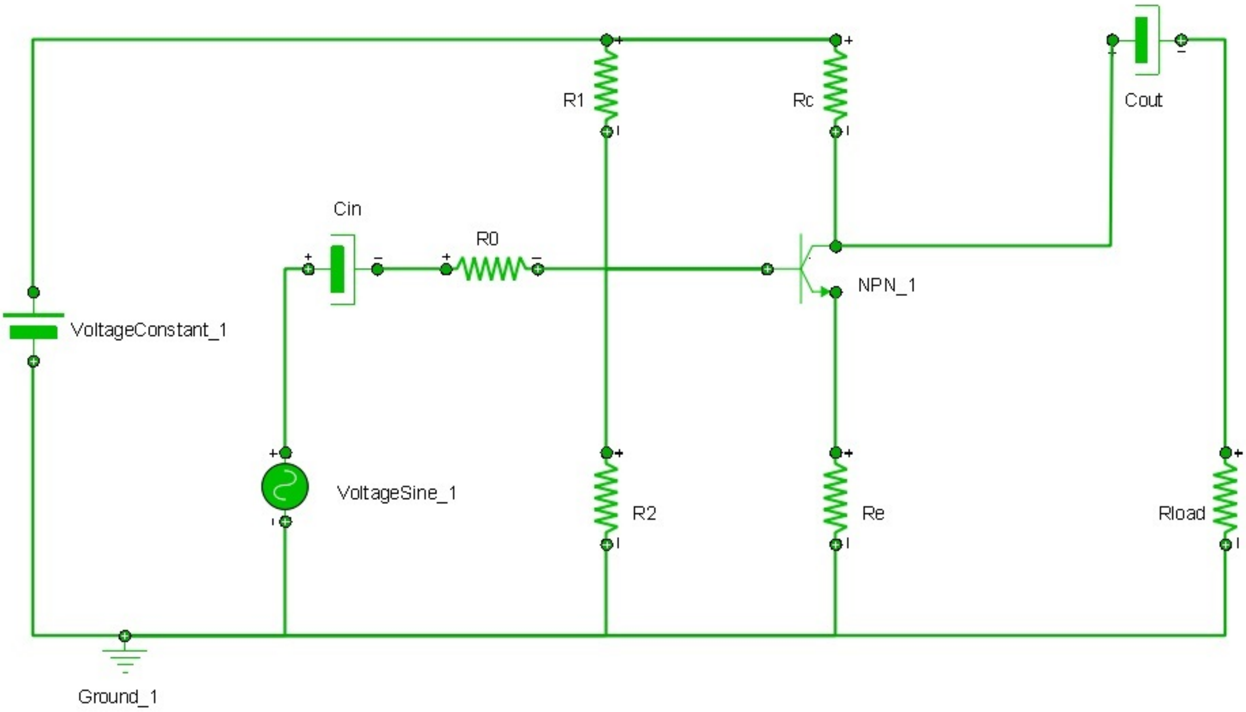
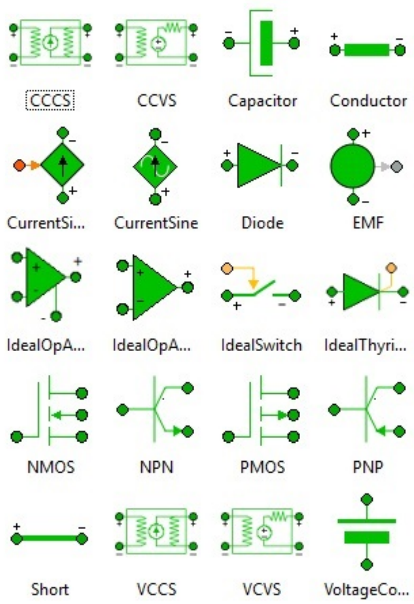
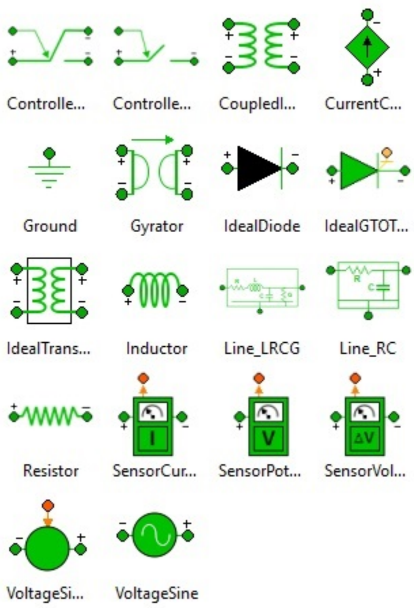
ELECTRICAL Library 3.1.2

Reference Manual







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Edition 2015

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Contents

1. Overview of the library

ELECTRICAL is an EcosimPro library for the transient and steady simulation of electrical circuits. Most of the typical electrical units are included as components ([1]) that can be used to build graphically complex systems.

1.1 Description

The following are the most important features of the library:

- The most basic two- or four-pin components are programmed based on Ohm's law (resistance devices), Faraday's law (devices storing energy in an electric field), and Henry's law (devices storing energy in a magnetic field).
- Special components simulating Amplifiers, RC lines, Switches, Diodes, Transistors and Electromotive Force are included.
- Generic sources of current & voltage are included.
- Sensor components measuring the current and the voltage in a branch (which allows coupling electrical circuits to control blocks) are also available.

A detailed examination of the formulation ([2]) reveals that components in the Electrical library calculate the current and the voltage in different ways; indeed, capacitive components explicitly calculate the voltage at their ports, while inductors explicitly calculate the current. Other components include linear or non-linear algebraic equations. A a result, the final model yields a complex system of equations with discrete events to be captured.

EcosimPro's job is to order all the equations involved, regardless of how the user includes the different components in a particular electrical network.

Typical electrical boxes that could be frequently used in complex models can be built topologically, and then considered as new components thanks to EcosimPro's object-oriented programming properties, i.e. Encapsulation, Inheritance and Aggregation.

1.2 Ports

ELECTRICAL Library uses the following types of elementary standard ports that are defined in the library PORTS_LIB:

[1] 1 A component is the basic simulation unit generated by Ecosimpro Language representing some physical/logical behaviour. Ecosimpro uses these components as symbols that can be dragged & pasted graphically to build more complex models.

[2] For a detailed description of the formulation and input data, please refer to the on-line Reference Manual available over any of the components inserted in a model diagram (documentation button of the Attributes Editor).

Port Type	Description	Colour
analog_signal	1-dimension array of analog signal	orange
elec	electrical pin	green
Mech_rot	1D rotational flange	black

The variables defined in each port are the following:

- analog_signal port

Name	Description	Units
signal[n]	Array of analog signals	-

- elec port

Name	Description	Units
i	Intensity (electrical current)	A
v	Voltage (electrical potential)	V

- mech_rot port

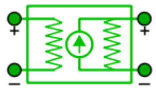
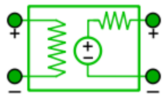
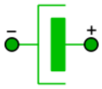
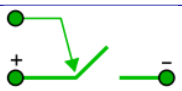
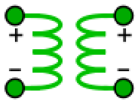
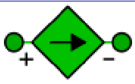
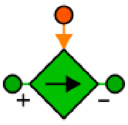
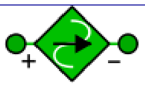
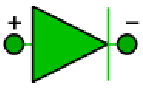
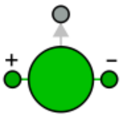
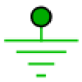
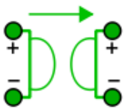
Name	Description	Units
T	Torque	N*m
n	Angular velocity	rpm
omega	Angular velocity	rad/s

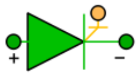
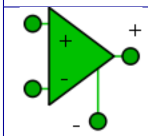
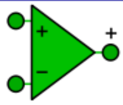
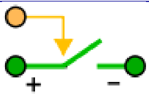
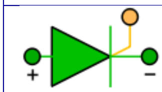
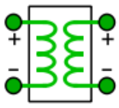
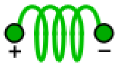
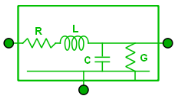
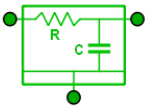
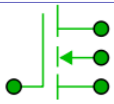
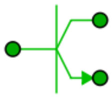
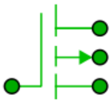
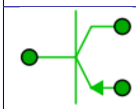
- bool_signal

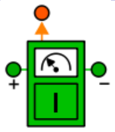
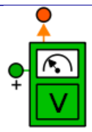
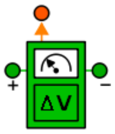
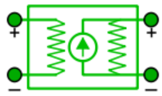
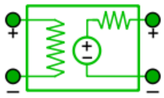
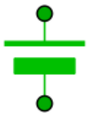
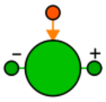
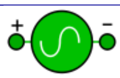
NAME	TYPE	INITIAL	RANGE	DESCRIPTION	UNITS
signal[n]	EQUAL OUT BOOLEAN			Boolean signal values	-

1.3 Palette of symbols

The components available in this library are depicted in the table below.

Symbol	Component Name	Description
	CCCS	Linear current-controlled current source
	CCVS	Linear current-controlled voltage source
	Capacitor	Device that stores energy in the electric field created between a pair of conductors
	Conductor	The linear conductor connects the voltage difference v with the branch current i by i = v*G
	ControlledIdealCommutingSwitch	Ideal commuting switch. If its voltage exceeds the level value, the inlet pin e_p is short cut to the pin e_n2. Otherwise, the pin e_p is short cut to the pin e_n1
	ControlledIdealSwitch	Controlled Ideal Switch. If its voltage exceeds the level value, the pins e_p and e_n are open, otherwise the pins e_p and e_n are shortcut
	CoupledInductor	It represents two inductors coupled by a mutual inductance
	CurrentConstant	Source for constant Current
	CurrentSignal	Generic Current source using the input signal as source Current
	CurrentSine	Sine Current source
	Diode	Semiconductor diode.
	EMF	Electromotive force (electric/mechanic transformer). It is used as basic building block of an electrical motor
	Ground	Ground of an electrical circuit
	Gyrator	Gyrator
	IdealDiode	Ideal electrical diode

Symbol	Component Name	Description
	IdealGTOThyristor	Ideal GTO thyristor. It acts as a switch, conducting when their gate receives a current pulse, and continue to conduct for as long as they are forward biased
	IdealOpAmp	Ideal Operational Amplifier.
	IdealOpAmp3Pin	Ideal Operational Amplifier with 3 pins.
	IdealSwitch	Ideal electrical switch
	IdealThyristor	Ideal Thyristor
	IdealTransformer	Ideal electrical transformer
	Inductor	An inductor is a passive electrical device that stores energy in a magnetic field, typically by combining the effects of many loops of electric current
	Line_LRCG	Lossy transmission line
	Line_RC	Uniform Distributed RC Line
	NMOS	Simple NMOS Transistor
	NPN	Bipolar NPN Junction Transistor component
	PMOS	Simple PMOS Transistor.
	PNP	Bipolar PNP Junction Transistor component
	Resistor	A resistor is a two-terminal electrical or electronic component that resists the flow of current, producing a voltage drop between its terminals in accordance with Ohm's law

Symbol	Component Name	Description
	SensorCurrent	Sensor to measure the current in a branch
	SensorPotential	Sensor to measure the potential in point
	SensorVoltage	Sensor to measure the voltage between two pins
	Short	Short cut branch
	VCCS	Linear voltage-controlled current source
	VCVS	Linear voltage-controlled voltage source
	VoltageConstant	Source for constant voltage
	VoltageSignal	Generic voltage source using the input signal as source voltage
	VoltageSine	Sine Voltage Source

Other components that a user may possibly require can be easily built by means of inheritance and aggregation of existing components.

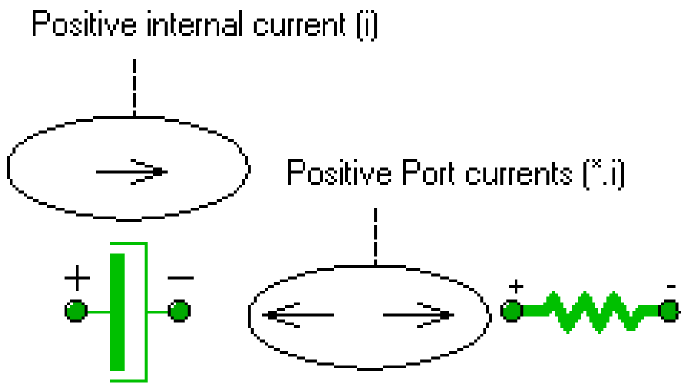
In this respect, the "Line_LRCG" component is an example of a topological model behaving as a new component where several more simple units have been aggregated.

For a detailed description of the formulation the input data, please refer to the "htm" file present in the DOC directory of the Library

1.4 Sign convention

The sign convention within a component is: Current ("i" variable) is positive if it goes from a positive electrical port (normally named e_p and marked with a + in the symbol) to a negative one (normally named e_n and marked with a - in the symbol).

Due to the "IN" definition of both, the positive and negative elec ports, the value of the current at a port (called *.i) is positive if it enters into the component to which the port is connected, independently of whether it is a positive or negative port, and it is negative if it goes out of the component:

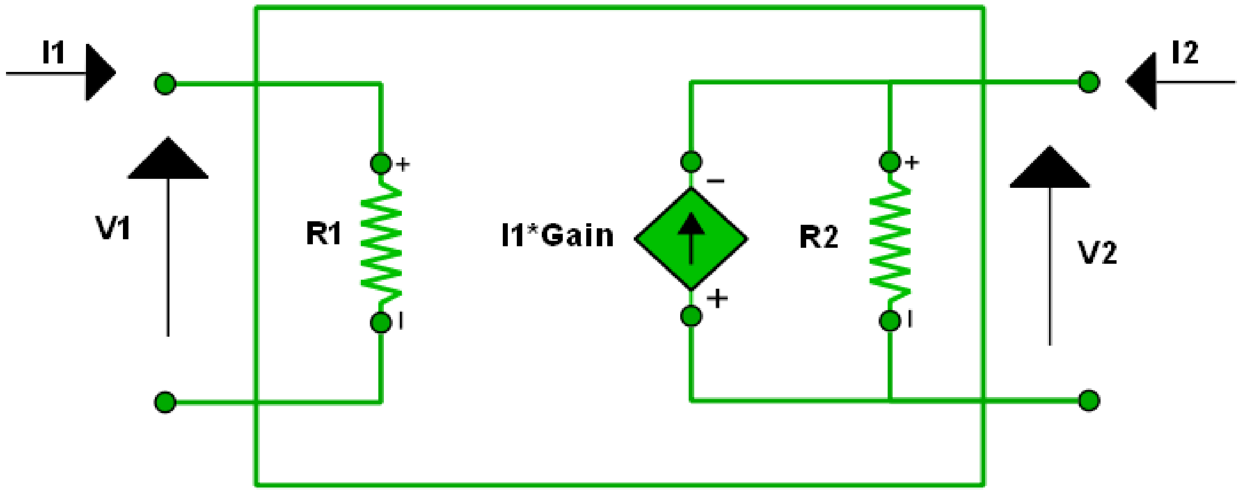


There is no restriction in the way the ports of a component are connected: Positive with negative, two positive ports together or two negative ports. Once the ports and the internal variables have been correctly formulated, the equation system is consequently assumed and solved.

2. Components

2.1 Linear current-controlled current source

The Linear current controlled current source component allows users to obtain an output current that is controlled by the input current. The relation between the input current and the output current is established by the component gain. The output current also contemplates an additional current that depends on the voltage established in the load terminals, v2. The component was modelled based on the abstract component "TwoPins". In this way, all the ports are defined as inputs. Therefore, the currents will be positive when they have an input direction, and negative in the opposite case. The operation of the source is defined as per?? the following diagram:



However, the component was not established in atopologically, but by establishing the following relations in the continuous section of the component:

$$i_2 = i_1 * gain - \frac{v_2}{R_2} \tag{2.1}$$

$$v_1 = i_1 * R_1 \tag{2.2}$$

Ports:

NAME	TYPE	PARAMETERS	DIRECTION	CARDINALITY	DESCRIPTION
e_n1	PORTS_LIB.elec		IN		Negative pin of port 1
e_n2	PORTS_LIB.elec		IN		Negative pin of port 2
e_p1	PORTS_LIB.elec		IN		Positive pin of port 1
e_p2	PORTS_LIB.elec		IN		Positive pin of port 2

Parameters:

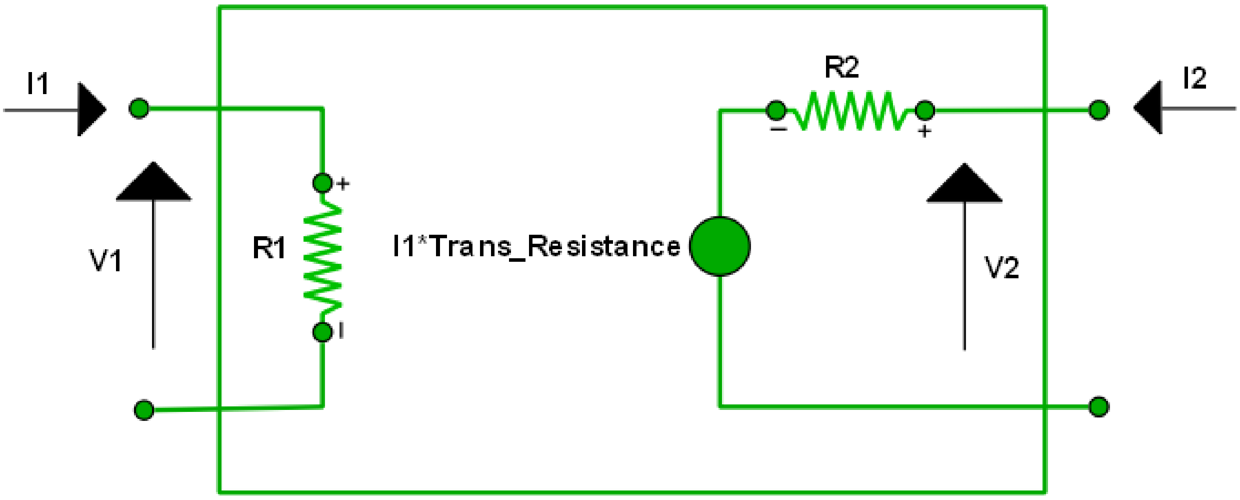
NAME	TYPE	DEFAULT	RANGE	DESCRIPTION	UNITS
R1	REAL	0		Input resistance	Ohm
R2	REAL	1e+040		Output resistance	Ohm
gain	REAL	1		Current gain	-

Variables:

NAME	TYPE	INITIAL	RANGE	DESCRIPTION	UNITS
i1	REAL			Current flowing from pos. to neg. pin of the left port	A
i2	REAL			Current flowing from pos. to neg. pin of the right port	A
v1	REAL			Voltage drop over the left port	V
v2	REAL			Voltage drop over the right port	V

2.2 Current Controlled Voltage Source

The component Current Controlled Voltage Source (CCVS), allows users to obtain an output voltage controlled by the input current. The input voltage determines the input current according to the input resistance of the source (R1). The relation between the input current and outlet voltage is established by means of a transfer resistance (transresistance). The output voltage also contemplates the voltage drop that takes place in the output impedance of the source (R2) as the output current passes through it. This component inherits its topology from the abstract component "TwoPort" and has the following structure:



The following equations comprise the continuous part of the component and define its behaviour:

$$v_2 = i_1 * trans\_Resistance - i_2 * R_2 \tag{2.3}$$

$$v_1 = i_1 * R_1 \tag{2.4}$$

Ports:

NAME	TYPE	PARAMETERS	DIRECTION	CARDINALITY	DESCRIPTION
e_n1	PORTS_LIB.elec		IN		Negative pin of port 1
e_n2	PORTS_LIB.elec		IN		Negative pin of port 2
e_p1	PORTS_LIB.elec		IN		Positive pin of port 1
e_p2	PORTS_LIB.elec		IN		Positive pin of port 2

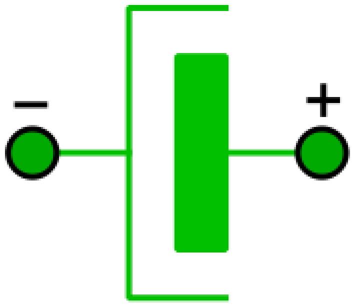
Parameters:

NAME	TYPE	DEFAULT	RANGE	DESCRIPTION	UNITS
R1	REAL	0		Input resistance	Ohm
R2	REAL	0		Output resistance	Ohm
transResistance	REAL	1		Transresistance	Ohm

Variables:

NAME	TYPE	INITIAL	RANGE	DESCRIPTION	UNITS
i1	REAL			Current flowing from pos. to neg. pin of the left port	A
i2	REAL			Current flowing from pos. to neg. pin of the right port	A
v1	REAL			Voltage drop over the left port	V
v2	REAL			Voltage drop over the right port	V

2.3 Capacitor



The capacitor model included in the ELECTRICAL library inherits the characteristics of the abstract component OnePort. Its formulation corresponds to the following well-known condenser equation:

$$v_C = \frac{1}{C} * \int i_C(t)dt \tag{2.5}$$

Said expression is restated in derivative terms in accordance with the EcosimPro/Proosis philosophy:

$$i_C = C\frac{dv_C(t)}{dt} \tag{2.6}$$

Ports:

NAME	TYPE	PARAMETERS	DIRECTION	CARDINALITY	DESCRIPTION
e_n	PORTS_LIB.elec		IN		Negative pin
e_p	PORTS_LIB.elec		IN		Positive pin

Parameters:

NAME	TYPE	DEFAULT	RANGE	DESCRIPTION	UNITS
C	REAL	1e-006		Capacitance	F

Variables:

NAME	TYPE	INITIAL	RANGE	DESCRIPTION	UNITS
i	REAL			Current flowing from pin e_p to pin e_n	A
v	REAL			Voltage drop between the two pins = e_p.v - e_n.v	V

2.4 Conductor

The conductor inherits its behaviour from the abstract component OnePort. Its formulation corresponds to Ohm's Law expressed in terms of conductivity. This law is descrbed by the following equation which is established in the continuous section.

$$i = v * G \tag{2.7}$$

Ports:

NAME	TYPE	PARAMETERS	DIRECTION	CARDINALITY	DESCRIPTION
e_n	PORTS_LIB.elec		IN		Negative pin
e_p	PORTS_LIB.elec		IN		Positive pin

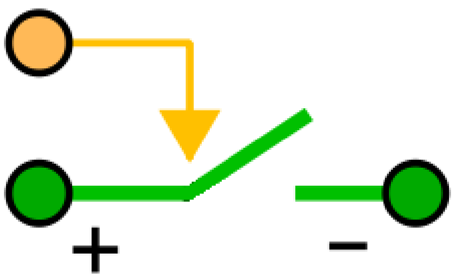
Parameters:

NAME	TYPE	DEFAULT	RANGE	DESCRIPTION	UNITS
G	REAL	1		Conductance	S

Variables:

NAME	TYPE	INITIAL	RANGE	DESCRIPTION	UNITS
i	REAL			Current flowing from pin e_p to pin e_n	A
v	REAL			Voltage drop between the two pins = e_p.v - e_n.v	V

2.5 Ideal Switch



The Ideal Switch component models the behaviour of an ideal switch controlled by means of a Boolean type signal. The behaviour of the control signal is evaluated in the discrete section of the component. When it changes from low level to high level, the switch is activated (ON mode). When it changes from 1 to 0, the switch is deactivated (OFF mode). The difference between one mode and the other one is given by the internal resistance, which will be high in OFF mode and low in ON mode.

```
WHEN (b_fire.signal[1]) THEN
open = FALSE
closed = TRUE
END WHEN
WHEN (NOT b_fire.signal[1]) THEN
closed = FALSE
open = TRUE
END WHEN
```

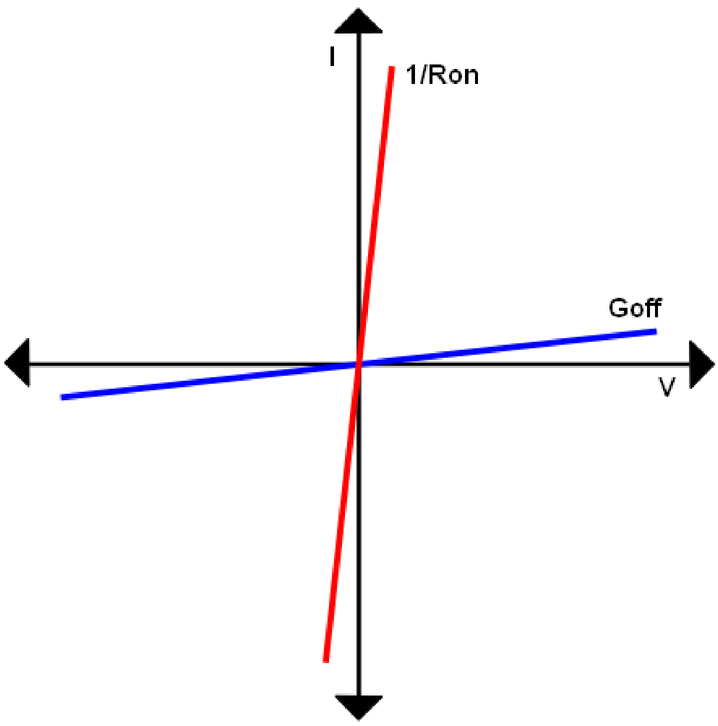
In order to model this component, an auxiliary variable "s" is used, which responds to the current when the component is in OFF mode and to the voltage when it is in ON mode. This component is described by means of Ohm's resistive and conductive laws using the ZONE statement.

COMMENT

There is an error in the component's code which is corrected here. Ron and Goff are inverted (in the code they are Roff and Gon). The same ocurrs in the rest of the switches.

```
v = ZONE (open) s
OTHERS Ron*s
i = ZONE (open) Goff*s
OTHERS s
```

The above analysis can be summarized by representing the ideal switch component by means of the following characteristic I-V curve, which shows the values of Ron and Goff far removed from the ideal to emphasize their influence.



Ports:

NAME	TYPE	PARAMETERS	DIRECTION	CARDINALITY	DESCRIPTION
b_fire	PORTS_LIB.bool_signal		IN		
e_n	PORTS_LIB.elec		IN		Negative pin
e_p	PORTS_LIB.elec		IN		Positive pin

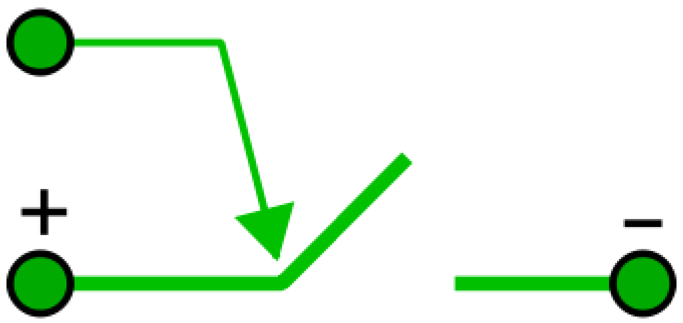
Parameters:

NAME	TYPE	DEFAULT	RANGE	DESCRIPTION	UNITS
Gon	REAL	1e-005	0,1e+038	Opened thyristor conductance	S
Roff	REAL	1e-005	0,1e+038	Closed thyristor resistance	Ohm

Variables:

NAME	TYPE	INITIAL	RANGE	DESCRIPTION	UNITS
closed	BOOLEAN	FALSE			
i	REAL			Current flowing from pin e_p to pin e_n	A
open	BOOLEAN	TRUE			
s	REAL			Auxiliary variable	
v	REAL			Voltage drop between the two pins = e_p.v - e_n.v	V

2.6 Controlled Ideal Switch



The component Controlled Ideal Switch responds to the same operation as described in the previous point for the component Ideal Switch, the only difference being the type of control signal used. It is no longer Boolean type, but an electrical signal. An infinite input impedance is also established for the control terminals, which rejects the current through it. The control therefore is carried out under voltage. For all other aspects, this component behaves identically to the above-mentioned Ideal Switch.

Ports:

NAME	TYPE	PARAMETERS	DIRECTION	CARDINALITY	DESCRIPTION
e_control	PORTS_LIB.elec		IN		Control pin: control.v > level open, otherwise closed
e_n	PORTS_LIB.elec		IN		Negative pin
e_p	PORTS_LIB.elec		IN		Positive pin

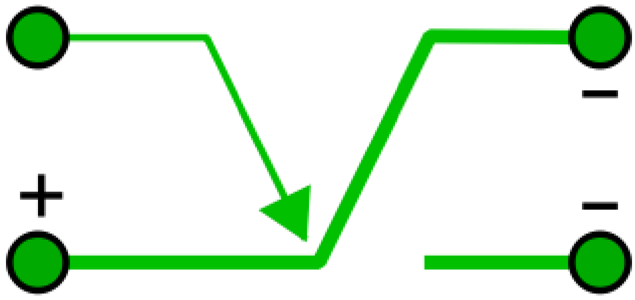
Parameters:

NAME	TYPE	DEFAULT	RANGE	DESCRIPTION	UNITS
Gon	REAL	1e-005	0,1e+040	Opened switch conductance	S
Roff	REAL	1e-005	0,1e+040	Closed switch resistance	Ohm
level	REAL	0.5		Switch level	V

Variables:

NAME	TYPE	INITIAL	RANGE	DESCRIPTION	UNITS
s	REAL			Auxiliary variable	

2.7 Controlled Ideal Commuting Switch



The ideal commuter has two output ports, and depending on the value of the control signal, the input port is connected to one of the two output ports. The formulation is completed by establishing the sum of the currents as null: the inlet current shall be equal to and of opposite sign to the sum of the two output currents.

Ports:

NAME	TYPE	PARAMETERS	DIRECTION	CARDINALITY	DESCRIPTION
e_control	PORTS_LIB.elec		IN		Control pin: control.v > level p–n2, otherwise p–n1
e_n1	PORTS_LIB.elec		IN		Negative pin 1
e_n2	PORTS_LIB.elec		IN		Negative pin 2
e_p	PORTS_LIB.elec		IN		Positive pin

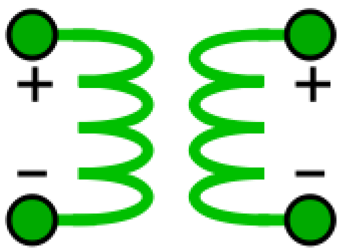
Parameters:

NAME	TYPE	DEFAULT	RANGE	DESCRIPTION	UNITS
Gon	REAL	1e-005	0,1e+040	Opened switch conductance	S
Roff	REAL	1e-005	0,1e+040	Closed switch resistance	Ohm
level	REAL	0.5		Switch level	V

Variables:

NAME	TYPE	INITIAL	RANGE	DESCRIPTION	UNITS
s1	REAL			Auxiliary variable 1	
s2	REAL			Auxiliary variable 2	

2.8 Coupled inductor



The component Coupled Inductor models a structure formed by two mutually coupled inductors. Each one has its own inductivity and in addition is sensitive to the inductivity of the other winding. Thus, the voltage at the ends of each inductor depends on its own internal current ... and, by means of a coupling coefficient, on the current through the other inductor. The law on which the component's behaviour is based is the same one as for the simple winding:

$$v_L = L * \frac{di_L(t)}{dt} \tag{2.8}$$

This equation adapts itself to the modelling concept that must be applied in EcosimPro, in which it is always necessary to try to establish the value of the derivatives so that the variables can be solved by means of an integrator as dynamic variables. If the influence of the second inductor and the coupling is taken into consideration, the continuous section of the couple inductor is completed by the following equations:

$$v_{L1} = L_1 * \frac{di_{L1}(t)}{dt} + M * \frac{di_{L2}(t)}{dt} \tag{2.9}$$

$$v_{L2} = L_2 * \frac{di_{L2}(t)}{dt} + M * \frac{di_{L1}(t)}{dt} \tag{2.10}$$

Where the mutual induction, M, is calculated according to the following expression:

$$M = K * \sqrt{L_1 * L_2} \tag{2.11}$$

Where K is the coupling coefficient.

Ports:

NAME	TYPE	PARAMETERS	DIRECTION	CARDINALITY	DESCRIPTION
e_n1	PORTS_LIB.elec		IN		Negative pin of port 1
e_n2	PORTS_LIB.elec		IN		Negative pin of port 2
e_p1	PORTS_LIB.elec		IN		Positive pin of port 1
e_p2	PORTS_LIB.elec		IN		Positive pin of port 2

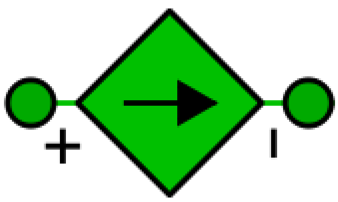
Parameters:

NAME	TYPE	DEFAULT	RANGE	DESCRIPTION	UNITS
K	REAL	0.5	0,1 - 1e-006	Coefficient of Coupling Coupling	-
L1	REAL	1	0,Inf	Primary inductance	H
L2	REAL	1	0,Inf	Secondary inductance	H

Variables:

NAME	TYPE	INITIAL	RANGE	DESCRIPTION	UNITS
M	REAL			Coupling inductance (H)	H
i1	REAL			Current flowing from pos. to neg. pin of the left port	A
i2	REAL			Current flowing from pos. to neg. pin of the right port	A
v1	REAL			Voltage drop over the left port	V
v2	REAL			Voltage drop over the right port	V

2.9 Current Constant



$$i(t) = I \tag{2.12}$$

The component Current Constant allows users to set the current of a branch to a constant value. It inherits the characterisitics of the abstract component OnePort. The value of the current is set by making the internal variable i of said component equal to a referred parameter like I. Its definition as OnePort means that it is has two electrical ports and that their internal variables are its internal current i and its positive to negative voltage.

Ports:

NAME	TYPE	PARAMETERS	DIRECTION	CARDINALITY	DESCRIPTION
e_n	PORTS_LIB.elec		IN		Negative pin
e_p	PORTS_LIB.elec		IN		Positive pin

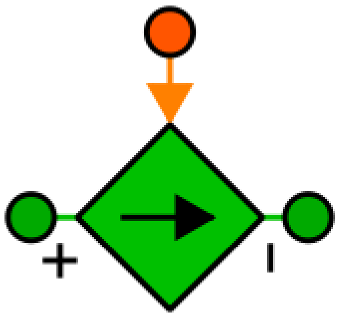
Parameters:

NAME	TYPE	DEFAULT	RANGE	DESCRIPTION	UNITS
I	REAL	1		Value of constant Current	A

Variables:

NAME	TYPE	INITIAL	RANGE	DESCRIPTION	UNITS
i	REAL			Current flowing from pin e_p to pin e_n	A
v	REAL			Voltage drop between the two pins = e_p.v - e_n.v	V

2.10 Current Signal



$$i(t) = s\_in.signal$$

The component Current Signal allows users to convert a control signal to electrical current along a branch. It adds a control port type analog_signal to a OnePort type component. The value of said control signal is made equal to the variable i of the source.

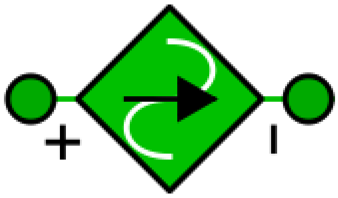
Ports:

NAME	TYPE	PARAMETERS	DIRECTION	CARDINALITY	DESCRIPTION
e_n	PORTS_LIB.elec		IN		Negative pin
e_p	PORTS_LIB.elec		IN		Positive pin
s_in	PORTS_LIB.analog_signal		IN		Control signal

Variables:

NAME	TYPE	INITIAL	RANGE	DESCRIPTION	UNITS
i	REAL			Current flowing from pin e_p to pin e_n	A
v	REAL			Voltage drop between the two pins = e_p.v - e_n.v	V

2.11 Current Sine



$$i(t) = \sin(Ipeak, freqHz, phase, offset, starttime)$$

The component Current Sine establishes a steady sinusoidal current in the branch in which it is located. Like the other one-phase current sources, it inherits its behaviour from the abstract component OnePort. In addition, by means of topological programming, a Sine type source is defined that acts as a control of Current Signal source. This type of source allows the configuration of amplitude, frequency, phase, offset and startup time of the signal. In addition, the inheritance and topological programming avoids redundancies and unnecessary lines of code.

Ports:

NAME	TYPE	PARAMETERS	DIRECTION	CARDINALITY	DESCRIPTION
e_n	PORTS_LIB.elec		IN		Negative pin
e_p	PORTS_LIB.elec		IN		Positive pin

Parameters:

NAME	TYPE	DEFAULT	RANGE	DESCRIPTION	UNITS
Ioffset	REAL	0		Current offset	A
Ipeak	REAL	1		Current amplitude	A
freqHz	REAL	1		Frequencies of sine waves	Hz
phase	REAL	0		Phases of sine waves	rad
startTime	REAL	0		Output = offset for time	s

Variables:

NAME	TYPE	INITIAL	RANGE	DESCRIPTION	UNITS
i	REAL			Current flowing from pin e_p to pin e_n	A
v	REAL			Voltage drop between the two pins = e_p.v - e_n.v	V

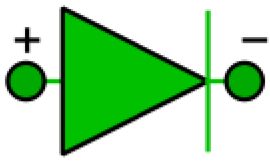
Component instances (Topology Block):

OBJECT	COMPONENT TYPE	DESCRIPTION
current	CurrentSignal	
source	Sine	

Component instances Data:

DATUM	VALUE	POS	TYPE	DESCRIPTION	UNITS
source.amplitude	Ipeak	DATA	REAL	Amplitudes of sine waves	"-"
source.freqHz	freqHz	DATA	REAL	Frequencies of sine waves	"Hz"
source.offset	Ioffset	DATA	REAL	Offsets of output signals	"-"
source.phase	phase	DATA	REAL	Phases of sine waves	"rad"
source.startTime	startTime	DATA	REAL	Output = offset for time	"s"

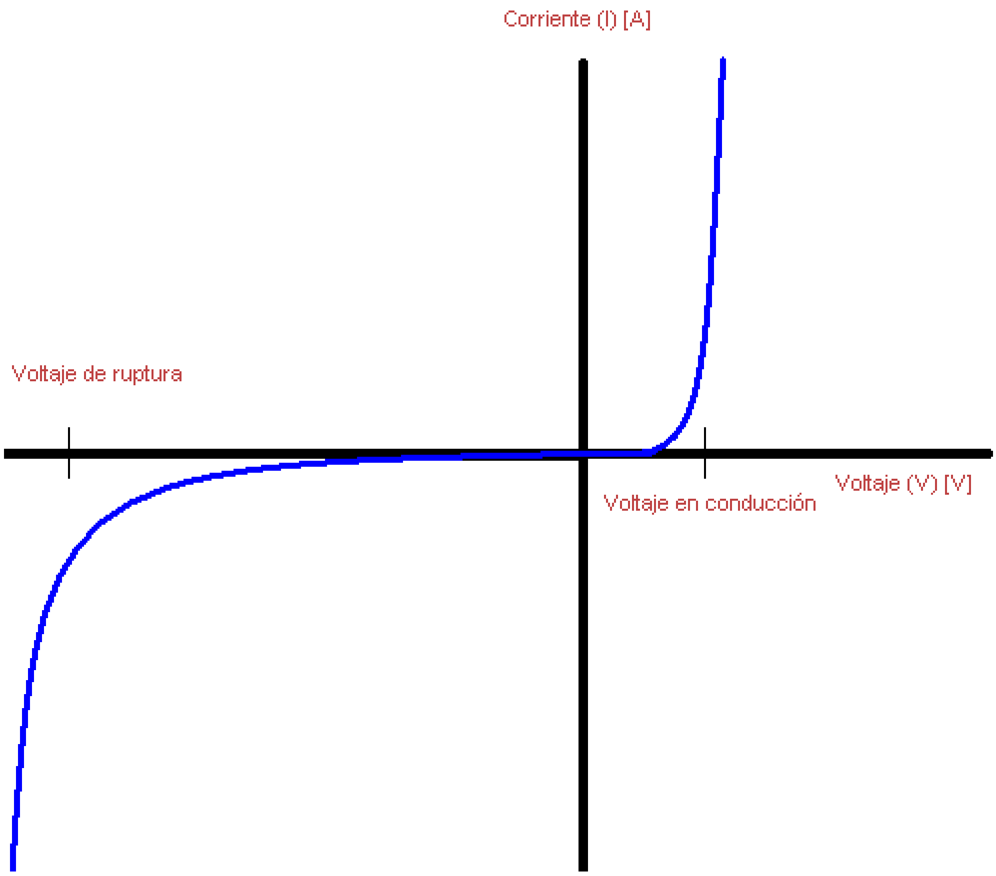
2.12 Diode



The Diode component inherits its characteristics from the component OnePort. The CONTINUOUS section contains the continuous equation of the diode. This equation establishes the current through the diode as a function of an exponential of the anode to cathode voltage of the component.

$$i_D = I_{DS} * (e^{v/V_T} - 1) + V_R \tag{2.13}$$

The graphical behaviour of the diode equation is represented by the following Voltage-Current characteristic curve:



Ports:

NAME	TYPE	PARAMETERS	DIRECTION	CARDINALITY	DESCRIPTION
e_n	PORTS_LIB.elec		IN		Negative pin
e_p	PORTS_LIB.elec		IN		Positive pin

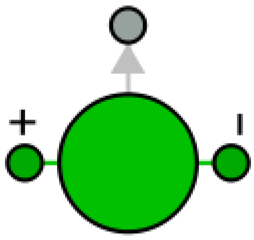
Parameters:

NAME	TYPE	DEFAULT	RANGE	DESCRIPTION	UNITS
Ids	REAL	1e-006		Saturation current	A
R	REAL	100000000		Parallel ohmic resistance	Ohm
Vt	REAL	0.04		Voltage equivalent of temperature = kT/qn	V

Variables:

NAME	TYPE	INITIAL	RANGE	DESCRIPTION	UNITS
i	REAL			Current flowing from pin e_p to pin e_n	A
v	REAL			Voltage drop between the two pins = e_p.v - e_n.v	V

2.13 Electromotive Force



The Electromotive Force component is an ideal version of a direct current motor. This component has two electrical terminals (positive and negative) and a rotary mechanical shaft. The rotation speed of the shaft depends on the voltage applied at the ends, while the torque depends on the current. The component does not contemplate the equivalent circuit of the motor, so the consumption of the motor deopends exclusively on the torque applied to the shaft. If there is no resistant torque, the current is null. It is assumed, therefore, that the speed is always determined by feed voltage independently of the mechanical load. Neither does it contemplate the dynamics of the motor: there are no mechanical or electrical time constants, nor are there any inertias or frictions. The voltage-speed and current-torque ratios are given by a constant *k*.

$$Shaft\_Torque(t) = K * i(t) \tag{2.14}$$

$$Shaft\_Speed(t) = K * v(t) \tag{2.15}$$

Ports:

NAME	TYPE	PARAMETERS	DIRECTION	CARDINALITY	DESCRIPTION
e_n	PORTS_LIB.elec		IN		Negative pin
e_p	PORTS_LIB.elec		IN		Positive pin

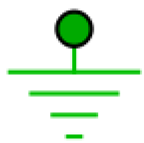
Parameters:

NAME	TYPE	DEFAULT	RANGE	DESCRIPTION	UNITS
k	REAL	1		Transformation coefficient	Nw.m/A

Variables:

NAME	TYPE	INITIAL	RANGE	DESCRIPTION	UNITS
i	REAL			Current flowing from positive to negative pin	A
omega	REAL			Angular velocity of flange_b	rad/s
v	REAL			Voltage drop between the two pins	V

2.14 Ground



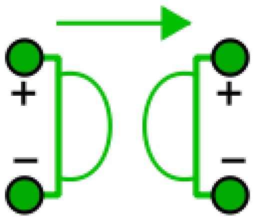
The Ground component is used to establish a reference potential based on which voltage levels at all points of a circuit can be determined. The currents through the component are not defined in any way, but it is the rest of the circuit that determines their values. Therefore, the component has a single elec type port and its voltage is set to zero.

$$Ground.v = 0 \tag{2.16}$$

Ports:

NAME	TYPE	PARAMETERS	DIRECTION	CARDINALITY	DESCRIPTION
e_p	PORTS_LIB.elec		IN		

2.15 Gyrator



The Gyrator component carries out an exchange between the voltage-current ratio at the input and output of a TwoPort type component. The current at the input depends on the voltage at the output, while the current at the output depends on the voltage at the input. These relationships are defined by the input and output conductances, G_1 and G_2. It inherits all its characteristics from the abstract component TwoPort.

$$i_1(t) = G_2 * v_2(t) \tag{2.17}$$

$$i_2(t) = -G_1 * v_1(t) \tag{2.18}$$

Ports:

NAME	TYPE	PARAMETERS	DIRECTION	CARDINALITY	DESCRIPTION
e_n1	PORTS_LIB.elec		IN		Negative pin of port 1
e_n2	PORTS_LIB.elec		IN		Negative pin of port 2
e_p1	PORTS_LIB.elec		IN		Positive pin of port 1
e_p2	PORTS_LIB.elec		IN		Positive pin of port 2

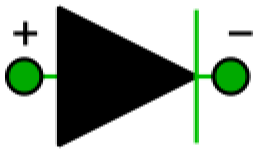
Parameters:

NAME	TYPE	DEFAULT	RANGE	DESCRIPTION	UNITS
G1	REAL	1		Gyration conductance	S
G2	REAL	1		Gyration conductance	S

Variables:

NAME	TYPE	INITIAL	RANGE	DESCRIPTION	UNITS
i1	REAL			Current flowing from pos. to neg. pin of the left port	A
i2	REAL			Current flowing from pos. to neg. pin of the right port	A
v1	REAL			Voltage drop over the left port	V
v2	REAL			Voltage drop over the right port	V

2.16 Ideal Diode



The Ideal Diode component approximates the characterstic C-V curve of the diode by means of straight sections. It uses a basic Ohm's Law in which the internal resistance of the diode changes as a function of the polarization of the diode. Depending on whether the anode-cathode voltage of the diode is positive or negative, the component takes on a high or low internal resistance, respectively. In this way it reproduces ON-OFF or conducting-insulating behaviour. The component inherits the characteristics of the abstract element OnePort.

Ports:

NAME	TYPE	PARAMETERS	DIRECTION	CARDINALITY	DESCRIPTION
e_n	PORTS_LIB.elec		IN		Negative pin
e_p	PORTS_LIB.elec		IN		Positive pin

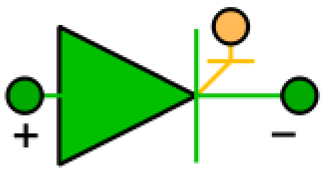
Parameters:

NAME	TYPE	DEFAULT	RANGE	DESCRIPTION	UNITS
Gon	REAL	1e-005		Opened diode conductance	S
Roff	REAL	1e-005		Closed diode resistance	Ohm

Variables:

NAME	TYPE	INITIAL	RANGE	DESCRIPTION	UNITS
i	REAL			Current flowing from pin e_p to pin e_n	A
off	BOOLEAN	TRUE		Switching state of diode	
s	REAL			Auxiliary variable	
v	REAL			Voltage drop between the two pins = e_p.v - e_n.v	V

2.17 Ideal GTO Thyristor



The ideal GTO thyristor models the behaviour of a thyristor in which, in addition, it is possible to interrupt its conductance even though the current through it has not been anulled. It is sufficient to remove the voltage applied at the control terminal gate. Its model inherits the characteristics of the abstract component OnePort and implements an internal resistance that is high or low depending on the polarization and on the control of the device. The device is controlled by a bool_signal type port.

Ports:

NAME	TYPE	PARAMETERS	DIRECTION	CARDINALITY	DESCRIPTION
b_fire	PORTS_LIB.bool_signal		IN		
e_n	PORTS_LIB.elec		IN		Negative pin
e_p	PORTS_LIB.elec		IN		Positive pin

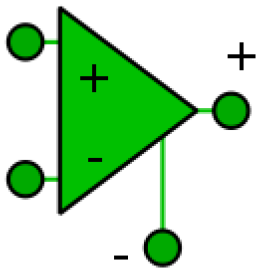
Parameters:

NAME	TYPE	DEFAULT	RANGE	DESCRIPTION	UNITS
Gon	REAL	1e-005	0,1e+038	Opened thyristor conductance	S
Roff	REAL	1e-005	0,1e+038	Closed thyristor resistance	Ohm

Variables:

NAME	TYPE	INITIAL	RANGE	DESCRIPTION	UNITS
closed	BOOLEAN	FALSE			
i	REAL			Current flowing from pin e_p to pin e_n	A
open	BOOLEAN	TRUE			
s	REAL			Auxiliary variable	
v	REAL			Voltage drop between the two pins = e_p.v - e_n.v	V

2.18 Ideal Operational Amplifier



The ideal operational amplifier component takes an input voltage and transfers it to the output via an infinite impedance, and in addition applies a given gain. The component is defined as TwoPort and the infinite inlet impedance is established by setting the inlet current to zero. The output current is established based on the output voltage and the rest of the circuit.

$$v_2(t) = G * v_1(t) \tag{2.19}$$

$$i_1(t) = 0 \tag{2.20}$$

Ports:

NAME	TYPE	PARAMETERS	DIRECTION	CARDINALITY	DESCRIPTION
e_n1	PORTS_LIB.elec		IN		Negative pin of port 1
e_n2	PORTS_LIB.elec		IN		Negative pin of port 2
e_p1	PORTS_LIB.elec		IN		Positive pin of port 1
e_p2	PORTS_LIB.elec		IN		Positive pin of port 2

Parameters:

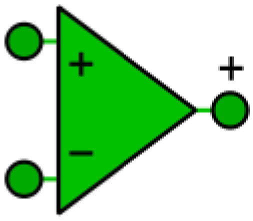
NAME	TYPE	DEFAULT	RANGE	DESCRIPTION	UNITS
G	REAL	1000000		Amplifier gain	-

Variables:

NAME	TYPE	INITIAL	RANGE	DESCRIPTION	UNITS
i1	REAL			Current flowing from pos. to neg. pin of the left port	A
i2	REAL			Current flowing from pos. to neg. pin of the right port	A
v1	REAL			Voltage drop over the left port	V
v2	REAL			Voltage drop over the right port	V

2.19 Three-Pin Ideal Operational Amplifier

The tree-pin ideal operational amplifier works in the same way as the four-pin ideal operational amplifier described above but, instead of supplying the outlet voltage between two pins, it supplies it at a single pin. Therefore, that voltage at this point is referred to zero. The use of this component makes it necessary to design the circuit on the basis of this criterion and to establish a reference voltage in order to determine the voltage drop at load extremes. Consequently, the component is not modelled as a TwoPort, but instead three electric points are defined to complete the model. The component lacks intenal variables as it is modelled using only the variables of the ports.



$$e\_out.v = G(e\_in\_p.v - e\_in\_n.v) \tag{2.21}$$

$$e\_in\_p.i = 0 \tag{2.22}$$

$$e\_in\_n.i = 0 \tag{2.23}$$

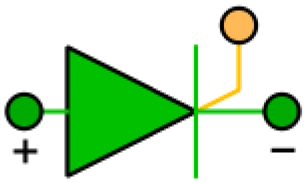
Ports:

NAME	TYPE	PARAMETERS	DIRECTION	CARDINALITY	DESCRIPTION
e_in_n	PORTS_LIB.elec		IN		Negative pin of the input port
e_in_p	PORTS_LIB.elec		IN		Positive pin of the input port
e_out	PORTS_LIB.elec		IN		Output pin

Parámetros:

NAME	TYPE	DEFAULT	RANGE	DESCRIPTION	UNITS
G	REAL	1000000		Amplifier gain	-

2.20 Ideal Thyristor



The model of the ideal thyristor is based on a combination of continuous and discrete formulations. This component responds to a basic Ohm's Law in which the resistance becomes very high when the device is blocked (OFF), and takes on a negligable value if it is conducting (ON). The activation of the thyristor, is established in the descrete section and it depends on the direct polarizarion of the thyristor and on the arrival of the activation signal at the gate terminal. Once activated, the thyristor continues to conduct until the current through it changes its direction. Therefore, in essence, the thyristor is a diode whose conduction can be controlled and even prevented by means of a control terminal. The component inherits the characteristics of the abstract element OnePort and is controlled by means of a bool_signal type port that acts as a gate terminal.

Ports:

NAME	TYPE	PARAMETERS	DIRECTION	CARDINALITY	DESCRIPTION
b_fire	PORTS_LIB.bool_signal		IN		Control gate pin
e_n	PORTS_LIB.elec		IN		Negative pin
e_p	PORTS_LIB.elec		IN		Positive pin

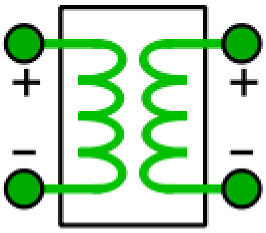
Parameters:

NAME	TYPE	DEFAULT	RANGE	DESCRIPTION	UNITS
Gon	REAL	1e-005	0,1e+038	Opened thyristor conductance	S
Roff	REAL	1e-005	0,1e+038	Closed thyristor resistance	Ohm

Variables:

NAME	TYPE	INITIAL	RANGE	DESCRIPTION	UNITS
closed	BOOLEAN	FALSE		Thyristor state = ON when TRUE	
i	REAL			Current flowing from pin e_p to pin e_n	A
open	BOOLEAN	TRUE		Thyristor state = OFF when TRUE	
s	REAL			Auxiliary variable	
v	REAL			Voltage drop between the two pins = e_p.v - e_n.v	V

2.21 Transformador Ideal



The ideal transformer model in ELECTRICAL Libraryignores all the undesired effects that arise in a real transformer [1]. The user has to establish the transformation ratio between the input and the output, which in a real transformer would be given by the quotient of the number of spirals in each winding. The component inherits the characteristics of the abstract component TwoPort and therefore it is necessary to invert the sign of the currents at its passage from the primary to the secondary to establish as positive the outgoing current from the secondary as all the ports are defined as inlets.

$$v_1 = n * v_2 \tag{2.24}$$

$$i_2 = -n * i_1 \tag{2.25}$$

Ports:

NAME	TYPE	PARAMETERS	DIRECTION	CARDINALITY	DESCRIPTION
e_n1	PORTS_LIB.elec		IN		Negative pin of port 1
e_n2	PORTS_LIB.elec		IN		Negative pin of port 2
e_p1	PORTS_LIB.elec		IN		Positive pin of port 1
e_p2	PORTS_LIB.elec		IN		Positive pin of port 2

Parameters:

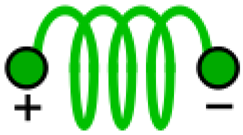
NAME	TYPE	DEFAULT	RANGE	DESCRIPTION	UNITS
n	REAL	2		Turns ratio	-

Variables:

NAME	TYPE	INITIAL	RANGE	DESCRIPTION	UNITS
i1	REAL			Current flowing from pos. to neg. pin of the left port	A
i2	REAL			Current flowing from pos. to neg. pin of the right port	A
v1	REAL			Voltage drop over the left port	V
v2	REAL			Voltage drop over the right port	V

[1] More detailed models of Electric Transformer considering undesired effects are available in ELECTRIC_-SYSTEMS Library.

2.22 Inductor



The model of the inductor inherits its hehaviour from the abstract component OnePort and from the following continuous equation:

$$\frac{di_L(t)}{dt} = \frac{v_L(t)}{L} \tag{2.26}$$

Ports:

NAME	TYPE	PARAMETERS	DIRECTION	CARDINALITY	DESCRIPTION
e_n	PORTS_LIB.elec		IN		Negative pin
e_p	PORTS_LIB.elec		IN		Positive pin

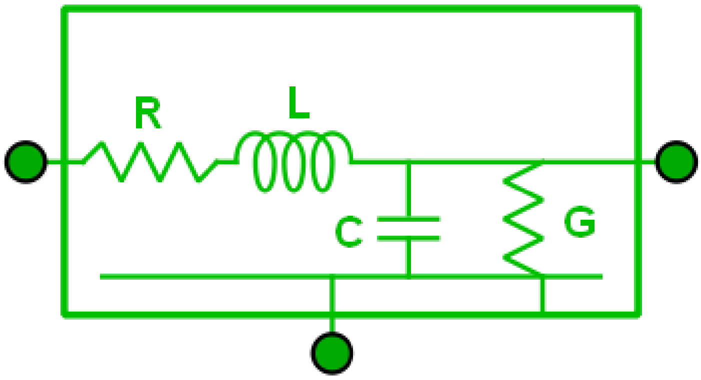
Parameters:

NAME	TYPE	DEFAULT	RANGE	DESCRIPTION	UNITS
L	REAL	1		Inductance	H

Variables:

NAME	TYPE	INITIAL	RANGE	DESCRIPTION	UNITS
i	REAL			Current flowing from pin e_p to pin e_n	A
v	REAL			Voltage drop between the two pins = e_p.v - e_n.v	V

2.23 Lossy transmission Line



The lossy transmission line (Line_LRCG) is modelled as a combination of elements that approximate the behaviour of a real long electrical connection. The value of the components that form the line will be proportional to the distance from the line which is configured as DATA. By this conception the transmission line has a common point at both extremes and two not common points between which transmission takes place via the undesired elements. The elements that form the equivalent circuit of the line are the capacitors, inductances and resistances of the actual ELECTRICAL library. Its formulation and object oriented language make it sufficient to define its connections to guarantee a joint behaviour as desired. The component comprises N parallel lines that simulate the number of conductors that comprise it.

Construction parameters:

NAME	TYPE	DEFAULT	DESCRIPTION	UNITS
N	INTEGER	10	Number of line components	

Ports:

NAME	TYPE	PARAMETERS	DIRECTION	CARDINALITY	DESCRIPTION
e_p1	PORTS_LIB.elec		IN		Input Positive Terminal
e_p2	PORTS_LIB.elec		IN		Output Positive Terminal
e_p3	PORTS_LIB.elec		IN		Common Terminal

Parameters:

NAME	TYPE	DEFAULT	RANGE	DESCRIPTION	UNITS
c	REAL	1	1e-040,1e+040	Capacitance per meter	F/m
g	REAL	1	1e-040,1e+040	Conductance per meter	S/m
l	REAL	1	1e-040,1e+040	Inductance per meter	H/m
length	REAL	1	1e-040,1e+040	Length of line	m
r	REAL	1	1e-040,1e+040	Resistance per meter	Ohm/m

Variables:

NAME	TYPE	INITIAL	RANGE	DESCRIPTION	UNITS
i1	REAL			Input positive terminal current	A
i2	REAL			Output positive terminal current	A
v13	REAL			Input voltage	V
v23	REAL			Output voltage	V

Component instances:

OBJECT	COMPONENT TYPE	DESCRIPTION
R	Resistor	Parasite resistance
L	Inductor	Parasite Inductance
C	Capacitor	Parasite Capacitance
G	Conductor	Parasite Conductance

Component instances data:

DATUM	VALUE	POS	TYPE	DESCRIPTION	UNITS
C[N].C	c * length / N	DATA	REAL	Capacitance	"F"
G[N].G	g * length / N	DATA	REAL	Conductance	"S"
L[N + 1].L	l * length / (N + 1)	DATA	REAL	Inductance	"H"
R[N + 1].R	r * length / (N + 1)	DATA	REAL	Resistance	"Ohm"

2.24 Uniformly Distributed RC Line

The RC line contemplates the undesired effects of a transmission line as uniformly distributed. Its model is formed by means of a series resistance and a condenser in parallel. The capacitance and resistance values are proportional to the distance of the line, which is indicated as DATA. The user also has to indicate, as a construction parameter, the width of the line (number of lines in parallel). It is modelled by means of topological programming, making use of capacitors and resistances from the actual library. The component communicates with the rest of the circuit by means of two electrical ports corresponding to the points of interconnection of the transmission line and a third point common to both.

Construction parameters:

NAME	TYPE	DEFAULT	DESCRIPTION	UNITS
N	INTEGER	10	Number of line components	

Ports:

NAME	TYPE	PARAMETERS	DIRECTION	CARDINALITY	DESCRIPTION
e_p1	PORTS_LIB.elec		IN		Input Positive Terminal
e_p2	PORTS_LIB.elec		IN		Output Positive Terminal
e_p3	PORTS_LIB.elec		IN		Common Terminal

Parameters:

NAME	TYPE	DEFAULT	RANGE	DESCRIPTION	UNITS
c	REAL	1	1e-040,1e+040	Capacitance per meter	F/m
length	REAL	1	1e-040,1e+040	Length of line	m
r	REAL	1	1e-040,1e+040	Resistance per meter	Ohm/m

Variables:

NAME	TYPE	INITIAL	RANGE	DESCRIPTION	UNITS
i1	REAL			Input positive terminal current	A
i2	REAL			Output positive terminal current	A
v13	REAL			Input voltage	V
v23	REAL			Output voltage	V

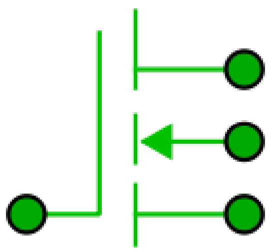
Component instances:

OBJECT	COMPONENT TYPE	DESCRIPTION
R	Resistor	Line resistance
C	Capacitor	Line capacitance

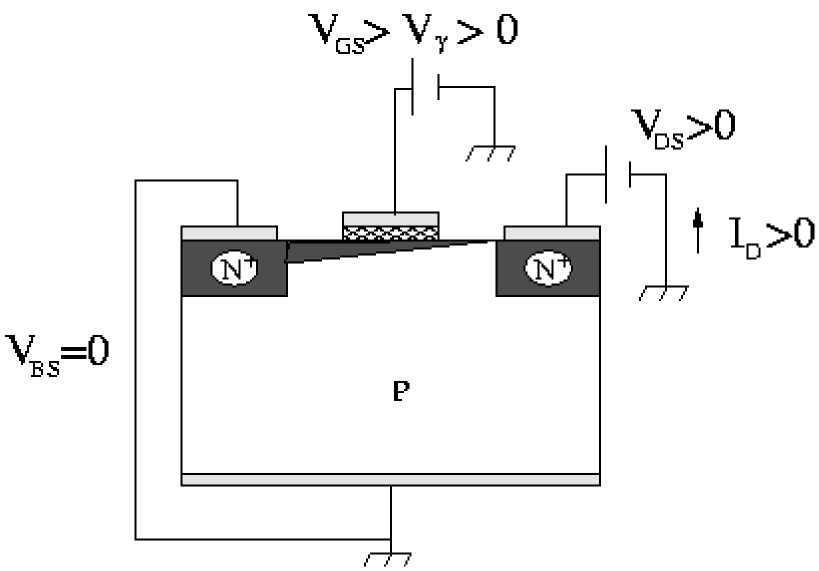
Component instances data:

DATUM	VALUE	POS	TYPE	DESCRIPTION	UNITS
C[N].C	c * length / N	DATA	REAL	Capacitance	"F"
R[N + 1].R	r * length / (N + 1)	DATA	REAL	Resistance	"Ohm"

2.25 NMOS Transistor



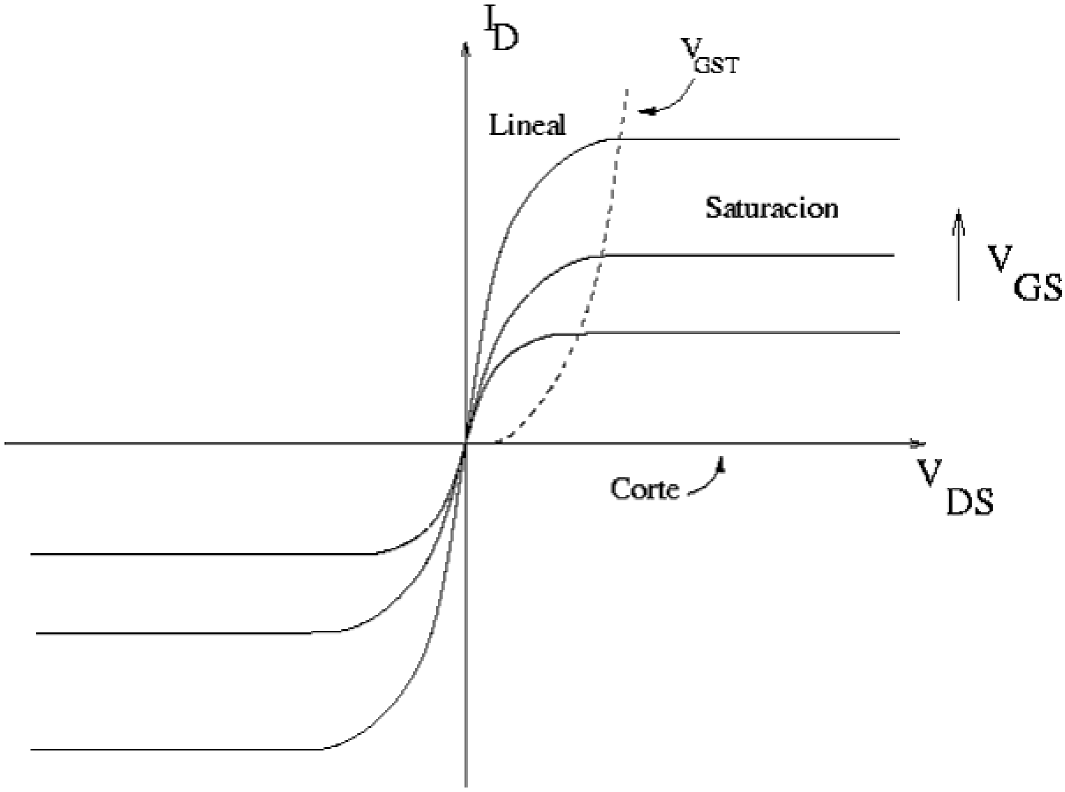
The NMOS field-effect transistor is modelled by establishing a series of characteristics using DATA for the channel. According to these channel characteristics and to the whole circuit configuration , the drain-source voltage of the transistor and the current through it are established. The field effect transistor requires the application of a positive gate voltage for it to conduct. The figure shows a slice image with the profile of an NMOS transistor. This type of transistor requires direct polarization of the gate-substrate junction. This polarization will attract the free electrons present in the P substrate and create a type N channel between the source and the drain that allows circulation of electrons between the terminals.



As can be observed in the physical structure of the transistor, there are two PN junctions (diodes) between the P substrate and the contact N+ regions of the source and drain. These diodes must be inversely polarized for the correct operation of the transistor. In addition, the current of the channel I_d depends on the voltages between Gate-Source, Drain-Source and Base-Source. Voltages that establish the region in which the transistor operates. In MOSFETs there are three regions of operation:

- Cut.
- Linear or Ohmic.
- Saturation.

In the model developed in EcosimPro, the PN junctions have been modelled by means of ZONE expressions, as a function of the status of these junctions, and three possible expressions are defined for the current of the drain, according to the region in which the transistor is located. In addition, it takes into account the shape of the channel (width-length ratio) and the modulation effect of the channel. The following characteristic C-V curve is produced:



Thus the equations that describe the current of the drain of a transistor with N channel and which were used as the basis for the model developed in Ecosimpro, are the following:

$$V_{GS} \leq V_T ; V_{DS} > 0 \rightarrow I_D = 0 \rightarrow Corte \tag{2.27}$$

$$V_{GS} > V_T ; 0 < V_{DS} < V_{GS} - V_T \rightarrow I_D = \frac{\beta W}{L}\left[(V_{GS} - V_T)V_{DS} - \frac{V_{DS}^2}{2}\right] \rightarrow Lineal - \acute{O}hmica \tag{2.28}$$

$$V_{GS} > V_T ; V_{DS} > V_{GS} - V_T \rightarrow I_D = \frac{\beta W}{2L}(V_{GS} - V_T) \rightarrow Saturación \tag{2.29}$$

Where V_T is the threshhold voltage, W and L is the width and length of the channel respectively, and β is the so-called trans-conductance parameter.

Ports:

NAME	TYPE	PARAMETERS	DIRECTION	CARDINALITY	DESCRIPTION
e_B	PORTS_LIB.elec		IN		Bulk
e_D	PORTS_LIB.elec		IN		Drain
e_G	PORTS_LIB.elec		IN		Gate
e_S	PORTS_LIB.elec		IN		Source

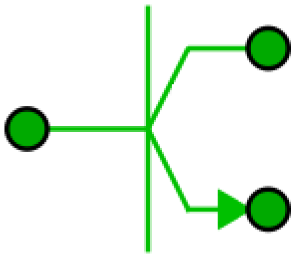
Parámetros:

NAME	TYPE	DEFAULT	RANGE	DESCRIPTION	UNITS
Beta	REAL	0.041		Transconductance parameter	A/V^2
K2	REAL	1.144		Bulk threshold parameter	-
K5	REAL	0.7311		Reduction of pinch-off region	-
L	REAL	6e-006		Length	m
Vt	REAL	0.8		Zero bias threshold voltage	V
W	REAL	2e-005		Width	m
dL	REAL	-1.5e-006		Shortening of channel	m
dW	REAL	-2.5e-006		Narrowing of channel	m

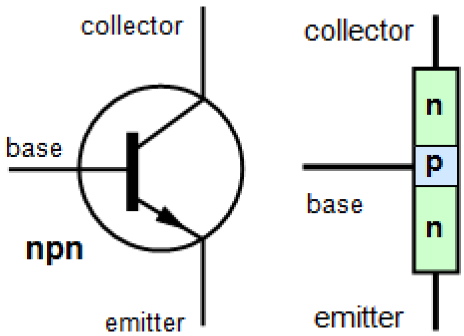
Variables:

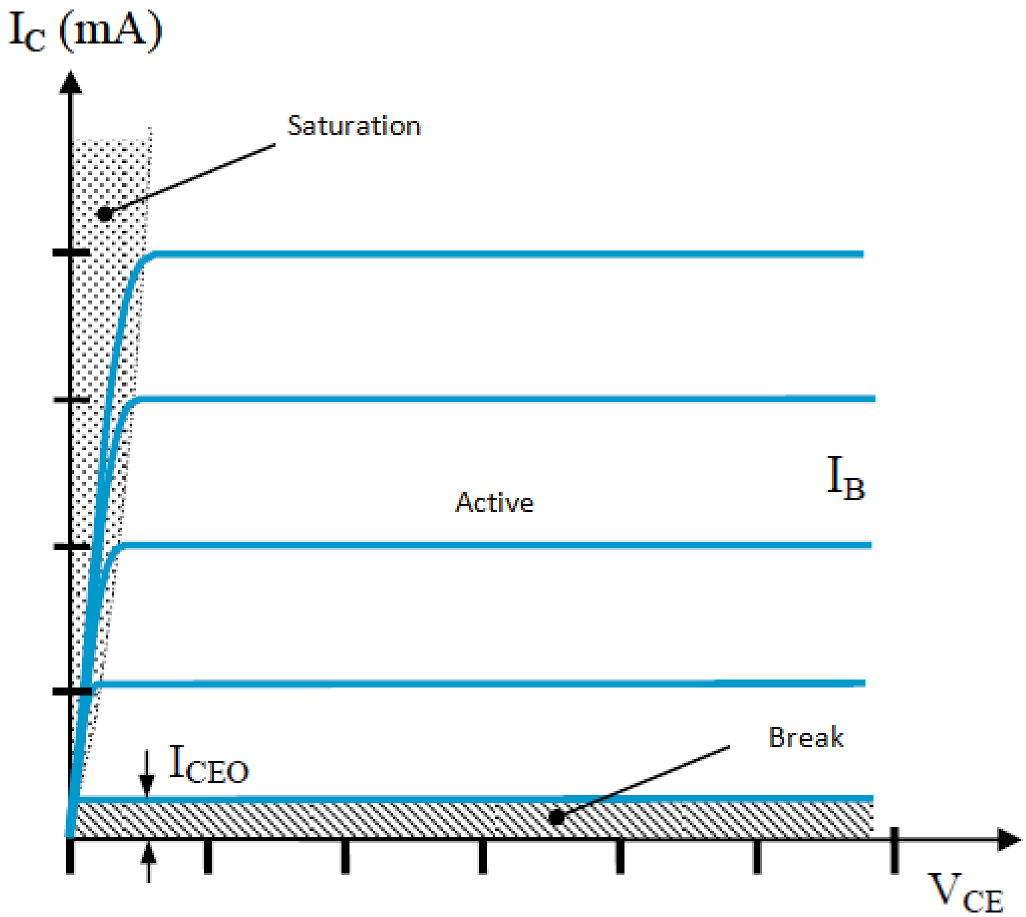
NAME	TYPE	INITIAL	RANGE	DESCRIPTION	UNITS
id	REAL			Drain current	A
ubs	REAL			Bulk-Source voltage	V
ud	REAL			Drain voltage	V
uds	REAL			Drain-Source voltage	V
ugst	REAL			Gate source thermical voltage	V
us	REAL			Source voltage	V
v	REAL			Channel transconductance	A/V^2

2.26 NPN Bipolar Transistor



The NPN transistor responds to the characteristic curves shown in the figure below. The model developed in EcosimPro reproduces the behaviour of the equivalent circuit with a small signal. The capacities of the different junctions are calculated by means of calls to the JunctionCap function, included in the ELECTRICAL library.





The model of the bipolar transmitter developed is based in the Ebers-Moll equations:

$$I_{bc} = I_S(e^{v_{bc}/v_t} - 1) + V_{bc}G_{bc} \tag{2.30}$$

$$I_{be} = I_S(e^{v_{be}/v_t} - 1) + V_{be}G_{be} \tag{2.31}$$

In addition, it models the existing capacities between the different PN junctions by means of the JunctionCap function and an estimation based on the polarization conditions.

Ports:

NAME	TYPE	PARAMETERS	DIRECTION	CARDINALITY	DESCRIPTION
e_B	PORTS_LIB.elec		IN		Base
e_C	PORTS_LIB.elec		IN		Collector
e_E	PORTS_LIB.elec		IN		Emitter

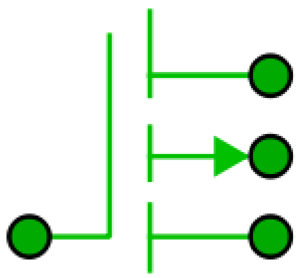
Parameters:

NAME	TYPE	DEFAULT	RANGE	DESCRIPTION	UNITS
Bf	REAL	50		Forward beta	-
Br	REAL	0.1		Reverse beta	-
Ccs	REAL	1e-012		Collector-substrat ground capacitance	F
Cjc	REAL	5e-013		Base-coll. zero bias depletion capacitance	F
Cje	REAL	4e-013		Base-emitter zero bias depletion capacitance	F
Gbc	REAL	1e-015		Base-collector conductance	S
Gbe	REAL	1e-015		Base-emitter conductance	S
Is	REAL	1e-016		Transport saturation current	A
Mc	REAL	0.333		Base-collector gradation exponent	-
Me	REAL	0.4		Base-emitter gradation exponent	-
Phic	REAL	0.8		Base-collector diffusion voltage	V
Phie	REAL	0.8		Base-emitter diffusion voltage	V
Tauf	REAL	1.2e-010		Ideal forward transit time	s
Taur	REAL	5e-009		Ideal reverse transit time	s
Vak	REAL	0.02		Early voltage inverse	1/V
Vt	REAL	0.02585		Voltage equivalent of temperature	V

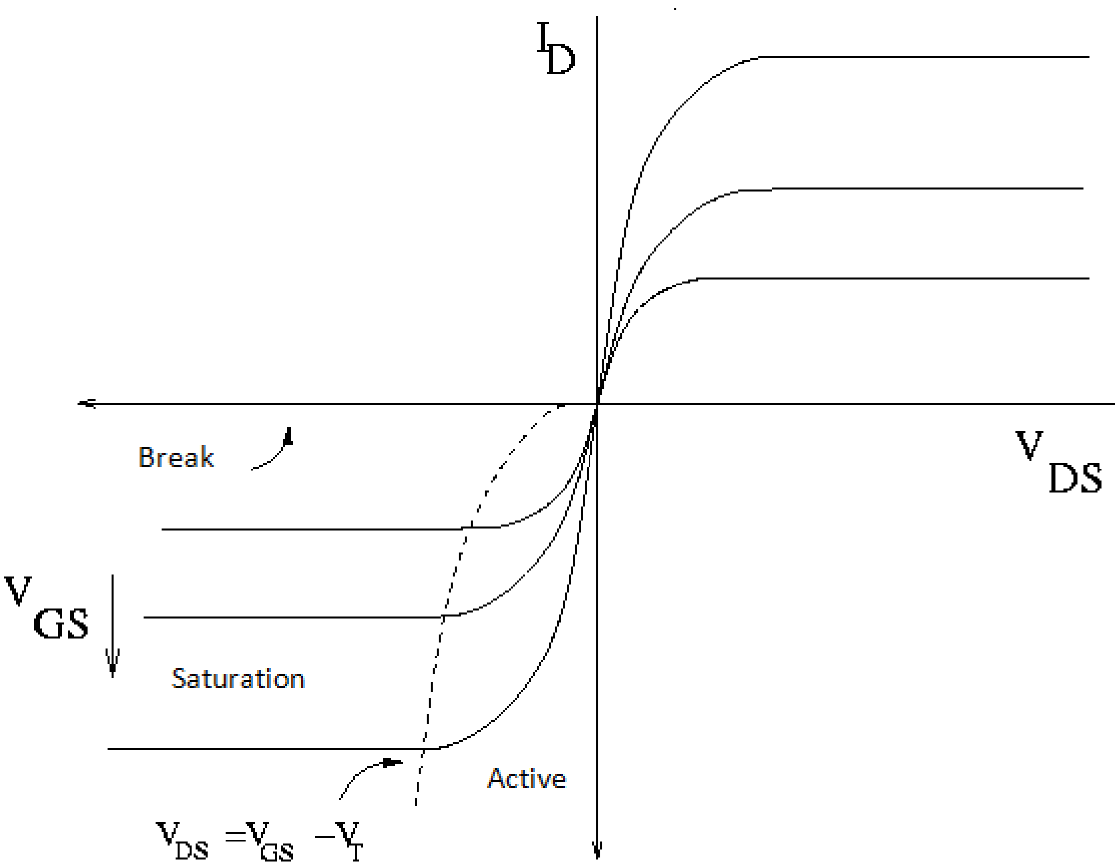
Variables:

NAME	TYPE	INITIAL	RANGE	DESCRIPTION	UNITS
Capcjc	REAL			Collector junction capacitance	F
Capcje	REAL			Emitter junction capacitance	F
cbc	REAL			Collector base capacitance	F
cbe	REAL			Emitter base capacitance	F
ibc	REAL			Base collector current	A
ibe	REAL			Base emitter current	A
qbk	REAL			Early Effect	
vbc	REAL			Voltage difference from collector to base	V
vbe	REAL			Voltage difference from emitter to base	V

2.27 PMOS Transistor



The essence of the model is the same as for the NMOS transistor. However, the P and N regions of each component are exchanged and therefore the voltages and currents are also exchanged. The model of the P channel MOS transistor can be summarized by means of the following charactetristic curves and equations:



$$V_{GS} \geq V_T ; V_{DS} < 0 \rightarrow I_D = 0 \rightarrow Corte \tag{2.32}$$

$$V_{GS} < V_T ; 0 > V_{DS} \geq V_{GS} - V_T \rightarrow I_D = \frac{\beta W}{L}\left[(V_{GS} - V_T)V_{DS} - \frac{V_{DS}^2}{2}\right] \rightarrow Lineal - \acute{O}hmica \tag{2.33}$$

$$V_{GS} < V_T ; V_{DS} < V_{GS} - V_T \rightarrow I_D = \frac{\beta W}{2L}(V_{GS} - V_T) \rightarrow Saturación \tag{2.34}$$

Ports:

NAME	TYPE	PARAMETERS	DIRECTION	CARDINALITY	DESCRIPTION
e_B	PORTS_LIB.elec		IN		Bulk
e_D	PORTS_LIB.elec		IN		Drain
e_G	PORTS_LIB.elec		IN		Gate
e_S	PORTS_LIB.elec		IN		Source

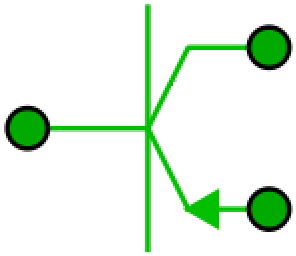
Parameters:

NAME	TYPE	DEFAULT	RANGE	DESCRIPTION	UNITS
Beta	REAL	0.0105		Transconductance parameter	A/V^2
K2	REAL	0.41		Bulk threshold parameter	-
K5	REAL	0.839		Reduction of pinch-off region	-
L	REAL	6e-006		Length (m)	m
Vt	REAL	-1		Zero bias threshold voltage	V
W	REAL	2e-005		Width (m)	m
dL	REAL	-2.1e-006		Shortening of channel	m
dW	REAL	-2.5e-006		Narrowing of channel	m

Variables:

NAME	TYPE	INITIAL	RANGE	DESCRIPTION	UNITS
id	REAL			Drain current	A
ubs	REAL			Base-source voltage	V
ud	REAL			Drain voltage	V
uds	REAL			Drain source voltage	V
ugst	REAL			Gate-Source thermical voltage	V
us	REAL			Source voltage	V
v	REAL			Channel transconductance	A/V^2

2.28 PNP Bipolar Transistor

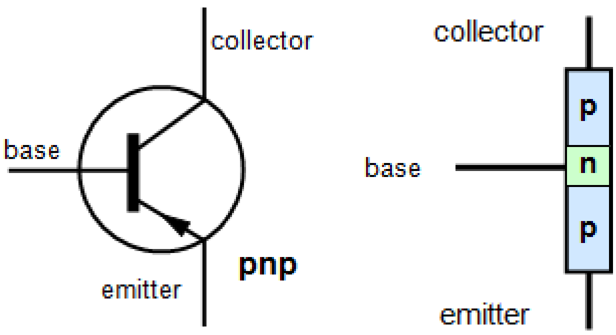


The model of the PNP transistor is the same as for the NPN transistor, but reversing the distribution of the P and N zones, as well as the signs of the voltages and currents. The model of the bipolar transistor developed is based on the Ebers-Moll equations:

$$I_{bc} = I_S(e^{v_{bc}/v_t} - 1) + V_{bc}G_{bc} \tag{2.35}$$

$$I_{be} = I_S(e^{v_{be}/v_t} - 1) + V_{be}G_{be} \tag{2.36}$$

It also models the capacitances existing between the different PN junctions by means of the JunctionCap functions and an estimation based on the polarization conditions.



Ports:

NAME	TYPE	PARAMETERS	DIRECTION	CARDINALITY	DESCRIPTION
e_B	PORTS_LIB.elec		IN		Base
e_C	PORTS_LIB.elec		IN		Collector
e_E	PORTS_LIB.elec		IN		Emitter

Parameters:

NAME	TYPE	DEFAULT	RANGE	DESCRIPTION	UNITS
Bf	REAL	50		Forward beta	-
Br	REAL	0.1		Reverse beta	-
Ccs	REAL	1e-012		Collector-substrat(ground) capacitance	F
Cjc	REAL	5e-013		Base-coll. zero bias depletion capacitance	F
Cje	REAL	4e-013		Base-emitter zero bias depletion capacitance	F
Gbc	REAL	1e-015		Base-collector conductance	S
Gbe	REAL	1e-015		Base-emitter conductance	S
Is	REAL	1e-016		Transport saturation current	A
Mc	REAL	0.333		Base-collector gradation exponent	-
Me	REAL	0.4		Base-emitter gradation exponent	-
Phic	REAL	0.8		Base-collector diffusion voltage	V
Phie	REAL	0.8		Base-emitter diffusion voltage	V
Tauf	REAL	1.2e-010		Ideal forward transit time	s
Taur	REAL	5e-009		Ideal reverse transit time	s
Vak	REAL	0.02		Early voltage inverse	1/V
Vt	REAL	0.02585		Voltage equivalent of temperature	V

Variables:

NAME	TYPE	INITIAL	RANGE	DESCRIPTION	UNITS
Capcjc	REAL			Collector junction capacitance	F
Capcje	REAL			Emitter junction capacitance	F
cbc	REAL			Collector base capacitance	F
cbe	REAL			Emitter base capacitance	F
ibc	REAL			Base collector current	A
ibe	REAL			Base emitter current	A
qbk	REAL			Early Effect	
vbc	REAL			Voltage difference from collector to base	V
vbe	REAL			Voltage difference from emitter to base	V

2.29 Resistor

The resistance has been modelled by means of direct inheritance from the abstract component OnePort. The only additional specification that this component requires is Ohm's Law as a continuous equation.

$$v(t) = R * i(t) \tag{2.37}$$

Ports:

NAME	TYPE	PARAMETERS	DIRECTION	CARDINALITY	DESCRIPTION
e_n	PORTS_LIB.elec		IN		Negative pin
e_p	PORTS_LIB.elec		IN		Positive pin

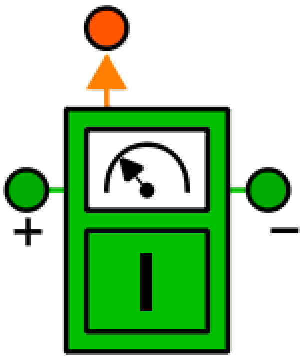
Parameters:

NAME	TYPE	DEFAULT	RANGE	DESCRIPTION	UNITS
R	REAL	1		Resistance	Ohm

Variables:

NAME	TYPE	INITIAL	RANGE	DESCRIPTION	UNITS
i	REAL			Current flowing from pin e_p to pin e_n	A
v	REAL			Voltage drop between the two pins = e_p.v - e_n.v	V

2.30 Current Sensor



The current sensor allows the user to measure the current in a branch without electrically altering its behaviour. It also provides the possibility of using the measured signal without influencing the rest of the circuit (filtering, mathematical operations, etc). The current sensor has a null impedance and shows the current that is flowing by means of an analog_signal type port. This is the format used in the majority of the components in the CONTROL library, which facilitates subsequent handling of the signal. Foe correct measuring of the current, the component should be placed in series with the branch to be measured, like an ampmeter. The component inherits the main charactetristics of the abstract component RelativeSensor.

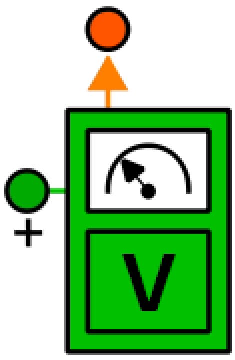
Ports:

NAME	TYPE	PARAMETERS	DIRECTION	CARDINALITY	DESCRIPTION
e_n	PORTS_LIB.elec		IN		Negative pin
e_p	PORTS_LIB.elec		IN		Positive pin
s_out	PORTS_LIB.analog_signal		OUT		Measured current

Variables:

NAME	TYPE	INITIAL	RANGE	DESCRIPTION	UNITS
i	REAL			Current in the branch from p to n	A

2.31 Voltage Sensor



The voltage sensor measures the voltage at a point with respect to level zero. This is the reference level that the Ground component established for a circuit and normally it will be the level used in the designs. The inlet impedance of this sensor is infinite, so it does not perturb the rest of the circuit. It is also possible to isolate the measurement of the electrical part and therefore to carry out post-treatments of the signal without affecting the behaviour of the electrical system being simulated.

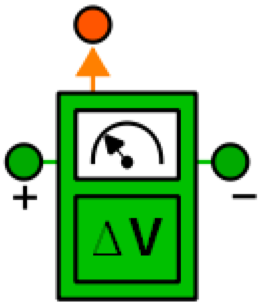
Ports:

NAME	TYPE	PARAMETERS	DIRECTION	CARDINALITY	DESCRIPTION
e_p	PORTS_LIB.elec		IN		Pin to be measured
s_out	PORTS_LIB.analog_signal		OUT		Measured Potential

Variables:

NAME	TYPE	INITIAL	RANGE	DESCRIPTION	UNITS
phi	REAL			Absolute voltage potential	V

2.32 Voltage Sensor



The voltage sensor allows users to measure the voltage between two points of a circuit without altering the electrical behaviour of the circuit. It also allows users to work with the measured signal without influencing the rest of the circuit (filtering, mathematical operations, etc). The voltage sensor has an infinite series impedance and shows the voltage in its ends by means of an analog_signal type port. This is the format used in most of the components in the CONTROL library, making subsequent work on the signal easier. For correct measurement of the signal, the component should be located in parallel with the branch to be measured like a voltmeter. The component inherits the main characteristics of the abstract component RelativeSensor.

Ports:

NAME	TYPE	PARAMETERS	DIRECTION	CARDINALITY	DESCRIPTION
e_n	PORTS_LIB.elec		IN		Negative pin
e_p	PORTS_LIB.elec		IN		Positive pin
s_out	PORTS_LIB.analog_signal		OUT		Measured voltage

Variables:

NAME	TYPE	INITIAL	RANGE	DESCRIPTION	UNITS
v	REAL			Voltage between pin p and n (= p.v - n.v)	V

2.33 Short-circuit

The component Short allows users to connect two points of a circuit with no difference in voltage between them. Therefore the current will be determined by the rest of the circuit. It inherits its main characteristics from the component OnePort.

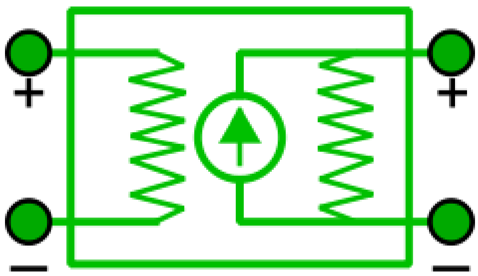
Ports:

NAME	TYPE	PARAMETERS	DIRECTION	CARDINALITY	DESCRIPTION
e_n	PORTS_LIB.elec		IN		Negative pin
e_p	PORTS_LIB.elec		IN		Positive pin

Variables:

NAME	TYPE	INITIAL	RANGE	DESCRIPTION	UNITS
i	REAL			Current flowing from pin e_p to pin e_n	A
v	REAL			Voltage drop between the two pins = e_p.v - e_n.v	V

2.34 Voltage Controlled Current Source



This component allows the users to generate an output current controlled by an input voltage. It is a component with four pins, and it inherits the characteristics of the abstract component TwoPort. The relation between the input voltage and the output current is established by means of trans-conductance of the source.

Ports:

NAME	TYPE	PARAMETERS	DIRECTION	CARDINALITY	DESCRIPTION
e_n1	PORTS_LIB.elec		IN		Negative pin of port 1
e_n2	PORTS_LIB.elec		IN		Negative pin of port 2
e_p1	PORTS_LIB.elec		IN		Positive pin of port 1
e_p2	PORTS_LIB.elec		IN		Positive pin of port 2

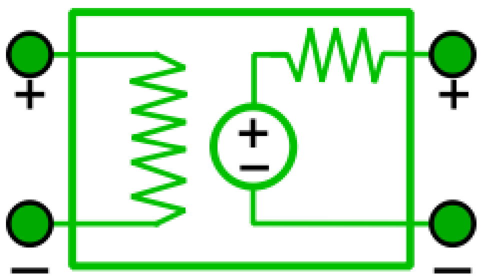
Parameters:

NAME	TYPE	DEFAULT	RANGE	DESCRIPTION	UNITS
R1	REAL	1e+040		Input resistance	Ohm
R2	REAL	1e+040		Output resistance	Ohm
transConductance	REAL	1		Transconductance	S

Variables:

NAME	TYPE	INITIAL	RANGE	DESCRIPTION	UNITS
i1	REAL			Current flowing from pos. to neg. pin of the left port	A
i2	REAL			Current flowing from pos. to neg. pin of the right port	A
v1	REAL			Voltage drop over the left port	V
v2	REAL			Voltage drop over the right port	V

2.35 Voltage Controlled Voltage Source



This component allows users to generate an output voltage controlled by an input voltage. It is a component with four pins and it inherits the characteristics of the abstract component TwoPort. The relation between the input voltage and the output voltage is established by means of the gain of the source.

Portsertos:

NAME	TYPE	PARAMETERS	DIRECTION	CARDINALITY	DESCRIPTION
e_n1	PORTS_LIB.elec		IN		Negative pin of port 1
e_n2	PORTS_LIB.elec		IN		Negative pin of port 2
e_p1	PORTS_LIB.elec		IN		Positive pin of port 1
e_p2	PORTS_LIB.elec		IN		Positive pin of port 2

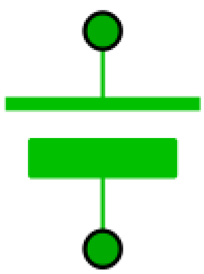
Parameters:

NAME	TYPE	DEFAULT	RANGE	DESCRIPTION	UNITS
R1	REAL	1e+040		Input resistance	Ohm
R2	REAL	0		Output resistance	Ohm
gain	REAL	1		Voltage gain	-

Variables:

NAME	TYPE	INITIAL	RANGE	DESCRIPTION	UNITS
i1	REAL			Current flowing from pos. to neg. pin of the left port	A
i2	REAL			Current flowing from pos. to neg. pin of the right port	A
v1	REAL			Voltage drop over the left port	V
v2	REAL			Voltage drop over the right port	V

2.36 Constant Voltage



The constant voltage source allows users to establish a given voltage between two points in a circuit. It inherits the characteristics of the abstract component OnePort and only adds one continuous equation by means of which variable v is made equal to a datum V. The current through the component is defined by the rest of the circuit. Specifically it will be defined by the total load connected. Usually a component Ground will be connected to the negative terminal of the source, even if the configuration may be different depending on the needs of the user and the model.

$$v(t) = V \tag{2.38}$$

Ports:

NAME	TYPE	PARAMETERS	DIRECTION	CARDINALITY	DESCRIPTION
e_n	PORTS_LIB.elec		IN		Negative pin
e_p	PORTS_LIB.elec		IN		Positive pin

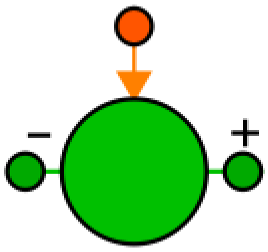
Parameters:

NAME	TYPE	DEFAULT	RANGE	DESCRIPTION	UNITS
V	REAL	1		Value of constant voltage	V

Variables:

NAME	TYPE	INITIAL	RANGE	DESCRIPTION	UNITS
i	REAL			Current flowing from pin e_p to pin e_n	A
v	REAL			Voltage drop between the two pins = e_p.v - e_n.v	V

2.37 Voltage signal



The voltage signal source allows users to establish a voltage between two points in a circuit at the same level as that indicated in the control terminal. This control terminal consists of an analog_signal type port in order to guarantee compatibility with the CONTROL library and to simplify as much as possible the need to create new components. Similarly to other one-phase components in the library, its formal characteristics are inherited directly from the abstract component OnePort. Thus the voltage signal source can also be interpreted as an *analog_signal* to *elec.v* format converter.

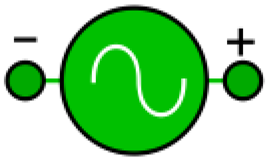
Ports:

NAME	TYPE	PARAMETERS	DIRECTION	CARDINALITY	DESCRIPTION
e_n	PORTS_LIB.elec		IN		Negative pin
e_p	PORTS_LIB.elec		IN		Positive pin

Variables:

NAME	TYPE	INITIAL	RANGE	DESCRIPTION	UNITS
i	REAL			Current flowing from pin e_p to pin e_n	A
v	REAL			Voltage drop between the two pins = e_p.v - e_n.v	V

2.38 Voltage Sine



The voltage sine wave source allows users to establish a steady state voltage sine wave difference between two points in a circuit. The source calls the sine function of the ELECTRICAL library. This function generates a sine wave at the frequency, amplitude, phase, startup instant and offset that are indicated as parameters. The signal returned by the function is assigned as the voltage of the component, which inherits its characteristics from the abstract component OnePort. In addition, this assignation is done indirectly as it uses the descibed component topologically as described above for Voltage Signal, where the control terminal of said component is associated to the sine wave function.

Ports:

NAME	TYPE	PARAMETERS	DIRECTION	CARDINALITY	DESCRIPTION
e_n	PORTS_LIB.elec		IN		Negative pin
e_p	PORTS_LIB.elec		IN		Positive pin

Parameters:

NAME	TYPE	DEFAULT	RANGE	DESCRIPTION	UNITS
Voffset	REAL	0		Voltage offset	V
Vpeak	REAL	1		Voltage amplitude	V
freqHz	REAL	1		Frequencies of sine waves	Hz
phase	REAL	0		Phases of sine waves	rad
startTime	REAL	0		Output = offset for time	s

Variables:

NAME	TYPE	INITIAL	RANGE	DESCRIPTION	UNITS
i	REAL			Current flowing from pin e_p to pin e_n	A
v	REAL			Voltage drop between the two pins = e_p.v - e_n.v	V

Instances to components (Topology block);

OBJECT	COMPONENT TYPE	DESCRIPTION
voltage	VoltageSignal	Voltage Signal topological reference.
source	Sine	Sine Function invocation.

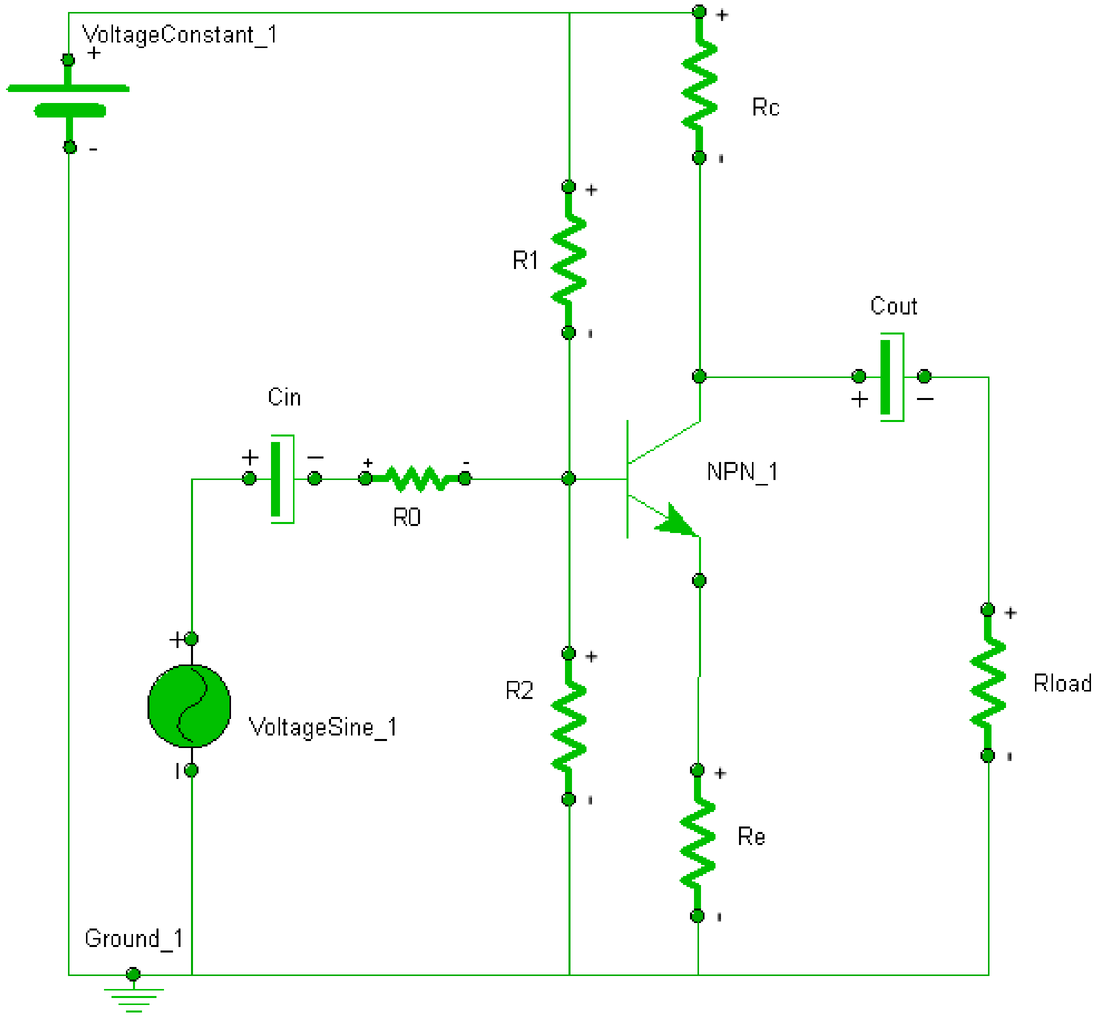
3. Building a Model

Models of electrical networks are built by arrangement of ELECTRICAL, CONTROL, MECHANICAL ... (engine shaft) components. This library is designed for building electrical models by dragging and pasting components as if it was a real circuit.

The following sections describe how to build a simple model, and how to simulate it. The basic methodology to create and simulate this simple model is the same as that for more complex models.

3.1 Description of the example

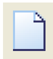
The model described in this chapter represents an emitter amplifier circuit:

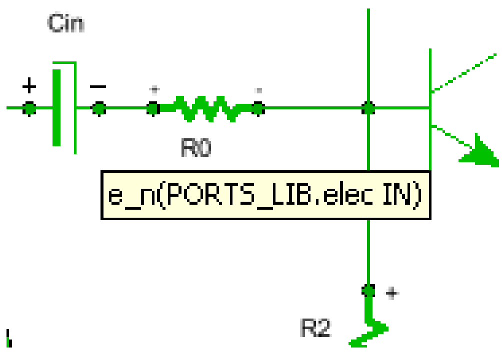


The system consists of an NPN transistor fed with constant and variable voltage sources, and provided with capacitors and resistors to accommodate the input/output voltage signals.

3.2 How to Build the Model

To build the model users should follow the steps under the schematic view of EcosimPro, as described below. The MATH, PORTS_LIB, ELECTRICAL, ELECTRICAL _EXAMPLES and CONTROL libraries must first be loaded into the active Workspace:

- Create a new schematic using the button  or the File -> New -> Schematics. Save it in the ELECTRICAL _EXAMPLES library and choose a name (for example, my_circuit).
- From the icon explorer tab of the ELECTRICAL library, select one by one the different components shown in the figure above and drag them to the schematic window
- Arrange the components in the schematic like in the figure above:
  - ◇ Use the Rotate buttons if necessary
  - ◇ To change the size of a component, select the component, right button, select "component shape option" and change the size by dragging the symbol's corners
  - ◇ To change the position of the component's name, press the SHIFT key at the same time as you move the mouse pointer over the labels, and drag it
- Draw connectors between the components like in the figure above. A tooltip will appear whenever the mouse hovers over a port, displaying the information of that port:



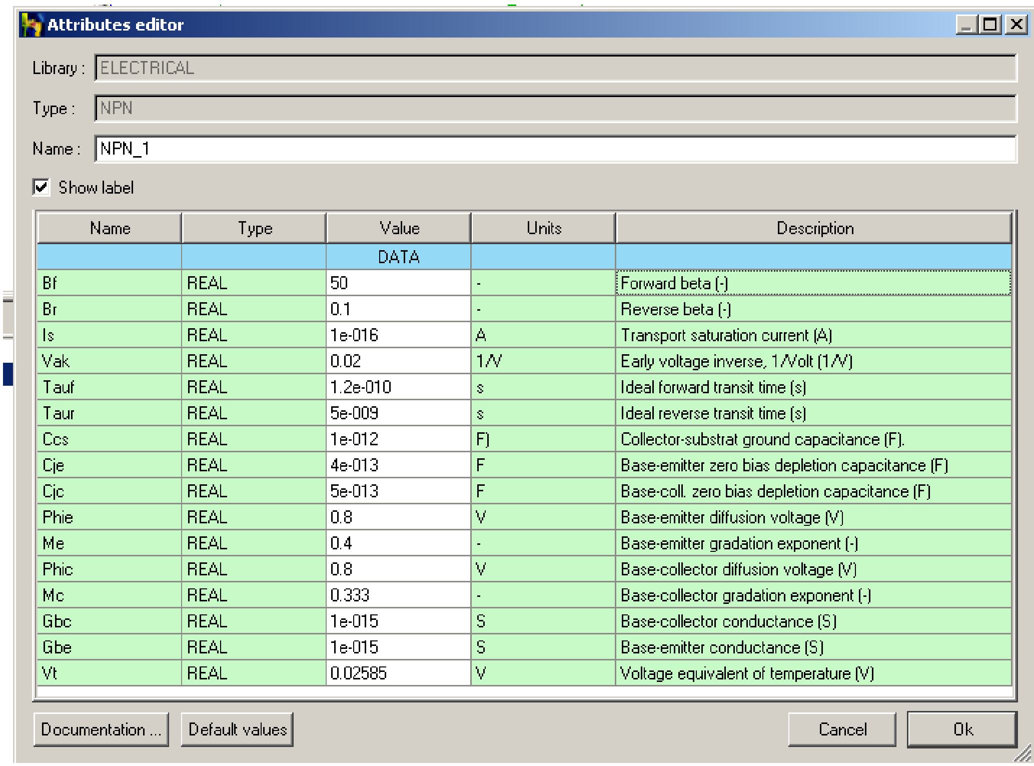
  - ◇ Select the connection button on the right-hand toolbar , or press the SHIFT key at the same time as you move the mouse pointer over a port
  - ◇ Left-click on the port to be connected
  - ◇ Click the various points of the schematic drawing where the connector is required to run (if any)
  - ◇ Left-click the target port, which must be of the same type as the origin port
  - ◇ To connect different components with right angles, there are two options: 1) select right angle connections mode by pressing the  button and connect components as explained before, or 2) Create a straight line connection between two components, press SHIFT and left click over the line. A point will be created to divide the line into two different segments. Drag the point to the desired place and use the  button to force right angles
  - ◇ To delete extra points of a connector line, just press SHIFT over the point and click on the point to be deleted

- Set the data of the components. Now you must customize the component data according to the table below:

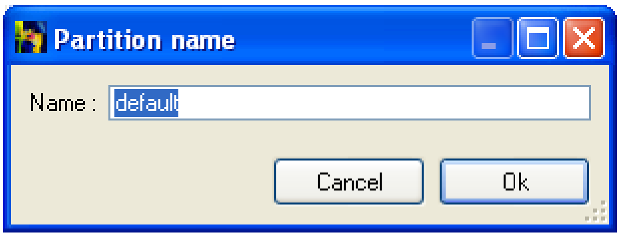
COMPONENT INSTANCES DATA:

DATUM	VALUE	DESCRIPTION	UNITS
Cin.C	1e-005	Capacitance (F)	"F"
Cout.C	0.0001	Capacitance (F)	"F"
NPN_1.Bf	50	Forward beta (-)	"-"
NPN_1.Br	0.1	Reverse beta (-)	"-"
NPN_1.Ccs	1e-012	Collector-substrat ground capacitance (F).	"F)"
NPN_1.Cjc	5e-013	Base-coll. zero bias depletion capacitance (F)	"F"
NPN_1.Cje	4e-013	Base-emitter zero bias depletion capacitance (F)	"F"
NPN_1.Gbc	1e-015	Base-collector conductance (S)	"S"
NPN_1.Gbe	1e-015	Base-emitter conductance (S)	"S"
NPN_1.Is	1e-016	Transport saturation current (A)	"A"
NPN_1.Mc	0.333	Base-collector gradation exponent (-)	"-"
NPN_1.Me	0.4	Base-emitter gradation exponent (-)	"-"
NPN_1.Phic	0.8	Base-collector diffusion voltage (V)	"V"
NPN_1.Phie	0.8	Base-emitter diffusion voltage (V)	"V"
NPN_1.Tauf	1.2e-010	Ideal forward transit time (s)	"s"
NPN_1.Taur	5e-009	Ideal reverse transit time (s)	"s"
NPN_1.Vak	0.02	Early voltage inverse, 1/Volt (1/V)	"1/V"
NPN_1.Vt	0.02585	Voltage equivalent of temperature (V)	"V"
R0.R	0.01	Resistance (Ohm)	"Ohm"
R1.R	9000	Resistance (Ohm)	"Ohm"
R2.R	1000	Resistance (Ohm)	"Ohm"
Rc.R	5000	Resistance (Ohm)	"Ohm"
Re.R	500	Resistance (Ohm)	"Ohm"
Rload.R	50000	Resistance (Ohm)	"Ohm"
VoltageConstant_1.V	10	Value of constant voltage (V)	"V"
VoltageSine_1.Voffset	0	Voltage offset (V)	"V"
VoltageSine_1.Vpeak	0.25	Voltage amplitude (V)	"V"
VoltageSine_1.freqHz	200	Frequencies of sine waves (Hz)	"Hz"
VoltageSine_1.phase	0	Phases of sine waves (radian)	"radian"
VoltageSine_1.startTime	0	Output = offset for time	"s"

- To change data of a component double-click on the corresponding symbol to open the Attributes Editor. For example, for the NPN_1 component, the data values should look like this:



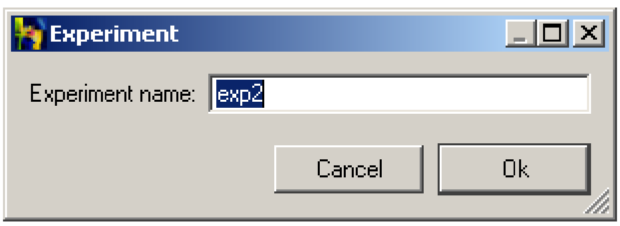
- Lastly, generate the EcosimPro model using the button . The following window will be displayed. Click OK and you will have finalized the construction of your model and you can simulate it as described in the following section, "Simulating the Model":



3.3 Simulate the Model

The model is now ready for simulation. Go to the Simulation View.

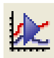
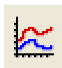
- Select "my_circuit.default" (if the name of the partition you have created is "default") from the ELECTRICAL_-EXAMPLES library, right-click, select option "New experiment". The following window will be displayed. Type a name for the experiment:

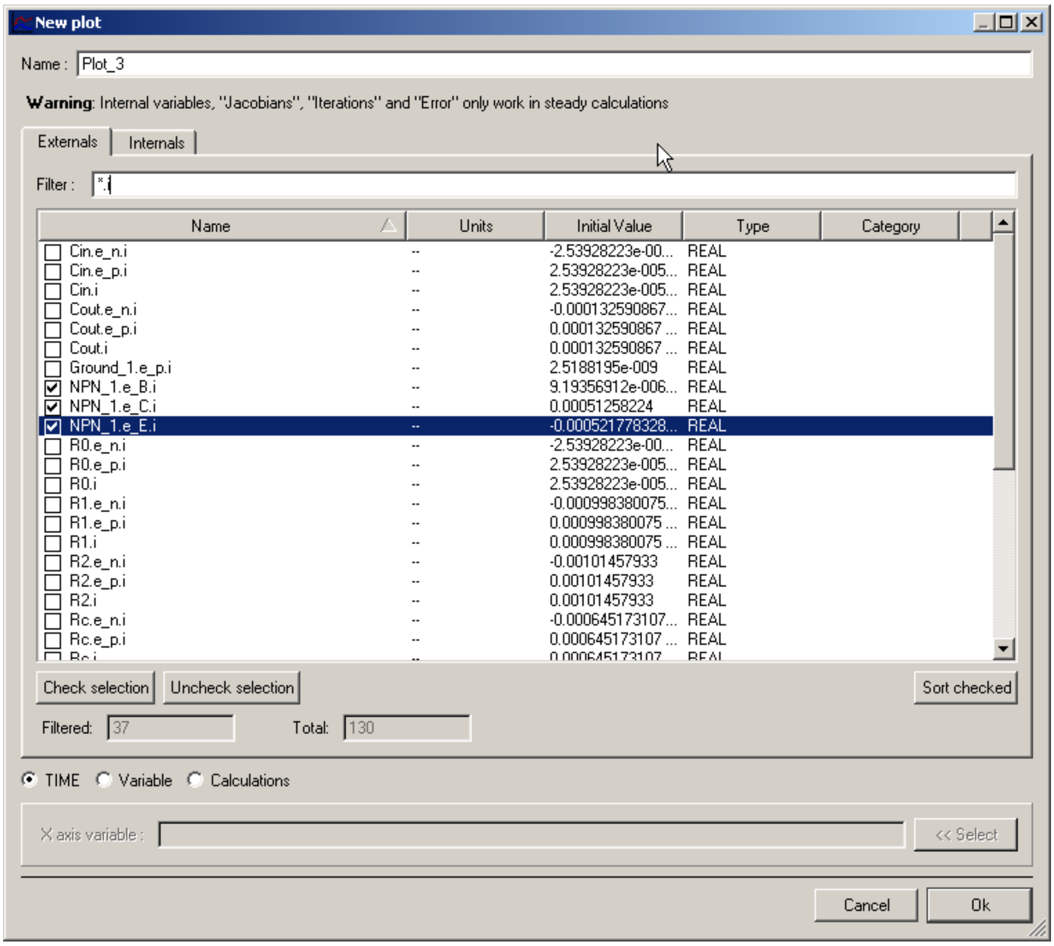


- A default experiment text should appear in the editing window. Change the TSTOP, CINT (Communications Interval) and other values as indicated below:

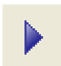
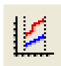
```
...
BODY
--   REPORT_TABLE("reportAll", " * ")
   REPORT_MODE = IS_STEP
   TIME = 0
   TSTOP = 0.1
   CINT = 0.011

   IMETHOD = DASSL_SPARSE
   INTEG()
END EXPERIMENT
```

  - Double dash (–) means a comment.
  - "IMETHOD = DASSL_SPARSE" means that the DASSL sparse integration method will be employed (See the EcosimPro User Manual.
  - "REPORT_MODE = IS_STEP" means that an output (in the plots and in the reports) will be produced at each internal time step (given by the integration method), that is normally shorter than the communication interval CINT.

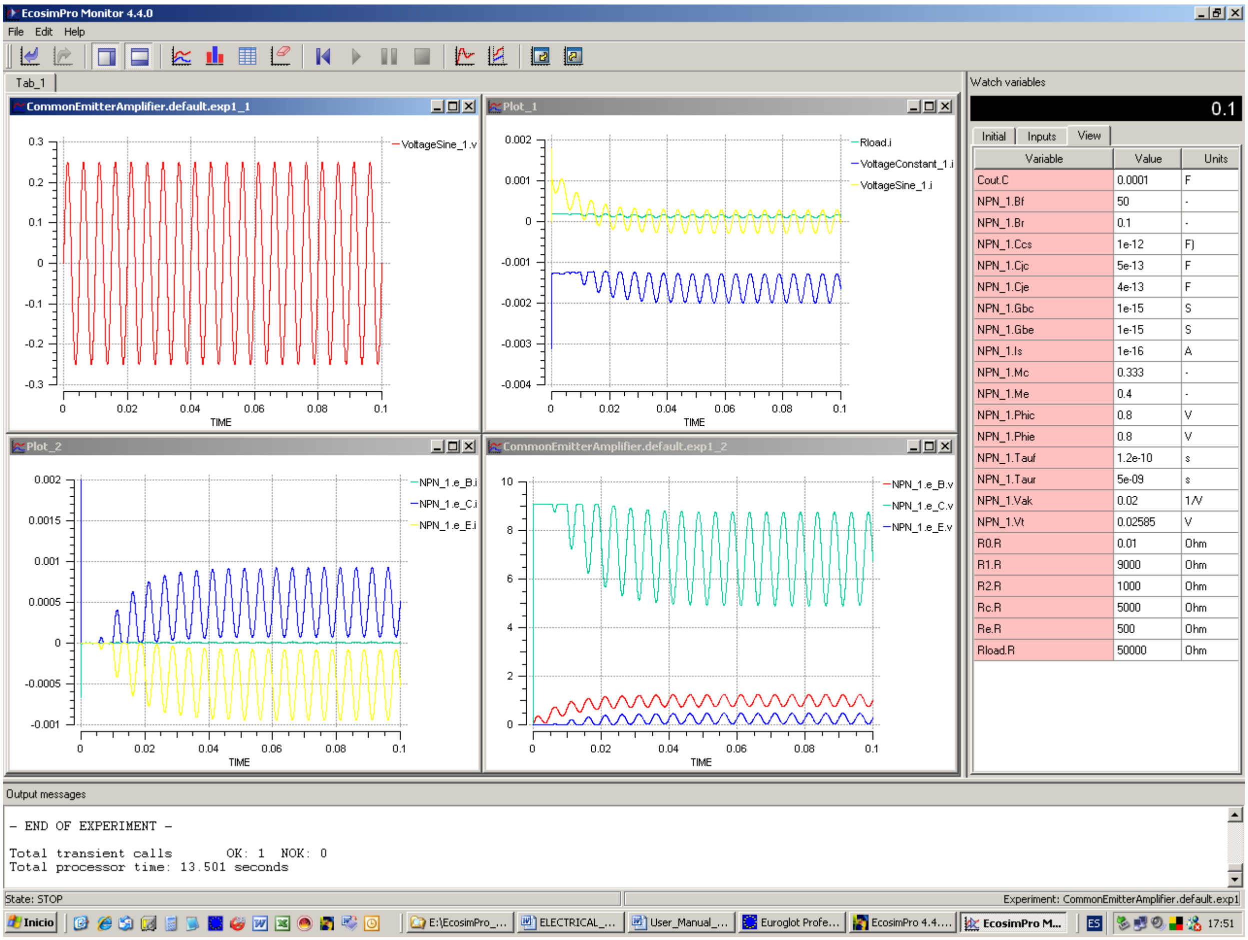
- Save the experiment. The experiment name will appear in the Workspace area
- Now you are ready to simulate the experiment using the Monitor. Right button over the experiment name in the Workspace area, and select "Simulate in Monitor". Clicking the  button will produce the same effect
- The Experiments monitor comes up. Add the necessary plots to view the results.
  - To add a plot click on "Tab_1" and then click "New Plot" . A window will appear with the "drawable / plotable" variables of the experiment.
  - Apply a filter to help you to select variables. Tick the boxes alongside the selected variables:



- Just as users may wish to plot the evolution of a variable compared to another, they may also wish to track the numerical values of the variables. The main task of Watch is to display the variable values of the experiment, enabling them to be modified wherever possible.
  - ◇ The first step is to add variables by right clicking on the Watch Area and selecting the option "Edit Watch"
  - ◇ A menu very similar to that of the plots will appear, enabling users to add or delete variables

- To simulate the experiment click "Simulate" . By clicking "New Integration"  on the toolbar, the simulation can be extended or started at new times

The figure below shows some typical time histories of the main variables of the model:


EcosimPro Monitor 4.4.0
File Edit Help
Tab_1
CommonEmitterAmplifier.default.exp1_1
VoltageSine_1.v
TIME
Plot_1
Rload.i
VoltageConstant_1.i
VoltageSine_1.i
Plot_2
NPN_1.e_B.i
NPN_1.e_C.i
NPN_1.e_E.i
CommonEmitterAmplifier.default.exp1_2
NPN_1.e_B.v
NPN_1.e_C.v
NPN_1.e_E.v
Watch variables
0.1
Initial
Inputs
View
Variable
Value
Units
Cout.C 0.0001 F
NPN_1.Bf 50 -
NPN_1.Br 0.1 -
NPN_1.Ccs 1e-12 F)
NPN_1.Cjc 5e-13 F
NPN_1.Cje 4e-13 F
NPN_1.Gbc 1e-15 S
NPN_1.Gbe 1e-15 S
NPN_1.Is 1e-16 A
NPN_1.Mc 0.333 -
NPN_1.Me 0.4 -
NPN_1.Phic 0.8 V
NPN_1.Phie 0.8 V
NPN_1.Tauf 1.2e-10 s
NPN_1.Taur 5e-09 s
NPN_1.Vak 0.02 1/V
NPN_1.Vt 0.02585 V
R0.R 0.01 Ohm
R1.R 9000 Ohm
R2.R 1000 Ohm
Rc.R 5000 Ohm
Re.R 500 Ohm
Rload.R 50000 Ohm
Output messages
- END OF EXPERIMENT -
Total transient calls OK: 1 NOK: 0
Total processor time: 13.501 seconds
State: STOP
Experiment: CommonEmitterAmplifier.default.exp1

4. References

EcosimPro User Manual

EcosimPro Getting Started

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EMPRESARIOS AGRUPADOS

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