

Implementation of PID Controller by Microcontroller of PIC (18 Series) and Controlling the Height of Liquid in Sources

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Abstract

This paper presents a comprehensive analysis of PID controller and implementation of PID by the microcontroller of PIC and the use of PWM in the DC controlling processes. First of all we use the PID controller to control a continuous process by using reasonable factors (P, I, D) in PID and PIC (18f452) will help us during this period of time and after that producing an adequate PWM signal for the use of our pump to take the motor under our control. We have to use an appropriate IC such as L298 which is a motor driver.

Keywords: Microcontroller; PID; Microchip technology; PIC

Introduction

These days many people are aware of the importance of controlling process in our factories and housekeeping. One of the most important factors that are vital for motors and pumps in factories, is the times the motors are in stand by mood and the operator wants to turn on them. This can cause a huge current in the rotors even eight times more than functional current. By being aware about this huge current, we have to be avoided about turning off motors. Now we can use a common controller like PID that can reduce the damages impressively. But determining reasonable factors for PID is very vital for the system which is designed to be able to control a continuous system that will be interrupted by one or more output valves.

After designing a probable software, we have to find a capable hardware such as motor driver, microcontroller and what it needs to run properly. PIC is a family of microcontrollers made by Microchip Technology, derived from the PIC1650 originally developed by General Instrument's Microelectronics Division. The name PIC initially referred to Peripheral Interface Controller. The first parts of the family were available in 1976; by 2013 the company had shipped more than twelve billion individual parts, used in a wide variety of embedded systems. In 2000, Microchip introduced the PIC18 architecture. Unlike the 17 series, it has proven to be very popular, with a large number of device variants presently in manufacture. In contrast to earlier devices, which were more often than not programmed in assembly, C has become the predominant development language. Because of this popularity this type of PICs is chosen (Figure 1).

As a bridge to the real world from assembly world, a driver is needed, which transfers the programs and orders from microcontroller to the pump input. PWM helps us to control the pump continuously and properly [1].

PID Controller in Mathematical Format

A proportional integral derivative controller is a control loop feedback mechanism commonly used in industrial control systems. A PID controller continuously calculates an error value $e(t)$ as the difference between a desired set point and a measured process variable. The controller attempts to minimize the error over time by adjustment of a control variable $u(t)$ such as the position of a control valve, a damper, or the power supplied to a heating element, to a new value determined by a weighted sum:

$$*u(t) = K_p e(t) + K_i \int_0^t e(t) dt + K_d \frac{de(t)}{dt}$$

Where K_p , K_i , K_d , all non-negative, denote the coefficients for the proportional, integral, and derivative terms, respectively (sometimes denoted P, I, and D). In this model:

- P accounts for present values of the error. For example, if the error is large and positive, the control output will also be large and positive.

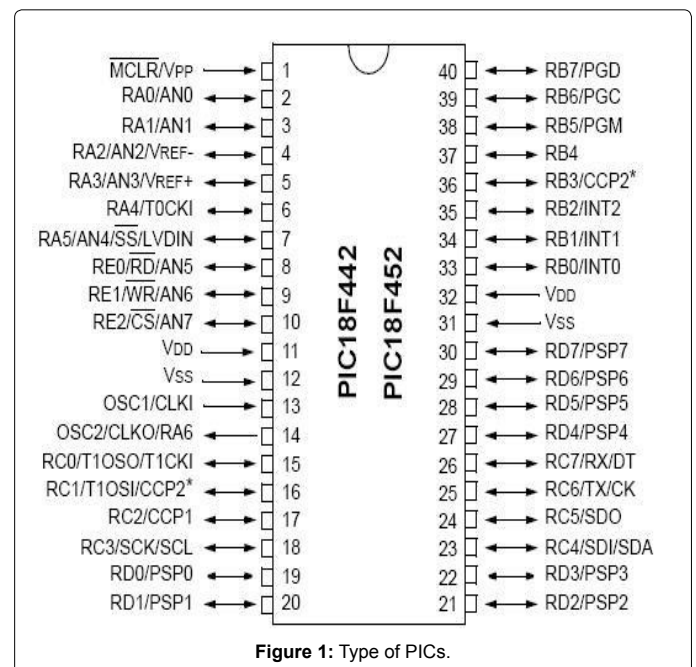


Figure 1: Type of PICs.

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- I accounts for past values of the error. For example, if the current output is not sufficiently strong, error will accumulate over time, and the controller will respond by applying a stronger action.
- D accounts for possible future values of the error, based on its current rate of change. Some applications can be controlled by PI in the absence of D factor or PD in the absence of I factor (Figure 2).

To approach to the factors of PID we can use Ziegler-Nichols method which is a heuristic method of tuning a PID controller. It is performed by setting I (integral) and D (derivative) gains to zero. The "P" gain, K_p is then increased (from zero) until it reaches the ultimate gain K_u , at which the output of the control loop has stable and consistent oscillations. K_u and the oscillation period T_u are used to set the P, I, and D gains depending on the type of controller used: (Table 1).

Discrete-time PID algorithm

The PID mathematical equation must be transferred to digital equation which will be understandable for the PIC. It can be changed with a good approximation like the below equation, for digital implementation, we are more interested in a Z-transform of (*):

$$U(z) = \left[K_p + \frac{K_i}{1-z^{-1}} + K_d(1-z^{-1}) \right] E(z)$$

By rearranging once again:

$$U(z) = \left[\frac{(K_p + K_i + K_d) + (-K_p - 2K_d)z^{-1} + K_d z^{-2}}{1-z^{-1}} \right] E(z)$$

$$K_1 = K_p + K_i + K_d$$

$$K_2 = -K_p - 2K_d$$

$$K_3 = K_d$$

It can be written:

$$U(z) - z^{-1}U(z) = [K_1 + K_2 z^{-1} + K_3 z^{-2}] E(z)$$

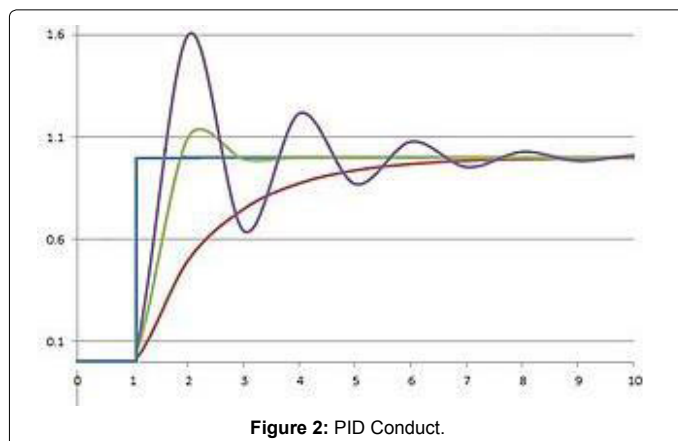


Figure 2: PID Conduct.

Control Type	K_p	K_i	K_d
P	$0.5K_u$	-	-
PI	$0.45K_u$	$1.2K_p/T_u$	-
PID	$0.6K_u$	$2K_p/T_u$	$8K_p/T_u$

Table 1: Ziegler-Nichols method.

Which can be converted to:

$$u[k] = u[k-1] + K_1 * u[k] + K_2 * u[k-1] + K_3 * u[k-2]$$

Now a digital output must be transferred to an analog output, to be understandable for the pump.

Pulse Width Modulation (PWM)

DC motors were the first type widely used, since they could be powered from existing direct-current lighting power distribution systems. A DC motor's speed can be controlled over a wide range, using either a variable supply voltage or by changing the strength of current in its field windings [2,3].

$$\dot{\omega}_{rm} = \frac{V}{K_e \phi} + \frac{R_a}{(K_e \phi)^2} T$$

As it can be seen from the equal, DC motors speed can be controlled by three parameter: voltage (V), flux (ϕ), resistance of motor (R_a).

In the past one of the most common ways for controlling DC motors is using a kind of variable resistance. This kind of control have been used in old sewing machines (Figure 3).

But it is not an economical way to control a DC motor because of its energy losses. So engineers had to find out a new controlling method [4,5].

First of all, engineers introduced Duty Cycle term. A duty cycle is the percentage of one period in which a signal or system is active. Duty cycle is commonly expressed as a percentage or a ratio. A period is the time it takes for a signal to complete an on-and-off cycle. As a formula, a duty cycle may be expressed as:

$$D = \frac{PW}{T} \times 100$$

where D is the duty cycle, PW is the pulse width, and T is the total period of the signal. Thus, a 60% duty cycle means the signal is on 60% of the time but off 40% of the time. So the motor can be controlled precisely with high output (Figure 4).

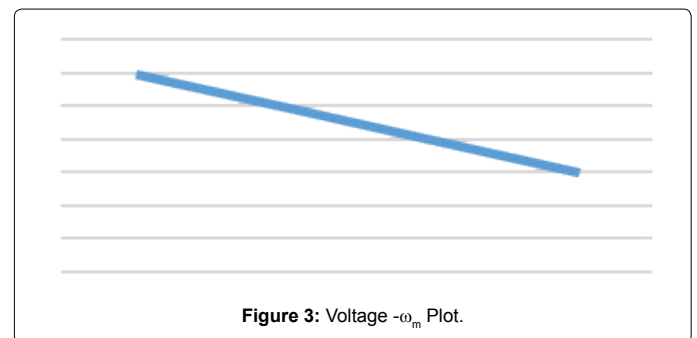


Figure 3: Voltage - ω_m Plot.

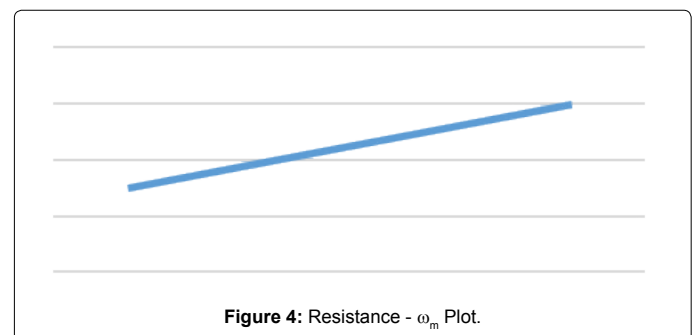


Figure 4: Resistance - ω_m Plot.

A technique to take analog output from digital input in various systems.

The pulse can be produced by many methods such as hardware techniques (ICs like 555 timer IC) or software methods.

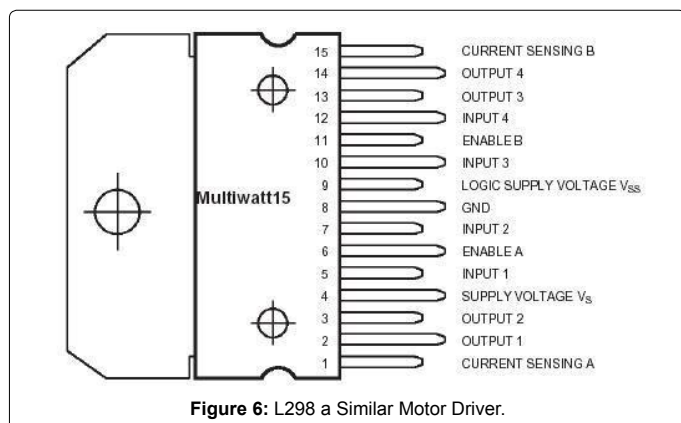
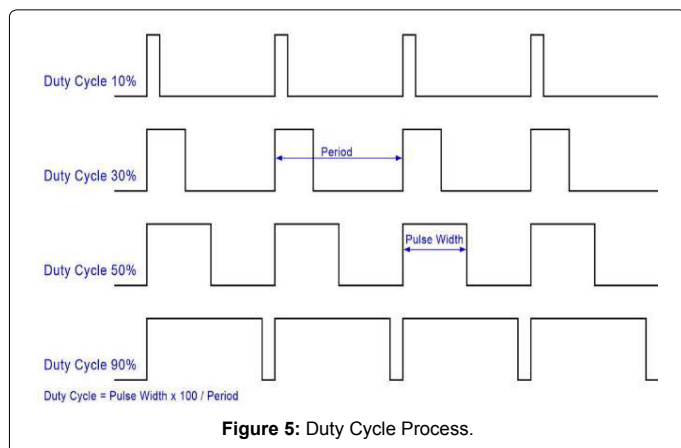
Since our microcontrollers do not have the acceptable power to run a motor, a driver is needed to make the analog output capable to operational (Figure 5).

Driver

The pulse which is on the microcontroller port is not able to run a motor such as a pump. So a motor driver such as L298 is needed (Figure 6).

The L298 is an integrated monolithic circuit in a 15-lead Multiwatt and PowerSO20 packages. It is a high voltage, high current dual full-bridge driver designed to accept standard TTL logic levels and drive inductive loads such as relays, solenoids, DC and stepping motors. Two enable inputs are provided to enable or disable the device independently of the input signals. The emitters of the lower transistors of each bridge are connected together and the corresponding external terminal can be used for the connection of an external sensing resistor. An additional supply input is provided so that the logic works at a lower voltage (Figure 7).

It can run two motors (50V, 2A) in the same time or its outputs can be used to activate one motor with high current whose form is used in this project.



Height Sensor

Strain gage sensors are one the most popular sensors which are used in industrial applications (Figure 8).

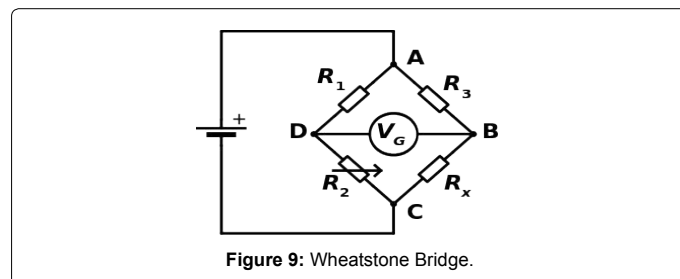
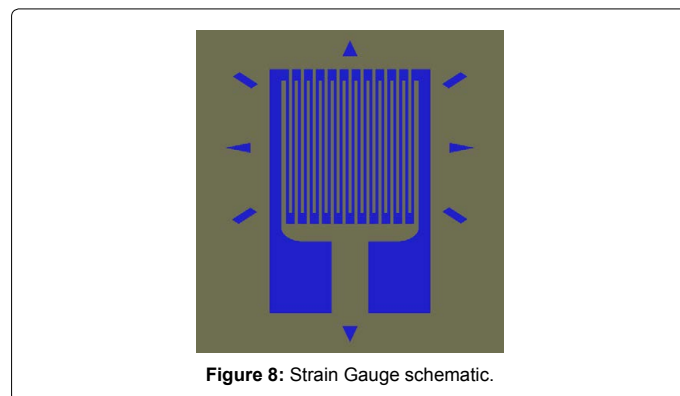
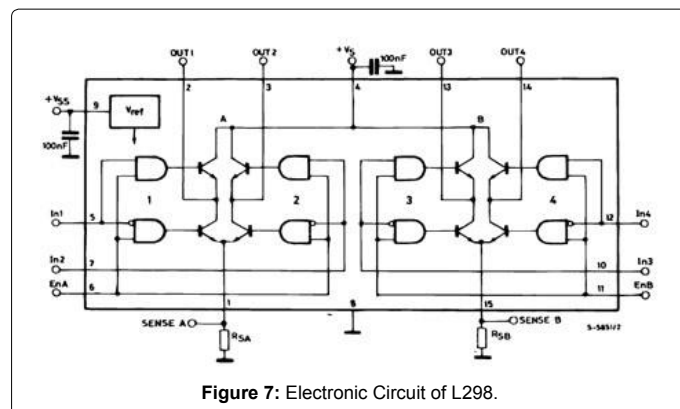
A strain gauge (or strain gage) is a device used to measure strain on an object. The gauge is attached to the object by a suitable adhesive, such as cyanoacrylate. As the object is deformed, the foil is deformed, causing its electrical resistance to change. This resistance change, usually measured using a Wheatstone bridge, is related to the strain by the quantity known as the gauge factor (Figure 9).

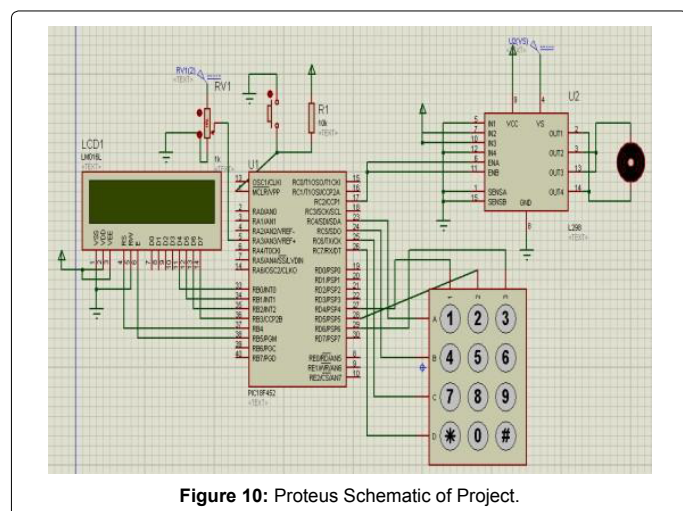
So VG will be changed by the changing of R2 and a resistance factor will be a voltage factor and understandable for the microcontroller.

It is very important that a low pass filter (such as a capacitance) is vital for the output of the sensor since there are various kinds of noises in Lab.

Programming

One of the most important parts of the project is programming process which can be done by C language. On the other hand, Flowcode





programming software is recommended to whom does not know C language very well (Figure 10).

Practical Industrial Application of PID Controller

In industrial country, particularly in oily oil-rich countries, engineers implement PID controller by PICs or PLCs to control the height of oil in tanks. Controlling the height of petroleum liquid in tanks of refineries is one of the most important factors of safety in oil industry.

As it has been said, many practical controllers had been used for many years to control turbulences in various systems, but PID controller has been very successful until today either in industrial applications or nonindustrial (Figure 11).

Conclusion

In this paper, implementation of PID controller, which has been one the most popular controller, is discussed. Implementing by PIC microcontroller, one of the high-wrought microcontrollers that is used in factories and industrial places commonly. First of all, a digital equal of PID is needed to be understandable for the microcontroller. The digital output will not be fit for the analog world and PWM is designed to control the pump properly. After all every project needs some sensors to make the brain of the project (microcontroller) be aware about interrupts. Using sensors in the right bridge is another vital point.

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