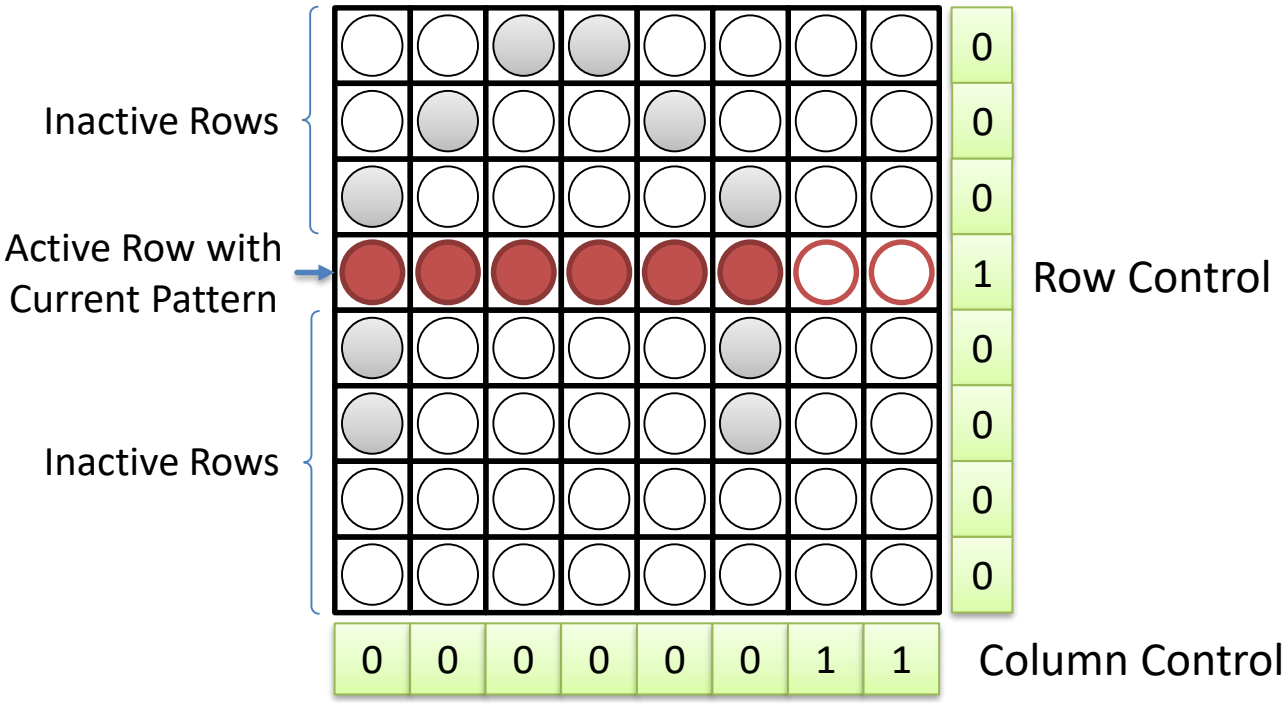


Column by Column



Dot-Matrix Displays (2)

- Physical Setup (row anode, row by row)



Dot-Matrix Displays (3)

- Programming Example (row anode, row by row)

```
#define COLS 8
#define ROWS 8
uint8_t row[ROWS] = { 0x30, 0x48, …}; // Row patterns
void display_rows_off(void)
{
  ROW_PORT.OUT = 0x00;    // Turn all rows off
}
void display_new_pattern(uint8_t n)
{
  COL_PORT.OUT = ~row[n]; // Display pattern active low
}
```

Dot-Matrix Displays (4)

- Programming Example (finished)

```
void display_select_row(uint8_t n)
{
  ROW_PORT.OUT = (1 << n); // Select n-th row
}
void display_drive(void)
{
  static n = 0;
  display_rows_off();
  display_new_pattern(n);
  display_select_row(n);
  n = n+1;
  if (n==ROWS) n = 0;
}
```

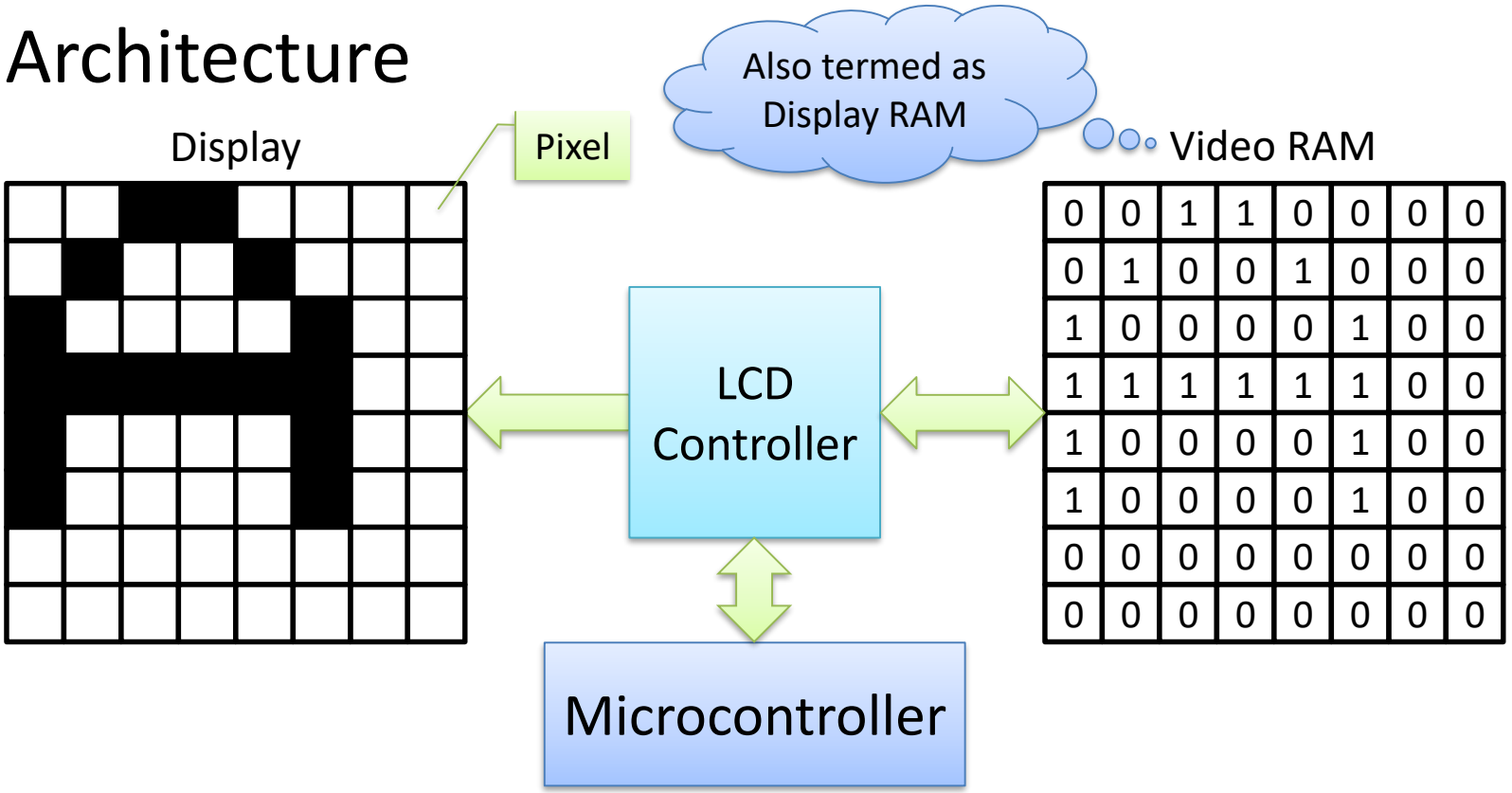
Dot-Matrix Displays (5)

- Pulse Mode
  - Duty cycle: 1/8
  - Series resistor
    - I_F = 20 mA → I_{Pulse} = 160 mA (check data sheet for limits)
    - U_F = 5 V → R = 5 V / 160 mA = 33 Ω
  - Attention 

    - Series resistor is for pulse mode operation
    - Continuous operation will destroy the display
    - Series resistor is only 33 Ω instead of 270 Ω

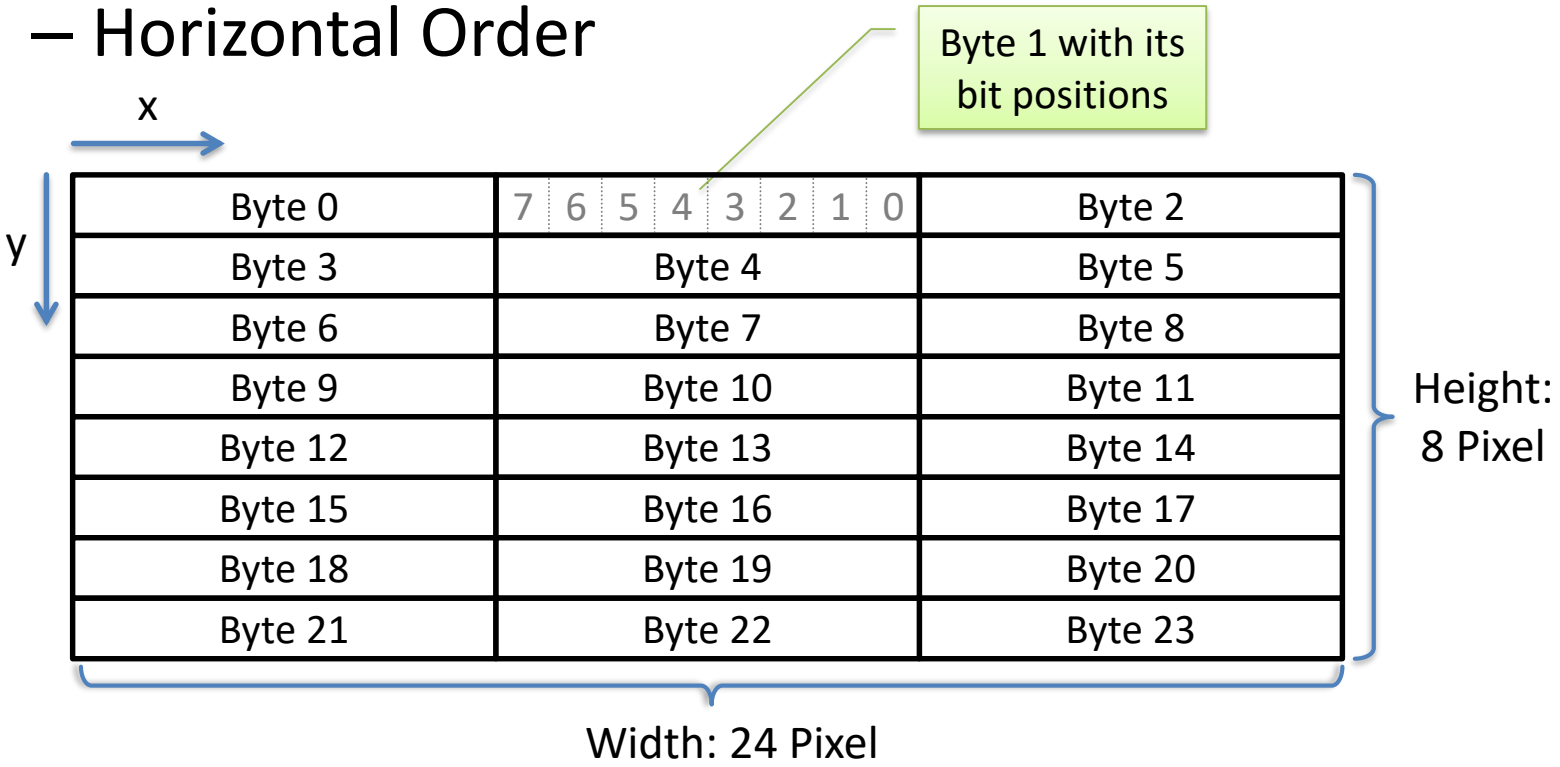
Monochrome Display (1)

- Architecture



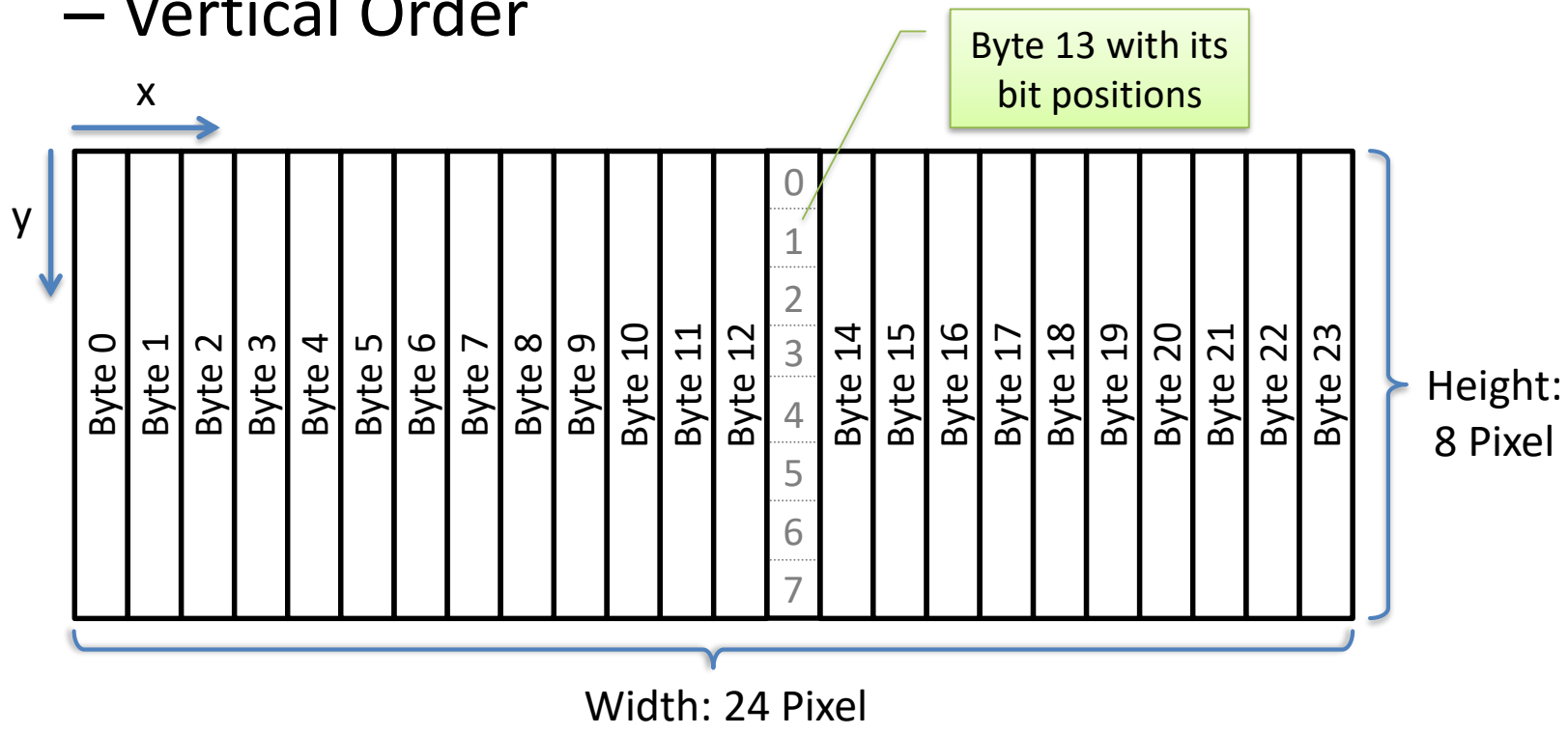
Monochrome Display (2)

- Byte Orientation
  - Horizontal Order



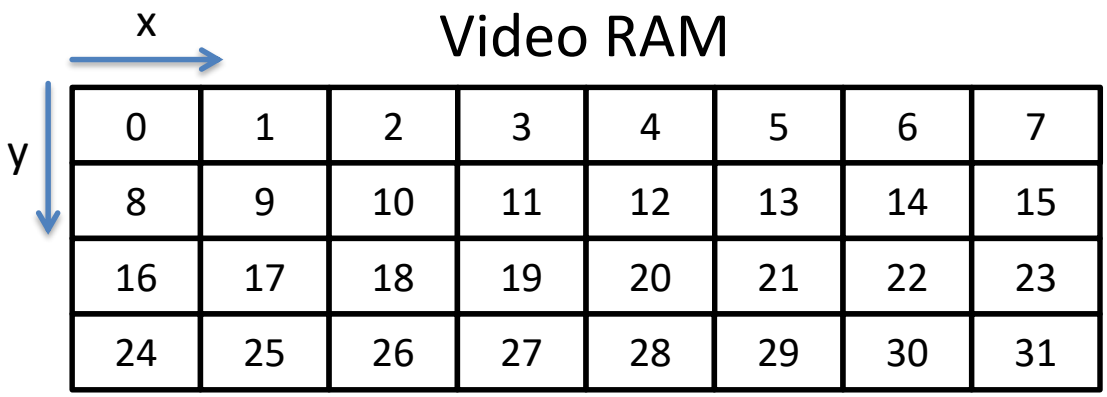
Monochrome Display (3)

- Byte Orientation
  - Vertical Order



Monochrome Display (4)

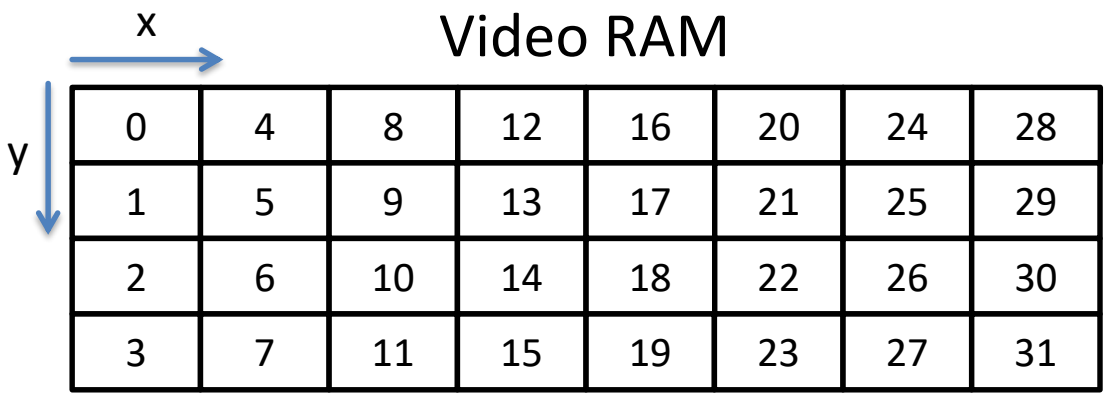
- Addressing Modes
  - Linear Horizontal Addressing (row-major)




```
uint8_t pixel[HEIGHT*WIDTH]; // Video RAM
pixel[WIDTH*y+x] = 1;        // Access individual pixel
```

Monochrome Display (5)

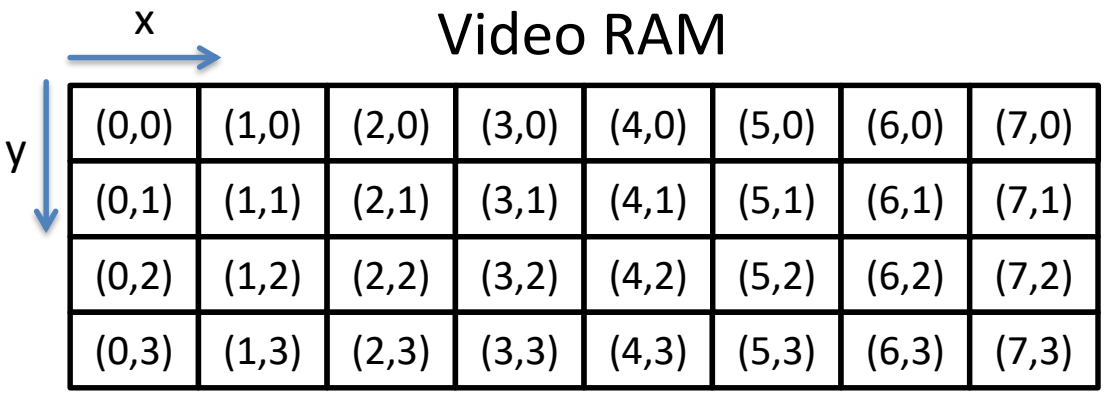
- Addressing Modes
  - Linear Vertical Addressing (column-major)




```
uint8_t pixel[HEIGHT*WIDTH]; // Video RAM
pixel[HEIGHT*x+y] = 1;       // Access individual pixel
```

Monochrome Display (6)

- Addressing Modes
  - Two-Dimensional Addressing



- `uint8_t pixel[HEIGHT][WIDTH];`
- `pixel[y][x] = 1;`

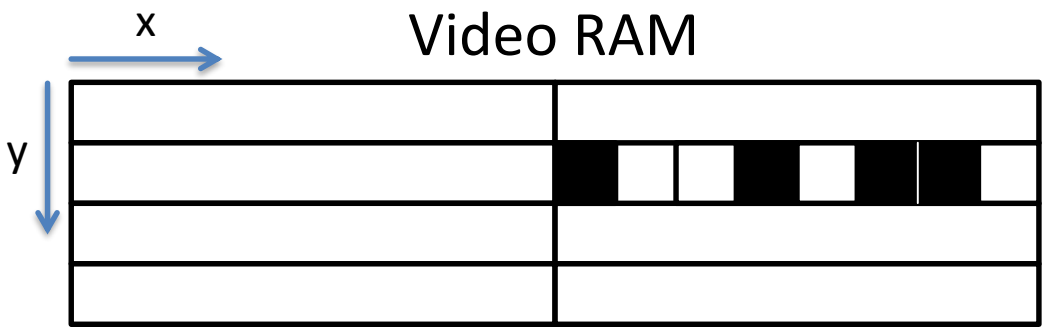
} If video RAM is row-major

- `uint8_t pixel[WIDTH][HEIGHT];`
- `pixel[x][y] = 1;`

} If video RAM is column-major

Monochrome Display (7)

- Programming Example
  - 4×16-bit display
  - Two-dimensional addressing mode
  - Horizontal byte orientation
  - Set pixel (1,8), (1,11), (1,13), (1,14).



Monochrome Display (8)

- Programming Example (continued)

```
#define WITDH 16
#define HEIGHT 4
#define CMD_SET_XADDR 0x40 // Command to set x position
#define CMD_SET_YADDR 0x80 // Command to set y position
void display_show_byte(uint8_t x, uint8_t y, uint8_t byte)
{
  display_send_command(CMD_SET_XADDR | x);
  display_send_command(CMD_SET_YADDR | y);
  display_send_data(byte);
}
display_show_byte(1, 1, 0x96);
```

Usually in LCD Controller Header

In Display Module

In Main Program