# Introduction to Embedded System Design

## Physical Interfacing-1

Dhananjay V. Gadre
Associate Professor
ECE Division
Netaji Subhas University of Technology, New Delhi

Badri Subudhi
Assistant Professor
Electrical Engineering Department
Indian Institute of Technology, Jammu

# Interfacing to the Physical World: Input Devices

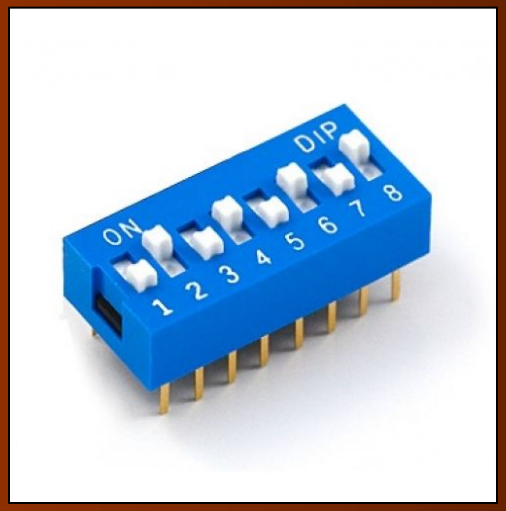
- Input Devices (Human Inputs)

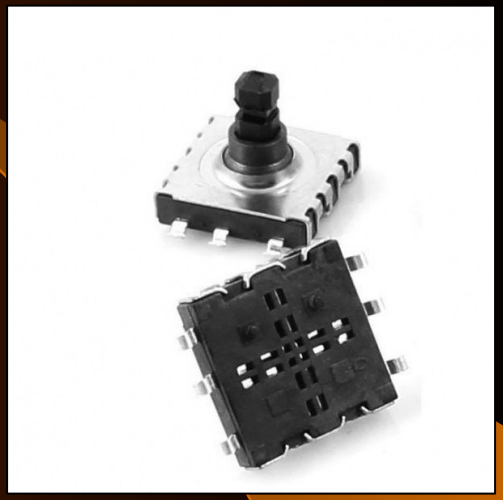
  Push Button, Toggle switch, MPMT, Keypad (Matrix of push buttons), DIP Switch, Capacitive/Resistive Touch, JoyStick, Rotary Encoder (Absolute or Incremental)

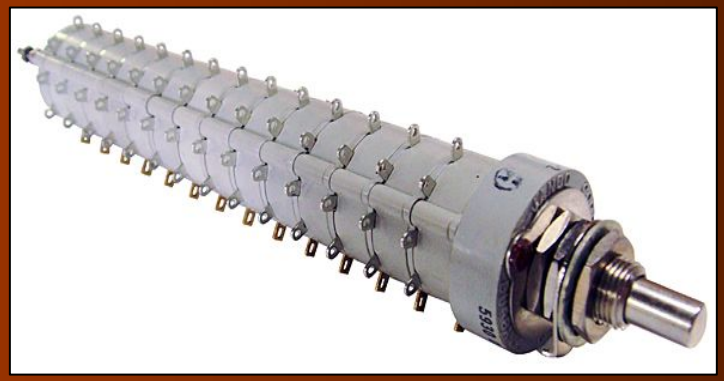
- Environment Inputs

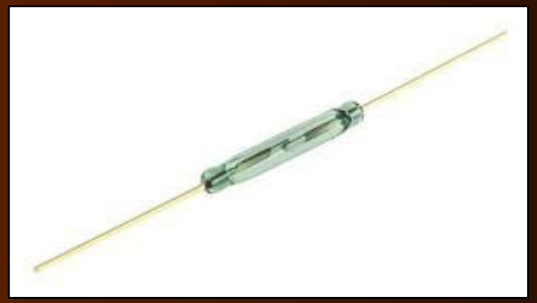
  Sound, Light, Temperature, Humidity, pH, air flow etc.

# Interfacing to the Physical World: Switches

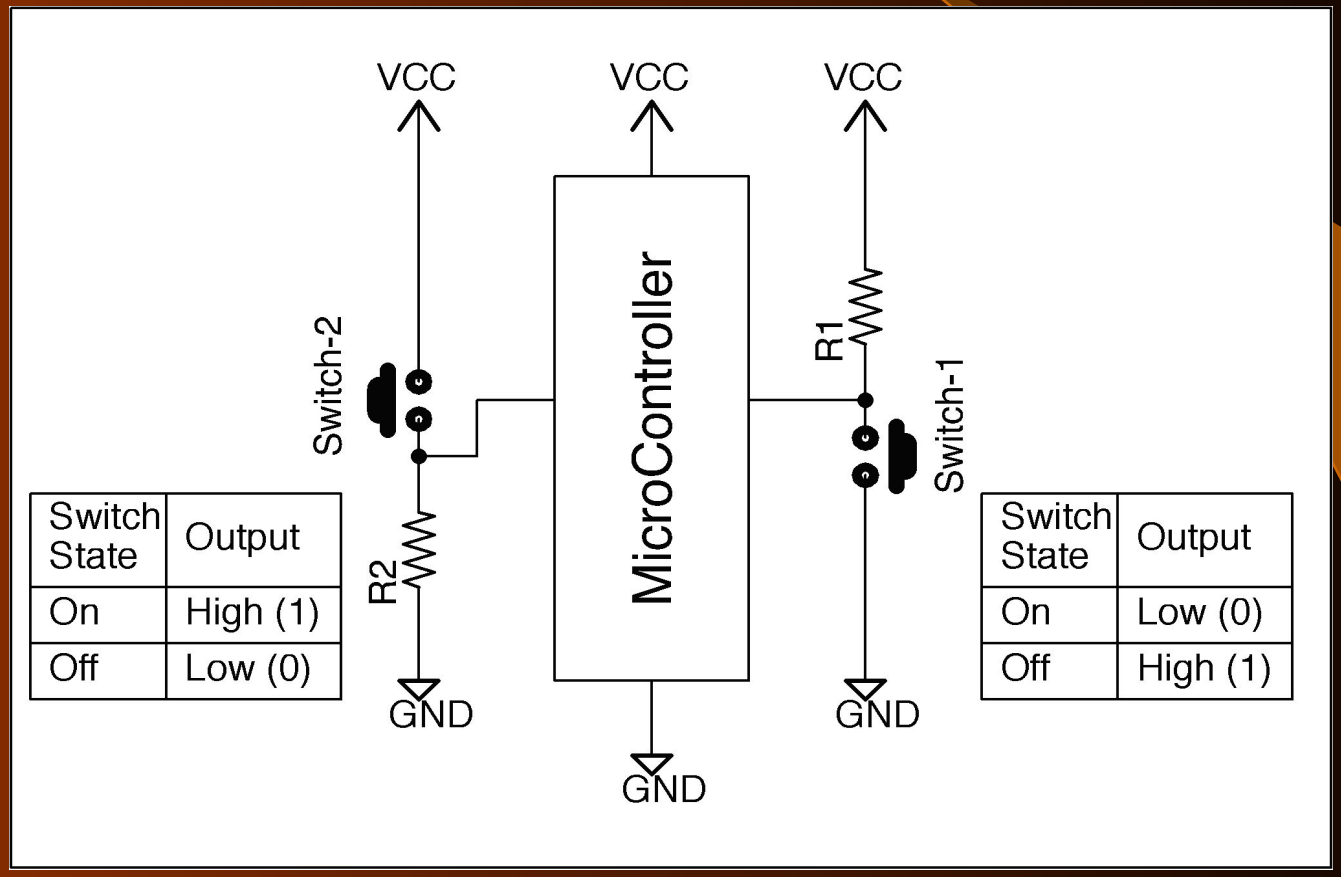






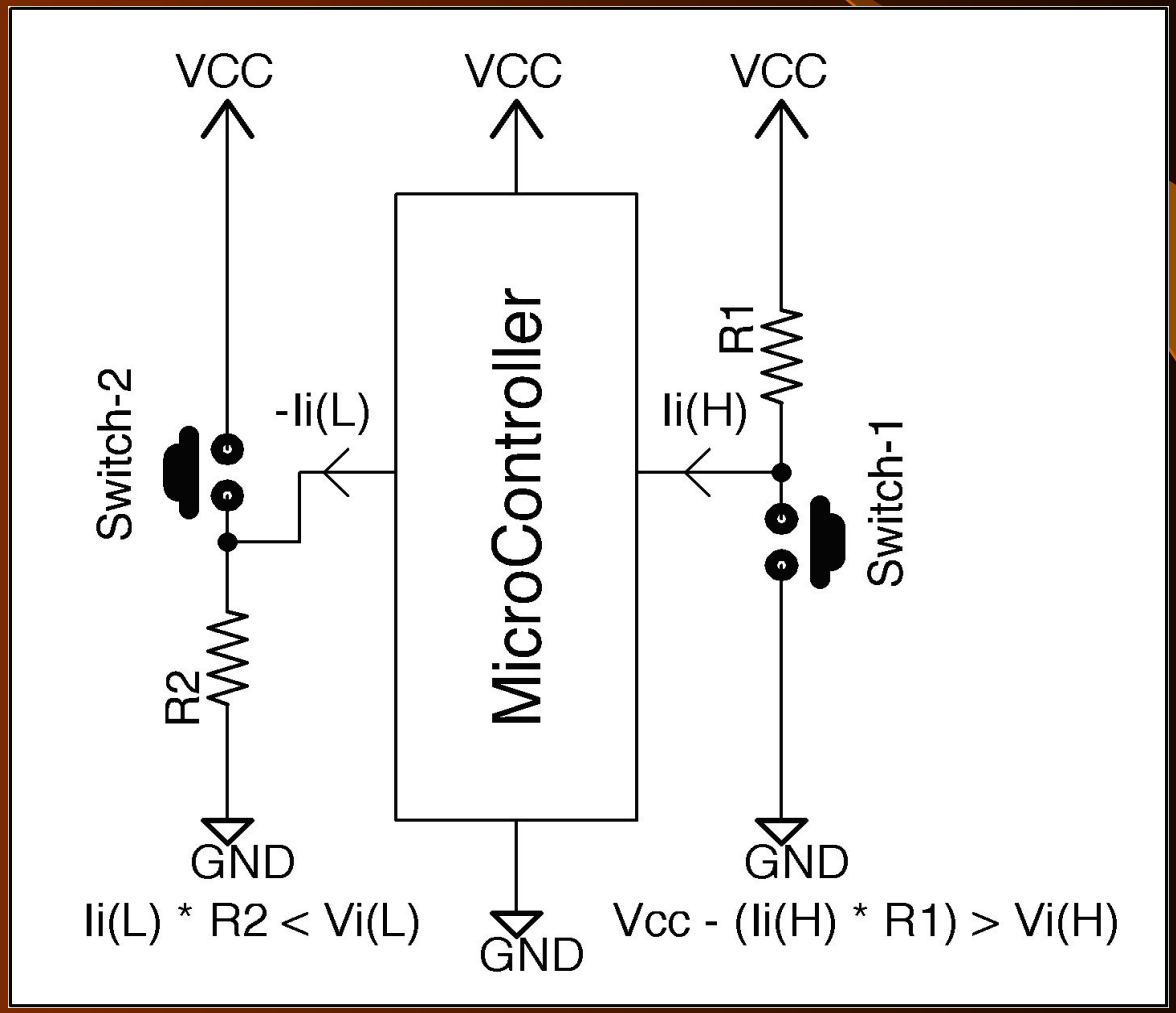
# Connecting Switches




| Switch State | Output |
|---|---|
| On | High (1) |
| Off | Low (0) |

| Switch State | Output |
|---|---|
| On | Low (0) |
| Off | High (1) |

# Pull-up and Pull-Down Resistor Values



## Schmitt-Trigger Inputs, Ports Px

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $V_{CC}$ | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $V_{IT+}$ | Positive-going input threshold voltage | | | 0.45 $V_{CC}$ | | 0.75 $V_{CC}$ | V |
| | | | 3 V | 1.35 | | 2.25 | |
| $V_{IT-}$ | Negative-going input threshold voltage | | | 0.25 $V_{CC}$ | | 0.55 $V_{CC}$ | V |
| | | | 3 V | 0.75 | | 1.65 | |
| $V_{hys}$ | Input voltage hysteresis ($V_{IT+} - V_{IT-}$) | | 3 V | 0.3 | | 1 | V |
| $R_{Pull}$ | Pullup/pulldown resistor | For pullup: $V_{IN} = V_{SS}$<br>For pulldown: $V_{IN} = V_{CC}$ | 3 V | 20 | 35 | 50 | kΩ |
| $C_I$ | Input capacitance | $V_{IN} = V_{SS}$ or $V_{CC}$ | | | 5 | | pF |

## Leakage Current, Ports Px

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $V_{CC}$ | MIN | MAX | UNIT |
|---|---|---|---|---|---|---|
| $I_{lkg(Px.y)}$ | High-impedance leakage current | (1) (2) | 3 V | | ±50 | nA |

(1) The leakage current is measured with $V_{SS}$ or $V_{CC}$ applied to the corresponding pin(s), unless otherwise noted.
(2) The leakage of the digital port pins is measured individually. The port pin is selected for input and the pullup/pulldown resistor is disabled.

## Outputs, Ports Px

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)

| PARAMETER | | TEST CONDITIONS | $V_{CC}$ | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $V_{OH}$ | High-level output voltage | $I_{(OHmax)} = -6$ mA(1) | 3 V | | $V_{CC} - 0.3$ | | V |
| $V_{OL}$ | Low-level output voltage | $I_{(OLmax)} = 6$ mA(1) | 3 V | | $V_{SS} + 0.3$ | | V |

(1) The maximum total current, $I_{(OHmax)}$ and $I_{(OLmax)}$, for all outputs combined should not exceed ±48 mA to hold the maximum voltage drop specified.

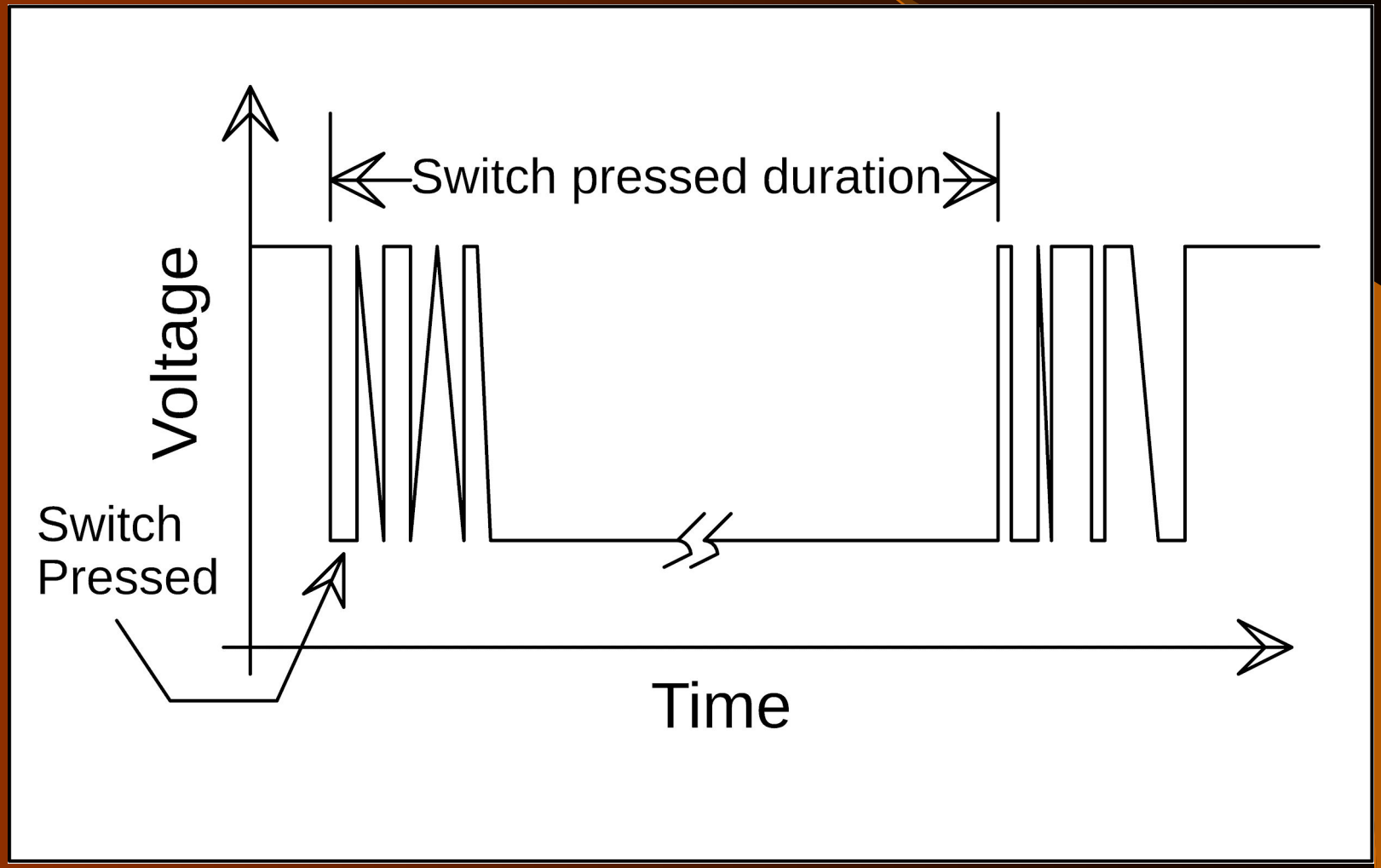
## Output Frequency, Ports Px

over recommended ranges of supply voltage and operating free-air temperature (unless otherwise noted)

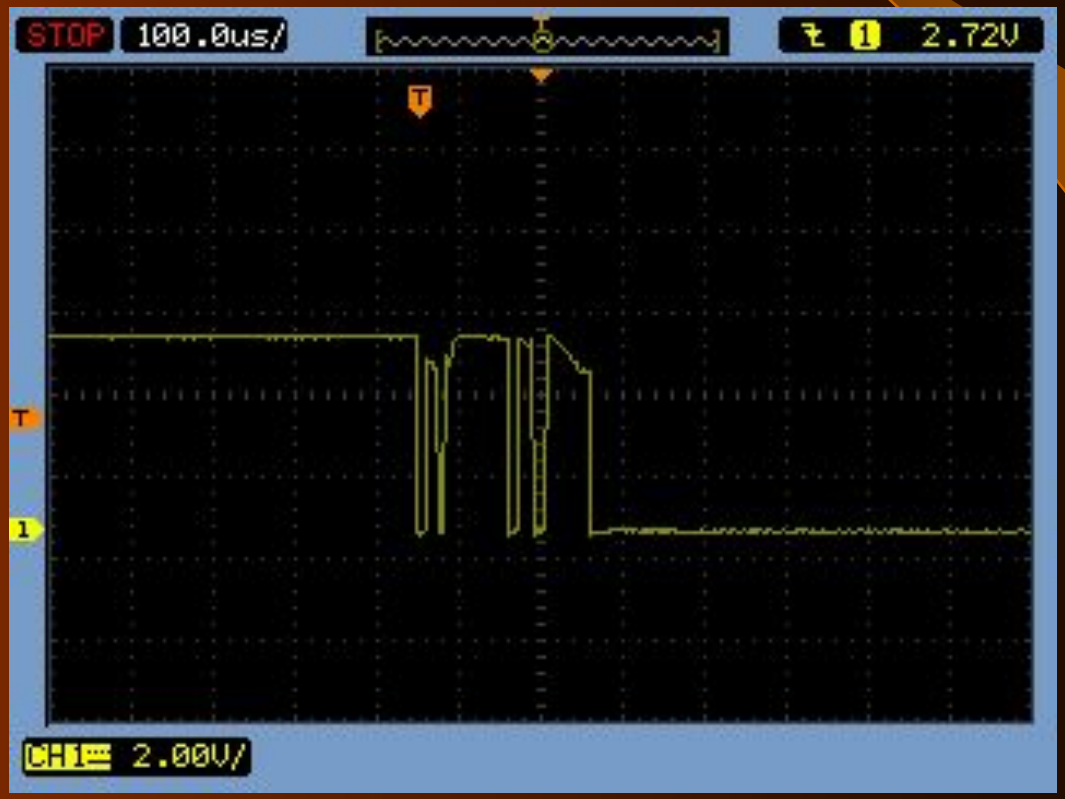
| PARAMETER | | TEST CONDITIONS | $V_{CC}$ | MIN | TYP | MAX | UNIT |
|---|---|---|---|---|---|---|---|
| $f_{Px.y}$ | Port output frequency (with load) | Px.y, $C_L = 20$ pF, $R_L = 1$ kΩ(1) (2) | 3 V | | 12 | | MHz |
| $f_{Port\_CLK}$ | Clock output frequency | Px.y, $C_L = 20$ pF(2) | 3 V | | 16 | | MHz |

(1) A resistive divider with two 0.5-kΩ resistors between $V_{CC}$ and $V_{SS}$ is used as load. The output is connected to the center tap of the divider.
(2) The output voltage reaches at least 10% and 90% $V_{CC}$ at the specified toggle frequency.

# Switch Bounce (With Pull-up Resistor)



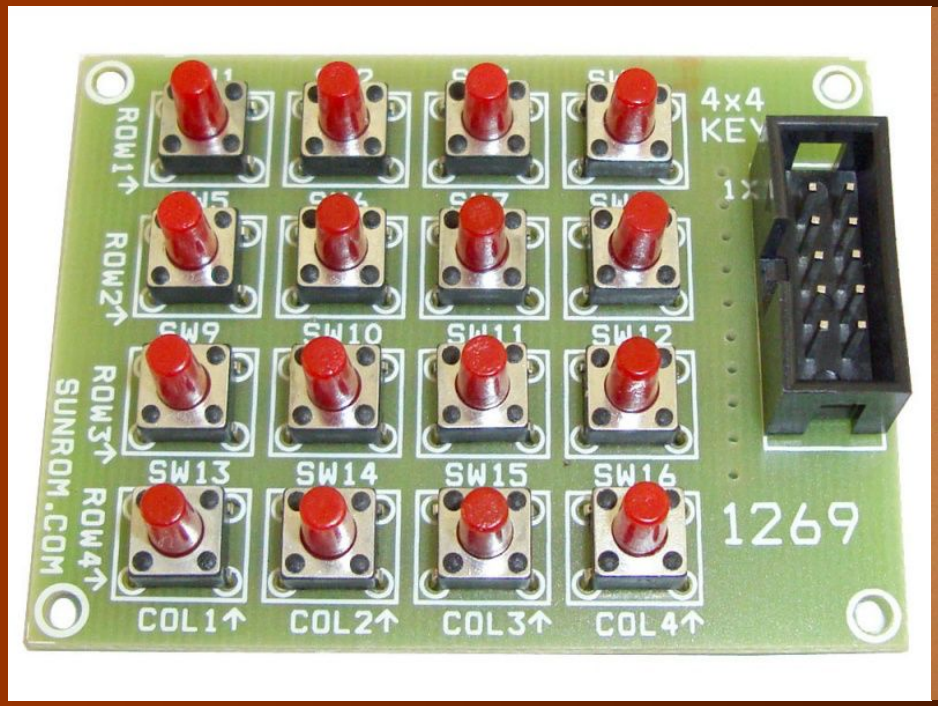
# Switch Bounce DSO Screen Capture



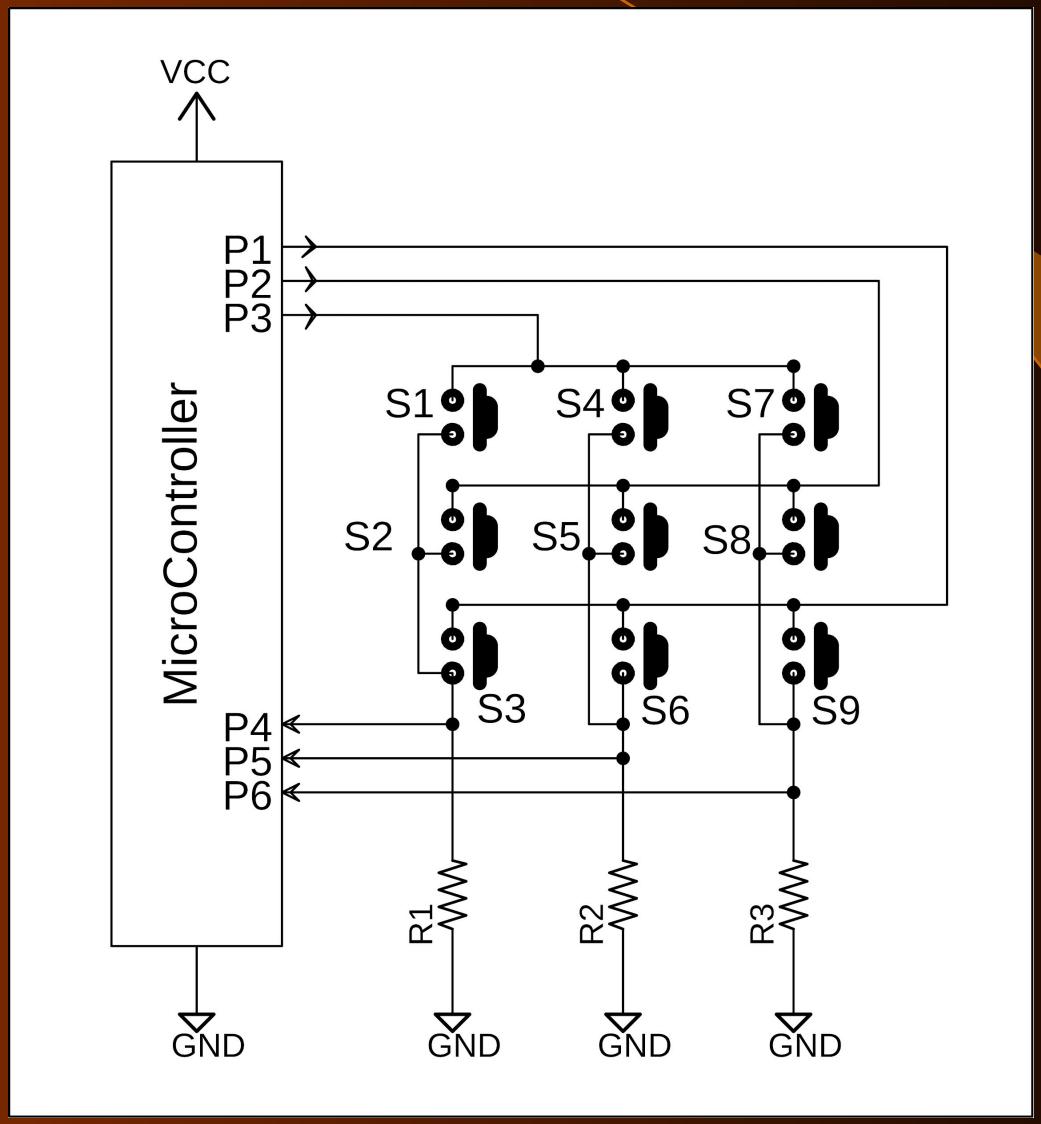
# Switch Debounce

- Hardware option (not preferred)
- Software option

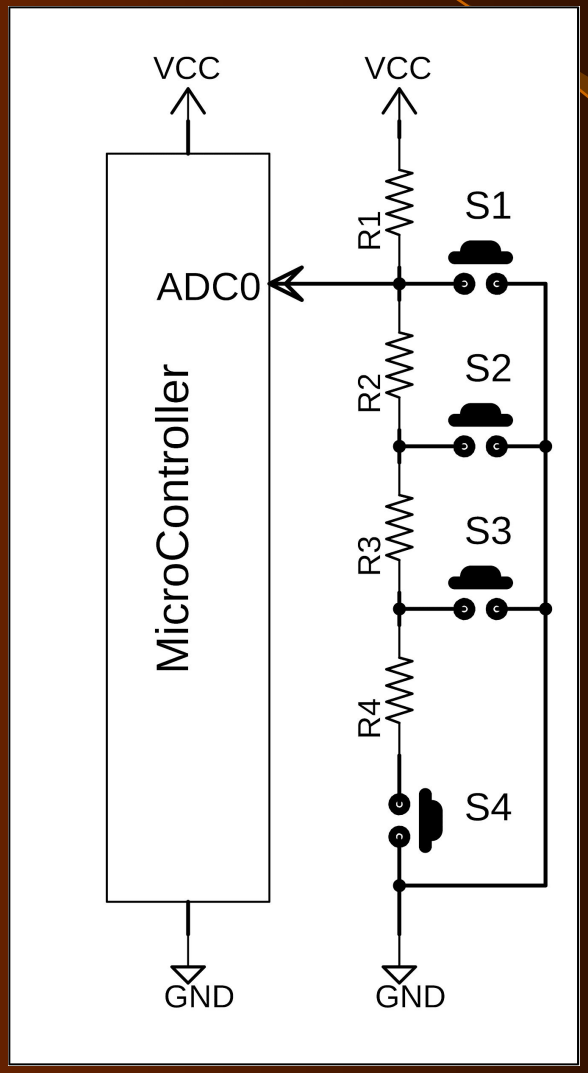
# Interfacing to the Physical World: More Inputs




# Matrix of Keys

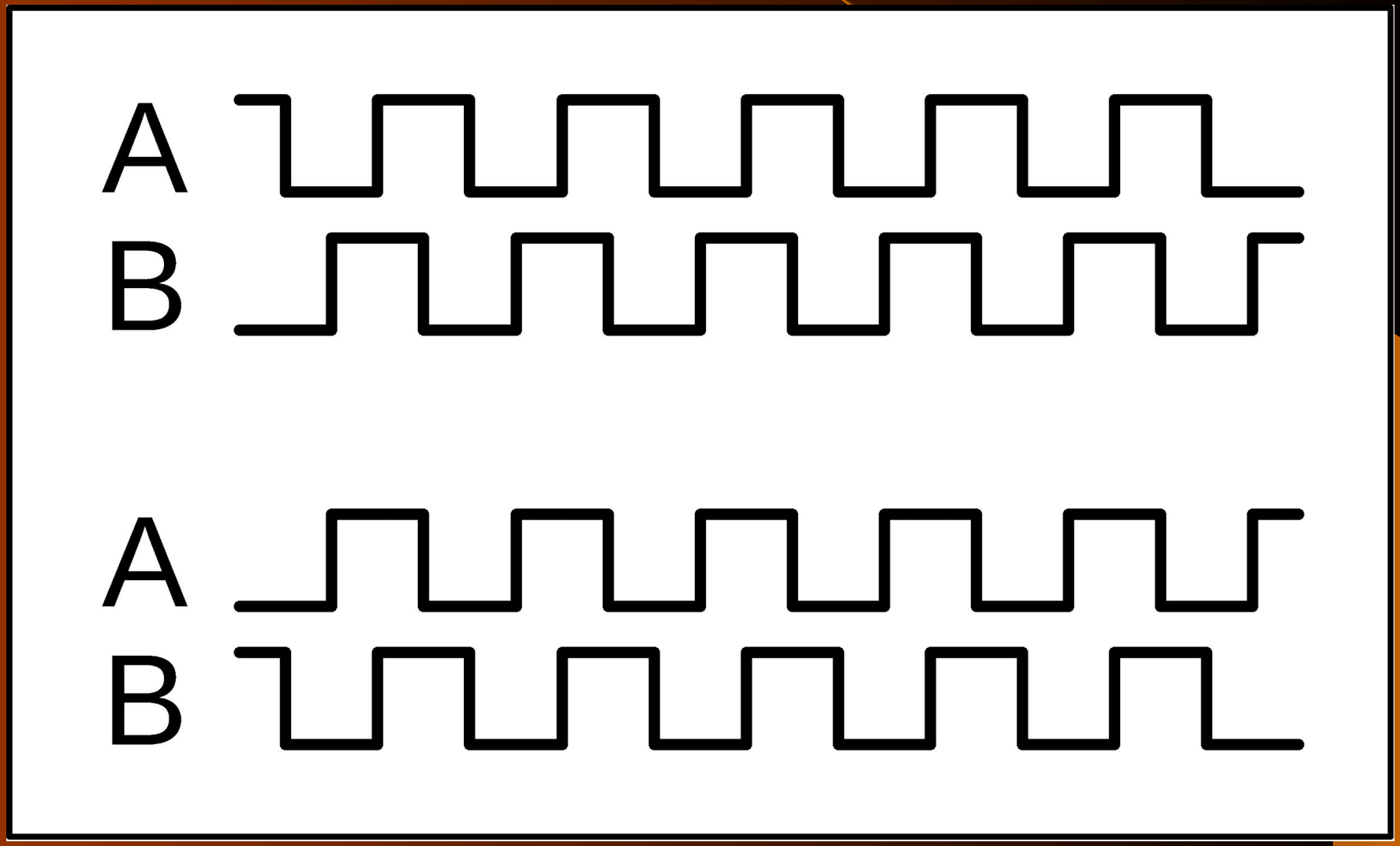


# Using an ADC To Read Multiple Switches



# Rotary Encoder

# Rotary Encoder



# Interfacing to the Physical World: Output Devices

- Output Devices (Human Outputs)

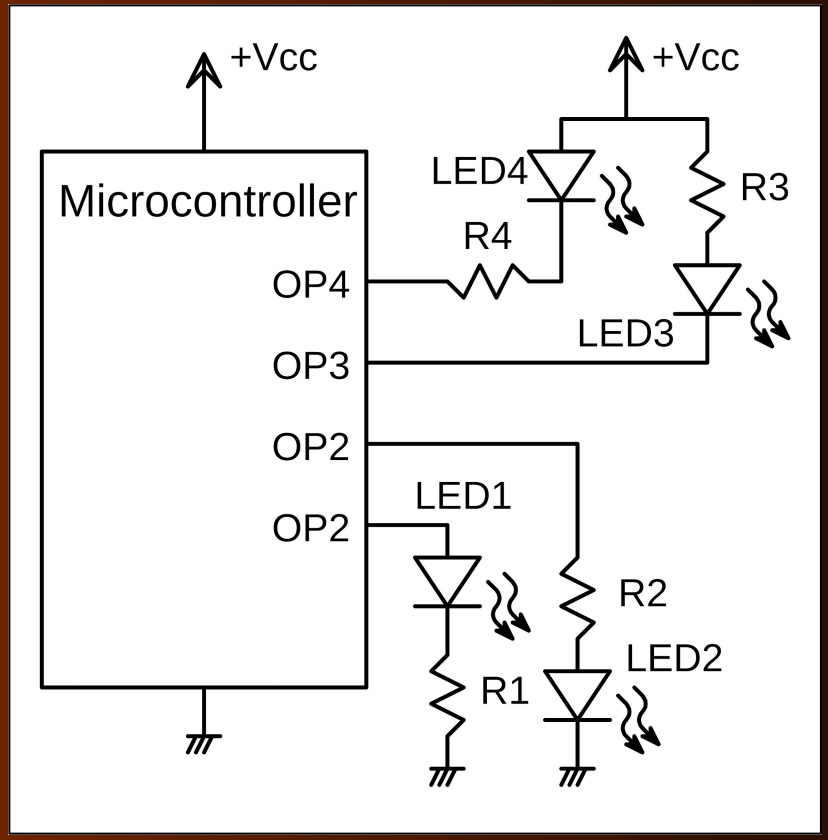
LED, RGB LED, Addressable RGB LED, Seven Segment Display, Dot-Matrix Display, LCD, Sound output

- Other Outputs

Relay, Motor, Heater, Peltier Module, DC Motor, Stepper Motor.

# Controlling LEDs

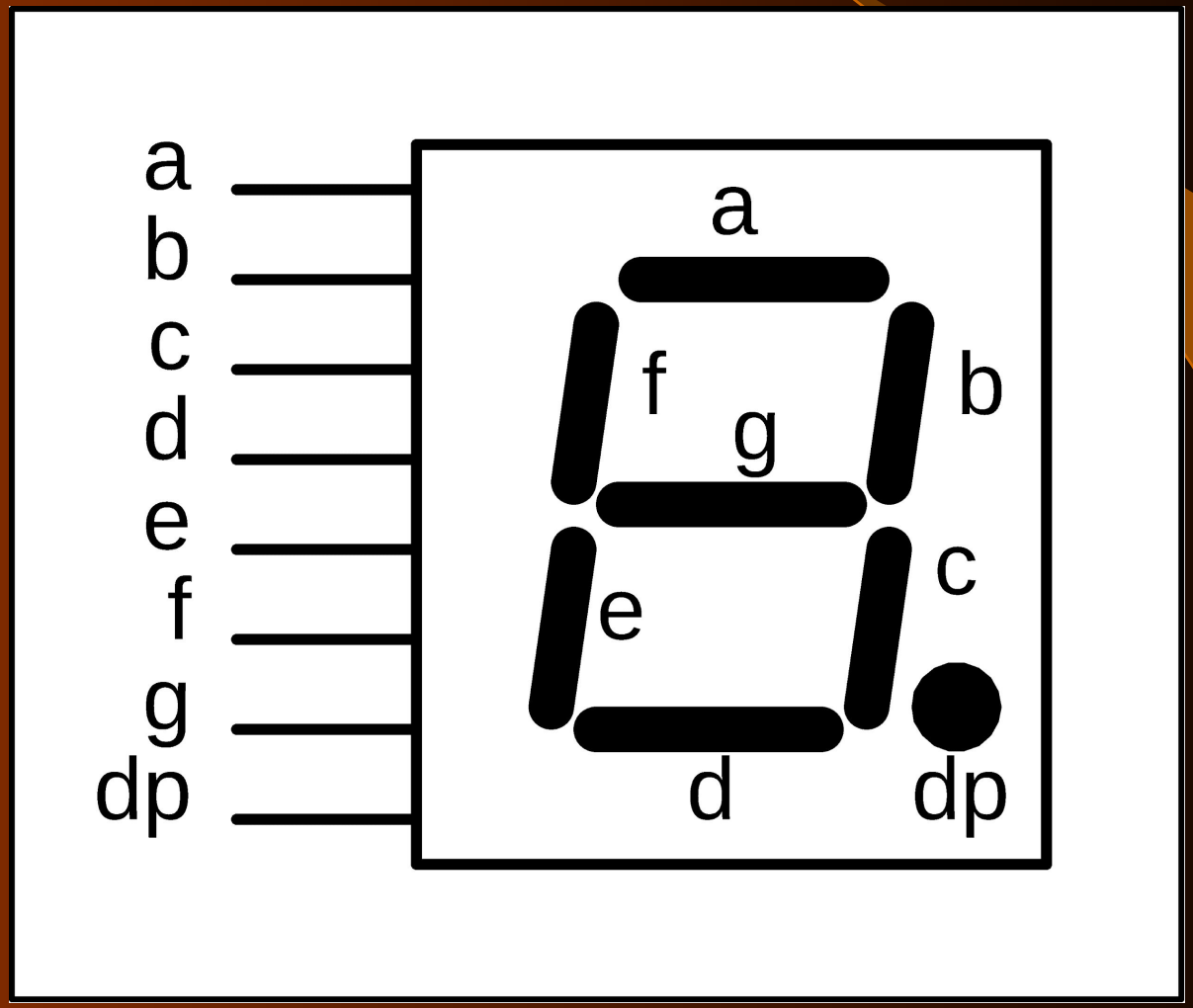
- **LED1 and LED2: High Side Control**
- **LED3 and LED4: Low Side Control**



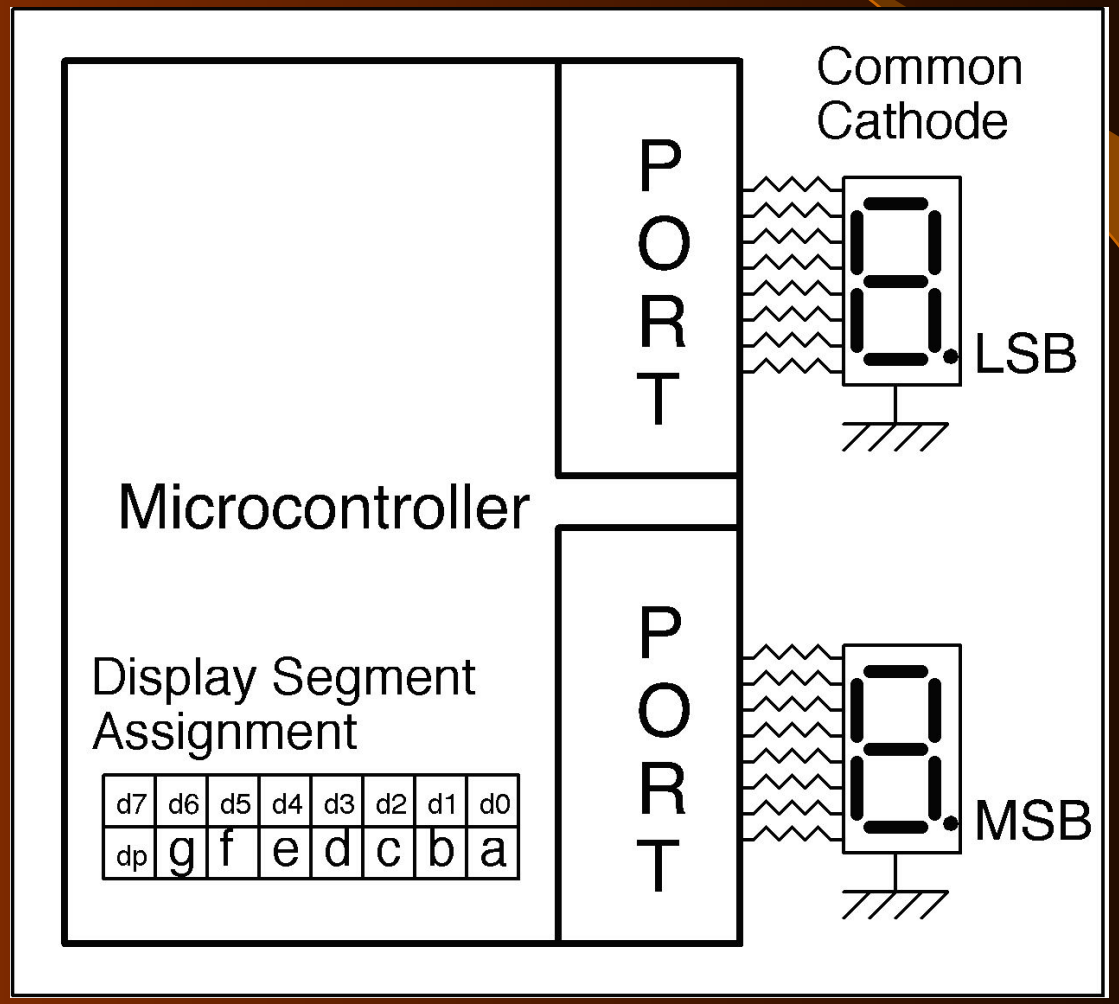
# Controlling LEDs

- What is the voltage drop across an LED?
- What is the value of the resistor?
- How to calculate the value

# Driving Seven Segment Displays



# Driving Seven Segment Displays



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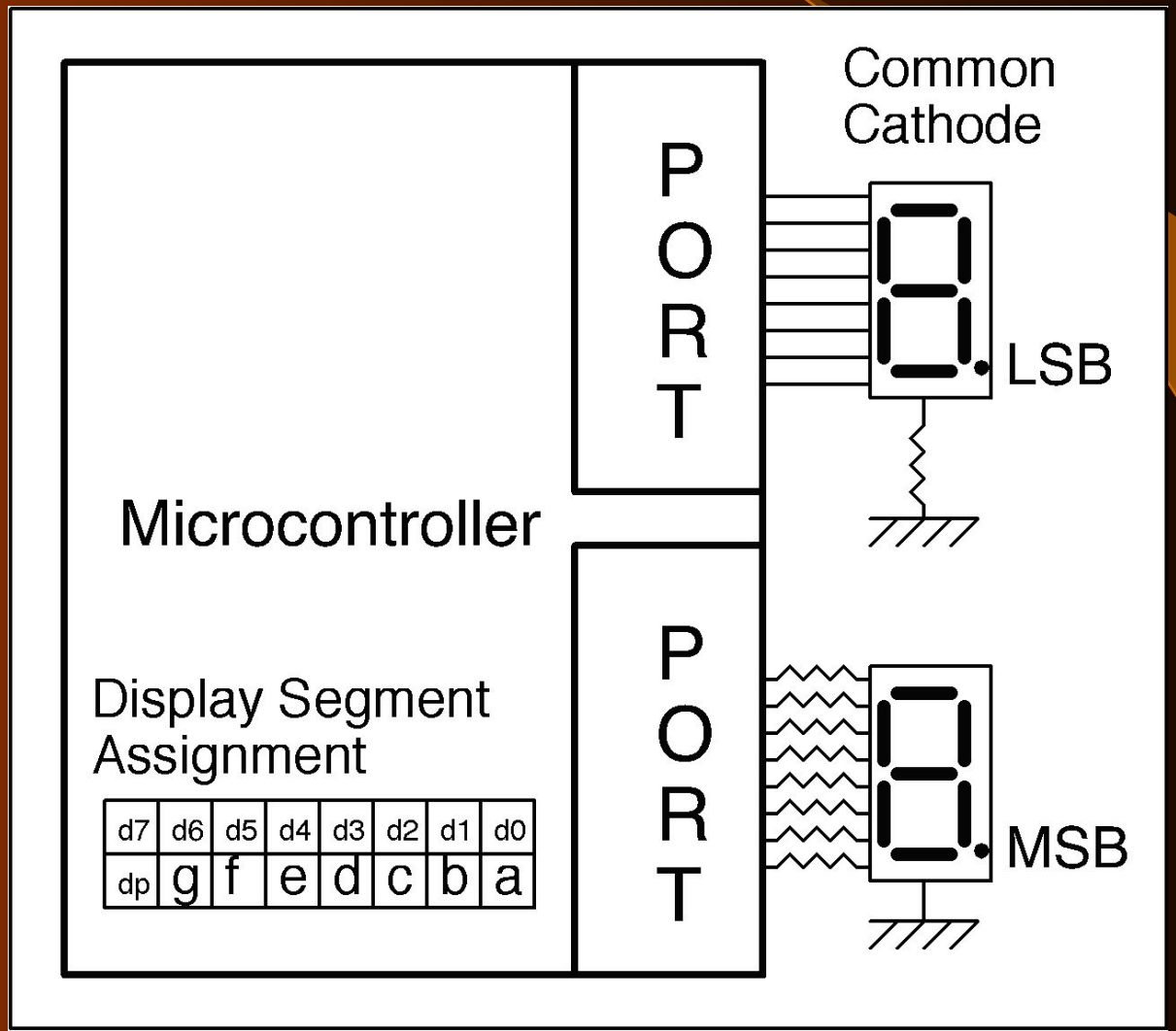

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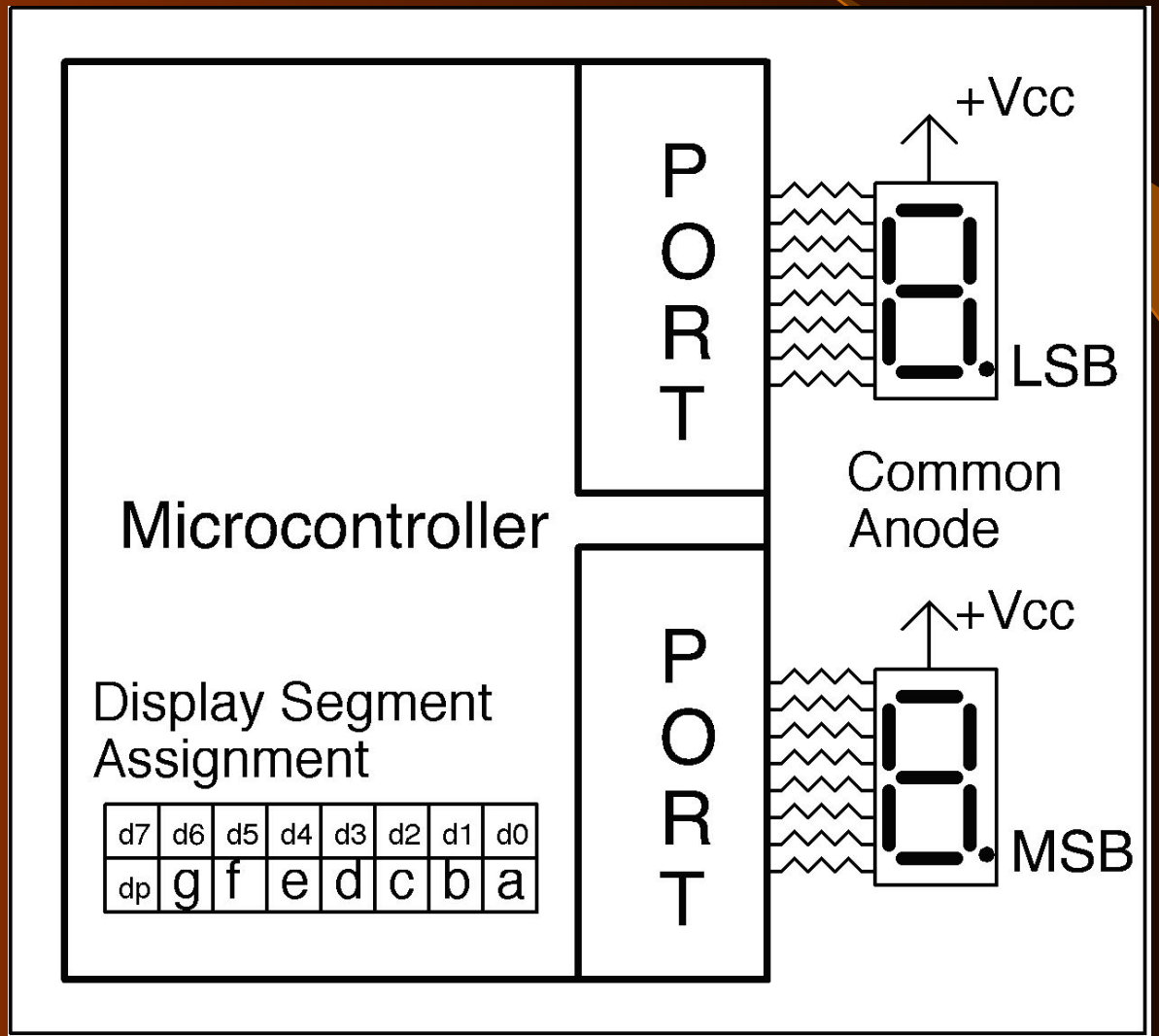
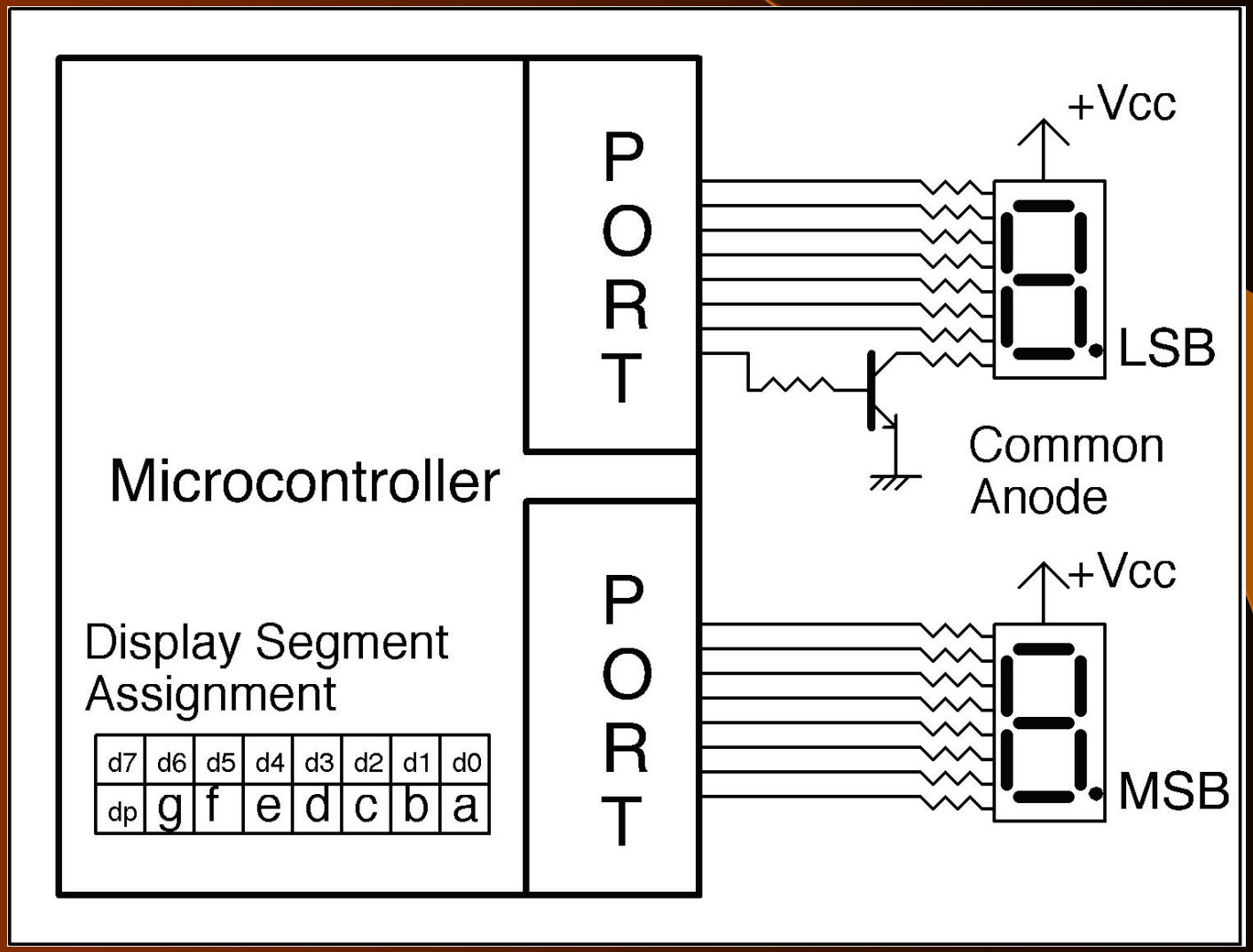


# Driving Seven Segment Displays



# Driving LEDs (Or Other loads): Low Side Driver