# Design of Lag Compensator for Process Control using MULTISIM®

Yugal K. Singh, Jayendra Kumar, Keshav K. Pandey, Rohit K. and Bhargav. A
Dept. of Electrical and Electronics Engg.,
RVS College of Engineering and Technology,
Jamshedpur-831012, INDIA

***Abstract*— This paper presents the procedure for designing a lag compensator using MULTISIM®. The stability of a process model is determined by its Phase Margin and Gain Margin. For robust design of a closed loop system it is required to keep these margins to be greater than zero. Lead, lag and lead-lag compensators are used to ensure that the stability margins are at the desired levels. In this paper we present the step wise procedure for designing a lag compensator to obtain the required stability margins with the help of suitable example.**

***Keywords*— Control System Design; Lag Compensator; Stability Margins .**

## I. INTRODUCTION

In the modern engineering systems design of stable control systems plays a significant role. Stable controllers for the plant process results in improved quality of the product, minimization of product price, time for production etc. It also prevents the occurrence of plant failures and other accidents. Several approaches are presented for designing of control systems such as Bode plot [1], Root Locus Technique [2], Nyquist plot [3] etc. These techniques are classified using the generic term classical control techniques. In the frequency domain approach, the stability of the system is measured using its stability margins namely the Phase Margin (P.M) and its Gain Margin (G.M). For a system to be stable these margins should be greater than zero. Compensators are used to ensure that the desired stability margins are achieved. Lead, Lag and Lead-Lag compensators are widely used for this purpose. In this paper we present the systematic procedure for designing of a lag compensator using MULTISIM®.

The organization of the paper is as follows: next section discusses the Lag Compensator followed by the discussion of its design procedure in the third section. In the fourth section simulation results are presented and in the last section presents the conclusion of the work

## II. LAG COMPENSATOR

A lead compensator is characterized by the transfer function '$G_c$' which is given in equation (1).

$$G_c = K_c \frac{\left(s+\frac{1}{T}\right)}{\left(s+\frac{1}{\alpha T}\right)} \qquad (1)$$

Here the parameter '$\alpha$' is a constant and should satisfy the following condition:

$$\alpha > 1$$

The Bode plot of the lag compensator with $\alpha$ = 10 [4] is shown in Fig. 1.

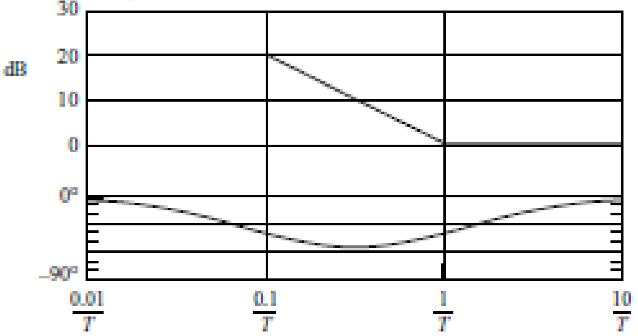

Fig.1. Bode Plot of the lead compensator with $\alpha$ = 10

From the magnitude plot it can be seen that the lag compensator is basically a low pass filter and it can be realized using active filters.

## III. LAG COMPENSATOR DESIGN PROCEDURE

The following are the steps involved in designing of a lag compensator for the plant process characterized by the transfer function '$G_s$'. The closed loop system along with the compensator is shown in Fig. 2.

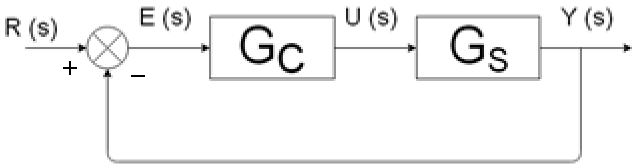

Fig.2. Closed loop system along with the compensator

1. The compensated system has an open loop gain determined by the equation (2).

$$G_cG_s = K_c\frac{\left(s+\frac{1}{T}\right)}{\left(s+\frac{1}{\alpha T}\right)}G_s = K_c\alpha\frac{(Ts+1)}{(\alpha Ts+1)}G_s$$

$$G_cG_s = \frac{(Ts+1)}{(\alpha Ts+1)}KG_s \tag{2}$$

The value of *K* is taken so as to satisfy the error constant value.

2. Bode plot of the $KG_s$ i.e. of the gain adjusted uncompensated system is plotted and the stability margins are calculated.
3. The new gain crossover frequency is chosen to be the frequency at which the phase is equal to -180 ° plus the phase margin, in the bode plot of the uncompensated system. Additional 5°-12° is added is order to accommodate the reduction in phase margin due phase lag of the compensator.
4. The value of the corner frequency ‘1/*T*’ is taken to be one decade lower than the new crossover frequency to prevent detrimental effects of phase lag nature of the compensator.
5. Next we determine the gain in dB needed to bring the gain at the new crossover frequency to 0 dB. This attenuation is equal to -20 *log*($\alpha$). From this we can find the value of $\alpha$.

## IV. SIMULATION RESULTS

Consider the system shown in Fig. 3. We want to design a lead compensator such that the compensated system has a position error constant of 10 $\text{sec}^{-1}$ phase margin of 150° and gain margin of at least 10 dB.

1. To satisfy the position error constant, the value of *K* should be 1.
2. The bode plot of the gain adjusted uncompensated system is shown in Fig. 4. The gain margin is found to be infinite and the phase margin was found to be 100 °.
3. The gain margin criterion has been satisfied and the phase margin has to be compensated for 50 °. An additional phase margin of 5° is added to compensate the shifting of the magnitude plot to the right. So, the total compensation needed is 55°.
4. To avoid the detrimental effect of the lag compensator ‘1/*T*’ is taken as 60.
5. The gain needed to bring the gain at the new crossover frequency to 0 dB is found as 13.97 dB. From the value of $\alpha$ is obtained to be 5.
6. For *K* being 1, the value of $K_C$ should be taken as 0.2.
7. The transfer function of the lag compensator becomes:

$$G_c = 0.2\frac{(s+60)}{(s+13.04)}$$

Finally the compensator is shown in Fig. 5. It can be seen that the compensator is a low pass filter and the parameters of the filter can be obtained easily obtained from the transfer function above. Bode plot of the compensated system is shown in Fig. 6 and it can be observed that the phase margin is close to 155°.

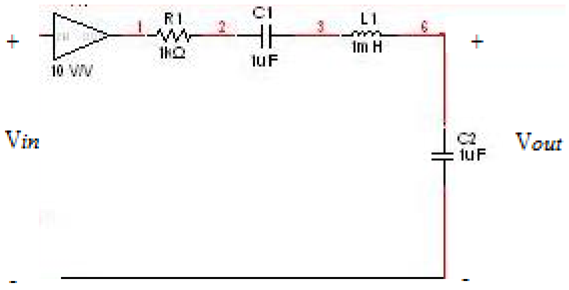

Fig. 3. The uncompensated system

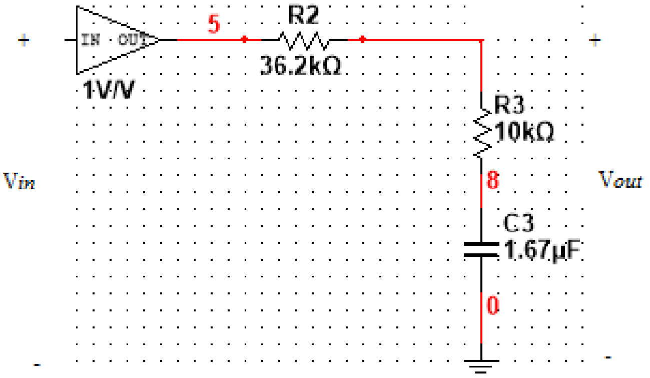

Fig. 5. The lag compensator

## V. CONCLUSION

We have presented the detailed procedure for the design of lag compensator using MULTISIM®. Design procedure was explained with the help of an example and the results are reported. It is observed that using the lag compensator, it is possible to achieve the desired stability margins.

## REFERENCES

[1] Bode,H.W., *Network Analysis and Feedback Design*. New York:Van Nostrand Reinhold, 1945.

[2] Evans,W. R., “Control System Synthesis by Root Locus Method,” AIEE Trans Part II, 69(1950), pp. 66–9

[3] Nyquist, H., “Regeneration Theory,” *Bell System Tech. J.*, **11** (1932), pp. 126–47.

[4] Ogata, K., “Modern Control Engineering,” Prentice-Hall, Upper Saddle River, NJ, pp. 493-502, 2010

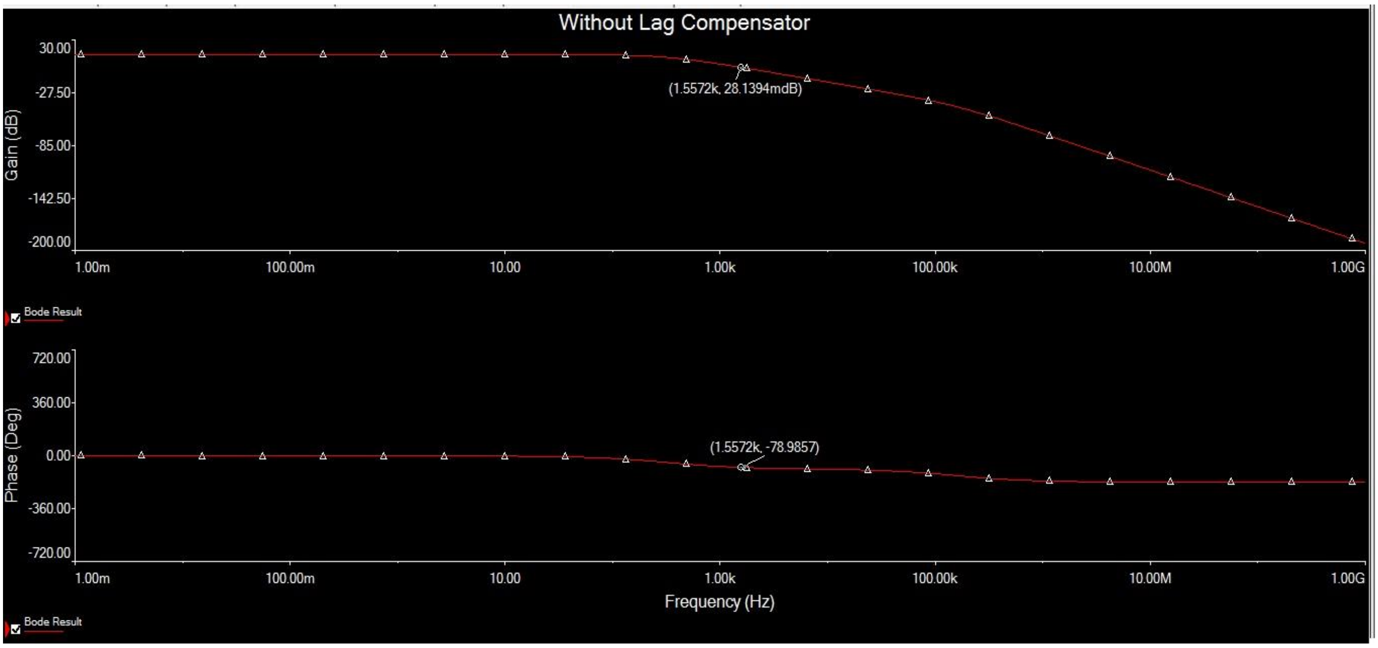

Fig. 4. Bode plot of the uncompensated system

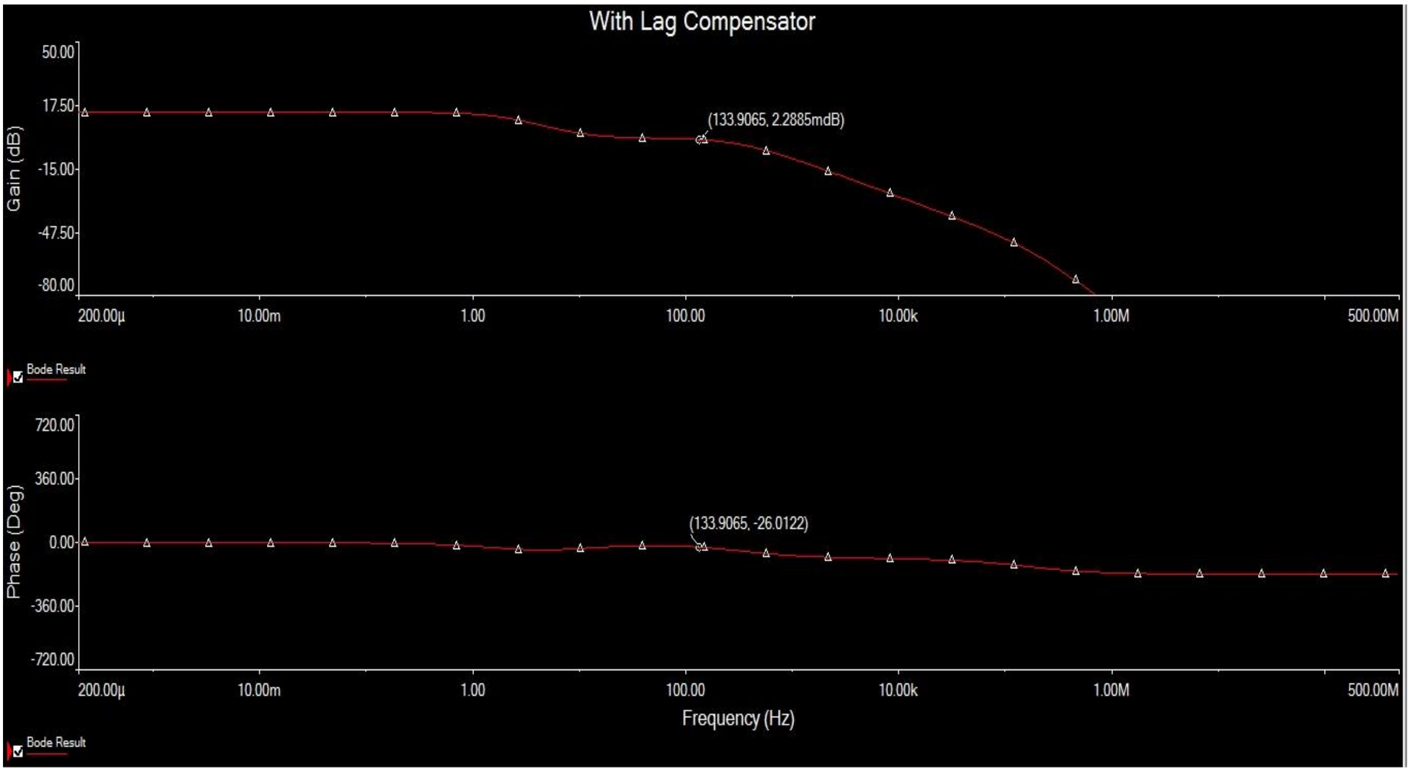

Fig. 5. Bode plot of the compensated system