Concept Design Report

of Doppler Radar

Submitted by

Claudio Fisch and Diego Belusky

Module: Electronics Project 2

Lectures: Patrick Rennhard and Dr. Igor Matic

Date: 17.03.23

Abstract

As part of project module 4, this concept design report focuses on the development of a 24GHz Doppler radar system to measure the velocity of a moving object. Although the radar system in this project has many potential applications, the focus is set on measuring the velocity of a hockey puck. In the hardware section, a solution is presented with a block diagram, detailing the various components and processes involved. The software component is divided into three main parts: signal processing, velocity calculation, and user interface. A separate section briefly describes the user interface, highlighting its functionality and appearance. Overall, the report provides a concise overview of the key topics related to the development of a Doppler radar system.

Table of Contents

Requirements and Overall Concept

The overall objective is to design a Doppler radar system that can be used to measure the velocity of a moving object, such as a hockey puck. To achieve this, the system consists of a hardware and a software component. The hardware component includes a transmitting antenna, a receiving antenna, a signal generator, an amplifier, and a filter. While the transmitting antenna, receiving antenna, and signal generator are provided by the manufacturer, it is necessary to develop the remaining filter and amplifier circuit. Correspondingly, the software component involves a signal processing algorithm, a velocity calculation, and a user interface. These elements work together to process the radar signals and display the velocity of the moving object. Overall, the success of the Doppler radar system depends on the effective integration of both the hardware and software components.

The requirements for the radar system are as follows.

- Doppler radar to measure velocity of objects
- Determine if the target is moving toward or away from the device
- Measurement of puck speed up to 200km/h with an accuracy of ±0.3km/h
- User interface that displays the maximum velocity of the puck
- 3D-printed dielectric lens for focusing
- Provide connectivity to share data with other devices such as smartphones

Hardware Concept

In this section, the design of the hardware which includes a filter and amplifier circuit will be presented. In figure 1 on the very left there is a provided radar module K-LC5. This module generates an output I and Q, where I is an in-phase cosine signal containing the Doppler frequency and Q the same signal shifted by 90 degrees. In other words, the I channel contains the real part of the signal, and the Q channel contains the imaginary part. Regarding the goal of measuring puck speed up to 200km/h, a maximum Doppler frequency of 8895Hz and a minimum Doppler frequency of 445Hz was calculated. Because of that the incoming Doppler frequency will be in the range of 445 to 8895Hz and the hardware will be designed accordingly. The two analog signals will get processed by the same hardware components. First the DC part of the signal is removed by the high pass filter, because only the AC signal is needed for further processing. Then each signal is amplified by a factor of about 1000 and an upper and lower cutoff frequency is set by a bandpass filter. These cutoff frequencies are calculated from the minimum and maximum speed to be measured. Finally, the signals are passed to the ADC.

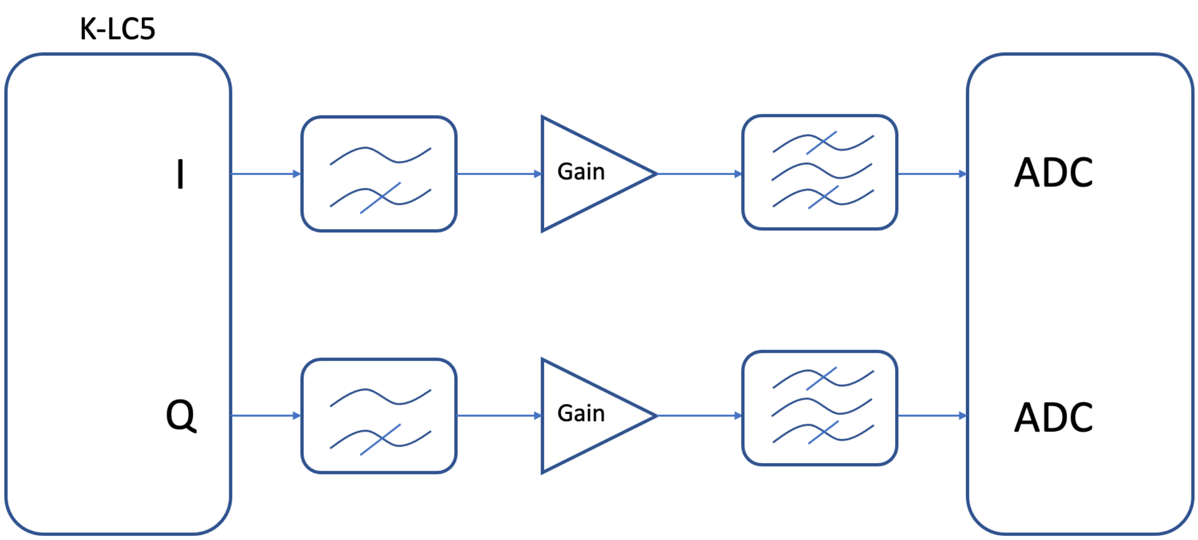

Figure 1: Block diagram

Microcontroller Software Concept

In this section, the software will be discussed. In specific, the signal processing, velocity calculation and the user interface. An overview of the signal progression is illustrated in figure 2. To calculate the velocity, the software performs a spectral analysis on a time-domain signal. Signal I and Q are added together which results in a complex valued signal. This result is going to be Fourier transformed using the fast Fourier transform. The “fftshift” function is then used to shift the zero-frequency component of the resulting Fourier transform to the center of the frequency spectrum. To find the Doppler frequency, it is necessary to find the maximum value in the shifted Fourier transform. After this, formula 1 can be used to determine the velocity, where f_d is the Doppler frequency and λ is the speed of light divided by the transmitting frequency.

$$f_d = \frac{2 \cdot v}{\lambda} \tag{1}$$

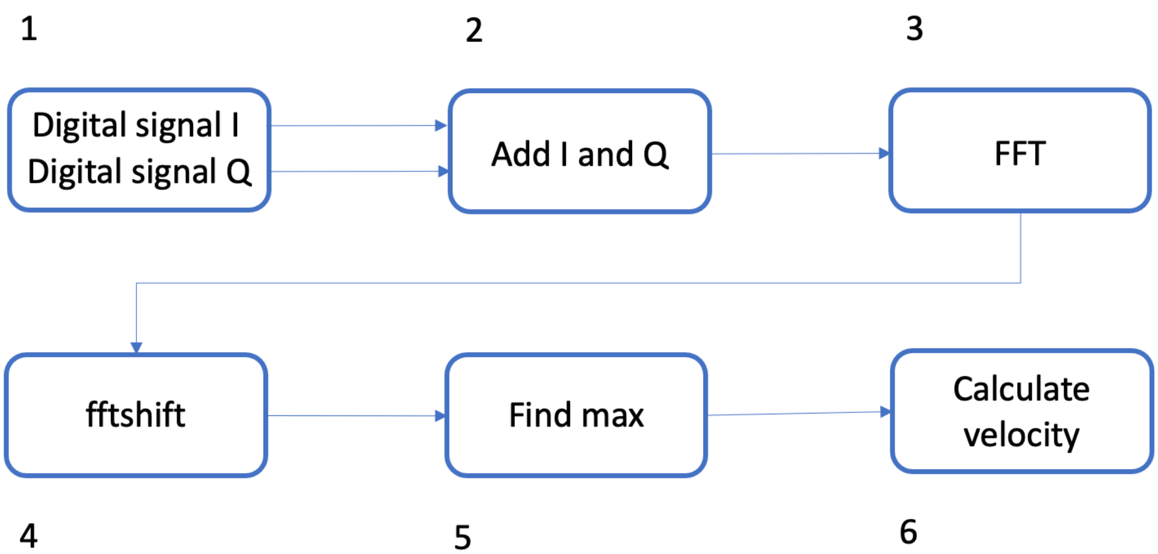

Figure 2: Software signal process

User Interface Concept

For the main application the user interface on the microcontroller will have a start button that initiates the measurement. After the measurement and the calculation are completed, the velocity will be displayed on the screen. Additionally, there is an option to export the data to an external device from which further analysis can be done. This is useful, if data wants to be stored for the purpose of tracking progress over time. To facilitate analysis of the stored data, an application is being developed on an external device.

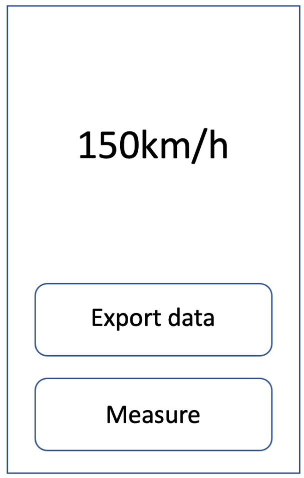

Figure 3: User Interface on the microcontroller

Additional Features

In addition to the basic function of measuring the speed of a puck and showing it on the display, the highest speed ever measured should also be visible as a high score. It is possible to display the last measurements on the edge of the display for a better overview of the measurement history. Also, it shall be possible to transfer measured values to external devices via Bluetooth or cable. Then different software applications can be implemented and the possibilities for processing the data are open.

As a hardware extension a dielectric lens could be attached to the device which has an influence on the focusing of the radar to optimize the measurement setup.

Conclusion

The goal is to develop a 24GHz Doppler radar system that can measure the speed of a hockey puck and output it on the display. Signals from the provided Doppler radar module K-LC5 need to be filtered and amplified for further processing which is done by the hardware part of the system. Then the signals are transferred to the ADC of a microcontroller where the digital processing of the signals is continued by an implemented firmware. As mentioned above, the system can be extended with any additional functions. For example, the transfer of measured values to external devices via Bluetooth or cable.