PROJECT REPORT

ON

ANALOG PID CONTROLLER USING OPAMPS

submitted by

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CERTIFICATE

This is to certify that the practical/ termwork carried out in the subject of Term Project recorded in this journal is a bonafide work of Mr. SHAH KATHAN JIGNESHKUMAR , Roll No.EC66 , Identity No.:18ECUOG023 of B.Tech semester V in the branch of Electronics and Communication during the academic year 2020-21.

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Abstract :

The PID control is the most commonly known for control process utilized as a part of industries for controlling action. The basic technique for PID controllers makes it simple to coordinate the process output. As the term PID suggest, it comprises of three separate constant parameters which are adjusted in order to get ideal, steady and faster response. In the control process, the majority of control loops based upon proportional, integral and derivative controller. For specific process, the tuning of three parameters of controller is able to provide specific control action to the system. Design methods leading to an optimal and effective operation of PID controllers are economically vital for process industries. The main focus of the project is about study of OPAMP and Simulation of an analog PID Controller using the three control parameters. The Controller design is demonstrated through simulation in order to get an output of better dynamic and static performance.

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Analog PID implementation using OP-amp

1 . Introduction

Proportional-Integral-Derivative (PID) controllers are one of the most commonly used types of controllers. They have numerous application relating to temperature control, speed control, position control, etc.

A PID controller provides a control signal that has a component proportional to the tracking error of a system(proportional), a component proportional to the accumulation of this error over time(Integral) and a component proportional to the time rate of change of this error(Derivative).

Usually PID Controller is being made in Micro-controller/Microprocessors's Algorithm, but here we want to develop PID using analog components (E.g. OP-amp, Resistor, Capacitor etc).

what is PID control system ?

PID consists of three blocks which process the error.

P – Proportional block ; **I** – Integral block ; **D** – Derivative block ;

- The **Proportional block** senses the error and it linearly increases/decreases the system response proportional to error multiplied by a constant- called its Gain.
- The **Integral Block** is used to minimize steady state error . It constantly adds up the error fed into it (multiplied by its gain), but even if the error decreases afterwards, it continues to increase response until error is negative which causes OVERSHOOT in output. So it needs to be controlled by derivative block.
- The **Derivative block** senses the change in error , so for small change in error it affects less but when there is a fast change in error (i.e. OVERSHOOT) the derivative is highly effective and according to it's gain it controls that overshoot.

2 . Block Diagram :

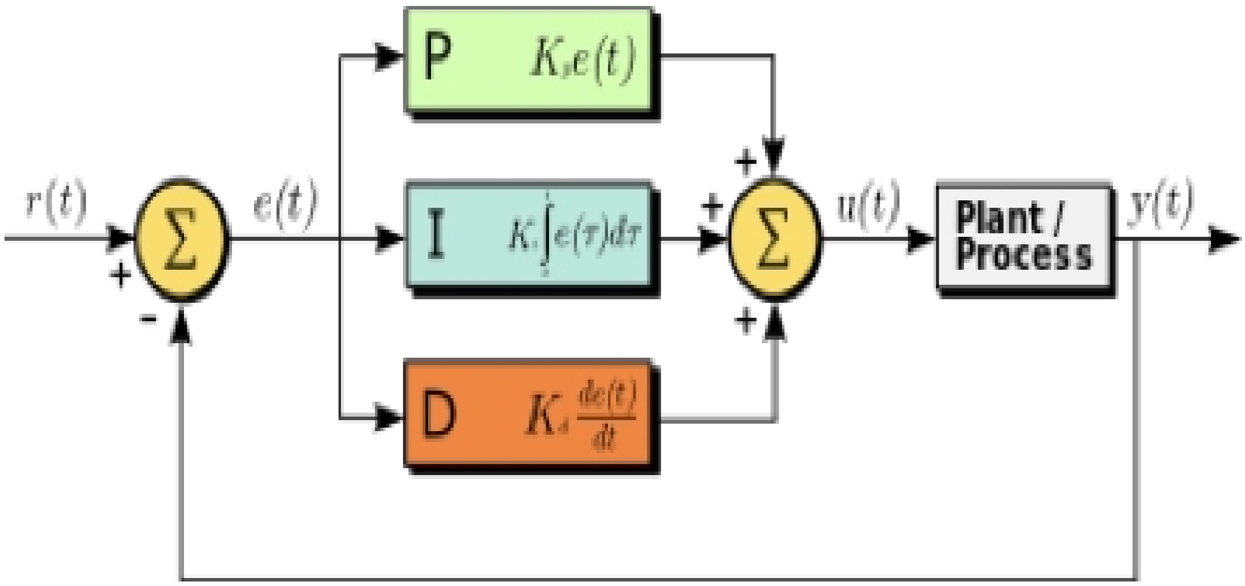

Fig 2.1 PID Control system Ideal block diagram

PID controller output : $U(t)=Kp+ki.\int e(\mu).d(\mu)+\frac{de(t)}{dt}$

where,

Kp = Proportional gain error signal : $e(t)=r(t)-y(t)$

Ki = intergral gian y(t) = output of system

Kd = Derivative gain r(t) = reference signal

Transfer function of PID : $K(s)=Kp+\frac{Ki}{s}+kd.s$

What we are implementing in Analog Domain

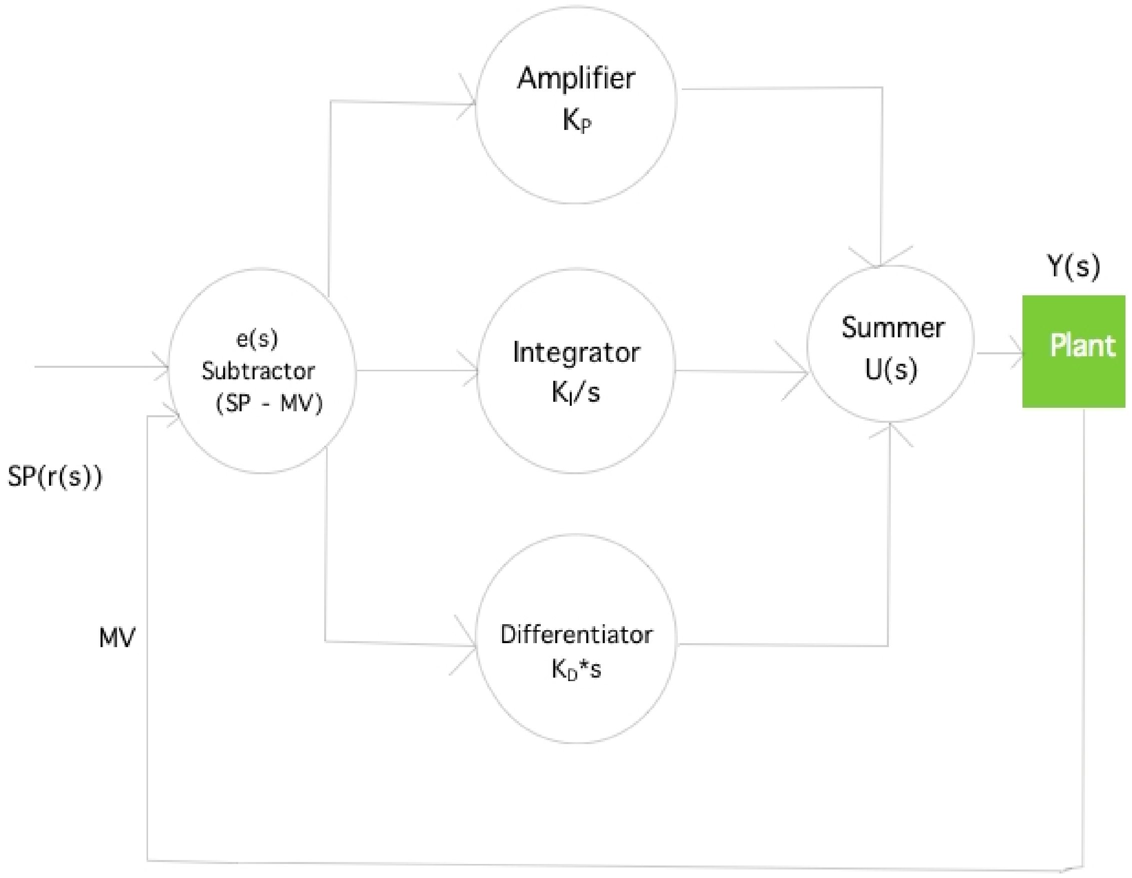

Fig2 .2 Block diagram of analog PID control System what we require to form Analog PID using Op-amp

Integrator	->	Ki – Integral gain
Differentiator	->	Kd – Differential gain
Amplifier	->	Kp – proportional gain
Summer	->	summing up PID output
Subtractor	->	error calculation

3 . Working :

Initially we have to set Reference Point , then it will be subtracted from measured value of that feedback parameter. It is called error signal , ideally we want to reduce error upto zero , so we give this error as input to PID controller which consists of three part - Proportional , Integrator , Differentiator . Then their output will give to summer circuit and it passes to original plant for getting exact output. This block diagram is overview of Analog PID controller. some parts will be added or removed afterwards to get proper & reliable Output.

A techniques determining the performances of a control system are :

- By set of specifications in time domain and/or in frequency domain such as peak overshoot, settling-time, gain-margin, phase-margin, steady - state error etc.

Tuning of PID :

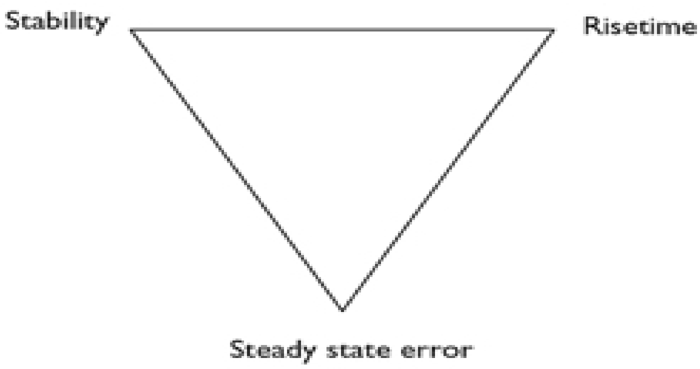

Fig 3.1 Triangle of parameters (stability , SSE , Rise-time)

By modifying Kp , Ki , Kd we can tune PID controller. Gains are directly related to stability , Rise-time , Steady state error and other stability parameters.There are so many methods to tune a PID block and not any fixed method so it is sometimes called to an art. But we preferred to tune it manually by observing the effect of change in each particular gain on the system, so that we could understand more how each of these blocks behave and also some practical issues that couldn't be described theoretically.

Table 3.1 – Impact of various gains on Control & stability parameter of system

Parameter	Rise-time	Overshoot	Settling time	Steady State Error	Stability
K_p	Decrease	Increase	Small Change	Decrease	Decrease
K_i	Decrease	Increase	Increase	Eliminate	Decrease
K_d	Minor changes	Decrease	Decrease	No effect	Improve if Kd is small

As per above table, setting of PID parameters can lead to nearly ideal response if perfectly tuned.

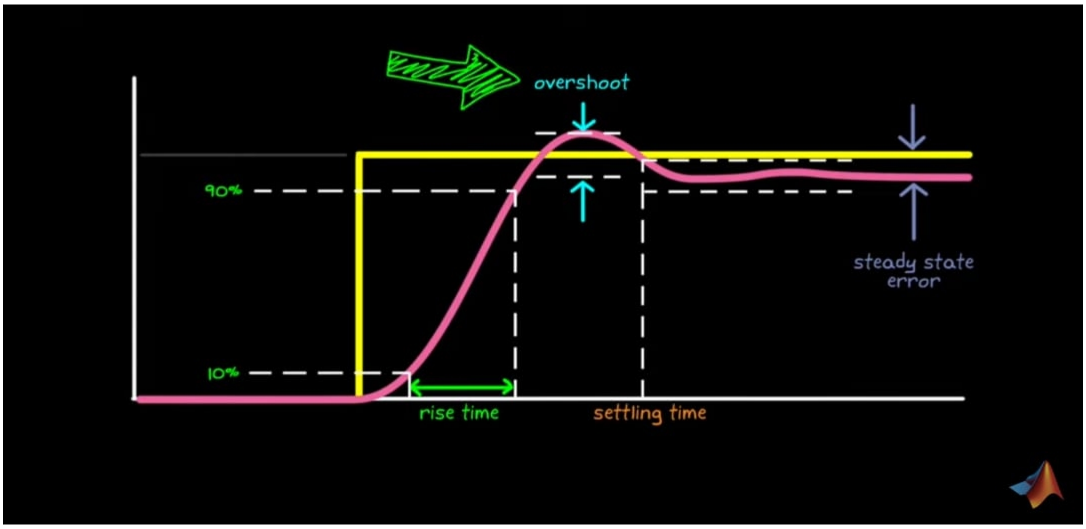

Fig. 3.2 Understanding of overshoot , setting time , SSE , rise-time

(reference – Mathworks.com)

4 . Component and its woking :

The Op-amp

The OPAMP stands for operational amplifier. It is specially design amplifier used for voltage amplification, buffering, analog filtering. An OPAMP is an amplifier with various typical properties such as very high gain, differential input, single ended output, very low output impedance. The amplified voltage is the output voltage

The basic operation of the OPAMP can be summarized. First we assume that there is a portion of the output that is fed back to the inverting terminal to establish the fixed gain for the amplifier. This is negative feedback. Any differential voltage across the input terminals of the OPAMP is multiplied5by the amplifier's open-loop gain. If the magnitude of this differential voltage is more positive on the inverting (-) terminal than on the non-inverting (+) terminal, the output will go more negative. If the magnitude of the differential voltage is more positive on the non-inverting (+) terminal8than on the inverting (-) terminal, the output voltage will become more positive. The open-loop gain of the amplifier will attempt to force the differential voltage to zero. As long as the input and output stays in the operational range of the amplifier, it will keep the differential voltage at zero, and the output will be the input by the gain set by the feedback. Note from this that the input respond to differential mode not common-mode input voltage

- **OPAMP LM741IC**

It is one of the popular used devices for analog circuit. Mainly available as IC in 8-pin dual, in-line package.

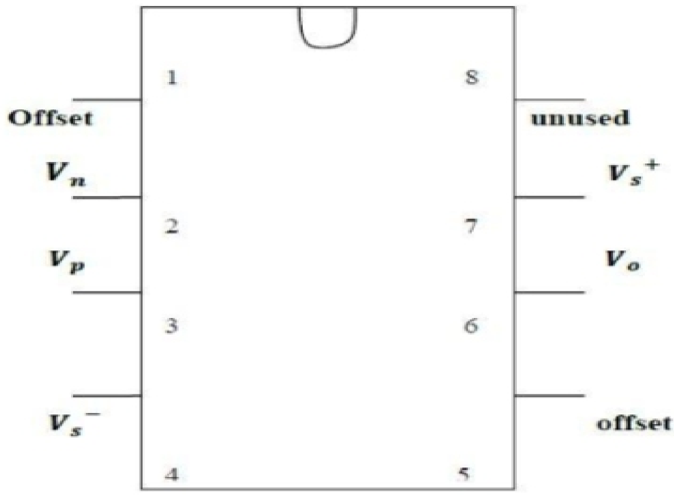

Fig 4.1 PIN CONFIRGURATION OF LM741IC

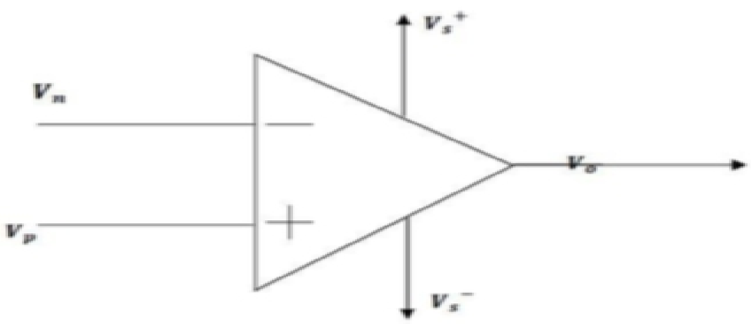

Fig 4.2:- Circuit Symbol of Opamp

LM741IC DATASHEET

Absolute maximum Ratings ,

Table 4.1

	LM741A8	LM7412	LM741C5
Supply Voltage5	±22V	±22V	±18V
Power Dissipation	500 mW	500 mW	500 mW
Differential Input Voltage	±30V	±30V	±30V
Input Voltage	±15V	±15V	±15V
Output Short Circuit Duration	Continuous	Continuous	Continuous

“Absolute Maximum Ratings “indicate the limits beyond which damage to the device may occur. Operating Ratings indicate the conditions for which the device is functional, but do not ensure specific performance limits. Fo operation at elevated temperatures, these devices must be derated based on thermal res- istance. For supply voltages less than ±15V, the absolute maximum input voltage is equal to supply voltage.

5 . Detailed Analysis of each blocks

1 .Integrator

Calculation :

$$Vout\,1 = -\frac{1}{R_3 C_f} \int V_1(t)\,dt = 5\,V \qquad V_1(t) = 2\,V\,;\, 0 < t < 50\,\mu s$$

$$Vout\,2 = -\frac{1}{R_3 C_f} \int V_2(t)\,dt = -5\,V \qquad V_1(t) = -2\,V\,;\, 50\,\mu s < t < 100\,\mu s$$

Note : Vout1 & Vout2 will combine make Triangular Wave 10Vpp , 10KHz signal

Schematic in Ltspice for Integrator

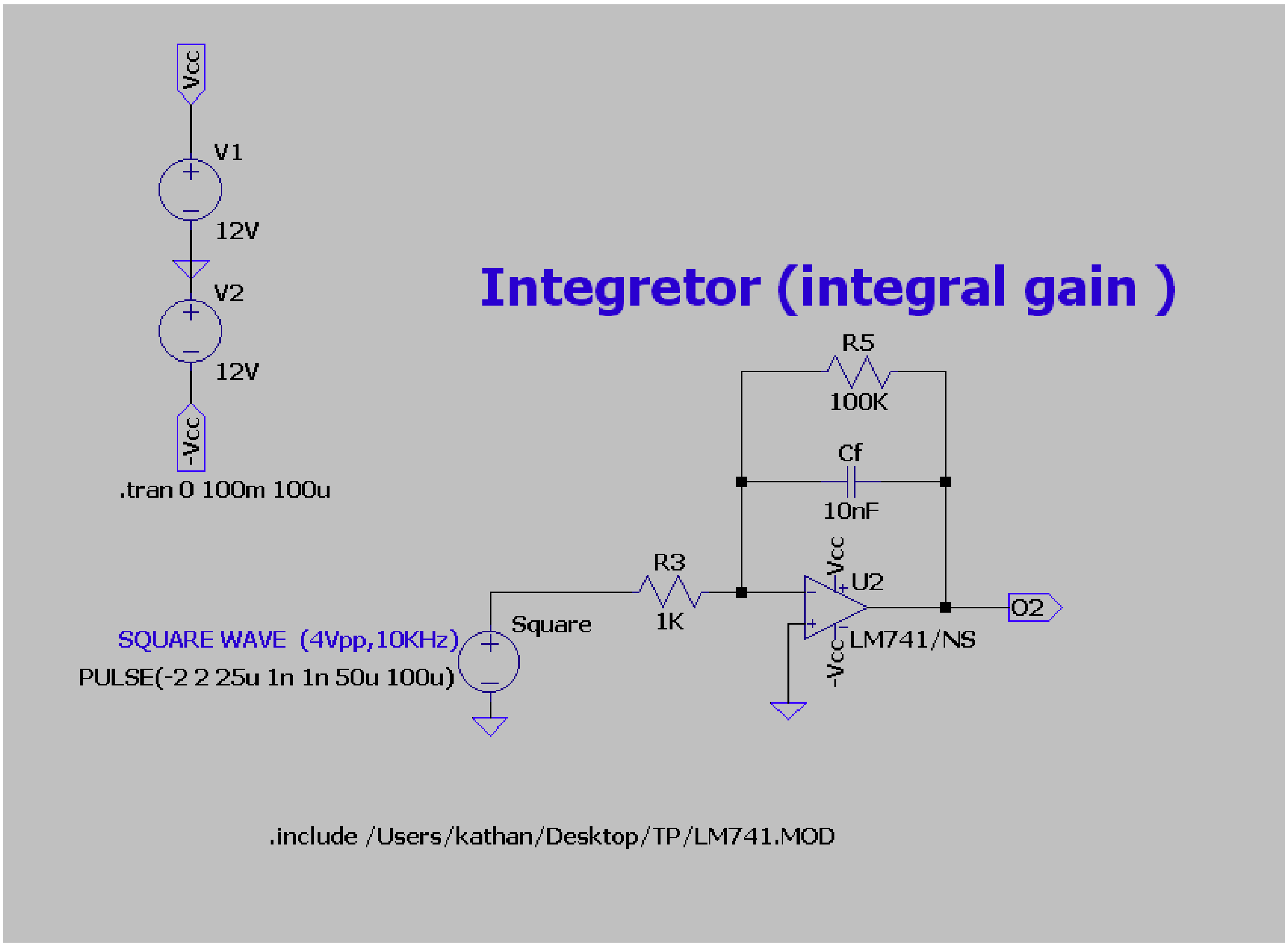

Fig 5.1.1 Practical Integretor using OP-amp for Integral gain

Observation :

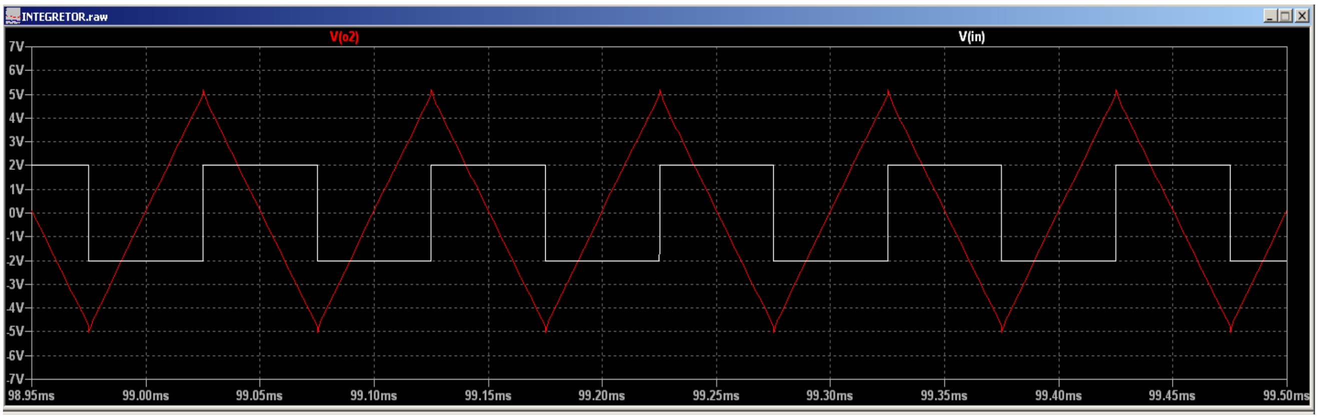

Fig 5.1.2

Measurements :

OUTPUT = V(O2) = 10Vpp , 9.99KHz
INPUT = V(in) = 4Vpp , 10KHz

2. Differentiator

Calculation :

$$Vout = -R_f C \frac{d}{dt}(Vin) \qquad \frac{d}{dt}(Vin) = slope\ of\ line\,(+Ve/-Ve)$$

$$Vout\,1 = -5\,K * 20\,nF * slope\ of\ line\,1 \qquad slope\ of\ line\,1 = 12000\,(+ve)$$

$$Vout\,2 = -5\,K * 20\,nF * slope\ of\ line\,2 \qquad slope\ of\ line\,2 = 12000\,(-ve)$$

$$Vout\,1 = 1.2\,V\,(-ve)$$

$$Vout\,2 = 1.2\,V\,(+ve)$$

Note : Vout1 &Vout2 will make combine Square wave of 4.2Vpp , 1KHz signal

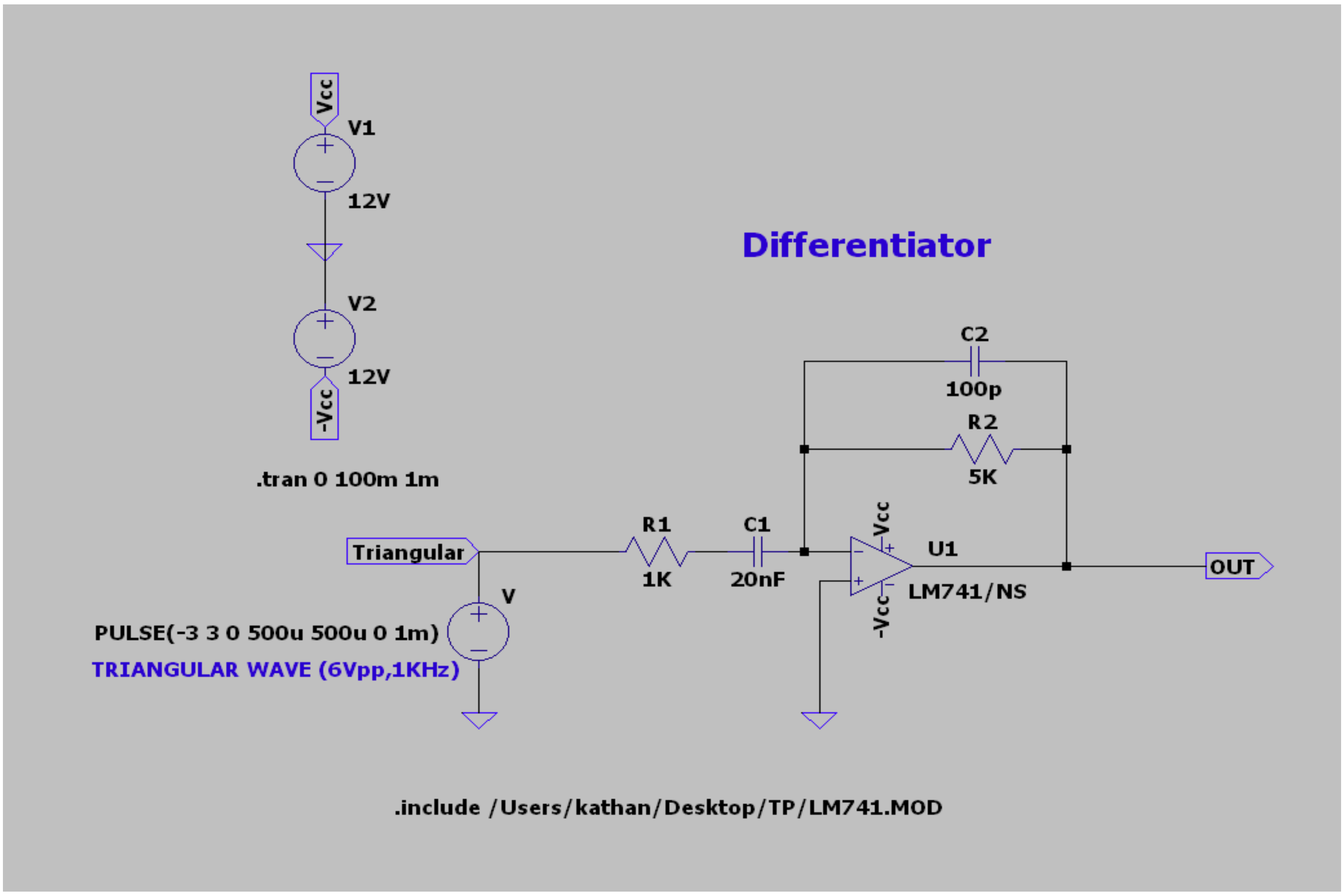

Fig 5.2.1 Practical Differentiator using OP-amp for Derivative gain

Observation :

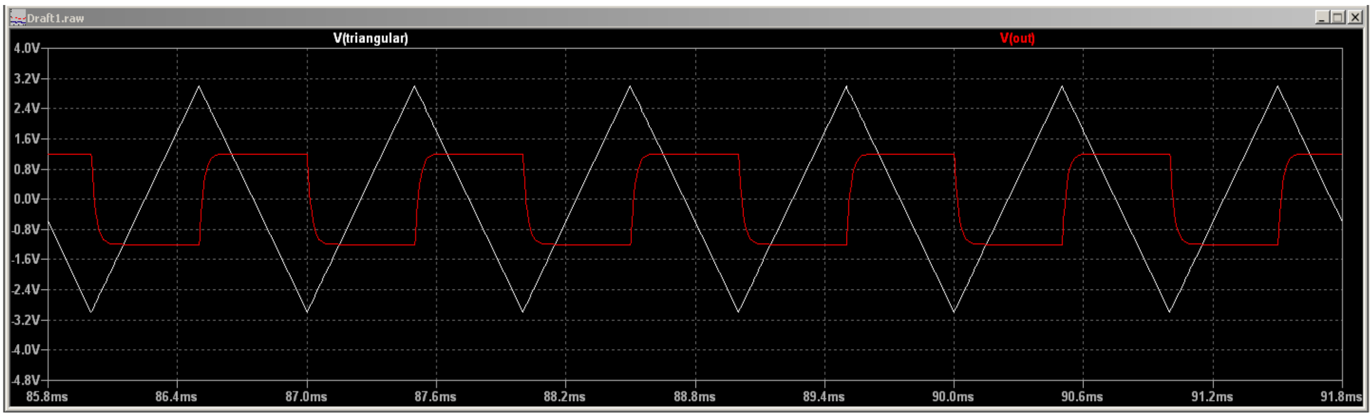

Fig 2.2.2

Measurements :

OUTPUT = V(Out) = 4.2Vpp , 0.99.KHz
INPUT = V(Triangular) = 6Vpp , 1KHz

3. ADDER

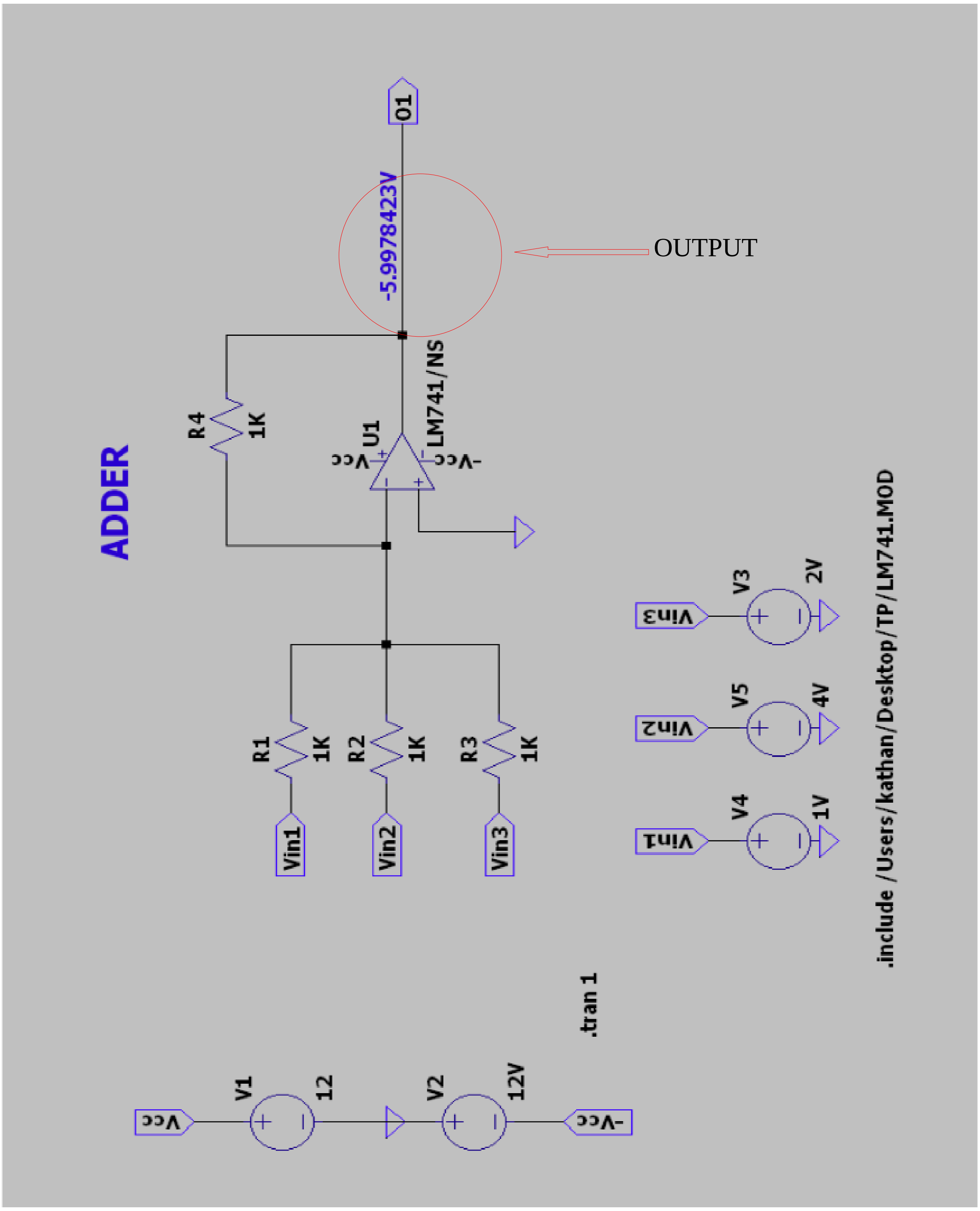

Fig 5.3 schematic for ADDER in Ltspice

4. SUBTRACTOR

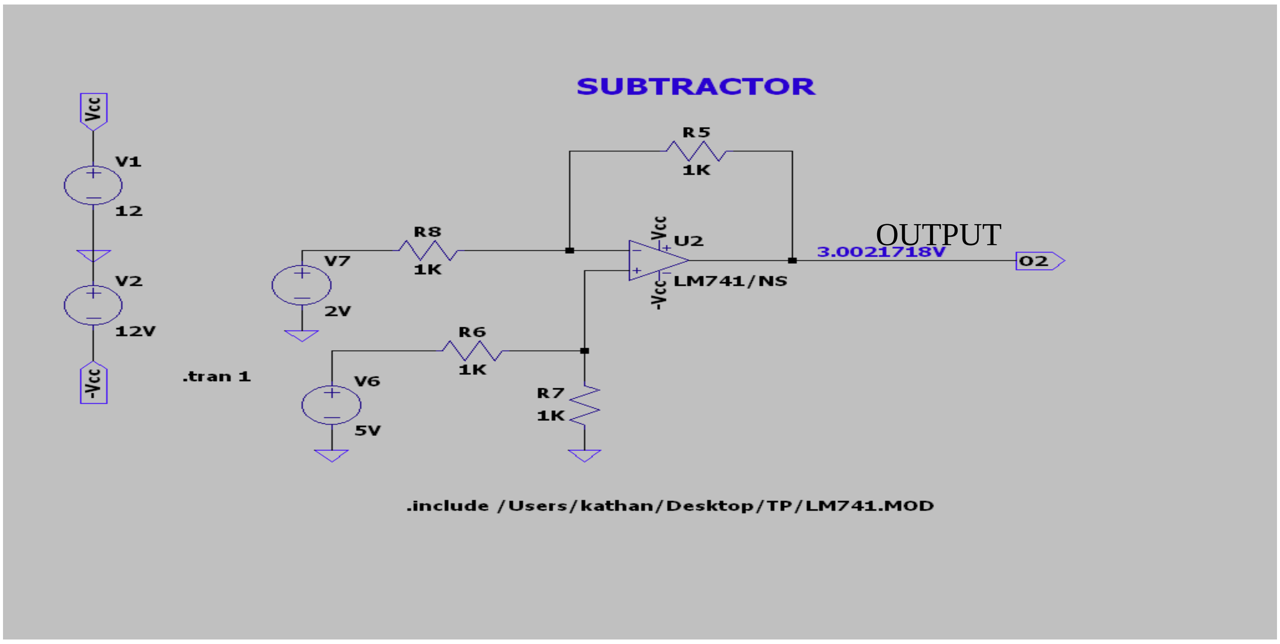

Fig 5.4 Schematic for SUBTRACTOR in Ltspice

5 .INVERTER

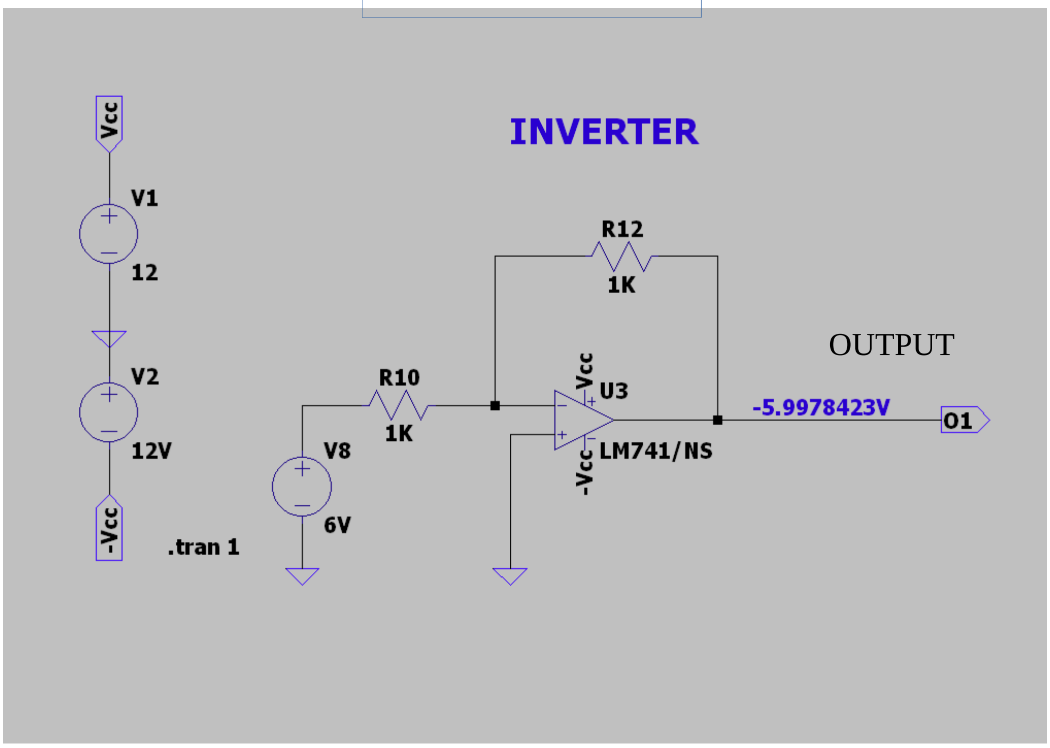

Fig 5.5 Schematic for Inverter in Ltspice

Learning Output :

By performing Different types of operations using op amp, we come to know, op amp can be utilized as Integrator, Differentiator, Inverter in PID Gains, Where Subtractor is used at to subtract value of SetPoint & Feedback value, Adder is used for summing up the out coming values of PID. In this simulation we analysed op amp basic operation using LM741 IC.if required, for more stability in Control system of Analog PID system, we can use LM324N-IC for getting precise & accurate output, also it decrease the Hardware because of 4 channel (4 op amp in one IC).

6 . Implementation of Analog PID system

Application : Reduce the Damping in LC oscillation

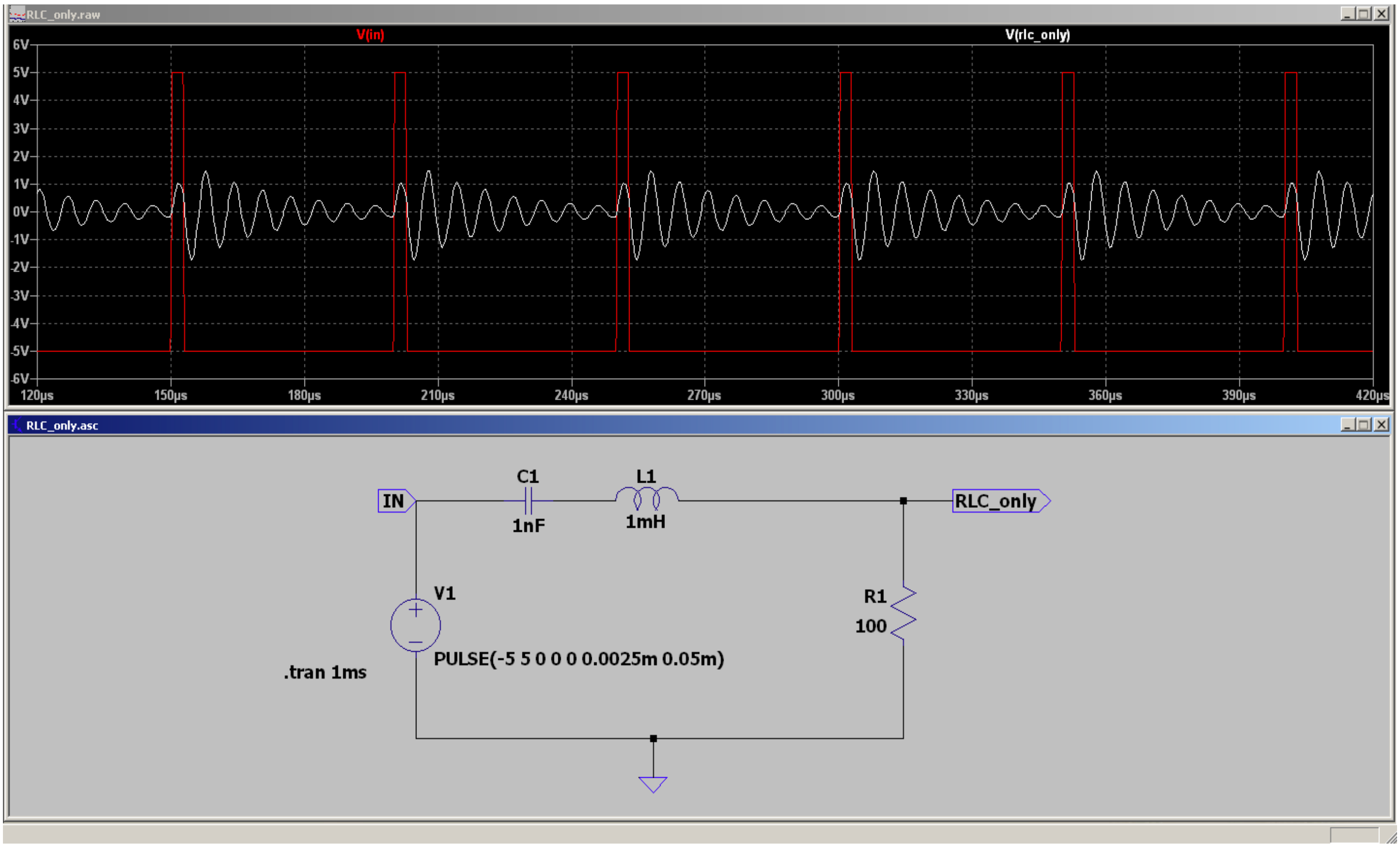

Fig 6.1 Damped RLC oscillations

- as shown in Fig 4.1 simulation result , RLC give damping response but we need damping free output so we can use Analog PID controller which measure error and apply according to it and transform out output to damped free signal

- for observing damping , we can apply
- input - > 5V square wave with 5% duty cycle

  Ton = 0.0025ms

  Period = 0.05ms

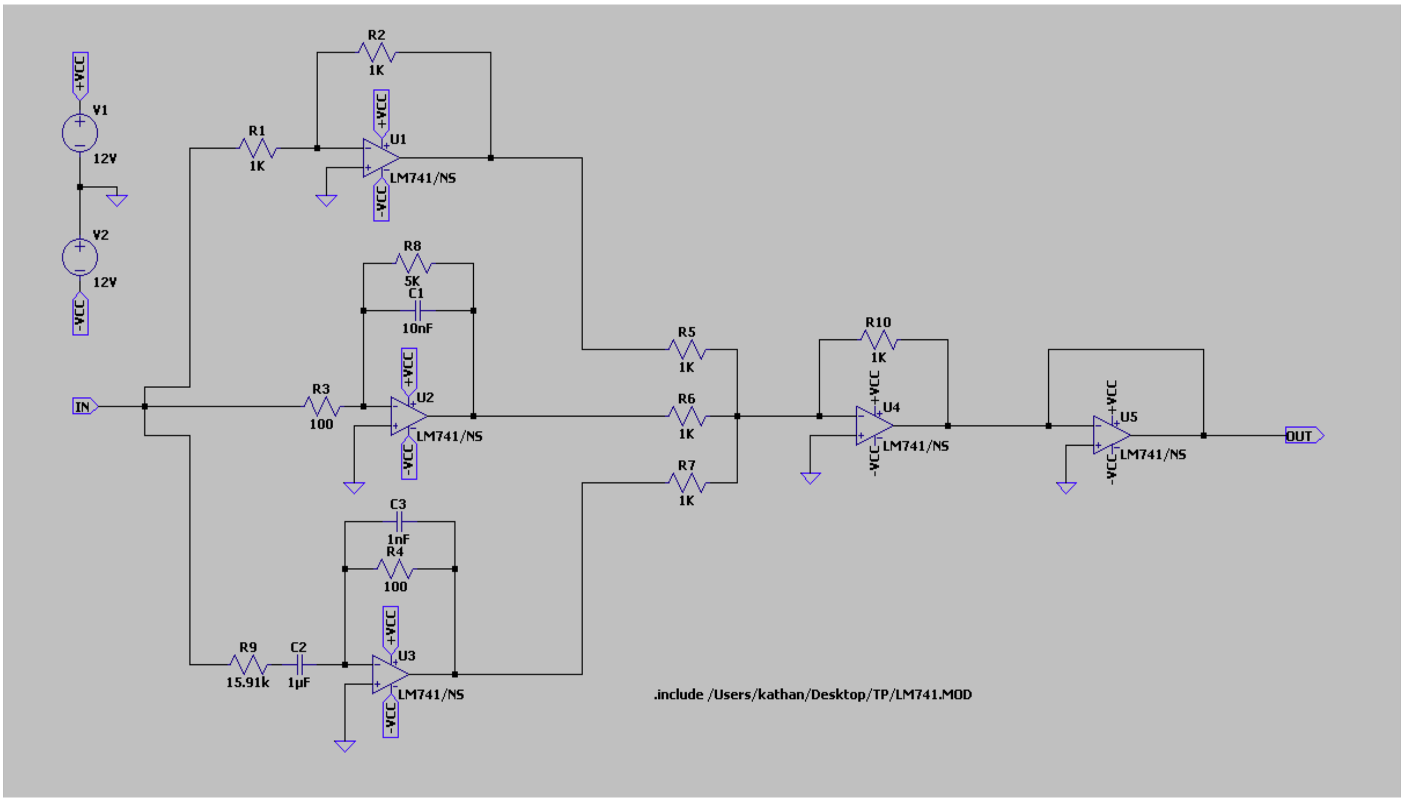

Fig 6.2 PID Circuit diagram

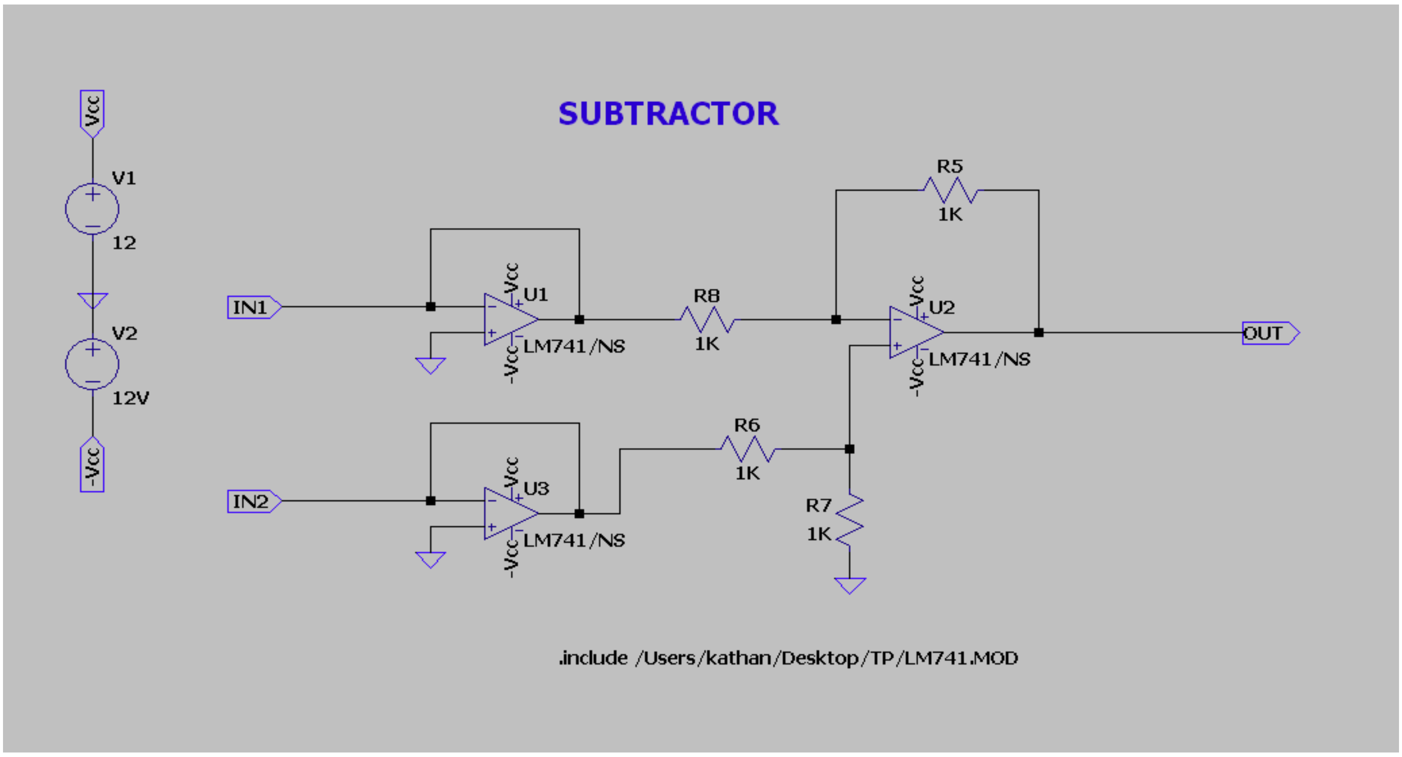

Fig 6.3 Subtractor Circuit for Error Calculating

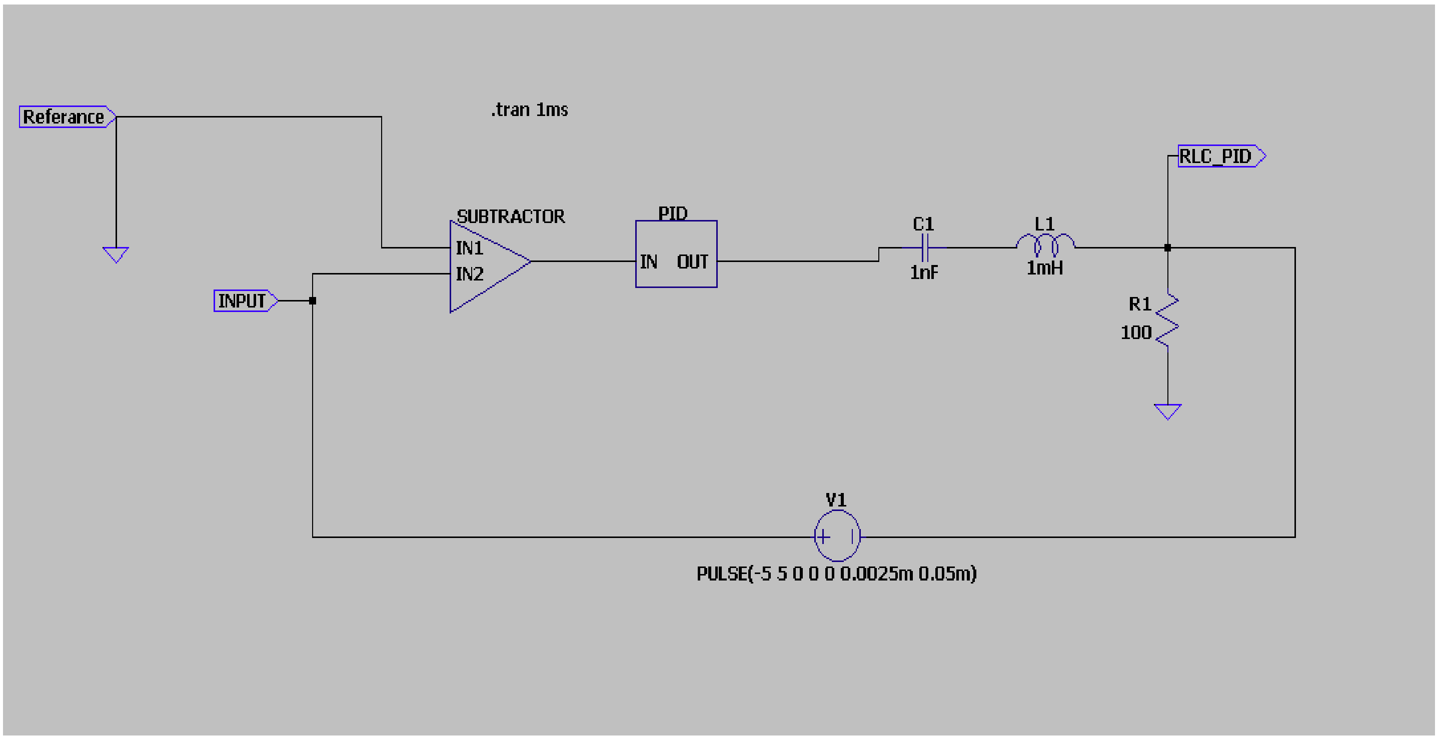

Fig 6.4 Final circuit

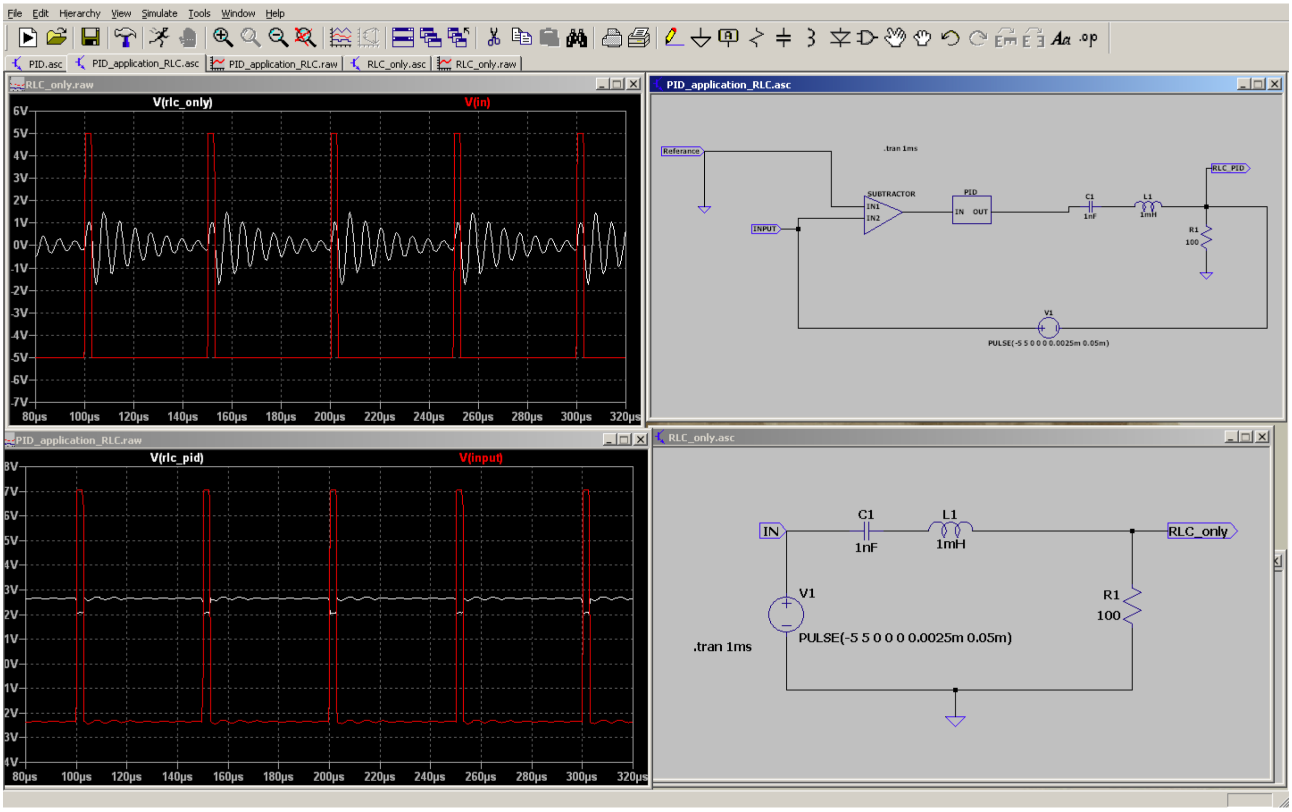

Fig 6.5 RLC oscillations with PID control system (damping Reduce)-final

As we know in Fig 4.2 , Gains in Analog PID system

Kp = proportional gain = $\frac{Rf}{Ri}$ = 1

Ki = Integral gain = $\frac{1}{Cf * Ri}$ = 1M

Kd = Differential gain = $Rf * Ci$ = 0.1m

by setting this value of gains we can Tune Controller and get errorless output.

If we modulate the gains then we'll observe change in settling time , overshoot etc.

As we ave set SET-POINT value o ground which is zero, so ideal outcome is zero frequency we can say

Kd = 0.01

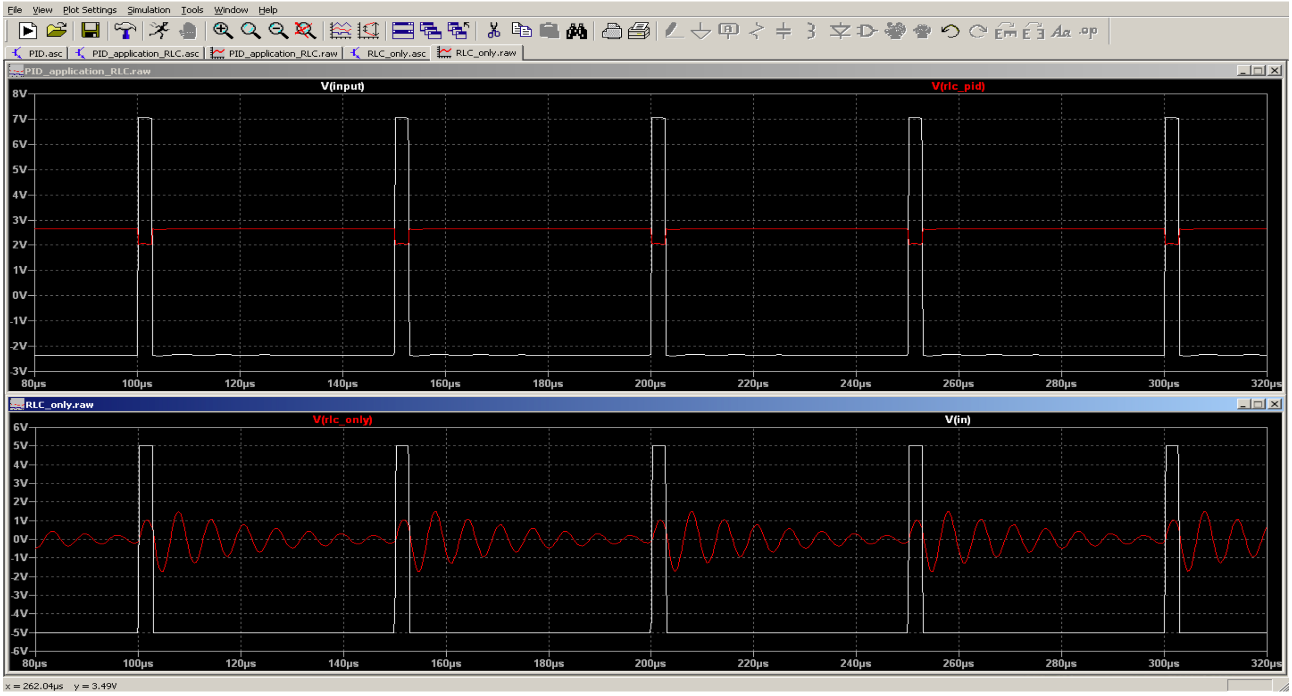

Fig 6.6 Response when Kd increases

- upper graph ->RLC with PID
- as shown in upper graph of Fig 4.7, by increasing Kd settling time of response decreases

7 . Conclusion :

here we are implementing PID control system concept using Analog electronics , we observed that utilizing of linear electronics component in such this type of application , it requires more precise analysis and calculations for choosing exact component for perform desired operations. We have successfully got output in which we connect our system with Along PID control system. We have also experienced the method of tuning gain , which is quite difficult but we can use any heuristic method (i.e nicolar ziglas , etc). this type of Analog PID system we connect anywhere ew want to control output with manual manipulation in industry. As we have explained in application section this can be used in Self-balance robot , controlling fluid in pipeline and much more industrial application. By Concluding we can say by performing Analog PID with RLC circuit we got less damping output with compare to its normal RLC circuit output as shown in figure 4.5 and 4.6 that means this type of concept can be apply anywhere in daily life problems also.

8. Future Scope

There is a great scope of research into this field of control system. This involves the realization of OPAMPS for tuning of the PID controller. The design of the controller is capable of ensuring closed loop stability for arbitrary order plants. But what lacks is the comparative analysis between different tuning techniques. This study would thus surely come handy to such need of comparative analysis and also help in understanding the changing trends in the field of PID controller design. Few of the recent trends in the field of PID control design are optimal design through graphical approach and minimization of error due to approximation in numerical analysis technique.

9. References:

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