INCUBABY IB03
TEAM DESİGN PROJECT:
A GUİDE FOR OVERALL SİMULATİON OF CYBER PHYSİCAL IB03 SYSTEM

May 2022

IncuBaby (IB03)
Design of simulation of *low end controller* for a *premature infant incubator* connected to NodeRed on a PC for high end user interfacing through Web Dashboard.
Cyber Physical Simulation by Signal Flow Diagram

OBJECTİVE:

A- Building a **cyber-physical simulation prototype** on SciLab XCOS or SciLab coding language to

i- test the conceptual interactions in cyber physical system and verify the temperature stability of the designed proportional control action for infant incubator function.

ii- determine the stable control law and parameters for the physical system which includes the ADC-sampling time, and the PWM heating action by your signal flow diagram.

INTRODUCTION

Newborn infant incubation is available in literature[1] including the effects of incubation temperature depending the baby weight and prematureness. British Medical Journal reported that

> "the baby's need to produce heat can be kept to a minimum without a thermal blanket, radiant shield, or double-walled incubator so long as the air temperature is adjusted to allow for the radiant loss, either by hand or by using a servocontrol probe. It reports that unfortunately, most incubators are still supplied with an unlockable control knob that is all too easily altered when touched or leant on, and many still have their safety thermostat adjusted so that air temperature cannot be set manually above 35°C. Servocontrol devices should not normally be necessary so long as room temperature is reasonably stable: they can cause overheating if the skin sensor comes loose, obscure the signs of early septicaemia, and subject an infected infant with a raised thermoregulatory "set point" to appreciable cold stress."

Our company already has a product, DigiTerm-01 and DigiTerm-02, with serial ports to transmit the measured environment temperature to PC by serial to USB converter at 9600 baud, and display it also on the LCD display module. It is built on an Arduino-Uno using Visual-coding. The new policy of our company implies re-design of the unit with product code DigiTerm-03, using Arduino-Sketch coding language.

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[1] Br Med J: first published as 10.1136/bmj.281.6253.1443 on 29 November 1980.

At this part of project, you should construct a signal flow diagram that describes the **IncuBaby-03** incubator system.

INFANT INCUBATOR UNİT STRUCTURE

a- The physical infant incubator system is made of the two main parts:

i- the transparent outer air jacket with heater-fan system to heat the air in the jacket. A simple **24V - 50 W heater** heats the air blown by a fan. The warm air circulates in the transparent jacket of the incubator. The air circulation transfers heat to baby mainly through the surface where infant is placed.

ii- the transparent double-wall cover that protects the heat in the inner chamber of the incubator. The inner chamber is the cavity in between the cover and the jacket, where baby is placed on an inflated silicon baloon pad that allows temperature flow by inner convection.

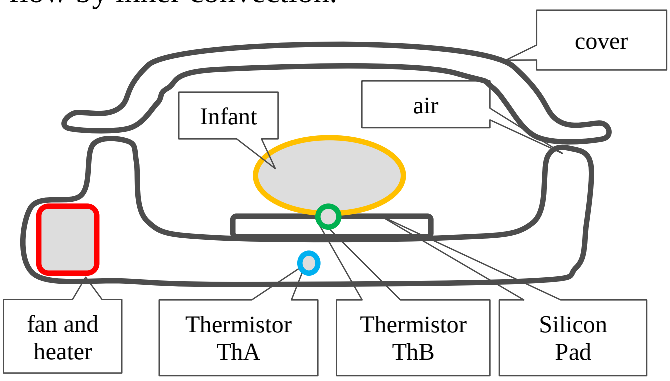


Figure 1 Crossectional view of the infant baby incubator unit.

b- Temperature control for desired *ThD* is provided by a proportional controller and a power inhibit logic at excess *ThA* to prevent harmful temperature rise. Heater shall be activated by PWM periodically at every second.

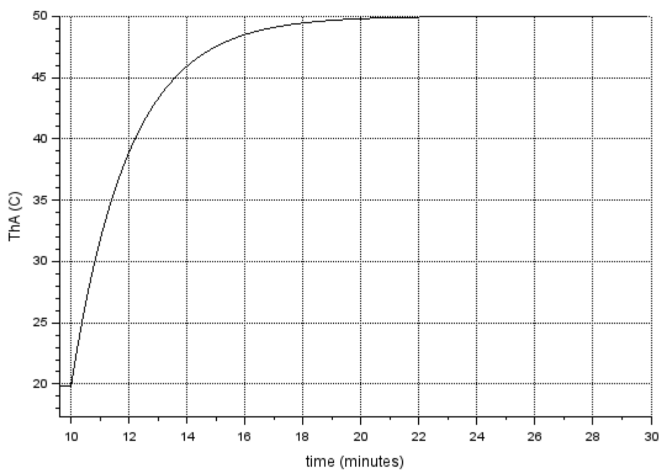


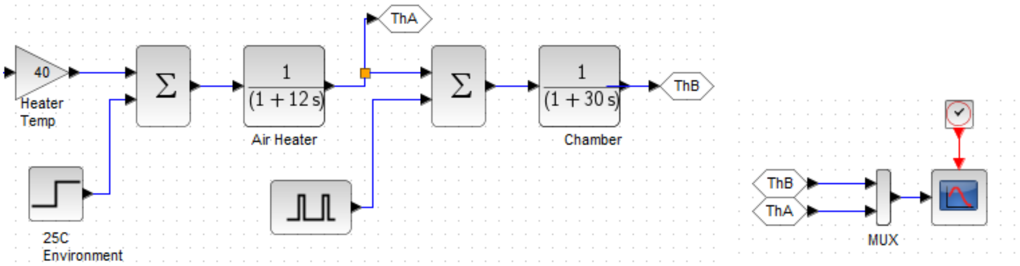
Figure 2. The response of Incubator jacket air temperature for full power applied to heater starting from time t=10. Test started at 20C room temperature.

i- Air jacket contains a **4k7 thermistor** with **beta=3900** as sensor. The heater-fan response is shown in Fig-1. The **time constant** and heating effect of the heater shall be determined by this plot.

ii- The **incubation chamber (including the infant) has a time constant about 30 minutes**. It may be twice high depending on weight of the infant. Heat loss to environment from the inner chamber is negligible while the cover is closed.

A. Physical Part of CPS

By these information, it is possible to build the signal flow diagram of the temperature model for ThA and ThB.



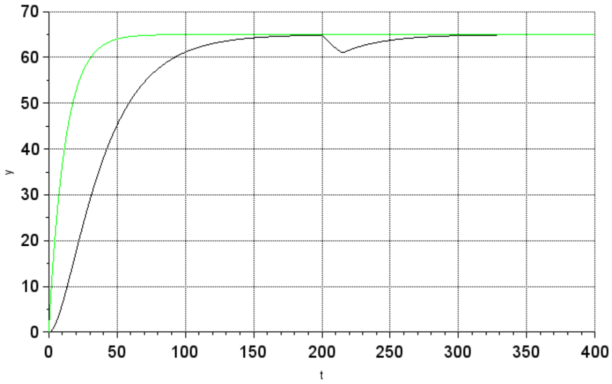
The heater increases the temperature of the air-heater output 40 C. That means, at 25C environment temperature, the airchamber temperature raise from 25C to 65C. We obtain it on signal flow diagram by a gain block.

Parameters of the blocks are:

GAINBLK for effective temperature of heater: 40, 0
STEP_FUNCTION for environment: 0, 0, 25
SUMMATION block for airheater: 1, [1;-1],0
CLR block for airheater: 1, (1+12*s)
GENSQR_f squarewavegenerator: 200, 5, 400, -10
GENSQR_f generates a single -10C pulse that represents the cover opened at 200 minutes.
SUMMATION block for container: 1, [1;1],0
CLR block for airheater: 1, (1+30*s)

You may test the circuit by applying a step input

Simulation Setup: Final integration time: 400
MUX for ThA-ThB CSCOPE: 2 (two inputs)
CSCOPE for ThA-ThB: (for 400 minutes display)
Ymin, Ymax, Refresh, Buffer: 0, 70, 400, 400
CLOCK_c for ThA-ThB cscope: 0.01 , 0 .
STEP_FUNCTION for environment: 0, 0, 1
Run
Use SciLab console commands:
`xgrid` to to get grid on graph.
`gca.font_size=4` for larger fonts.



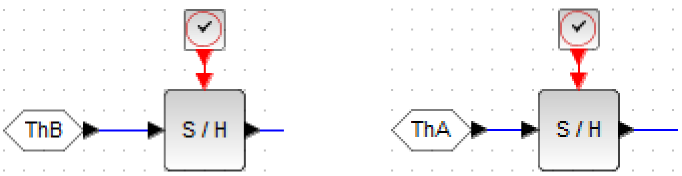
You should notice that at t=200 the container cover opened for 5 minutes.

B. CYBER PART

The PID+PWM temperature controller should be implemented using an Arduino UNO, which bounds ThA at 37C, and controls ThB to stay at desired temperature ThD=32 C.

i. Sample Hold for ADC of ThA and ThB

1. ADC of ThA and ThB should have a sampling period Ts. We will set Ts=1 minutes.

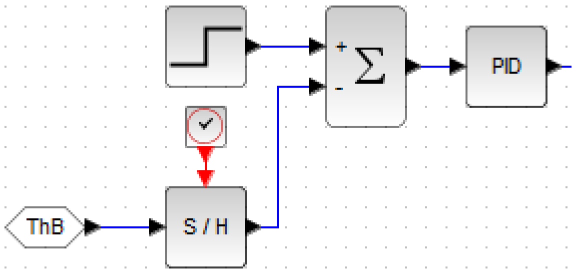


Parameters of the blocks are:

SAMPHOLD_m for ThB: datatype: 1
CLOCK_c for ThA samphold: 1 , 0 .

ii. ThD and PID output

PID controller should be composed by a step input for ThD, and the sampled ThB value.

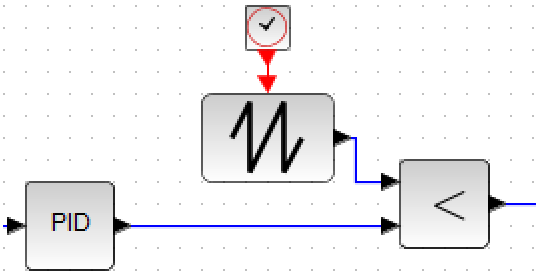


Parameters of the blocks are:

STEP_FUNCTION for ThD: 0, 0, 32
SUMMATION block for PID : 1, [1;-1],0

iii. Heater PWM for PID output

The PID control output is boundless. To apply it to the heater, we need a PWM generator. Easiest method to build a PWM is to compare PID output by a sawtooth function.



Parameters of the blocks are:

PID : You may start by setting it 10, 0, 0. In the design you shall find a proper value that reduce the oscillatory behaviour and at the same time the error. You will see that higher values of Kp is not beneficial for this case.

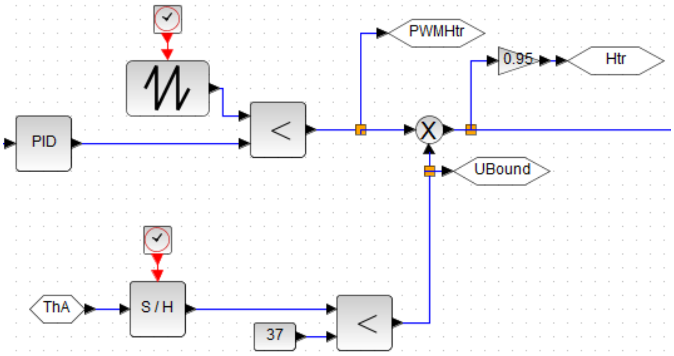
SAWTOOTH_f for PWM: no parameter. It generates ramps in 0..1 range with period specified by its clock input.

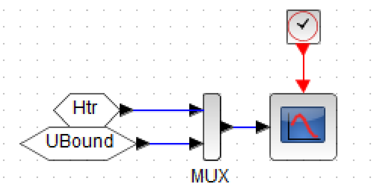
CLOCK_c for ThA samphold: 1 , 0. This clock will restrict the chattering of heater relay to less than once per minute. A typical relay that drives a heater is expected to have maximum contact life of about 100000 on-off cycles.

RELATIONALOP operation, zero-cross, datatype: 2, 0, 1.
At this settings, output is 0 if first input is less than the second input.

iv. Upper bound restriction for ThA.

ThA should never exceed 37 degrees. For this purpose, we should compare sampled value of ThA by 37C, and multiply (for logical AND action) the result to PWM output.



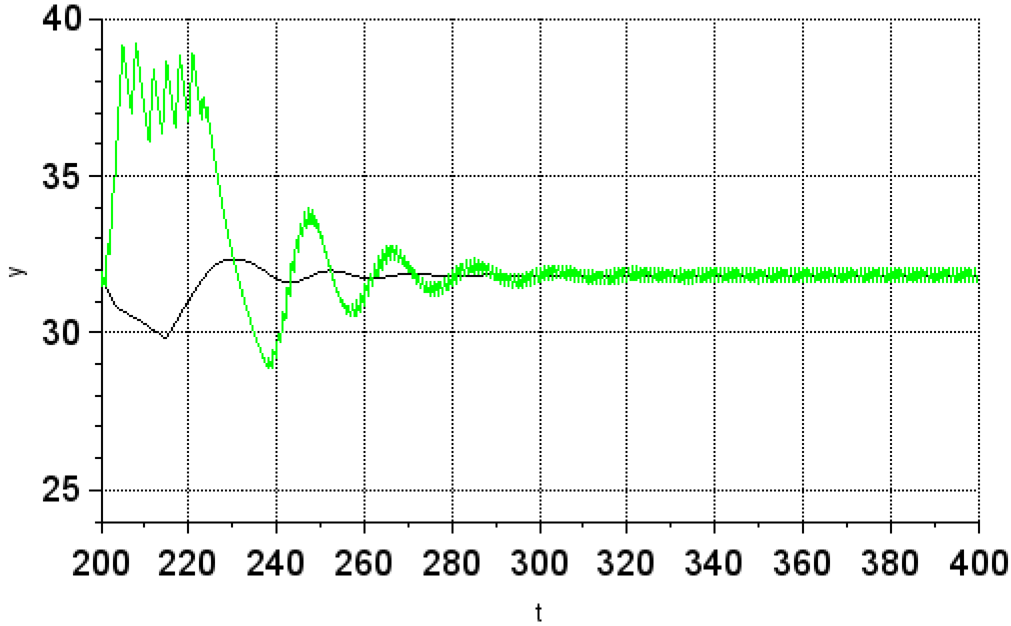


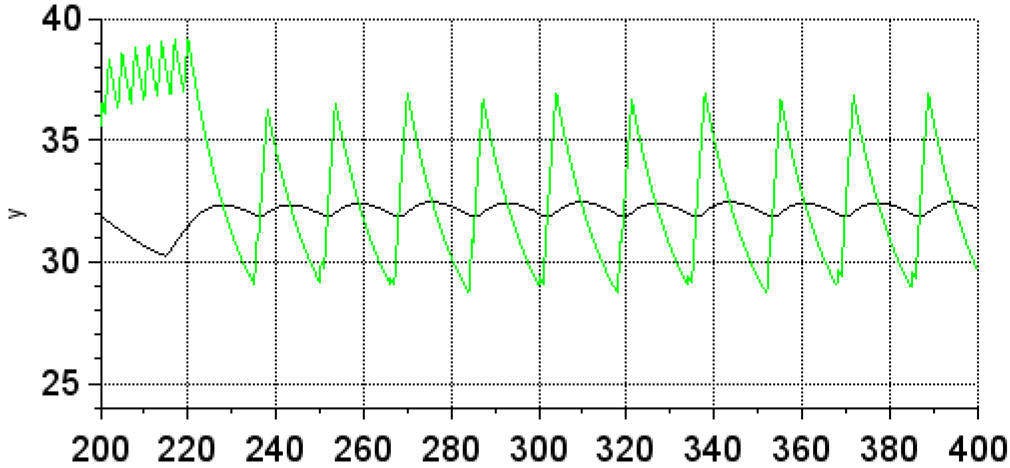
Parameters of the blocks are:

CONST for 37C: 37
RELATIONALOP operation, zero-cross, datatype: 2, 0, 1.
PROD_f: no parameter, output is product of inputs.
GAINBLK : 0.95, It shifts Htr curve on CSCOPE for better visibility.
MUX for ThA-ThB CSCOPE: 2 (two inputs)
CSCOPE for Htr-UBound: (for 400 minutes display)
Ymin, Ymax, Refresh, Buffer: 0, 1, 400, 400
CLOCK_c for ThA-ThB cscope: 0.01 , 0 .

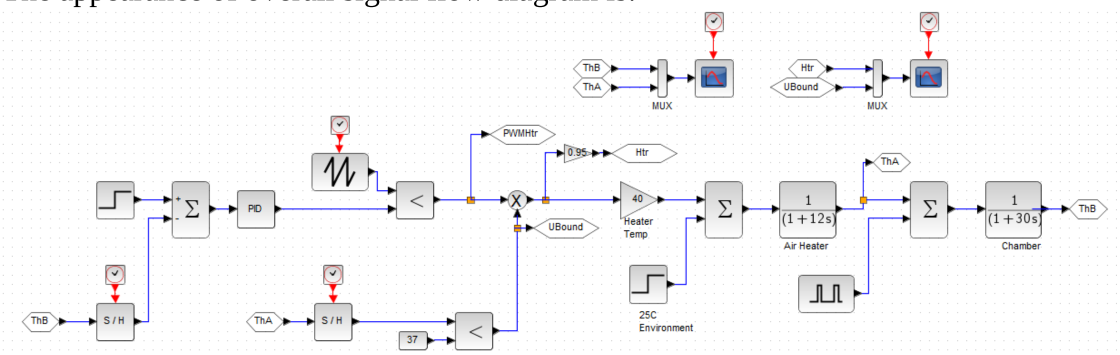
iv. Running overall simulation diagram

Use 400 minutes final simulation time at simulation setup. For better view of ThA-ThB set CSCOPE to (Ymin, Ymax, Refresh, Buffer: 25, 40, 200, 400). By this settings you eliminate the first 200 minutes, the initialization phase of test. Use the console commands `xgrid` and `gca.font_size=4;` to get grid and large fonts. Following plots are obtained by two different Kp values:





The appearance of overall signal flow diagram is:



REPORTİNG:

This practice targets to prepare you for the first part of the team design, which will be included also into the final exam questions. You shall prepare individual reports describing input-output of each part of the overall system.