EE 316 - Electronic Design Project

Project:

Optic Angular Encoder

Group 3

First Project Report

19 March 2021

Objective

An encoder is an electromechanical feedback device used for providing information about count, position and direction in lots of application. The most common used type of encoder motion translation technology is optic.[1] An optical encoder has an electrical output in digital form according to the angular position of the input shaft. Optical encoders give us to a converted digital form from angular displacement. An optical encoder work as an angular position sensor.[2] One type of optical encoder is absolute encoder. According to the shaft rotation, absolute encoder display location and position information. For each increasing rotation, absolute encoder ensures a different bit. Because of that, absolute encoders are the best election for practices which certain locations to be known such as flood gate control, cranes, telescopes, industrial robotic or microelectronics.

Mechanically, Absolute encoder has a shaft coupled to an input driver. The ray of light which generated by LED and crossing through a transparent slit of the rotating disc with a radial opaque line is the main element of the optical increment encoder.

We observed sinusoidal wave result of sensor response to the light when the light crossed through opaque lines. This sinusoidal wave converted to square wave like series of low and high pulses. After that this signal transferred to the data processor. [1] For each shaft position, absolute encoder has a unique bit, this ensure that they can provide unique position information. In the event of a power loss, this also ensures absolute encoders an advantage works of rotation to an initial position. [3] In this work, our purpose to design an optical angular encoder and display the angle of light passing through the disc using by transimpedance amplifier, comparator operational amplifier and logic circuits.

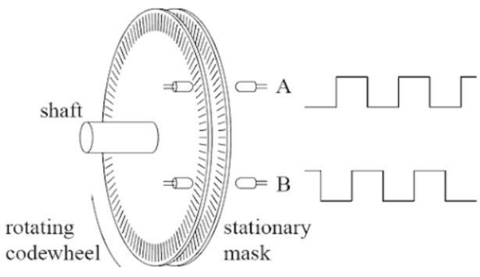

Figure 1
Absolute Encoder Working Principle [4]

Group Members

Korkut Emre Arslanturk: Objective and Analog-to-Digital Converter

Berke Eren: Light Source and Detection and Amplifier

Melek Tuğçe Çüçen: Quadrature Encoder Principles and Counting

1. Background Information

1.1 Quadrature Encoder Principles

A quadrature encoder is an encoder with two out-of-phase output channels that is used in many general automation applications to detect movement direction. It is also known as an incremental rotary encoder. The direction of motion is detected by the phase relationship of one channel leading or trailing the other channel, and each channel has a fixed number of evenly spaced pulses per revolution (PPR). Quadrature encoders are used in applications such as bidirectional position sensing and length measurement. [11]

The speed and position of a rotating shaft are measured by this encoder. Quadrature encoders may use a number of sensors, the most popular of which are optical and hall effect sensors. [12]

A quadrature encoder's code disk features two channels that are often referred to as Channel A and Channel B. As seen in the picture below, these tracks or channels are coded ninety electrical degrees out of phase.[11] A controller can determine the direction of travel in applications that involve direction sensing depending on the phase relationship between Channels A and B. As seen in the example optical encoder figure below, as the encoder rotates clockwise, the signal will display Channel A ahead of Channel B, and when the quadrature encoder is rotated counterclockwise, the reverse occurs. [11]

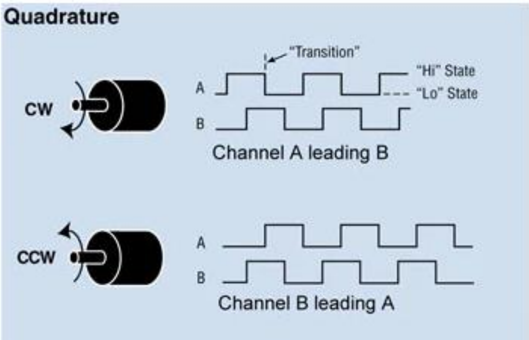

Figure 2.
Quadrature encoder working principle [11]

1.2 Light Source and Detection

Light-emitting diodes (LEDs) and laser diodes are two types of devices that are often used as light sources. In general, LEDs are less expensive and simpler to use than laser diodes, but they perform poorly. An LED's output varies from that of a laser diode since a laser diode can couple more light power to an optical fibre than an LED can, and an LED's spectral linewidth is much wider than that of a laser diode. The lower power coupling from an LED stems partially from the fact that LEDs emit less light power than laser diodes but also from the fact that LED light spreads out over a wider beam than laser diode light.[8]

Another case, The detector is a semiconductor device known as a photodiode which provides an electrical current output which is proportional to the intensity of light falling on it. Briefly, a device that detects an optical signal produced by a light source and propagated in an environment in an optical transmission system.

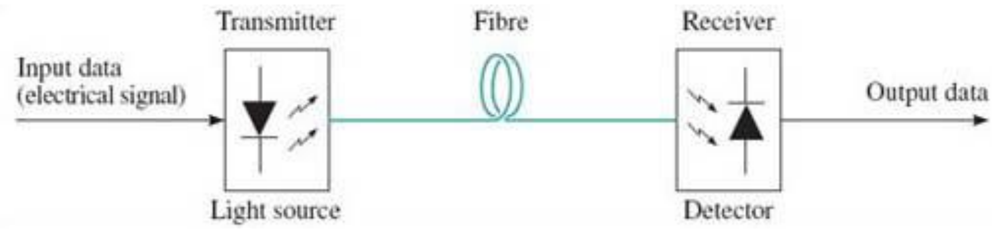

Figure 3: An optical-fibre link [8]

1.3 Amplifier

A trans-impedance amplifier is a circuit that converts an input current into an output voltage. The transimpedance amplifier generates an output voltage equal to an input current using an op-amp and a feedback resistor. Since the magnitude of the gain is proportional to the input resistance, the circuit's transfer function is inverted [9]

$$V_{OUT} = -I_{IN} \times R_F$$

A trans-impedance amplifier, like a resistor, converts current to voltage, but unlike a resistor, it has low input and output impedance, even at high gain.

The most important current signal measuring instrument for light sensing operations is a transimpedance amplifier.

There may be problems with interference and noise in the transimpedance circuit, so choosing the right amplifier increases the effect.

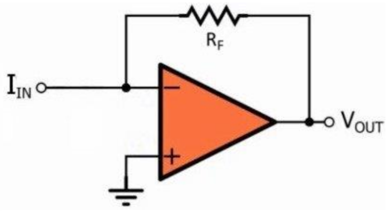

Figure 4:Trans-Amp [9]

1.4 Analog-to-Digital Converter

Many physical signals found in nature are analog signals. Analog signals are infinite in nature. Therefore, these signals are quite difficult to process or store. Digital signals, on the other hand, have no Infinity. For example, analog signals have an infinite number between 1 and 3, while digital signals have only '2'.[5] Analog to digital converter converts an analog signal to a digital representation. In other words, it transfers the signal in continuous time to discontinuous time. A small amount of error and noise may occur as a result of this conversion. This transform process is done periodically. [6]

Digital signals work in a binary way, while Analog signals work at a continuous and infinite number of voltages. In other words, digital signals only take the value '0' or '1'. Simply, an analog to digital converter takes a snapshot of the analog signal and generates the digital code that represents it. The number of bits used for this code depends on the quality of the ADC's resolution. [5]

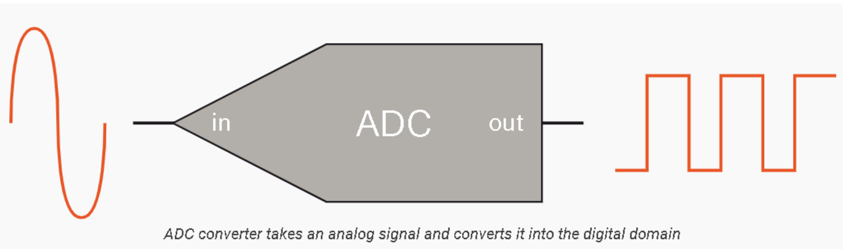

Figure 5: Analog to Digital Converter[5]

1.5 Counting

Counter is a device that keeps particular processes in memory and shows how many times particular operations occur in relationship to a clock. Sequential digital logic circuits are the most common type of counters. The binary or BCD number system is represented by the values on the output lines. Increasing or decreasing the number in the counter is done by applying to the clock input. Counters are a common component in digital circuits, and they are available as separate integrated circuits as well as parts of larger integrated circuits. [13]

Electronic counters may be classified as asynchronous (ripple) counters and synchronous counters. Each flip-flops in synchronous counters share a joint clock flip-flops are connected together and state is changed at the same time. On the other hand in asynchronous counter flip-flop has its own clock and the state is changed at different times. Up/down counters are an one type of synchronous counters. [13] Up/Down counters are also known as bidirectional counters. It can count in either direction over any given count sequence and can be reversed at any point in their count sequence by using the additional control input shown below. [14]

The circuit in Figure 6 is a simple 3-bit Up/Down synchronous counter that employs JK flip-flops programmed to act as toggle or T-type flip-flops to provide a maximum count of zero (000) to seven (111) and back to zero. [14]

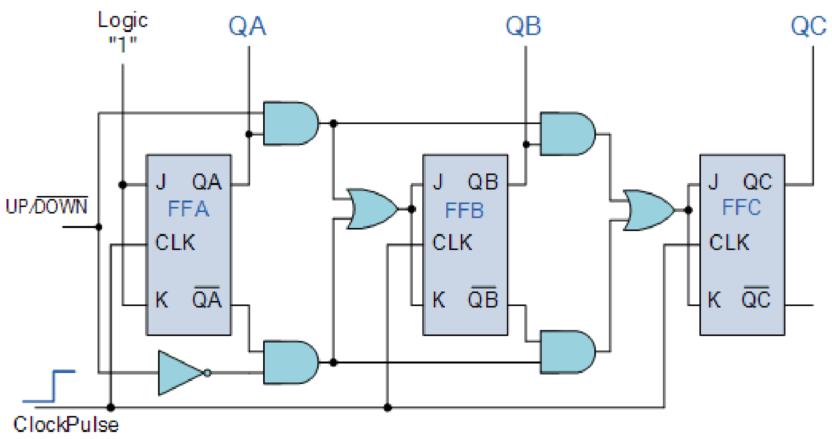

Figure 6: A 3-bit synchronous up/down counter using JK flip-flops[14]

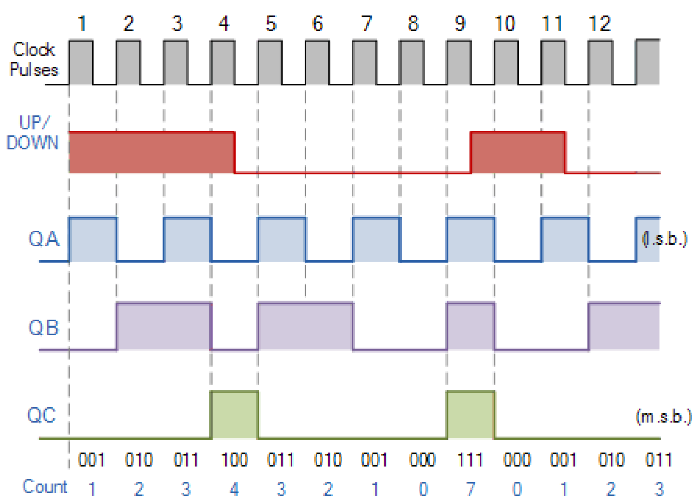

Figure 7: Synchronous 3 bit Up/Down Counter Waveform Timing Diagram [14]

2. Methods and Proposed Solutions

2.1 Overview

We use infrared light for photodiode and detectors to work compatible each other. We use two light sources to observe the direction. The photodiode is a source of current because of that we procure current when the light comes to the detectors. In order to move forward in a simpler way in the design and operations of the circuit, we need to convert this current to voltage. To ensure that the rest of the circuit and the equivalent resistance do not change, we perform the current-to-voltage conversion using transimpedance amplifier instead of connecting the resistance to the circuit. After this procedure, we will get a sinus wave. To make the counting process, we need to digitize this wave. This meaning is we need to convert sinus wave to square wave. We do this by using Comparator operational amplifier in a simpler way instead of using analog to digital converter because we only need one-bit information. After that, we perform counting and displaying with logic operations. We pay attention to the direction, the appearance of an increase or decrease, and the direction. On the other hand, when performing the counting operation, we increase other counters when counting forward and counting down, and we go to the result by subtracting these two from each other.

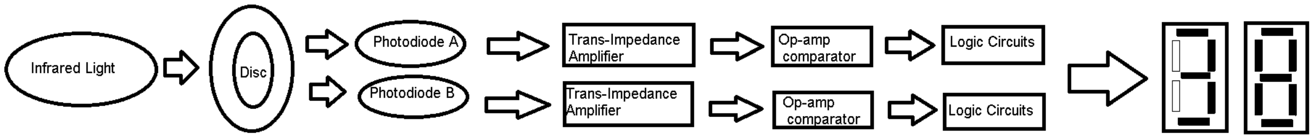

Figure 8: Block Diagram of Our Propose

2.2 Trans-Impedance Amplifier

Using the infrared BPV10NF photodetector to detect the light emitting from the light source, we will convert this light beam into current. The reason we chose this photodetector is the dark current is very low (1nA) [10], there will be little fluctuations in the current we obtain.

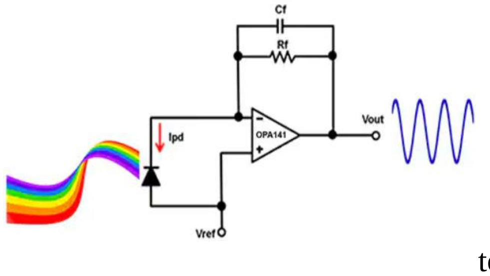

Figure 9: TransImpedance Amplifier[16]

We need to convert the electrical power to voltage source to use for analog digital converter. For this, we need to design a specific trans-impedance amplifier circuit. The Trans-Amp circuit is integrated that converts the current source to a voltage source.
We have obtained a voltage source of Vpeak. We connect a capacitor parallel to the feedback resistance to ensure stability at frequency.

2.3 Analog to Digital Converter

We get analog signal with output of the trans impedance amplifier. We have to digitalized it because we need to do digital operations for counting and displaying. At this stage, when converting our analog signal to a digital signal, we only need 1-bit information, so instead of using a complex converter, we can perform this process using comparator operational amplifier.

The comparator operational amplifier has two input voltage and 1 binary digital output voltage. Comparator operational amplifier compares two input voltages and we get an output accordingly that. [6]

We choose a reference voltage level for one input voltage. We get digital output according to comparing between reference voltage and trans-impedance amplifier output. Thanks to Hysteresis loop, we can clear the output from comparator from noise.

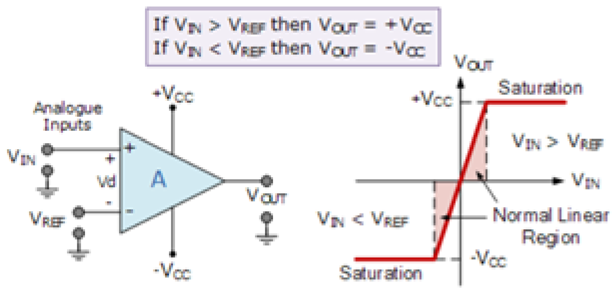

Figure 10: Analog to Digital Converter [6]

2.4 Counting and Displaying

Today's world, both up and down counters are built into a single integrated circuit (IC). 74HC190 4-bit BCD decade Up/Down counter, the 74F569 is a fully synchronous Up/Down binary counter and the CMOS 4029 4-bit Synchronous Up/Down counter are proper chips for our project. [14]

We use two 74HC190 4-bit BCD decade Up/Down counter to decide angular position as CW, CCW and to make a BCD subtractor circuit with these counters.

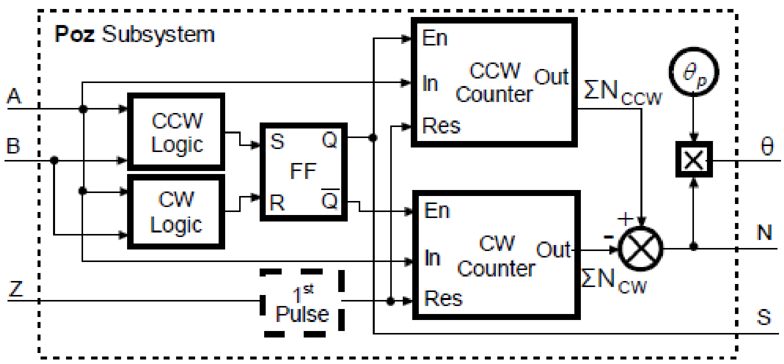

Figure 11: The simulation structure of the position computing subsystem [15]

For displaying part, we suggest to use two 7-Segment (IC-74xx47) displays. Our aim is by use this two 7 segment displays to obtain the output from counting and to show angle and sign.

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