

# MATHEMATICAL SIMULATION OF CONTROL SYSTEM IN MODAL VISION STUDIUM

Author : Konstantin Melnikov

Advisor : professor Yuri Senichenkov

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- ▣ History and hierarchy of MVStudium
- ▣ MvStudium's mathematical models
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# MvStudium

is the tool with  
graphical, UML-based  
language for  
modeling and simulation  
of complex dynamical systems  
(Object Oriented Modeling)

UML - unified modeling language, object-oriented language of  
prototyping of big program complexes and computing systems

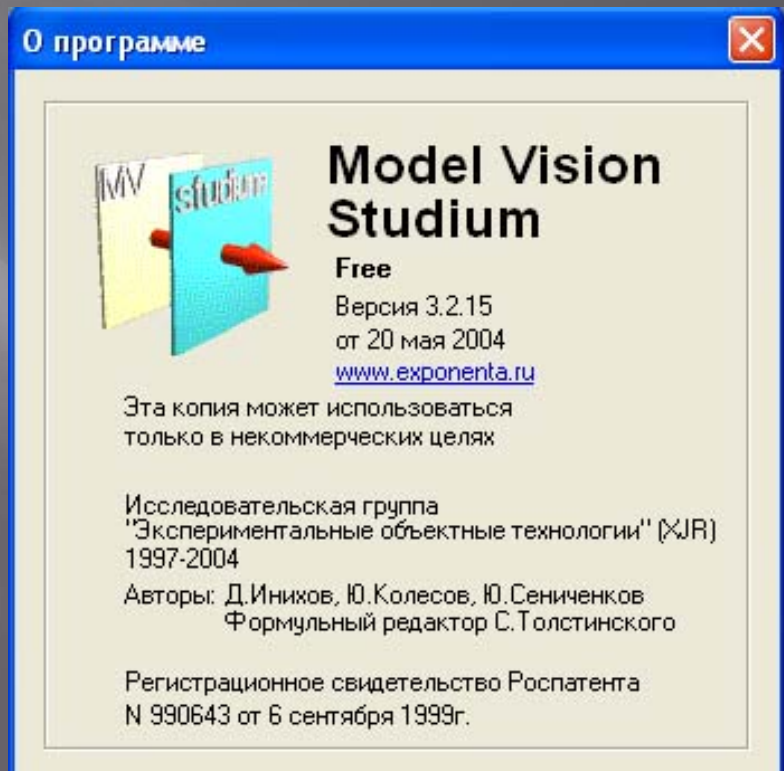
<http://www.mvstudium.com>

# Complex dynamical system is

Large scale,  
Hierarchical,  
Event-driven (hybrid)  
mathematical model  
with dynamically changed  
behavior in short time  
interval

# The Model Vision Family

- ▣ MV 2.1 - 1994-1996
- ▣ MVS 3.0 - 1996-2003
- ▣ MVS 4.X - 2004-2005
- ▣ MVS 5.X - 2005 – our days



# CONCEPTS AND DEVELOPMENTS, INCLUDED IN BASIS OF MVS

Ole-Johan Dahl, Bjorn  
Myhrhaug, Kristen Nygaard

SIMULA 67

Glushkov V., Gusev V.,  
Marjanovich T., Sachnjak M.

Tools for modeling mixed  
continuous and discrete systems.

1975

Booch G. Jacobson I.,  
Rumbaugh J.  
The unified modeling  
language for object-oriented  
modeling  
1977

A. Alan Pritsker.  
Introduction to Simulation and  
SLAM II .

1986



MvStudium

Maler O., Manna Z,  
Pnueli A.

A formal approach to  
hybrid systems.  
1992

Fillipov A.

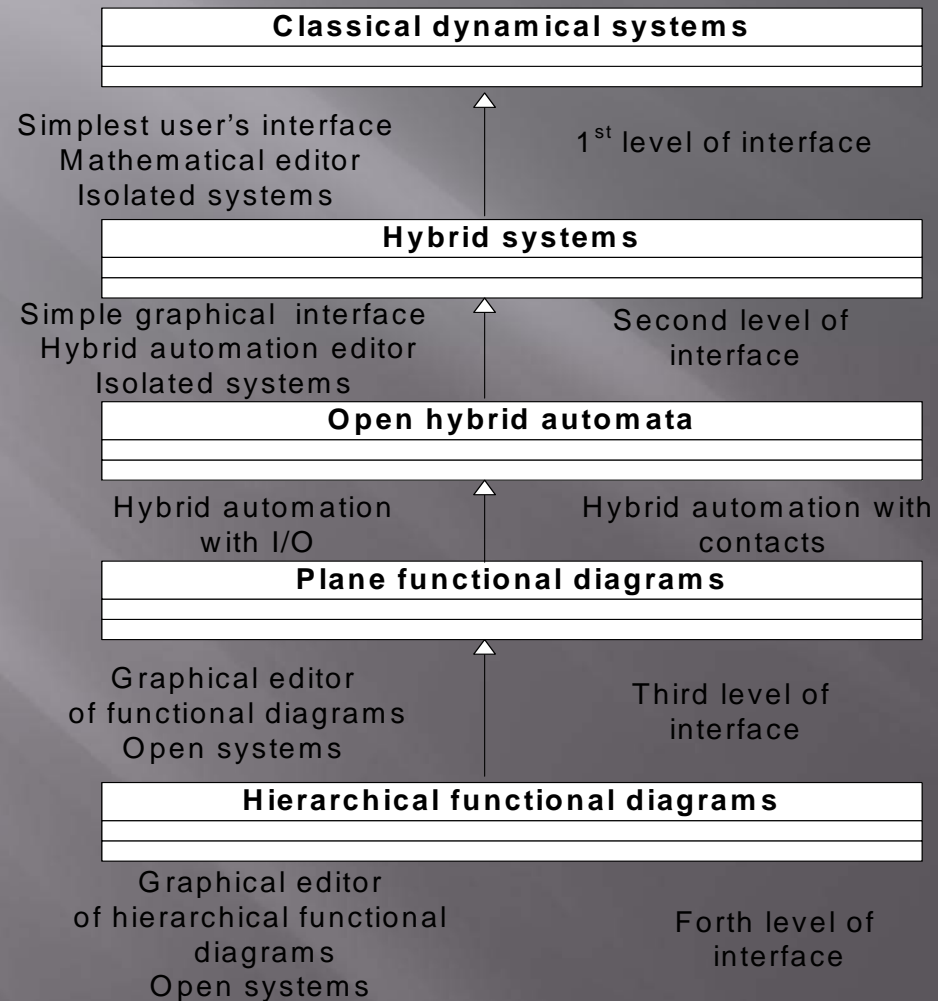
Differential equations with  
discontinuous right-hand  
side.  
1985



The authors of SIMULA  
67 offered for the first  
time idea of creation of  
special models - classes  
for the description of  
objects with internal  
properties and behavior.  
So there was a new  
approach - object-oriented

# BRIEF REVIEW OF THE HIERARCHY OF MODELS

## MvStudium models



# MvStudium's mathematical models



# Classical dynamical system (continuous time)

is a system of differential equations

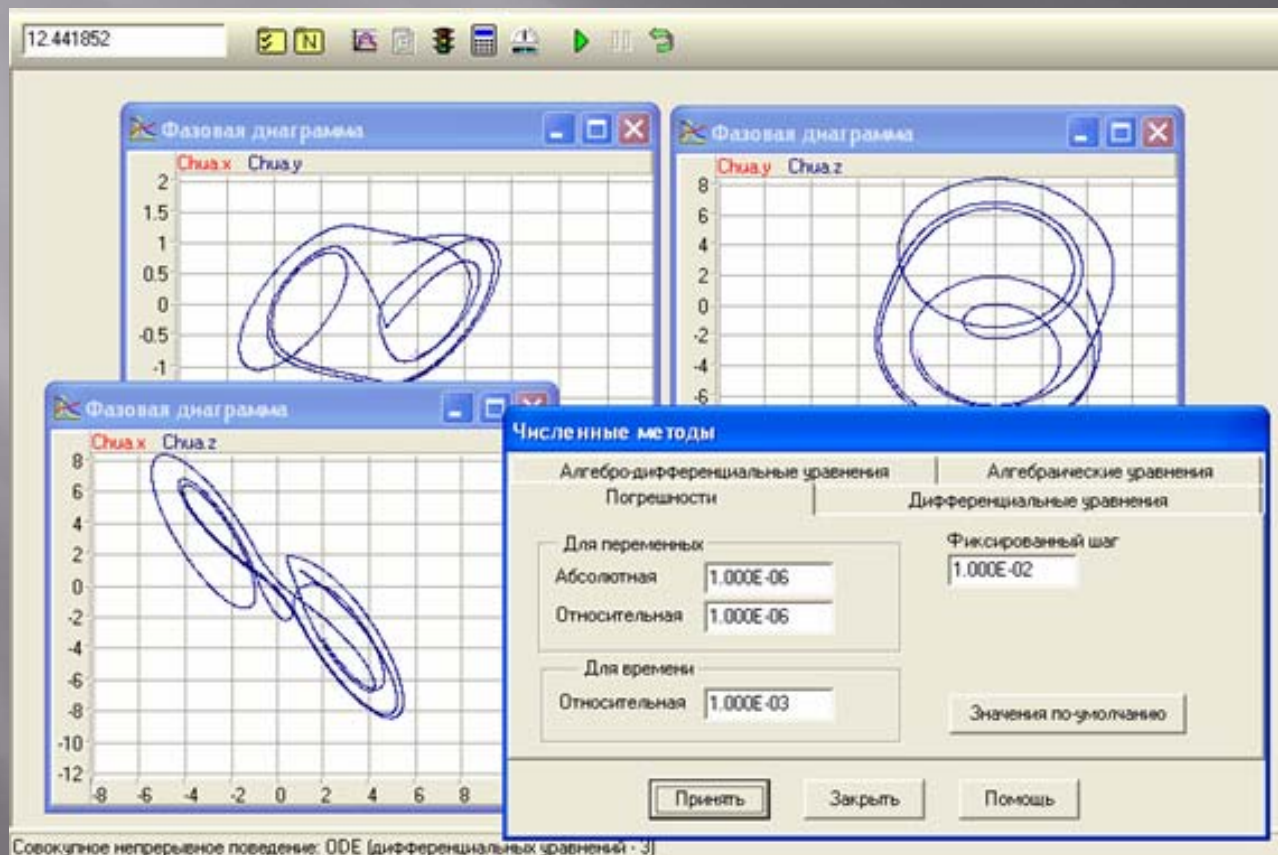
$$\frac{dx}{dt} = f(x), x \in \mathfrak{R}^n, x(0) = x^0$$

with right hand side  $f(x)$ , ensuring  
existence and uniqueness of the solution

$$x = x(t; x^0)$$

$t$  – an independent real variable - continuous  
time

Here evident result of modeling of similar system in MVS. It is possible to be convinced, that these schedules - phase characteristics of system – are really continuous.

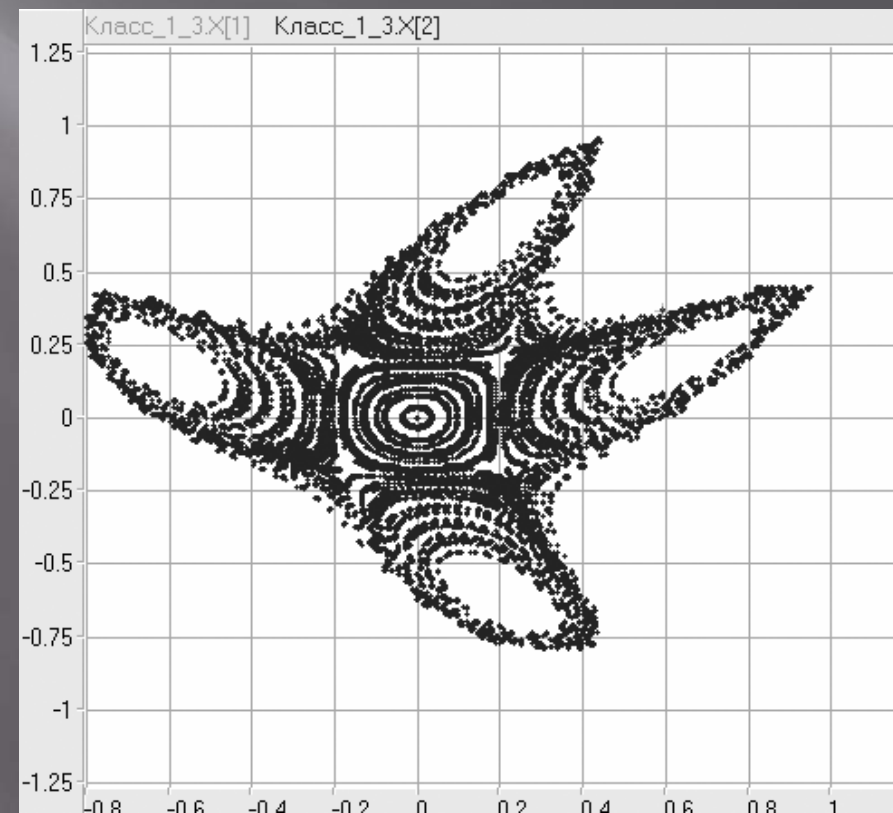
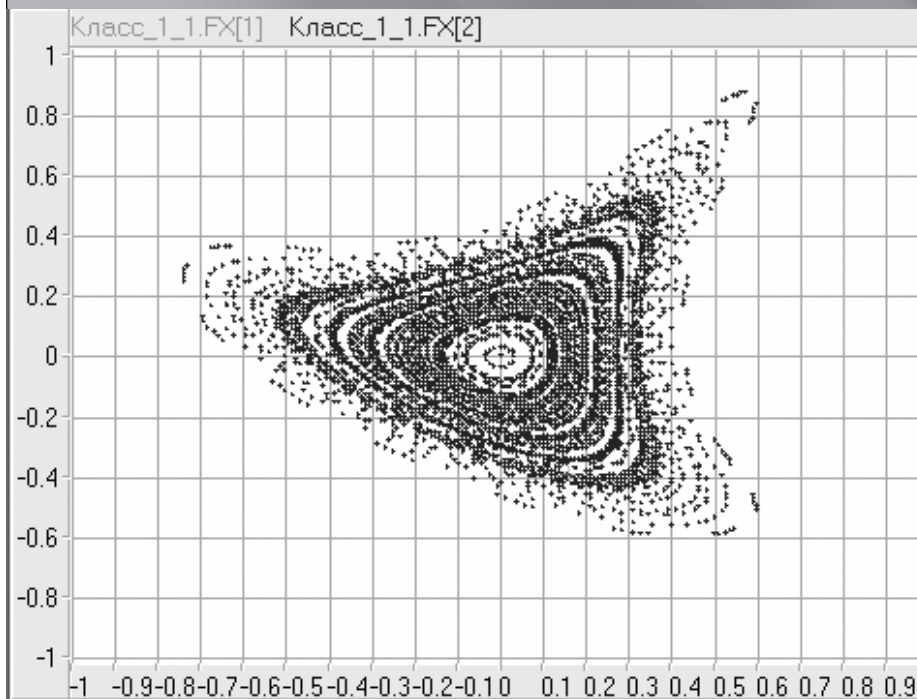


# DISCREET DYNAMICAL SYSTEMS (DISCREET TIME).

$$\begin{cases} x_{n+1} = x_n \cdot \cos \alpha - (y_n - x_n^2) \cdot \sin \alpha \\ y_{n+1} = x_n \cdot \sin \alpha - (y_n - x_n^2) \cdot \cos \alpha \end{cases}$$

In discrete models we cannot speak about the differential equations because can not be a speech about derivative of function when it depends on discrete time. In such models we deal with systems of the difference equations.

Here the result of modeling of discrete system in MVS – the received characteristic consists of separate points that corresponds to discrete system.



# Discrete-continuous systems

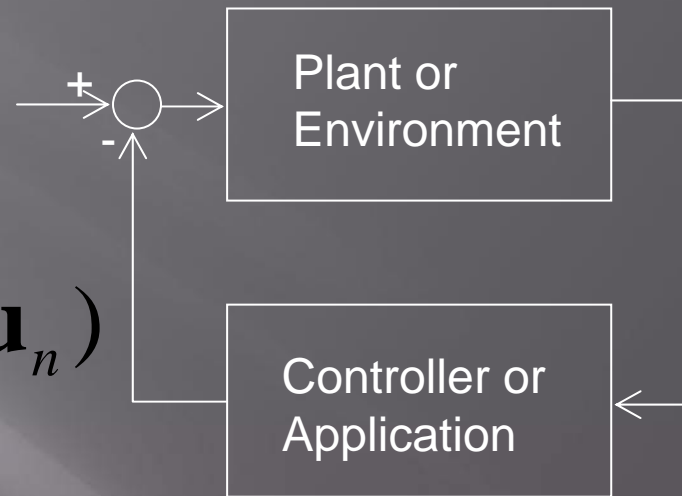
- Object of control

- Control

$$\frac{d\mathbf{x}}{dt} = \mathbf{f}(\mathbf{x}(t), \mathbf{u}_n)$$

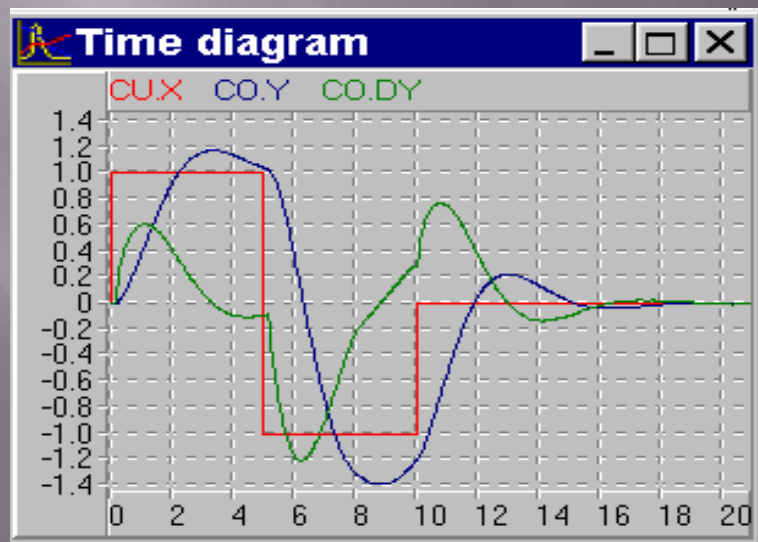
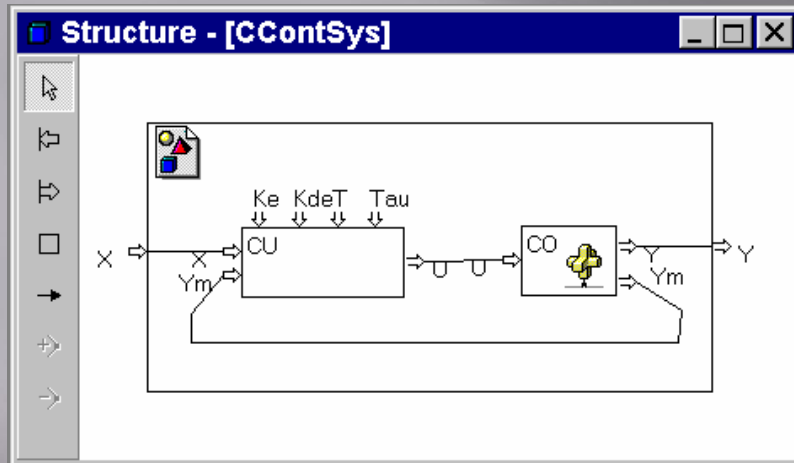
$$\mathbf{u}_{n+1} = \mathbf{G}(\mathbf{x}(t_n), \mathbf{u}_n),$$

$$\mathbf{u}_n = \mathbf{u}(t_n), t_{n+1} = t_n + h,$$



In dynamic systems can arise the processes with different scales of time. Difficulties of reproduction of such systems are obvious.

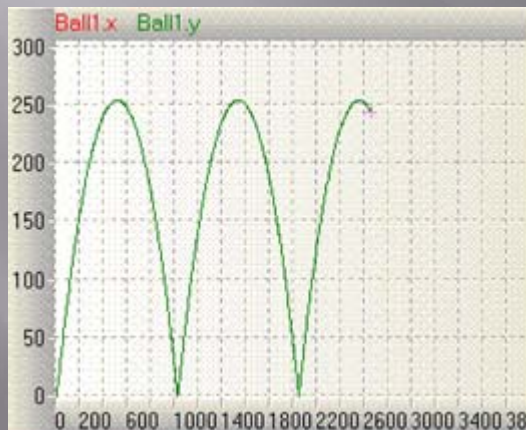
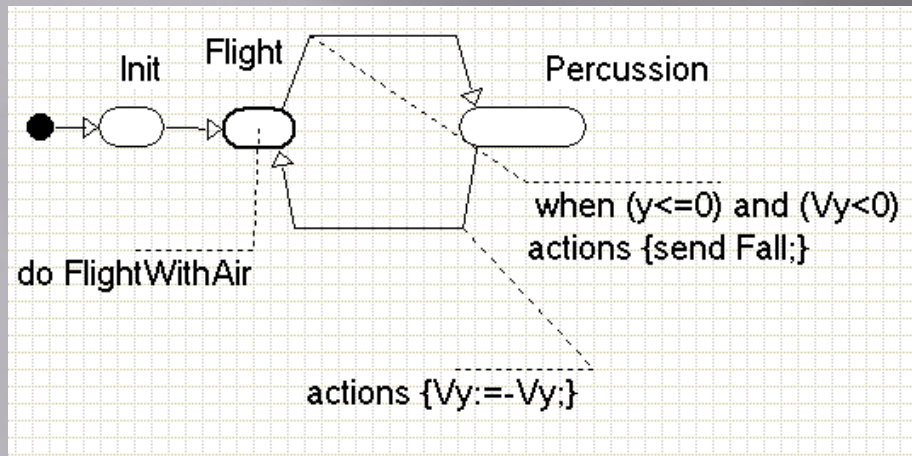
# Control system



The researcher solves, which processes in object are long, and which fast. Speed of fast processes is accepted by the infinite. Such processes are authorized to change value jump, unlike the slow, no separable. Let consider a usual control system. The object of control works constantly, it is system of continuous time, and here an operating input signal comes periodically. It is discrete system.



# Hybrid systems



For this purpose we will allocate special condition - a contact of a body with the earth, and it allowed to replace vertical making speed at the moment of its approach a sign with the opposite, then again we reproduce the set system with new entry conditions, and so again and again. It is possible to name the mechanism generating it the hybrid automat.

# MvStudium's Blocks



# OPEN INPUT/OUTPUT BLOCK

The screenshot displays the Model Vision Studium 3.0 interface. The main window shows a control system model with the following components:

- CU (Control Unit):** Receives input  $X$  and  $Y_m$ . It is parameterized by  $K_e$ ,  $K_{deT}$ , and  $Tau$ . Its output is  $U$ .
- CO (Control Output):** Receives  $U$  and  $SOFF$ . It produces output  $Y$  and  $Y_m$ .

The **Continuous behavior - [CContObj.CF1]** window shows the following equations:

$$\frac{d(Y)}{dt} = DY$$
$$\frac{d(DY)}{dt} = K * Km * U$$
$$Y_m = \text{round}(X \text{Lim}(Y/Km, -127, 127))$$

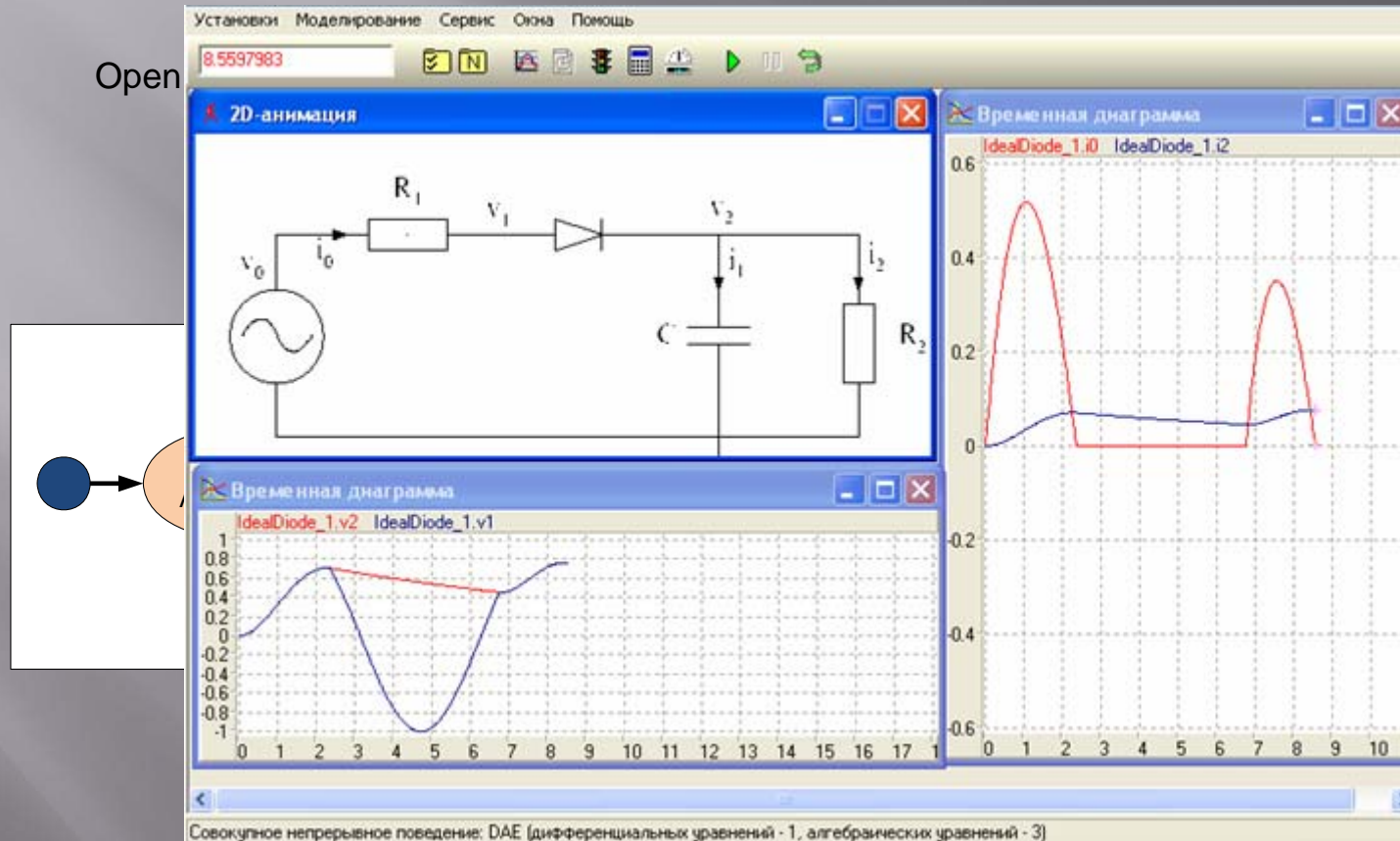
The **B-Chart - [CContUnit...]** window shows an **Init** block with the label **do Con**.

The Project Manager on the left shows the following structure:

- Class - [CContObj]
  - Superclass: CDevice
  - Icon
  - Parameters
  - Inputs
  - Outputs
  - State
  - Constants
  - Functions and Procedures
  - Behavior
    - Main B-Chart
    - Local B-Charts
    - Continuous
      - CF1
    - Structure
    - Comment
  - Continuous
    - Structure
    - Comment

# OPEN CONTACT BLOCK

Open



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chains.

Activity:  $F\left(\frac{dx}{dt}, x, t; x_0\right)$

# Examples

# Example 1: breaking pendulum

Редактор Формул - [pendulum]

$$\frac{d^2 \text{Alpha}}{dt^2} = -g \cdot \sin(\text{Alpha})$$

Оscillation (First Class)

Редактор Формул - [flight]

$$\frac{d^2 y}{dt^2} = -g$$
$$\frac{d^2 x}{dt^2} = 0$$

Free fall (Second Class)

Описание модели

- Id Model
  - Суперкласс: нет
  - Иконка класса
  - Стереотип
  - Параметры
    - Alpha: double := rad(-90)
    - AlphaMax: double := rad
    - Omega: double := 0;
  - Входы
    - Break: signal := false;
  - Выходы
  - Внутренние переменные
    - Teta: double := 0;
    - V: double := 0;
    - X: double := 0;
    - Y: double := 0;
  - Константы
  - Функции и процедуры
  - Комментарий

do Flight(V0=V, Teta0=Teta, x0=X, y0=Y)

SOsc → Sflight

when Break actions {  
X:=SOsc.L\*sin(SOsc.Alpha);  
Y:=-SOsc.L\*cos(SOsc.Alpha);  
V:=d(SOsc.Alpha)/dt\*SOsc.L;  
Teta:=SOsc.Alpha;  
}

do Pendulum(Alpha0=Alpha, Omega0=Omega)

after t

Карта поведений Структура

# Example 2: statistical test:shell flight

## Equations

### A shell flight

Описание модели

- Id Model
- Суперкласс: нет
- Иконка класса
- Стереотип
- Параметры
  - Teta: double := rad(4)
  - V: double := 100;
- Переменные
  - L: double := 0;
- Константы
- Функции и процедуры

when (F.y<=0) and (d(F.y)/dt<0)  
actions {L:=F.x;}

do Flight(V0=V,Teta0=Teta)

Карта поведений

Описание модели

- Id Model
- Суперкласс: нет
- Иконка класса
- Стереотип
- Параметры
  - g: double := 9.81;
  - m: double := 1;
  - Teta0: double :=
  - V0: double := 100
- Переменные
  - Fx: double := 0;
  - Fy: double := 0;

Система уравнений

- $m \cdot d^2(y)/dt = Fy - m \cdot g;$
- $m \cdot d^2(x)/dt = Fx;$

Искомые переменные

- y, x

Начальные значения производных

- $d(y)/dt = V0 \cdot \sin(Teta0)$
- $d(x)/dt = V0 \cdot \cos(Teta0)$

Уравнения

### Statistical experiment

Описание модели

- Id Model
- Суперкласс: нет
- Иконка класса
- Стереотип
- Параметры
  - N: integer := 100;
  - Teta\_D: double := rad(1)
  - Teta\_M: double := rad(4)
  - V\_D: double := 1;
  - V\_M: double := 100;
- Переменные
  - L: vector[N];
  - n: integer := 0;
- Константы
- Функции и процедуры

do Throw(V=normal(V\_M,V\_D),Teta=normal(Teta\_M,Teta\_D))  
entry actions {n:=n+1;}

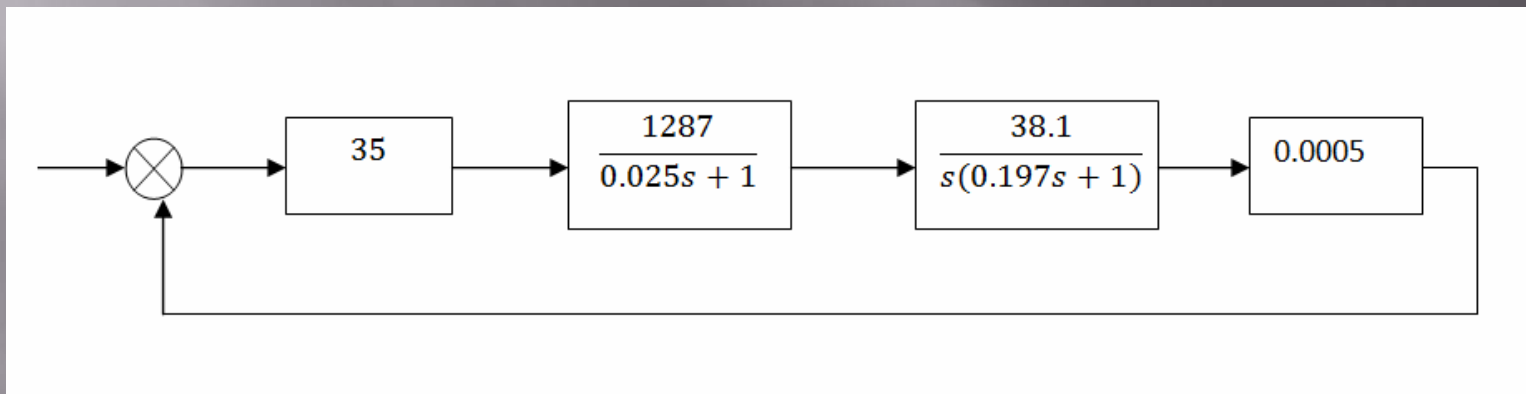
actions {L[n]:=T.L;}

Карта поведений

# Modeling of real complex system

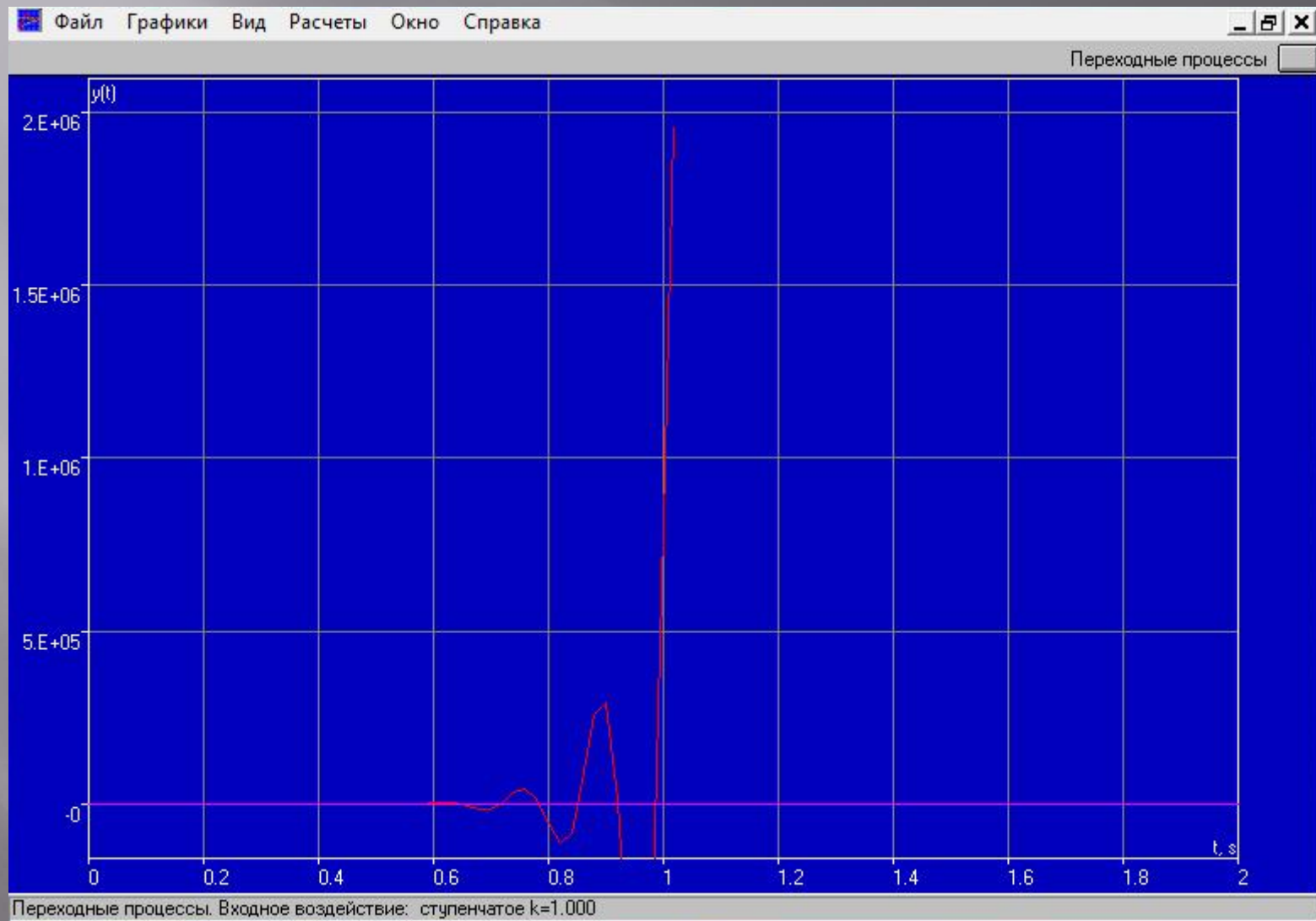
This system consists of four elements:

- Sensitive element which accepts a mismatch signal
- The amplifier which strengthens an operating signal and transmit him in the engine.
- The dysphasic asynchronous engine
- Reducer, witch transforms rotation of a shaft of the engine in turn on small degree.



It is classical configuration of systems of such class with a negative feedback.

# Model in Classic 3.0





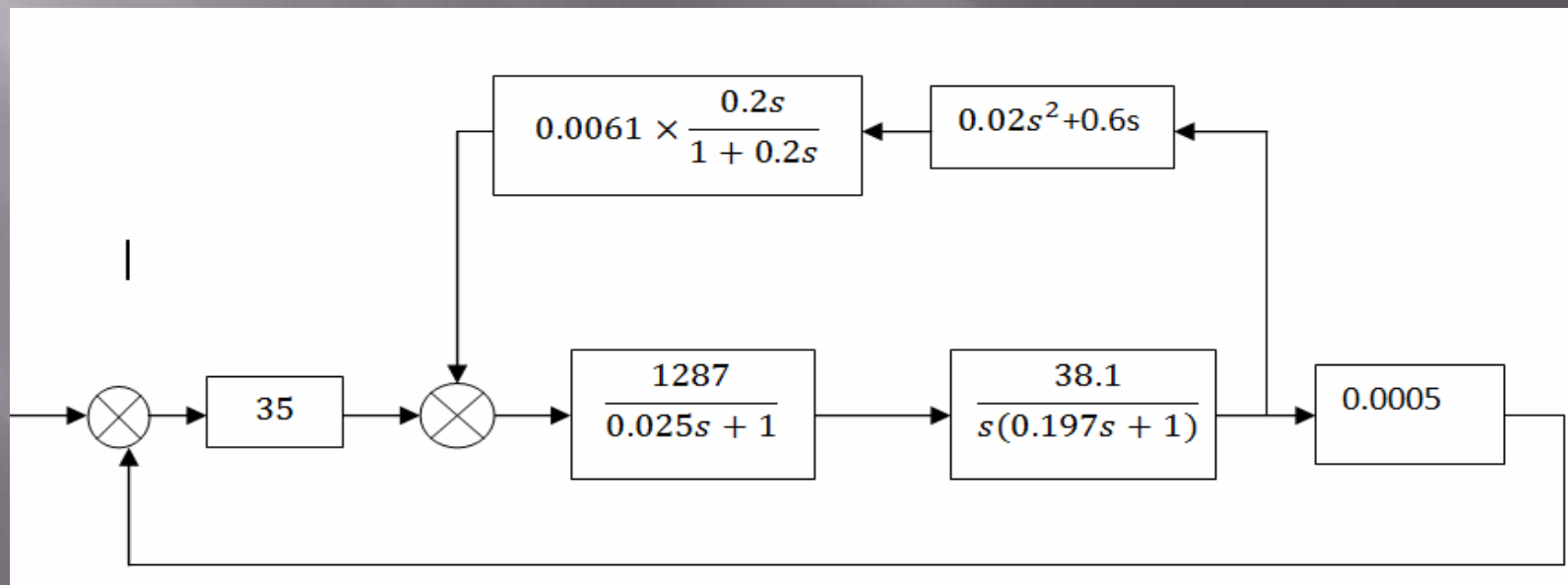
# Modeling in MVStadium



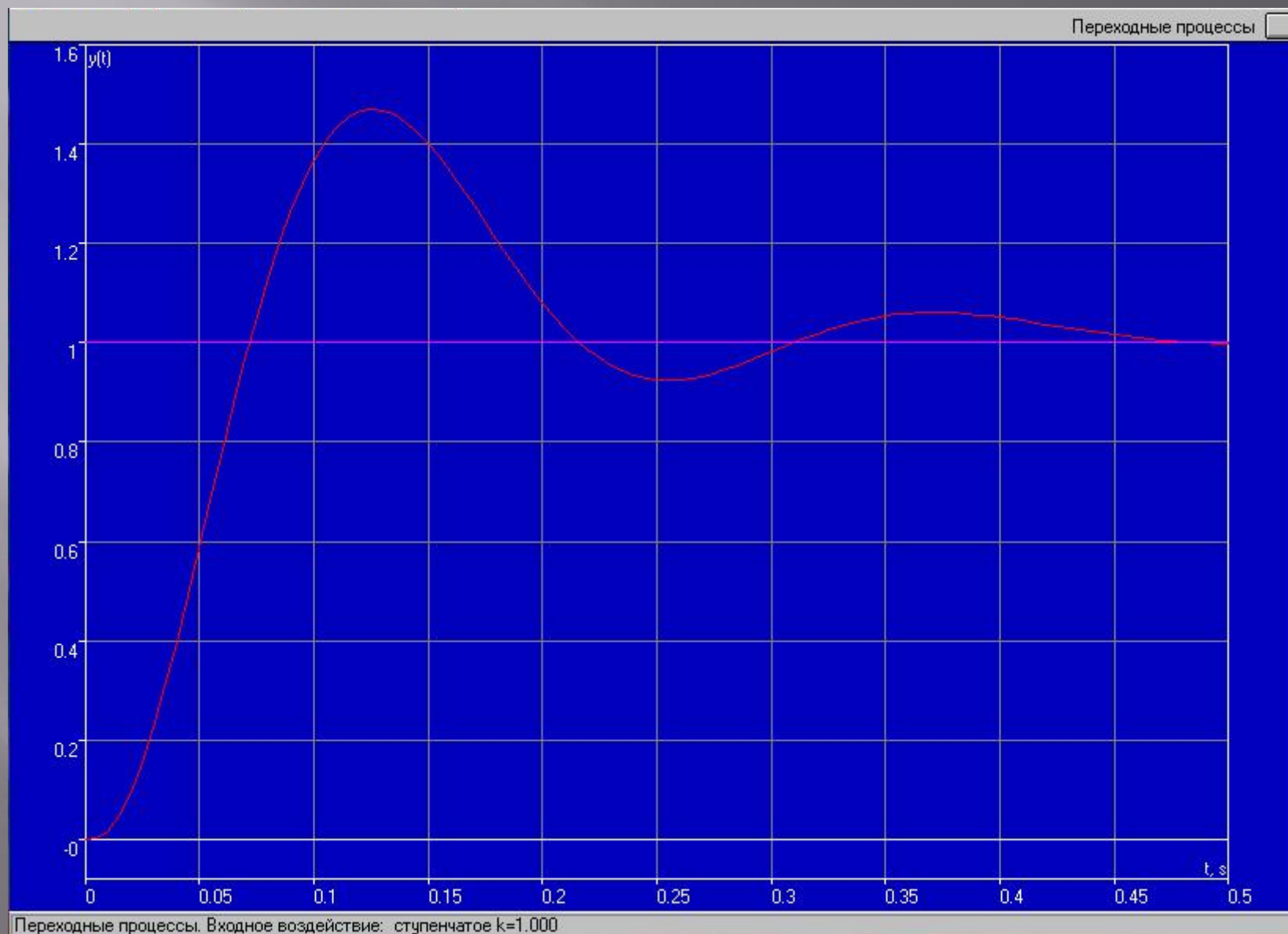


# CREATION OF CORRECTED SYSTEM

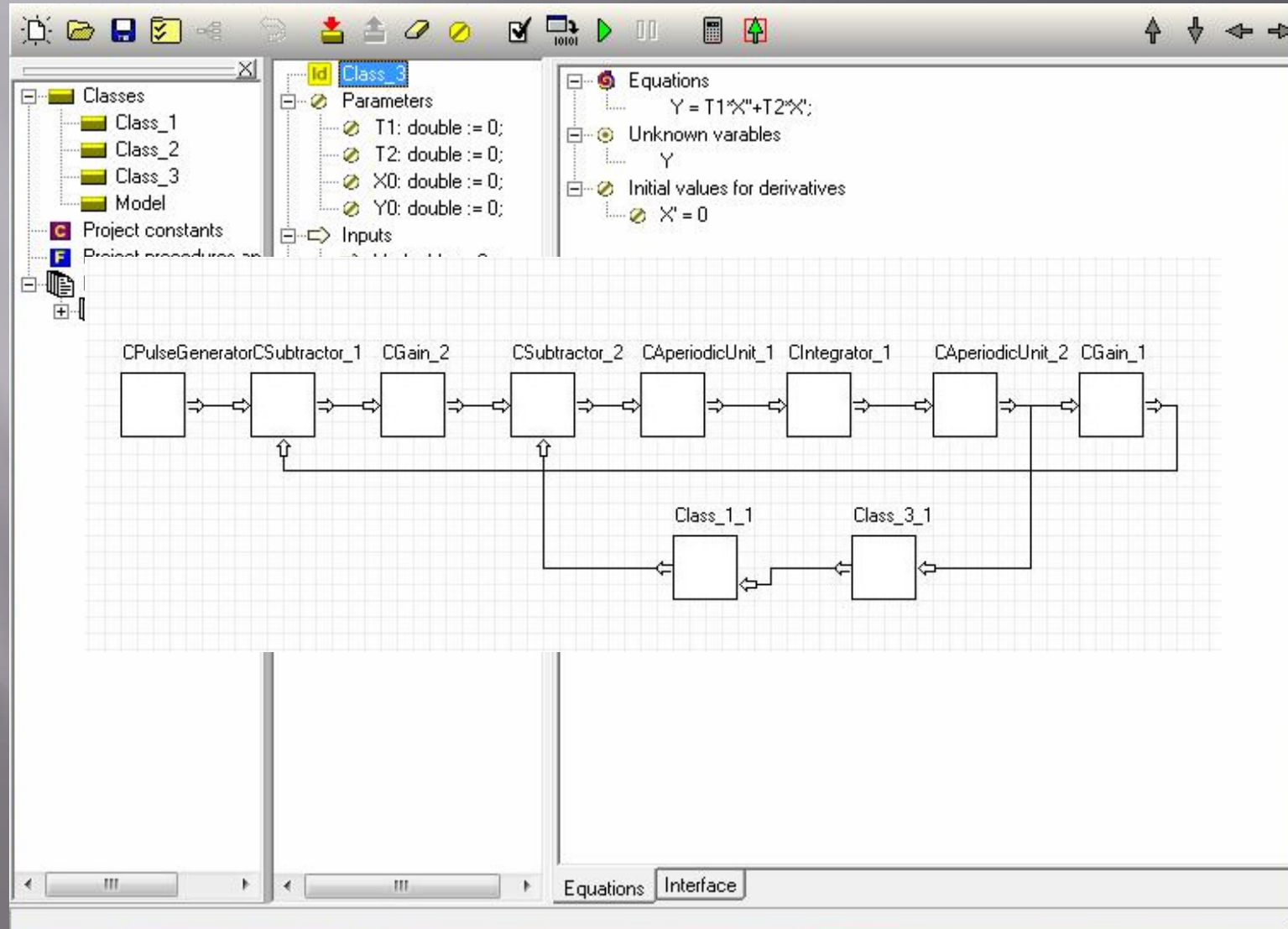
For construction of this device I used a method of construction of the desirable logarithmic characteristic offered by Russian scientist Besekersky. The given type of correction is called as parallel correction of a part of system. To the engine it is connected tachogenerator – the special device, reformative speed of rotation of the engine in pressure. And to it we include the calculated correcting device.



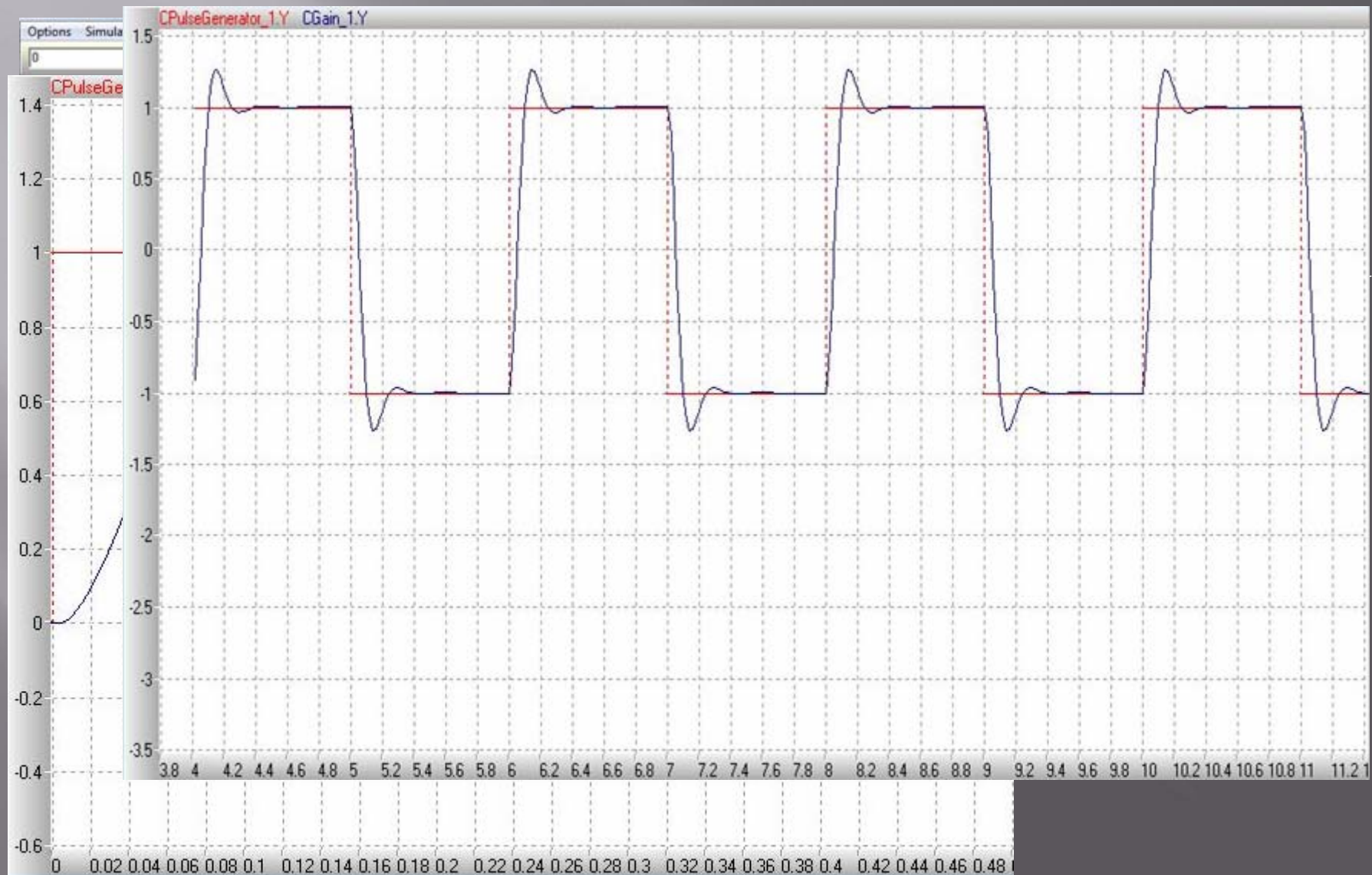
# Corrected system in Classic 3.0



# CORRECTED SYSTEM IN MVSTUDIUM CREATION OF PERSONAL BLOCK



# MODELING OF CORRECTED SYSTEM IN MVSTUDIUM



# Conclusion

In summary I can tell, that the sphere of applications MVS is really very wide, and the considered examples not a limit of its possibilities. In general, MVS – excellent tool, and I hope, that you liked it and my presentation about him.

**THANKS!**

<http://www.mvstudium.com>