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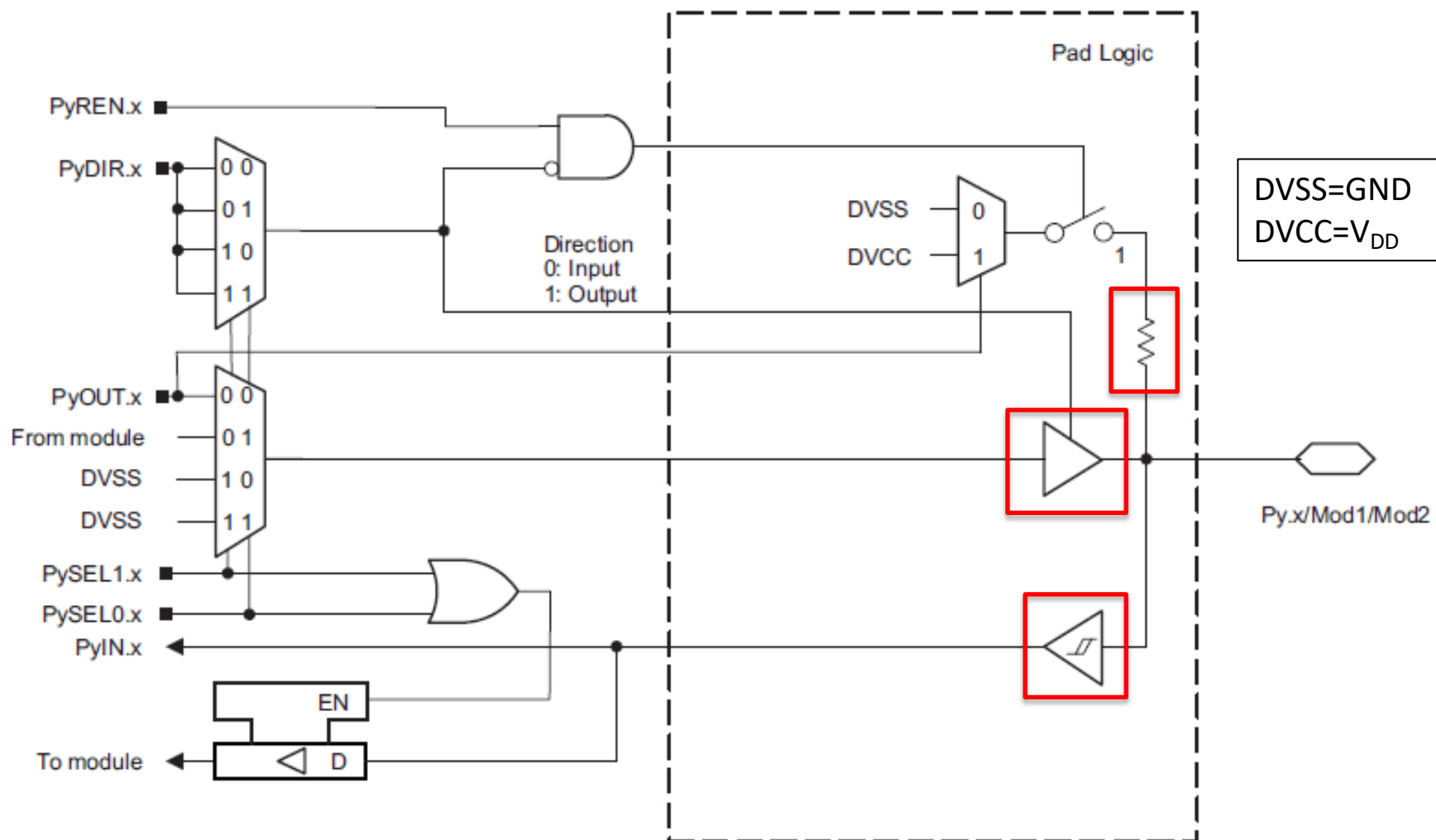
**Real-Time Embedded System
Co-Design
CMPE 146 Section 1
Fall 2024**

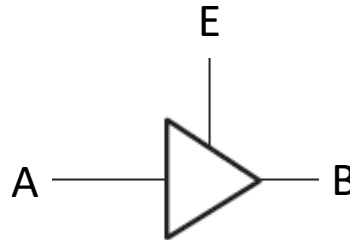


MCU Digital Interfaces

- 84 I/O bits are implemented
- All individual I/O bits are independently programmable
- Any combination of input and output is possible
- Programmable pullup or pulldown on all ports
- Edge-selectable interrupt capability is available on 6 ports
- Wake-up capability from low-power modes on 6 ports
- Ports can be accessed byte-wise or in pairs (16-bit wide)
- Capacitive-touch functionality is supported on all pins of ports
 - For user interface
- 20-mA high-drive on 4 pins
 - Others at 6 mA max
- Glitch filtering capability on 8 pins
 - Analog filter suppresses a minimum of 250-ns wide glitches
 - Can be used to prevent unintentional interrupts

- Typical port structure

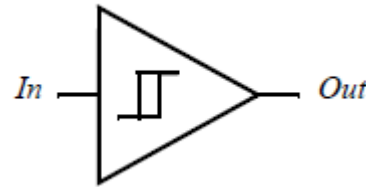




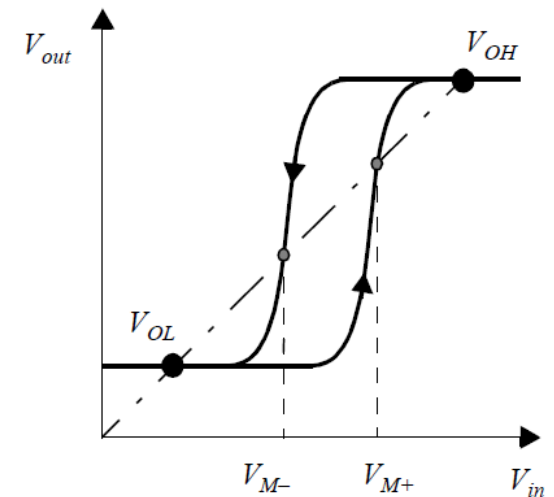
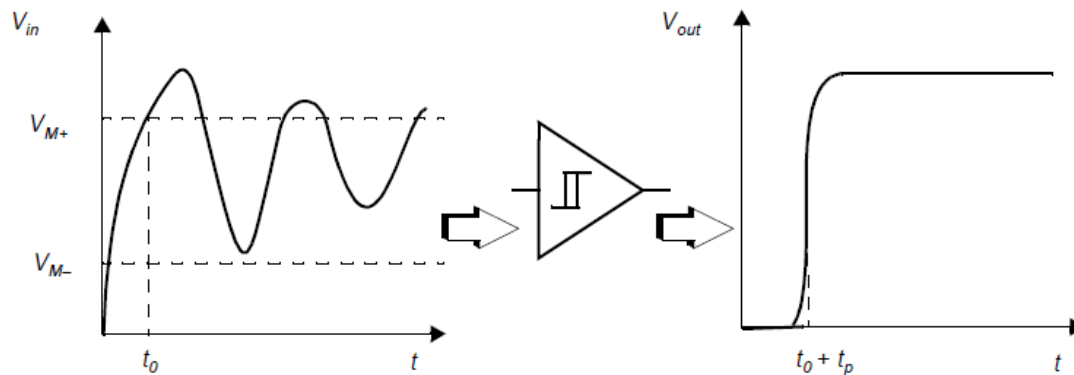
- Output has three states
 - 1, 0, high impedance (Hi-Z)
- When E is 0, the driver is disabled and the equivalent circuit is an open circuit (Hi-Z)



- When E is 1, the driver is enabled, i.e., $B = A$

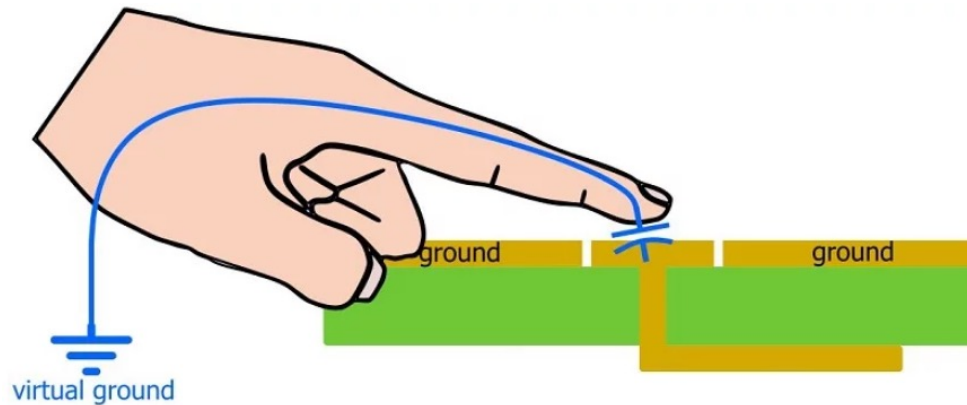


- Logically, Output = Input
- Different low-to-high and high-to-low switching thresholds
- Effective in suppressing input noise

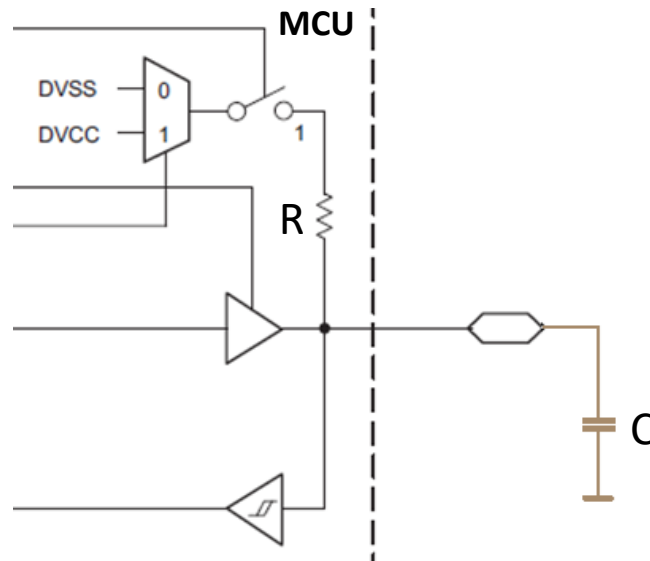


Voltage-Transfer Characteristic

- GPIO port configuration allows change of capacitance detected at the pin
 - Commonly used for detecting the interaction of human finger on a surface
- Capacitance at the I/O pin is not fixed
 - GPIO pin connects to a touch surface
 - Some capacitance exists at the pin due to material of the circuit board, connecting wire and surrounding environment
 - Presence of a finger introduces additional capacitance

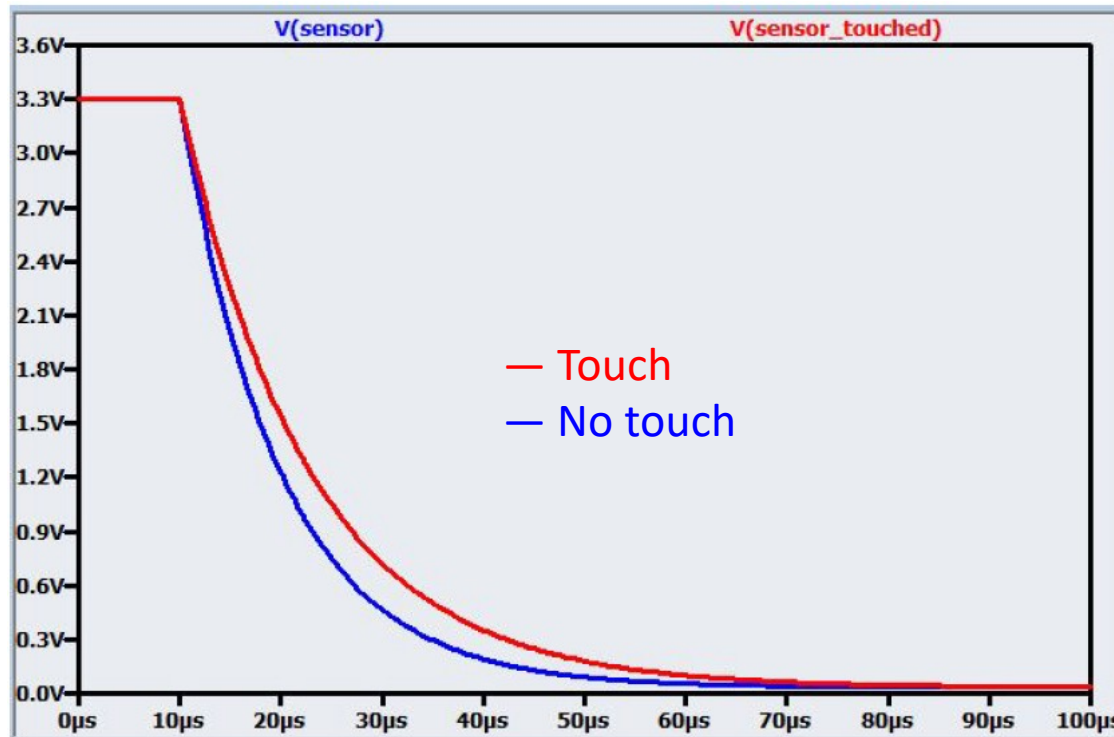


- The equivalent circuit at the GPIO pin
 - With the addition of a “variable” capacitor



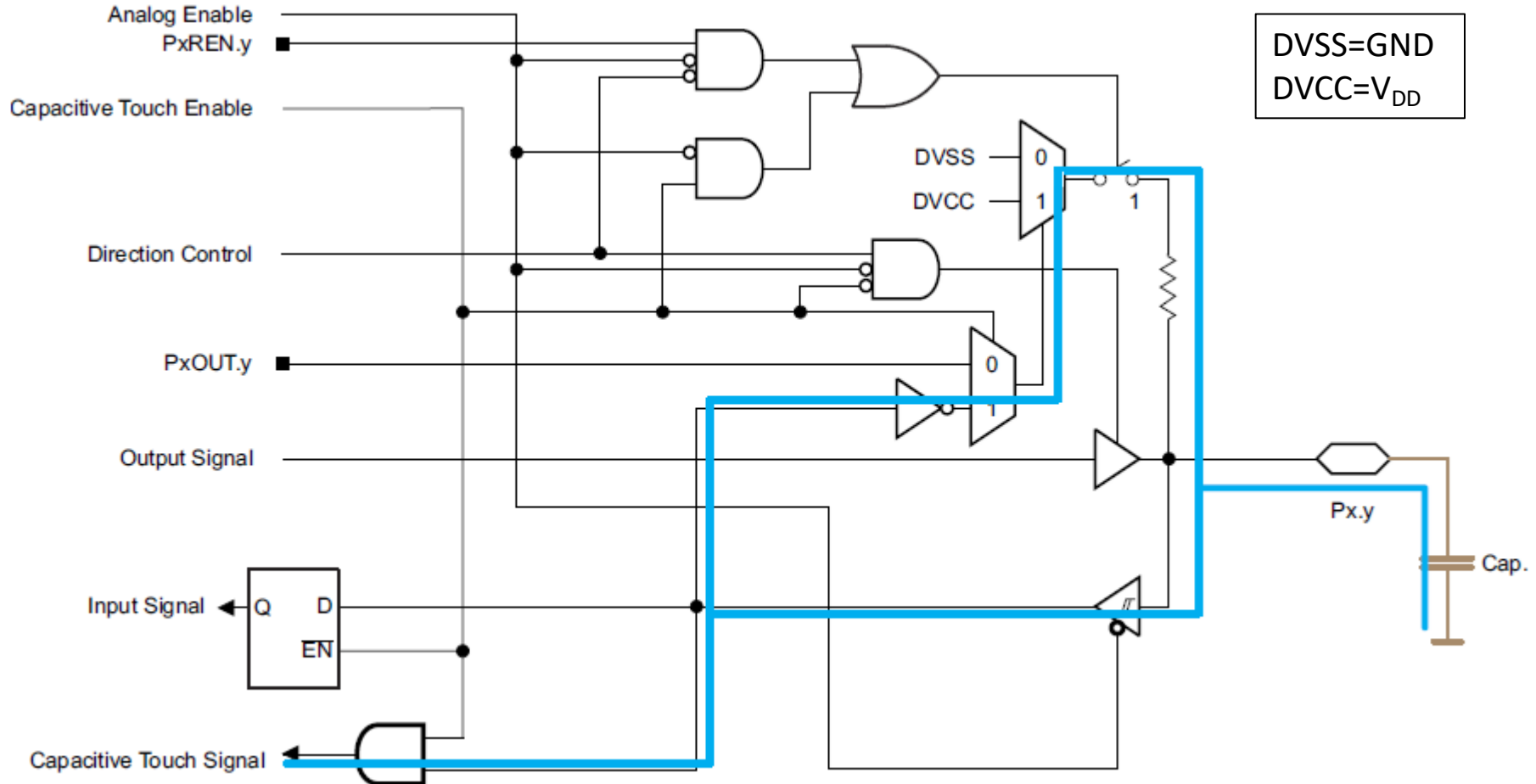
- A small RC circuit exists
 - Pullup-pulldown resistor provides the R
 - Collective capacitance forms the C

- If we charge up C to logic-high voltage and discharge it, we will observe difference discharge characteristics between a touch and no-touch conditions



- That is, if we can build an oscillator with the RC circuit, we can generate different frequencies in those two conditions

- With very little circuitry added to provide a feedback loop, an oscillator can form at the GPIO port



- Use additional timer/counter to measure the oscillator ticks captured in a fixed time window
- Establish a baseline measurement with no touch
 - MCU measures the count continually
 - Lower count → lower frequency → higher capacitance → human touch

