Interfacing with Quadrature Encoders

TI Precision Labs – Timers and Control

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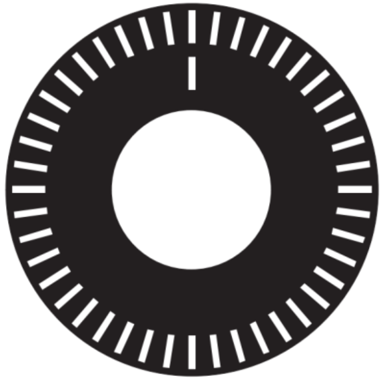
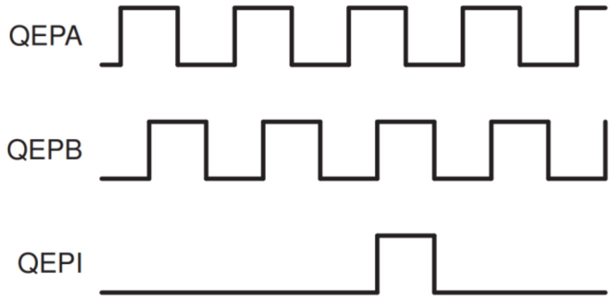
What is an encoder?

- **Encoders** – device used to obtain **position**, **direction**, and **speed** information from machines in order to determine the position or relational position of an object





Sensing Techniques

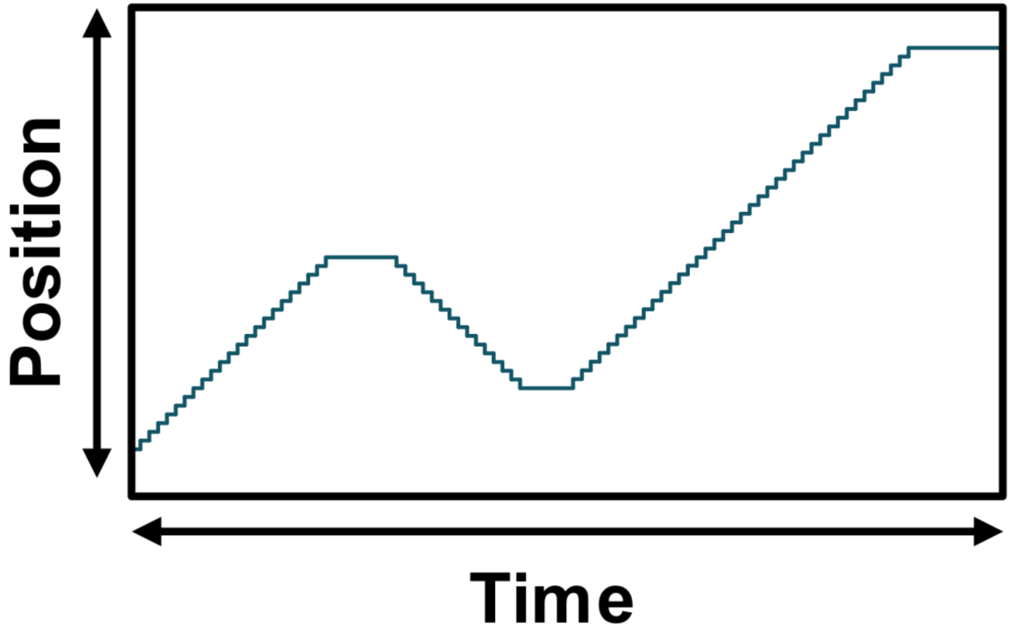
Mechanical
Magnetic
Optical
Electromagnetic

Measurement Types

Absolute
Incremental/Quadrature

Using timers with incremental encoders

- The **timer modules** on microcontrollers can interface with **incremental quadrature encoders** to track the movement and position of an object over time
  - Some devices feature specialized modules for interfacing with quadrature encoders



- Typically used in sensor-based motor control applications

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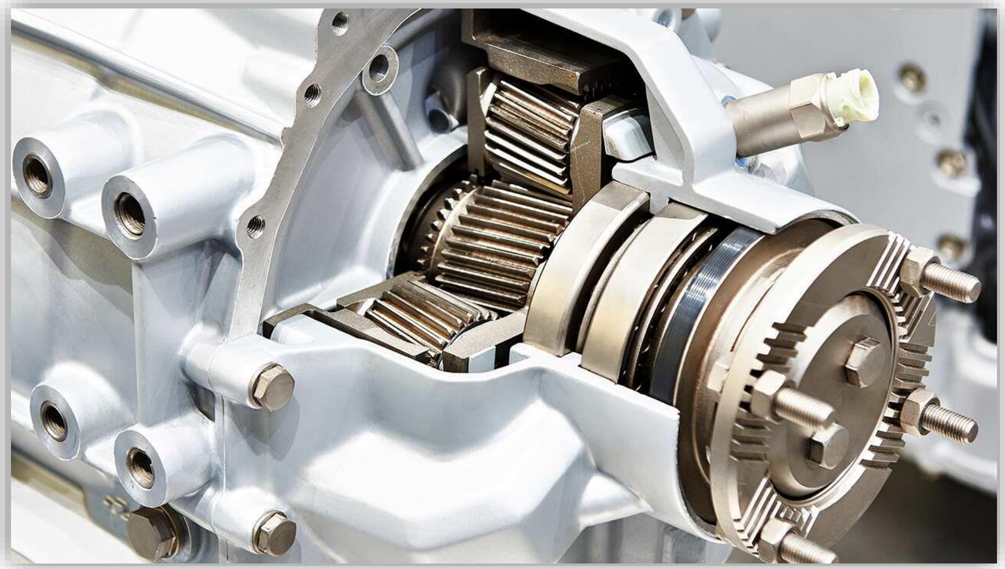

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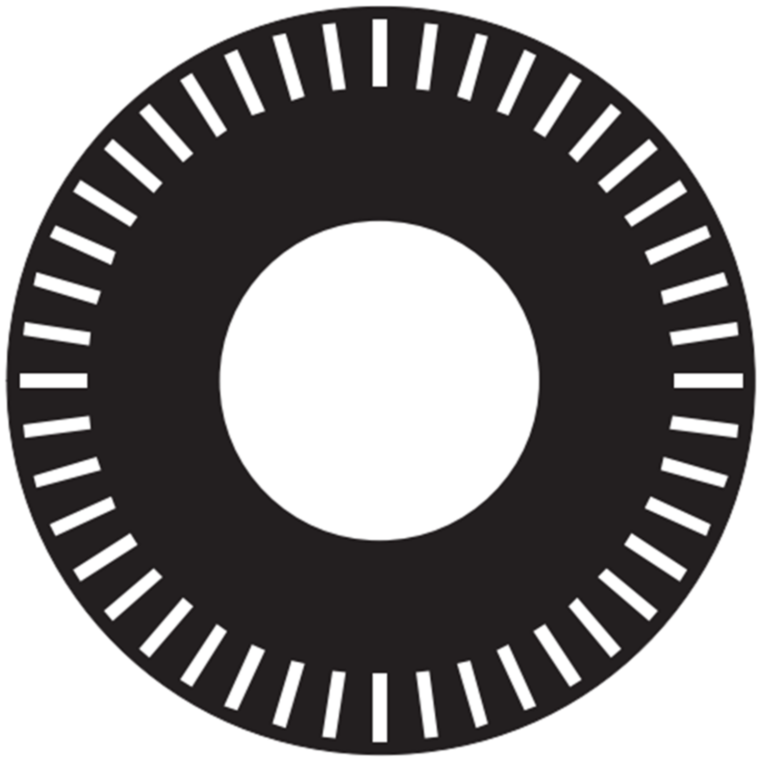
Quadrature encoder disk

- An optical quadrature encoder consists of a **disk** with a number of slots around its perimeter
  - Number of slots correspond to **encoder resolution**

- It also consists of a light source on one side of the disk and a pair of photo sensors on the other
  - Photo sensors are slightly offset from each other



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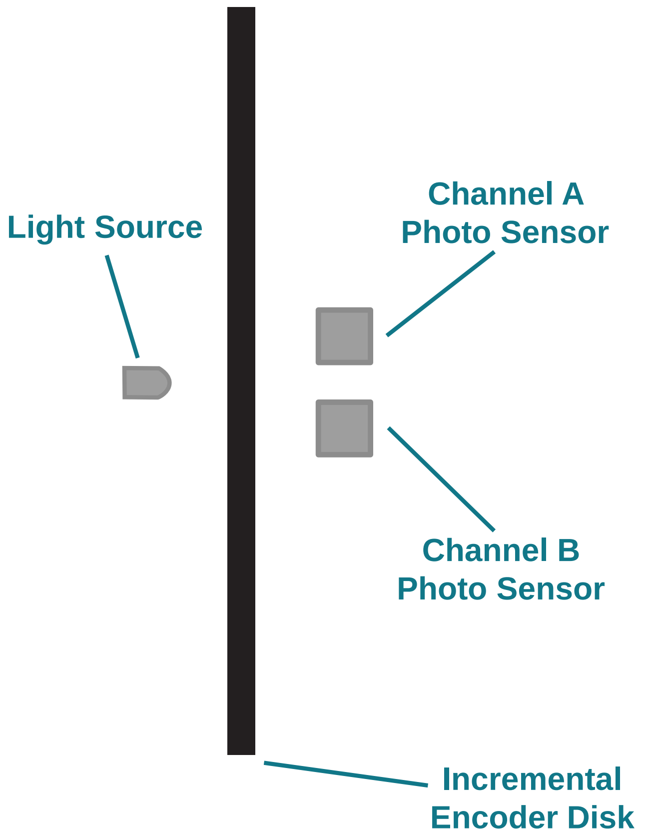
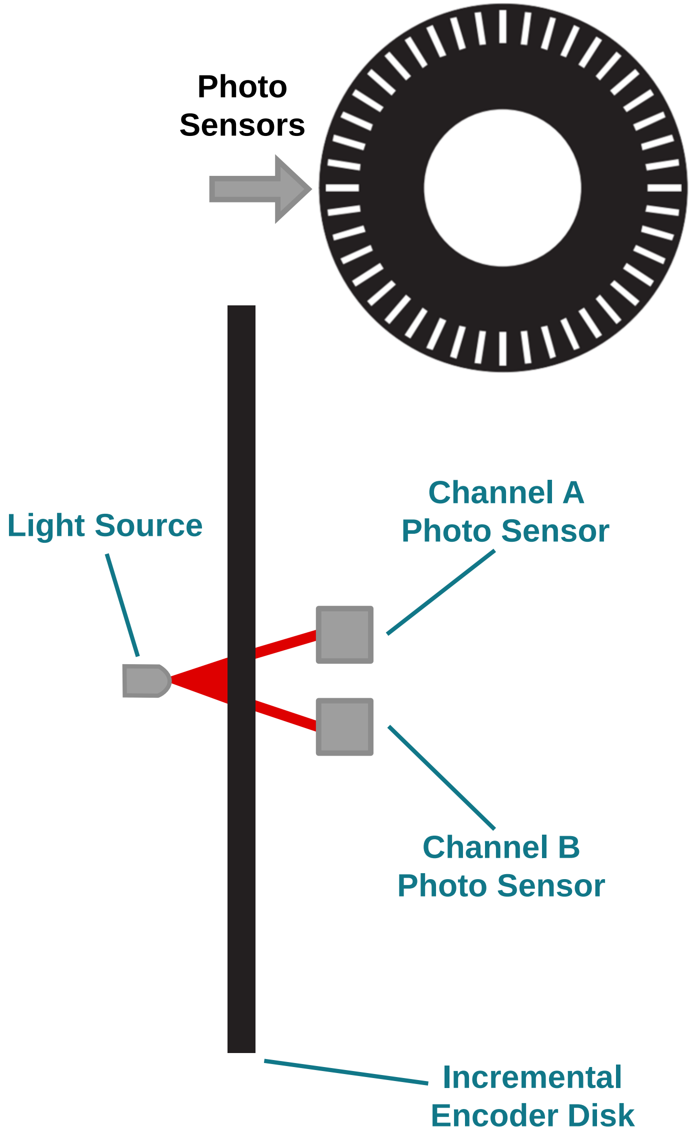


Quadrature signals

- The light shines across the slots of the encoder disk and is obstructed by the opaque parts of the disk
  - As the shaft of the encoder rotates, the photo sensors detect a series of **darkness** (low) and **light** (high)

- This is encoded into a set of pulses known as **quadrature signals**
  - Consist of two channels (**Ch. A** and **Ch. B**) that are offset by 90°
  - The **frequency** and **relative phase** of these waveforms are used to determine the movement of the motor
  - Quadrature signals fed into microcontroller for decoding



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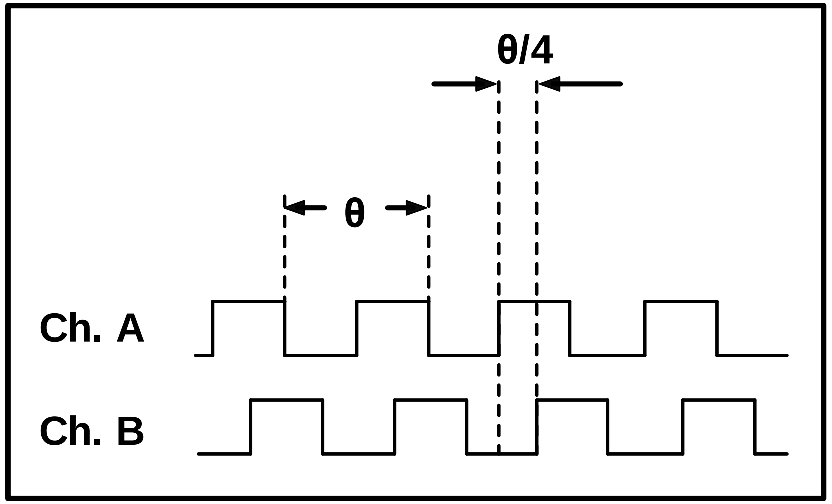
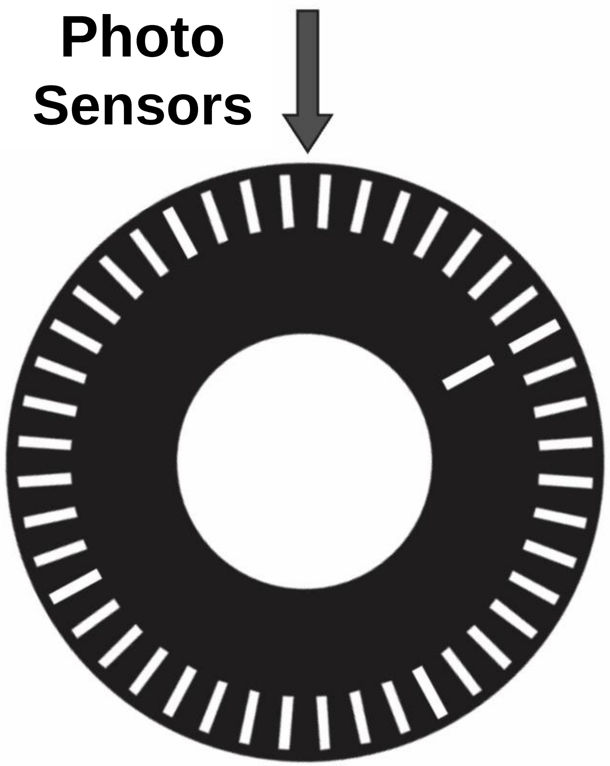
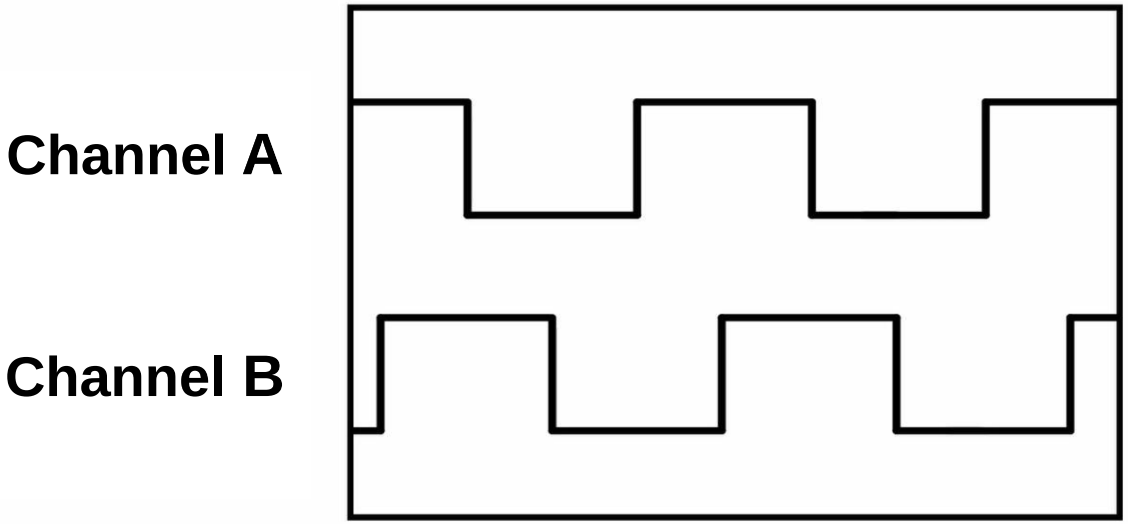


Quadrature signals in motion



Incremental Encoder

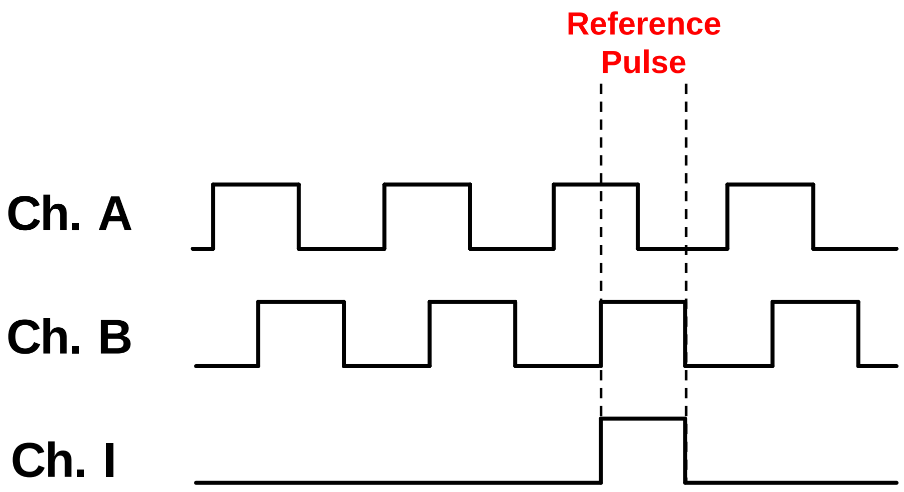
Clockwise Movement

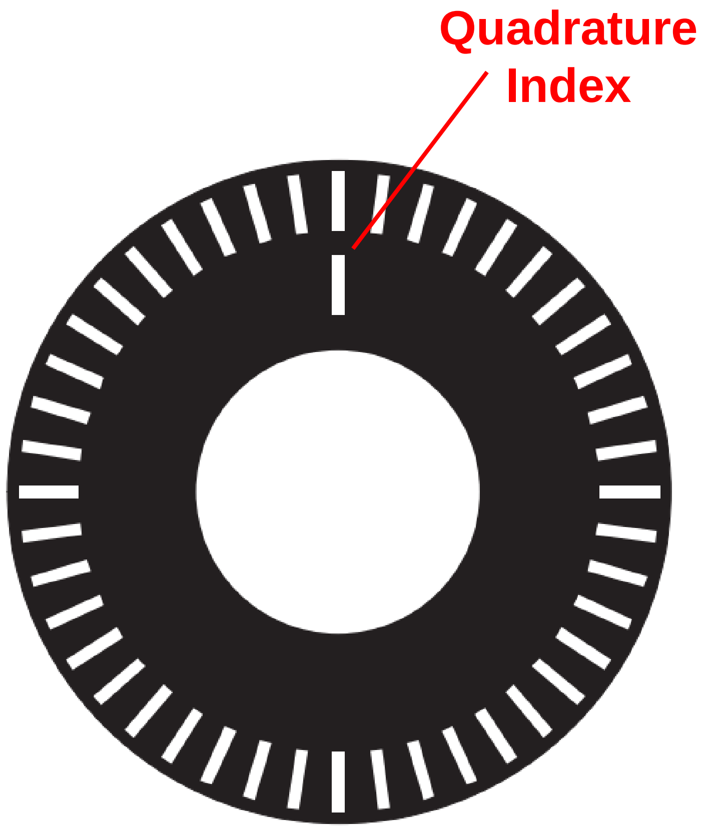


Quadrature Waveform

Quadrature encoder index signal

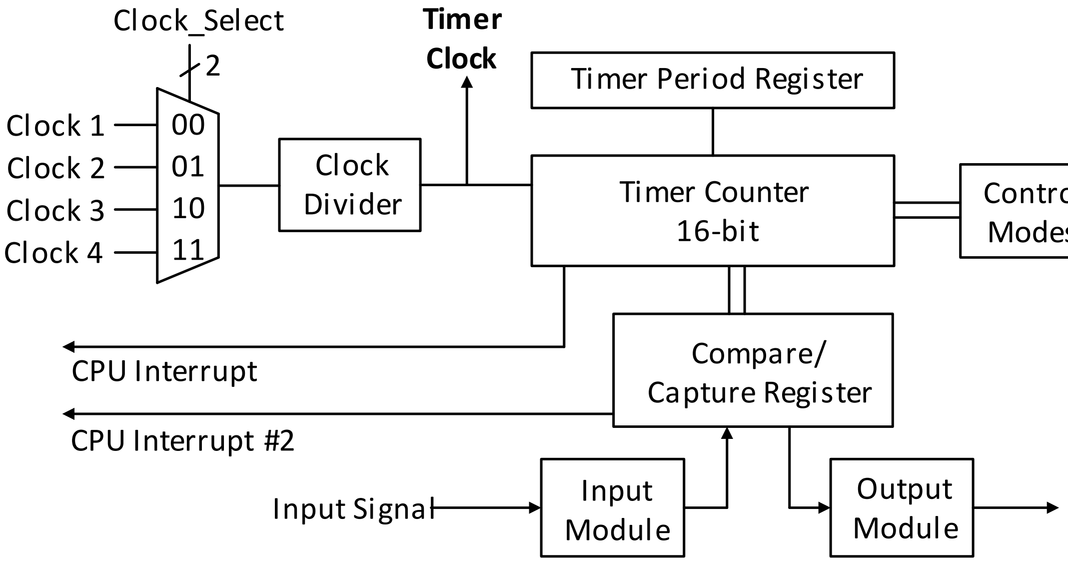
- **Quadrature Index** – an additional row with a single slot at a fixed location
  - Used as a reference point for the encoder
  - Indicate when to begin monitoring position
  - Signals a complete revolution of the disk
  - Can be used for position verification

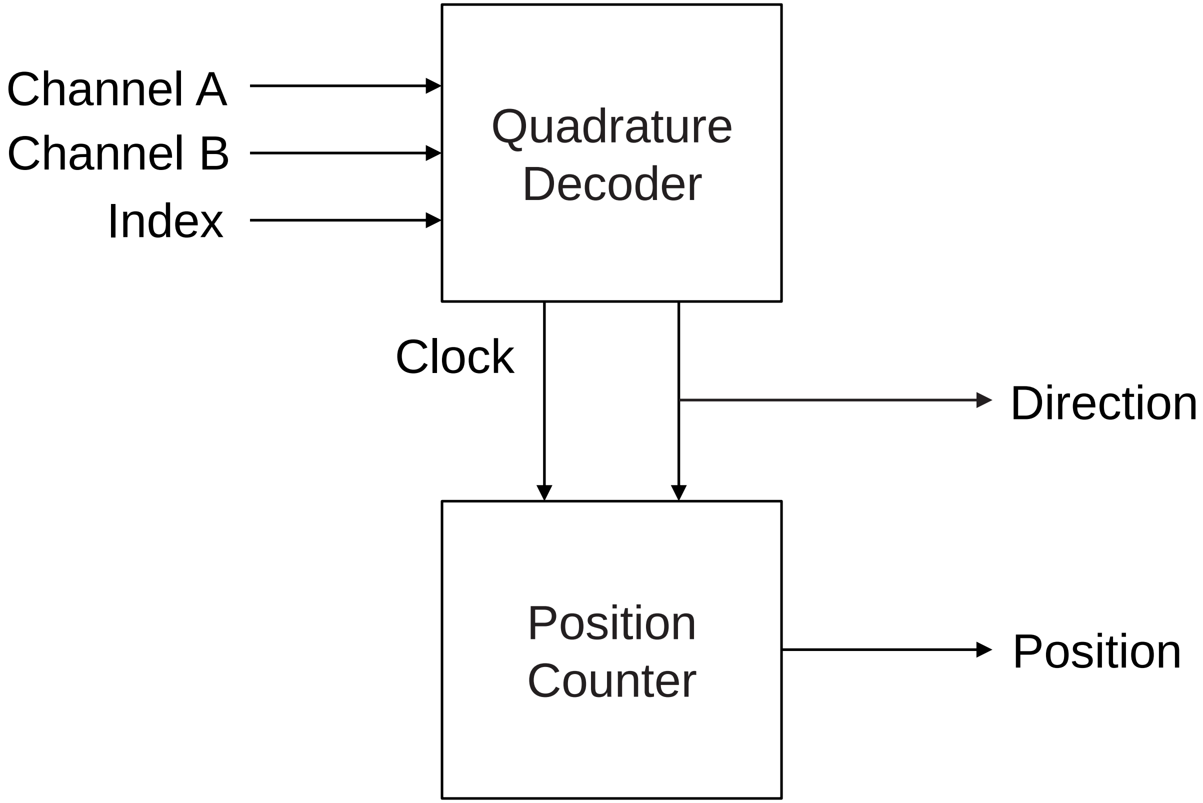




Decoding quadrature signals with timer module

- Decoding involves a **quadrature decoder** attached to a **position counter**
  - Quadrature signals decoded into **direction** and **clock** signals for position counter



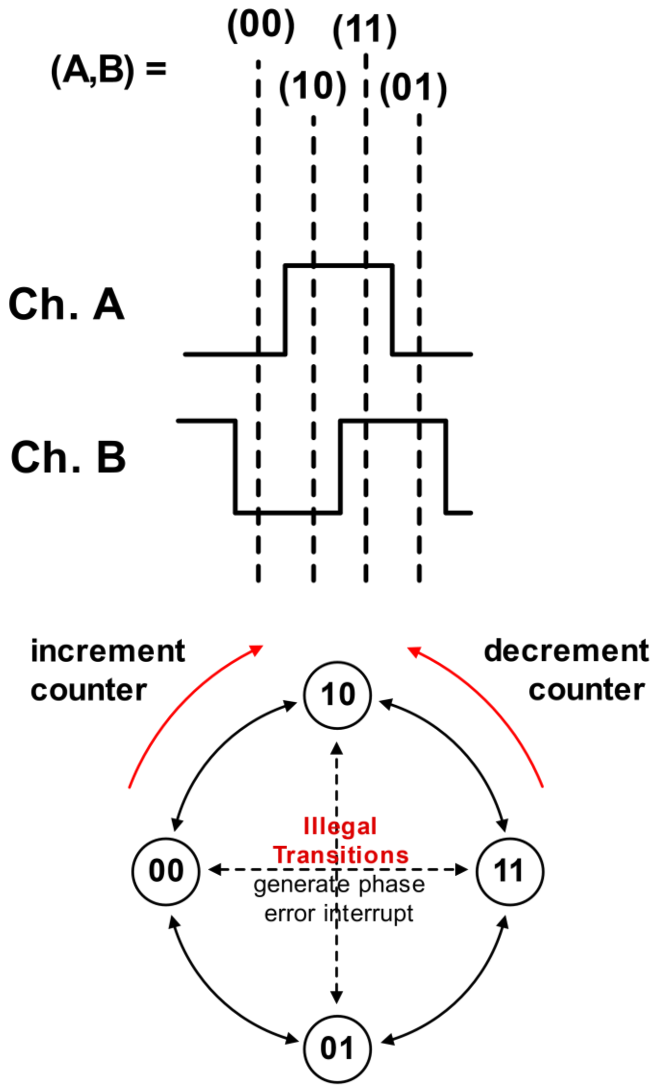


Quadrature decoder

- Motor movement information like **rotation direction**, **position** and **velocity** are decoded from the quadrature signals

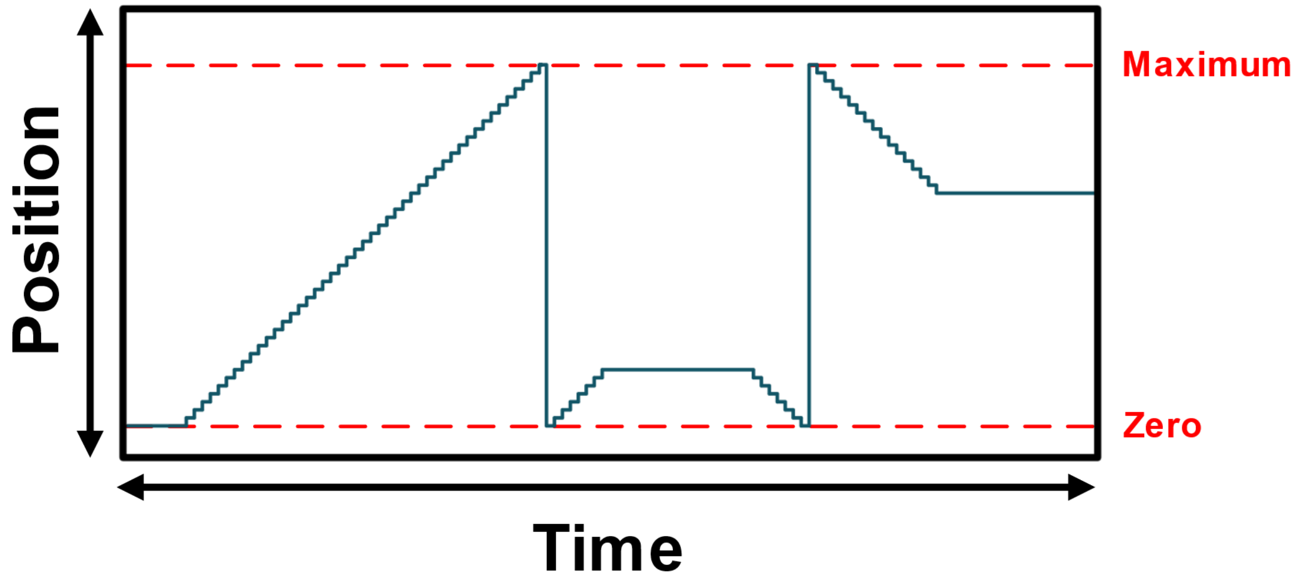
- A **state machine** determines the direction of motion
  - Clockwise movement = increment counter
  - Counter-clockwise movement = decrement counter
  - Illegal transition occurs when channels switch simultaneously

- **Quadrature clock** is sampled from the quadrature inputs
  - clocking can be 1x, 2x, or 4x the frequency of the quadrature inputs



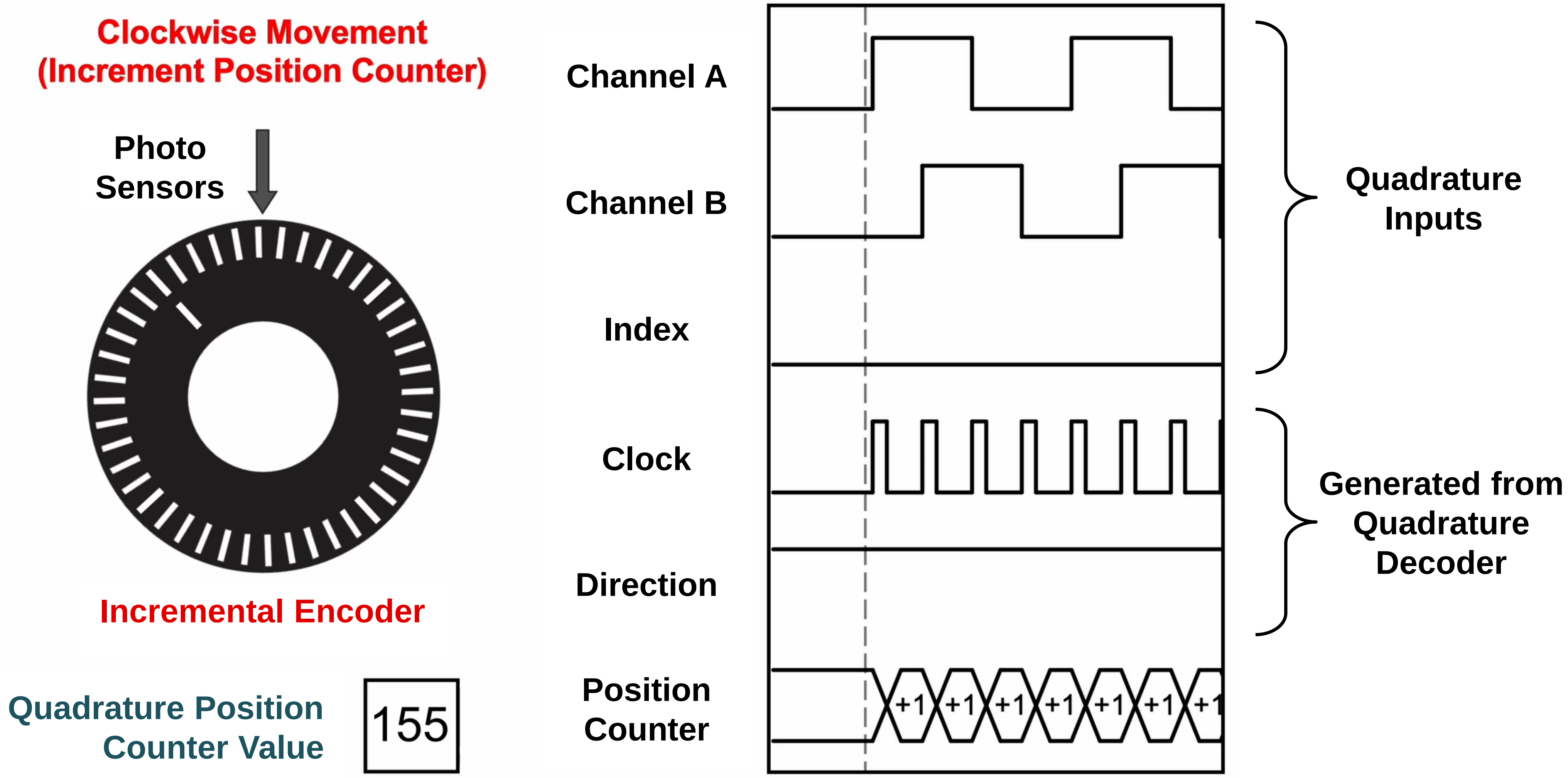
Position counter

- A position counter continuously tracks the current position of the motor encoder
  - The counter increments/decrements according to direction of motion
  - Increment/decrement occurs each pulse of the quadrature decoder clock



- Counter resets to zero when it increments past the maximum position
  - Position counter can be reset on index reference for position verification

Quadrature decoder & position counter in motion



Calculating motor speed

- The **speed/velocity** of the motor is **directly proportional** to the **frequency** of the quadrature waveforms
  - Faster rotation of a motor corresponds to high-frequency quadrature waveforms
- Speed is found using the following equation

$$v = \frac{f \times 60}{(encoder\ resolution)}$$

- Example) Suppose we have a 1000-slot encoder with quadrature signals pulsing at a constant 16.667 kHz. What is the speed of the motor (in RPM)?

$$v = \frac{16{,}667 \times 60}{1000}$$

$$v = 1{,}000.02$$

- Speed of the motor is approximately 1000 RPM

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