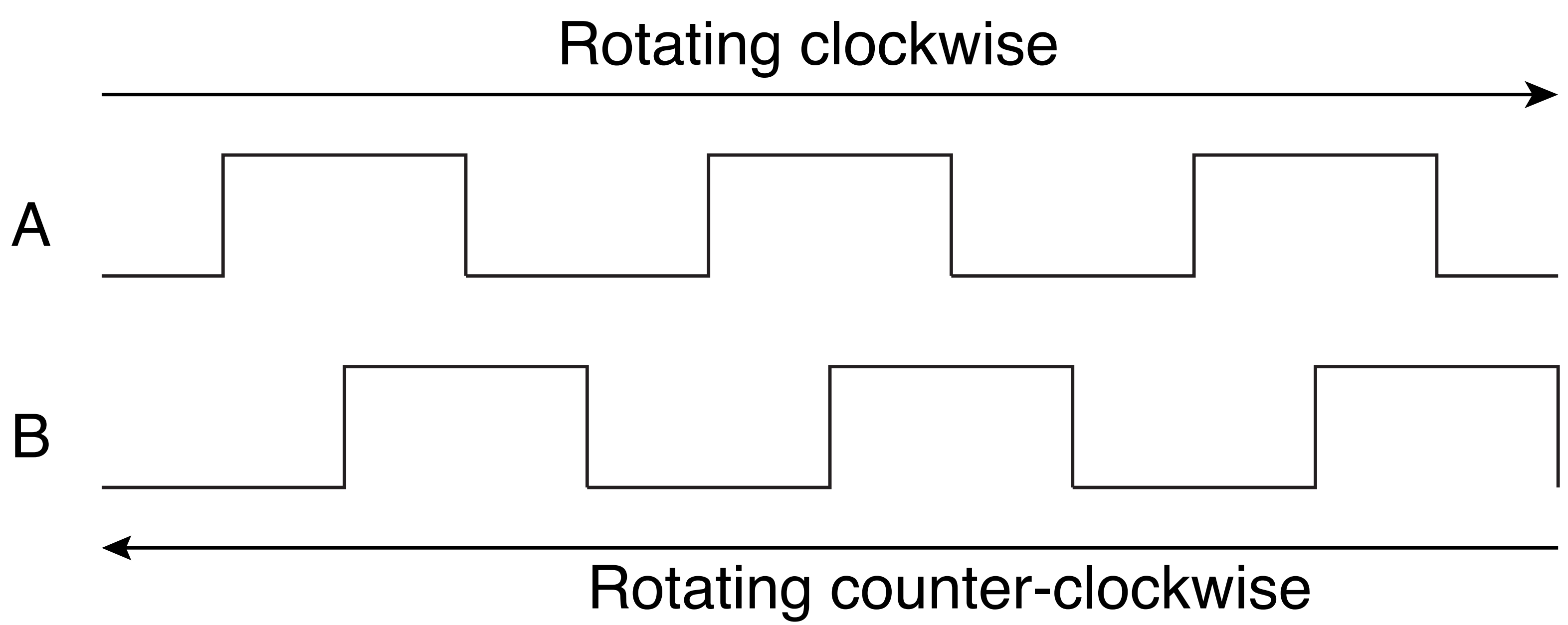
Unit B - Rotary Encoders

Rotary Encoders

- Electromechanical devices used to measure the angular position or rotation of a shaft.
- Two types:
  - Absolute: Output a binary number for the current angular position of the shaft.
    - 0000 = 0˚, 0001 = 22.5˚, 0010 = 45˚, etc.
  - Incremental: Outputs signals that indicate a change in angular position and the direction of rotation.
- Many uses in controlling mechanical devices
  - Scanners, printers, mice, robots, manufacturing equipment, etc.

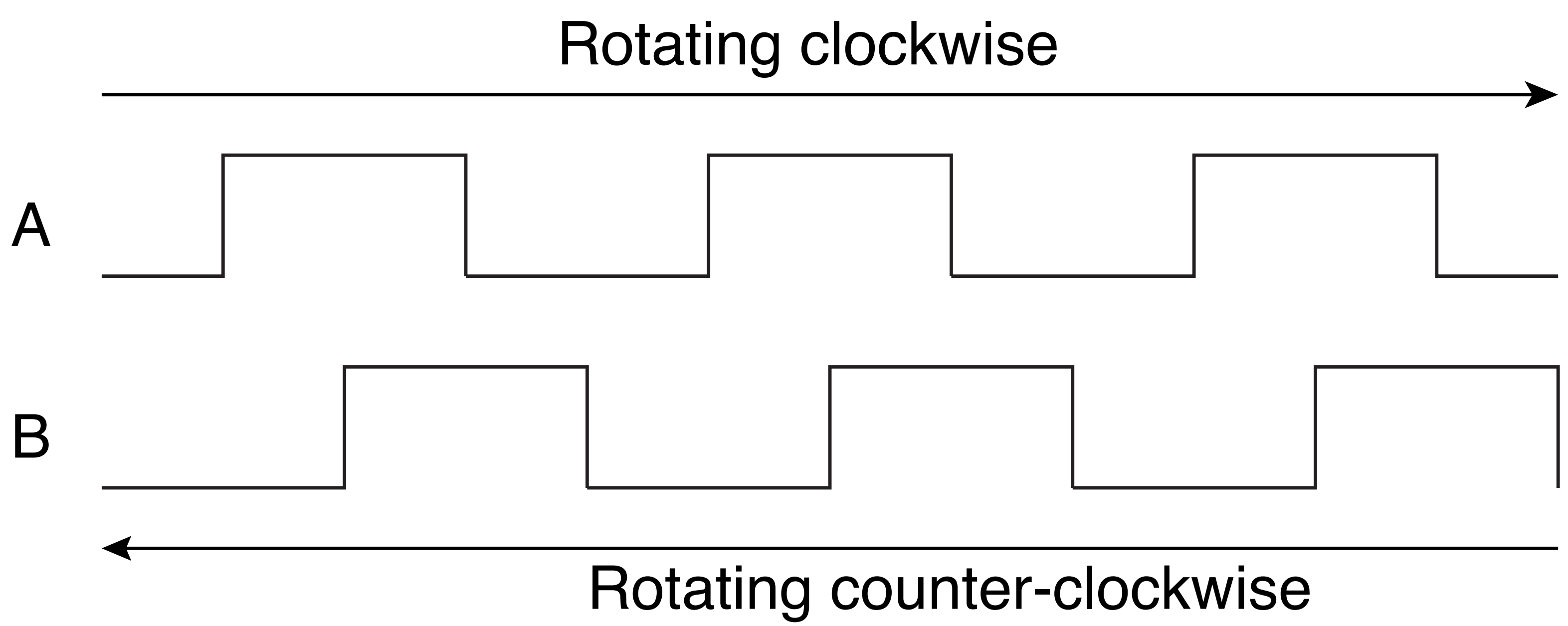
Rotary Encoders

- Incremental encoders produce **quadrature** outputs
- Output is two square waves, 90° out of phase, as the device is rotated
- By examining the state of the two outputs at the transitions, we can tell which way it's being rotated.



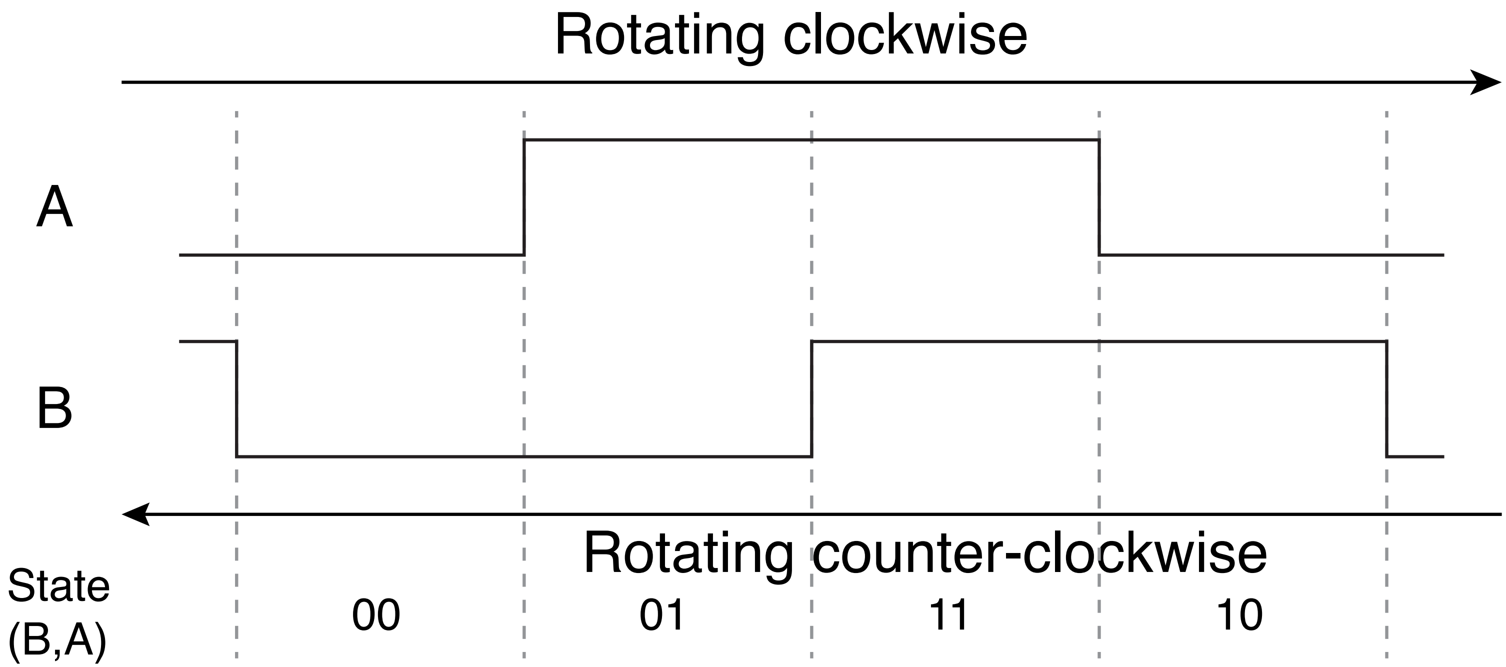
Rotary Encoders

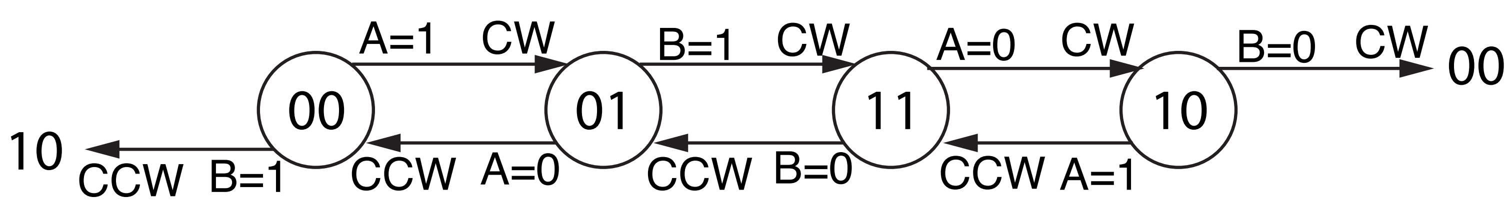
- If B = 0 when A $\uparrow \Rightarrow$ Clockwise
- If B = 0 when A $\downarrow \Rightarrow$ Counter clockwise
- If A = 1 when B $\uparrow \Rightarrow$ Clockwise
- If A = 1 when B $\downarrow \Rightarrow$ Counter clockwise



Rotary Encoders

- Can implement this as a state machine





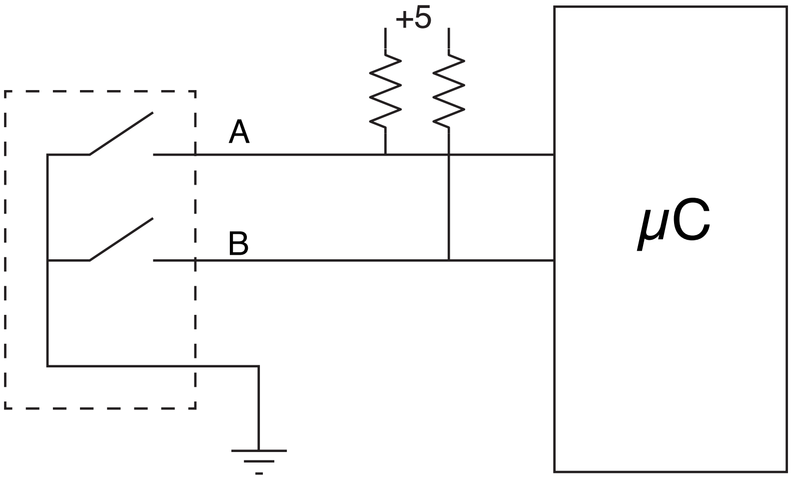
Gray Codes

- The two bit output sequence is a “Gray Code”.
  - Each adjacent element differs by only **one** bit.
- In normal binary codes, multiple bits change from one code to the next (011→100)
- Impossible for hardware to make sure all the bits change at the same time.
- Gray codes are used with many electromechanical devices.

3-Bit Binary	3-Bit Gray
0 0 0	0 0 0
0 0 1	0 0 1
0 1 0	0 1 1
0 1 1	0 1 0
1 0 0	1 1 0
1 0 1	1 1 1
1 1 0	1 0 1
1 1 1	1 0 0

Rotary Encoders

- Encoder has three terminals
  - A, B and common
- As it rotates the two switches open and close
- Ones used in our lab have 64 states per revolution
- Must have pull-up resistors on switch outputs



Rotary Encoder Lab

- Write a program that monitors the two inputs from the encoder and increments or decrements a count value each time the encoder changes state.
- Display the count value on the LCD, update only when it changes.
- When the count is a multiple of eight, play one of eight musical tones for one second.
- Implement a state machine with four states:
  - "A" and "B" inputs from encoder cause state transitions.
  - State transitions cause count to go up or down.

Rotary Encoder Lab

- Test the program by rotating the encoder and seeing if the count value changes correctly.
- Problem: When a tone is being played, the program ignores the encoder inputs (try it).
  - Transitions can be lost while the program is in delays and other time-consuming tasks.
- Solution: Modify the program to use interrupts to handle the encoder inputs.
  - Use "Pin Change Interrupts" to generate interrupts whenever an input from the encoder changes.
  - Program responds to input transitions regardless of what it is doing, allowing the count value to change properly when tones are being played.

Pin Change Interrupts

- All the input pins in Ports B, C and D can trigger a pin change interrupt.
- When enabled, a 0→1 or 1→0 transition on the pin will cause an interrupt.
- Separate ISRs for each of the three ports:
  - Port B: PCINT0_vect
  - Port C: PCINT1_vect
  - Port D: PCINT2_vect
- All the pins in one port must use the same interrupt service routine. Up to the ISR to figure out what to do.

Pin Change Interrupts

- Pin change interrupt registers

Pin Change Int. Control Register (PCICR)						PCIE2	PCIE1	PCIE0
Pin Change Int. Flag Register (PCIFR)						PCIF2	PCIF1	PCIF0
Pin Change Mask Register 0 (PCMSK0) for Port B	PCINT7	PCINT6	PCINT5	PCINT4	PCINT3	PCINT2	PCINT1	PCINT0
Pin Change Mask Register 1 (PCMSK1) for Port C		PCINT14	PCINT13	PCINT12	PCINT11	PCINT10	PCINT9	PCINT8
Pin Change Mask Register 2 (PCMSK2) for Port D	PCINT23	PCINT22	PCINT21	PCINT20	PCINT19	PCINT18	PCINT17	PCINT16

- To enable a pin change interrupt:
  - Set the PCIEx bit to a one for the port
  - Set the PCINTxx bit in the mask register for the I/O pin
  - Call sei() to enable global interrupts

Pin Change Interrupts

- Pin Change Interrupt numbers:

(PCMSK0) PORTB			(PCMSK1) PORTC			(PCMSK2) PORTD		
						7	(D7)	PCINT23
						6	(D6)	PCINT22
5	(D13)	PCINT5	5	(A5)	PCINT13	5	(D5)	PCINT21
4	(D12)	PCINT4	4	(A4)	PCINT12	4	(D4)	PCINT20
3	(D11)	PCINT3	3	(A3)	PCINT11	3	(D3)	PCINT19
2	(D10)	PCINT2	2	(A2)	PCINT10	2	(D2)	PCINT18
1	(D9)	PCINT1	1	(A1)	PCINT9	1	(D1)	PCINT17
0	(D8)	PCINT0	0	(A0)	PCINT8	0	(D0)	PCINT16

- Use the names above to enable interrupts for various pins:

```
PCMSK0 |= ((1 << PCINT5)| (1 << PCINT1));
```

Interrupt-Based Rotary Encoder Lab

- Start with your polling-based rotary encoder lab and modify it to use interrupts to handle the encoder inputs.
- Decide what tasks should be done in the ISR and what stays in the main loop.
  - Hint: Don't do anything that requires delays in the ISR.
- Test the program by continuing to rotate the knob while a tone is being played. Once the tone is finished the new count value should be displayed.