AN IMPROVED TEMPERATURE CONTROL SYSTEM FOR NEONATAL INCUBATOR

Presentation by:
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Reference material:

AN IMPROVED TEMPERATURE CONTROL SYSTEM FOR NEONATAL INCUBATOR

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ABSTRACT

This work is aimed at modeling an improved system to regulate the temperature inside a neonatal incubator. A neonatal incubator is a device consisting of a rigid box-like enclosure in which an infant may be kept in a controlled environment for medical care. An infant incubator provides stable levels of temperature, relative humidity and oxygen concentration. Temperature control is the most important part of a baby incubator which has to be maintained around 37^0C. In this work, we regulated the temperature at the incubator by adopting an automation technique in which PID temperature control parameters were implemented in microcontroller. Mathematical models of the incubator subsystem, actuator and PID controller were developed and controller design based on the models was also developed using Simulink. The models were validated through simulation, adopting Zeigler-Nichol tuning method as the tuning technique for varying the temperature control parameters of the PID controller in order to achieve a desirable transient response of the system when subjected to a unit step input. After several assumptions and simulations, a set of optimal parameters were obtained at the result of the 3rd test that exhibited a commendable improvement in the overshoot and peak time, thus improving the robustness and stability of the system.

System Design:

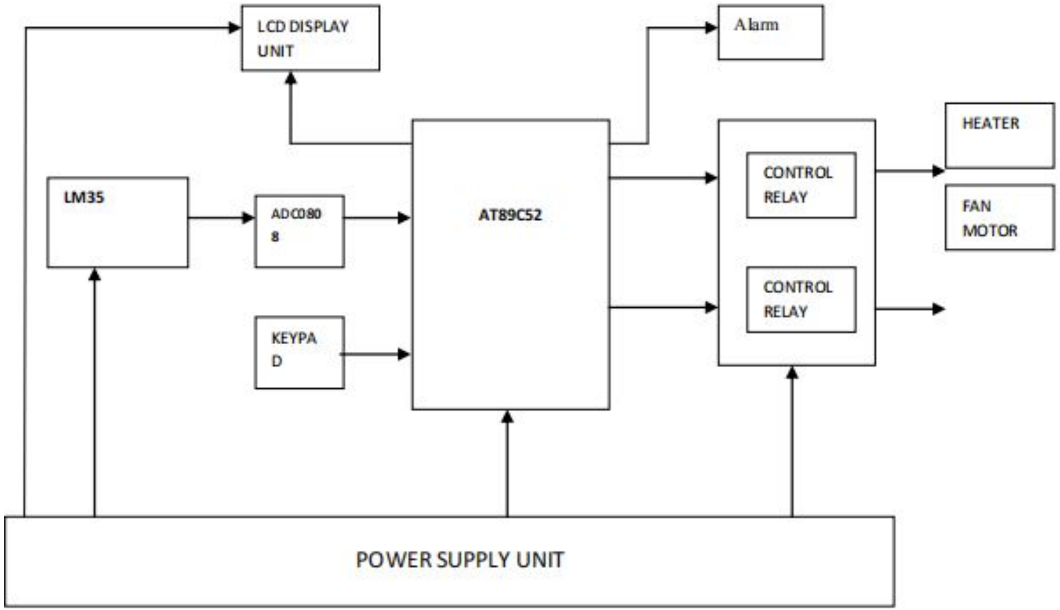
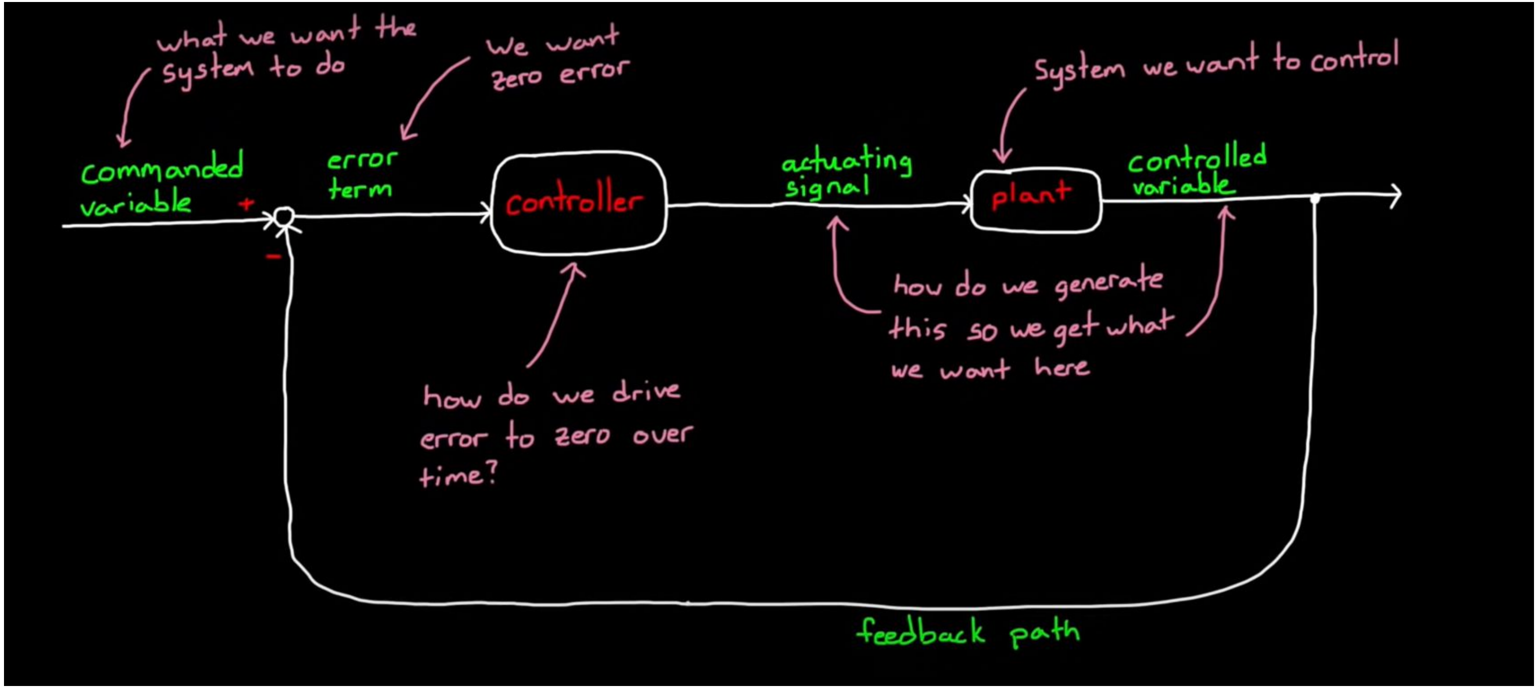


Figure 2.1: Proposed Neonatal Incubation System

A Generalised PID Controller:



PID Controller for our simulation:

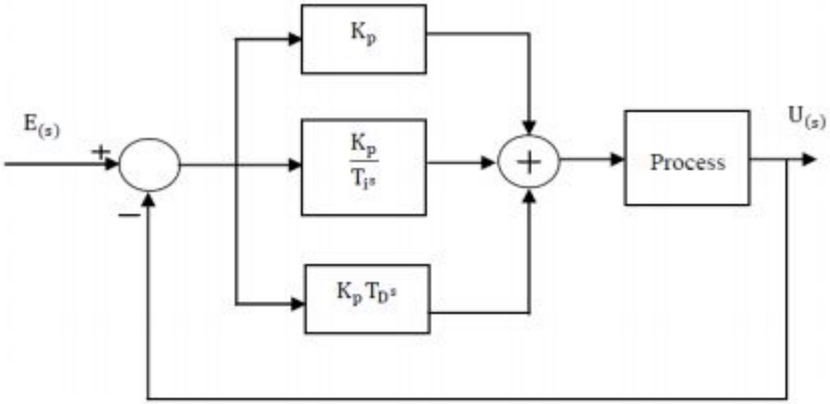


Figure 2.3: Block Diagram of a Continuous Parallel PID Controller [9]

Role of Weighing Factors:

Kp: can reduce the rise time but never eliminate the steady-state error

Ki= Kp/Ti: has the effect of eliminating the steady-state error, but it may make the transient response worse

Kd= Kp*Td: has the effect of increasing the stability of the system, reducing the overshoot, and improving the transient response.

Closed loop model of incubator

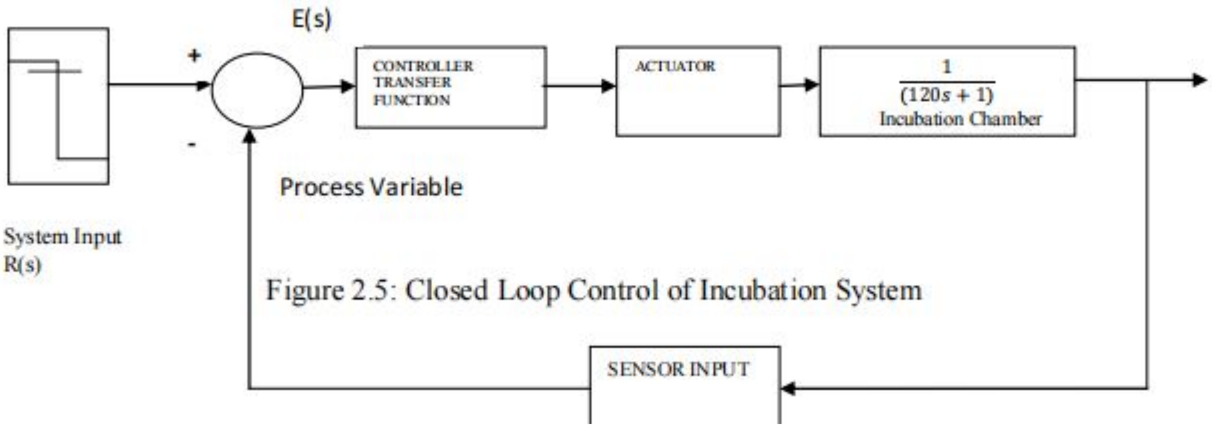


Figure 2.5: Closed Loop Control of Incubation System

Simulink Model provided by the paper:

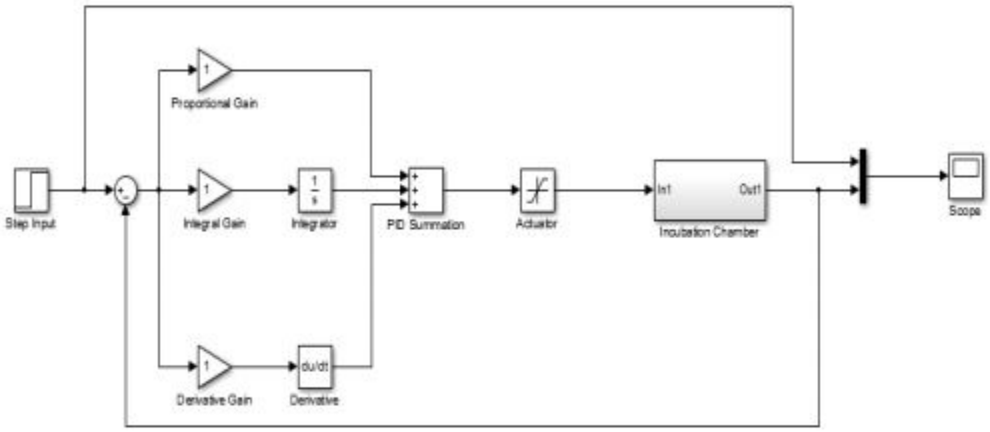
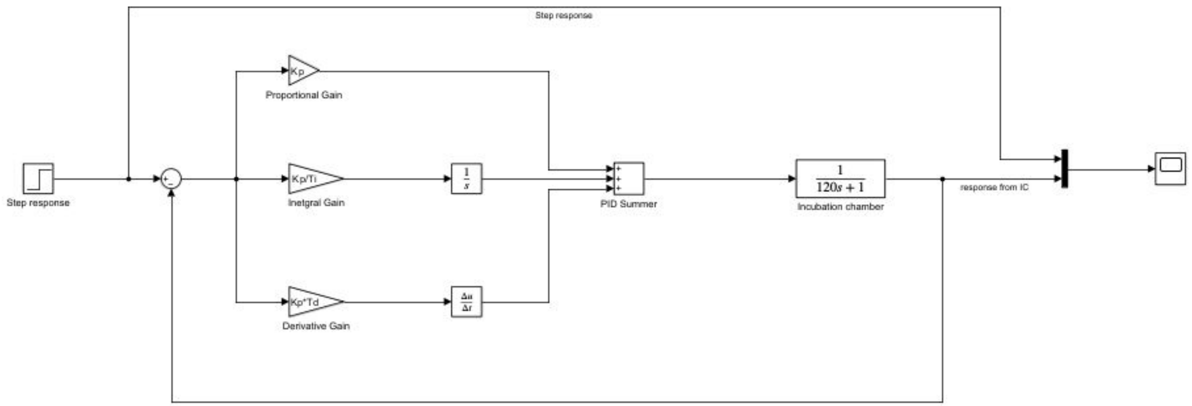


Figure 3.1: Simulink Block Diagram of the incubation temperature control system

Simulink Model designed by me:



The actuator (saturation) block is missing in my model because the required parameters have not been mentioned in the paper.

After trying to guess the upper and lower limits, all of them distorted the graphs heavily.

So, I tried to tune the weighing factors without the actuator block.

Discussion of Results:

Test-1:

TEST 1:

Consider the following assumed values of the parameters of the PID controller and the response of the system to these values

TABLE 3.1
The first assumed values of the PID temperature control parameters

Parameter	K_p	T_i	T_d
Values (sec)	0.2850	0.1170	0.3626

Test-1:

From paper

PLOT:

Figure 3.2: Scope of the unit step response of the system for test 1

TABLE 3.2: Result of test 1

parameter	T_r (sec)	T_p (sec)	T_s (sec)	Mp (%)
Values	37.8	100	728	58

Test-1:

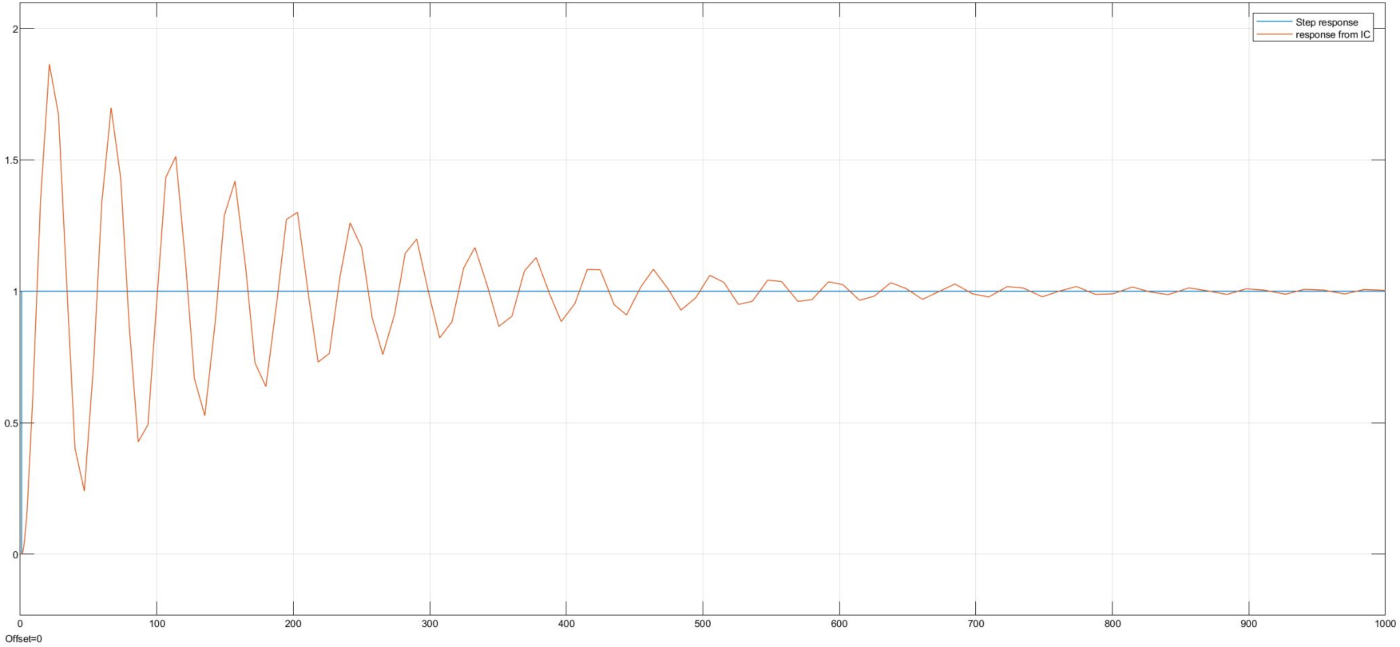
From my model

Tr=13.074s

Tp= 22.011s

Ts=707s

Mp=86.2%



Test-2:

TEST 2:

TABLE 3.3
The second assumed values of the PID temperature control parameters

Parameter	K_p	T_i	T_d
Value	1.9689	0.0504	0.6300

Test-2:

From paper:

PLOT:

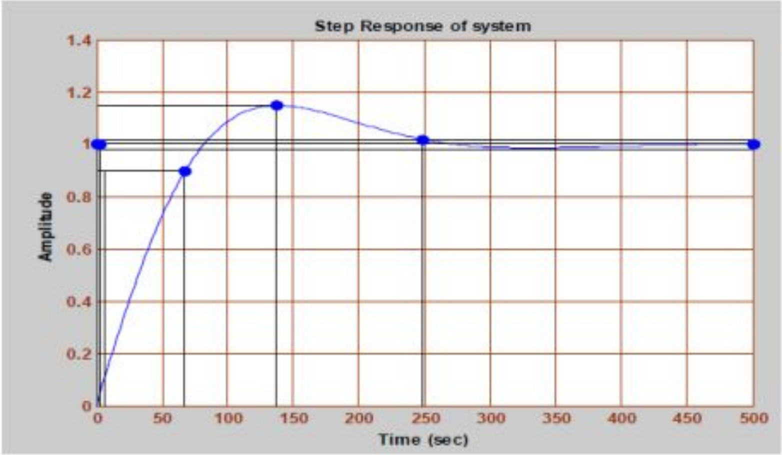


Figure 3.3: Scope of the unit step response of the system for test 2

RESULT:

TABLE 3.4: Result of test 2

Parameter	T_r (sec)	T_p (sec)	T_s (sec)	M_p (%)
Values	62.0	138	249	15.0

Test-2

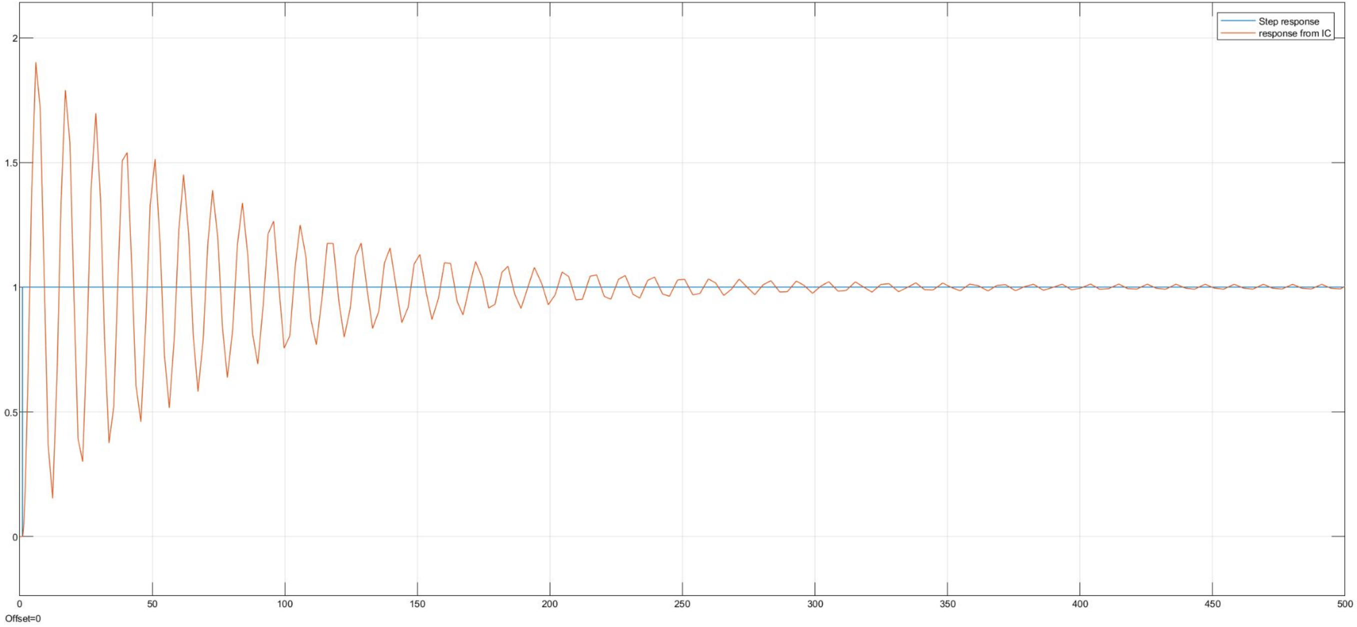
From my model

Tr=2.25s

Tp= 6.389s

Ts=292s

Mp=86.3%



Test-3:

TEST 3:

TABLE 3.5

The third assumed values of the PID temperature control parameters

Parameter	K_p	T_i	T_d
Values (sec)	16.374	0.1325	3.3288

Test-3

From paper:

PLOT:

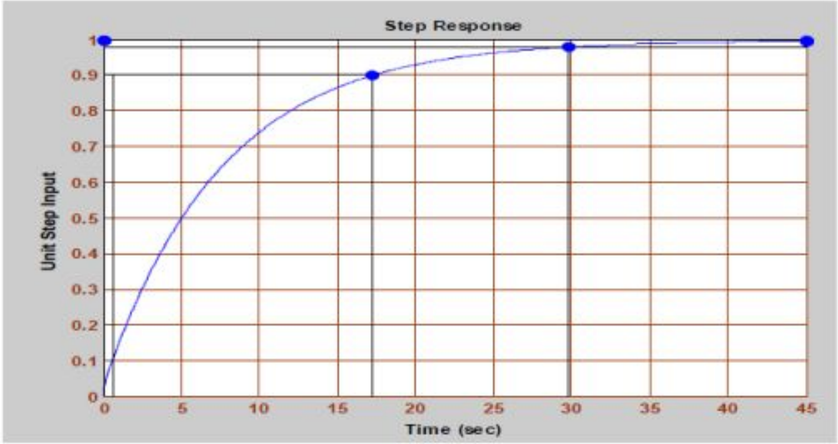


Figure 3.4: Scope of the unit step response of the system for test 3

RESULT:

TABLE 3.6: Result of test 3

Parameter	T_r (sec)	T_p (sec)	T_s (sec)	M_p (%)
Values	16.8	----	30.0	----

Test-3:

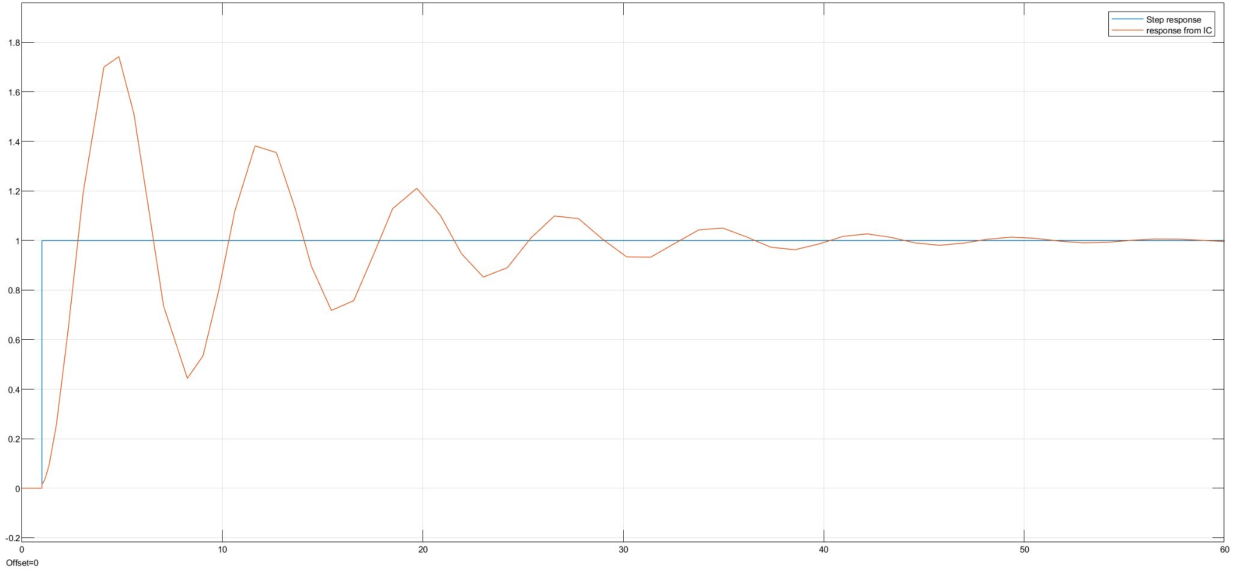
From my model

Tr=2.2s

Tp= 4.783s

Ts=39.5s

Mp=73.5%



Test-4:

```
Kp=16.374;
Ti=150;
Td=0.01;
```

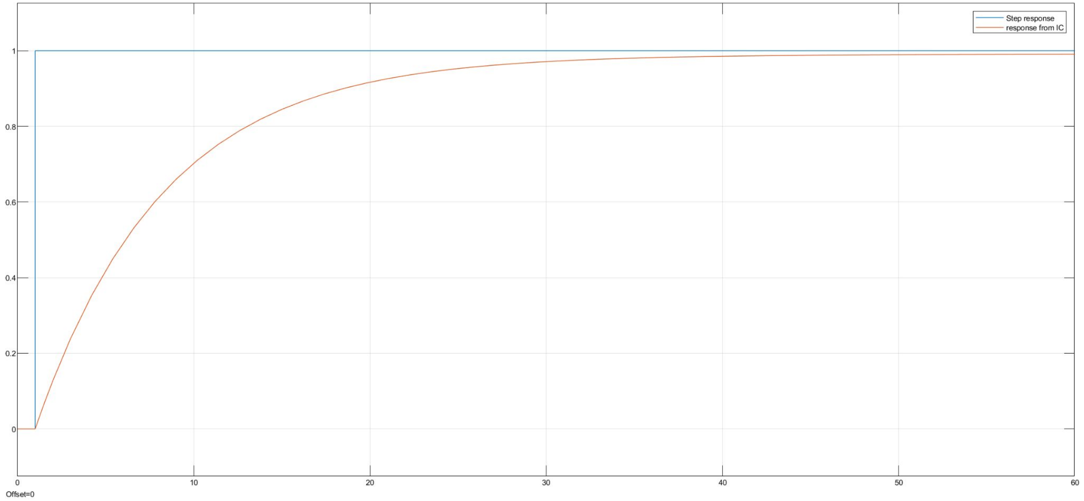
From my model

Tr=24.5s

Tp=--

Ts=32.8s

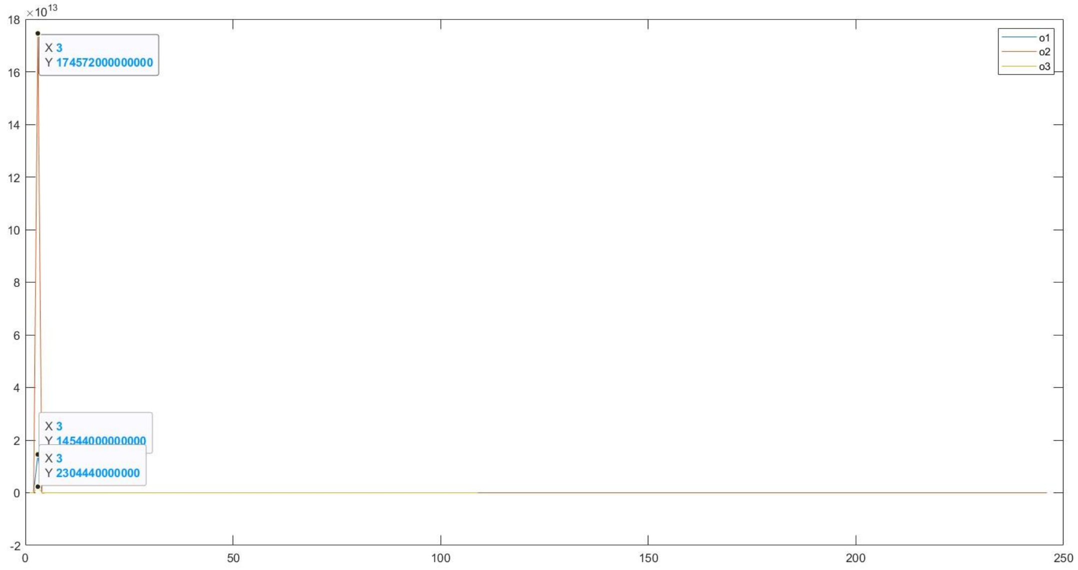
Mp=--



Thank you for listening

Feel free to ask any questions.

Appendix:



$\times 10^{13}$
X 3
Y 174572000000000
X 3
Y 14544000000000
X 3
Y 2304440000000
o1
o2
o3
18
16
14
12
10
8
6
4
2
0
-2
0
50
100
150
200
250

Appendix:

$dq = cd\theta_1$
(2.1)
c = heat capacity
By dividing both sides by dt

$$\frac{dq}{dt} = \emptyset = \frac{cd\theta_1}{dt}$$

(2.2)
The rate of heat transfer into the incubator is $\emptyset = \frac{cd\theta_1}{dt}$ and the rate is governed by the thermal resistance between the air and the incubator. This obeys a law similar to ohms law so:

$$\emptyset = \frac{(\theta_2 - \theta_1)}{R}$$

(2.3)
Where R is the thermal resistance in Kelvin per watt. Equating for $\emptyset$ we have

$$\frac{cd\theta_1}{dt} = \frac{(\theta_2 - \theta_1)}{R}$$

(2.4)

$$\frac{d\theta_1}{dt} = \frac{(\theta_2 - \theta_1)}{RC}$$

(2.5)

$$\frac{d\theta_1}{dt} + \frac{\theta_1}{RC} = \frac{\theta_2}{RC}$$

(2.6)
In all system, the product of the resistance and capacitance is the time constant τ so we have:

$$\frac{d\theta_1}{dt} + \frac{\theta_1}{\tau} = \frac{\theta_2}{\tau}$$

(2.7)
Changing from a function of time into a function of "s" we have

$$s\theta_1 + \frac{\theta_1}{\tau} = \frac{\theta_2}{\tau}$$

(2.8)

Appendix:

$$\theta_1(\tau s + 1) = \theta_2$$

(2.9)

$$\frac{\theta_1}{\theta_2}(s) = \frac{1}{(\tau s + 1)}$$

(2.10)

Where $\tau = 120$ seconds, assumed time it takes to reach maximum temperature

Therefore

$$\frac{\theta_1}{\theta_2}(s) = \frac{1}{(120\, s + 1)}$$

(2.11)

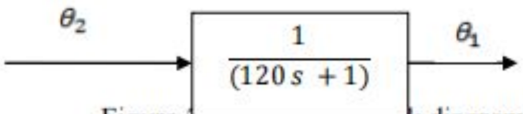


Figure 2.2. Modeled block diagram of the incubation subsystem