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Automatic Motion Detection and Distance Measure Using Doppler Radar

G. Viswanath[1], A. Mounika[2], P. Naga Lakshmi[3], E. Ramesh[4]
[1]Madanapalle Institute of Technology and Science, JNTU_A, India, 20695A0428@mits.ac.in
[2]Madanapalle Institute of Technology and Science, JNTU_A, India, 20695A0411@mits.ac.in
[3]Madanapalle Institute of Technology and Science, JNTU_A, India, 19691A04B5@mits.ac.in
[3]Madanapalle Institute of Technology and Science, JNTU_A, India, rameshe@mits.ac.in

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ABSTRACT

The proposed device is a versatile and multi-functional system that uses an HB100 Doppler radar sensor and Arduino microcontroller to detect motion, measure velocity, and distance. The device is capable of detecting motion in real-time, measuring the velocity of the object, and calculating the distance between the object and the sensor.

The HB100 Doppler radar sensor emits a microwave signal that reflects off the object and returns to the sensor. By analyzing the changes in frequency of the reflected signal, the radar can determine the speed and direction of the object. The sensor is connected to an Arduino microcontroller, which receives the digital signal from the sensor and processes it to determine the presence, velocity, and distance of the object.

The proposed device offers several benefits, including increased accuracy and efficiency compared to other motion detection systems. The device can be used in a variety of applications, such as security systems, traffic monitoring systems, and industrial automation. The device's ability to detect motion, measure velocity, and calculate distance can also be used to monitor and analyze data for further applications.

Key words : Motion, Doppler, Radar, Microcontroler

1. INTRODUCTION

Automatic motion detection and measuring distance and velocity are essential components of various applications, such as security systems, traffic monitoring systems, and industrial automation.[1] The use of Doppler radar sensors has become increasingly popular due to their ability to detect motion and determine the velocity and distance of an object.[1,2] The HB100 Doppler radar sensor is a popular sensor in this category.

This paper proposes a versatile and multi-functional device that uses an HB100 Doppler radar sensor and Arduino microcontroller to automatically detect motion, measure velocity, and distance. The proposed device is designed to detect motion in real-time and provides accurate measurements of velocity and distance of the object. The device can be used in a wide range of applications, including security systems, traffic monitoring systems, and industrial automation.

The proposed device offers several advantages over other motion detection systems. Firstly, it is more accurate and efficient compared to other systems. Secondly, the device's ability to measure velocity and distance provides more information about the detected object, allowing for a more comprehensive analysis of the data. Lastly, the device is versatile and can be used in a wide range of applications, making it a valuable tool for many industries.

1.1 Doppler Principle

When a microwave signal is emitted from a source and travels through space, its frequency remains constant.[6] However, when the signal is reflected off a moving object, the frequency of the reflected signal is shifted due to the Doppler effect (Figure 1). If the object is moving towards the source of the signal, the frequency of the reflected signal will be higher than the original frequency.[7] If the object is moving away from the source, the frequency of the reflected signal will be lower than the original frequency.

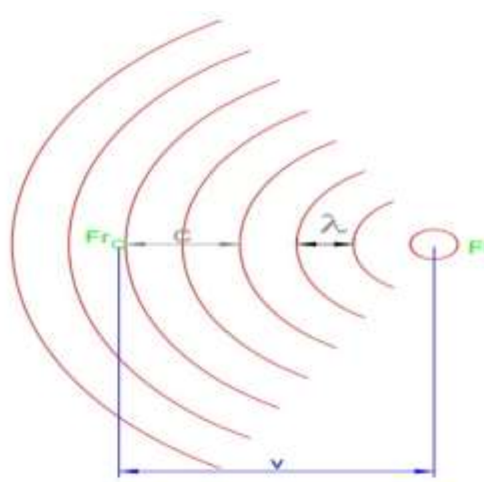

Figure 1: Classical Doppler Effect

This change in frequency is directly proportional to the velocity of the object, as well as the frequency of the original signal (Figure 2). The Doppler shift in microwave signals is commonly used in radar systems, such as the HB100 Doppler radar sensor, to detect the velocity and direction of moving objects. [4]

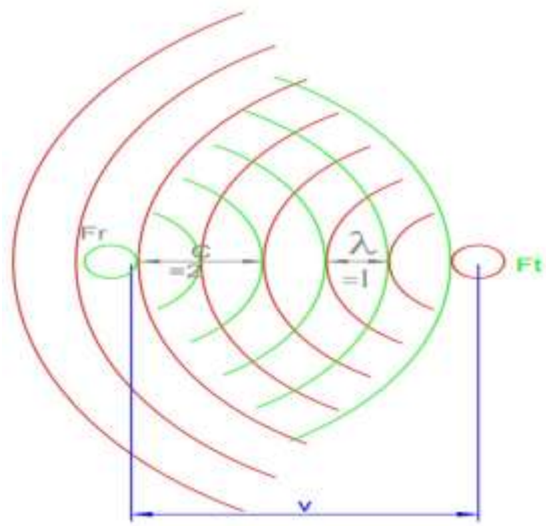

Figure 2: Classical Doppler Effect

$$f' = f (c + vr) / (c + vs)$$

where f is the frequency of the wave emitted by the source, f' is the observed frequency of the wave, c is the speed of light, vr is the radial velocity of the object relative to the source (positive if the object is moving towards the source), and vs is the velocity of the source relative to the medium.
If the object is moving towards the source (vr > 0), then the observed frequency f' will be higher than the emitted frequency f. Conversely, if the object is moving away from the source (vr < 0), then the observed frequency f' will be lower than the emitted frequency f.[3,5]
In the case of the HB100 Doppler radar sensor, the frequency shift of the reflected waves is used to calculate the velocity of a moving object. By measuring the frequency shift, the radial velocity of the object relative to the sensor can be determined, which can then be used to calculate the object's speed and direction of movement.

2. HB100 DOPPLER RADAR

HB series of microwave motion sensor module are X-Band Mono-state DRO Doppler transceiver front-end module. These modules are designed for movement detection, like intruder almost occupancy modules and other innovative ideas.
The module consists of Dielectric Resonator Oscillator (DRO), microwave mixer and patch antenna.[11]

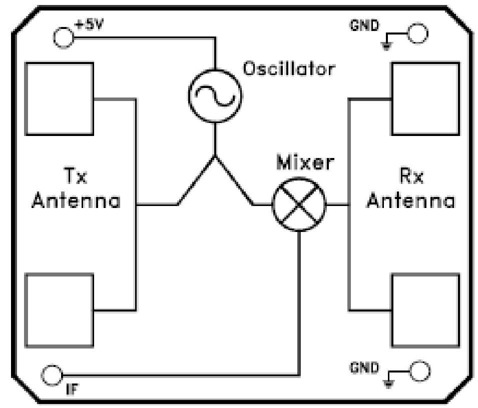

Figure 3: HB100 outline diagram

The HB 100 sensor (Figure 3) required a 5v supply is directly driven to oscillator, which generates 10.5GHz frequency. These microwave frequencies transmitted through two patch transmitting antenna. The Receiving patch antennas detects the reflected microwave signal. The received signal is fed to a mixer. This mixer compares the received frequency signal with oscillator signal frequency and generates an Intermediate frequency signal at output.

2.1 Mixer

A mixer (Figure 4) is an electronic device that is commonly used in radio frequency (RF) and microwave systems to combine two or more input signals to produce an output signal. The output signal of the mixer is usually the sum and difference frequencies of the input signals.
In the case of the HB100 Doppler radar module, the mixer is used to combine the incoming microwave signal with a local oscillator signal.[13] The local oscillator signal is usually generated by a crystal oscillator or other stable frequency source.
The mixer is a non-linear device, which means that its output signal contains a combination of frequencies that are not present in either of the input signals. When the mixer combines the incoming microwave signal with the local oscillator signal, it produces an output signal that contains both the sum and the difference frequencies of the input signals. [12] The frequency of the output signal depends on the frequency of the incoming microwave signal and the frequency of the local oscillator signal.
The frequency of the local oscillator signal is carefully selected so that it is slightly different from the frequency of the transmitted signal.[13] This frequency difference creates a beat frequency between the incoming signal and the local oscillator signal, which is proportional to the Doppler shift caused by any moving objects in the sensor's range.

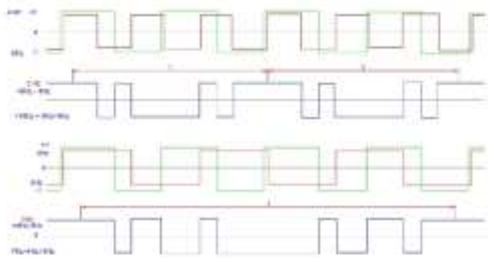

Figure 4 : Frequency Mixer Process

3. LIMPKIN'S AMPLIFIER

Limpkin amplifier is a low noise amplifier (LNA) (Figure 5) The primary function of an LNA is to amplify very weak signals, while adding as little noise as possible to the signal. In radar systems, an LNA is often used to amplify the received signal from the radar sensor before it is processed and analyzed.
This limpkin amplifier classified into some types:
First Order Limpkin's Amplifier: This is a basic version of the Limpkin's amplifier with only one operational amplifier.[7] It provides a gain of around 100 and is suitable for low-frequency signals.
Second Order Limpkin's Amplifier: This variation includes two operational amplifiers and provides a higher gain of around 10,000. It's ideal for signals with higher frequencies.
Third Order Limpkin's Amplifier: This is the most complex variation of the Limpkin's amplifier and includes three operational amplifiers.[7] It provides a gain of up to 1,000,000 and is suitable for high-frequency signals.
The modifications made to the original Limpkin's amplifier circuit can vary depending on the specific application and requirements. [7,8] The modified Limpkin's amplifier can include additional components such as filters, mixers, and oscillators to improve its performance in specific applications.

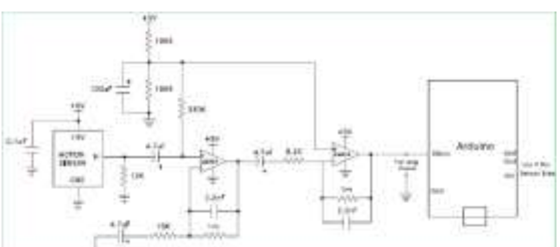

Figure 5: Proposed System Circuit Model

The IF output is fed to Limpkin's amplifier, it consists of second ordered op-amp gain amplifier and a comparator at end. In first stage the IF is given to non-inverting amplifier.[15] Here we setup a 4.7uf used for DC coupling for IF input. We used 10k resistor as Ri and 1M resistor as Rf which gives 100 times gain for if frequency. The Intermediate Frequency has 10mV source signal which present in 50mV noise signal. So we are filter out the noise with voltage divider network. For second stage also doing the same process, but hare the amplifier is connected in Inverting configuration. Here also the gain is 100 times.[7,6] Then the resultant signal is given to a comparator which generates a PWM signal based on frequency variation.

4. FreqMeasure

The FreqMeasure library is an Arduino library that allows you to measure the frequency of an input signal. It is particularly useful for applications that require accurate frequency measurements, such as in the fields of communications, electronics, and physics. [9,4]
The library works by measuring the time between two consecutive rising edges (or falling edges) of an input signal. It uses an interrupt-based approach to ensure that the measurements are accurate and reliable, even in noisy environments. The library supports a wide range of input frequencies, from a few hertz up to several megahertz.
To use the FreqMeasure library, you first need to initialize it by calling the FreqMeasure.begin() function in your setup code.[14] This sets up the interrupt service routine (ISR) that will be used to measure the frequency. You then need to attach your input signal to one of the Arduino's digital input pins, and call the FreqMeasure.available() function in your main loop to check if a new frequency measurement is available.
When a new measurement is available, you can retrieve the frequency value by calling the FreqMeasure.read() function. This returns the frequency in hertz (Hz), which you can then use for further processing.
One of the key advantages of the FreqMeasure library is its high accuracy.[14] It can measure frequencies with an accuracy of up to 0.1 Hz, depending on the input frequency and the Arduino board being used. This level of accuracy makes it well-suited for applications that require precise frequency measurements, such as in the calibration of electronic equipment or the measurement of physical phenomena.
Another advantage of the FreqMeasure library is its simplicity.[8] It is easy to use and requires only a few lines of code to get started. This makes it accessible to beginners and experienced users alike.
In addition to measuring frequency, the FreqMeasure library also supports measurement of the duty cycle of an input signal. This can be useful for applications that require precise control of pulse-width modulation (PWM) signals, such as in motor control or LED lighting.[9]
The library is also highly customizable. You can adjust the measurement range and resolution by changing the values of several configuration parameters, such as the number of samples per measurement and the timer prescaler. This allows you to optimize the library for your specific application requirements.[13]
The FreqMeasure library is open-source software, which means that the source code is freely available for anyone to use, modify, and distribute. This makes it a popular choice among the Arduino community, who have contributed to its development and improvement over time.

5. CONCLUSION

In conclusion, the project of automatic motion detection and velocity measurement using the HB100 Doppler radar, Limpkin amplifier, and FreqMeasure library is a valuable contribution to the field of motion detection and measurement. The combination of these components provides an efficient and accurate method for detecting motion, measuring velocity, and calculating distance. The HB100 Doppler radar, with its ability to detect the motion of objects based on the Doppler effect, serves as the main component for the system. The Limpkin amplifier, which converts the IF signal to a PWM signal, plays a crucial role in ensuring that the system is capable of accurately detecting motion and measuring velocity. Finally, the FreqMeasure library used with the Arduino Uno provides a simple and effective method for processing the PWM signal and calculating the motion and velocity of the object.

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