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Research paper

Automatic Speed Detection and PWM Signal Generation for Application in Dual Fuel System

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Abstract

Dual fuel injection can be implemented in vehicle by changing engine injector or manipulating signal from vehicle's Electronic Control Unit (ECU). Changing engine injector is costly, thus this paper focuses study to discover possibility to manipulate ECU signal using microcontroller. The study desired to detect motor speed automatically, and then produce a new Pulse Width Modulation (PWM) signal to navigate fuel injector. The capture/compare/PWM (CCP) module of PIC18F4520 device is utilized to record timing of input signal, determine its correseponding speed, and generate PWM signal with the designated duty cycle. The predefined duty cycles for the PWM signal are 25%, 50%, and 75% in the system. The program is debugged using MPLAB software and verified with a test circuit operating at 10MHz frequency using specific engineering software. The experimental results demonstrated the program manifests a promising achievement to the expected theoretical results.

Keywords: *Duty-cycle, CCP module, PWM*

1. Introduction

Today, people from different part of the world could experience rapid climate change and high temperature. Climate scientists believe these events are related to global warming, which mainly caused by the increasing emissions of carbon dioxide and greenhouse gases due to fossil fuels combustion, and many other human activities [1-3]. The uncontrolled human development activities have gradually increased the Earth's atmosphere temperature, the rising sea level and severe weather events. These effects are expected getting worst in time, unless we seriously and substantially cut down the volumes of harmful emissions in the near future.

In cities, private car has become a dominate mode of transport due to flexibility and mobility to move from one place to another. The report of Malaysia Automotive Association indicates a dramatically growth in the number of vehicles in Malaysia since the past decade (MAA). Therefore, fossil fuel combustion from transportation turn out to be a significant source to air pollution and eventually lead to global warming [4].

Dual fuel combustion is a new concept that has been introduced for engine efficiency improvement and emissions reduction. The dual fuel technology allows vehicles running in a mixed fuel by blending two different fuels together, for example natural gas and fossil fuel. Compressed Natural Gas (CNG) is high efficiency natural gas because its combustion emits lower carbon dioxide, CO_2 and heat-trapping gases [5].

In practice, the dual fuel vehicle starts the sparking ignition by using fossil fuel, then gradually increases the quantity of natural gas to drive vehicle engine. A dual fuel engine usually can operate on 100% fossil fuel or substitution mixture of fossil fuel and natural gas. The release of fossil and natural gas in vehicle is regulated by Electronic Control Unit (ECU).

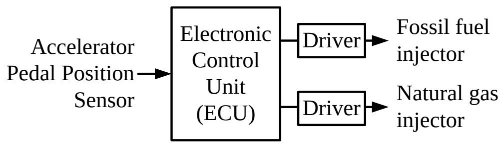


Figure 1: The ECU control for fuel injector

As seen in Figure 1, the ECU receives electrical signal from Accelerator Pedal Position (APP) sensor which monitors the position of the throttle pedal. Meanwhile, the vehicle's speed is determined by sensing crank shaft rotation by using APP sensor. After identifying the speed, the ECU generates an electrical signal which determines timing to excite fossil fuel injector and natural gas injector. Subsequently, fossil fuel and natural gas could be mixed and released into combustion chamber to power the engine.

This paper presents groundwork concerning registers, configurations and programming of microchip that being utilized as controller unit to generate a specific timing signal, pulse width modulation (PWM) to control gasoline and gas injector. To ease the testing process, a motor2 circuit is utilized to represent APP sensor as illustrated in Figure 2.
The motor2 circuit is developed so that it could generate three different signals to indicate three vehicle speeds. Then, the micro-

controller generates a 2.5 kHz PWM signal with duty-cycle 25%, 50% or 75% that used to drive motor1.

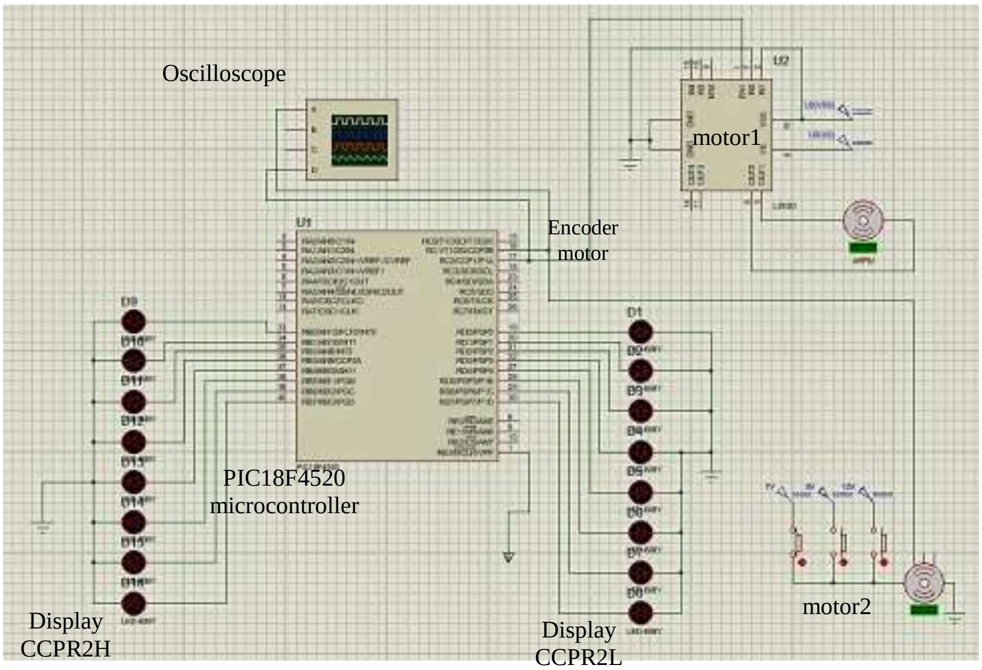


Figure 2: Schematic circuit to test functionality of the program on microcontroller.

2. Schematic Circuit Simulation

2.1 Microcontroller Configuration

Figure 2 demonstrates the schematic diagram to simulate behaviour of the incoming signal from the motor2 circuit and the generated PWM signal corresponds to various speeds of the incoming signal using engineering software.

In the circuit, motor2 is employed to produce the incoming signal and its rotation speed is captured via RC1 pin. The generated PWM signal is outputted through RC2 pin to control motor1 which representing injector. Moreover, the CCP1 and CCP2 pins respectively connected to channel D and channel A of an oscilloscope to examine the waveforms. In order to monitor the speed of incoming signal, 16 LEDs are connected to PORTB (CCPR2L) and PORTD (CCPR2H) so that the particular speed of incoming signal in binary format could be observed.

As the motor rotation speed is captured in round per minute (rmp) and proportional to motor's voltage supply. Hence, three different voltages have been tied to motor2 for driving it to move in different speeds. The voltages are 7V, 9V, and 12V, respectively driving the motor to rotate at speed less than 3000 rpm, between 3000-3500 rpm, and greater than 3500 rpm.

2.2 Setup Input Signal

In Figure 3, the simulation result indicates the value <CCPR2H:CCPR2L>, referred to values displayed across PORTB and PORTD is E94D in hexadecimal. Its equivalent decimal value is 59,725.

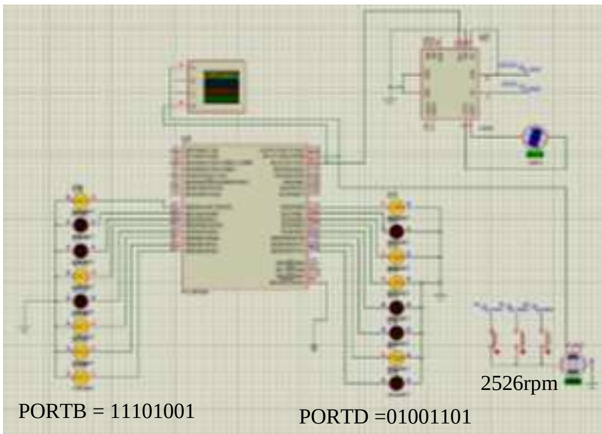


Figure 3: Evaluate speed of input signal.

As the microcontroller is clocked with 10MHz frequency, the period T of the input signal can be approximated using the equation given below;

$$T = (CCPR2H{:}CCPR2L) \times \frac{4}{F_{osc}}$$

This result indicates the T value of input signal is 23.89ms. Timing waveforms in Figure 4 respectively indicating the speed of motor2 and the PWM signal generated in relation to the speed of motor2. These waveforms were capture using oscilloscope. The measurement indicates the speed of motor2, which is the signal that fed into the microcontroller device is 23.75ms. The following formula is adopted to define the relation between pulse period and speed of pulse, in unit rpm.

$$rpm = \frac{1}{T} \times 60$$

where T is the period of signal. The calculation demonstrates the motor2 rotating at 2526 rpm while it is supplied with 7V voltage source. Table 2 lists three voltage supplies with its respective speed produced by the motor2.

Table 1: The rotation speed of Motor2

Voltage (V)	<CCPR2H: CCPR2L> (decimal)	Speed (rpm)
7	59725	2526
9	46487	3200
12	34867	4316

3. Results and Discussion

3.1 Driving Motor With 25% PWM Signal

Figure 4 illustrates simulation result on Channel A and D of oscilloscope. With the connection as depicted in Figure 2, the channel A and channel D show incoming signal from motor2 and the PWM signal to motor1, respectively. Figure 4(a) shows motor2 moving slower than motor1 because the period of channel A waveform is longer than channel D. The Figure 4(b) indicates T for the PWM signal is 0.4ms, thus the frequency, $1/T$ of the PWM signal is 2.5kHz.

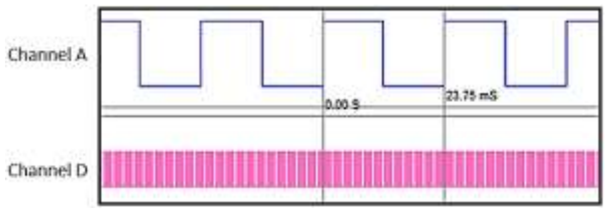
By measuring on-time and period of the waveform, the duty cycle can simply be determined by calculating the ratio of the on-time over the period, as given in Eqn. 3. The calculation indicates the duty-cycle of the waveform is 25%.

$$DC = \frac{Time\ on}{Time\ on + Time\ off} \times 100\%$$

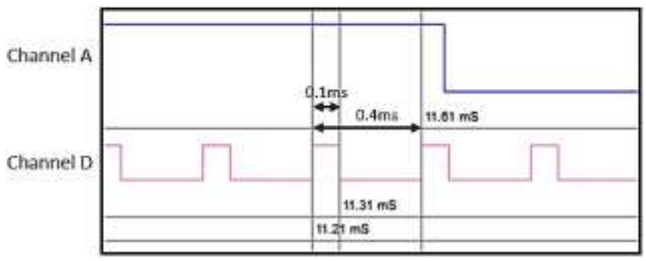
Since the result indicates the speed of motor2 is less than 3000rpm, therefore a 25% duty cycle with 2.5kHz frequency has been delivered to drive the motor1.

3.2 Driving Motor With 50% PWM Signal

The waveform in Figure 5(a) shows that the motor2 introduces waveform with speed 3200 rpm to microcontroller. This is similar as depicted in Table 1. As the programming has designated that if the speed of incoming signal is between 3000 rpm and 3500 rpm, a 50% PWM signal would be produced to drive the motor1. The result in Figure 5(b) provides evidence that a 2.5kHz square signal with 50% duty cycle is captured on Channel D.

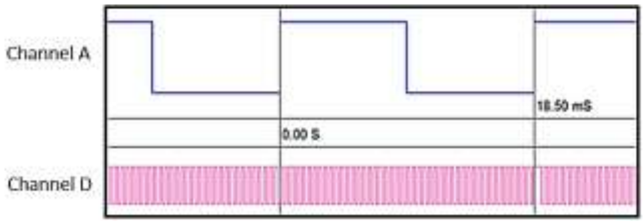


(a)

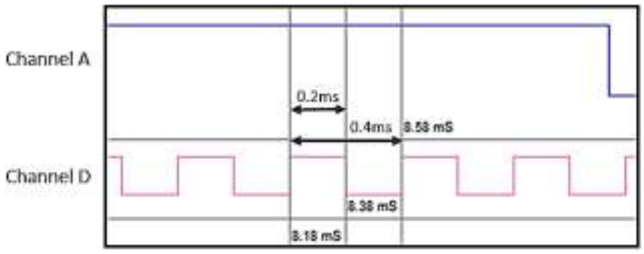


(b)

Figure 4: Incoming signal and generated PWM signal captured on oscillopscpe; (a) Normal view; (b) Enlarge view to examine PWM signal with 25% duty-cycle.



(a)

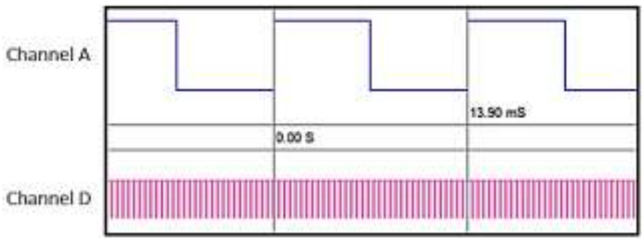


(b)

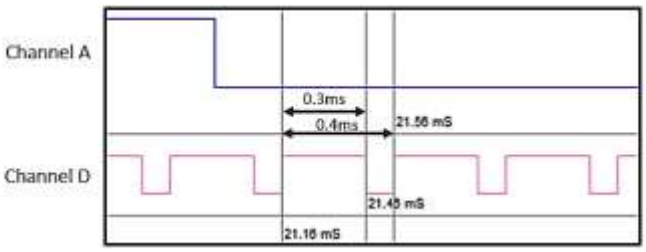
Figure 5: Incoming signal and generated PWM signal captured on oscillopscpe; (a) Normal view; (b) Enlarge view to examine PWM signal with 50% duty-cycle.

3.3 Driving Motor With 75% PWM Signal

Figure 6(a) indicates that a 4316 rpm signal is generated when supply a 12V voltage to the motor2, as indicated in Table 1. For the programming, while receive a signal where its speed is greater than 3500rpm, the corresponding response is to produce a 75% PWM signal. This has been proven with the result as depicted in channel D of Figure 6(b), a 2.5 kHz square wave signal with 75% duty cycle.



(a)



(b)

Figure 6: Incoming signal and generated PWM signal captured on oscillopscpe; (a) Normal view; (b) Enlarge view to examine PWM signal with 75% duty-cycle.

4. Conclusion

This study has computed a C programming to utilize the CCP module of PIC18F4520 microchip to capture the speed of motor2 via CCP1 pin. The program is able to determine the range of speed and automatically identify duty-cycle of the PWM signal that outputs through CCP2 pin to control operation of motor1. The results indicated the PWM signal with right duty-cycle has been yielded once tested the program in engineering software.

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