Unclocked Quadrature Decoder

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Introduction

This app note will explain how to create an Unclocked Quadrature Decoder with a GreenPAK4 device. Quadrature Decoders translate signals received from Quadrature Encoders similar to the one shown in Figure 1. They are used in a mechanical system to determine rotation around an axis.

Since this Quadrature Decoder is unclocked, it will consume less power than a clocked version. The GreenPAK design shown in Section 2 of this App Note only includes digital components, so when the inputs are static the device has very low current consumption.

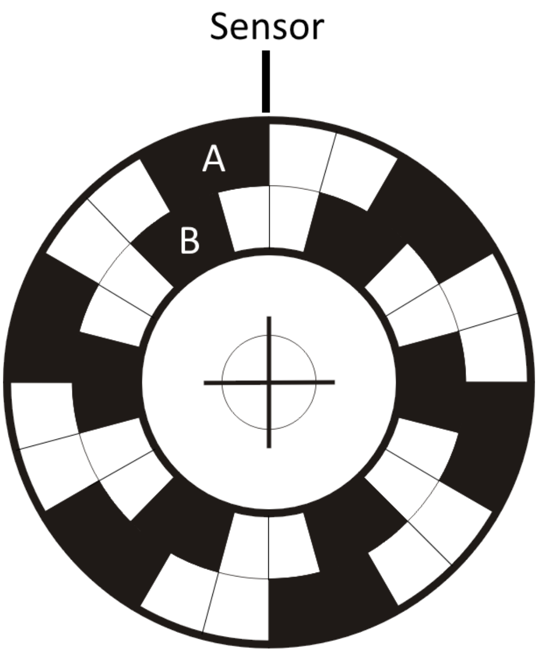

Figure 1. Quadrature Encoder

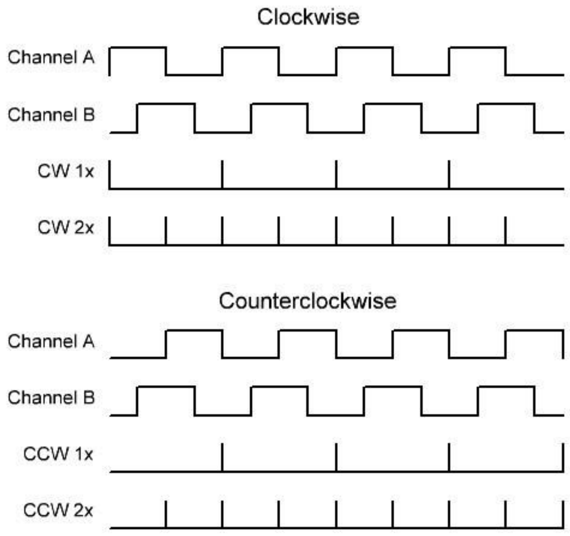

Figure 2. Quadrature signals

Quadrature Decoder

Think of the dial controller used in to control the volume in a digital radio. As you turn the dial clockwise and counterclockwise, you are able to increase and decrease the volume of the radio. Quadrature signals are used to interface between the dial rotation information and the radio's microcontroller.

Quadrature decoders generate two square waves, which are typically designated as Channel A and Channel B. These signals have a 90 degree phase difference as shown in Figure 2. The state transition outputs, or the rising and falling edges of Channel A, can be used to determine the degree of dial rotation or number of steps moved. In this application, there are two possible units of measurement: 1x and 2x.

Take a look back at Figure 1. When Channel A's rising edge leads Channel B, the rotation around the axis is in the clockwise direction. Alternately, when Channel B leads Channel A, the rotation occurs in the counterclockwise direction. In Figure 2, if you count the number of rising edges on Channel A in the clockwise direction, you can conclude that the axis moved by 4 steps. However, if you count both rising and falling edges of Channel A, the axis moved by 8 steps. The further the mechanical dial turns, the more pulses are generated.

Figure 3 illustrates the transitions and outputs for a Quadrature Decoder in a state machine format.

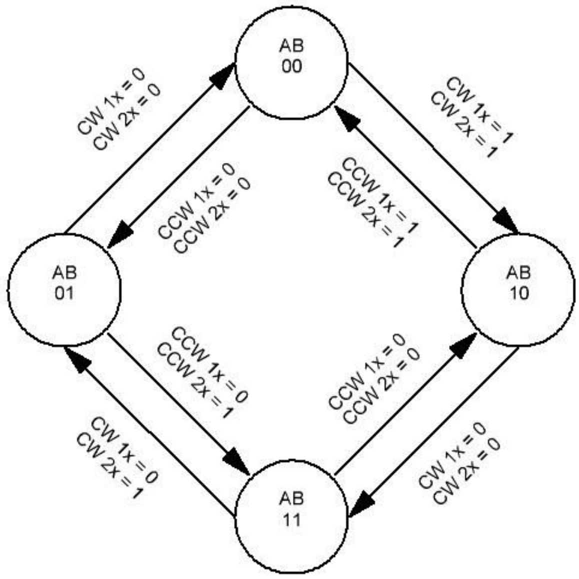

Figure 3. Quadrature Decoder State Machine

In this App Note we will design a system that receives three inputs and has two outputs. The first two inputs are the Channel A and Channel B quadrature signals, while the third input is a selector bit to control whether the outputs will be 1x or 2x as shown in Figure 2. One output indicates clockwise movement (CW) and the other counterclockwise movement (CCW).

GreenPAK Design

In order to create our output pulses, we need to look at state transitions. We used 2-L0 and 2-L1 to create a delayed version of the Channel A signal, and did the same thing with 2-L2 and 2-L3 for Channel B. This technique allows us to compare the previous state to the current state.

Input 1x/2x from Pin 2 is a selector bit used in Look-Up Tables 3-bit LUT4 and 3-bit LUT5 to determine whether the outputs should have 1x resolution or 2x resolution. When Pin 2 is LOW, the resolution is 1x. When it is HIGH, the resolution is 2x.

Figure 4 lists the conditions under which the four LUTs will go HIGH. These LUT outputs generate the bits which determine when the CW and CCW outputs will go HIGH. Each output is dependent on the signals A_DEL, B_DEL, A, and B. (A_DEL and B_DEL are the delayed A and B signals.)

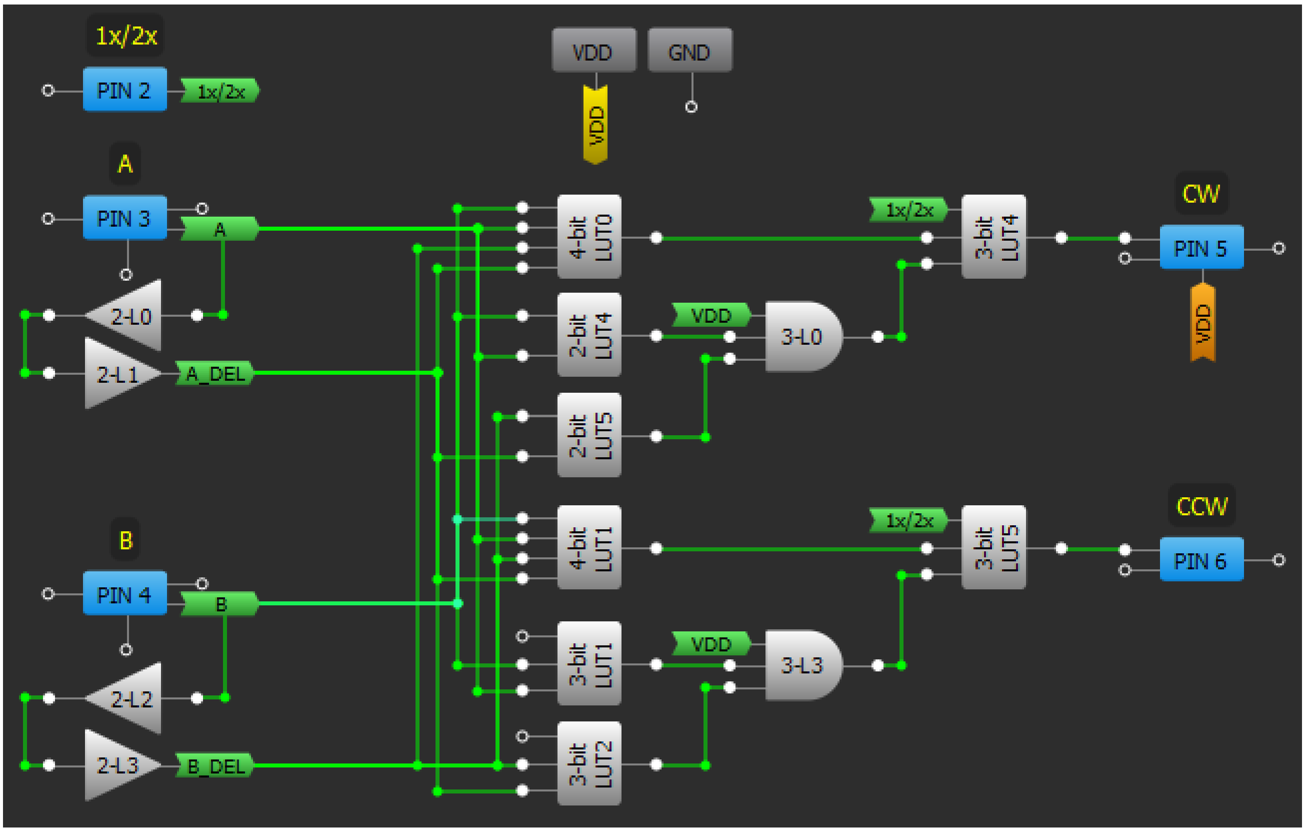

Figure 4. GreenPAK Designer File

LUT	A_DEL	B_DEL	A	B	OUTPUT
4-bit LUT0	1	1	0	1	CW 2x
3-bit LUT0	0	0	1	0	CW 1x
4-bit LUT1	0	1	1	1	CCW 2x
3-bit LUT3	1	0	0	0	CCW 1x

Table 1. LUT Inputs and Outputs

Waveforms

D0 – PIN#2 Input 1x/2x

D1 – PIN#3 Input A

D2 – PIN#4 Input B

D3 – PIN#5 Output CW

D4 – PIN#6 Output CCW

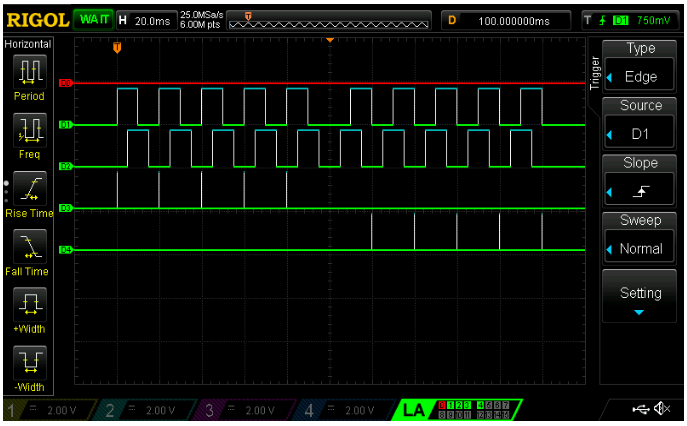

Figure 5. 1x Back and Forth Rotation

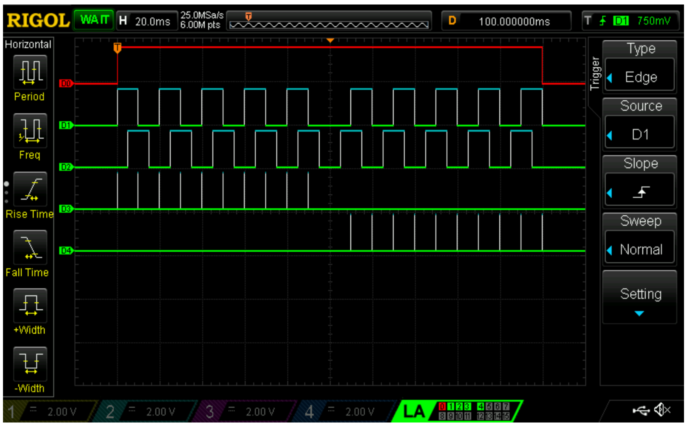

Figure 6. 2x Back and Forth Rotation

Figure 5 and Figure 6 illustrate back and forth rotation where Channel A and Channel B follow typical alternating patterns.

Since the 1x/2x signal stays low in Table 1, the output pulses occur once every period. With 1x/2x enabled in Figure 5, the output pulses occur twice per period.

Figure 7 and Figure 8 show what happens if the dial is moved back and forth over a very small degree of rotation.

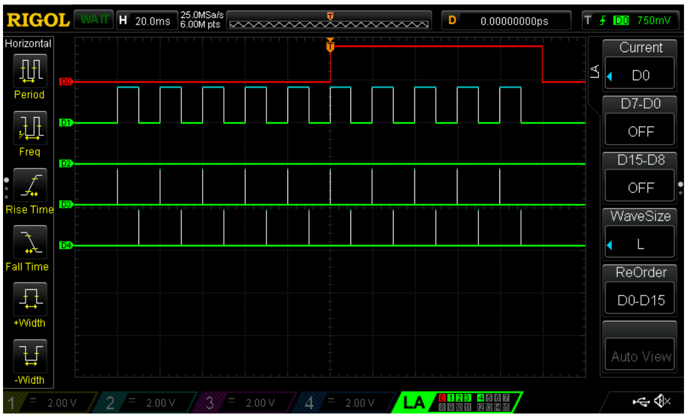

Figure 7. Small Degree Rotation Scenario 1

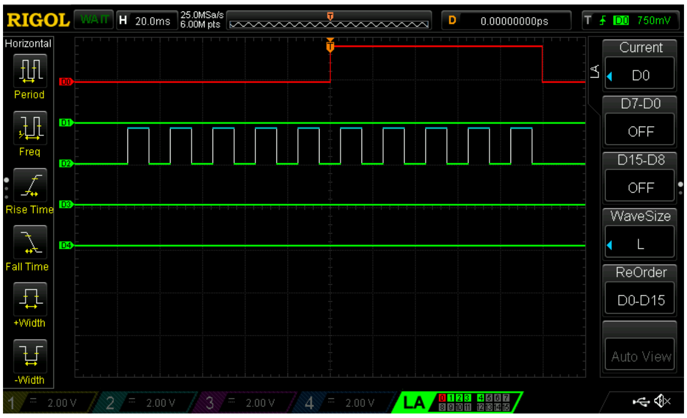

Figure 8. Small Degree Rotation Scenario 2

In both cases the CW and CCW rotations cancel each other out, leaving us with an equal number of pulses on each output.

Conclusion

In this App Note we explored using a GreenPAK4 device to create an Unclocked Quadrature Decoder with 1x and 2x resolution capabilities. This chip can be used to interface between a microcontroller and a rotating dial or axis. This Quadrature Decoder design is one of the many applications for which the GreenPAK platform can be used thanks to its high flexibility and configurability.

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