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Design of a Cruise Control System using PID Controller

Rihab Gafar Abdalla, Mohammed A. A. Elmaleeh
Control Engineering Department, Faculty of Engineering, ALNeelain University
Khartoum, Sudan

E mail: rereasal@hotmail.com; **maleeh_mowafu@yahoo.com**

ABSTRACT: This paper aims to design a cruise control system using PID compensation technique. Since the cruise control system is primarily depends on speed control, the proposed system is supposed to work at a constant speed. Therefore the controller tries to keep the speed constant. The proposed mechanism was modelled using Mat Lab and Simulink. Different vales of kp, Ki and kd were used in the simulation program to test the efficiency of the proposed system in controlling the cruise car. The best values of these parameters were used to design the system. The results obtained satisfy the goal of the paper.

KEYWORDS: Cruise Control System, PID controller, Speed Control

1. INTRODUCTION

Control systems in general are used to modify the behaviour of the systems so they behaves in a specific desirable way over time. For instance to hold the speed of a car on the highway to remain as close as possible to 60 miles per hour in spite of possible hills or adverse wind; or we may want an aircraft to follow a desired altitude, heading, and velocity profile independent of wind gusts; or we may want the temperature and pressure in a reactor vessel in a chemical process plant to be maintained at desired levels. All these are being accomplished today by control methods and the above are examples of what automatic control systems are designed to do, without human intervention. Control is used whenever quantities such as speed, altitude, temperature, or voltage must be made to behave in some desirable way over time [1].

The cruise control system is a driver sets a constant desired speed, it is automatically controls the throttle to maintain the desired speed. Cruise control system is the deriver's responsibility to ensure that the vehicles can indeed safety travel at the speed on the highway. If there happens appear a preceding vehicle on the highway that is traveling at a slower speed or is too close to the ego vehicle, the driver must take action and if necessary apply brakes. Application of the brakes automatically disengages the cruise control system and returns control of the throttle to the driver [2].

The purpose of cruise control is to keep the velocity of a car constant. The driver drives the car at the desired speed, the cruise control system is activated by pushing a button and the system then keeps the speed. The major disturbance comes from changes of the slope of the road which generates forces on the car due to gravity. There are also disturbances due to air and rolling resistance. The cruise control system measures the difference between the desired and the actual velocity and generates a feedback signal which attempts to keep the error small in spite of changes in the slope of the road. The feedback signal is sent to an actuator which influences the throttle and thus the force generated by the engine [3].

Most cruise control systems don't allow the use of cruise control below a certain speed. The use of cruise control would be significantly increased if the vehicle speed could automatically adapt to the traffic flow. This feature can be handy for long drives along sparsely populated roads and usually results in better fuel efficiency. It is also known in some places as "poor man's radar detector", as by cruise control, a driver who otherwise tends to unconsciously increase speed over the course of a highway journey may avoid a speeding ticket. The blind inventor and mechanical engineer Ralph teeter invented cruise control in 1945. His idea was born out of the frustration of riding in a car driven by his lawyer, who kept speeding up and slowing down as he talked. The Chrysler Corporation on the 1958 Chrysler imperial introduced first car with cruise control systems. The only danger with cruise control is the use of cruise control in wet and slippery roads. You should turn off cruise control while driving through such conditions. It is very dangerous to use cruise control in any slippery conditions like rain, snow, or ice as it takes the complete control of the vehicle out of your hands. That is because most cruise control systems are designed for normal dry conditions and can't sense whether the wheels are spinning uselessly. If your car begins to careen out of control, cruise control will continue to accelerate as it tries to maintain a constant speed. It would put your car into a sideway spin cause the vehicle to flip over [4].

The cruise control used designed in this paper is accomplished via PID. The control method used PID is one of the classical control which is powerfully contributed to the stability and achieving satisfactory responses for the desired controlled system.

One of the traditional ways to design a PID controller was to use empirical tuning rules based on measurements made on the real plant. It is suggested that it is Preferable for the PID designer to employ model based techniques. If necessary they can be packaged as simple recipe procedures. Since the classical techniques are still referred to by practitioners, the following sections review the best known of the classical tuning methods [5].

2. MODELLING THE PROPOSED SYSTEM

Automatic cruise control is an excellent example of a feedback control system found in many modern vehicles.

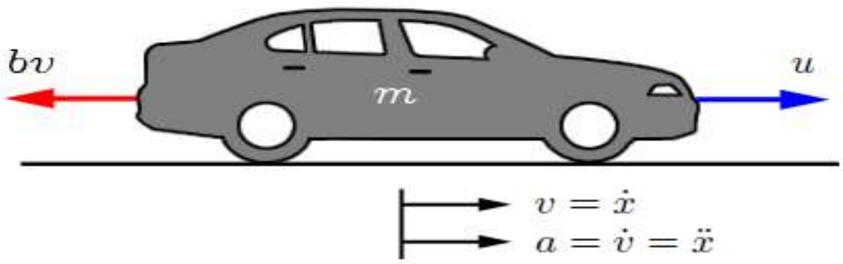

Figure 1. Cruise Control System [4]

Model of the vehicle dynamics is shown in Figure 1, in the free-body diagram above. The vehicle, of mass m, is acted on by a control force, u. The force u represents the force generated at the road/tire interface. For this model it assumed to control this force directly and neglecting the dynamics of the powertrain, tires, etc., that go into generating the force. The resistive forces, by, due to rolling resistance and wind drag, are assumed to vary linearly with the vehicle velocity, v, and act in the direction opposite the vehicle's motion [4].

3. MODELLING OF THE SYSTEM EQUATIONS

With these assumptions stated above the system is a first order mass-damper. The Summing forces in the x-direction and by applying Newton's second law of motions, results in [1-4]:

$$m\dot{v} + bv = u \qquad (1)$$

Where:
m: vehicle mass
v: vehicle velocity
b: : damping coefficient
u: control force
Since it is interested to control the speed of the vehicle, the output equation is chosen as follows:

$$y = v \qquad (2)$$

Where y is the output

4. . STATE-SPACE MODEL

The first-order systems have only has a single energy storage mode, in this case the kinetic energy of the car, and therefore only one state variable is needed, the velocity. The state-space representation is therefore [1-5]:

$$\dot{x} = [\dot{v}] = \left[\frac{-b}{m}\right][v] + \left[\frac{1}{m}\right][u] \qquad (3)$$

$$y = [1][v] \qquad (4)$$

5. TRANSFER FUNCTION MODEL`

Taking the Laplace transform of the governing differential equation and assuming zero initial conditions, we find the transfer function of the cruise control system to be:

$$P(s) = \frac{V(s)}{U(s)} = \frac{1}{ms+b} \quad \left[\frac{m/s}{N}\right] \qquad (5)$$

5. 6. SYSTEM REQUIREMENTS

The proposed cruise control system should meet the following requirements:

- Rise time < 5 s
- Overshoot < 10%
- Steady-state error < 2%

With following parameter values:
m = Vehicle mass = 2000 kg
b = damping coefficient 100 N.s/m
r= reference speed 20 m/s

6. DESIGN OF CRUISE SYSTEM CONTROLLER

The proposed control system is designed using PID compensation technique. A PID controller attempts to correct the error between a measured process variable and a desired set point by calculating and then outputting a corrective action that can adjust the process accordingly. The Proportional value determines the reaction to the current error, the Integral value determines the reaction based on the sum of recent errors, and the Derivative value determines the reaction based on the rate at which the error has been changing.

- A proportional control (Kp) will have the effect of reducing the rise time and will reduce, but never eliminate, the steady state error.
- An integral control (Ki) will have the effect of eliminating the steady-state error, but it may make the transient response worse.
- A derivative control (Kd) will have the effect of increasing the stability of the system, reducing the overshoot, and improving the transient response.

The block diagram of a typical unity feedback system is shown in Figure2.

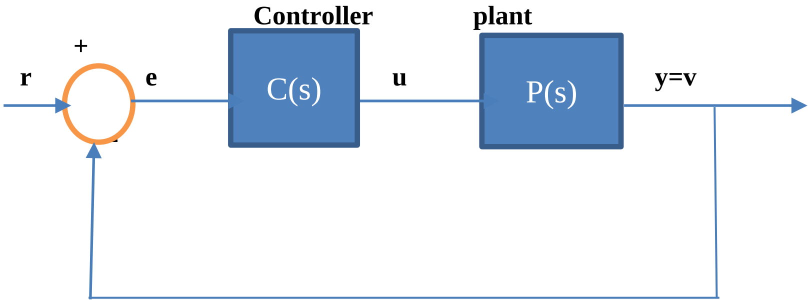

Figure2. Block Digram of the proposed System

The transfer function of a PID controller is [5]:

$$C(s) = k_p + \frac{K_i}{s} + k_d s = \frac{K_d s^2 + K_p s + K_i}{s} \qquad (6)$$

Where:
Kp= proportional control
Ki= integral control
Kd= derivative control

Firstly proportional control has been used with kp equal to 200.then using MATLAB the closed loop response was found as plotted in figure(3)

$$T(s) = \frac{Y(S)}{R(S)} = \frac{P(s)C(s)}{1+P(s)C(s)} = \frac{K_p}{ms+b+K_P} \qquad (7)$$

It is was noticed that the addition of proportional controller, Kp, decreases the rise time, which is desirable in this case. But making the response worse, stated as steady state error

From MAT LAB:

Num = [200];
Den = [2000 300];
T=tf(num,den)

$$T = \frac{200}{2000\,s + 300}$$

Step(T)

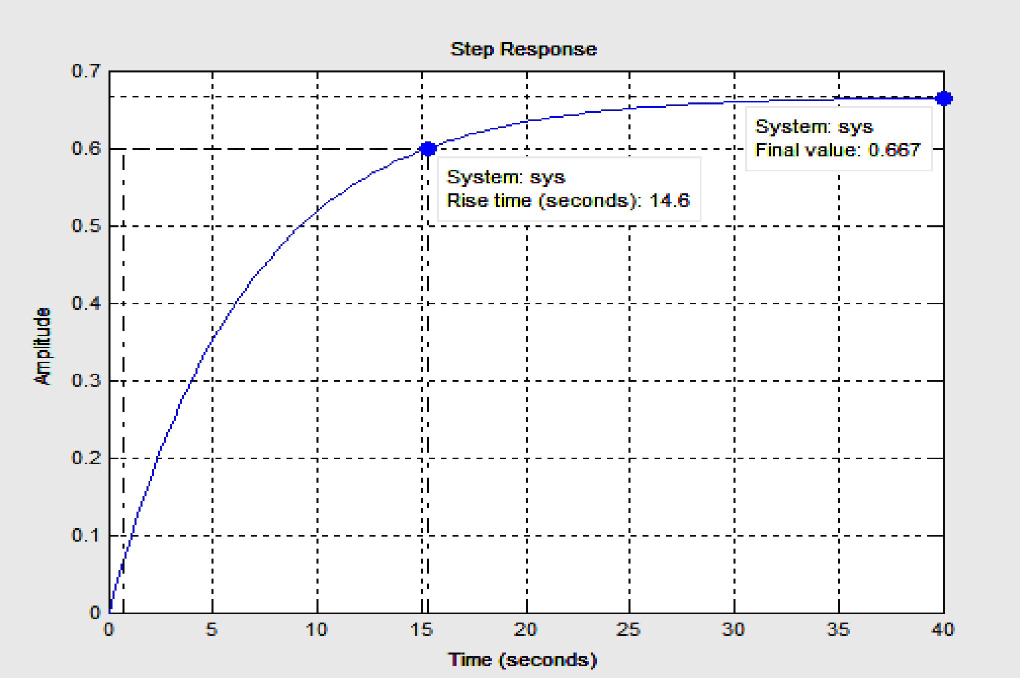

Figure [3]: Closed Loop Response with kp=200

From the figure above it obviously apparent that the rise time and the steady error values are not satisfactory, then hence a pi must be used.

Secondly the proportional integral control is used kp equals to 300 and ki equals to 50. Then using MAT LAB the closed loop response was found as plotted in Figure 4.

It was noticed that the addition of proportional integral controller, the steady state error is eliminate. But making the response worse, stated as overshoot. The closed-loop transfer function of this cruise control system with a PI controller

$(C(s) = k_p + \frac{k_i}{s})$ is:

$$T(s) = \frac{P(s)C(s)}{1+P(s)C(s)} = \frac{K_p s + K_i}{ms^2 + (b + K_p)s + K_i} \qquad (8)$$

Form MATLAB:
Kp = 300;
Ki = 50;
Num=[300 50];
Dum=[2000 400 50]
T=tf(num,den)

$$T = \frac{300\,s + 50}{2000\,s^2 + 400\,s + 50}$$

step(T)

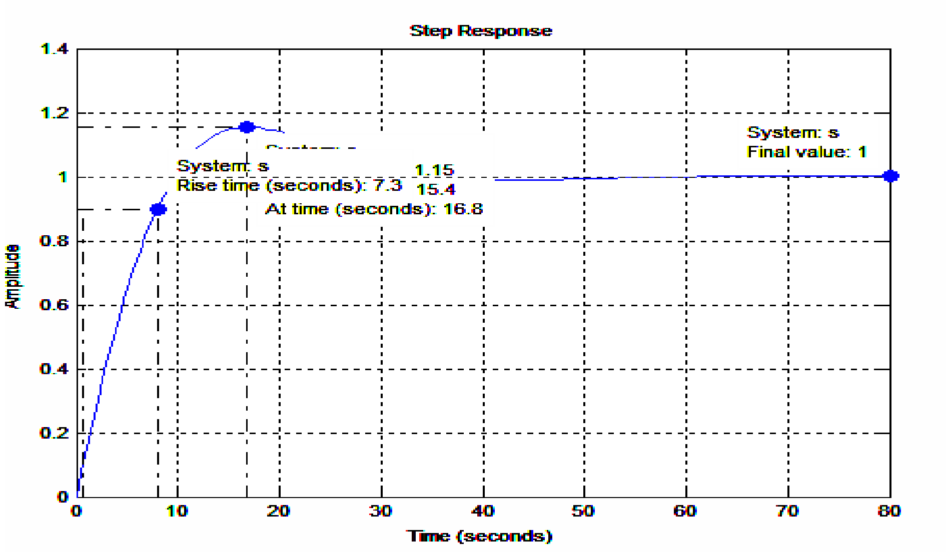

Figure 4. The Closed Loop Response with kp=300 and ki=50

From the figure above it obviously apparent that the rise time and the overshoot values are not satisfactory, then hence a PID must be used.

- **The closed-loop transfer function for the proposed cruise control system with PID controller**

$$(C(s) = K_p + \frac{K_i}{s} + K_d s) \text{ is:}$$

$$T(S) = \frac{P(s)C(s)}{1+P(s)C(s)} = \frac{K_d S^2 + K_p S + K_i}{(m+K_d)S^2 + (b+K_p)S + K_i} \qquad (9)$$

Form MATLAB:
Kp = 500;
Ki = 95;
Kd = 50;
Num=[50 400 95];
Den=[2050 600 50];
T=tf(num,den)

$$T = \frac{50s^2 + 400s + 95}{2050s^2 + 500s + 95}$$

Step (T)

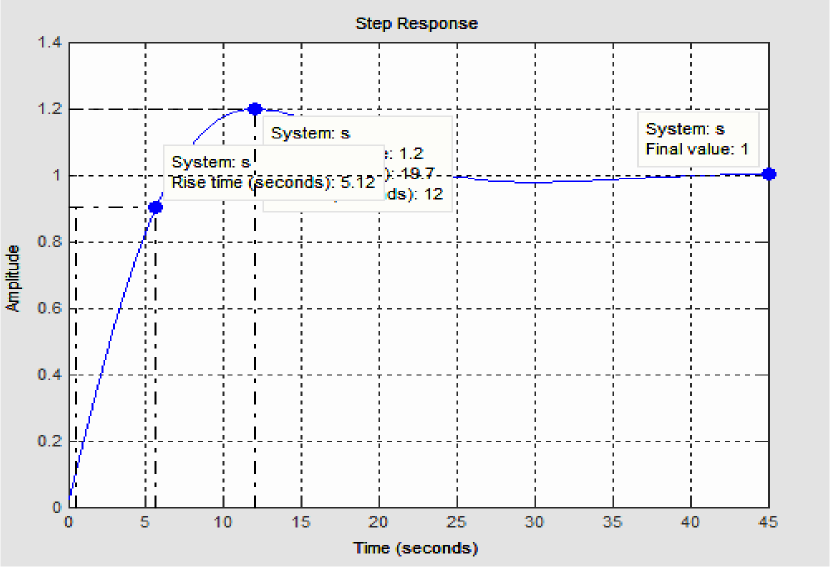

Figure 5. Closed Loop Response with kp=500, ki=95and kd=50

The closed loop response for the PID shown above resulted in quite good response but still did not meet the exact required response and therefore another different values has been taken.

Pid controller with different values for kp=700 and ki = 90 and kd= 30.
From MATLAB:
Kp=700, Ki=90, Kd=30
Num=[30 700 90];
Den=[2030 800 90]
T=tf(num,den)

$$T = \frac{30s^2 + 700s + 90}{2030s^2 + 800s + 90}$$

Step(T)

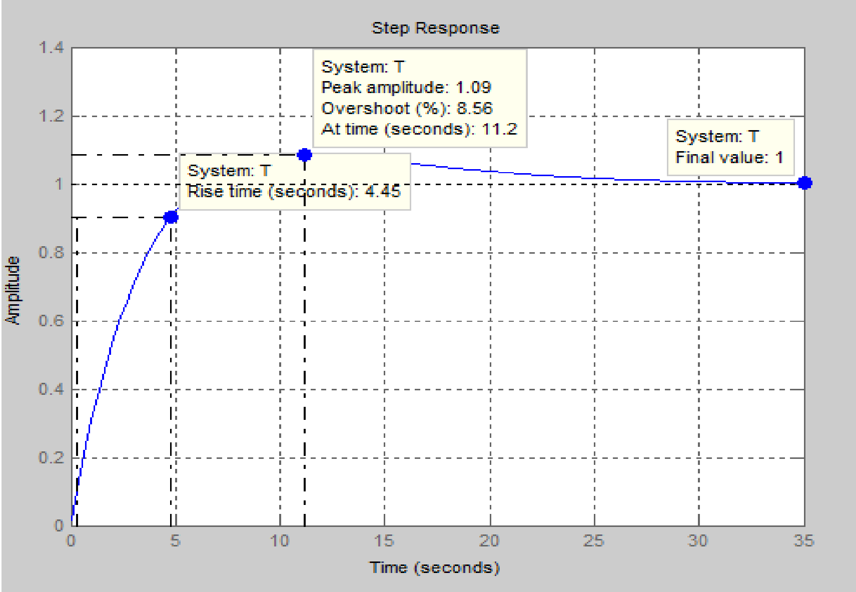

Figure 6. Closed Loop Response with kp=700 and ki=90 kd=30

The resulting plot above satisfies the desired response.

7. SIMULATION RESULTS

The simulations are carried out using Mat Lab and the results obtained are shown in Figures 7 and 8.

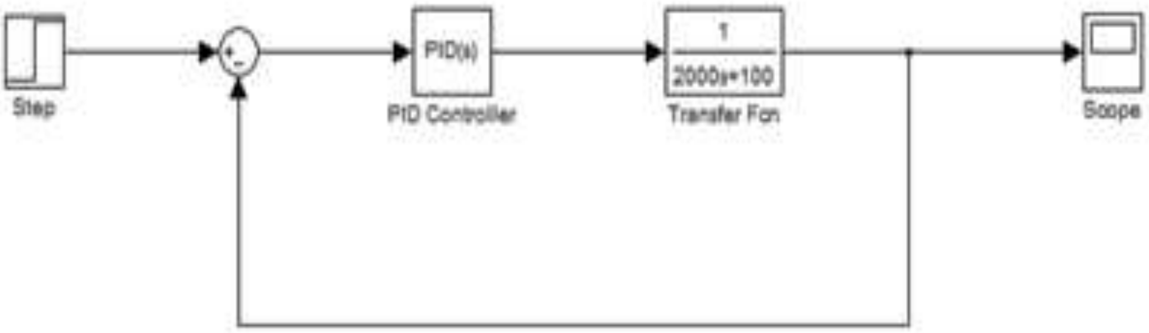

Figure 7. The Simulink of the System

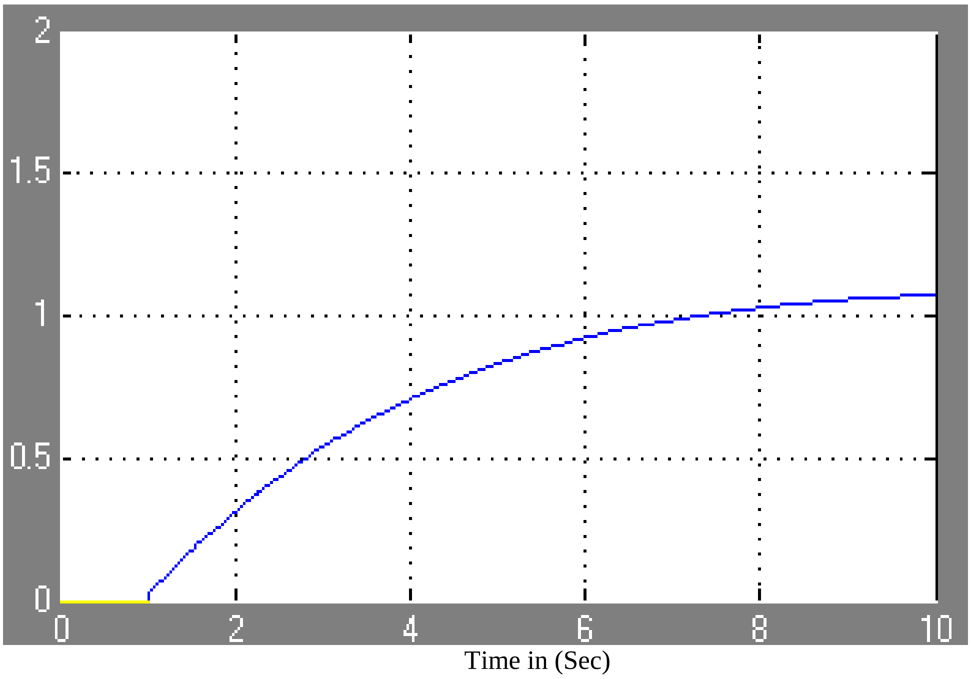

Figure 8. Step Response of the proposed Cruise Control System

CONCLUSION

This paper has achieved its main objectives in the best design model for the cruise control system. The proportional controller was added to the process to satisfy the requirement but it participated increasing the rise time, then the proportional integral was added, it quietly participated in the elimination of the steady state error but it made the response too worse, stated as overshoot, finally when the complete proportional, integral, derivative were added it helped successfully in minting a satisfied system response as well as high stability and butter design characteristics, from the difference stages above it is obvious that the proposed system gives it's best response only when the PID is used together, the values of the Kp, Ki, and Kd, which provided the stated response are 700, 90 and 30 respectively.

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