Design And Analysis Of Doppler Radar-Based Vehicle Speed Detection

Su Myat Paing, Su Su Yi Mon, Hla Myo Tun

Abstract: The most unwanted thing to happen to a road user is road accident. Most of the fatal accidents occur due to over speeding. Faster vehicles are more prone to accident than the slower one. Among the various methods for detecting speed of the vehicle, object detection systems based on Radar have been replaced for about a century for various purposes like detection of aircrafts, spacecraft, ships, navigation, reading weather formations and terrain mapping. The essential feature in adaptive vehicle activated sign systems is the accurate measurement of a vehicle's velocity. The velocities of the vehicles are acquired from a continuous wave Doppler radar. A very low amount of power is consumed in this system and only batteries can use to operate. The system works on the principle of Doppler Effect by detecting the Doppler shift in microwaves reflected from a moving object. Since, the output of the sensor is sinusoidal wave with very small amplitude and needs to be amplified with the help of the amplifier before further processing. The purpose to calculate and display the speed on LCD is performed by the microcontroller.

Keywords: CW Doppler Radar, Doppler Effect, Doppler Shift, Microcontroller, Amplifier.

I. INTRODUCTION

Radar stands for radio detection and ranging. It operates by radiating electromagnetic waves and detecting the echo returned from the target. Although radar cannot reorganize the collar of the object and resolve the detailed features of the target like the human eye, it can see through darkness, fog and rain, and over a much longer range. This system uses HB series of microwave motion sensor module are X-Band Mono-static DRO Doppler transceiver front-end module(HB100). These modules are designed for movement detection, like intruder alarms, occupancy modules and other innovative ideas. The module can detect the distance within 20m and its transmitted frequency is 10.525GHz. It consists of Dielectric Resonator Oscillator (DRO), microwave mixer and path antenna. The oscillator is used to produce a sinusoidal wave of frequency 10.525GHz, patch antenna connected to the oscillator radiates the wave towards the target and the reflected wave is received by another set of patch antenna. The mixer mixes these two signals to generate a sinusoidal wave with frequency equal to the difference between the two signals. Figure 1 shows the internal structure of HB100.

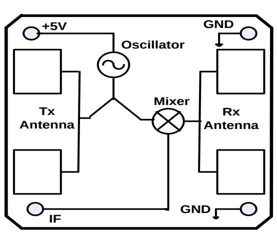

Figure 1: *Internal structure of HB100*

II. SYSTEM DESCRIPTION

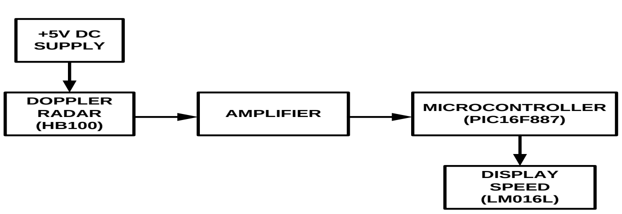

Figure 2: *General Block Diagram of the System*

The overall system configuration is shown in Figure 2. There are two main sections in this system: (1) an amplification circuit, and (2) a frequency counter and speed display. The Doppler radar transmits the frequency of 10.525GHz to the vehicle. It reflects back some portion of the transmitted signal with a shift in the frequency. Since, the output voltage of the sensor is in small dc value. So, it needs to amplify with the help of the amplifier circuit. The output of the amplifier is fed to the microcontroller. The microcontroller performs the tasks of calculation of frequency, calculation of speed and displays them on the LCD.

III. DESIGN PROCEDURE

(1) Amplification Circuit

3The output of the sensor is in the audio frequency range and small dc value. So, an audio amplifier with low pass active filter is desired for the design to meet this requirement. The complete diagram of the amplifier circuit used is shown in Figure 3. LM324 Quad op-amp is the amplifier IC used for this purpose as the output gets nearly 4.5V which is enough to drive the microcontroller.

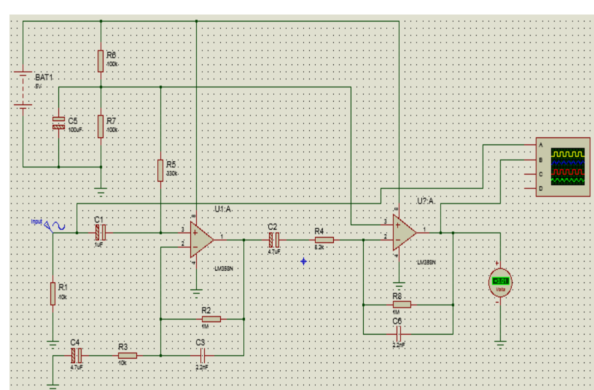

Figure 3: *Circuit Diagram of the Amplifier using LM358N*

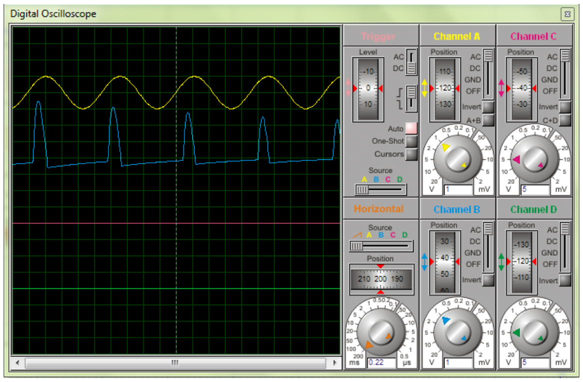

Figure 4: *Output Waveform of the amplifier using LM358N*

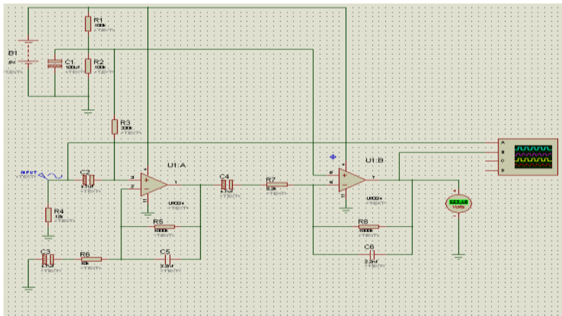

Figure 5: *Circuit Diagram of the Amplifier using LM324*

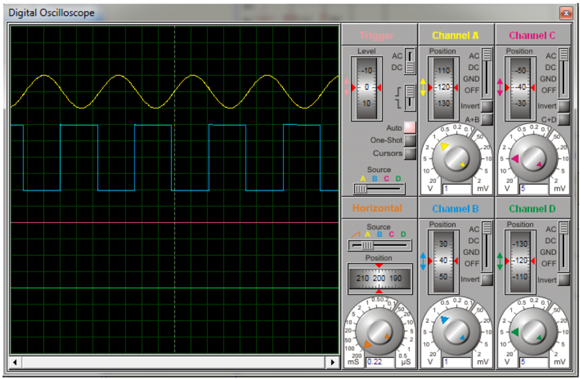

Figure 6: *Output Waveform of the amplifier using LM324*

To minimize the effect of the noise, the amplification is achieved in two stages. The first stage is configured as non-inverting amplifier. Since the output of the sensor is a small dc value (0.01 to 0.2Vdc), AC coupling of the output is necessary. The output of the first stage is a sinusoidal signal with a small dc offset. The dc component at the output is filtered by the capacitor at the output terminal. The second stage is configured as inverting amplifier. The 2.2nF capacitor in the feedback path of the amplifier makes this configuration an active low pass filter. The high frequency noises are filtered and the accuracy of the system is improved. The two stages are cascaded to achieve the overall gain of the amplifier. The second stage acts as a comparator and the output produced is a digital waveform that can be sensed by the digital pin of a microcontroller.

Design Calculation of Amplifier Circuit to drive the Microcontroller To use LM324 op-amp as driver, it is selected 5V as V_{cc}. For cascaded stages, V_{bias} for each stage must be 2.5V.

$$V_{bias} = \frac{R_2}{R_1 + R_2}.V_{cc}$$

$$2.5V = \frac{R_2}{R_1 + R_2}.5V$$

$$\frac{R_2}{R_1 + R_2} = \frac{1}{2}$$

Therefor , $R_1 = R_2 = 100\text{k}\Omega$ is selected.

For minimum error due to inupt bias current, it must be reduced to nearly 0.01mA.

$$I_{bias} = \frac{V_{bias}}{R_3}$$

$$R_3 = \frac{2.5V}{0.01mA} = 250\text{k}\Omega$$

Therefore, standard value $330\text{k}\Omega$ is selected for R_3.

For First Stage (Amplification)

Since the output of the sensor is a small dc value, it must be amplified at least 100 times to drive the microcontroller.

$\therefore$ Assume $A_{v1} = 100$

For non-inverting amplification,

$$A_{v1} = 1 + \frac{R_{f1}}{R_{in1}}$$

From the data sheet of LM324, R_{in1}=10kΩ is selected to achieve output voltage about 5V.

$$100 = 1 + \frac{R_{f1}}{10k}$$

$$R_{f1} = 99 \text{ x } 10k = 990\text{k}\Omega \cong 1\text{M}\Omega$$

$\therefore R_{f1} = R_{f2} = 1\text{M}\Omega$ is selected for both stages.

For AC coupling amplification, $C_{in} = 4.7\mu F$ is convenient with $R_{in} = 10\text{k}\Omega$.

$\therefore C_{in1} = C_{in2} = 4.7\mu F$ is selected for both stages.

For Second Stage (low-pass filter)

$$f_c = \frac{1}{2\pi R_{in2} C_{in2}}$$

$$4Hz = \frac{1}{2\pi R_{in2}(4.7\mu F)}$$

$\therefore R_{in2} \cong 8.4\text{k}\Omega$

Therefore, standard value $8.2\text{k}\Omega$ is selected for R_{in2}.

(2) Frequency Counter and Speed Display

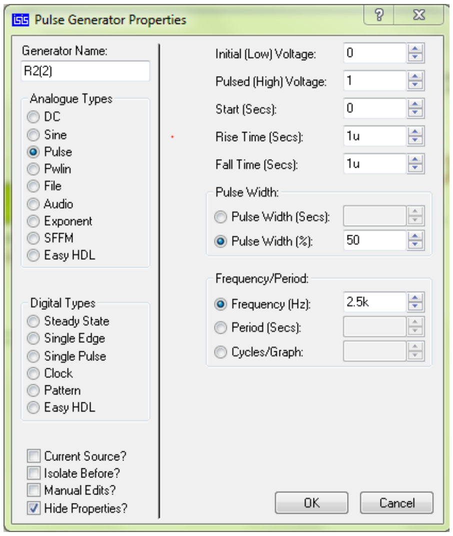

Figure 6: *Pulse Generator Properties window (adding the frequency with 2.5kHz)*

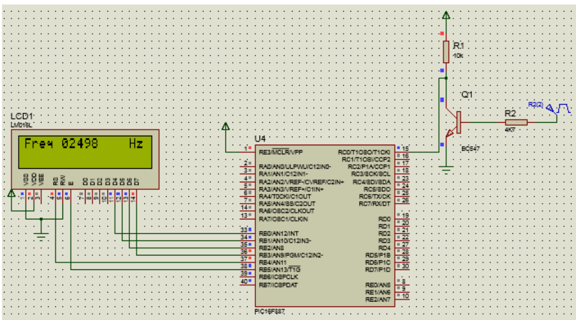

Figure 7: *Simulation of the frequency counter after running*

Frequency of the signal is the factor representing the speed of the moving object. So, the frequency of the incoming pulse from the amplifier is measured by connecting the output of the amplifier to the timer1 clock input pin of PIC16F887. The corresponding pin in PIC16F887 is pin 15. When used with an internal clock source, the module is a timer. When used with an external clock source, the module can be used as either a timer or counter. In this paper, it is operated as an external clock source. When counting, Timer1 is incremented on the rising edge of the external clock input T1CKI. In addition, the Counter mode clock can be synchronized to the microcontroller system clock or run asynchronously. In Counter mode, a falling edge must be registered by the counter prior to the first incrementing rising edge after one or more of the following conditions:

- Timer1 is enabled after POR or BOR Reset
- A write to TMR1H or TMR1L
- T1CKI is high when Timer1 is disabled and when Timer1 is reenabled T1CKI is low.

The frequency of the input signal can be obtained from counted value and the clock of the counter. A number of such measurements can be taken and averaged for better accuracy.

Relation Between Frequency and Speed

$$\Delta f = f_r - f_o \text{............Eq:(1)}$$

$$\lambda = \frac{c}{f_o} \text{...............Eq:(2)}$$

$$\Delta f = \frac{2v}{\lambda} \text{...............Eq:(3)}$$

where; Δf = Doppler shift
f_r = received frequency
f_o = transmitted frequency
λ = wavelength of transmitted wave
c = speed of light
v = speed of the vehicle

For $\Delta f = 2.5\text{kHz}$,

$$\lambda = \frac{c}{f_o} = \frac{3\text{x}10^8 \text{ms}^{-1}}{10.525\text{x}10^9 \text{cycles/s}} = 0.0285\text{m}$$

$$\Delta f = \frac{2v}{\lambda}$$

$$2.5\text{kcycles/s} = \frac{2v}{0.0285\text{m}}$$

$$v = 128250\text{mph}$$

$$= 128.25\text{kmph}$$

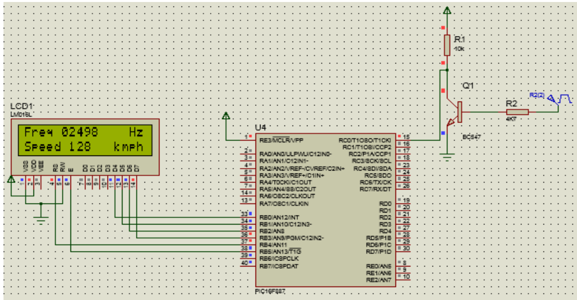

Figure 8: *Simulation for the speed display*

The speed is calculated by writing the equation of the relation between frequency and speed in the existing program.

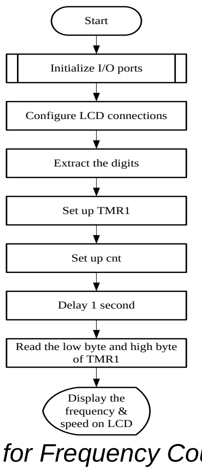

Figure 9: *Flow Chart for Frequency Counter and Speed Display*

IV. CONCLUSION

In this paper, a low cost and efficient embedded vehicular speed detecting system is presented. The work aimed at implementing the better results by comparing the existing methods such as FFT, DSP and LASAR based techniques. The output was more accurate with no other moving objects in the surrounding. In reality, the radar will not measure the actual velocity when the vehicle is not travelling directly towards the radar and slightly inclined at an angle.

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