# Scicos/Modelica for modeling and simulation

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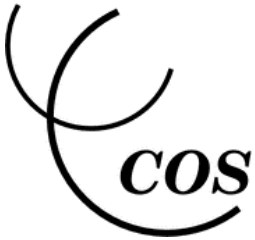
# Outline

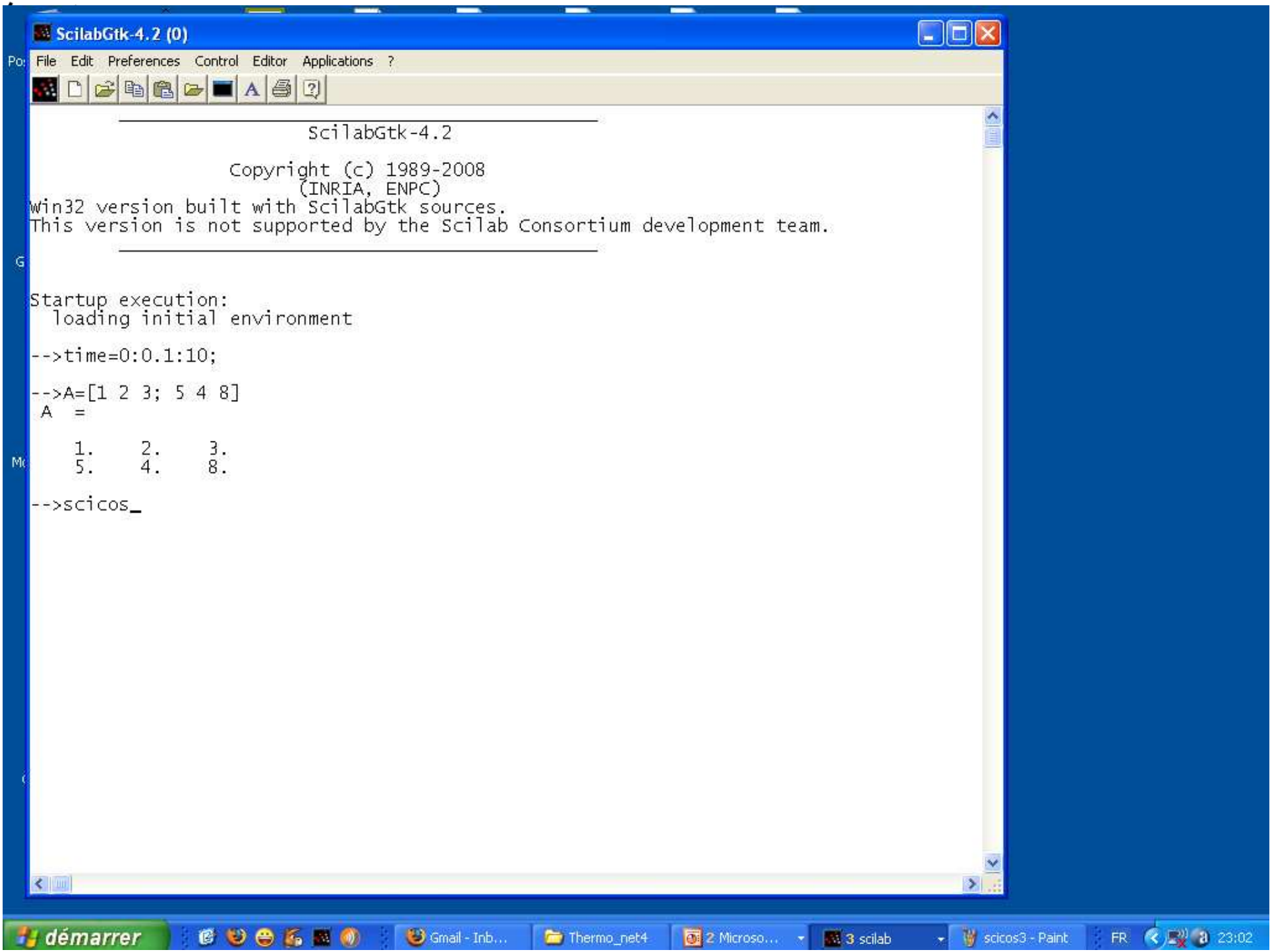
- Introduction to Scilab & Scicos
- Modeling approaches
- Overview on Modelica
- Idle speed engine control
- Drilling station




# Introduction to Scilab and Scicos

- **Scilab:** A Free and Open-source software for scientific computing.

- **Scicos:** A toolbox in Scilab for Modeling and Simulation of hybrid dynamical systems
  - **Available for Unix Work Stations, Linux, Windows, and Mac OSx**
  - **Available at www.Scicos.org**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(INRIA, ENPC)
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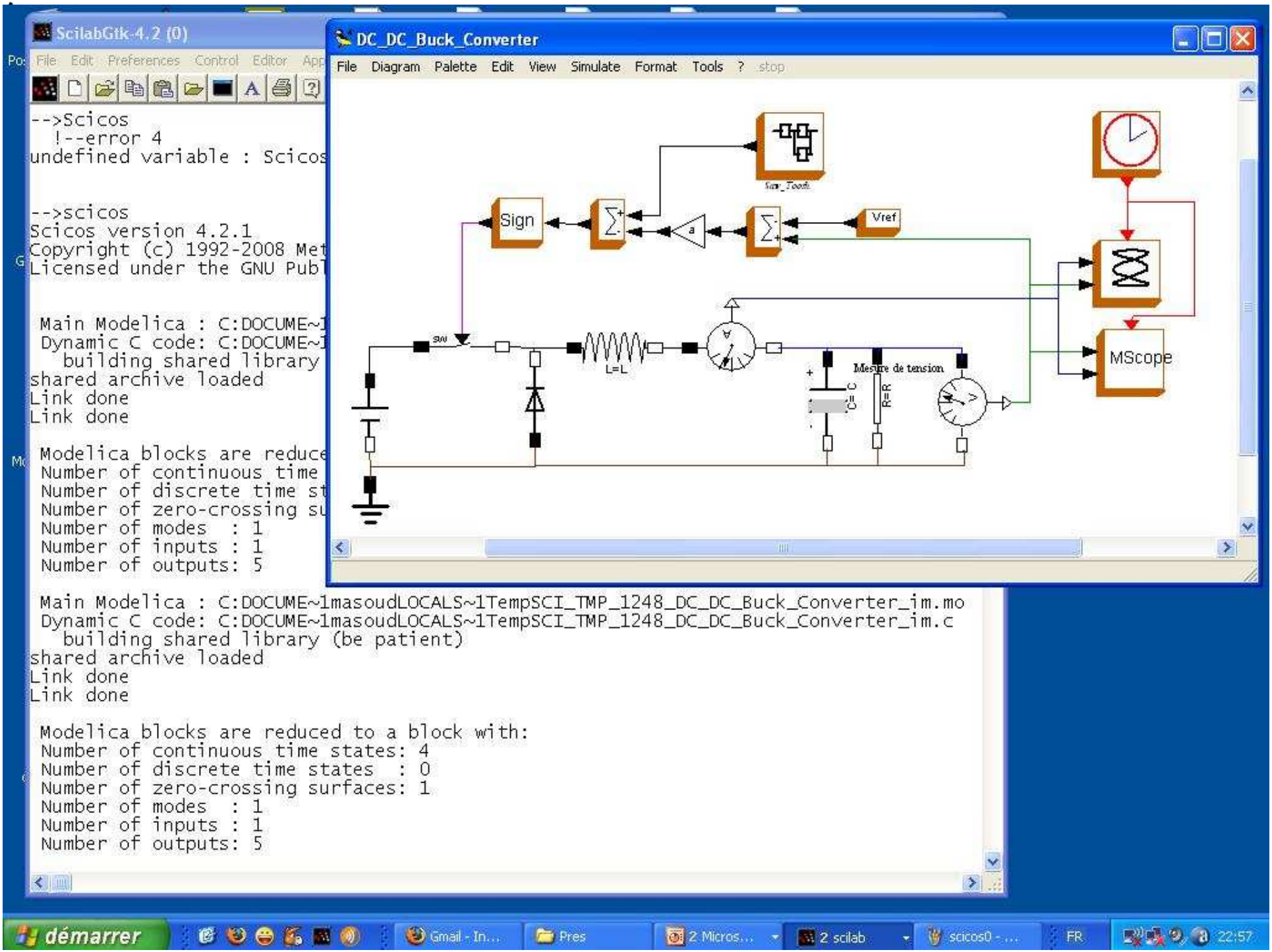
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Number of discrete time states : 0
Number of zero-crossing surfaces: 1
Number of modes : 1
Number of inputs : 1
Number of outputs: 5
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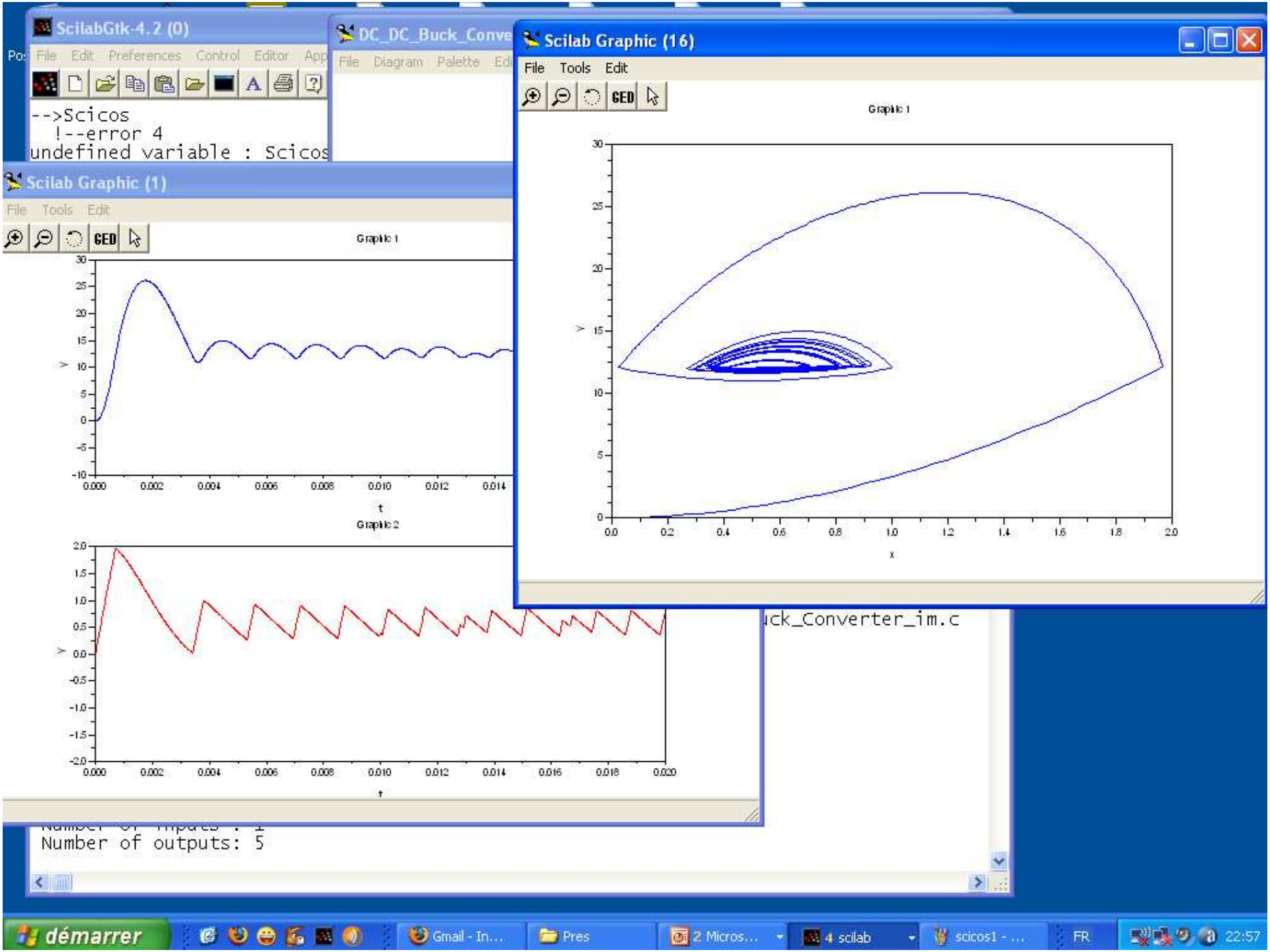
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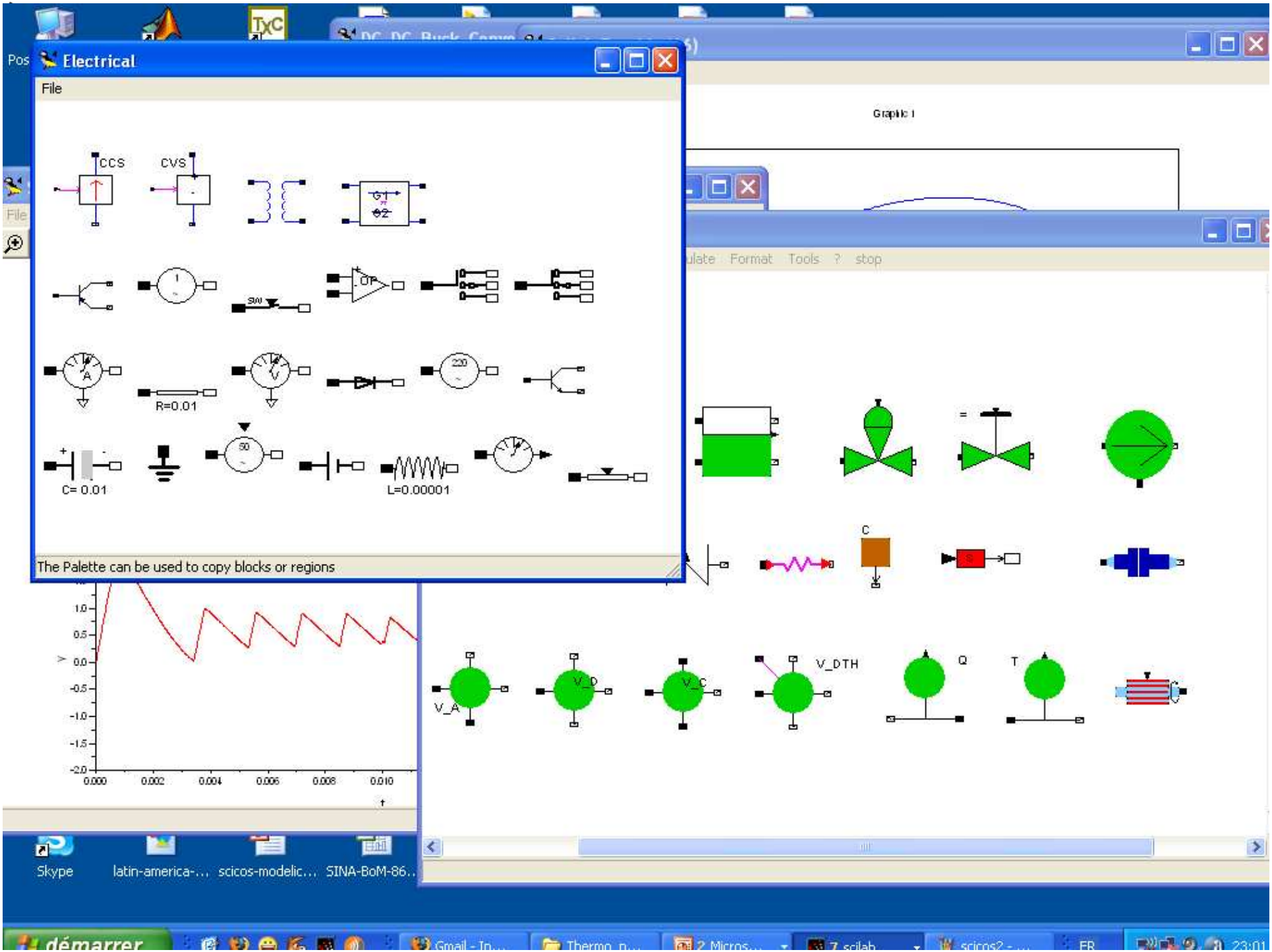
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The Palette can be used to copy blocks or regions
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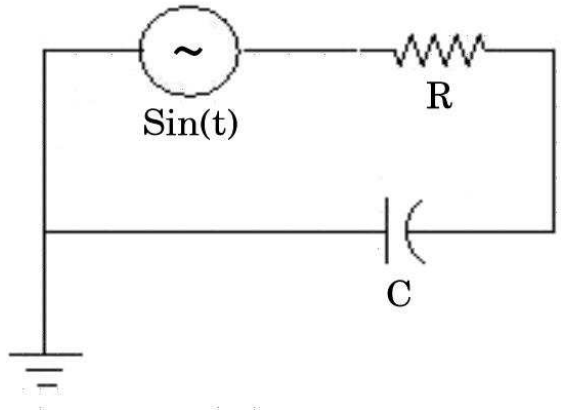
# Modeling approaches

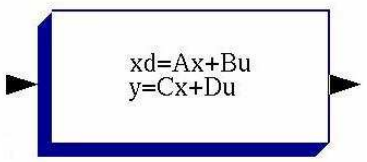
- A model is build by interconnecting blocks
  - Causal modeling (system based modeling)
  - Acausal modeling (component based modeling)

- Modeling this physical systems



# Causal modeling (explicit blocks)

- Inputs and outputs ports are explicitly defined
- In the model there is a information flow
- The input/output behavior is written in C or Fortran
- They are considered as black boxes by Scicos

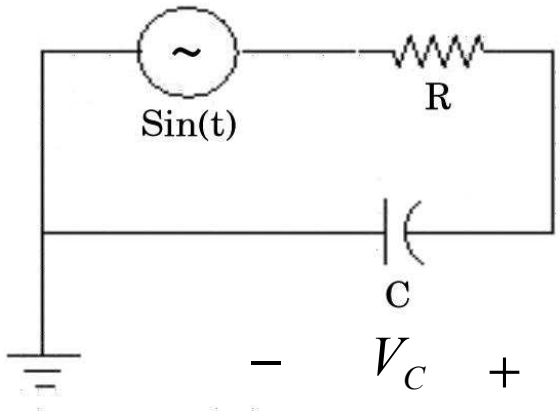



$$\begin{cases} x' = Ax + Bu \\ y = Cx + Du \end{cases}$$

An explicit block

# Causal modeling (explicit blocks)

- To model with explicit blocks the user should write all equations manually
- Then the user should simplify the equations to obtain an ordinary differential equation (ODE/DAE)

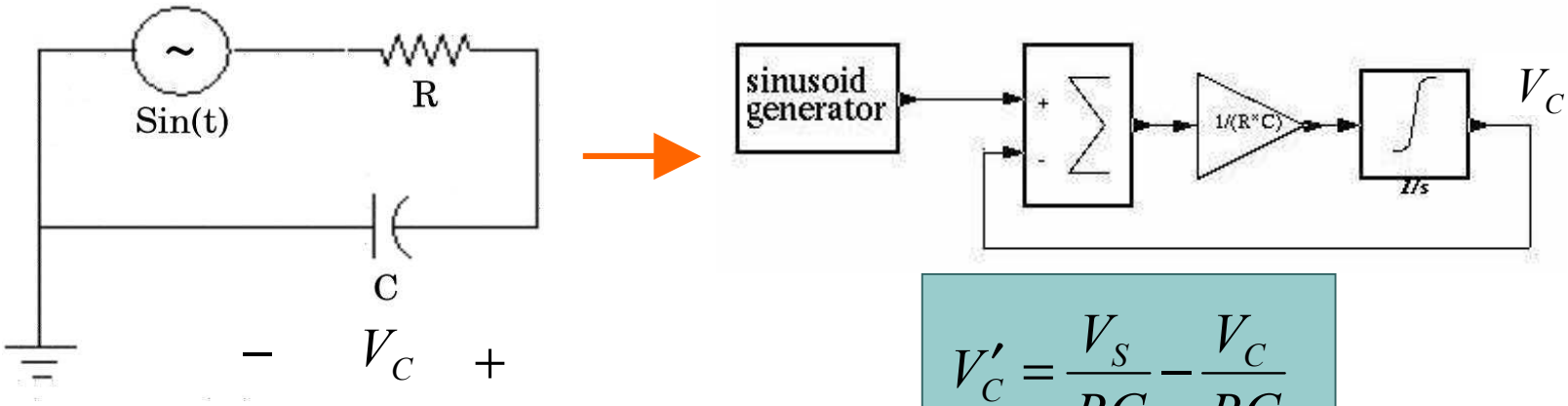



$$\begin{cases} V_s - V_R - V_C = 0 \\ V_C = \dfrac{\int I_C}{C} \\ V_R = I_C R \\ Output = V_C \end{cases}$$

$$V_C' = \frac{V_S}{RC} - \frac{V_C}{RC}$$

# Causal modeling (explicit blocks)

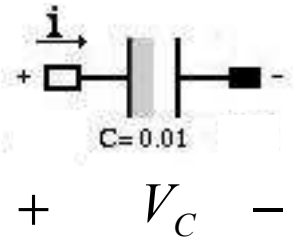
- Constructing the model using explicit blocks based on the ODE
- Time consuming, error prone, no similarity




$$V_C' = \frac{V_S}{RC} - \frac{V_C}{RC}$$

# Acausal modeling (Implicit blocks)

- Have implicit ports (not a priory inputs or outputs)
- Each implicit block represents a physical component

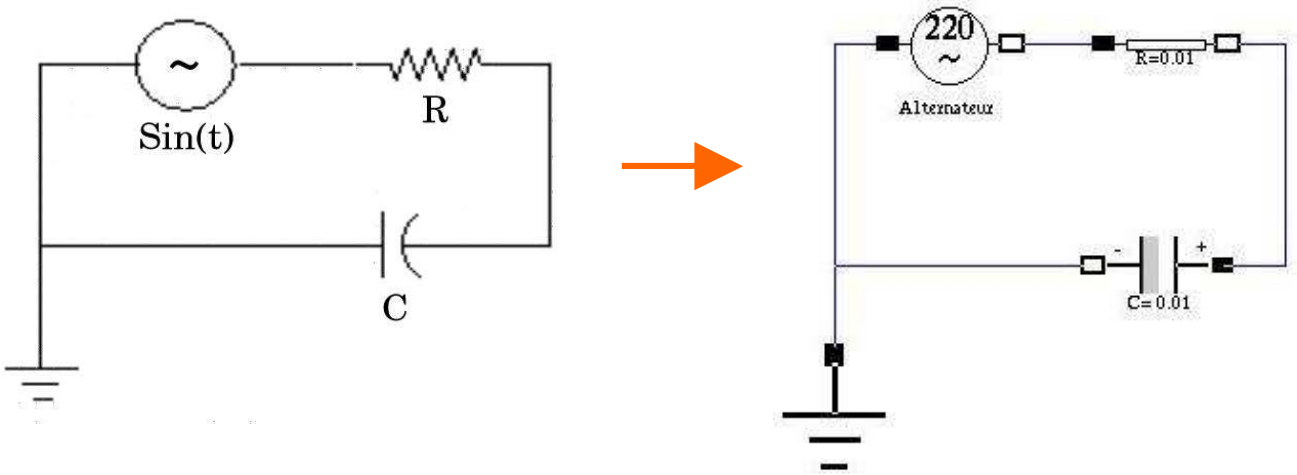



$$I_C = C\frac{dV_C}{dt}$$

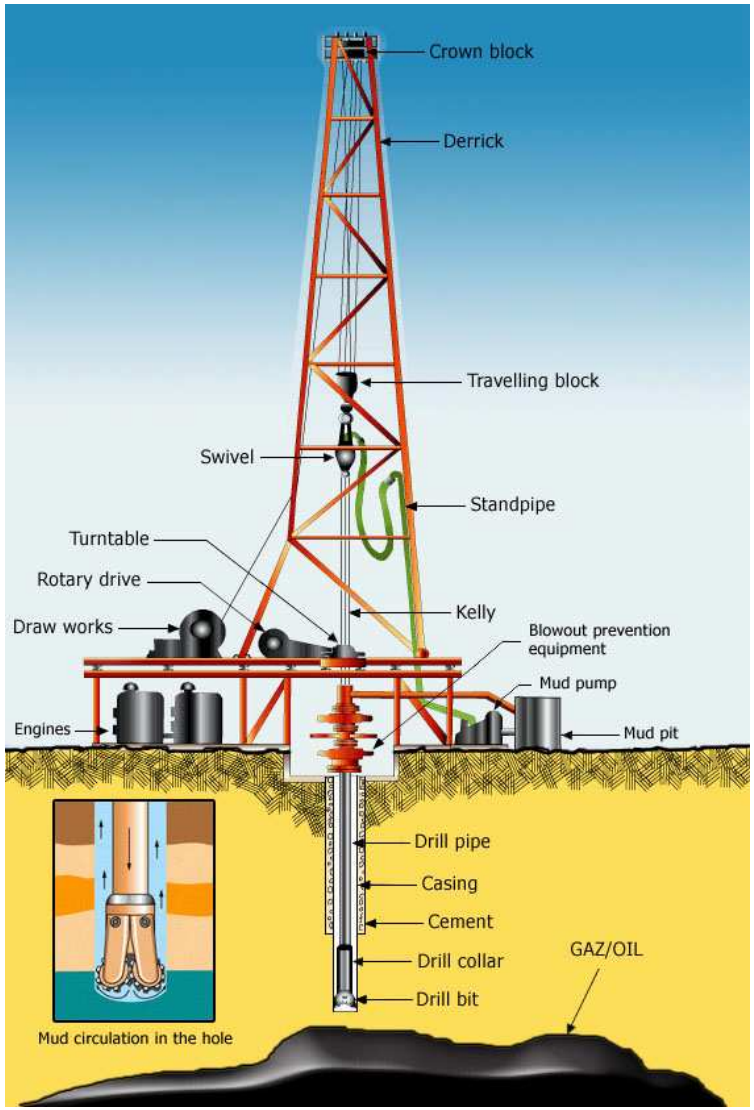
An implicit block

# Acausal modeling (Implicit blocks)

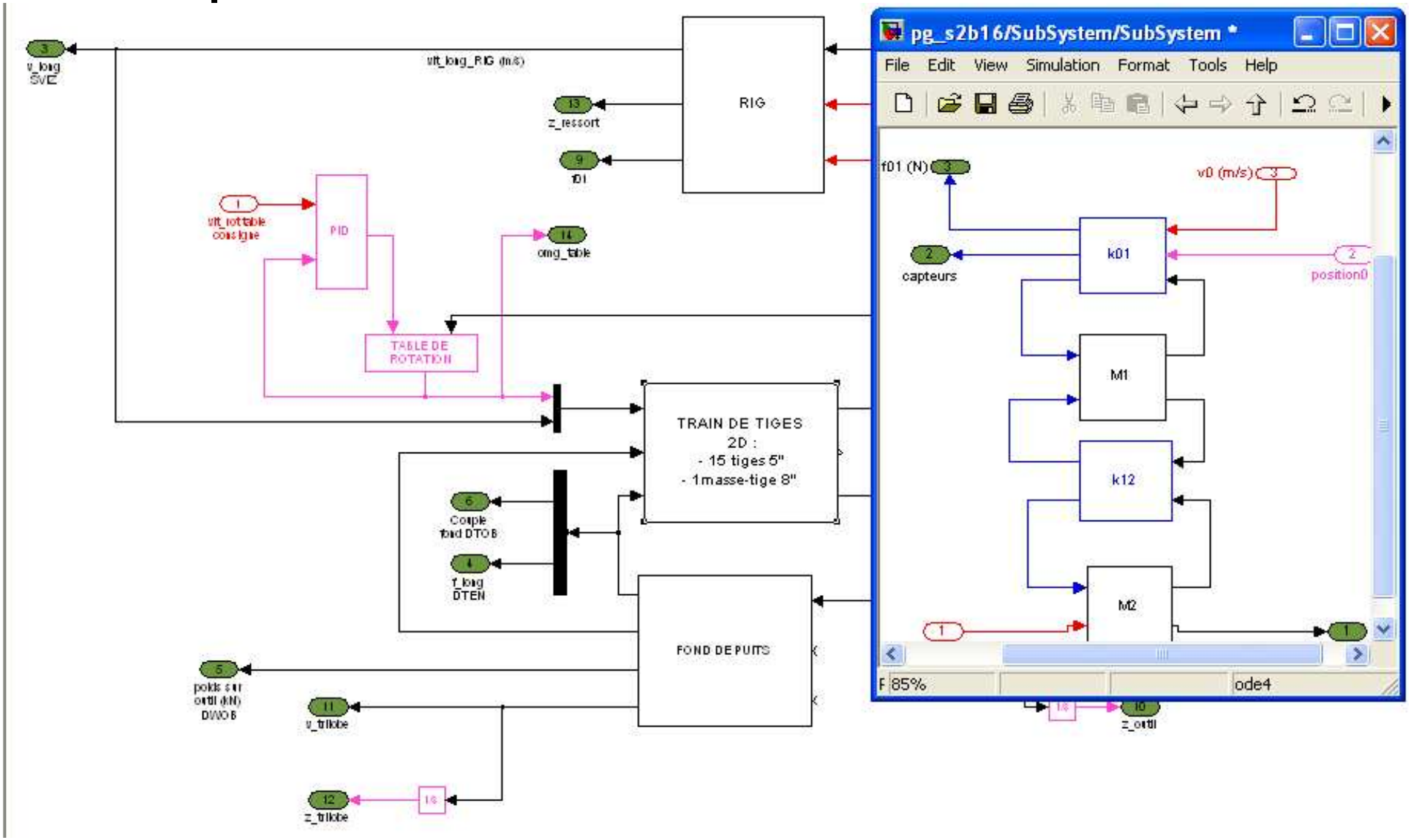
- Connected with special links (no flow direction)
- Modeling is just connecting the components
- The model looks like the physical system
- The behavior is written in the Modelica language



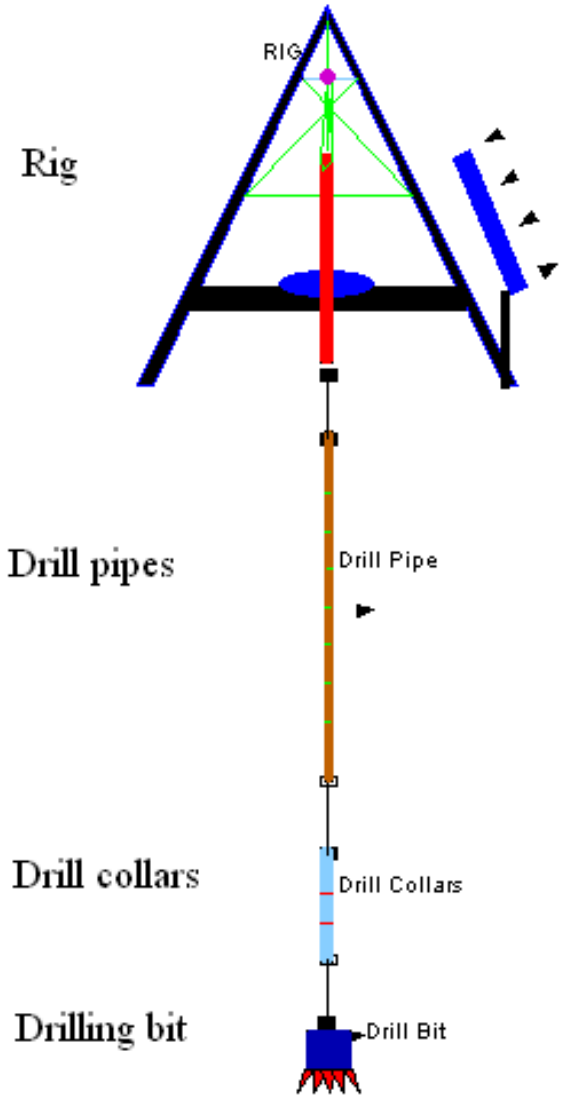
# Example: Drilling station

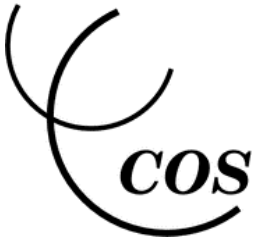


# Example: Drilling station (causal)



# Example: Drilling station (acausal or component based)



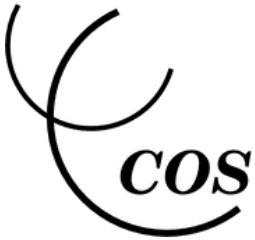



# What is Modelica?

- Declarative instead of procedural
- Object oriented modeling language
- Typed language
- Standardized by Modelica consortium
- Allows heterogeneous models (multi-domain models)
- Modeling using components
- Equation based, i.e., using mathematical equations
- Hybrid modeling, i.e., event-based and continuous-time models.

# Advantages of Modelica:

- **Modelica is a non property language and exists since 1996.**
- **Distributed under GPL.**
- **The Modelica models, being independent of the tool, can be simulated on any Modelica simulator.**
- **Available tools: Scicos, AMESim, Dymola, OpenModelica, SimulationX,…**
- **Several free and commercial libraries are available.**
- **Non-causal modeling: using a single model for all causalities**
- **Symbolic analysis: model size reducing**
- **Inverse model is done by changing the input/outputs in the model**
- **Parameter sizing is done by the same model**




# Modelica in Scicos

- Scicos is originally a simulator based on causal systems, i.e., blocks with explicit inputs and outputs

- In 2002, the RNTL "**Simpa**" project with the participation of INRIA, Imagine, EDF, IFP, ... started to develop Scicos to support modeling and simulation of Modelica models.

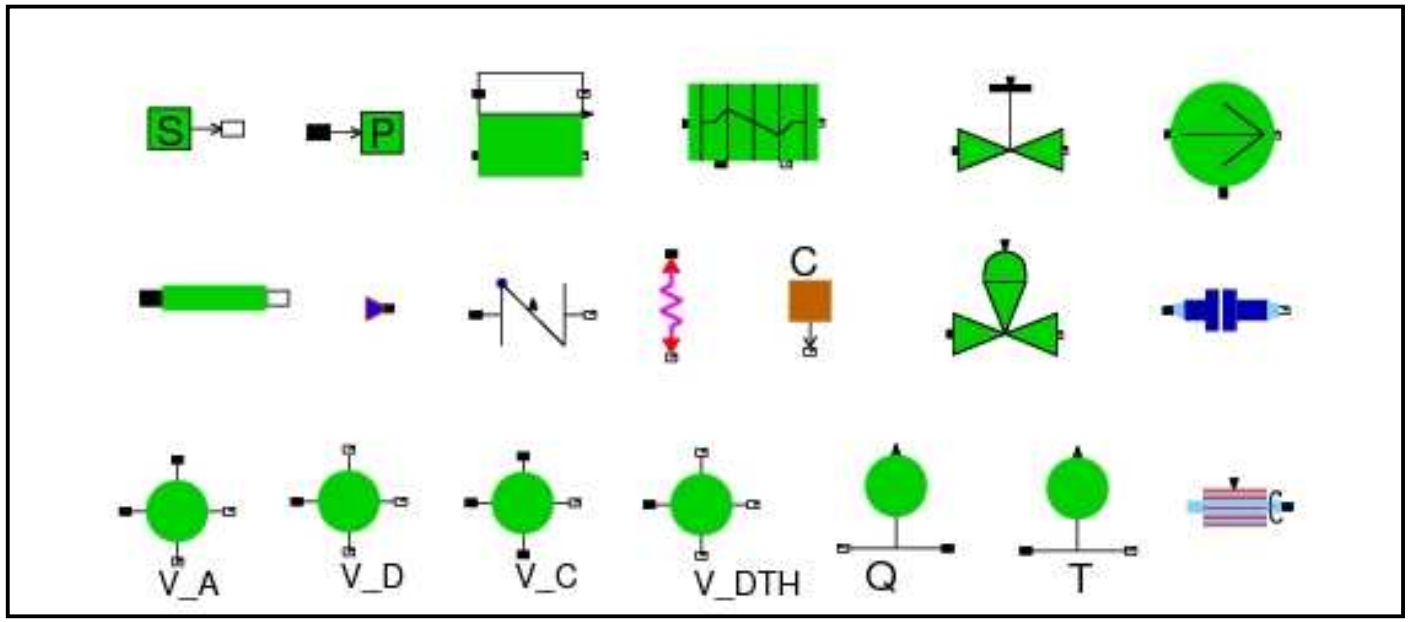
# Modelica in Scicos

- In 2006, the ANR “Simpa2” project started with the collaboration of INRIA, LMS.Imagine, IFP, EDF, INSA, PSA, …

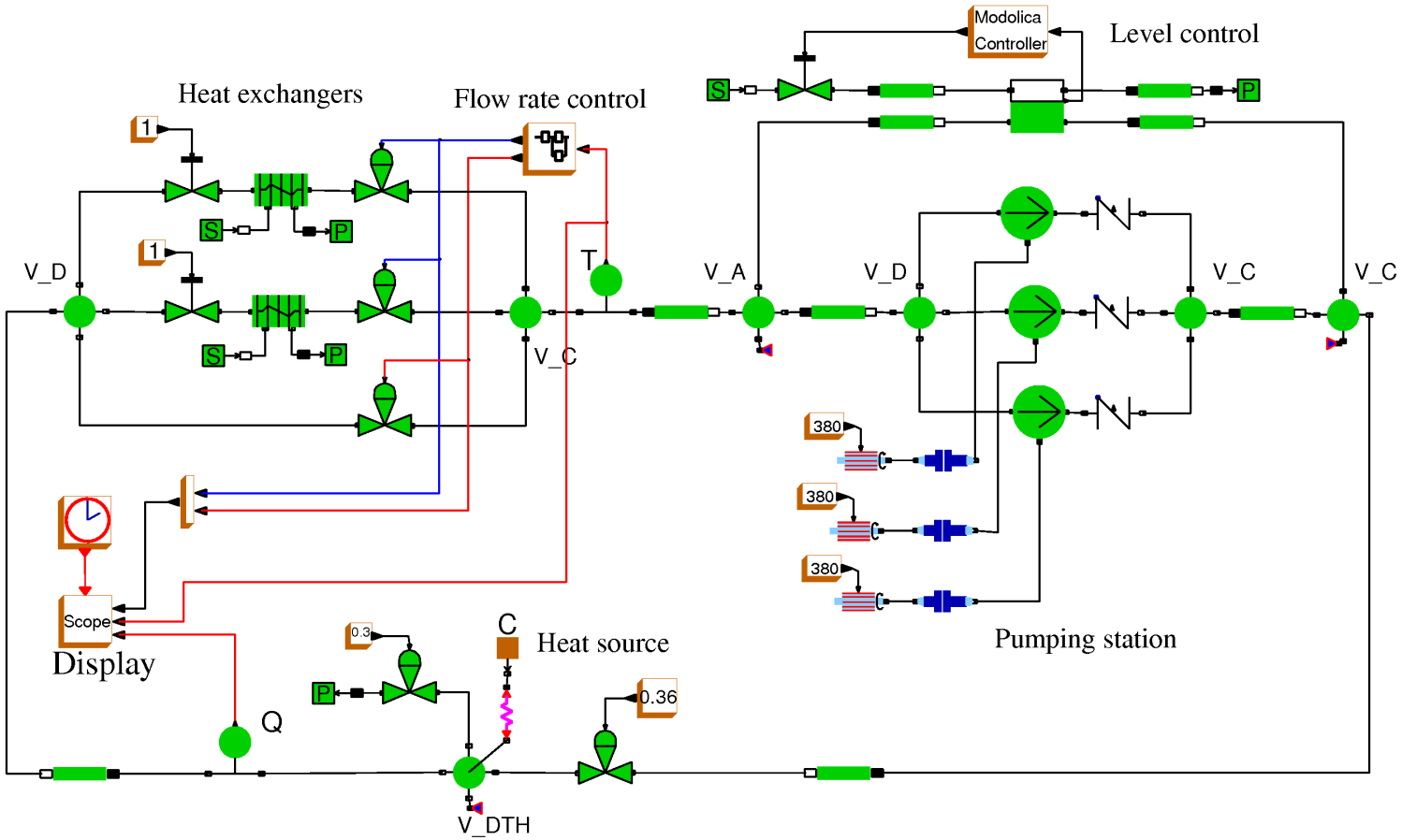
- Now, Scicos uses a free/open-source Modelica compiler (Modelicac) developed at LMS.Imagine Co.
  - **Support for most essential continuous-time features (index-1 DAE)**
  - **Modeling discrete-time systems and event synchronism**

# Available toolboxes in Scicos

## Thermo-hydraulic toolbox (EDF)

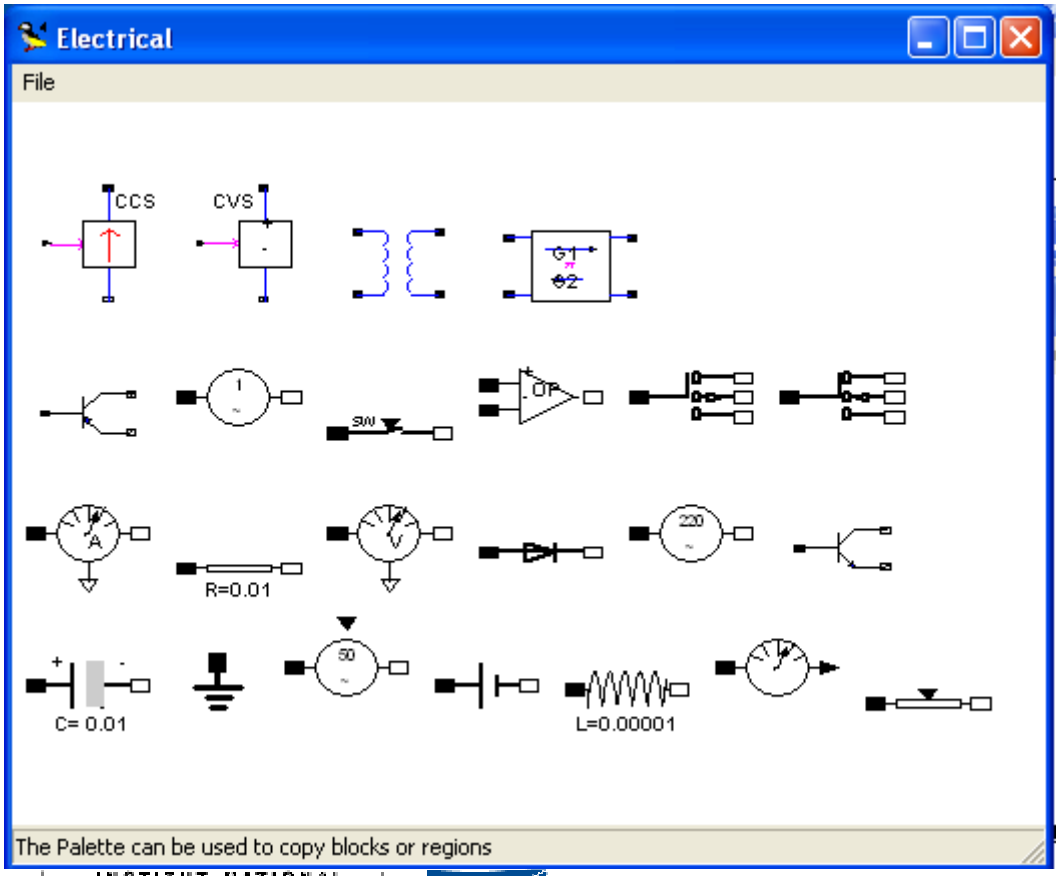


# Example: A cooling system (EDF)

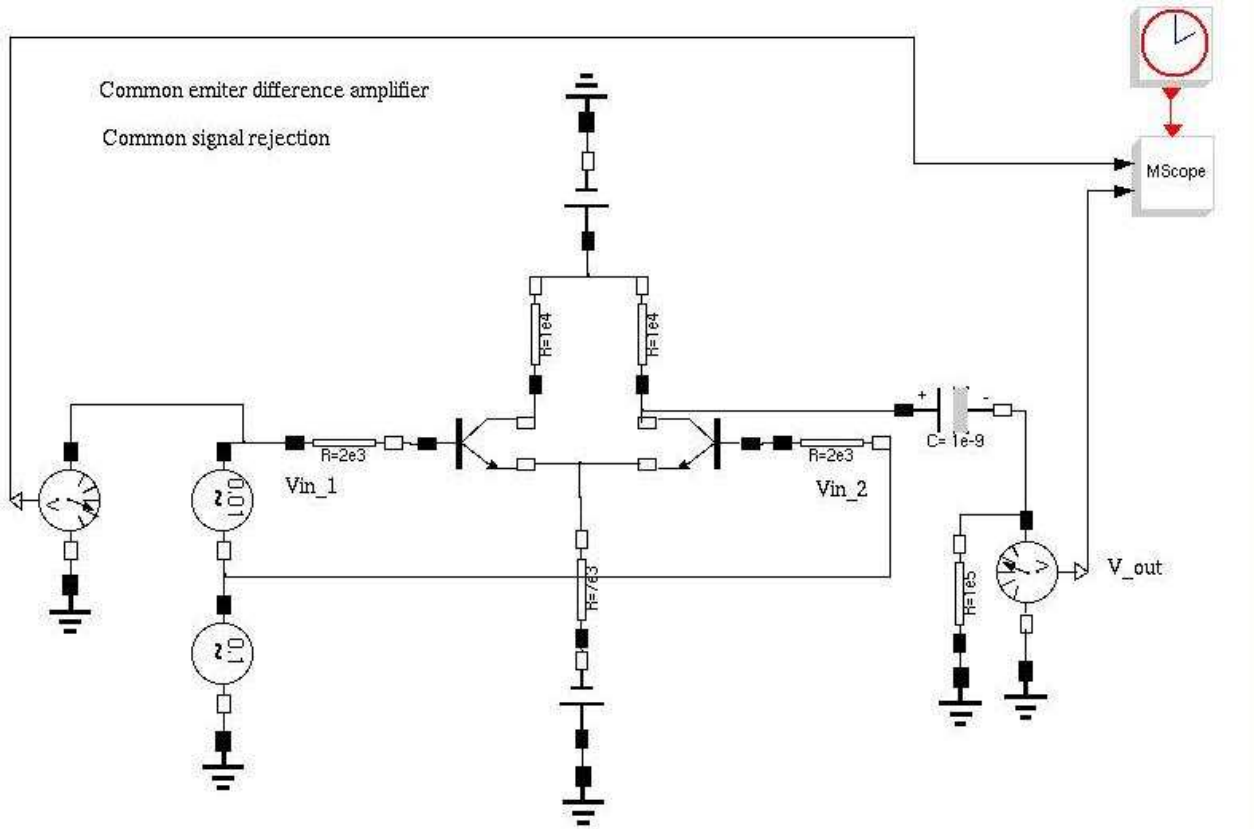


# Available toolboxes in Scicos

## Electrical (Modelica library)

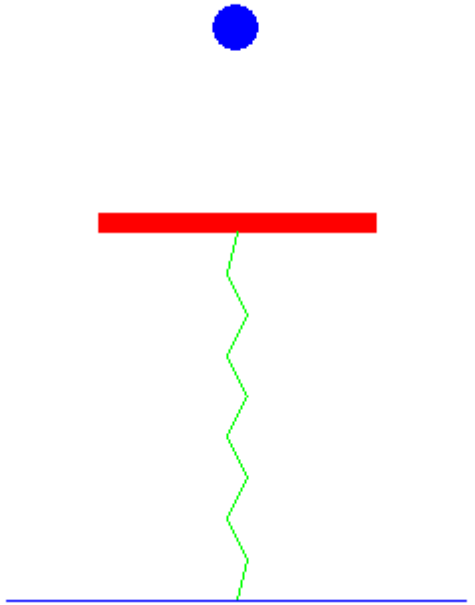


# Example: Difference amplifier



# Short demonstration in Scicos
# Ball and platform

```
class Ball_Platform
  parameter Real g=9.8;
  parameter Real m1=0.50; //platformKg
  parameter Real m2=0.30;//Kg
  parameter Real k=2; //Kg/sec
  Real y1(start=11),v1(start=0);//Platform
  Real y2(start=15),v2(start=1);//ball
  Real y0;
  discrete Real v1p,v2p;
equation
  der(y1)=v1;
   m1*der(v1)=if noEvent(v1<0.001 and v1>-0.001) then 0
                 else -m1*g-k*(y1-y0)-0.2*v1;
  der(y2)=v2;
  der(v2)=if noEvent(v2<0.001 and v2>-0.001) then 0
             else -g;
 when y2<y1 then
    v1p=(m1*v1+2*m2*v2-m2*v1)/(m1+m2);
    v2p=(m2*v2+2*m1*v1-m1*v2)/(m1+m2);
    reinit(v1,v1p*0.98);
    reinit(v2,v2p*0.98);
 end when;
end Ball_Platform;
```



# Two industrial models in Scicos/Modelica

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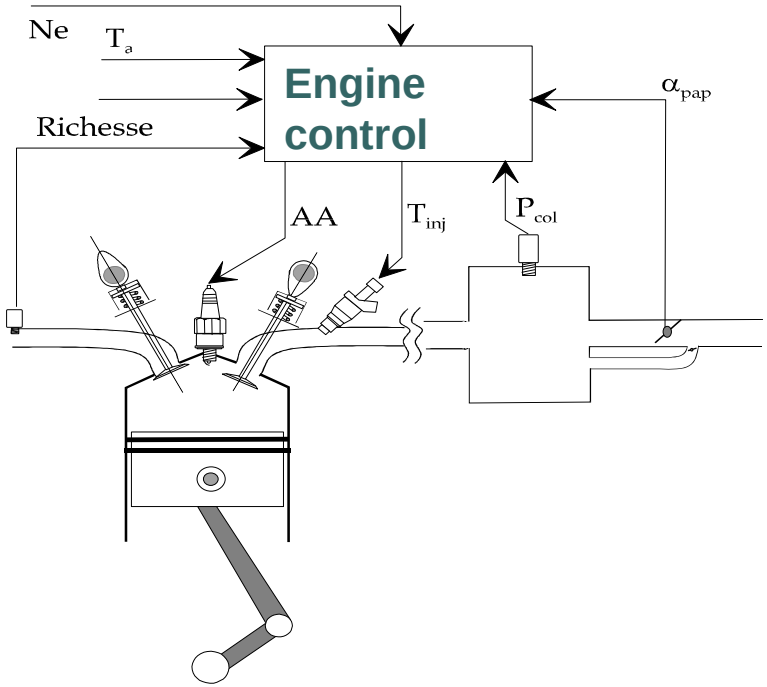
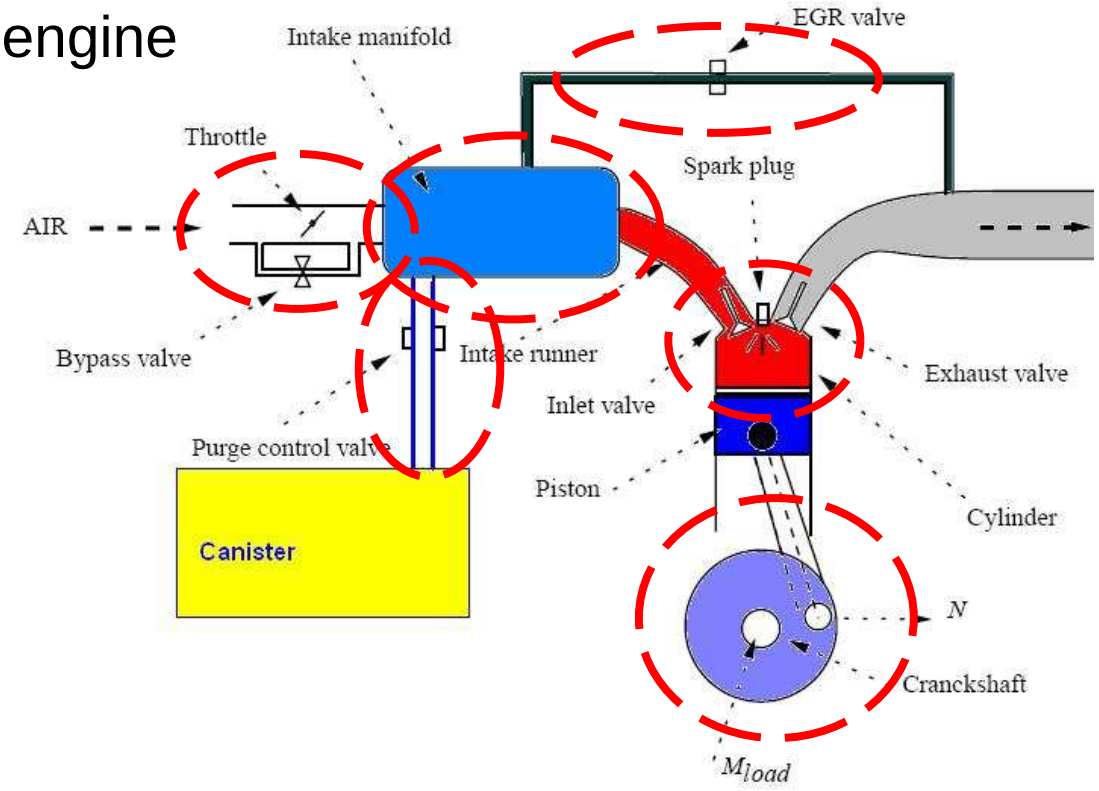
# Automotive test case

- Spark-ignited (SI) four cylinders engine,
- Mean value engine (0D)
  - Ignoring fast event and high frequency
  - Using average of cyclical dynamics
  - Used in engine control strategy
  - Speed, torque, Manifold pressure



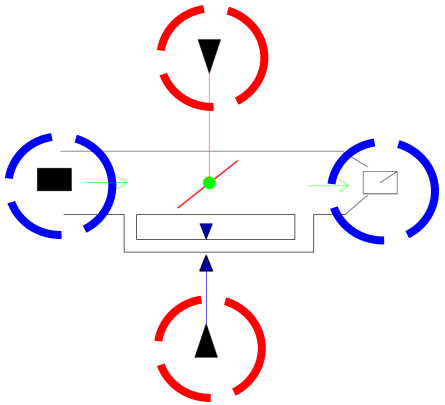
# Mean value engine model

- Principal Sketch of the engine
  - Air intake throttle
  - Intake manifold
  - Canister
  - EGR
  - Combustion chamber
  - Crankshaft dynamics
- 6 Modelica blocks



# Mean value engine model - Air intake valve

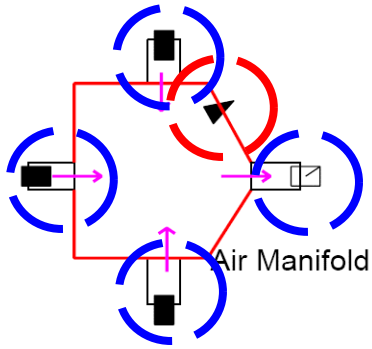
- Air Intake throttle
  - Controls the intake air flow rate
  - Modeled as a flow restriction
  - In low pressure air is incompressible
  - In high pressure air is compressible
  - Now backflow
  - Idle air bypass



- Two explicit ports (to communicate with standard Scicos)
- Two implicit ports (modeled by “connector” in Modelica)

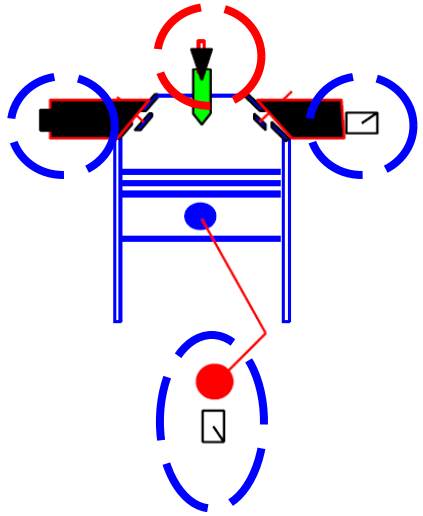
# Mean value engine model - air intake manifold

- Air intake manifold
  - Three input flows
  - Mixing air flows
  - Output torque control
  - Isothermal manifold
- 4 implicit ports for input/output air flows
- 1 output (explicit) port for pressure sensor used in the controller



# Mean value engine model - Combustion chamber

- Combustion chamber
  - Air/fuel mixture enters & reacts
  - Burnt gas are expelled
  - Ignoring effects of the air/fuel ratio
  - Torque production
  - Effects of spark timing advance



- 3 Implicit ports  for input/output airflows and crankshaft connector
- 1 explicit input for timing advance
- Using external C functions (DLL)

$$\tau_{gen}^{opt} = F(\omega, P_{man})$$

$$\eta = \frac{\tau_{gen}}{\tau_{gen}^{opt}} = H(|SA|)$$

# Engine Idle speed control


Controllers for idle mode speed regulation

- **PID: developed in Modelica**
- **LQG: developed with Scilab/Scicos blocks**

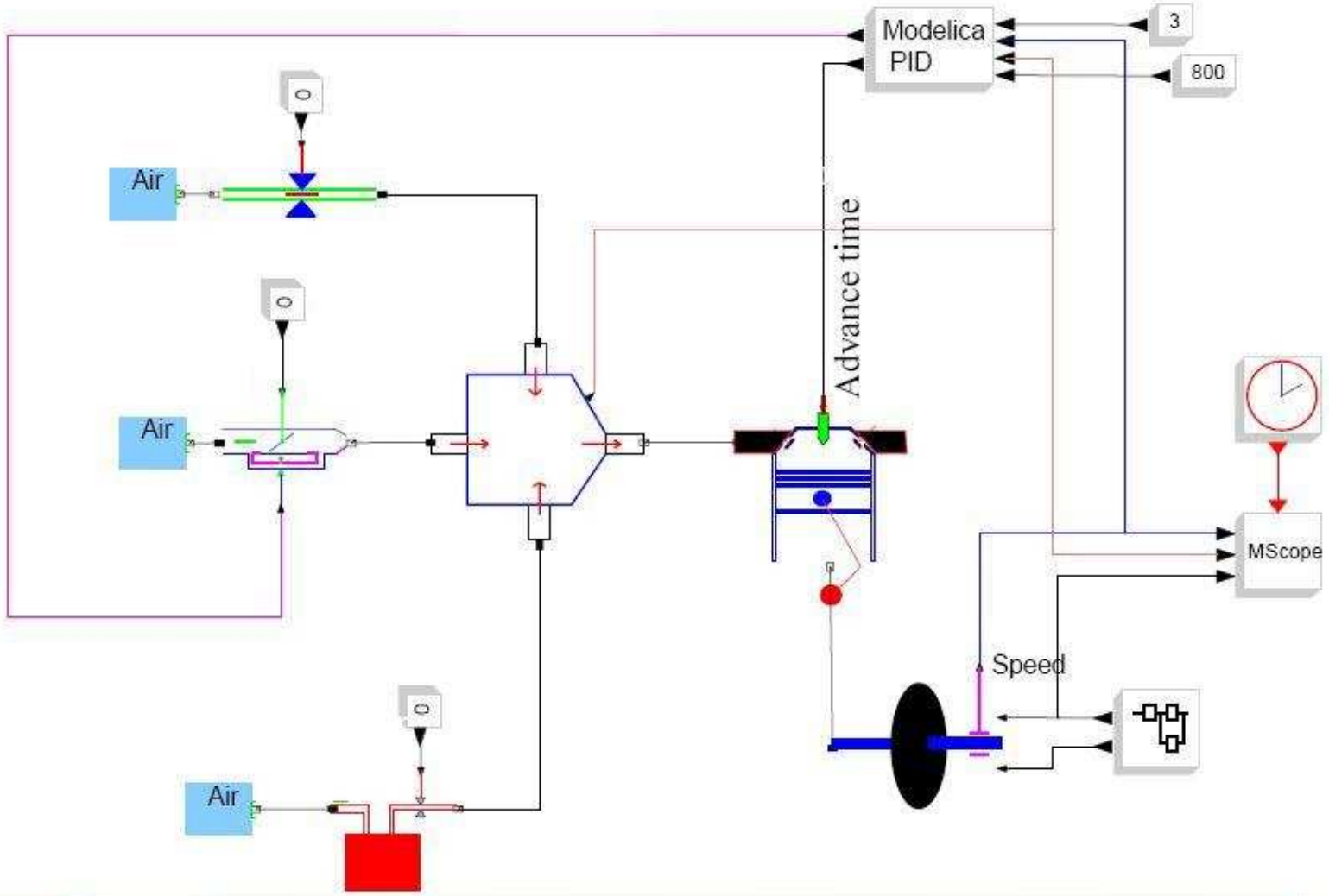
Control variables (outputs):

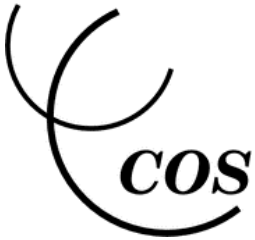
- Throttle bypass air inputs
- Spark advance time

Observable variables (inputs):

- Engine rotational speed
- Pressure in the manifold
- set points

# Engine Idle speed control






# Engine Idle speed control- Advantages of Modelica

Idle speed engine control already modeled in Simulink

- The Simulink model:
  - More than 200 blocks
  - 30 subsystems
  - 5 levels of hierarchy
  - Slow when using a variable step size solver

With Modelica in Scicos:

- Very few  blocks
- Easy to edit and navigate in the model
- Using components instead of modules with input/outputs
- Possibility of doing inverse model and model sizing

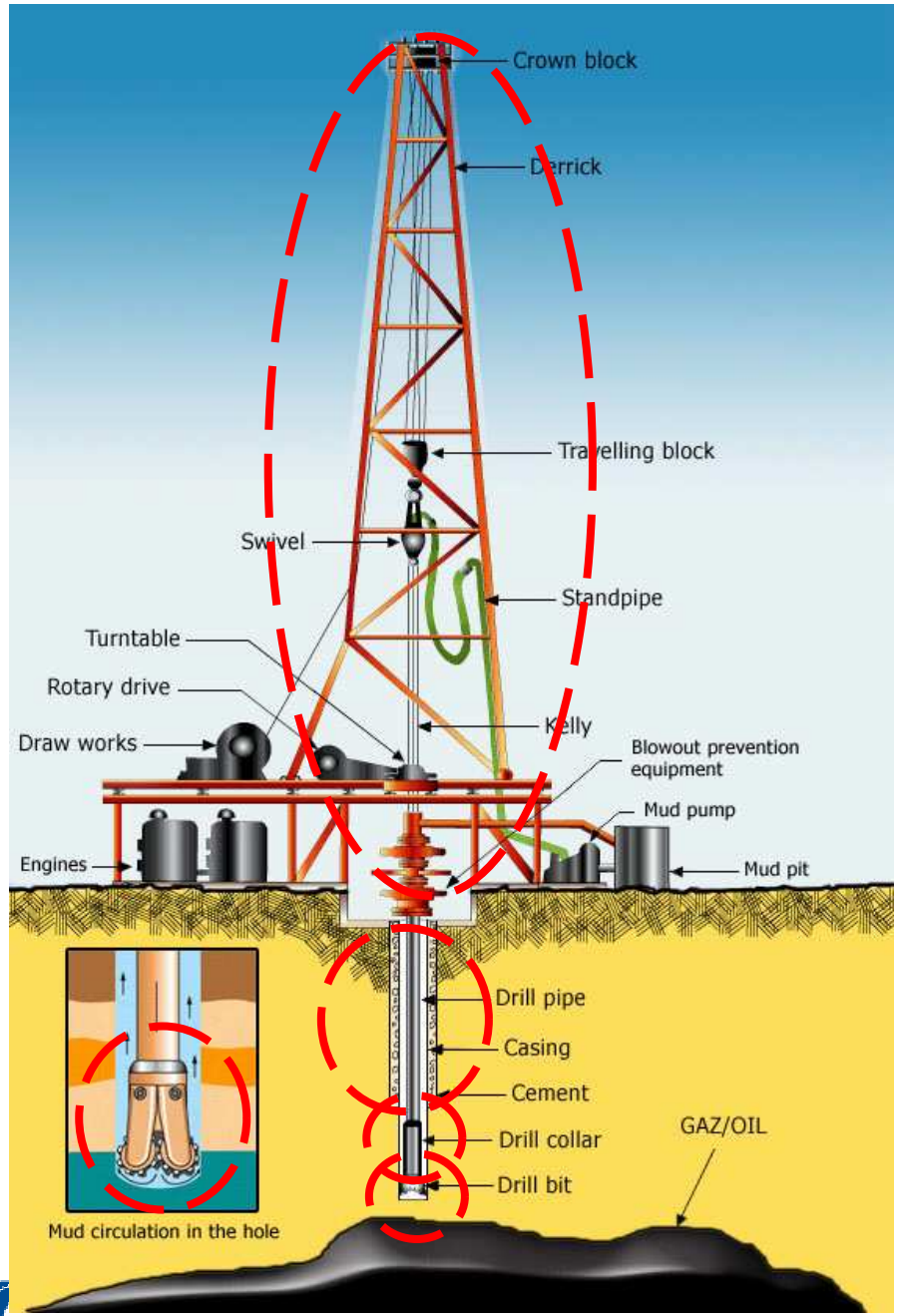
# Drilling station

Used for drilling oil/gas wells

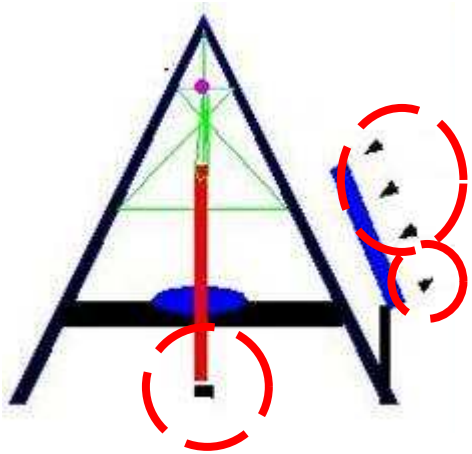
Composed of

- Rig
- Drill pipe
- Drill collar
- Drill bit

The model is used to predict if the system dysfunctions and detects instabilities



# Drilling station, Rig

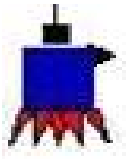


- Supports the weight of drill-string
- Control inputs
  - Longitudinal force
  - Longitudinal speed
  - Rotary torque
- (Observable) outputs
  - Rotary speed
- Implicit port
  - Connection to drill pipes

# Drilling station, Drill pipe, Drill collars

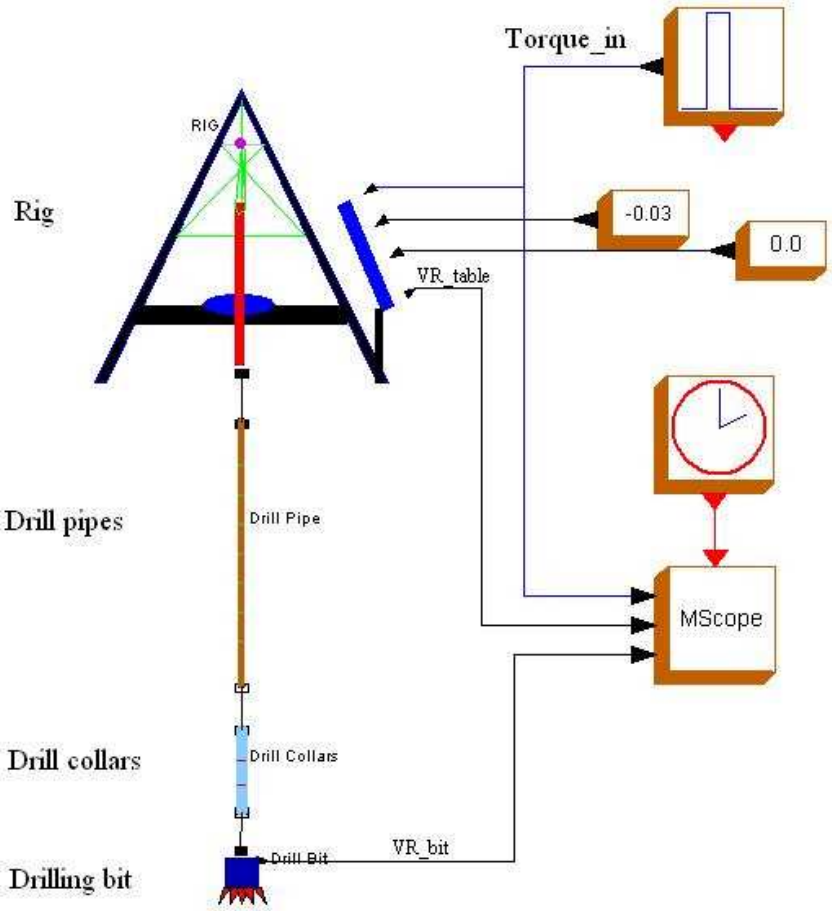
- Drill Pipe and Drill Collars:
  - Composed of several hundred short pipes
  - Due to it length exhibiting torsional, longitudinal, and lateral movements.
  - The drill pipe is discretized into N=15 segments
  - The drill collar is considered as a single segment

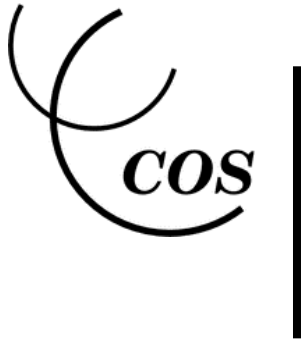
- Drill bit
  - Interaction of Longitudinal and rotational dynamics
  - Using external lookup tables (C functions + DLL libs)



# Drilling station

- Already modeled in Simulink
- The Simulink model is built with
  - 116 subsystems
  - >500 blocks
  - 7 levels of hierarchy
  - Difficult to navigate in the model
  - Fixed-step solver does not converge or needs very small step size
  - Variable-step solver is slows
- Scicos model
  - Very few blocks
  - Easy to edit and navigate in the model
  - Uses SUNDIALS
  - Using components instead of modules






# Questions/Demonstration….

**The Scilab 4.2 is released 17 April 2008.**

**Available at www.Scicos.org**

**Try Scicos today!**