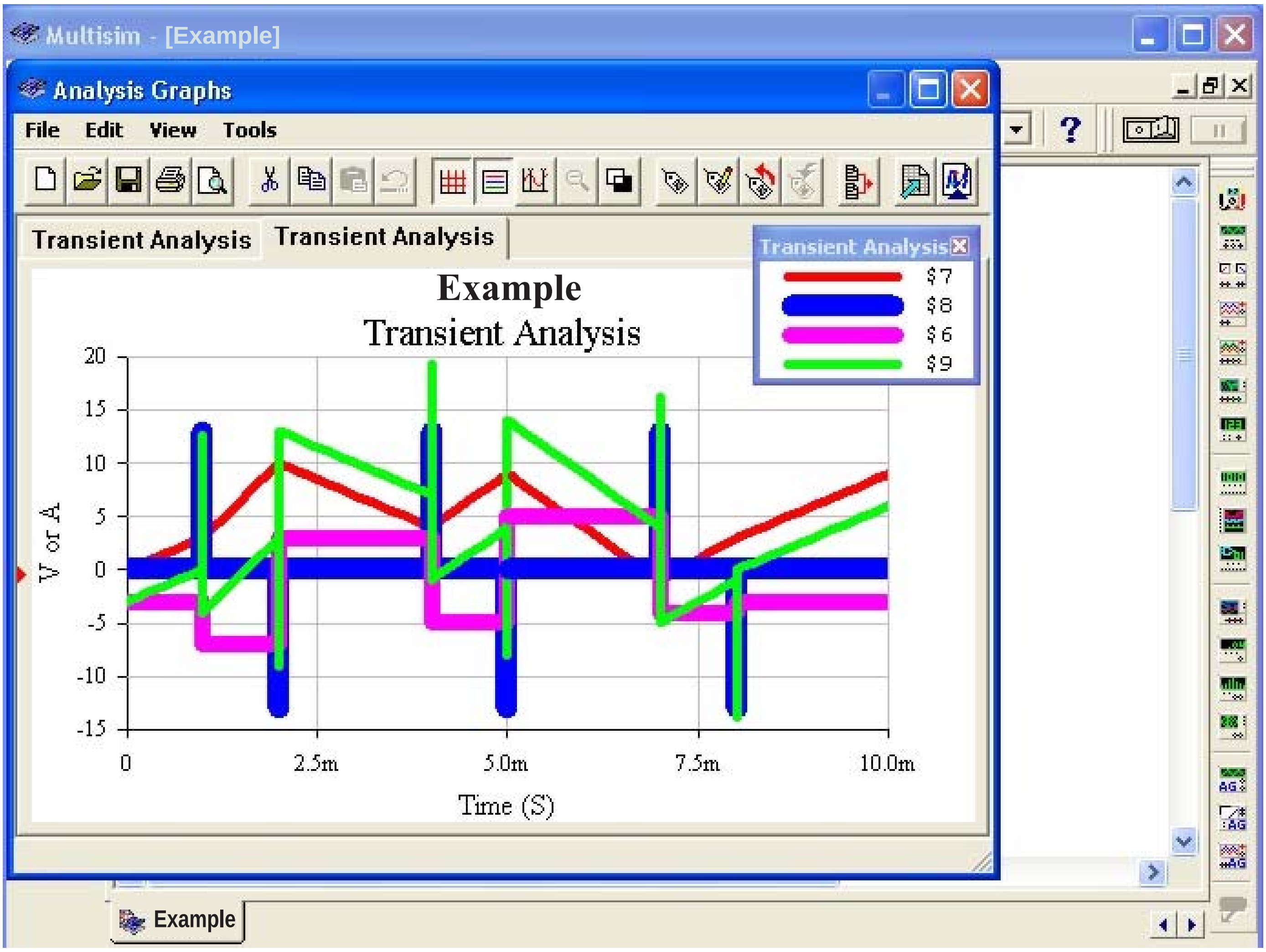
Controllers with Multisim



Electronics WORKBENCH
THE GLOBAL STANDARD IN ELECTRONICS EDUCATION

Dr. Julio R. García Villarreal
San José State University
San José, California - USA

Index

The Transient Analysis studies the circuits' responses in very short times. On the following pages and using Multisim, the circuits' responses are described when we apply variable signals with a period of ten milliseconds.

Process Control

The measurement and the control of the process are essential parts of all industry because it improves the quality, the quantity increases and it reduces the cost of manufacturing.

Manual Control of a Process

Figure 1 describes the manual control of a heater where we need to obtain, at the output, hot water at a temperature of 50º C.

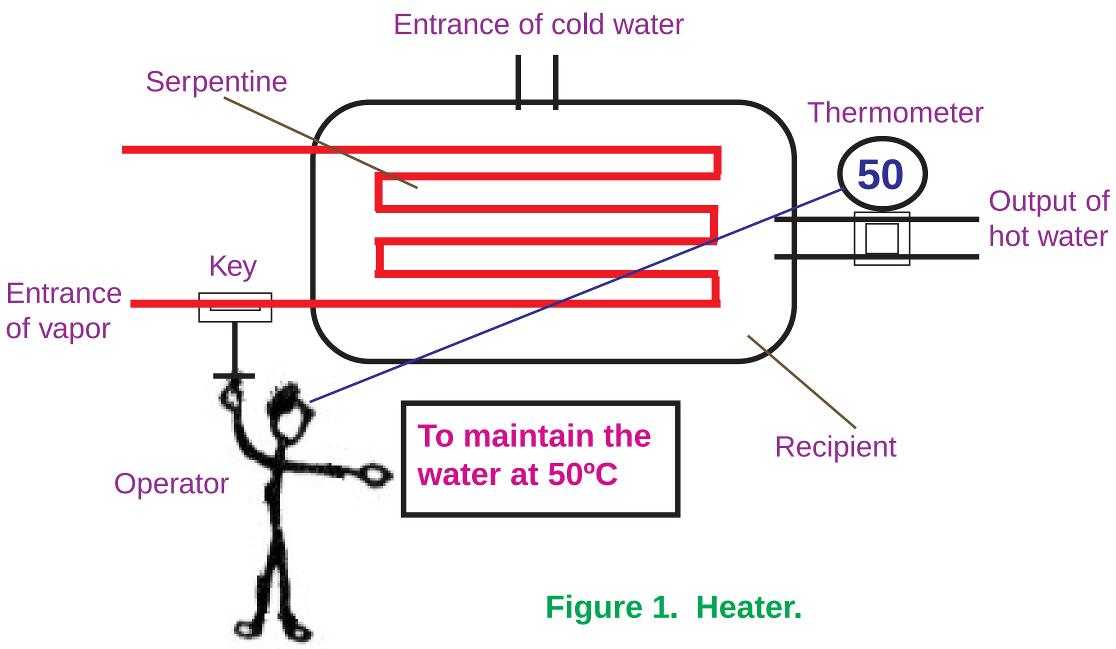


Figure 1. Heater.

The cold water contained in the recipient warms by means of the heat provided by the vapor that circulates for a pipe in serpentine form. In figure 1 we can see that the operator is observing the reading of the thermometer and compares it with the poster that indicates him «**To maintain the water at 50º C**.»

If the thermometer marks more than 50º C, the operator will close the key of entrance of the vapor little by little until reaching the temperature of 50ºC. If the thermometer registers less than 50º C, the operator will open the key of entrance of the vapor little by little until the water reaches the temperature of 50º C.

Variables of the Process Control

In every process control we find the following variables:

Controlled variable: In figure 1, it is the temperature of the output water.

Manipulated variable: In figure 1, it is the entrance of the vapor. Controlling the flow of the vapor, we will regulate the output of the process.

Variable interference: They are all the parameters that destabilize the system. In our example of figure 1, the variable interference is the flow of entrance of cold water.

Block Diagram of the Process Control

The block diagram of figure 1 is the following:

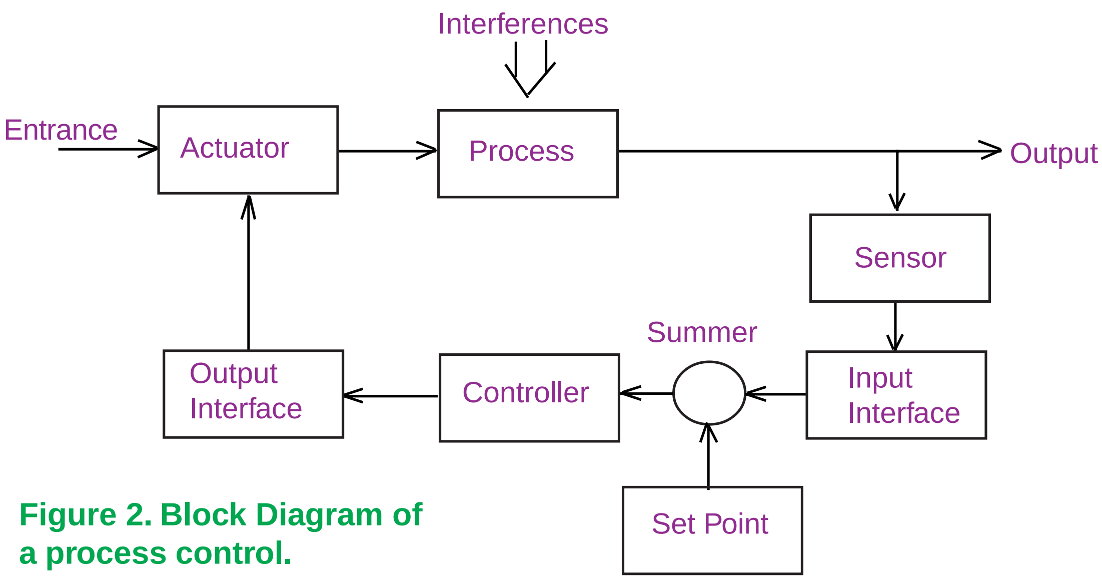


Figure 2. Block Diagram of a process control.

Where:

Entrance: it corresponds to the entrance of the vapor.
Process: it is equivalent to the tank of the heater.
Interferences: it is equal to the entrance of cold water.
Sensor: it replaces to the thermometer.
Set Point: it is equivalent to the poster that indicates to the operator to maintain the temperature of the water to a certain value.
Summer: it is equivalent to the comparison that the operator executes between the reading of the thermometer and the poster.
Controller: it replaces the operator.
Actuator: it is equivalent to the key that controls of entrance of the vapor.

The Sensor

It measures the output of the Process and transforms it in an electric signal. The sensors can be of: level, pressure, temperature, flow, viscosity, etc

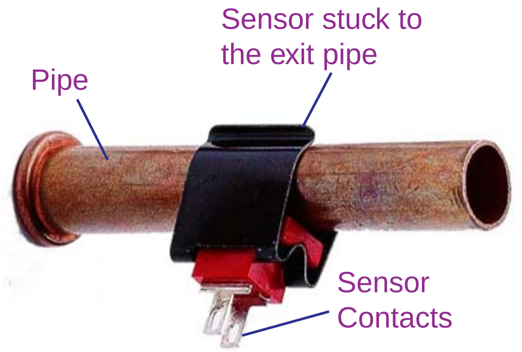


Figure 3. Temperature sensor

Input Interface

It conditions the electric signal provided by the Sensor and converts it to an acceptable format for the Controller.

Set Point

Also called desired value or reference point, is a value that the Controller should try to maintain in the output of the process.

Figure 4. Instruments adjusted to the Set Point value.

Voltage Summer

It adds the signal voltage coming from the Input Interface with the reference value (Set Point) and sends it to the Controller.

The Controller

It processes the information coming from the Summer and it produces an output signal (corrected signal) that sends it to the Actuator by means of the Output Interface

Figure 6. Controller.

Output Interface

It conditions the electric signal provided by the Controller so that it is able to activate the Actuator appropriately.

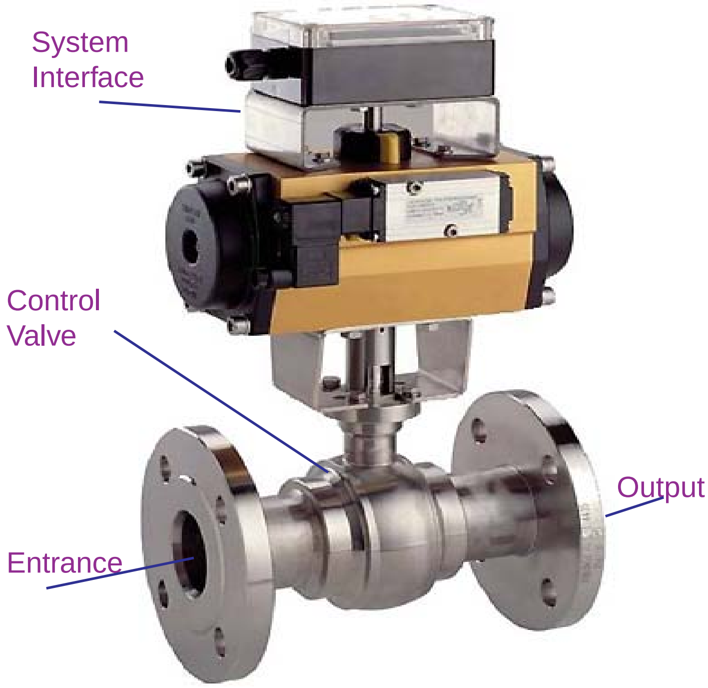


Figure 7. Actuator.

The Actuator

Also called **element of final control**, it alters the input variable (in our example it is the vapor) to stabilize the output of the process.

Figure 8. Heater.

Types of Control Systems

1. Programmable Logical control (**PLC**).
2. Distributed Control system (**DCS**).
3. Personal computers (**PC**).

Programmable Logical Control (PLC)

It is a device that was developed to replace the sequential circuits of relays for the control of processes. The **PLC** works by checking its inputs and depending on its states, it changes its outputs to **ON/OFF**. The user enters a program, via software, with the results that he wants to obtain.

Figure 9. Typical PLC.

Distributed Control System (DCS)

They are based on electronic circuits or special dedicated modules for the independent control of the temperature, pressure, flow or other variables.

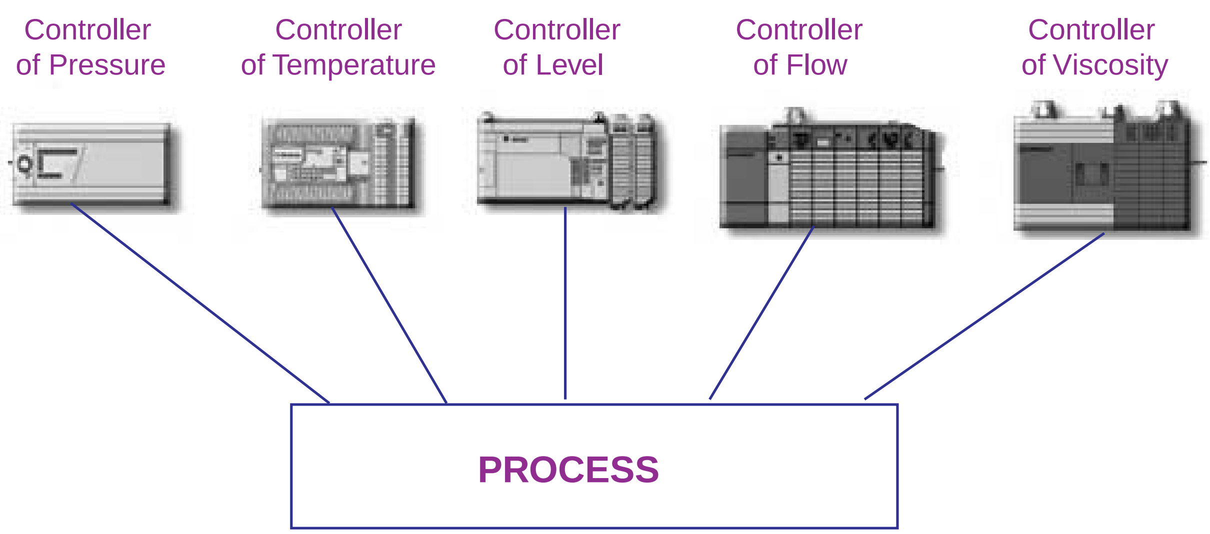


Figure 10. Distributed Control system.

Personal Computers (PC)

Monitor the whole industrial process calculating in real time the reference points or Set Points and send them to the Voltage Summers of individual Controllers, external to the computer.

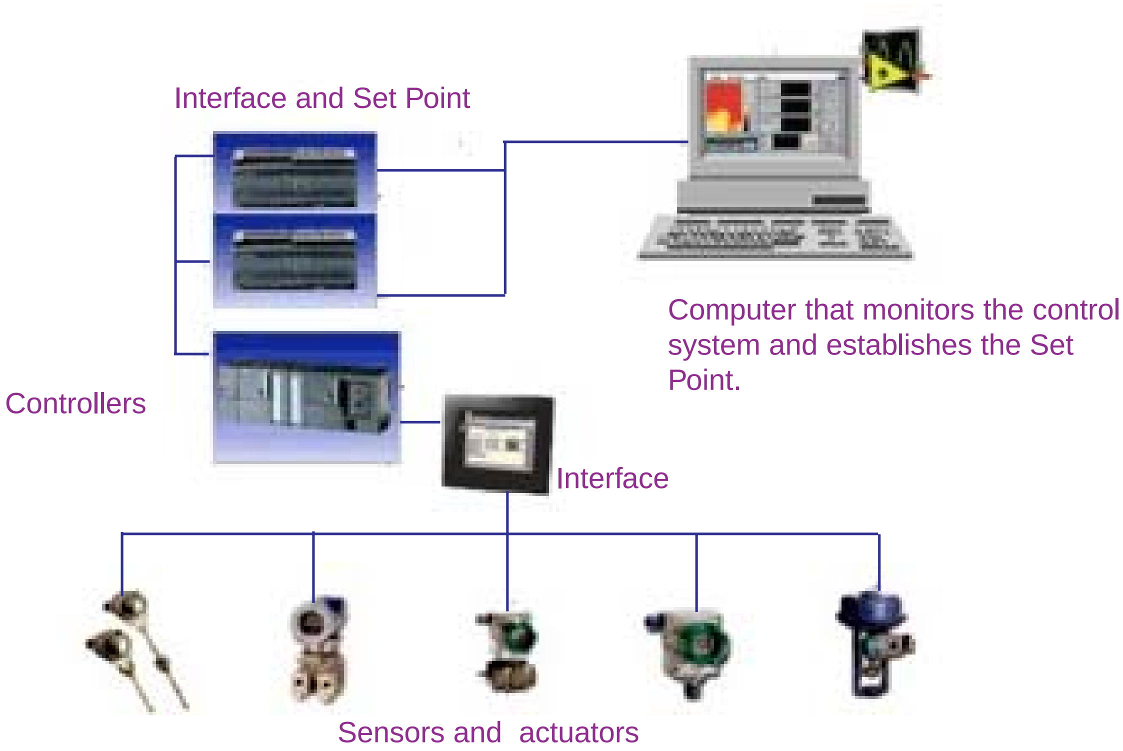


Figure 11. Combination of the Distributed System and the PC.

The Electronic Controller

The Electronic Controller is made up of one or more Operational Amplifiers (Op Amps) configured as an Inverter, Integrator, and Differentiator. These configurations of the Op-Amp are known with the names of Proportional (**P**), Integral (**I**), Derivative (**D**) controllers, respectively.

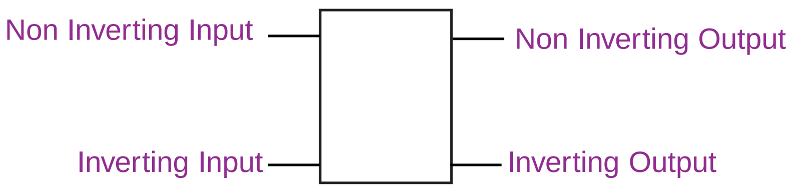
In practice two or more control actions are usually used, such as Proportional-Integral (**PI**), Proportional-Derivative (**PD**), Proportional- Integral-Derivative (**PID**), etc.

The Electronic Controller in Multisim

Multisim incorporates a series of modules for the simulation of the process control; among them we have:

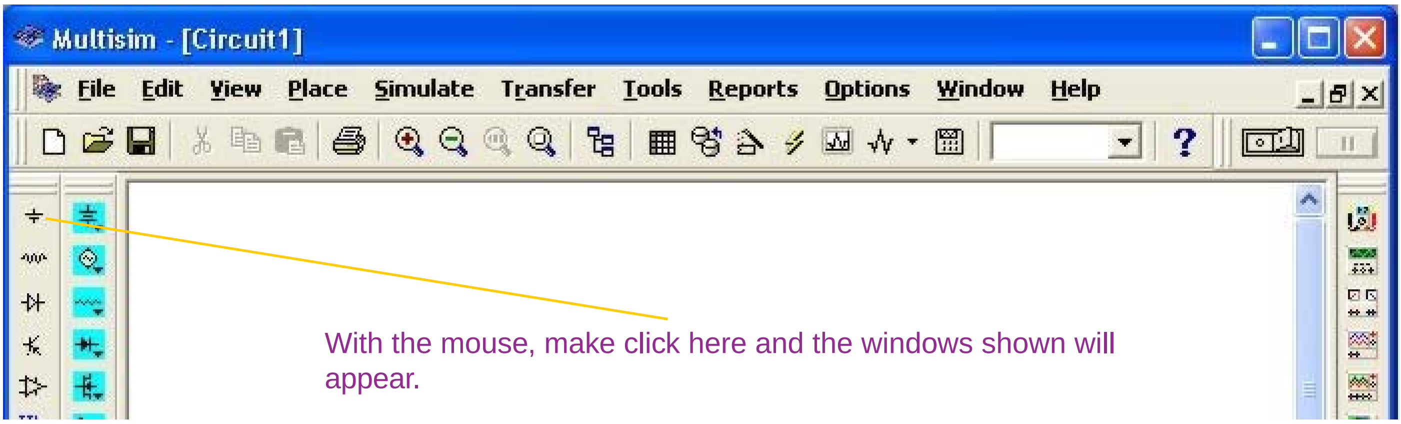
1. **Voltage Gain Block or Proportional Controller.**
2. **Voltage Differential or Derivative Controller.**
3. **Voltage Integrator or Integral Controller.**
4. **Voltage Summer or Summer.**

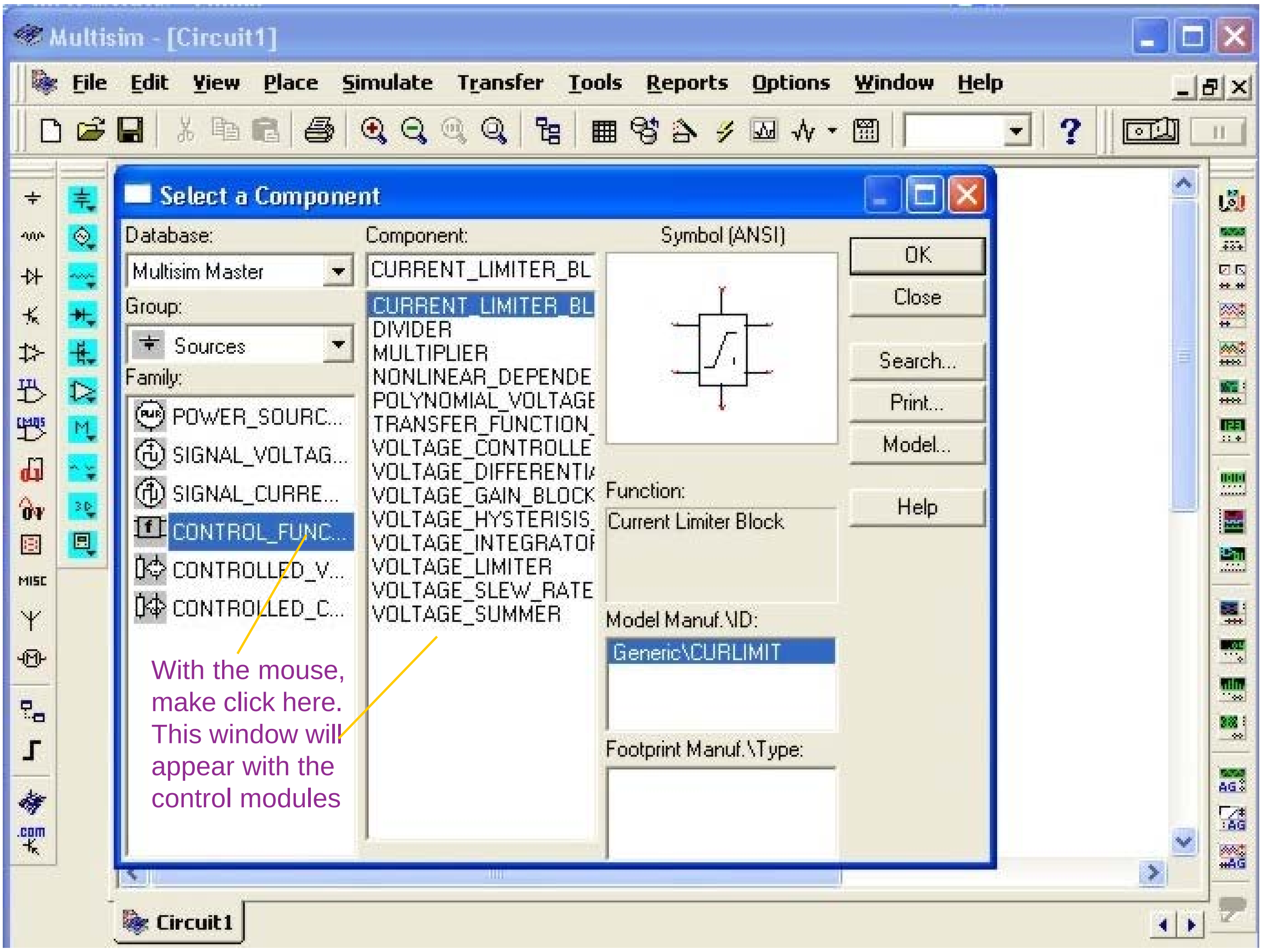
All the control modules, except the Voltage Summer, have the following diagram: :



Note: The unused output and input should be connected to ground.

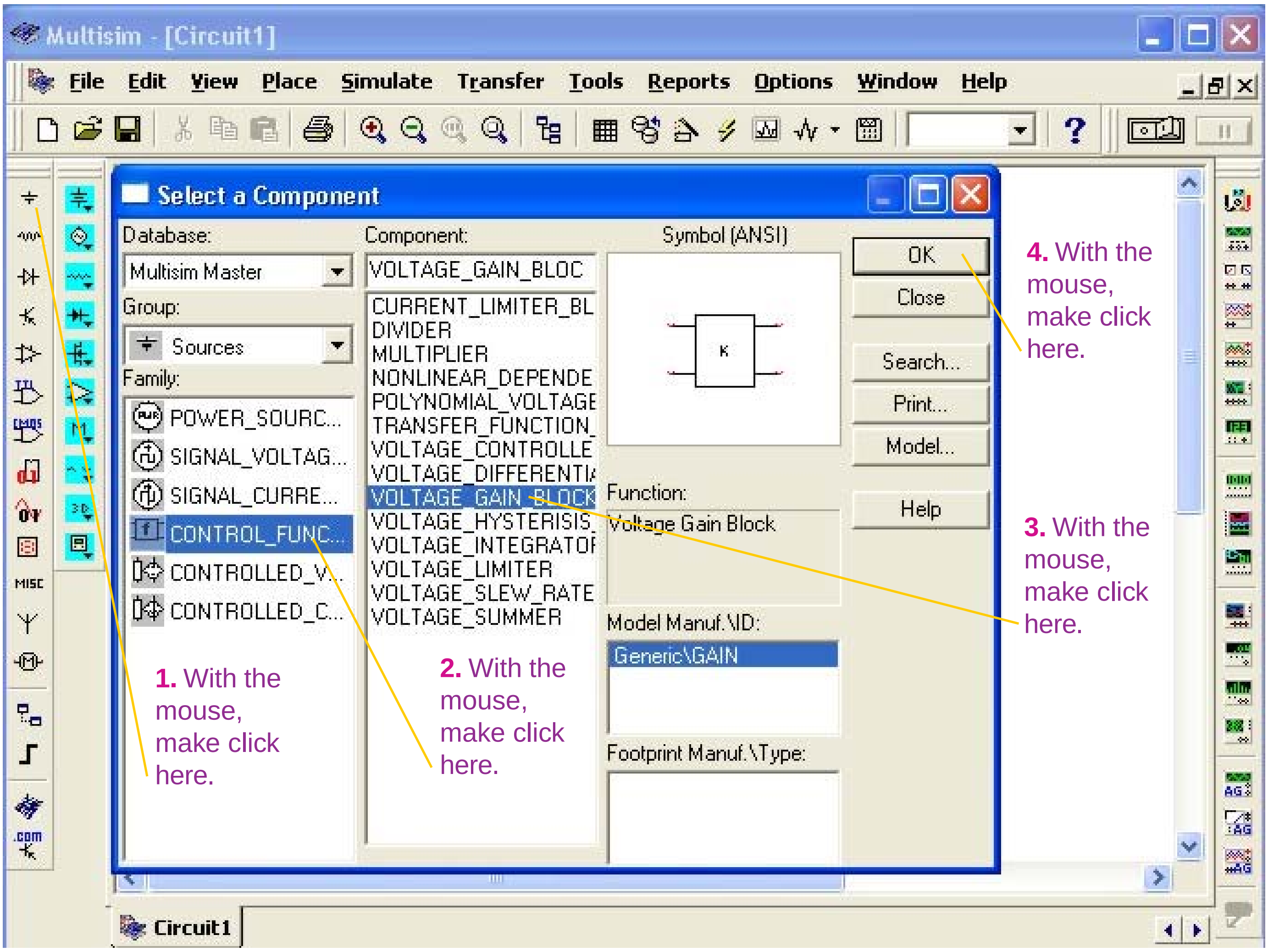
To access to the control modules or Controllers, from Multisim, proceed this way:

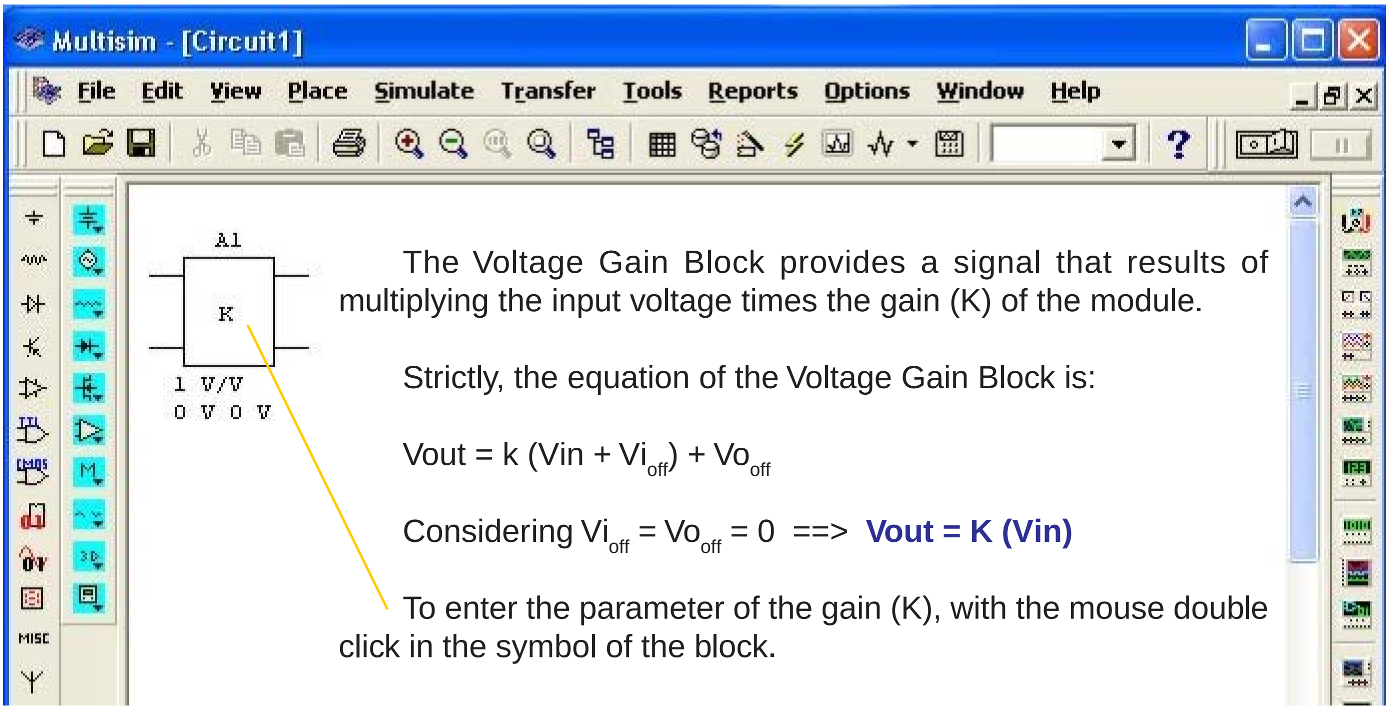




Next, we will describe each one of the Controllers.

1. Voltage Gain Block (Proportional Controller)





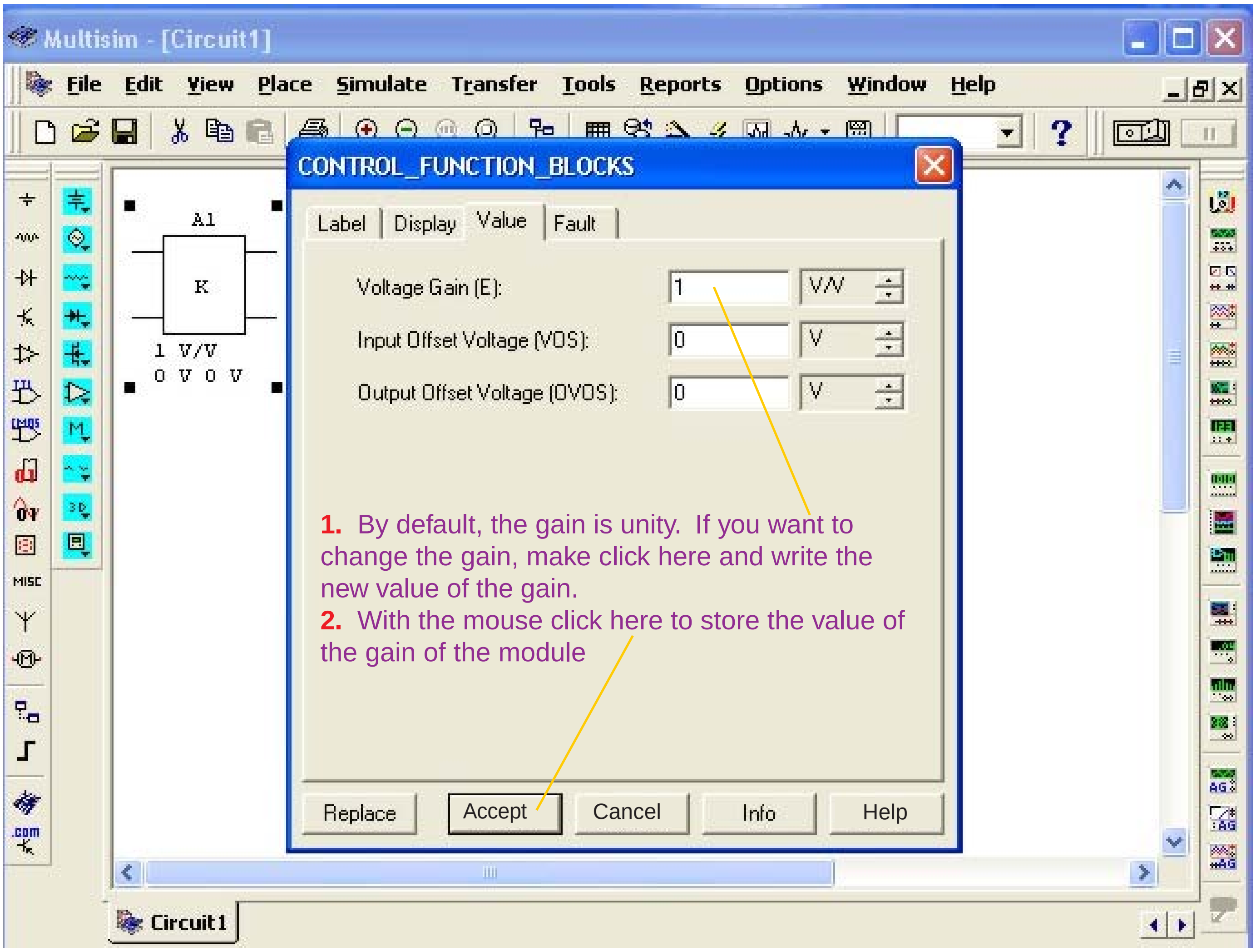
The Voltage Gain Block provides a signal that results of multiplying the input voltage times the gain (K) of the module.

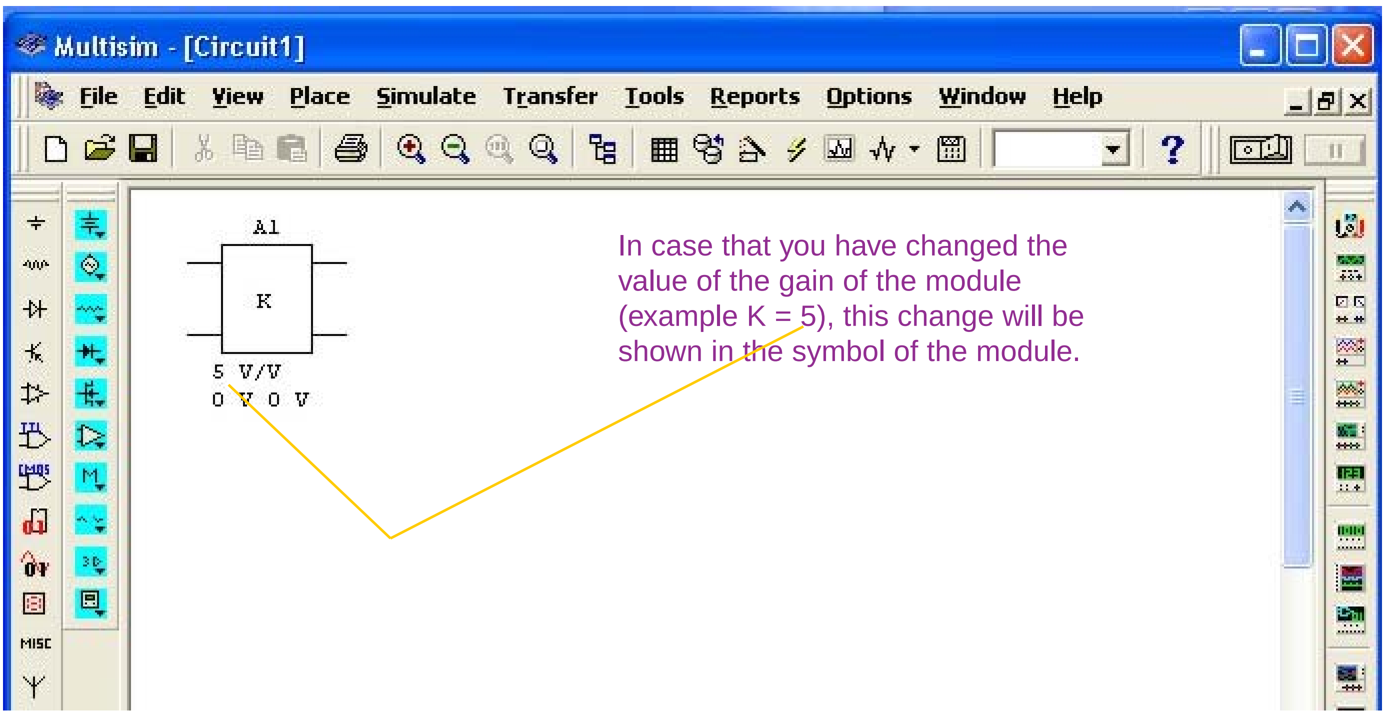
Strictly, the equation of the Voltage Gain Block is:

$$Vout = k\,(Vin + Vi_{off}) + Vo_{off}$$

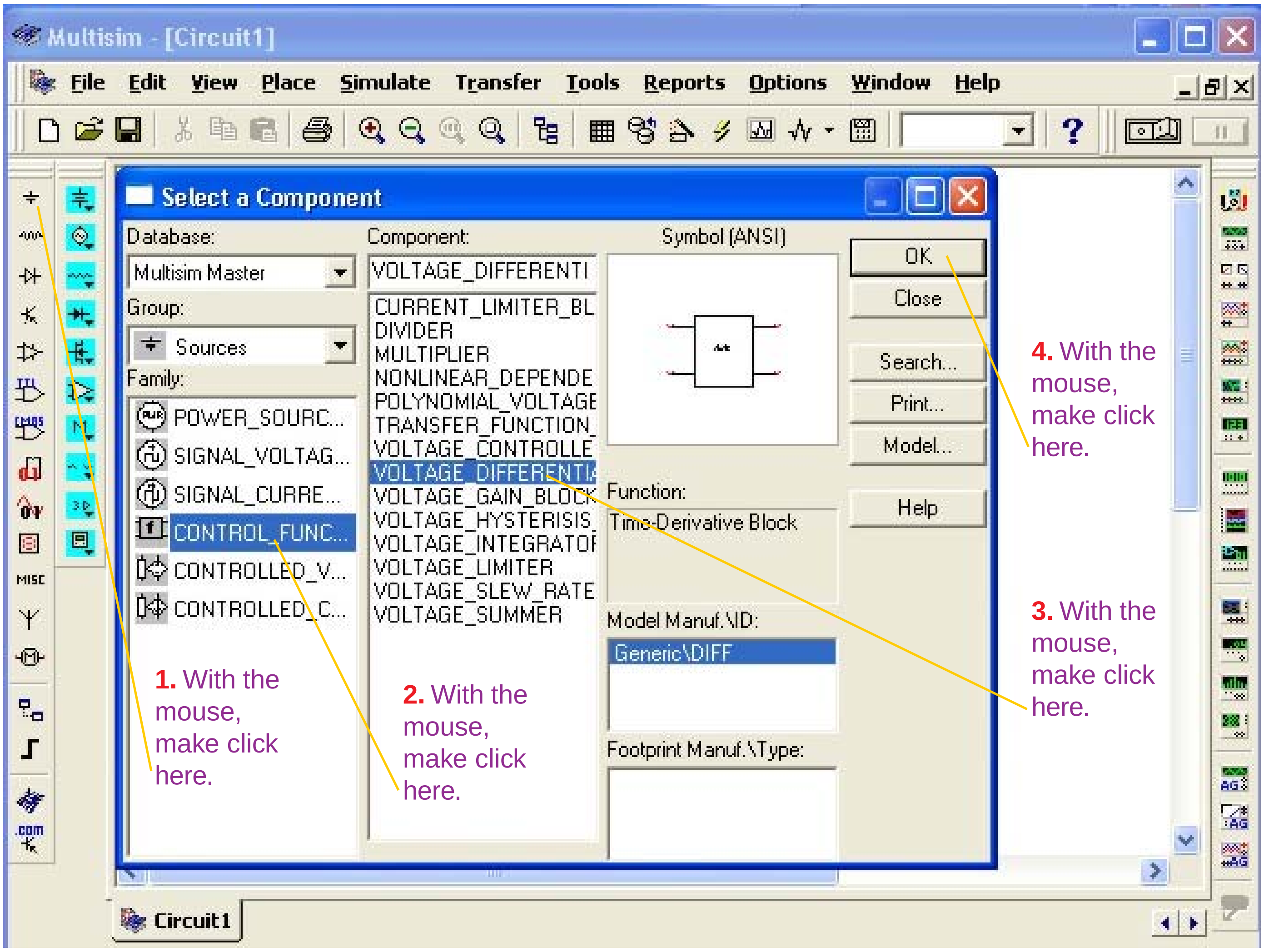
Considering $Vi_{off} = Vo_{off} = 0$ ==> **Vout = K (Vin)**

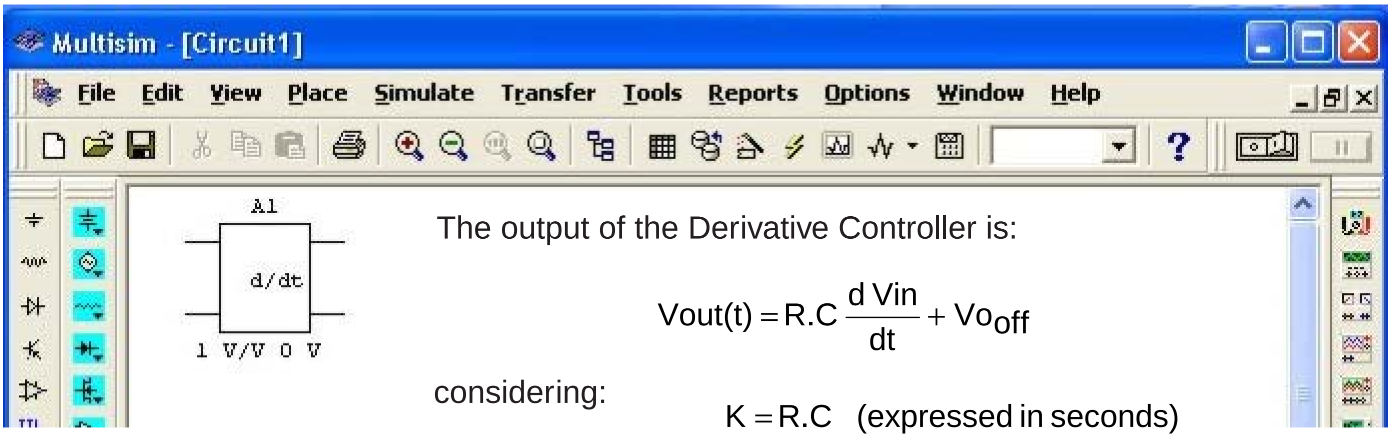
To enter the parameter of the gain (K), with the mouse double click in the symbol of the block.


Multisim - [Circuit1]
File Edit View Place Simulate Transfer Tools Reports Options Window Help
CONTROL_FUNCTION_BLOCKS
Label Display Value Fault
Voltage Gain (E): 1 V/V
Input Offset Voltage (VOS): 0 V
Output Offset Voltage (OVOS): 0 V
1. By default, the gain is unity. If you want to change the gain, make click here and write the new value of the gain.
2. With the mouse click here to store the value of the gain of the module
Replace Accept Cancel Info Help
A1
K
1 V/V
0 V 0 V
Circuit1


Multisim - [Circuit1]
File Edit View Place Simulate Transfer Tools Reports Options Window Help
A1
K
5 V/V
0 V 0 V
In case that you have changed the value of the gain of the module (example K = 5), this change will be shown in the symbol of the module.

2. Voltage Differential (Derivative Controller)





The output of the Derivative Controller is:

$$Vout(t) = R.C \frac{d\,Vin}{dt} + Vo_{off}$$

considering:

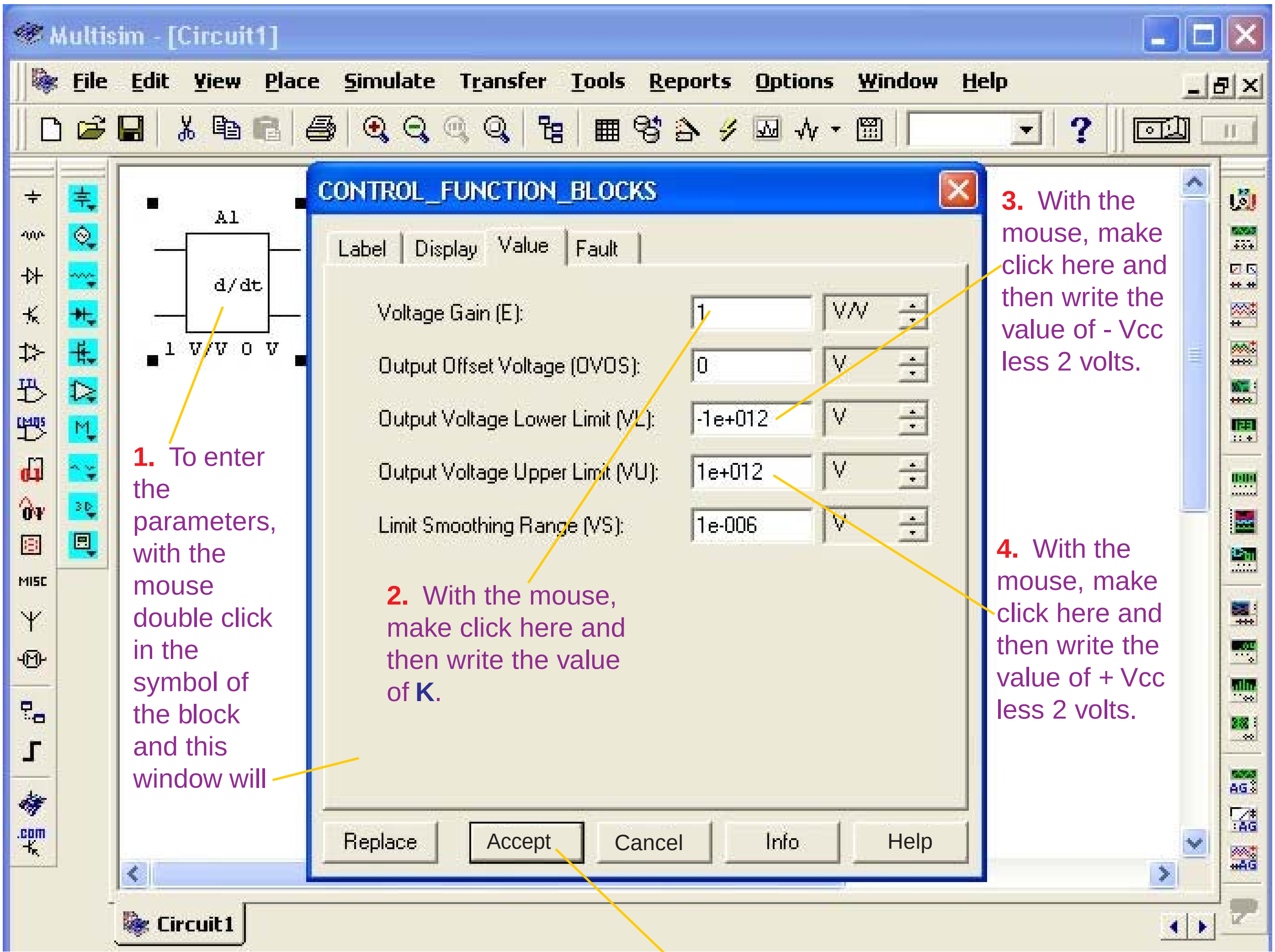
$$K = R.C \quad \text{(expressed in seconds)}$$

$$Vo_{off} = 0 \quad \text{(output offset voltage)}$$

then $$Vout(t) = K \frac{d\,Vin}{dt}$$

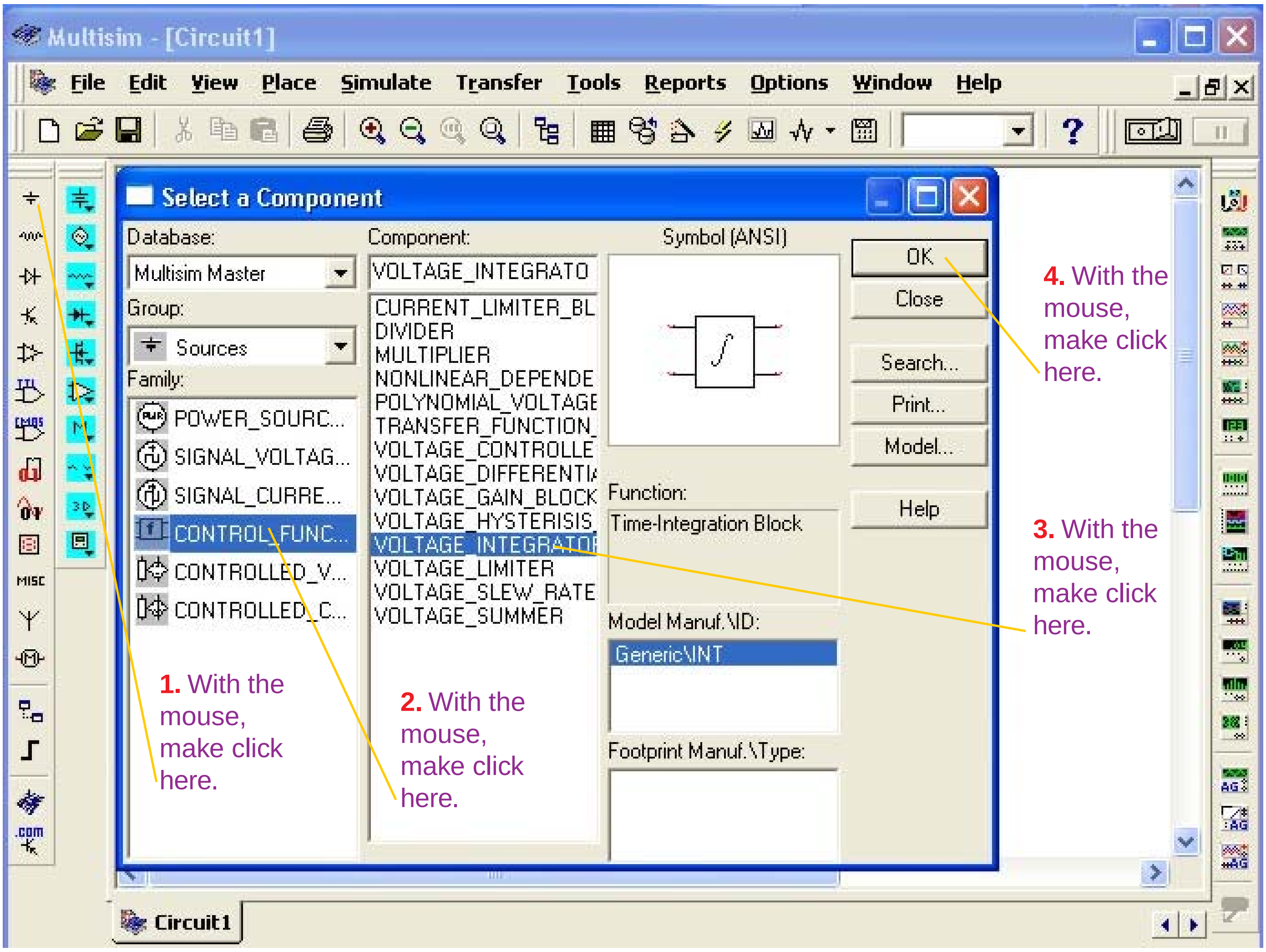
This equation indicates that the output of the Derivative Controller is the product of the derivative of the input voltage times the constant **K**. For this reason the constant **K** is known as **voltage gain**.

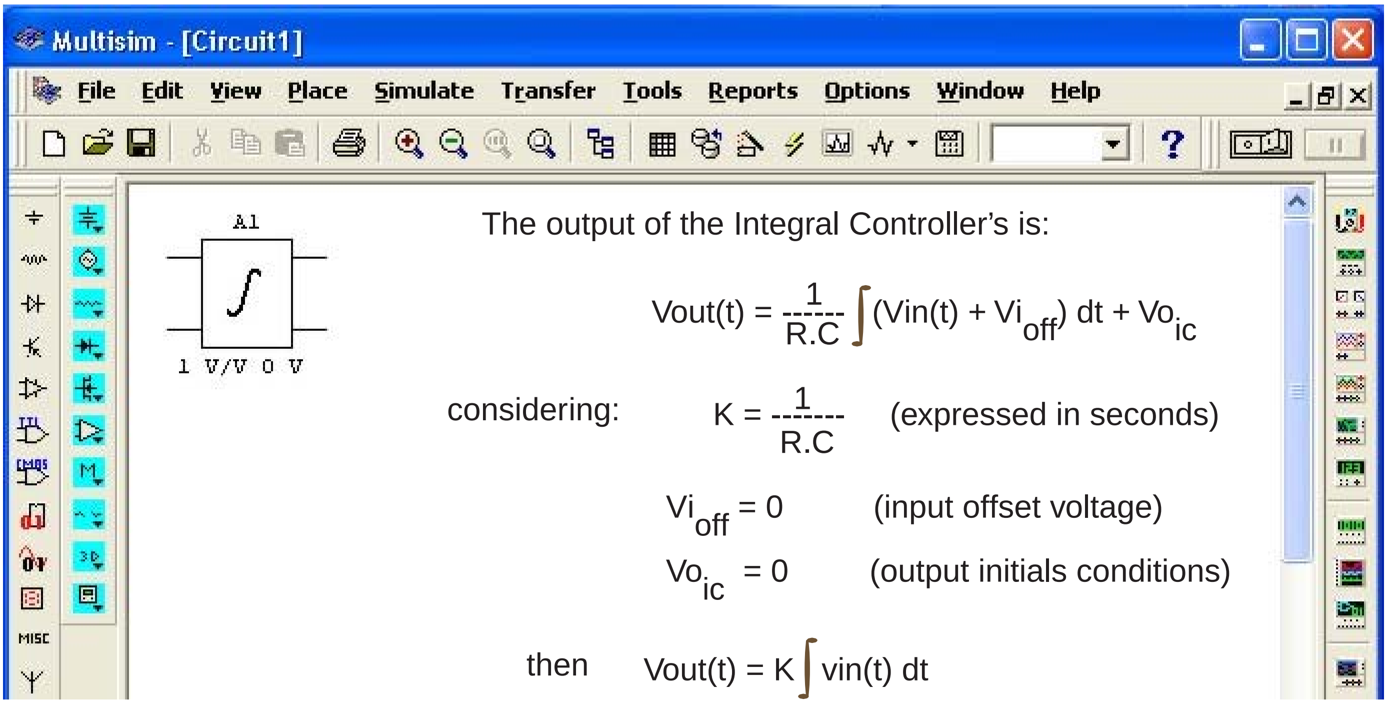
$$V_{out}(t) = K \frac{d\,V_{in}}{dt}$$



5. After having entered all the parameters, with the mouse, make click in **Accept**.

3. Voltage Integrator (Integral Controller)





The output of the Integral Controller's is:

$$Vout(t) = \frac{1}{R.C} \int (Vin(t) + Vi_{off})\, dt + Vo_{ic}$$

considering: $K = \frac{1}{R.C}$ (expressed in seconds)

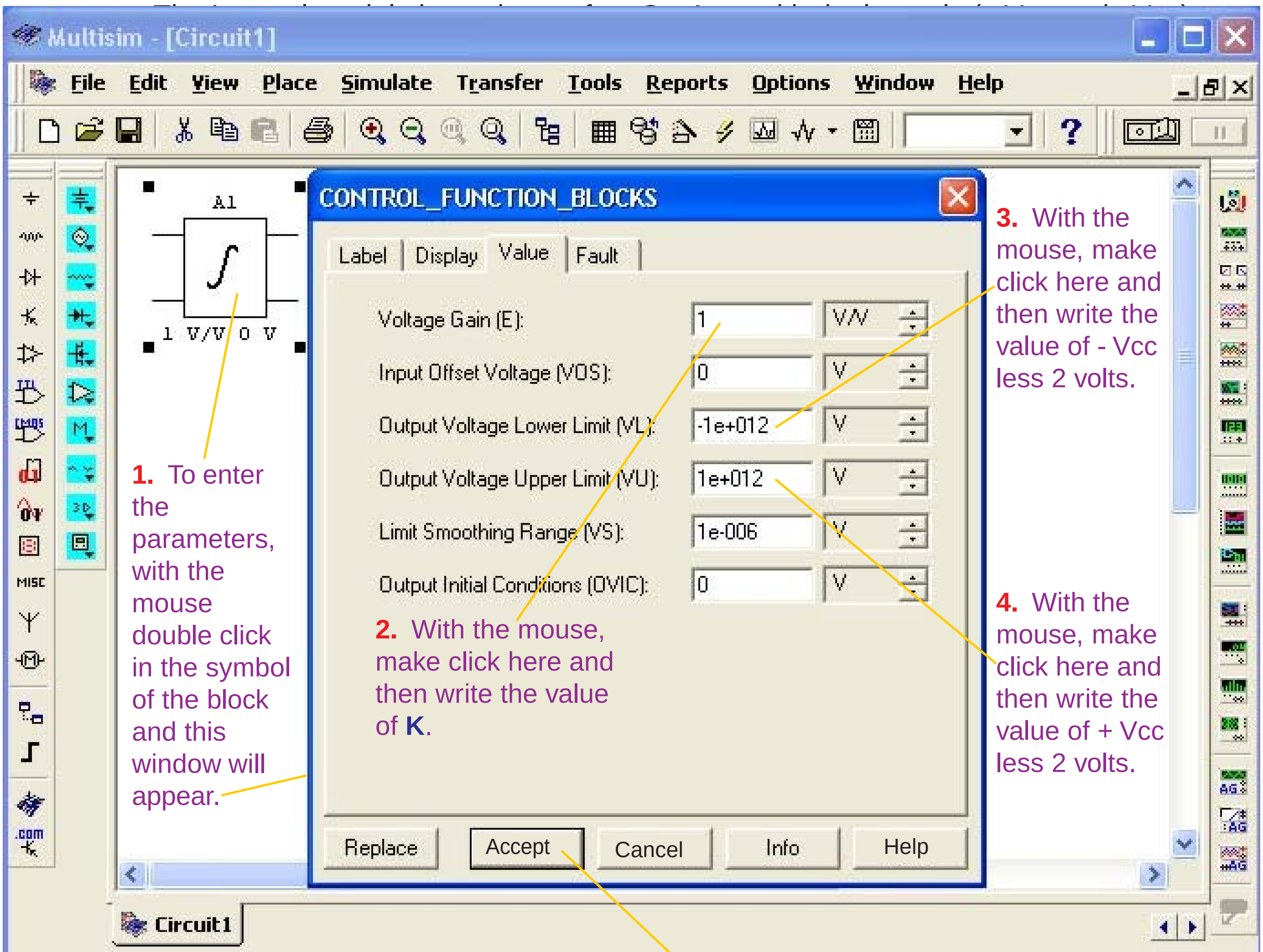
$Vi_{off} = 0$ (input offset voltage)

$Vo_{ic} = 0$ (output initials conditions)

then $Vout(t) = K \int vin(t)\, dt$

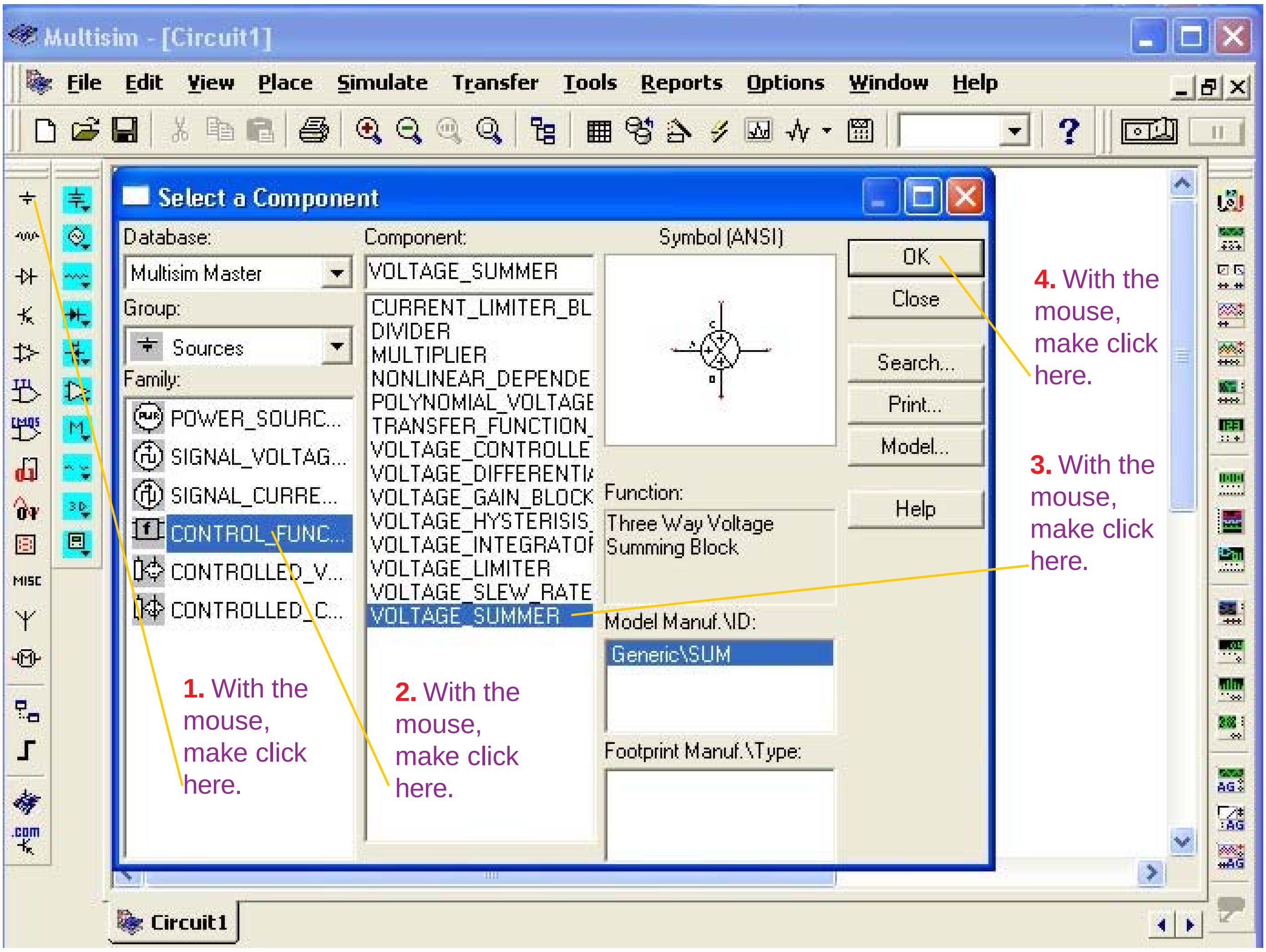
This equation indicates that the output of the Integral Controller is the product of the integral of the input voltage times the constant **K**. The constant **K** is known as **voltage gain**.

$$Vout(t) = K \int vin(t)\, dt$$



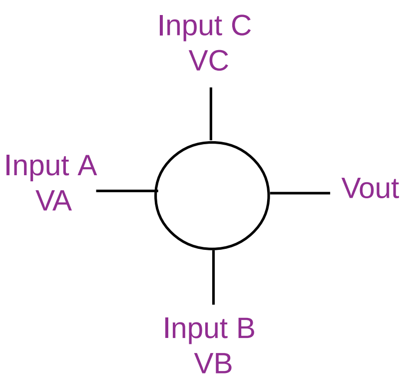
5. After having entered all the parameters, with the mouse, make click in **Accept**.

4. Voltage Summer (Summer)



The output of the summer is:

$$Vout = Kout\ [\ KA\ (VA + VA_{off}) + KB\ (VB + VB_{off}) + KC\ (VC + VC_{off})\ ] + Vo_{off}$$



Voltage Summer Block (Summer)

considering:

$VA_{off} = 0$ (input A offset voltage)

$VB_{off} = 0$ (input B offset voltage)

$VC_{off} = 0$ (input C offset voltage)

$Vo_{off} = 0$ (output offset voltage)

then:

$Vout = Kout\ (KA.VA + KB.VB + KC.VC)$

Vout = Kout (KA.VA + KB.VB + KC.VC) (equation of the summer)

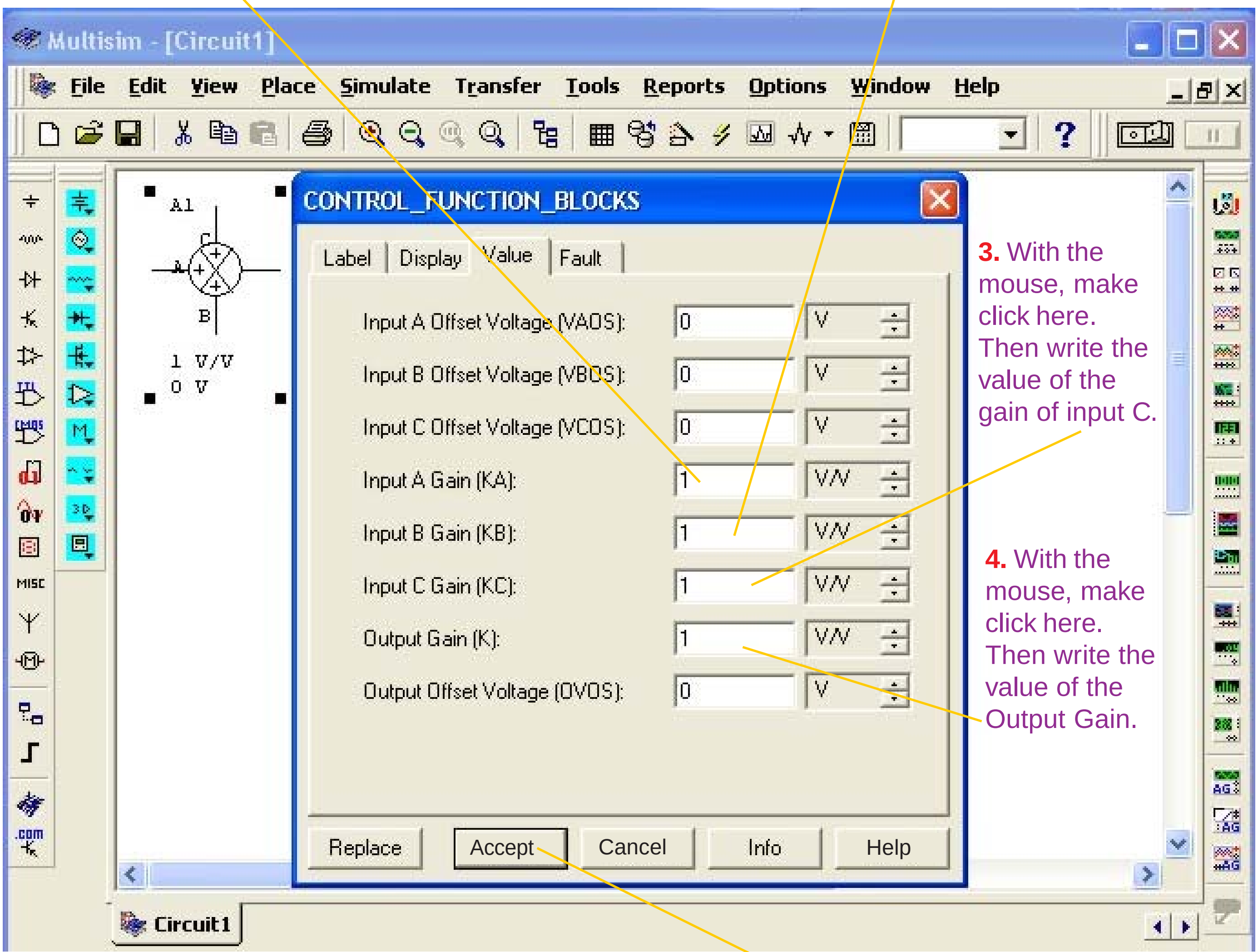
where:
KA: Gain of input A.
KB: Gain of input B.
KC: Gain of input C.
Kout: Output gain.
VA, VB, VC: Input signals.

If we consider KA = KB = KC = Kout = 1 then the output of the Summer is similar to the arithmetic sum of the input signals.

To enter the parameters of the Summer, proceed in the following way:

1. With the mouse, make click here. Then write the value of the gain of input A.

2. With the mouse, make click here. Then write the value of the gain of input B.



5. After having entered all the parameters, with the mouse click in **Accept**.

Example of Simulation of a Process Control

In the block diagram of figure 12, we observe the signals that provide the Sensor, the input Interface and the Set Point. The resultant of the sum of the signals of the input Interface and the Sep Point, carried out by the Summer, is applied to the Controller's input.

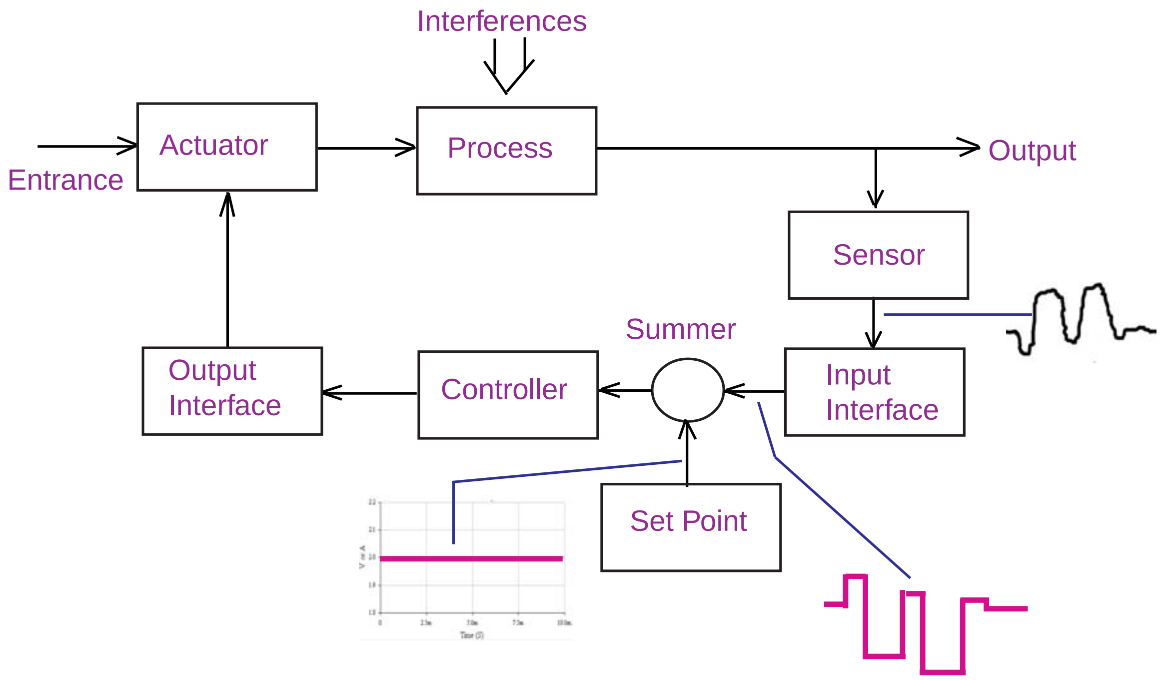


Figure 12. Block Diagram of a process control with signals of the Sensor, Input Interface and Set Point.

Next we will simulate, with Multisim, the behavior of the Summer and the Controller in their different configurations or control actions (Proportional, Integral, Derivative executing the following steps:

Step 1: We tabulate the signal of the Input Interface and the Set Point.

Step 2: We store the tabulation of the signals in Multisim.

Step 3: With Multisim we'll draw the following circuit:

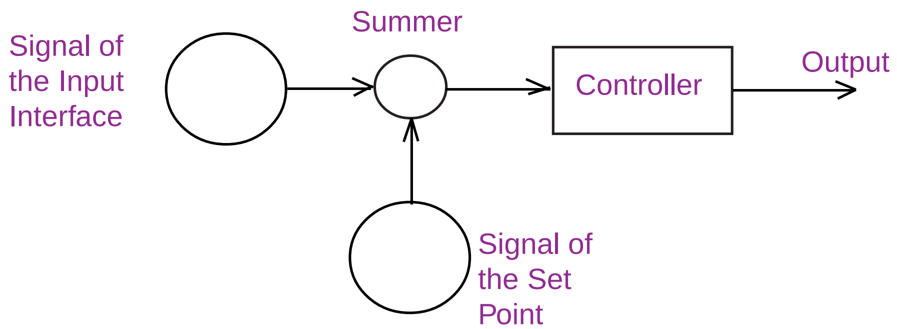


Figure 13. Controller Circuit with two signals (Input Interface and Set Point) and a Summer.

Step 4: We incorporate the Proportional Controller (P) and we will observe the signals of the Input Interface, Set Point, Summer and output of the Proportional Controller.

Step 5: We replace the Proportional Controller for the Derivative Controller (D) and we will observe the signals of the Input Interface, Set Point, summer and output of the Derivative Controller.

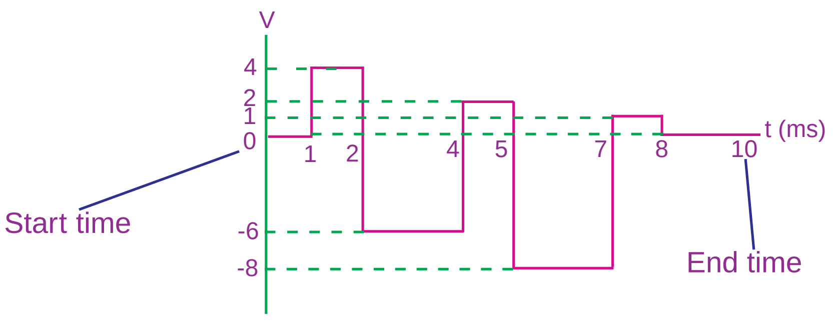
Step 6: We replace the Derivative Controller for the Integral Controller (I) and we will observe the signals of the Input Interface, Set Point, summer and output of the Integral Controller.

Step 7: We insert the Proportional, Derivative and Integral Controllers (PID) and we will observe the input and output signals of the PID.

To continue with our example, consider the following:

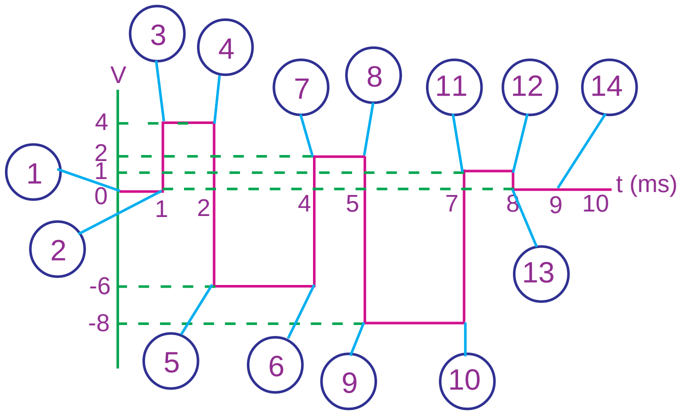
1. The Proportional Controller (P) will have a unity gain.
2. The Derivative (D) and Integral (I) Controllers will have an RC constant = 1 millisecond.
3. The Summer will have a unity gain.
4. The whole electronic system will have a dual-supply of +VCC = 15 V and - Vcc = -15 V
5. In all the Controllers, use the non-inverting input and the inverting output.

Tabulation of the signal of the Input Interface



Signal of the Input Interface.

We set the coordinates of the main points of the wave form of the Input Interface.



In a table, we write the coordinates of the fixed points.

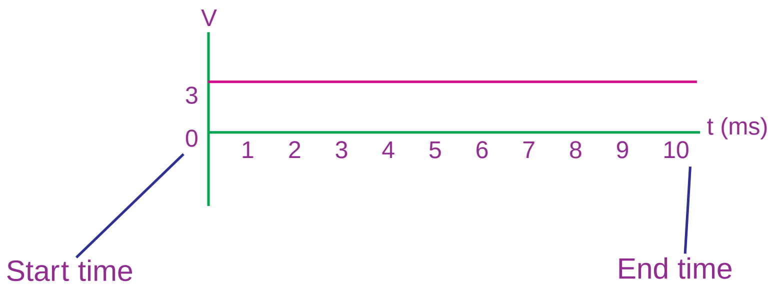
Point	Time (s)	Voltage
1	0	0
2	0.001	0
3	0.001001	4
4	0.002	4
5	0.002001	-6
6	0.004	-6
7	0.004001	2
8	0.005	2
9	0.005001	-8
10	0.007	-8
11	0.007001	1
12	0.008	1
13	0.008001	0
14	0.009	0

Notes

1. In the table, the Time is specified in seconds and the Voltage in volts.

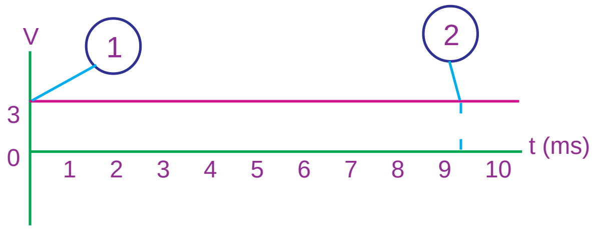
2. Multisim works with continuous functions. For this reason, observe that in points 3, 5, 7, 9, 11 and 13, we have added a millionth of second to indicate to Multisim that the signal is a continuous function (remember that in the study of Limits, when for a single value in the «x» axis it corresponds two different values in the «y» axis, the function is discontinuous)

Tabulation of the signal of the Set Point



Signal of the Set Point.

We set the coordinates of the main points of the wave form of the Set Point.

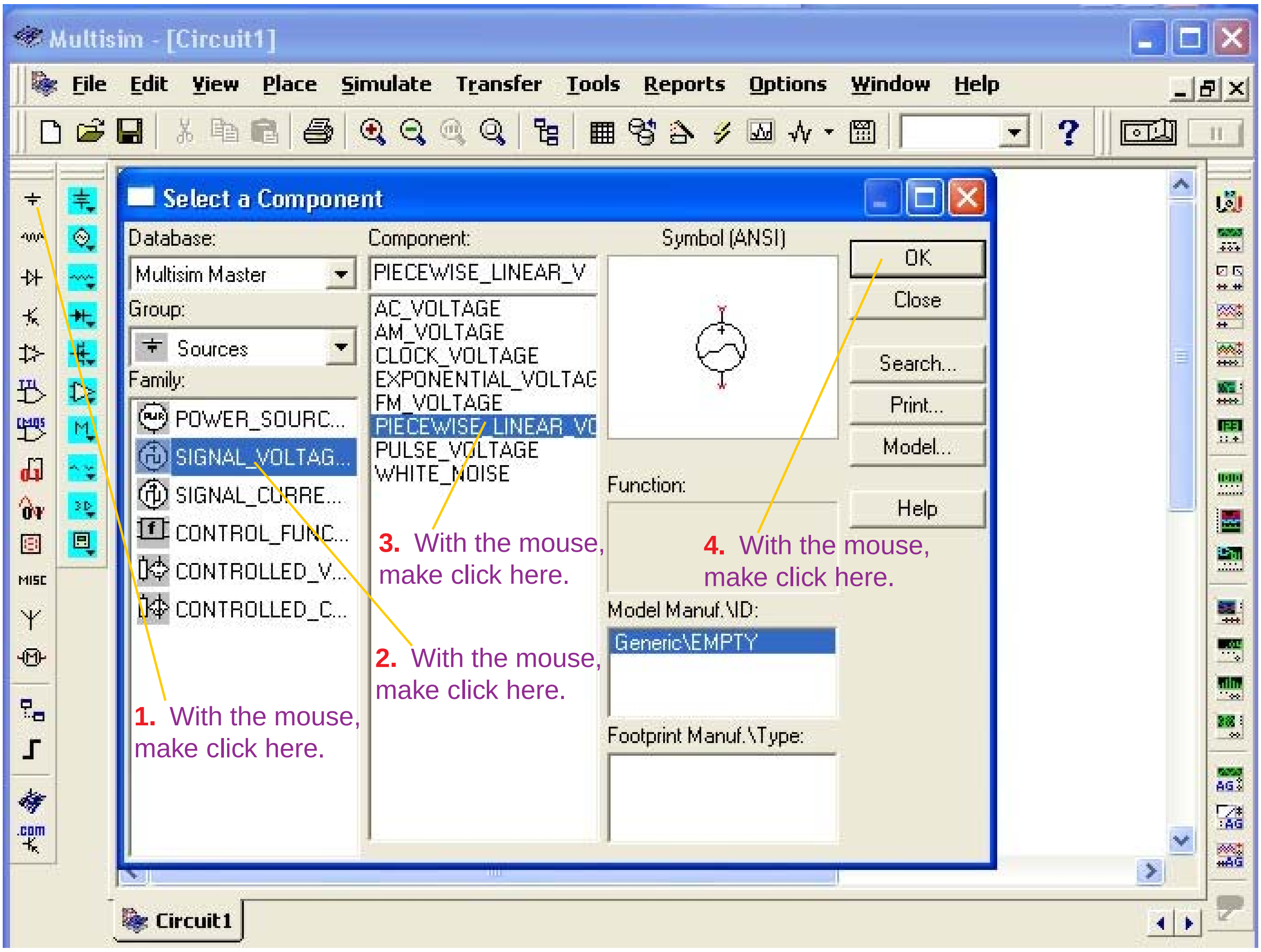


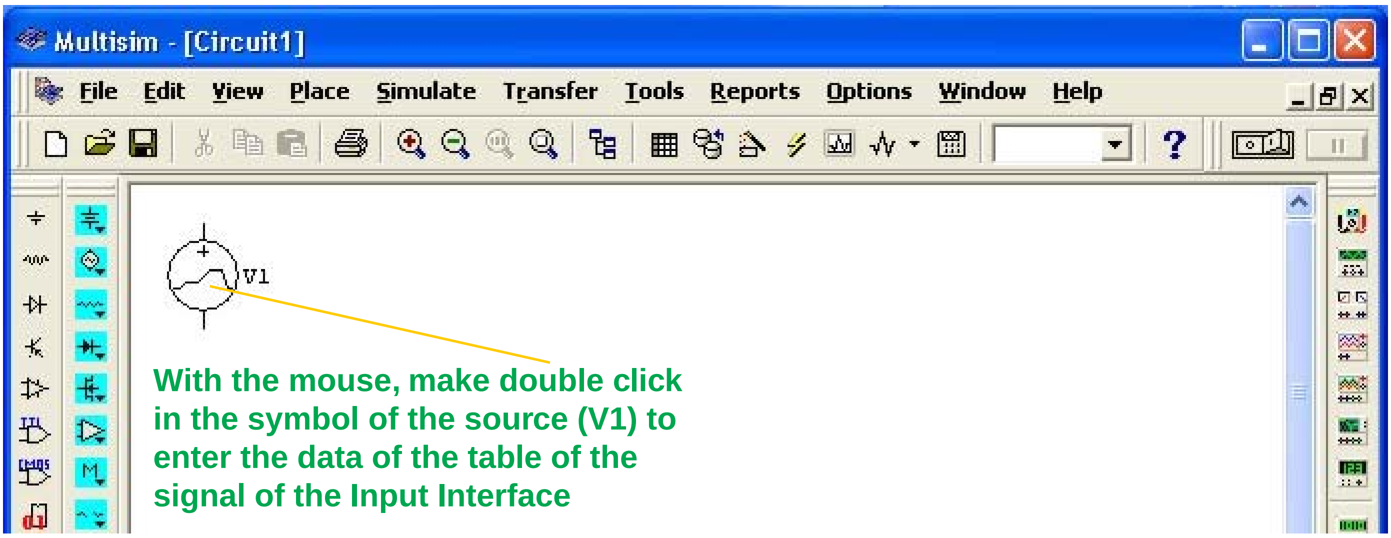
In a second table, we write the coordinates of the points indicated in the previous step.

Point	Time (s)	Voltage
1	0	3
2	0.009	3

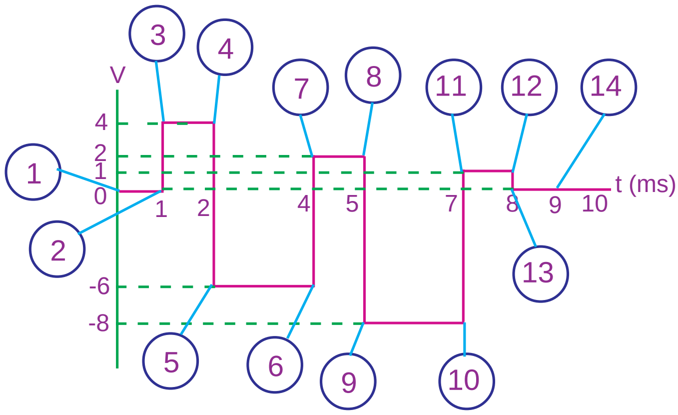
Since the Set Point signal is a straight line, it will be enough with taking two points (at the beginning and the end of the straight line) so that it is mathematically defined.

Storage of the signal of the Input Interface in Multisim

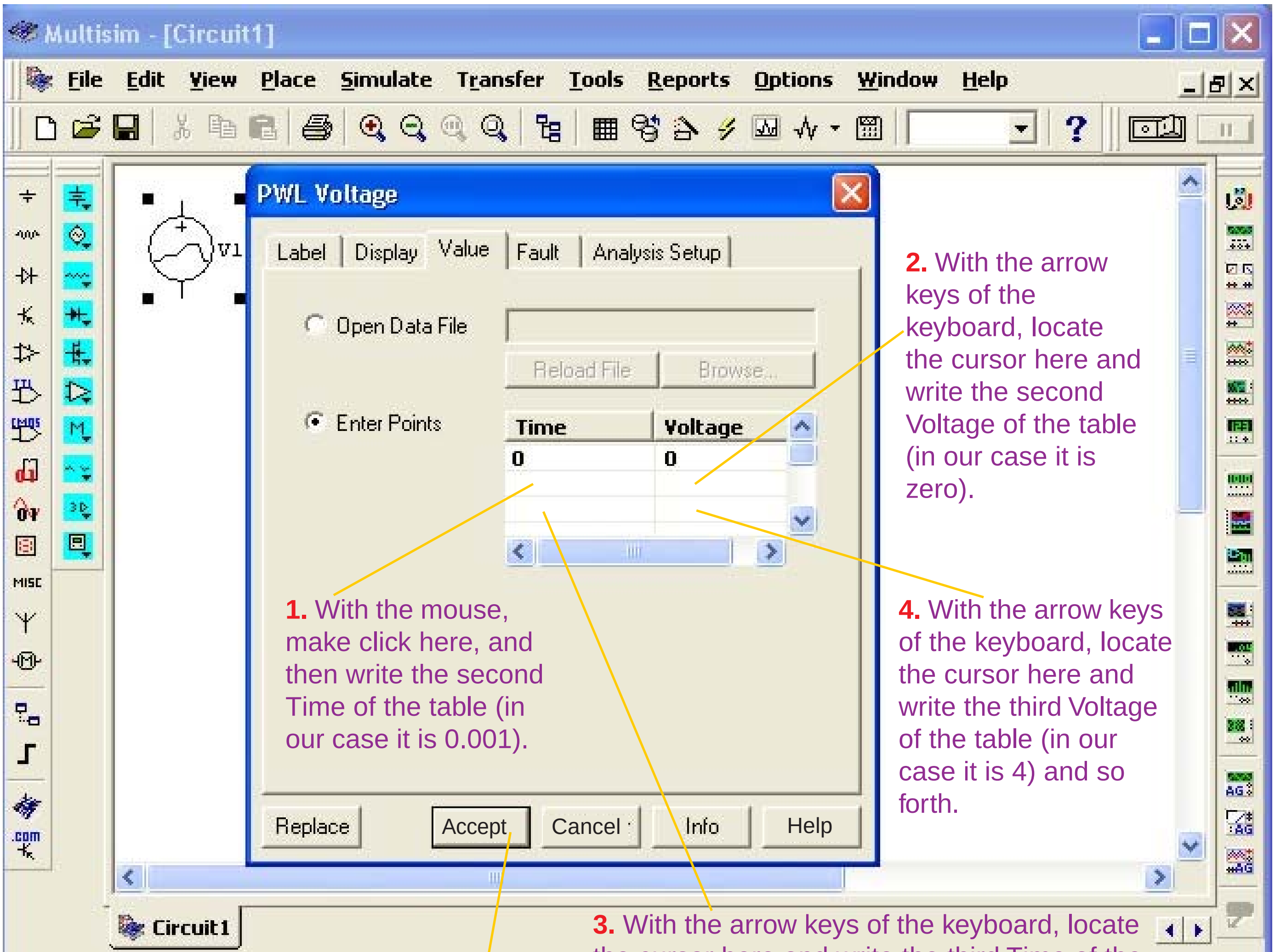




Point	Time (s)	Voltage
1	0	0
2	0.001	0
3	0.001001	4
4	0.002	4
5	0.002001	-6
6	0.004	-6
7	0.004001	2
8	0.005	2
9	0.005001	-8
10	0.007	-8
11	0.007001	1
12	0.008	1
13	0.008001	0
14	0.009	0



Tabulation of the signal of the Input Interface



1. With the mouse, make click here, and then write the second Time of the table (in our case is 0.001).

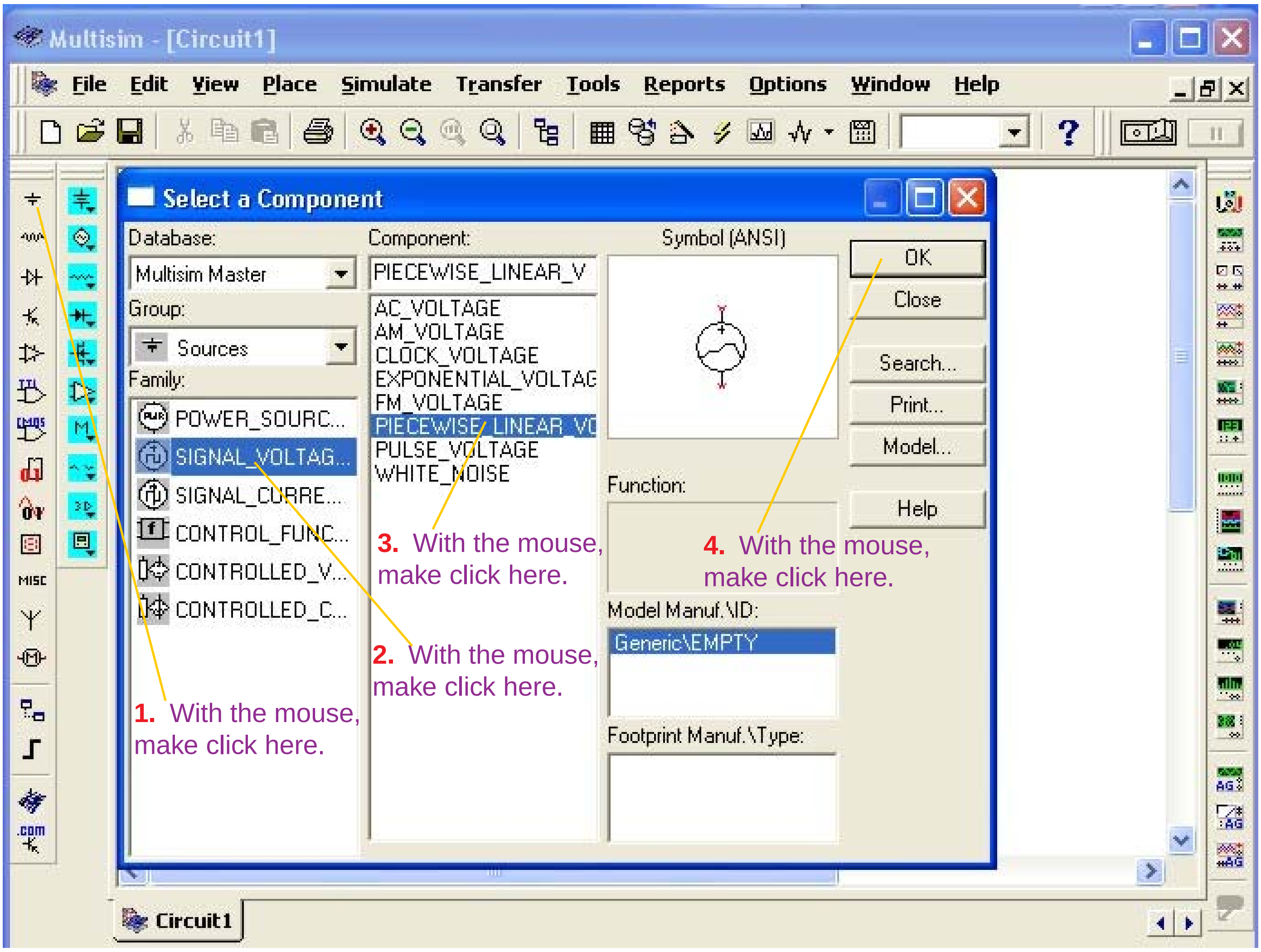
2. With the arrow keys of the keyboard, locate the cursor here and write the second Voltage of the table (in our case it is zero).

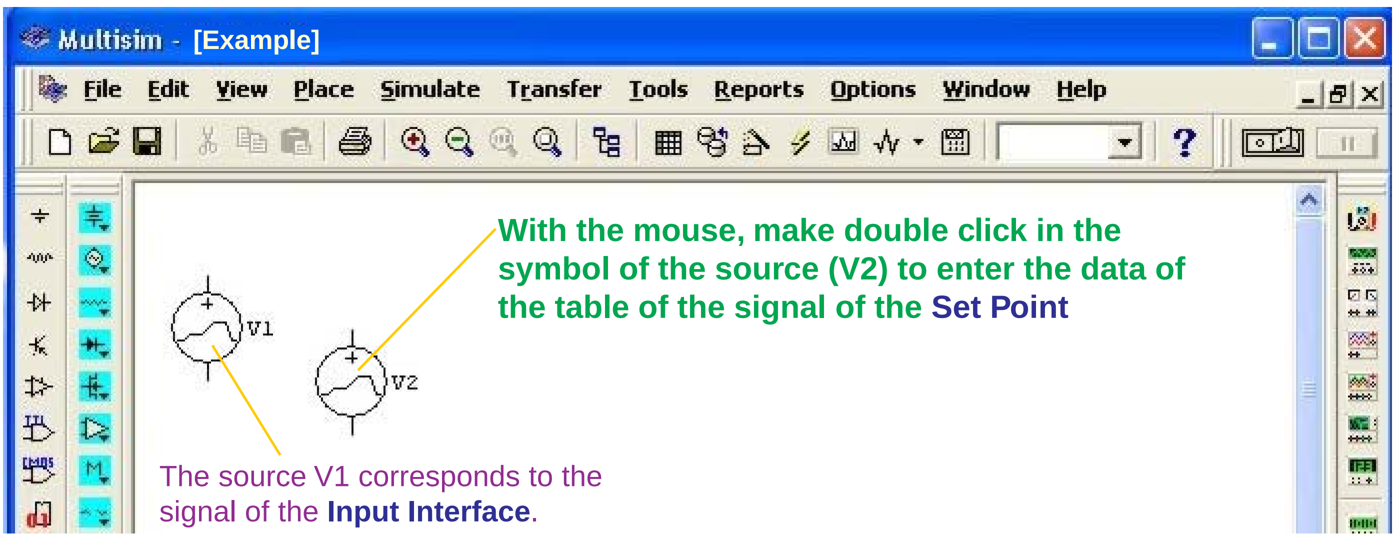
3. With the arrow keys of the keyboard, locate the cursor here and write the third Time of the table (in our case it is 0.001001).

4. With the arrow keys of the keyboard, locate the cursor here and write the third Voltage of the table (in our case it is 4) and so forth.

After having entered the fourteen points of the signal of the Input Interface; with the mouse make click in **Accept** to record the information

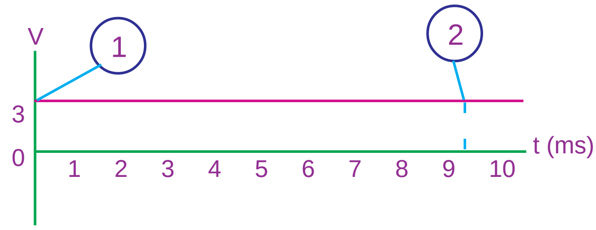
Storage of the signal of the Set Point in Multisim.

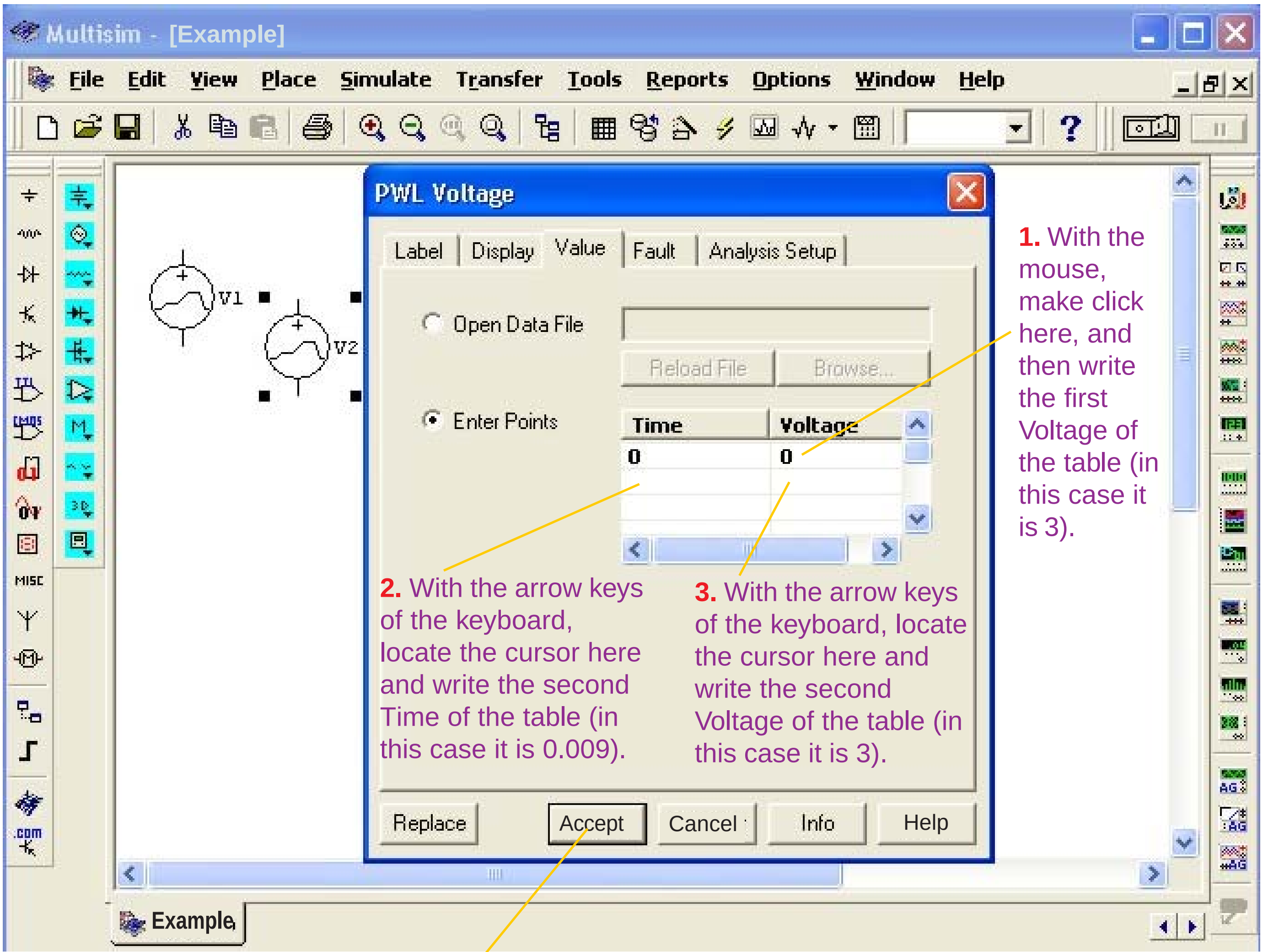




Point	Time (s)	Voltage
1 2	0 0.009	3 3

Tabulation of the signal of the Set Point.

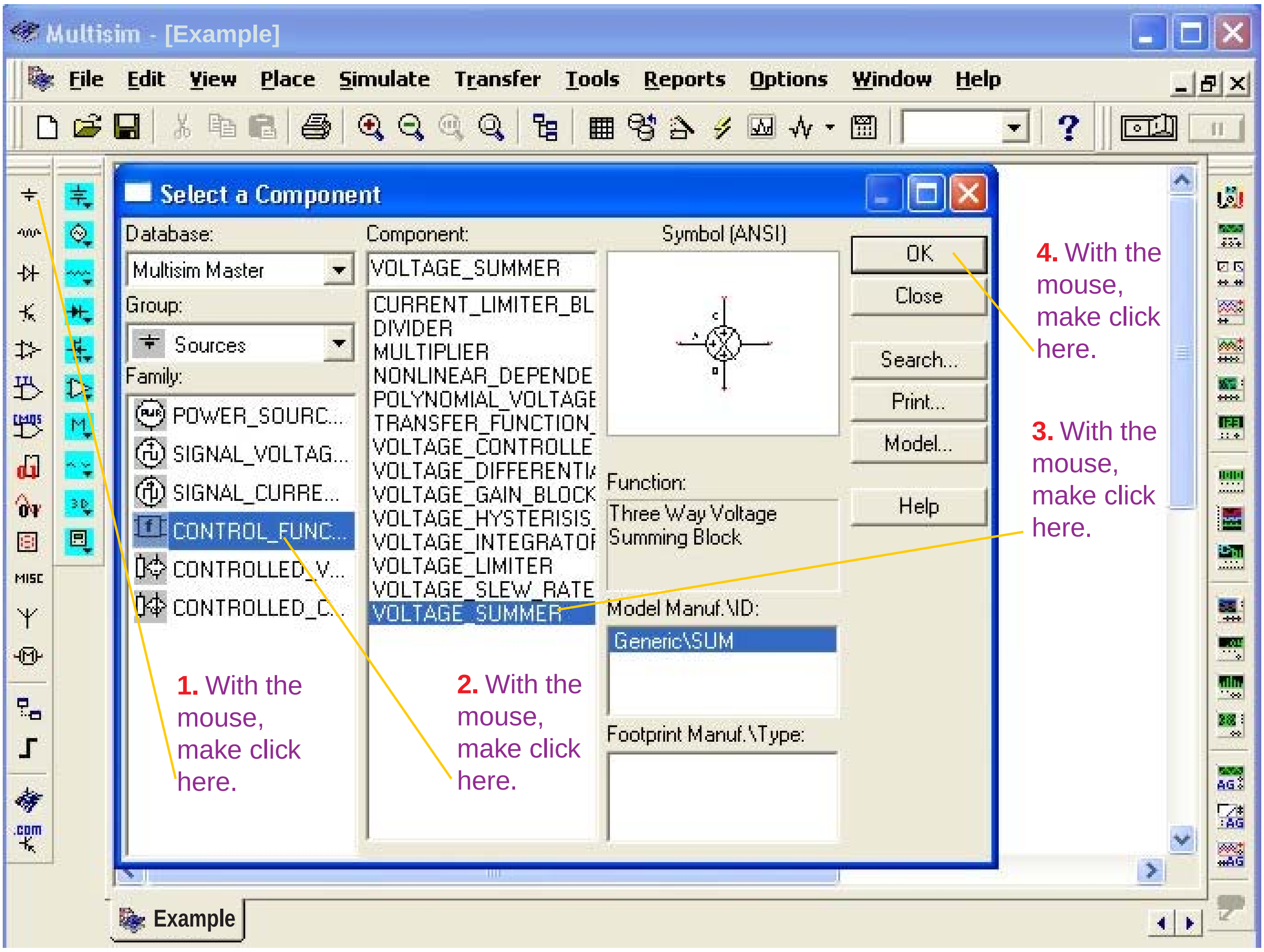


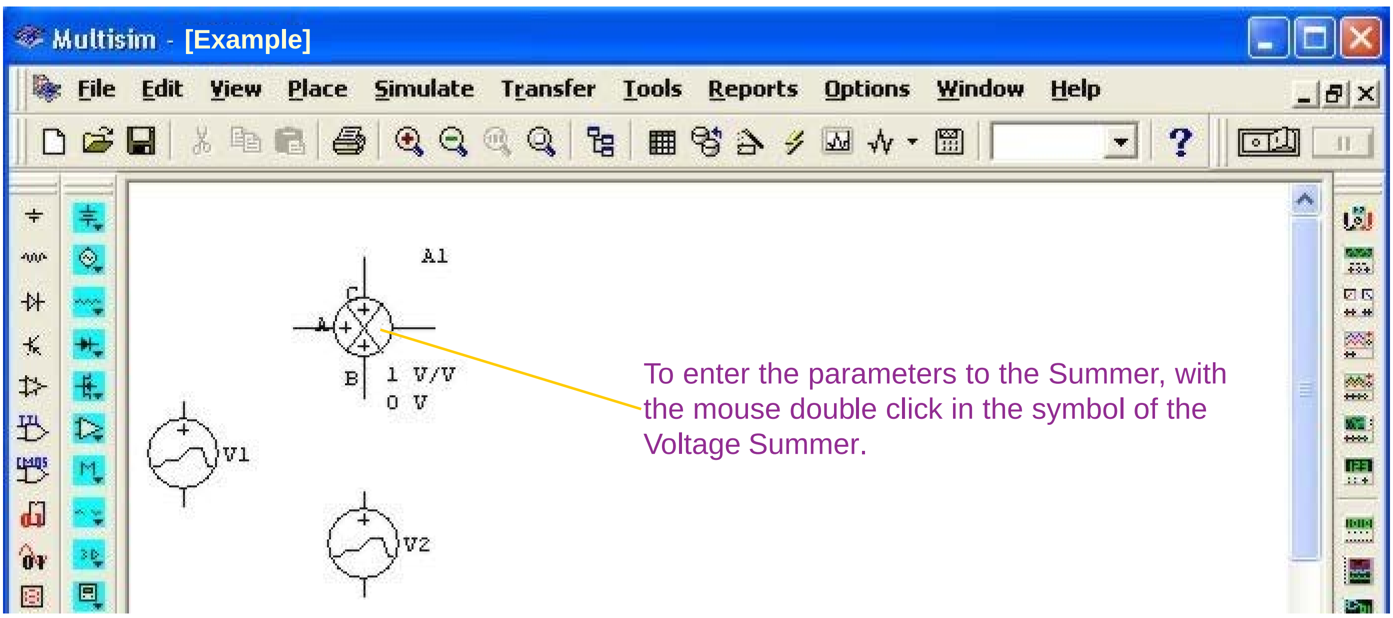


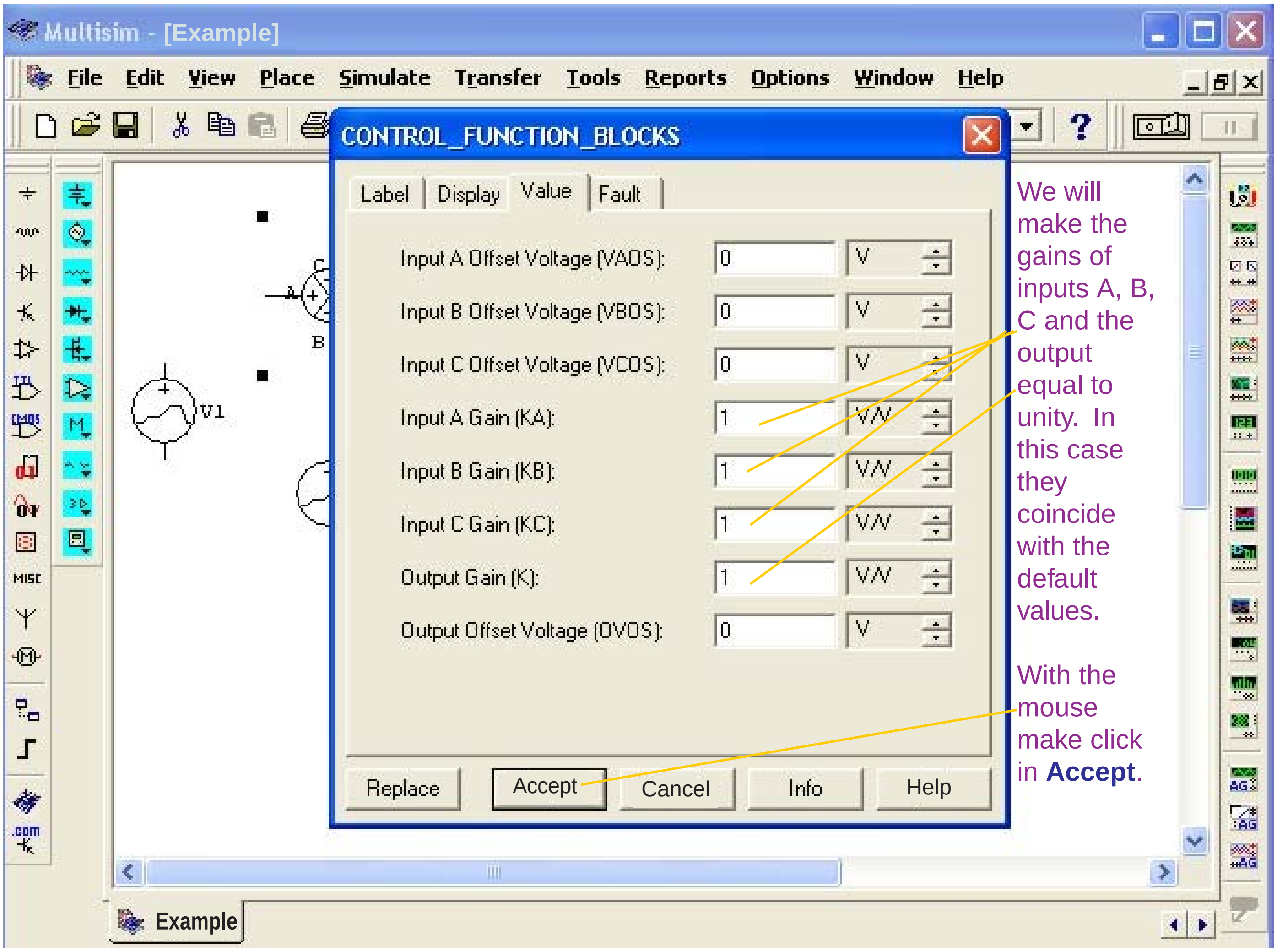
After having entered the two points of the signal of the Set Point; with the mouse click in **Accept** to record the information

The Summer with the signals of the Input Interface and Set Point.

We will insert the **Summer**.

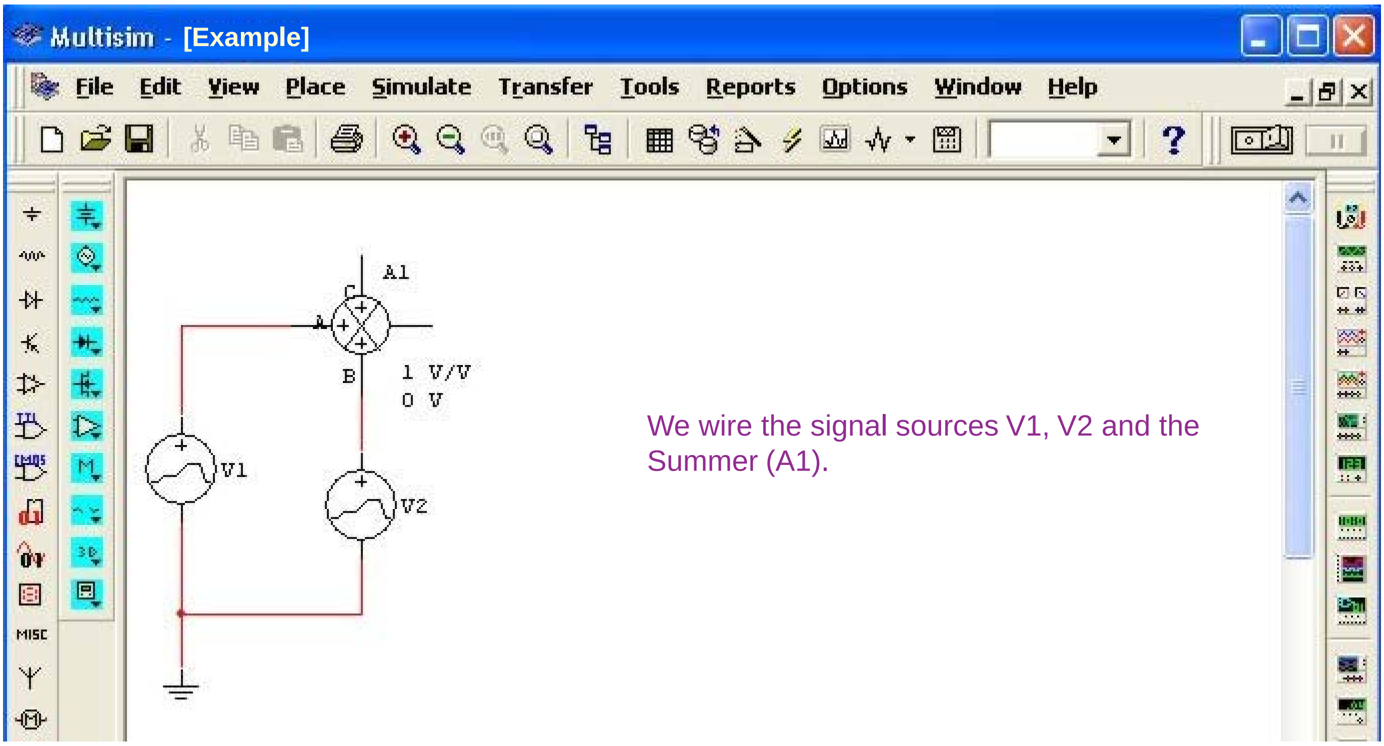






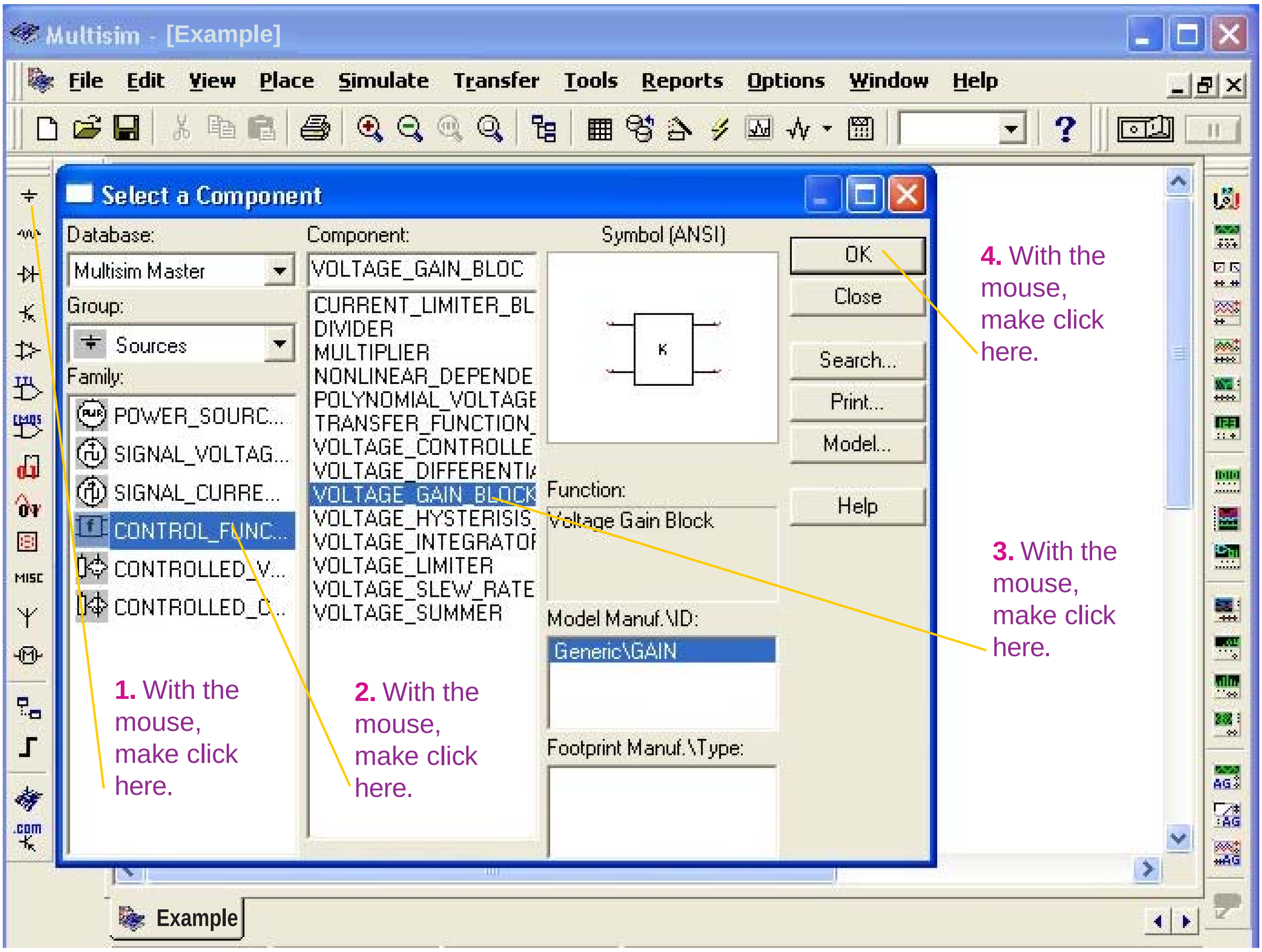
We will make the gains of inputs A, B, C and the output equal to unity. In this case they coincide with the default values.

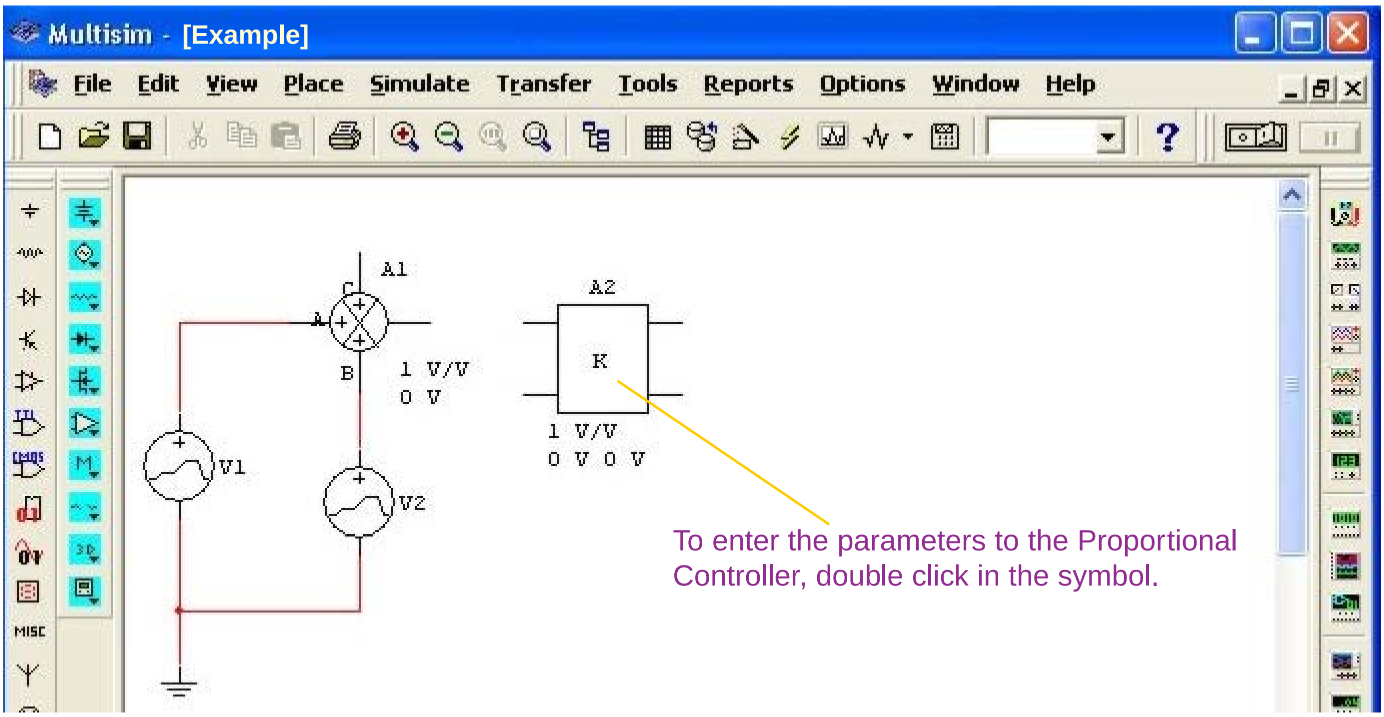
With the mouse make click in **Accept**.

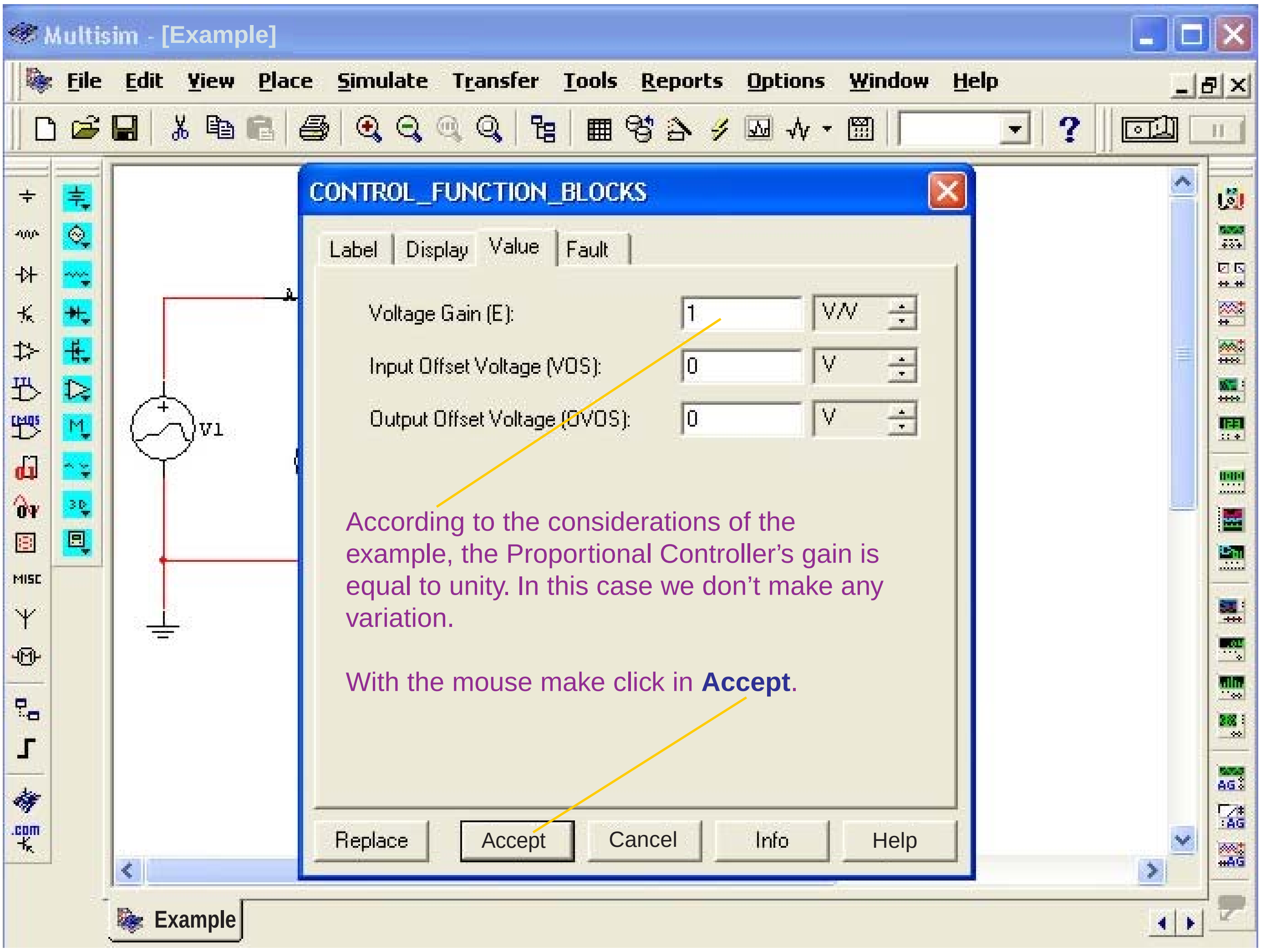


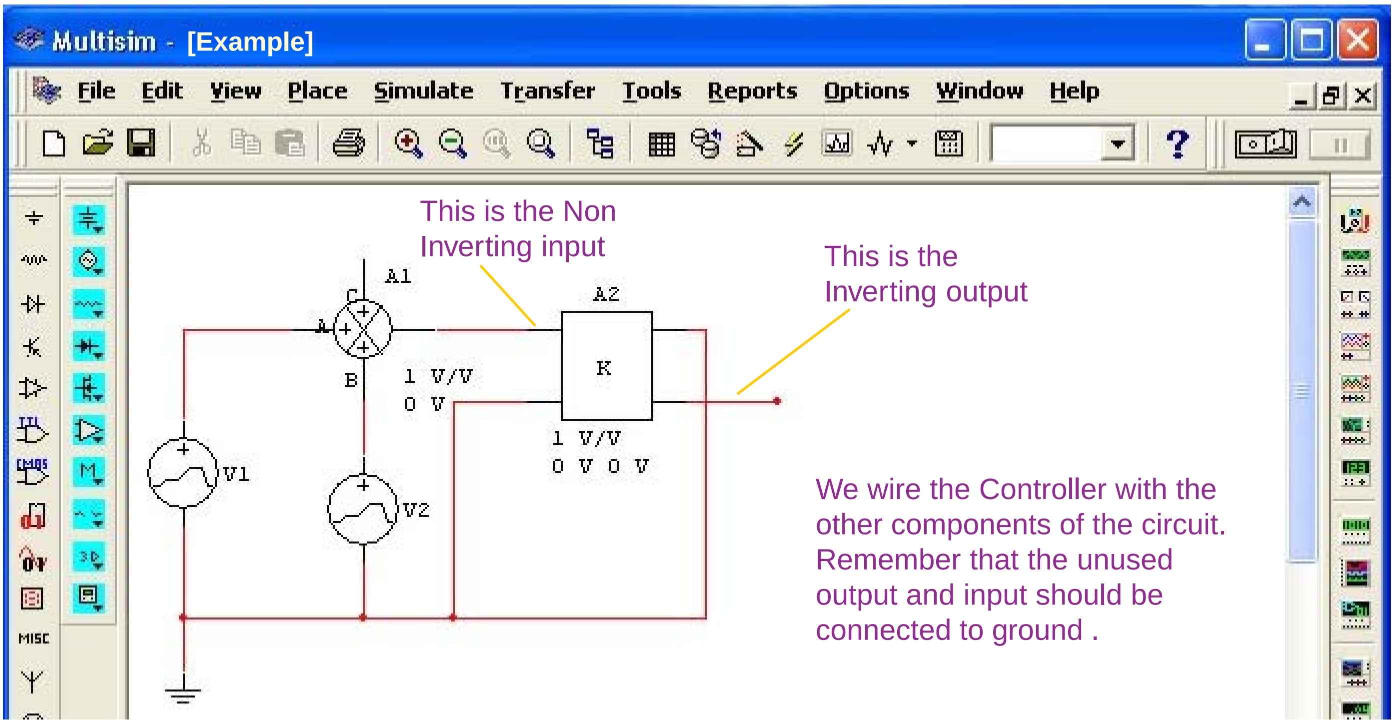
We wire the signal sources V1, V2 and the Summer (A1).

The Proportional Controller with the summer and input signals.





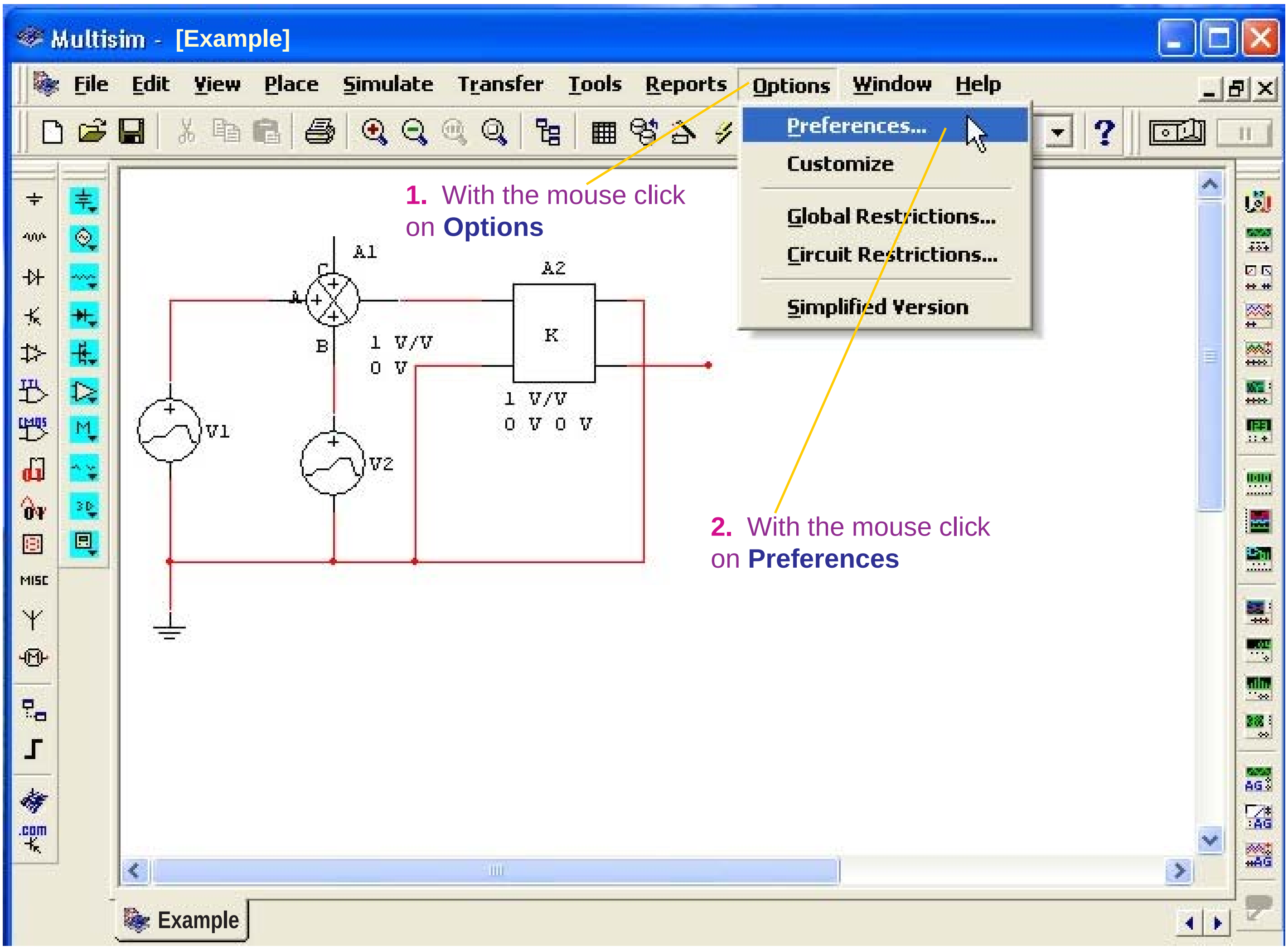

Multisim - [Example]
File Edit View Place Simulate Transfer Tools Reports Options Window Help
CONTROL_FUNCTION_BLOCKS
Label Display Value Fault
Voltage Gain (E): 1 V/V
Input Offset Voltage (VOS): 0 V
Output Offset Voltage (OVOS): 0 V
According to the considerations of the example, the Proportional Controller’s gain is equal to unity. In this case we don’t make any variation.
With the mouse make click in Accept.
Replace Accept Cancel Info Help
V1
Example

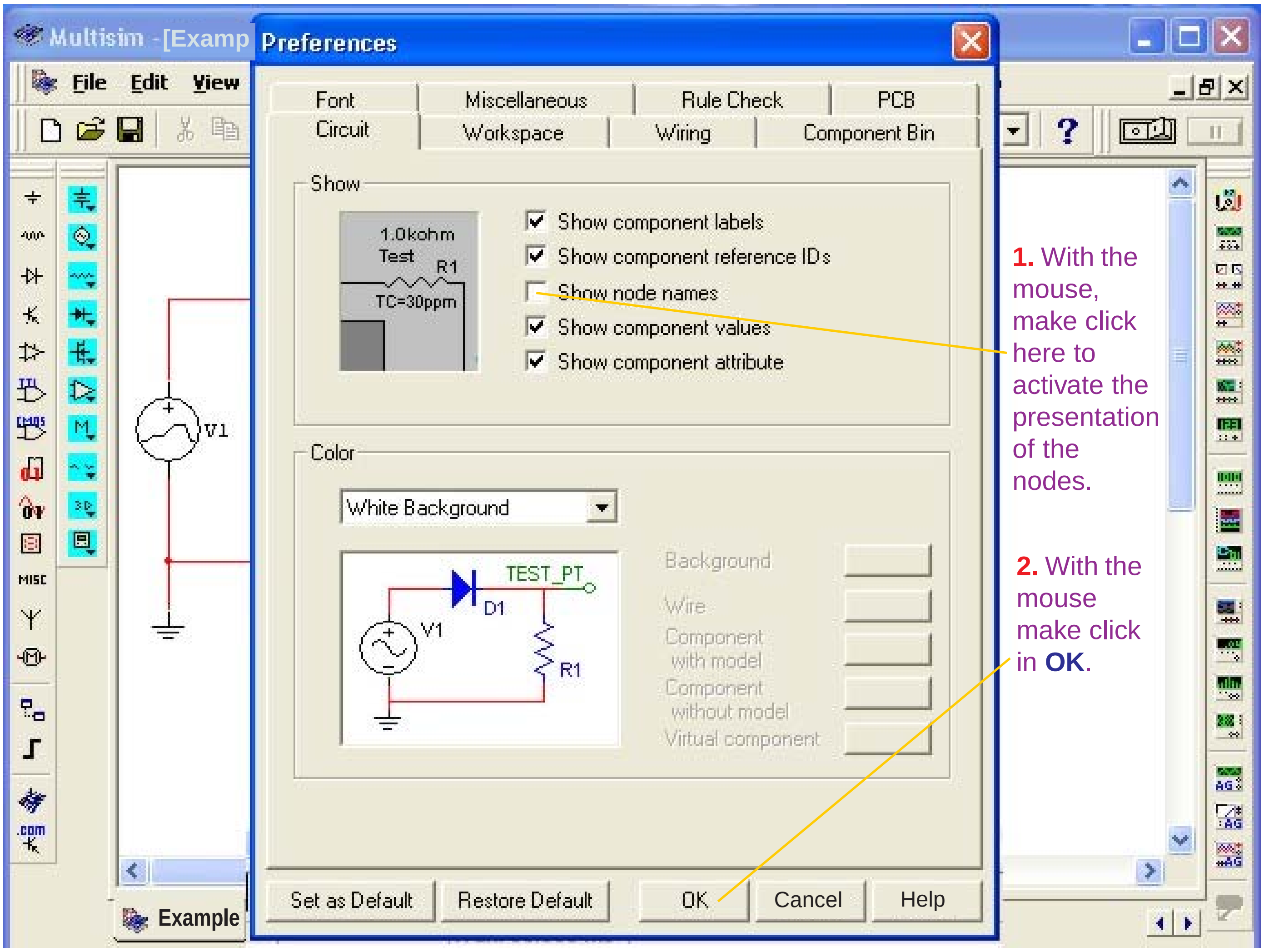

Multisim - [Example]
File Edit View Place Simulate Transfer Tools Reports Options Window Help
This is the Non Inverting input
This is the Inverting output
A1
A2
K
1 V/V
0 V
1 V/V
0 V 0 V
V1
V2
We wire the Controller with the other components of the circuit. Remember that the unused output and input should be connected to ground .

Activation of the Nodes in the Circuit, with Multisim

A node is a junction point of two or more component in a circuit. The node is important because it is the reference point to observe the signals of interest in specific points of the circuit.

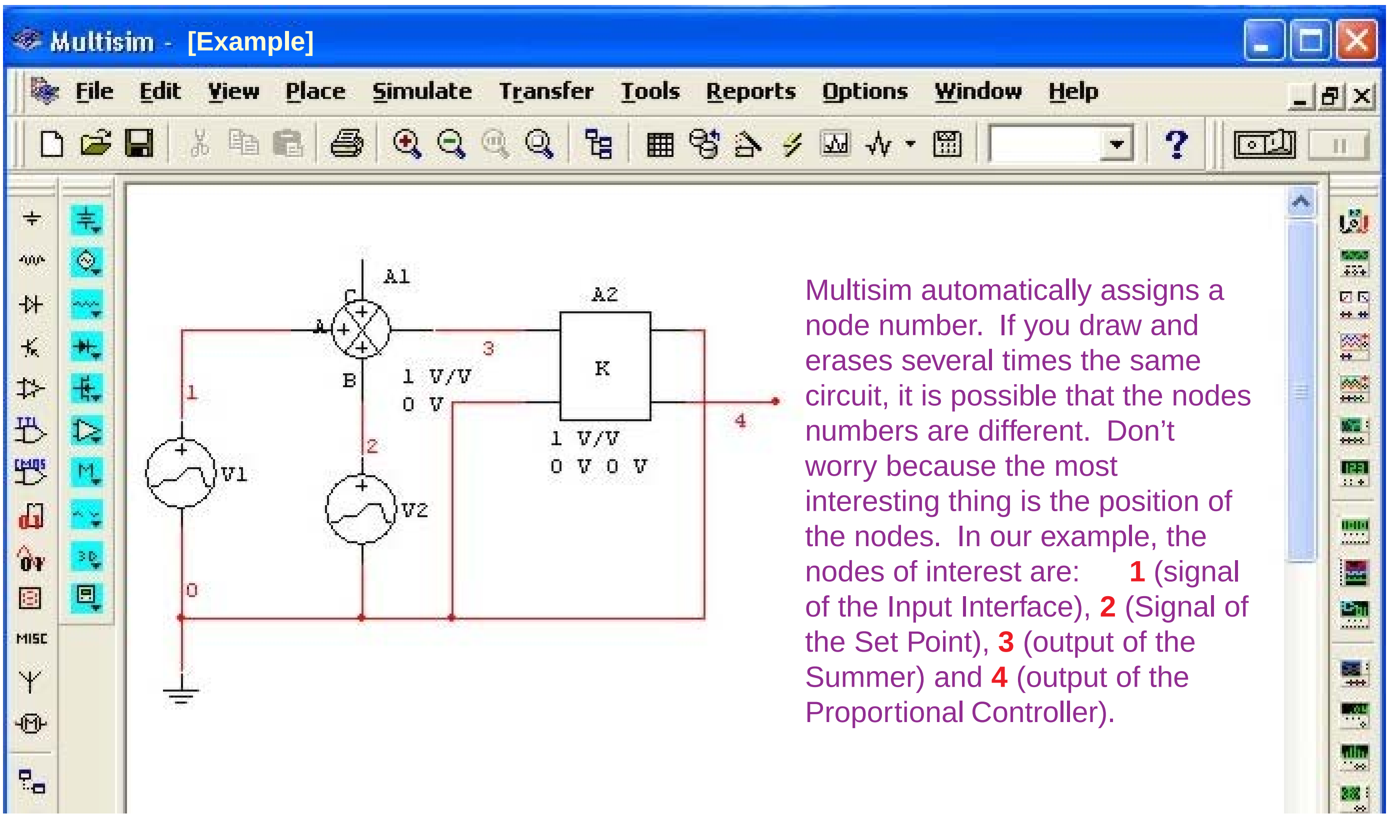
For this reason it is better to activate the presentation of the nodes, in case that they are not activated, in the following way:





1. With the mouse, make click here to activate the presentation of the nodes.

2. With the mouse make click in **OK**.

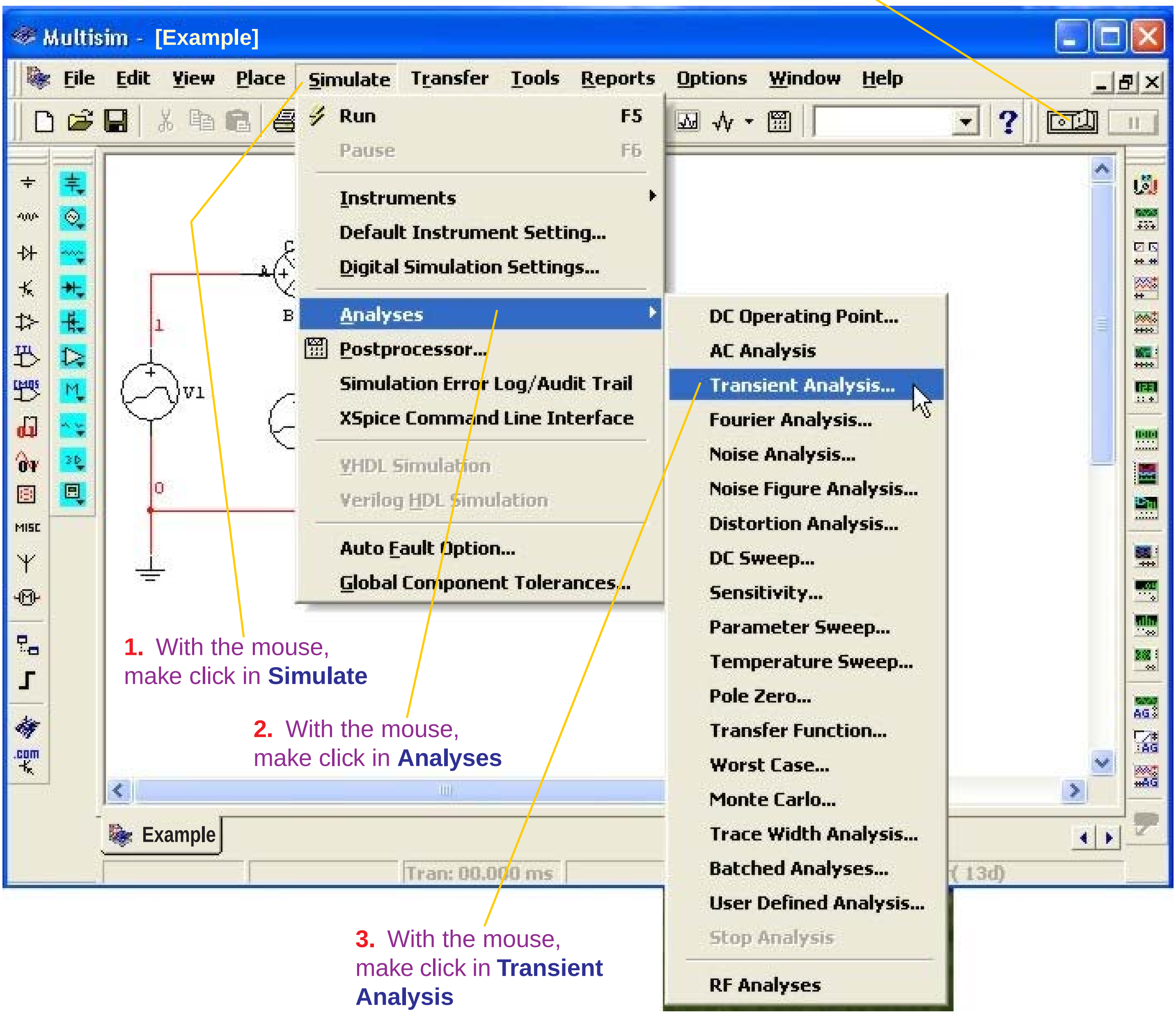


Multisim automatically assigns a node number. If you draw and erases several times the same circuit, it is possible that the nodes numbers are different. Don't worry because the most interesting thing is the position of the nodes. In our example, the nodes of interest are: **1** (signal of the Input Interface), **2** (Signal of the Set Point), **3** (output of the Summer) and **4** (output of the Proportional Controller).

Transient Analysis Configuration of the Proportional Controller.

DON'T TURN ON THE SWITCH of Multisim.

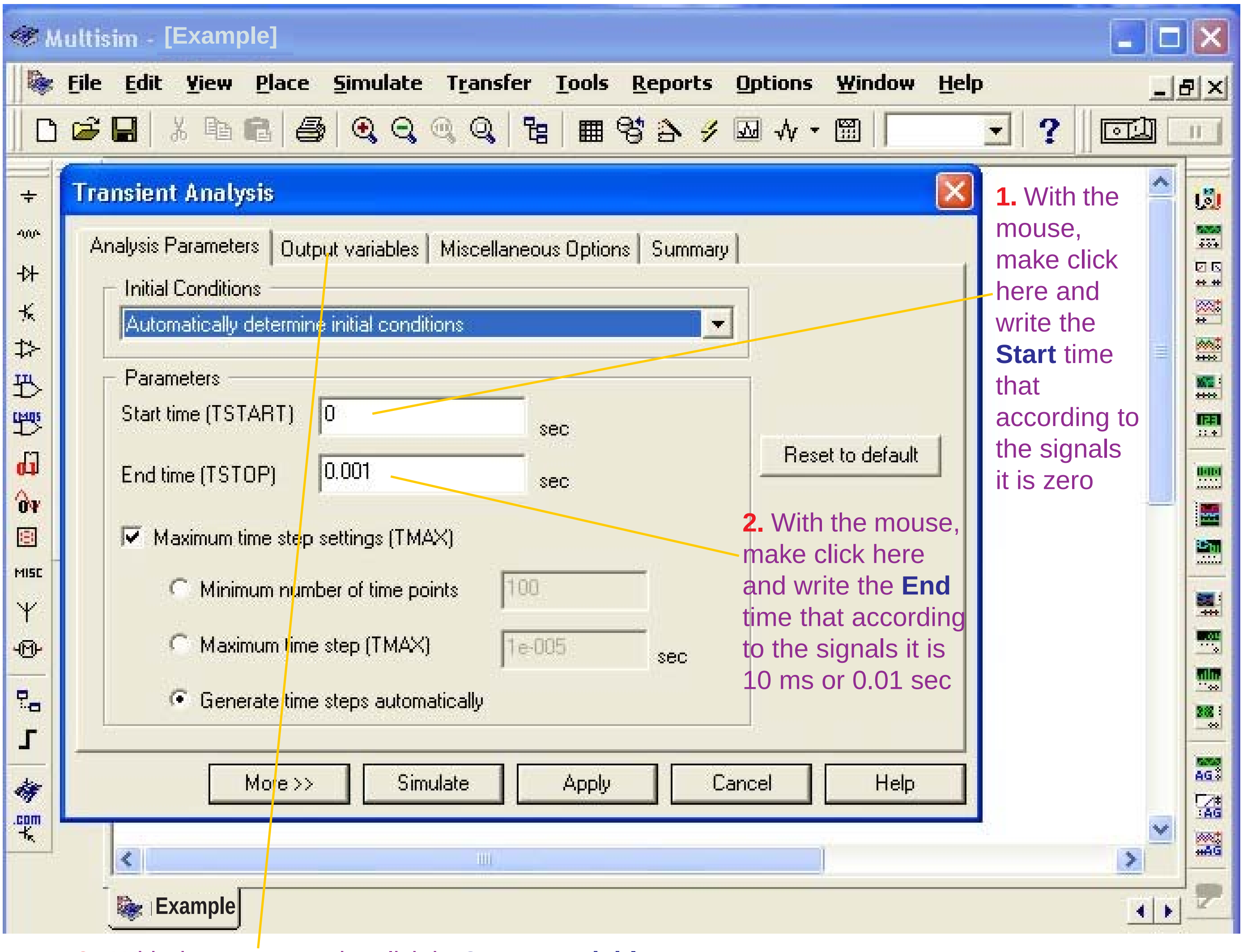
Follow the following procedure:



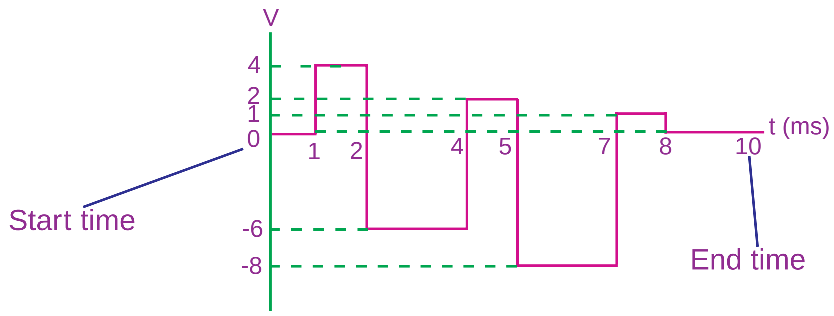
1. With the mouse, make click in **Simulate**

2. With the mouse, make click in **Analyses**

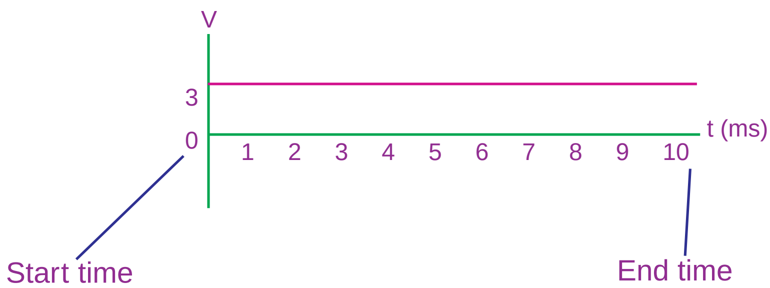
3. With the mouse, make click in **Transient Analysis**



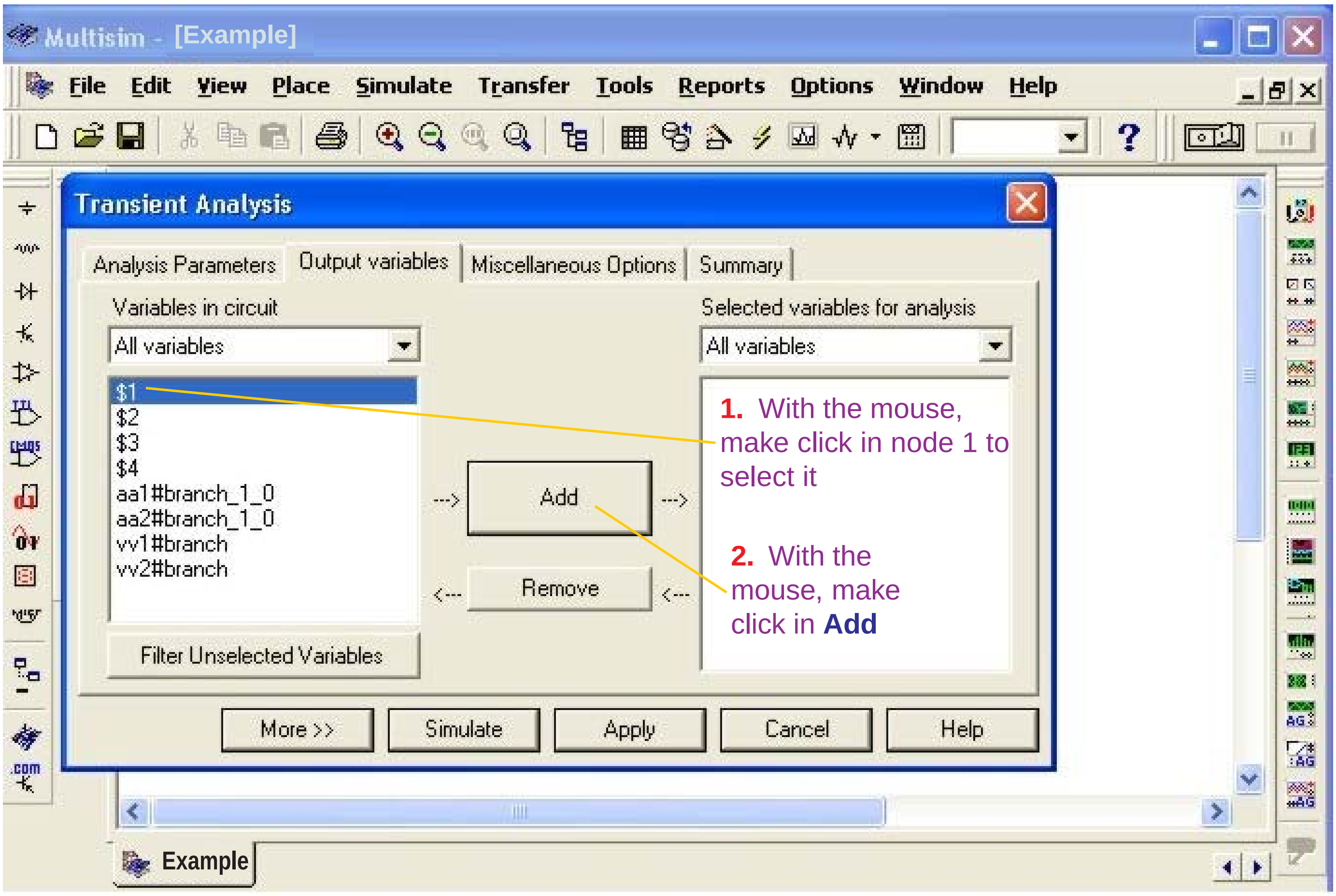
3. With the mouse make click in **Output variables**

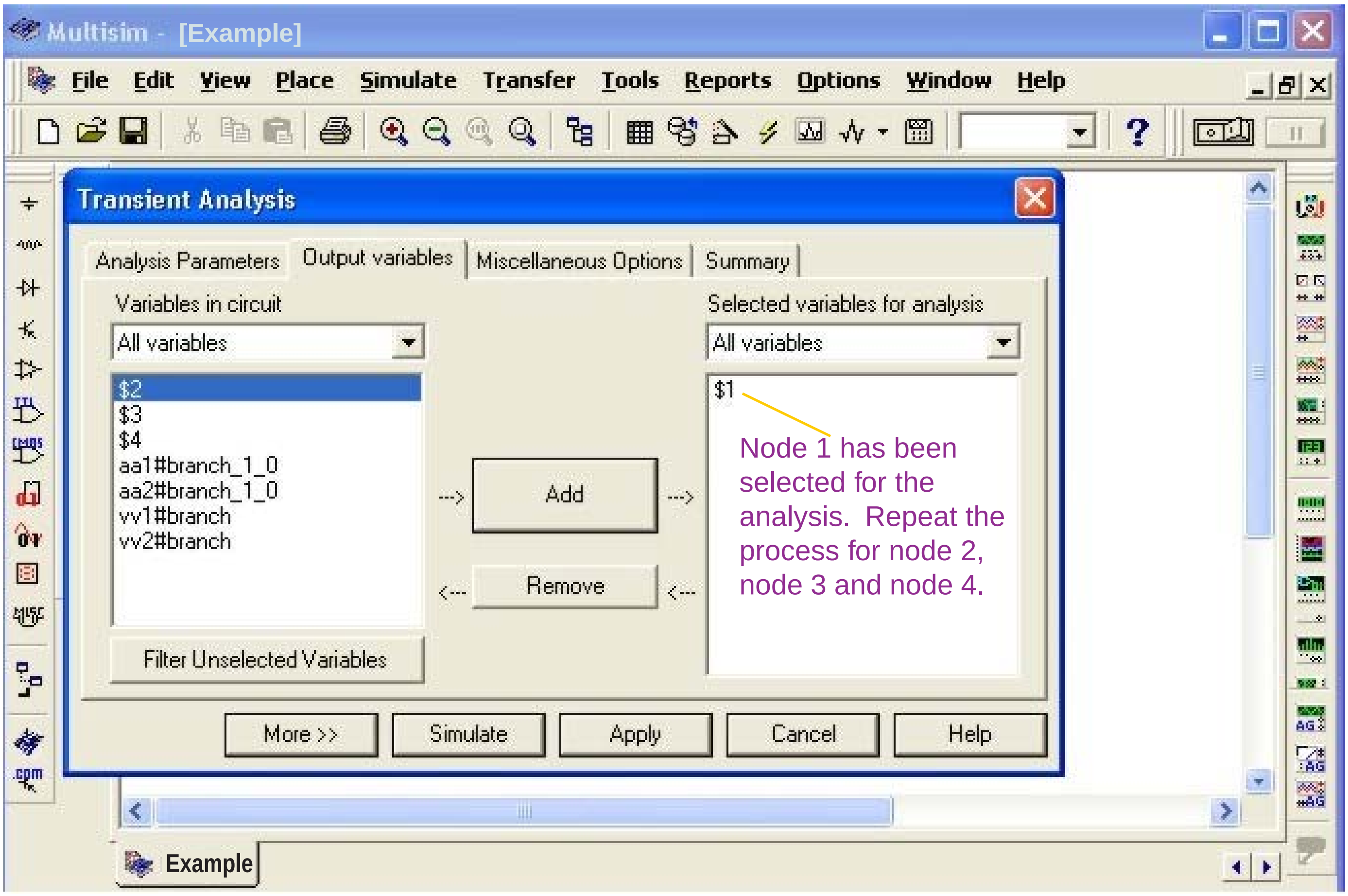


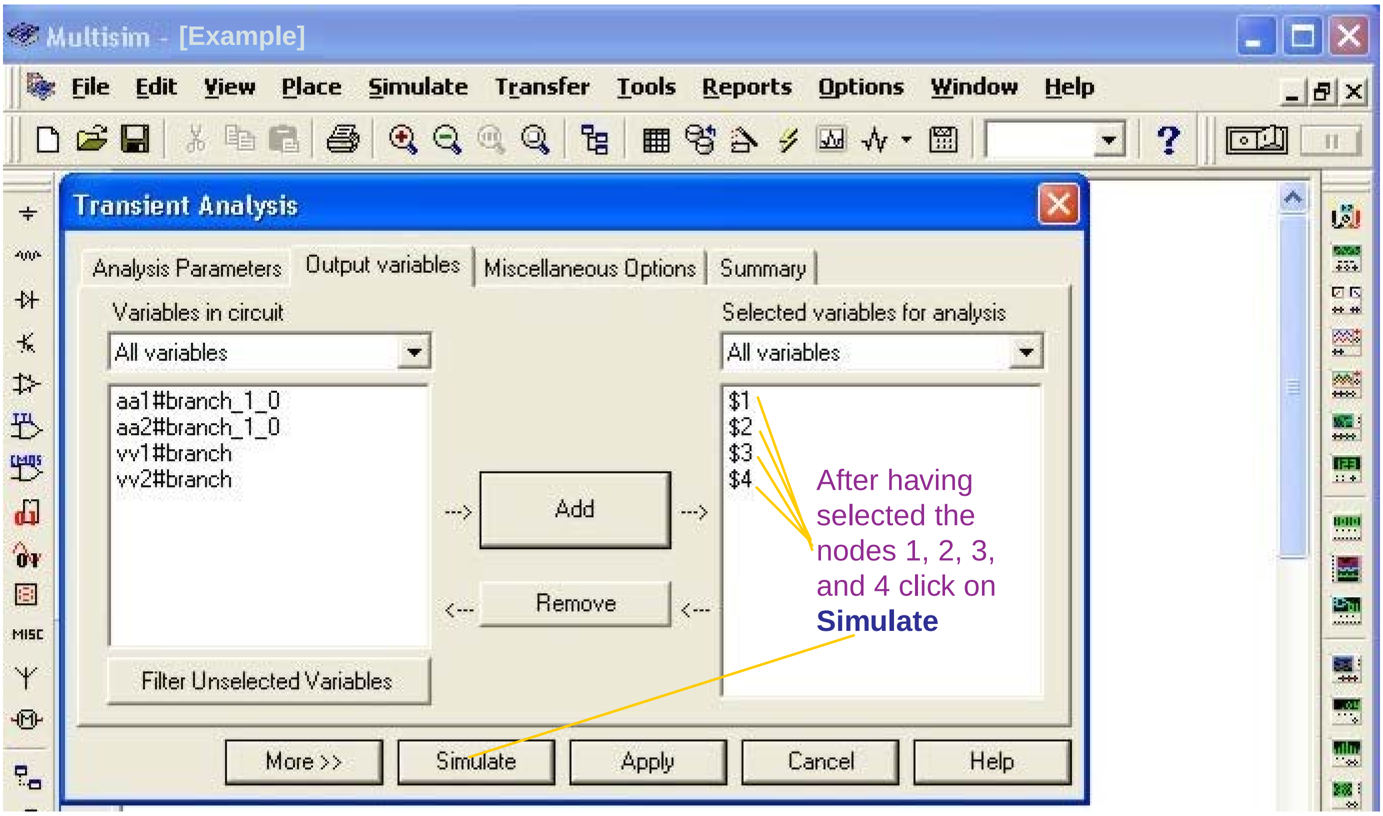
Signal of the Input Interface.

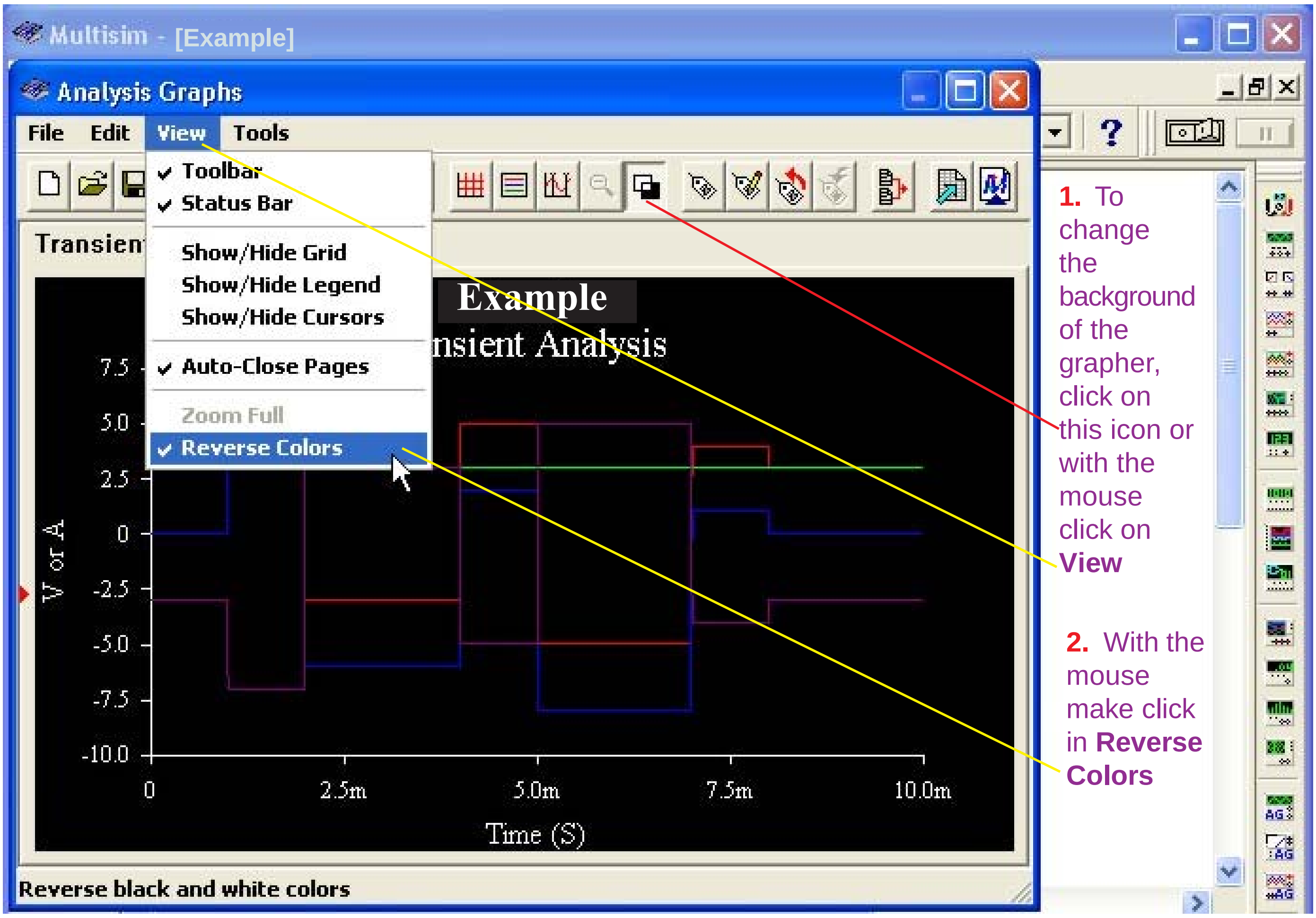


Signal of the Set Point.


Multisim - [Example]
File Edit View Place Simulate Transfer Tools Reports Options Window Help
Transient Analysis
Analysis Parameters
Output variables
Miscellaneous Options
Summary
Variables in circuit
All variables
$1
$2
$3
$4
aa1#branch_1_0
aa2#branch_1_0
vv1#branch
vv2#branch
Selected variables for analysis
All variables
Add
Remove
Filter Unselected Variables
1. With the mouse, make click in node 1 to select it
2. With the mouse, make click in **Add**
More >>
Simulate
Apply
Cancel
Help
Example

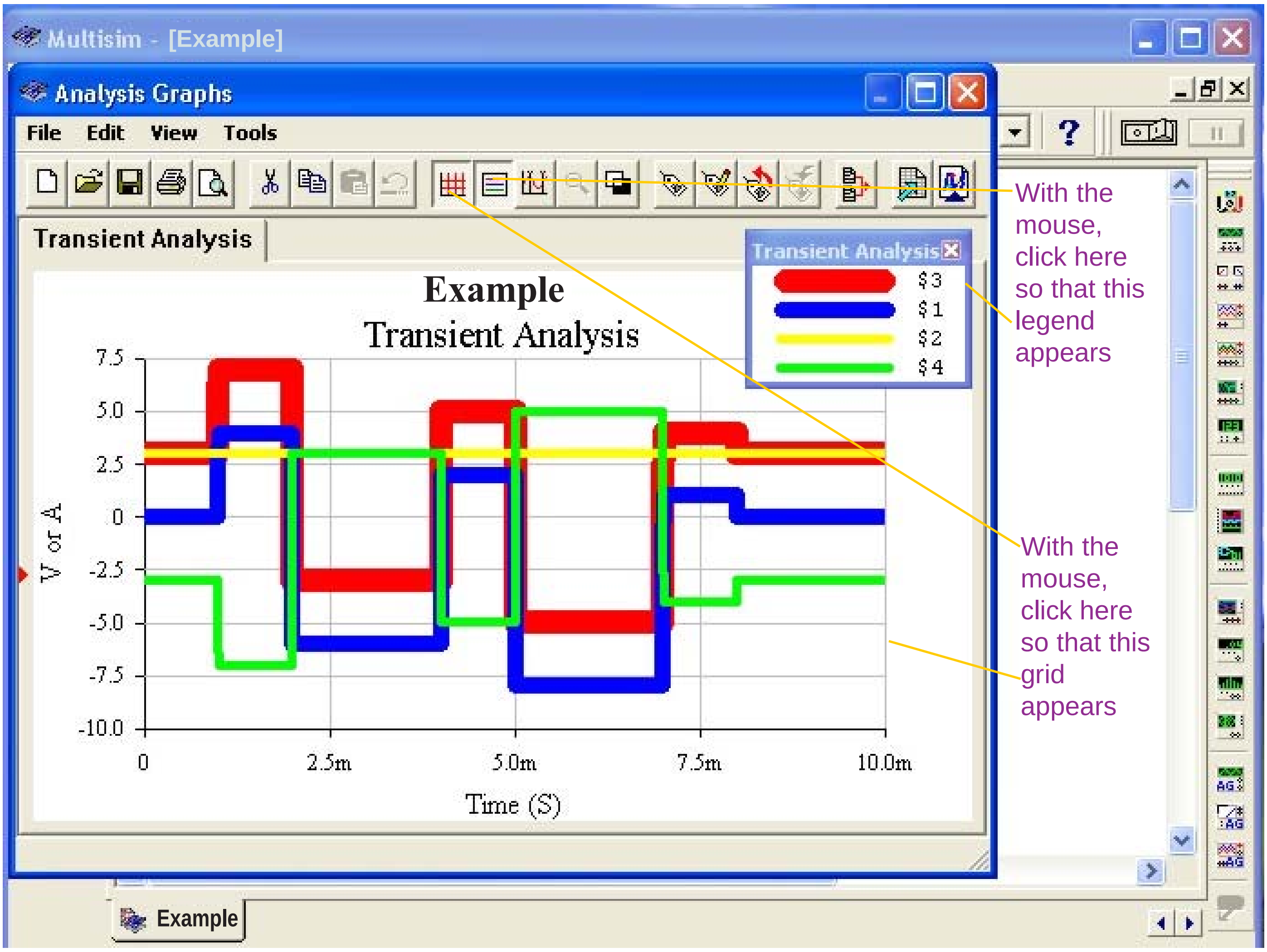

Multisim - [Example]
File Edit View Place Simulate Transfer Tools Reports Options Window Help
Transient Analysis
Analysis Parameters
Output variables
Miscellaneous Options
Summary
Variables in circuit
All variables
$2
$3
$4
aa1#branch_1_0
aa2#branch_1_0
vv1#branch
vv2#branch
Selected variables for analysis
All variables
$1
Node 1 has been selected for the analysis. Repeat the process for node 2, node 3 and node 4.
Add
Remove
Filter Unselected Variables
More >>
Simulate
Apply
Cancel
Help
Example


Multisim - [Example]
File Edit View Place Simulate Transfer Tools Reports Options Window Help
Transient Analysis
Analysis Parameters
Output variables
Miscellaneous Options
Summary
Variables in circuit
All variables
aa1#branch_1_0
aa2#branch_1_0
vv1#branch
vv2#branch
Selected variables for analysis
All variables
$1
$2
$3
$4
Add
Remove
Filter Unselected Variables
More >>
Simulate
Apply
Cancel
Help
After having selected the nodes 1, 2, 3, and 4 click on **Simulate**

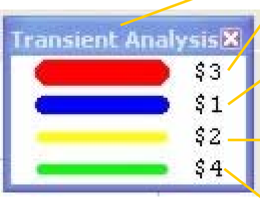

Multisim - [Example]
Analysis Graphs
File Edit View Tools
Toolbar
Status Bar
Show/Hide Grid
Show/Hide Legend
Show/Hide Cursors
Auto-Close Pages
Zoom Full
Reverse Colors
Transien
Example
nsient Analysis
V or A
Time (S)
Reverse black and white colors
1. To change the background of the grapher, click on this icon or with the mouse click on **View**
2. With the mouse make click in **Reverse Colors**

Presentation of the Proportional Controller's signals

With the mouse, click here so that this grid appears



For the legend of the Transient Analysis:



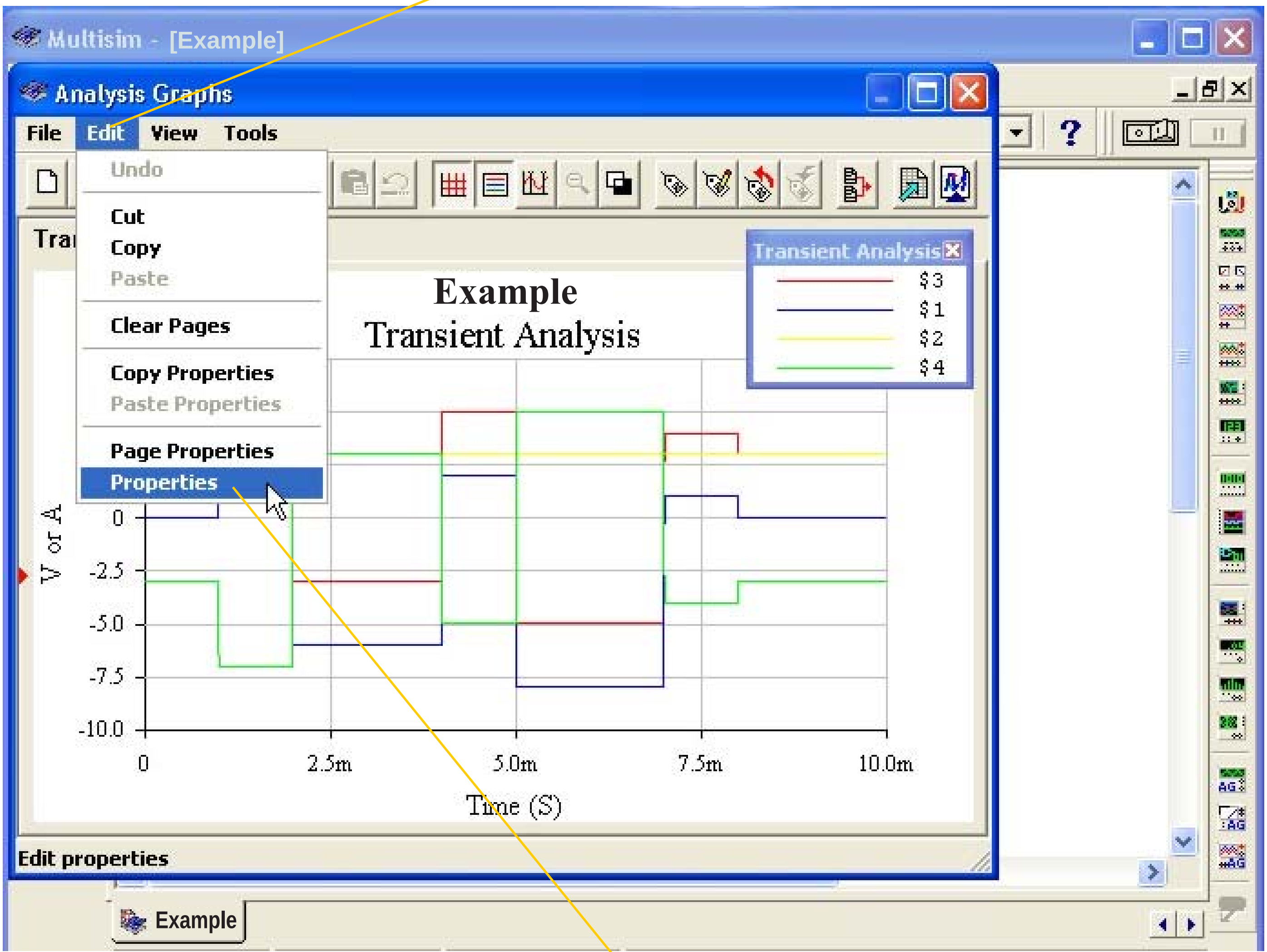
The **red** color (node 3) corresponds to the output signal of the **Summer**.
The **blue** color (node 1) corresponds to the signal of the **Input Interface.**
The **yellow** color (node 2) corresponds to the signal of the **Set Point.**
The **green** color (node 4) corresponds to the output signal of the **Proportional Controller**.

Width and Color for the presentation of the output signals.

The presentation of the signals in the Analysis Graphs has a width of a typographical point with the purpose of taking measurements accurately.

However, to be able to distinguish the signals one from the other, we have opted to increase the width of the lines in 10 points for the red color, 7 points for the blue color, 4 points for the green color and 4 points for the yellow color, in the following way:

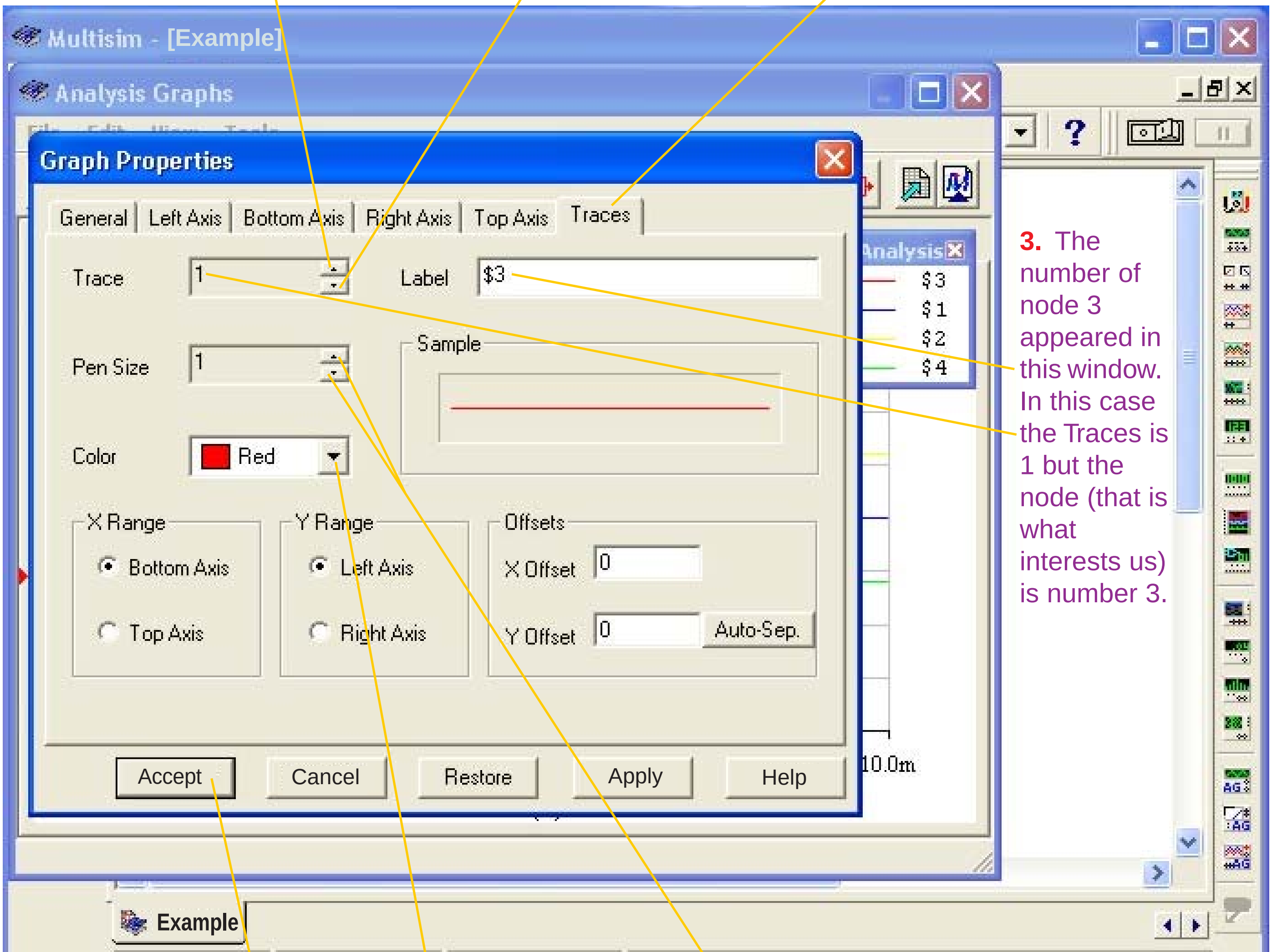
1. With the mouse make click in **Edit**.



2. With the mouse make click in **Properties**.

1. With the mouse, click on **Traces**

2. To select the node number, with the mouse click here to advance, or click here to go back.

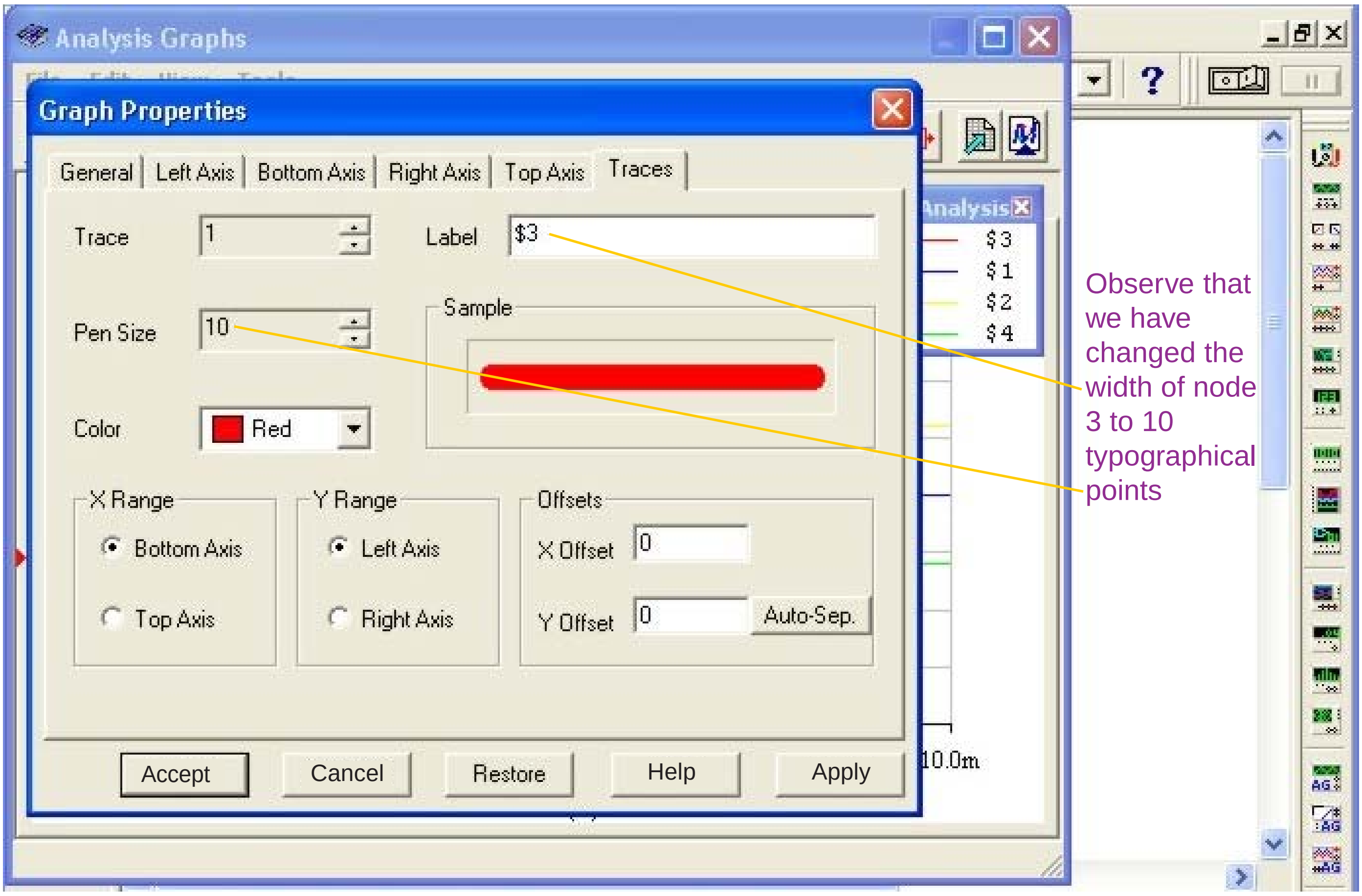


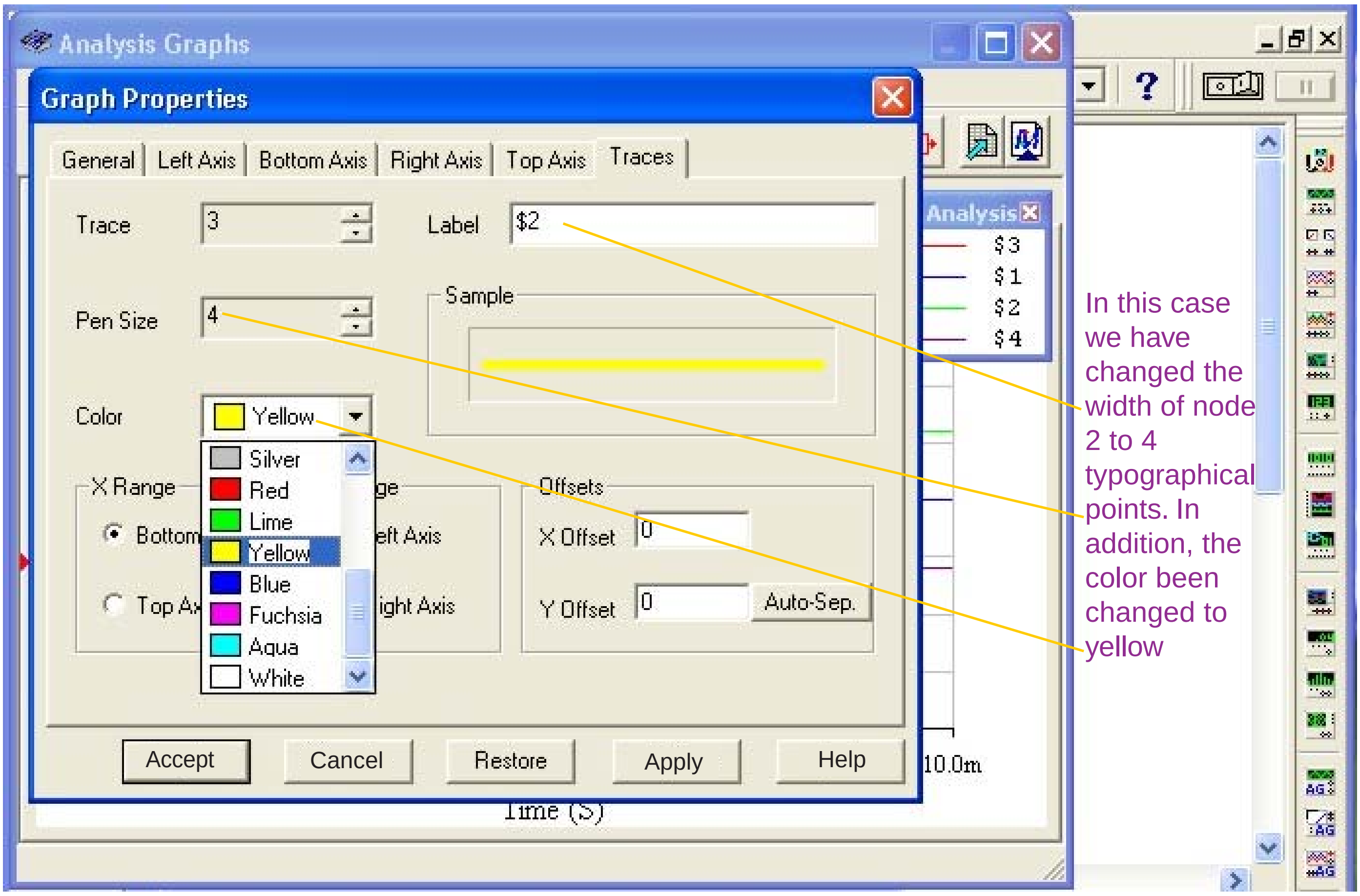
3. The number of node 3 appeared in this window. In this case the Traces is 1 but the node (that is what interests us) is number 3.

4. We can increase or decrease the width of the line by clicking on the **Pen Size** tab

5. We can also change the color of the line of the signal by clicking on the **Color** tab

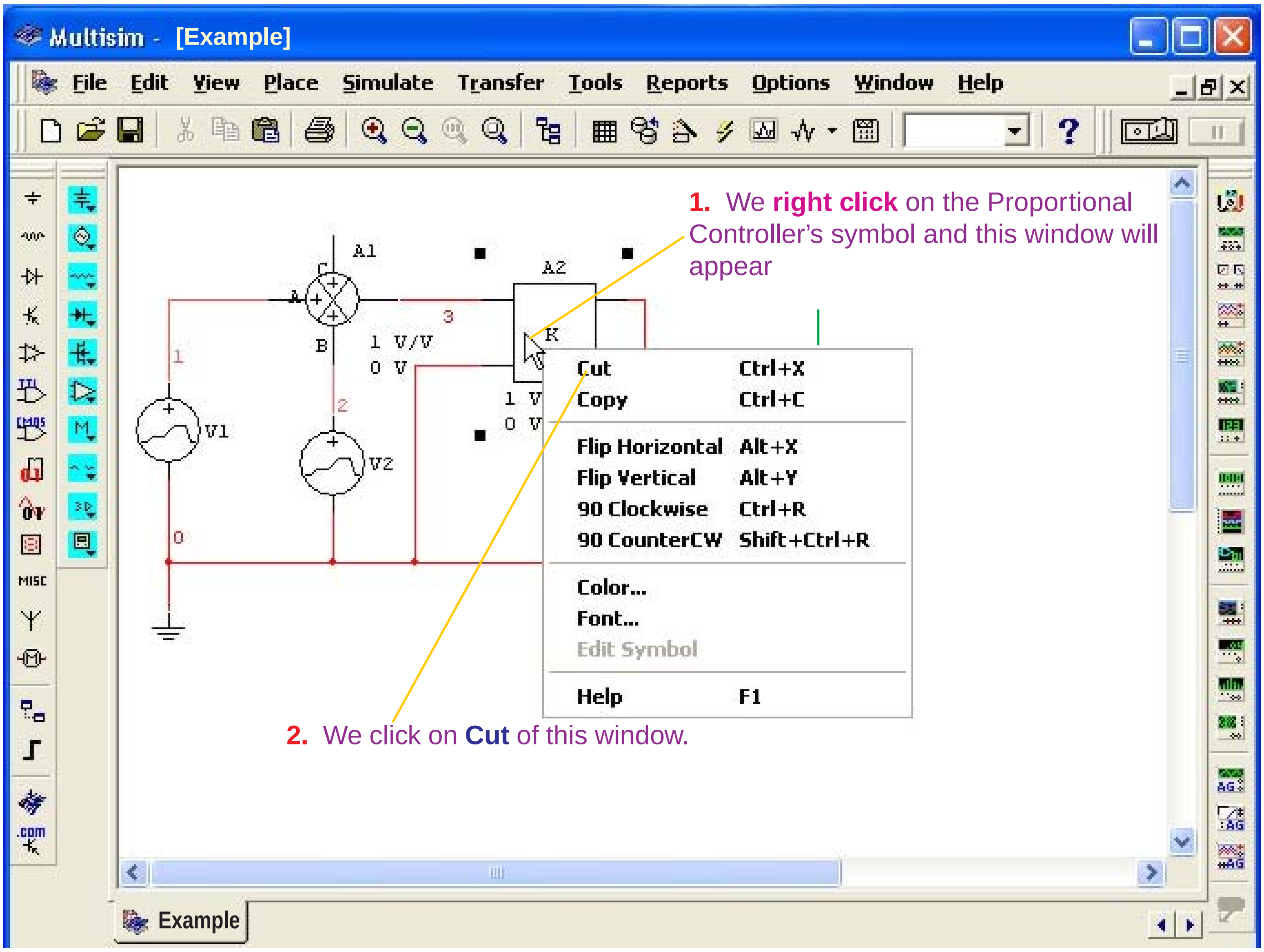
6. After making all the changes that we believe necessary, click on **Accept**.


Analysis Graphs
Graph Properties
General
Left Axis
Bottom Axis
Right Axis
Top Axis
Traces
Trace
1
Label
$3
Pen Size
10
Sample
Color
Red
X Range
Bottom Axis
Top Axis
Y Range
Left Axis
Right Axis
Offsets
X Offset
0
Y Offset
0
Auto-Sep.
Accept
Cancel
Restore
Help
Apply
Analysis
$3
$1
$2
$4
10.0m
Observe that we have changed the width of node 3 to 10 typographical points

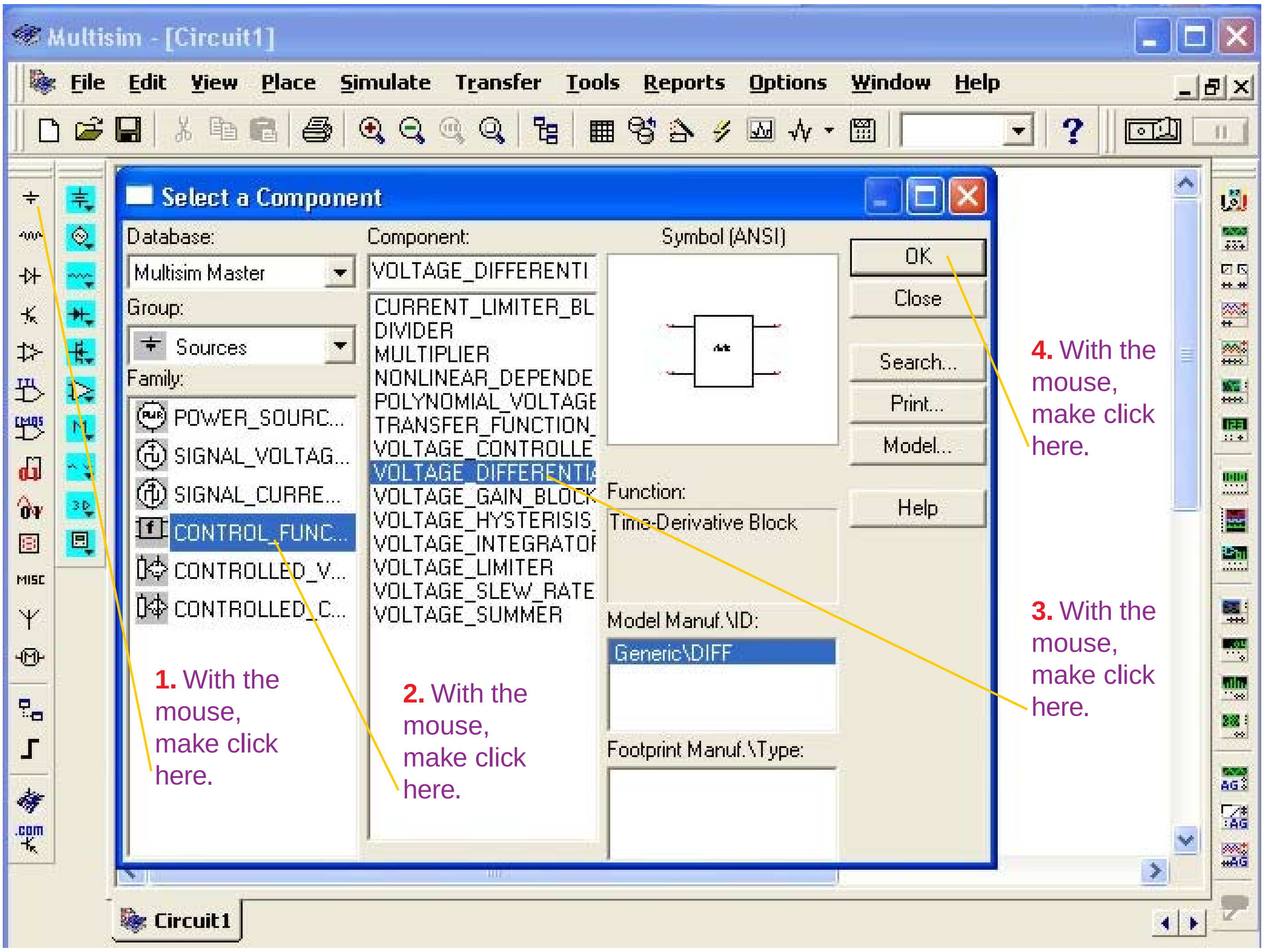

Analysis Graphs
Graph Properties
General
Left Axis
Bottom Axis
Right Axis
Top Axis
Traces
Trace
3
Label
$2
Pen Size
4
Sample
Color
Yellow
Silver
Red
Lime
Yellow
Blue
Fuchsia
Aqua
White
X Range
Offsets
X Offset
0
Y Offset
0
Auto-Sep.
Accept
Cancel
Restore
Apply
Help
Analysis
$3
$1
$2
$4
10.0m
Time (S)
In this case we have changed the width of node 2 to 4 typographical points. In addition, the color been changed to yellow

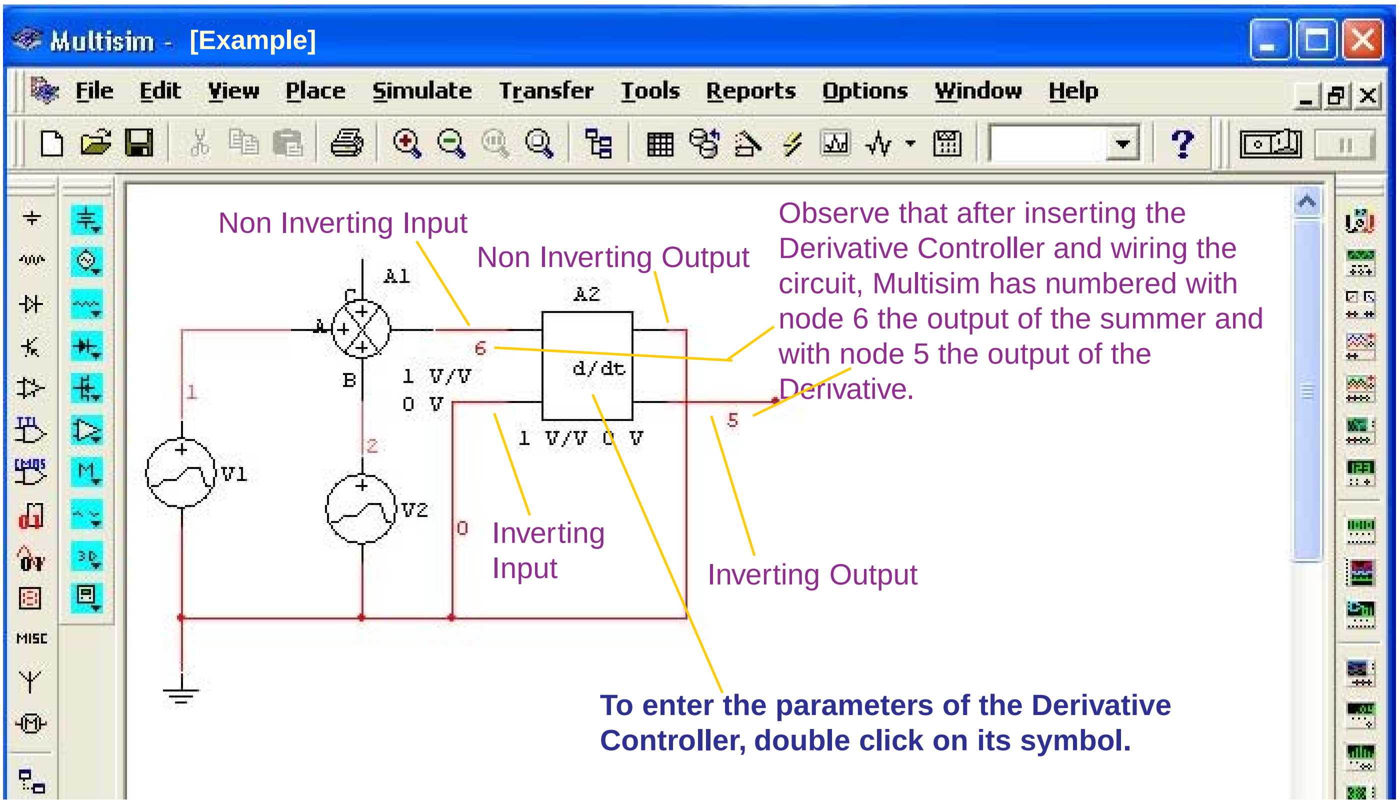
The Derivative Controller with the summer and output signals.

We take the circuit of page 31 where we have wired the signal of the Input Interface, the Set Point, the Summer and the Proportional Controller. This Proportional Controller should be removed to replace it for the Derivative Controller.

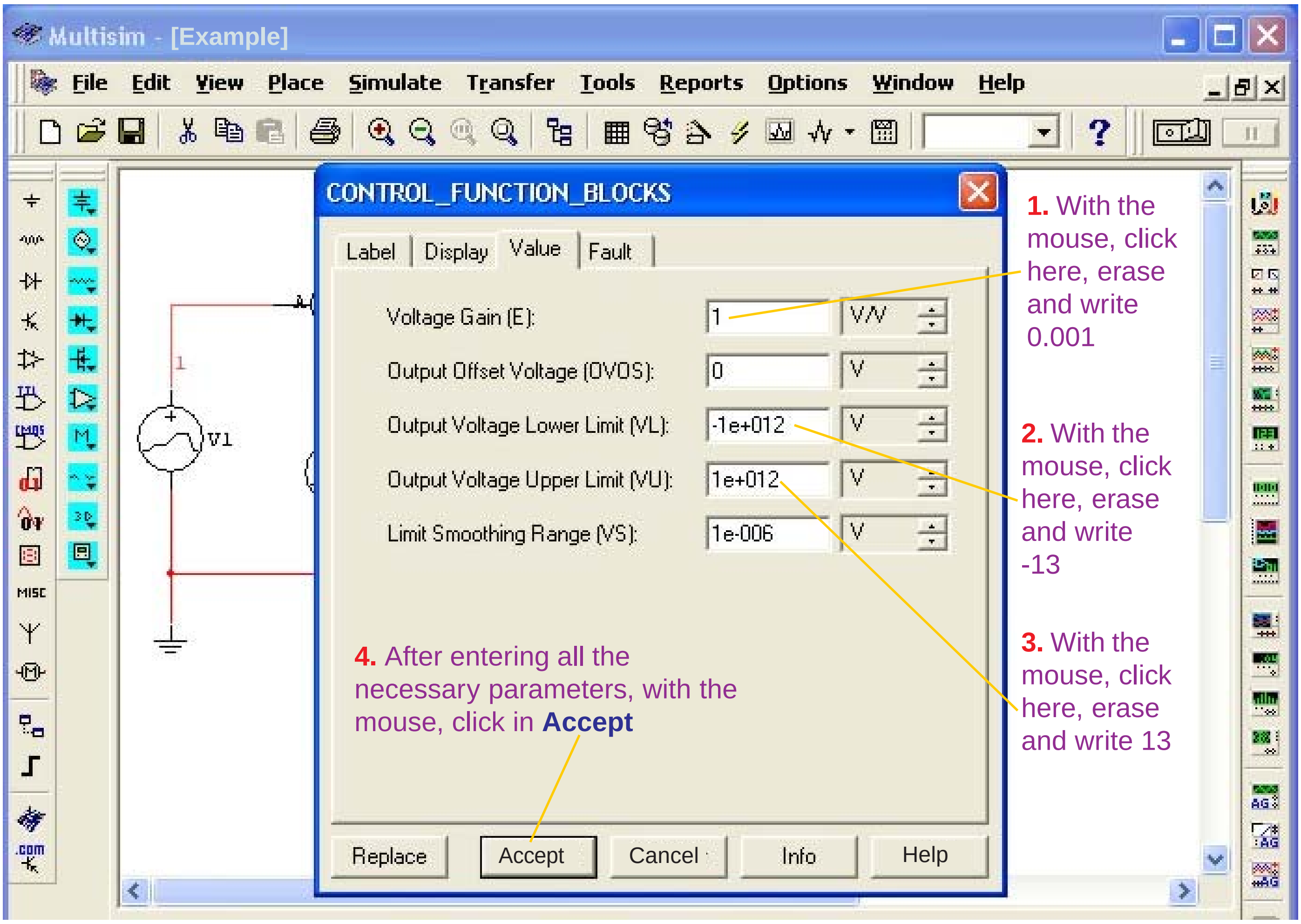


The Proportional Controller is eliminated; we proceed to insert the Derivative Controller in the way indicated on the following page.


Multisim - [Circuit1]
File Edit View Place Simulate Transfer Tools Reports Options Window Help
Select a Component
Database:
Multisim Master
Group:
Sources
Family:
POWER_SOURC...
SIGNAL_VOLTAG...
SIGNAL_CURRE...
CONTROL_FUNC...
CONTROLLED_V...
CONTROLLED_C...
Component:
VOLTAGE_DIFFERENTI
CURRENT_LIMITER_BL
DIVIDER
MULTIPLIER
NONLINEAR_DEPENDE
POLYNOMIAL_VOLTAGE
TRANSFER_FUNCTION_
VOLTAGE_CONTROLLE
VOLTAGE_DIFFERENTIA
VOLTAGE_GAIN_BLOCK
VOLTAGE_HYSTERISIS_
VOLTAGE_INTEGRATOR
VOLTAGE_LIMITER
VOLTAGE_SLEW_RATE
VOLTAGE_SUMMER
Symbol (ANSI)
OK
Close
Search...
Print...
Model...
Help
Function:
Time-Derivative Block
Model Manuf.\ID:
Generic\DIFF
Footprint Manuf.\Type:
Circuit1
1. With the mouse, make click here.
2. With the mouse, make click here.
3. With the mouse, make click here.
4. With the mouse, make click here.


Multisim - [Example]
File Edit View Place Simulate Transfer Tools Reports Options Window Help
Non Inverting Input
Non Inverting Output
A1
A2
C
A
B
6
1 V/V
0 V
d/dt
1 V/V 0 V
5
1
2
0
V1
V2
Inverting Input
Inverting Output
Observe that after inserting the Derivative Controller and wiring the circuit, Multisim has numbered with node 6 the output of the summer and with node 5 the output of the Derivative.
To enter the parameters of the Derivative Controller, double click on its symbol.

Configuration of the Derivative Controller's Parameters



The Derivative Controller's output is:

$$Vout(t) = K \frac{d\,Vin}{dt}$$

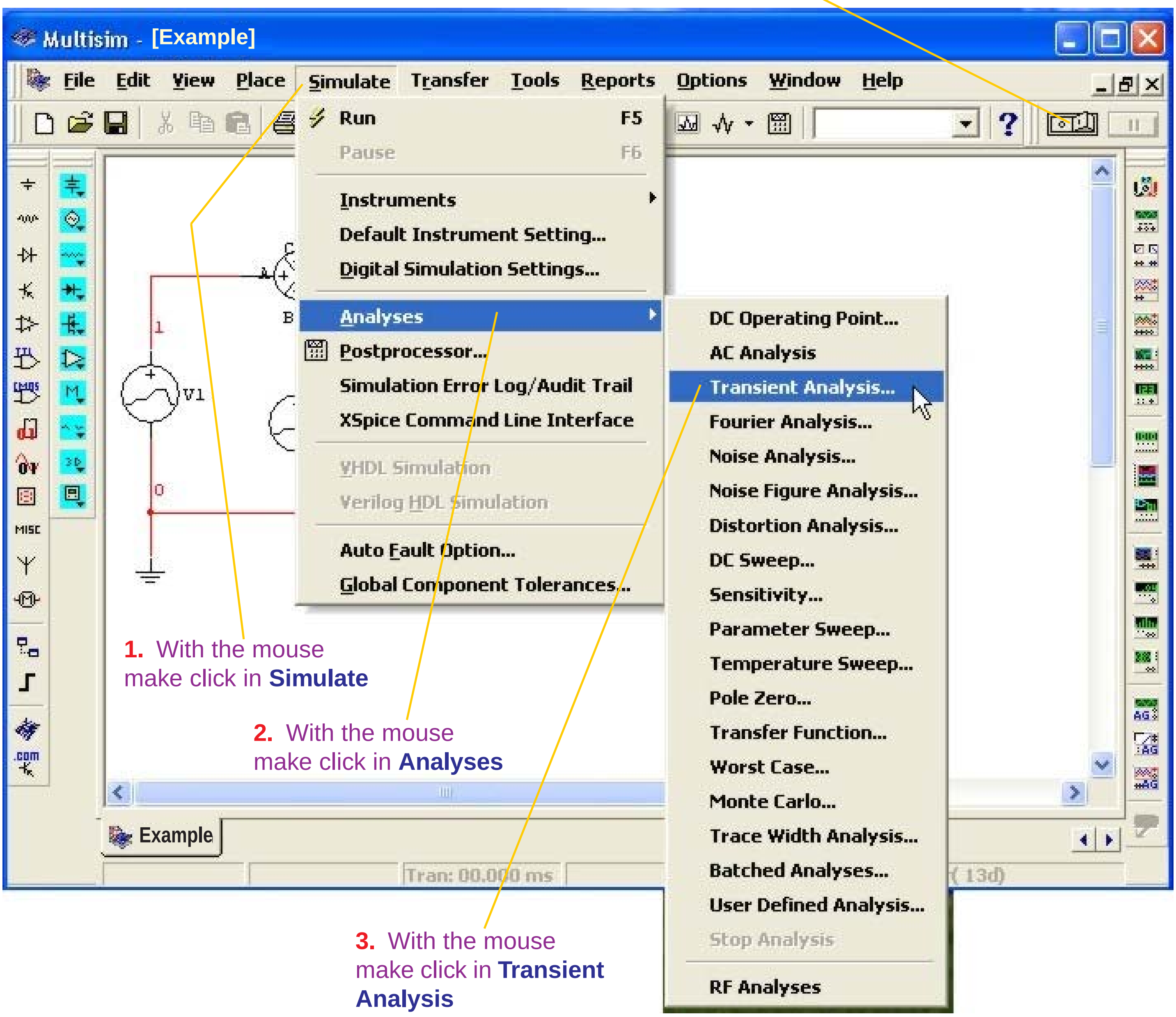
For the considerations of the example (see page 21), the RC constant is of 1 millisecond. Also, K = R.C is expressed in seconds (see page 14), then we have that: K = 0.001

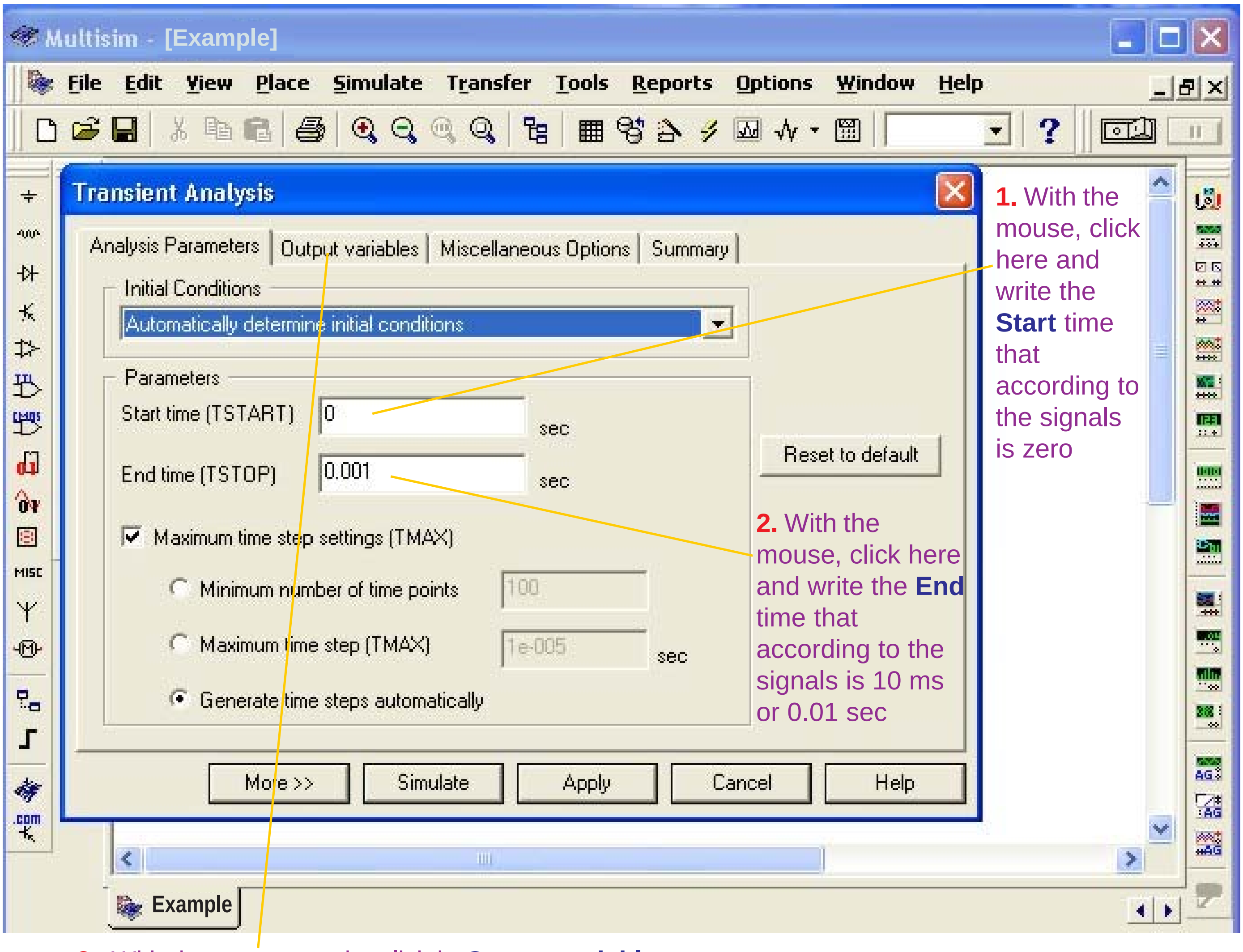
For the considerations of the example (see page 21), the Derivative Controller will use a dual-supply with +Vcc = +15V and - Vcc = -15V then (see page 15) the Output Voltage Lower Limit will be -13 V and the Output Voltage Upper Limit is 13 V.

Transient Analysis Configuration of the Derivative Controller

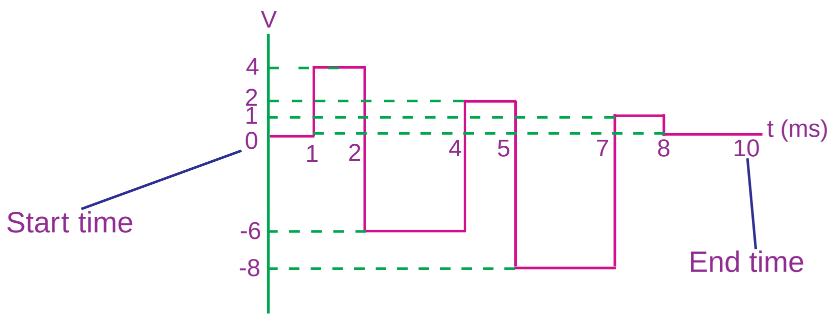
DON'T TURN ON THE SWITCH of Multisim.

Follow the following procedure:

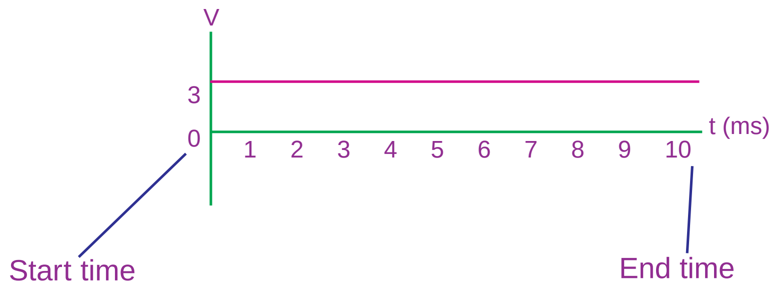




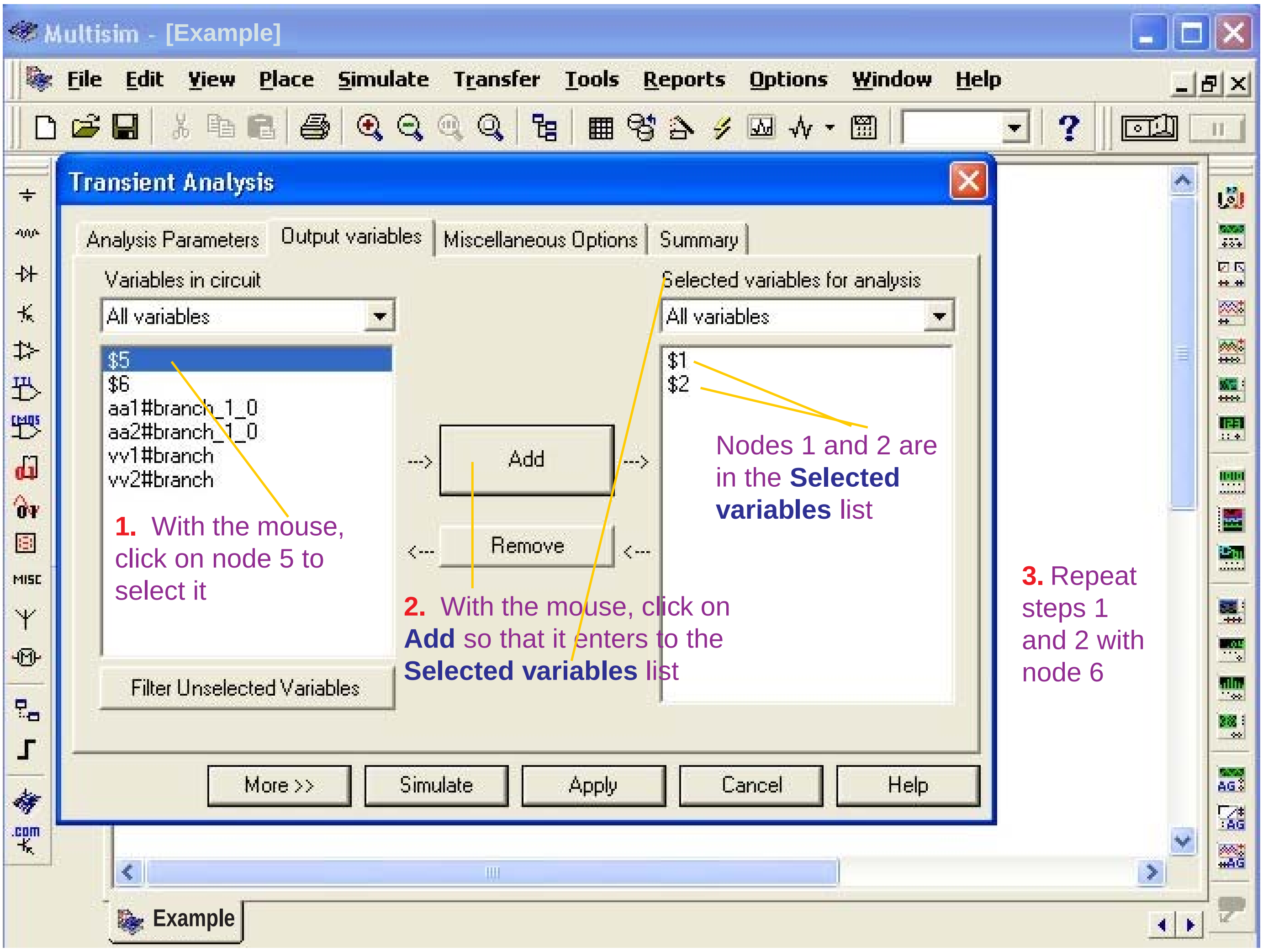
3. With the mouse, make click in **Output variables**

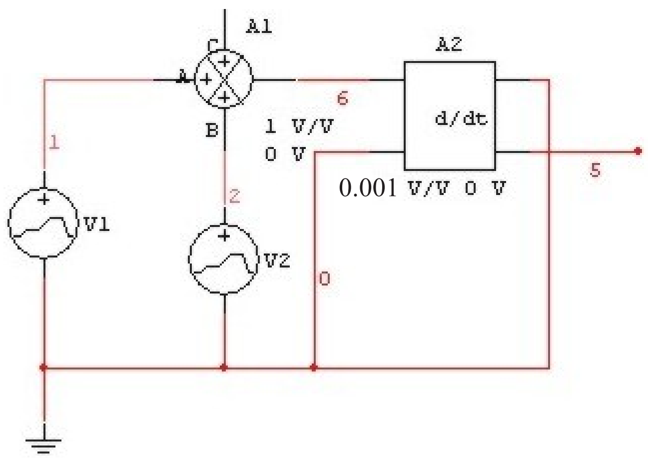


Signal of the Input Interface.



Signal of the Set Point.

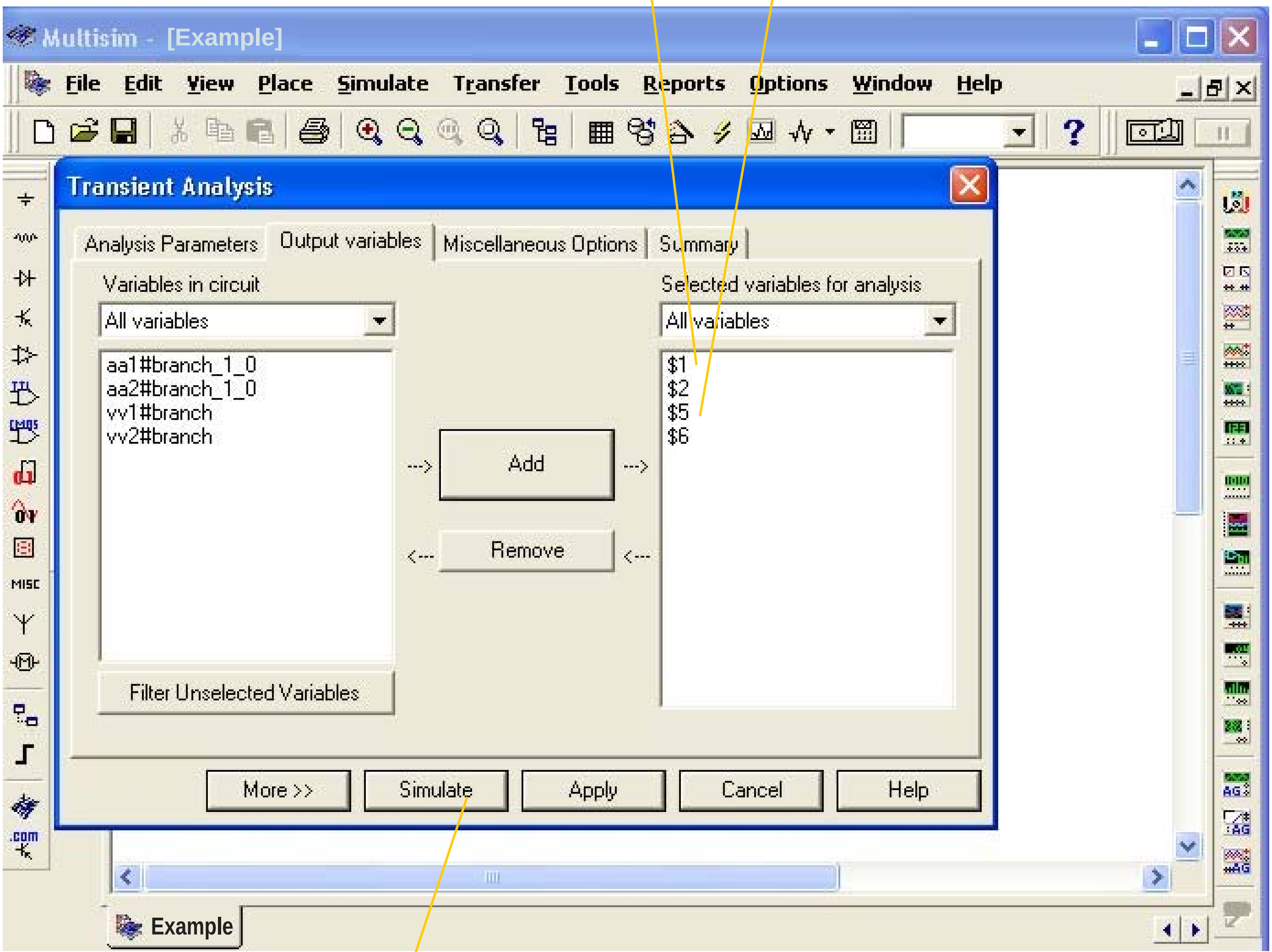




Looking at the circuit, the nodes of interest are:

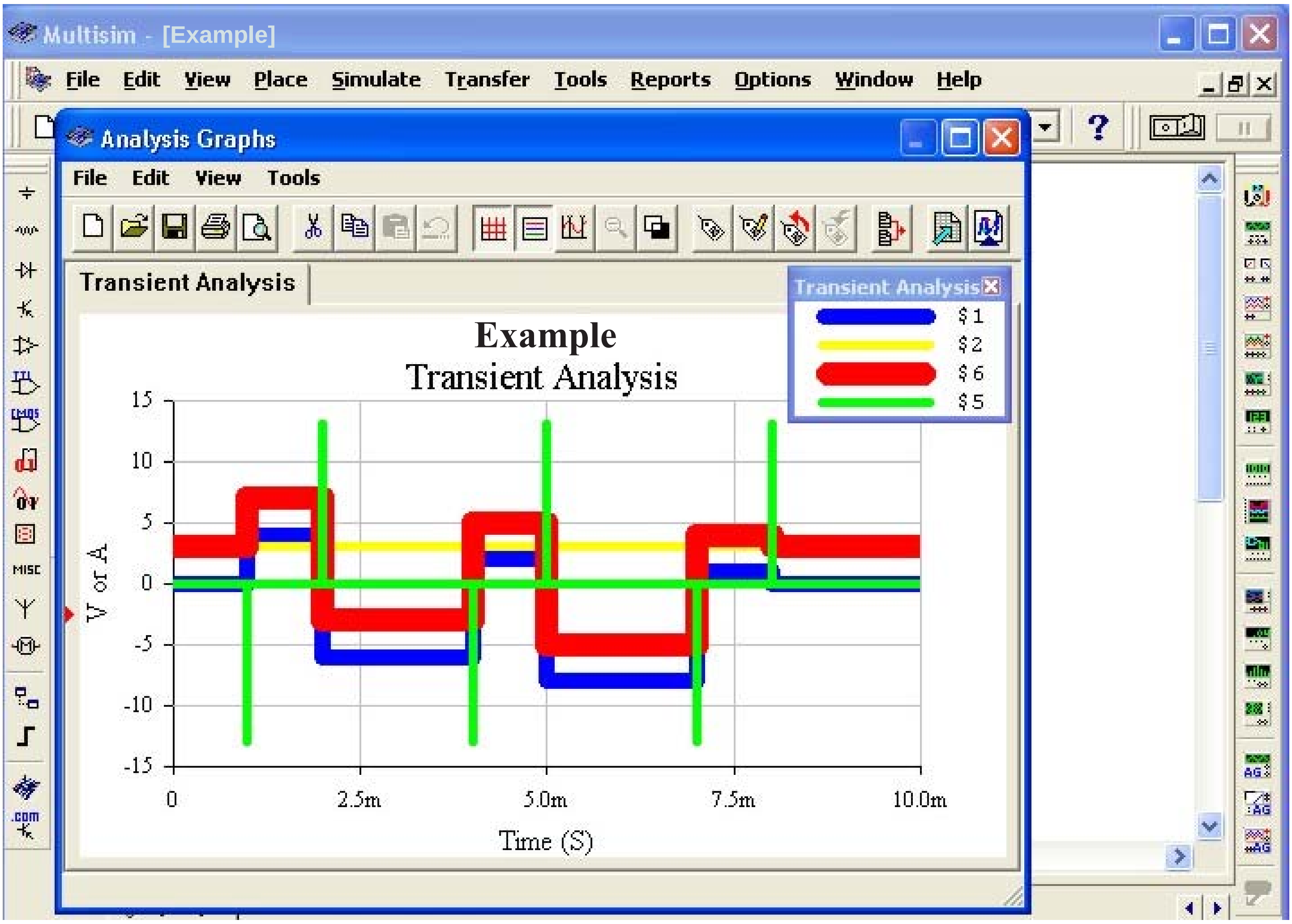
node 1: Signal of the Input Interface.
node 2: Signal of the Set Point.
node 6: Summer output.
node 5: Output of the Derivative Controller.

In the **Selected variables** list we have nodes 1, 2, 5 and 6 selected.

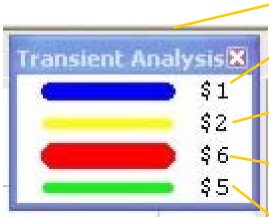


To observe the signals of the selected nodes, with the mouse click on **Simulate**

Presentation of the Derivative Controller’s signals.



For the legend of the Transient Analysis:

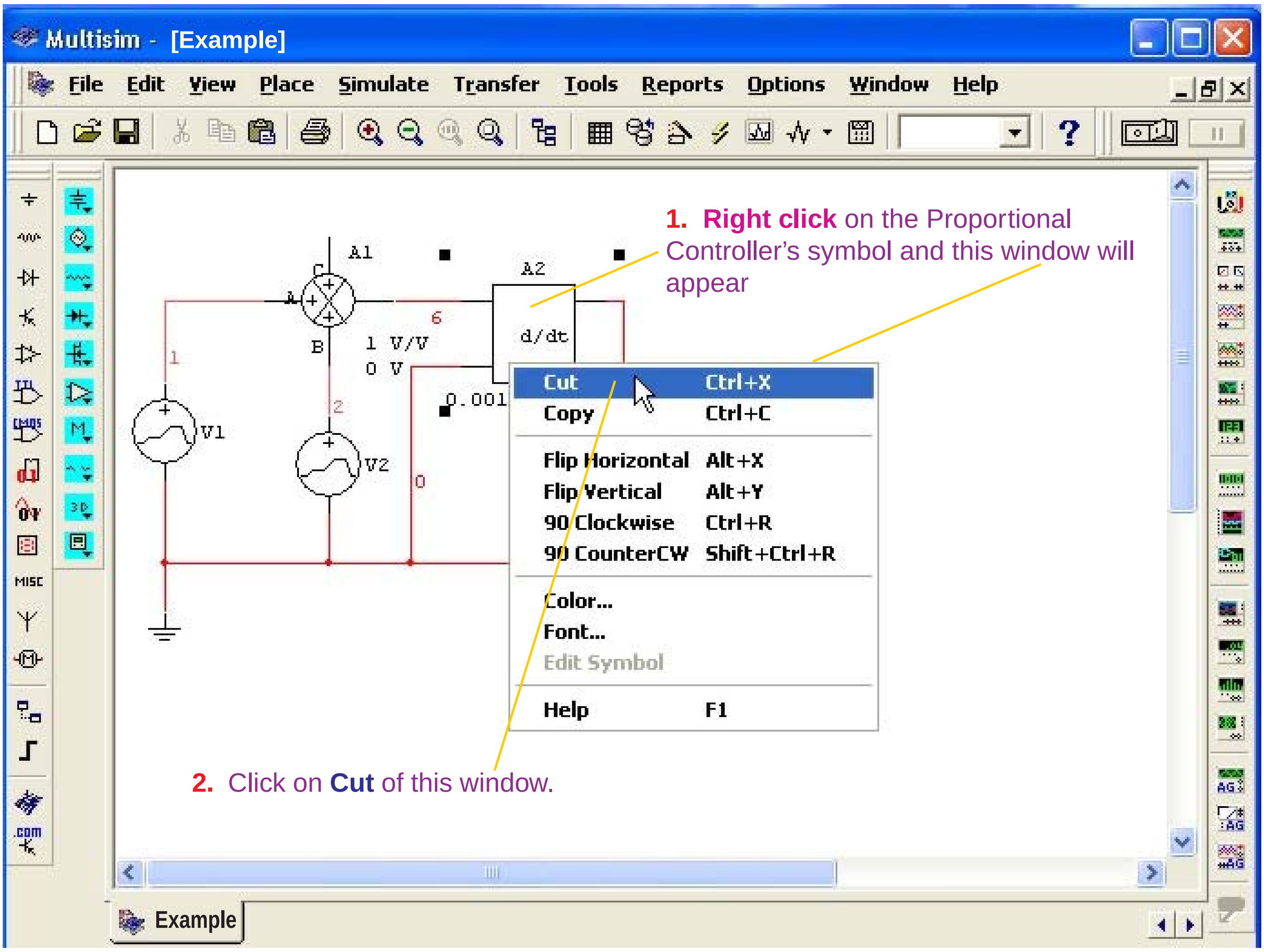


The **blue** color (node 1) corresponds to the signal of the **Input Interface.**
The **yellow** color (node 2) corresponds to the signal of the **Set Point.**
The **red** color (node 6) corresponds to the output signal of the **Summer**.
The **green** color (node 5) corresponds to the output signal of the **Derivative Controller**.

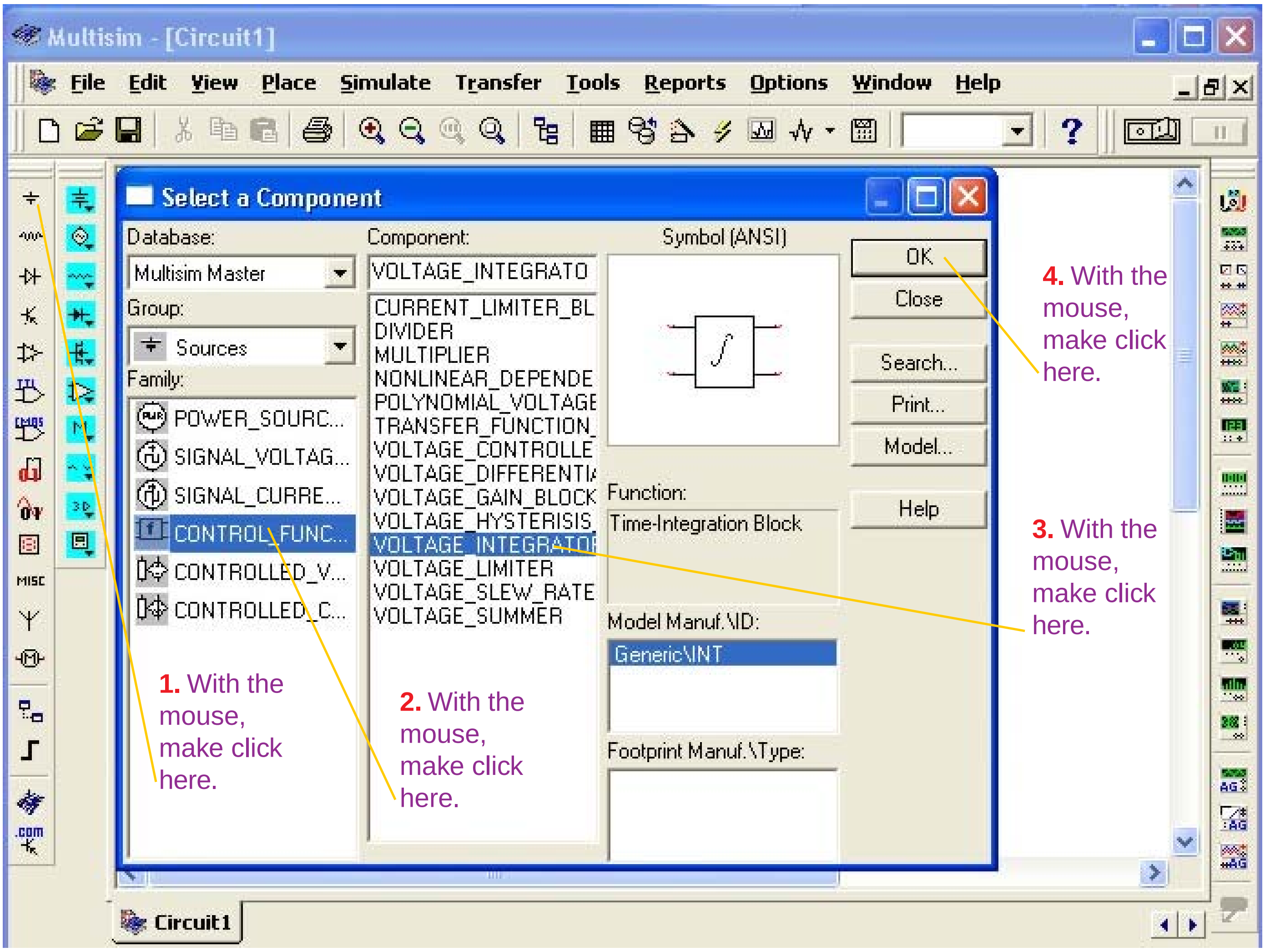
For the width and color of the signals, see pages 39, 40 and 41.

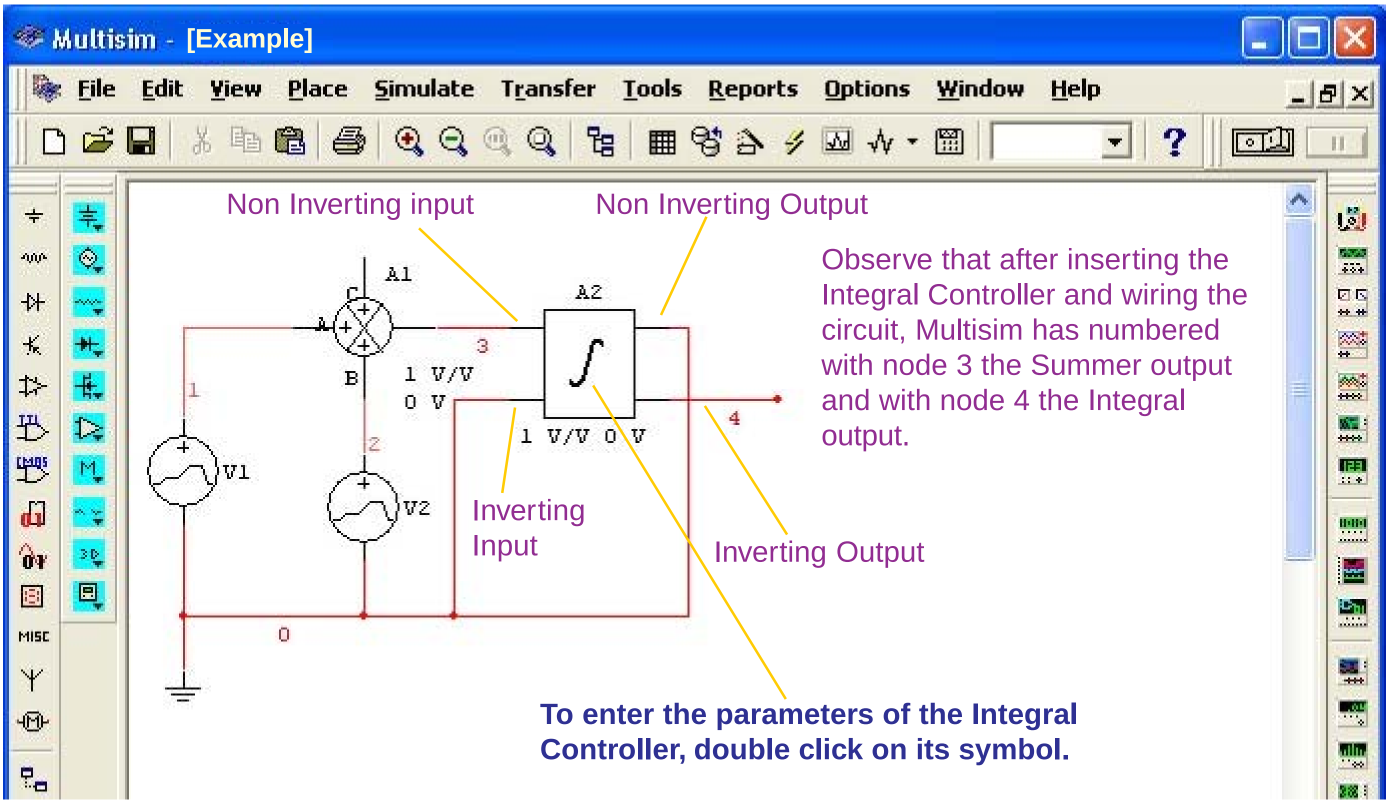
The Integral Controller with the Summer and input signals.

We take the circuit of page 43 where we have wired the signals of the Input Interface, the Set Point, the summer and the Derivative Controller. This Derivative Controller should be removed to replace it for the Integral Controller.

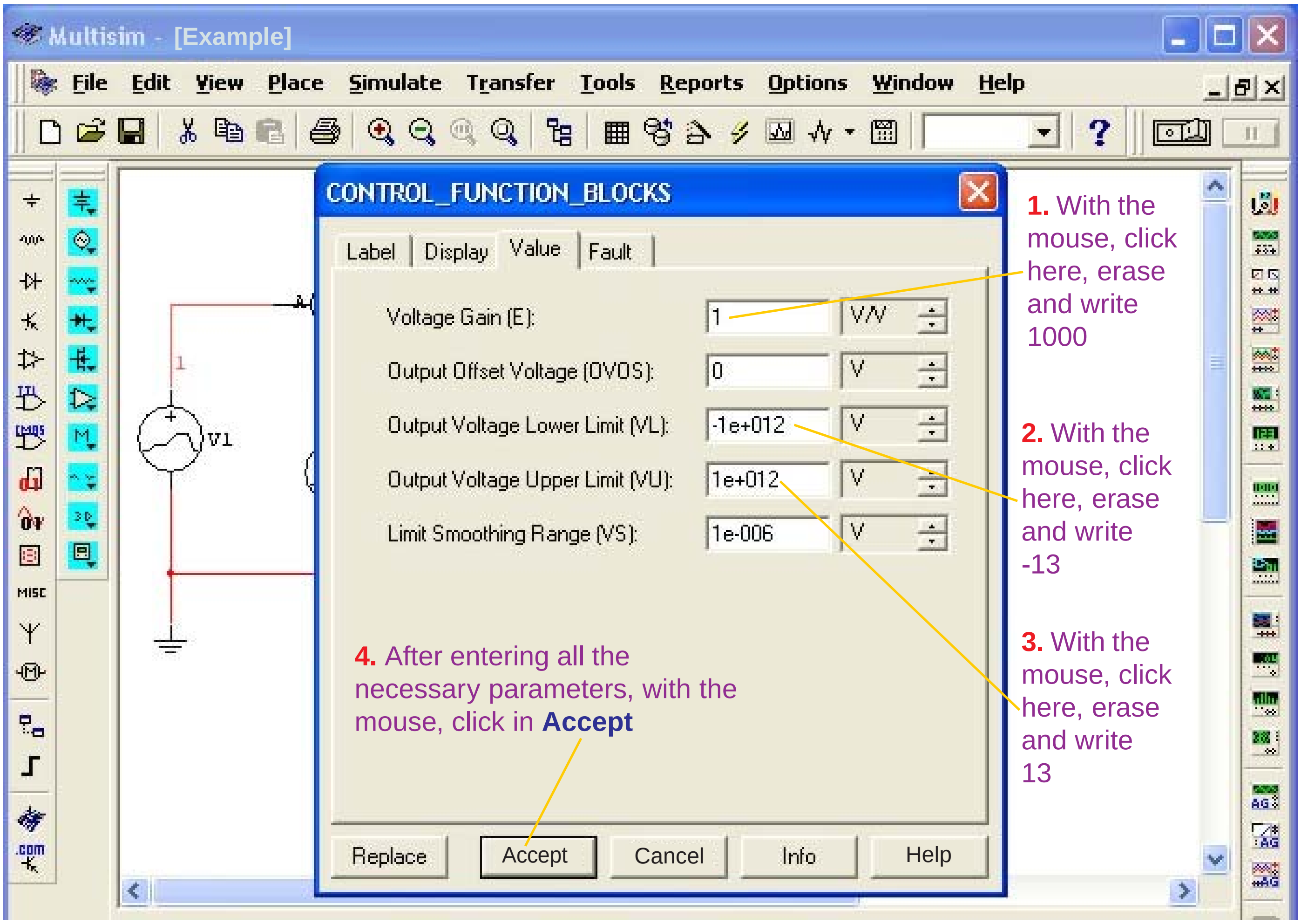


The Derivative Controller has been eliminated; we proceed to insert the Integral Controller in the way indicated on the following page.


Multisim - [Circuit1]
Select a Component
1. With the mouse, make click here.
2. With the mouse, make click here.
3. With the mouse, make click here.
4. With the mouse, make click here.


Multisim - [Example]
Non Inverting input
Non Inverting Output
Observe that after inserting the Integral Controller and wiring the circuit, Multisim has numbered with node 3 the Summer output and with node 4 the Integral output.
Inverting Input
Inverting Output
To enter the parameters of the Integral Controller, double click on its symbol.

Configuration of the Integral Controller's Parameters



The Integral Controller's output is: $$Vout(t) = K \int (Vin(t)\ dt$$

also $$K = \frac{1}{R.C} \quad \text{(expressed in seconds)}$$

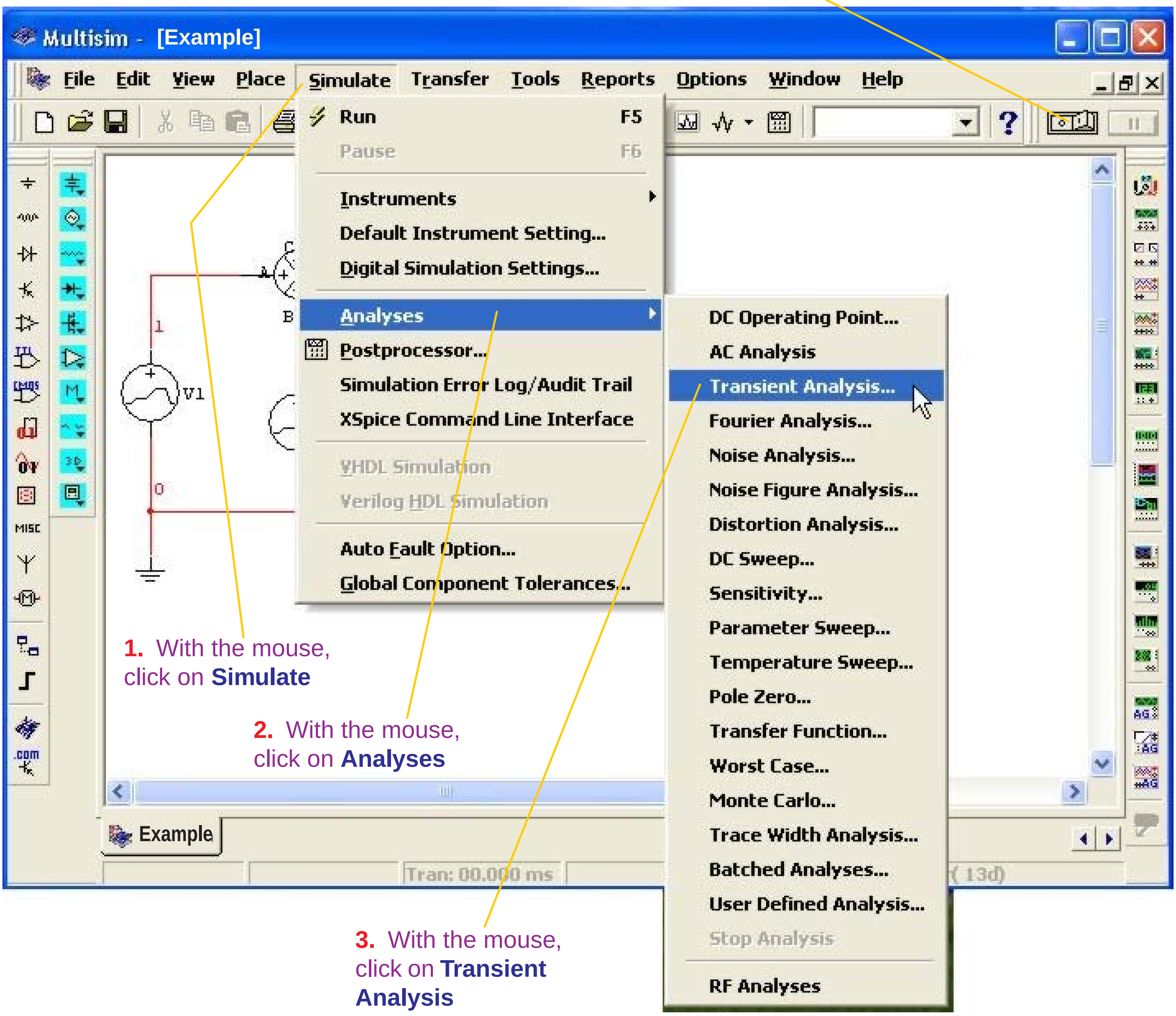
For the considerations of the example (see page 21), the RC constant is 1 millisecond. Also, K is expressed in seconds (see page 16), then we have that:
K = 1/0.001 = 1000

For the considerations of the example (see page 21), the Integral Controller will have a dual-supply with +Vcc = +15V and - Vcc = -15V then (see page 17) the Output Voltage Lower Limit will be -13 and the Output Voltage Upper Limit it is 13

Transient Analysis Configuration of the Integral Controller.

DON'T TURN ON THE SWITCH of Multisim.

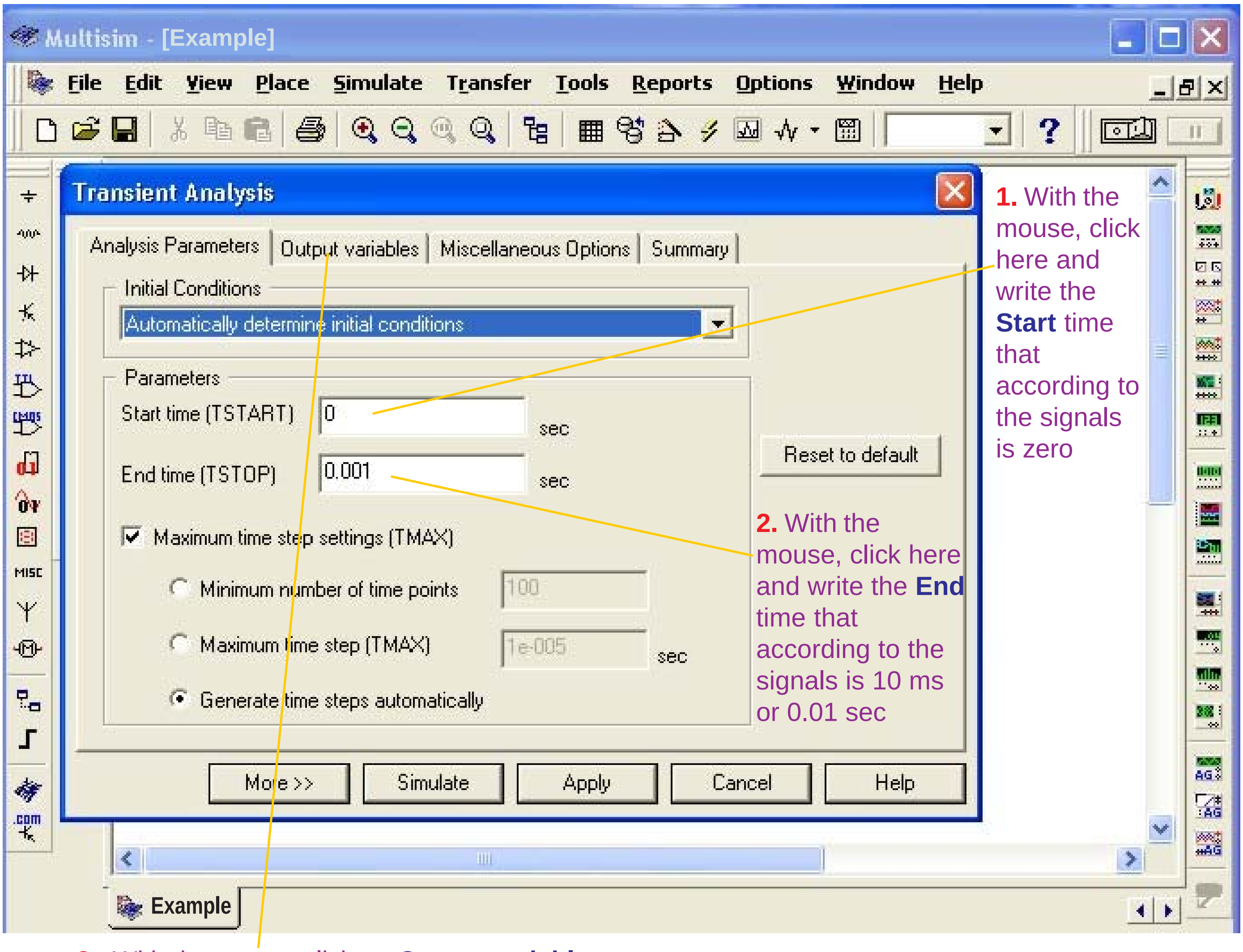
Follow the following procedure:



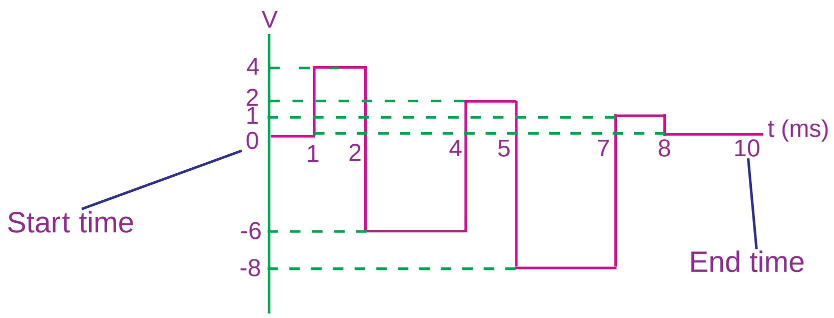
1. With the mouse, click on **Simulate**

2. With the mouse, click on **Analyses**

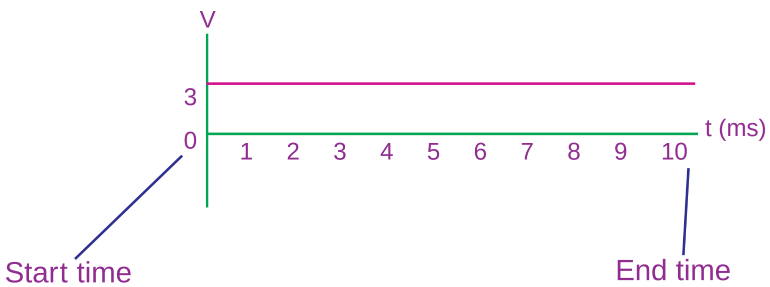
3. With the mouse, click on **Transient Analysis**



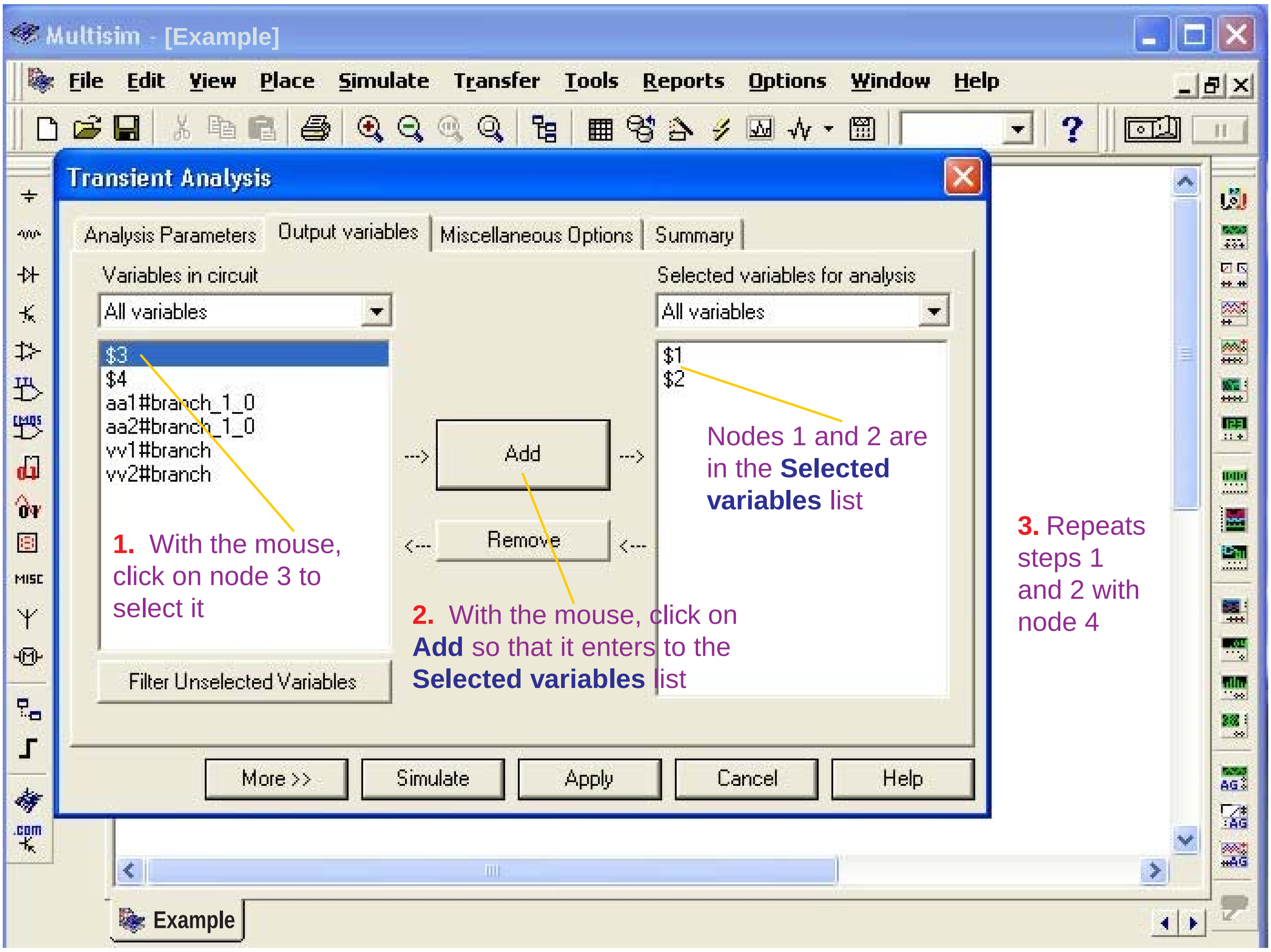
3. With the mouse click on **Output variables**

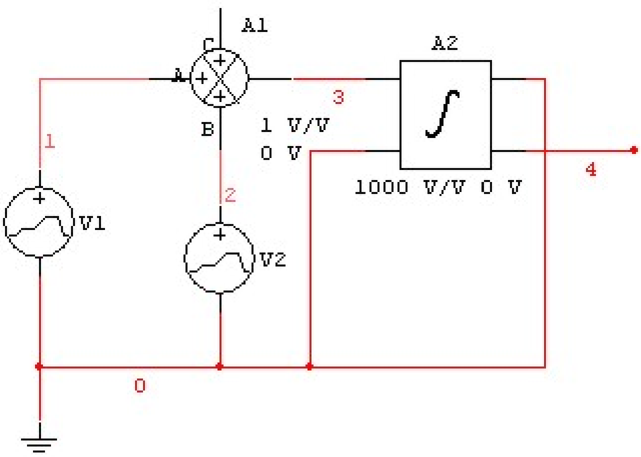


Signal of the Input Interface.



Signal of the Set Point.

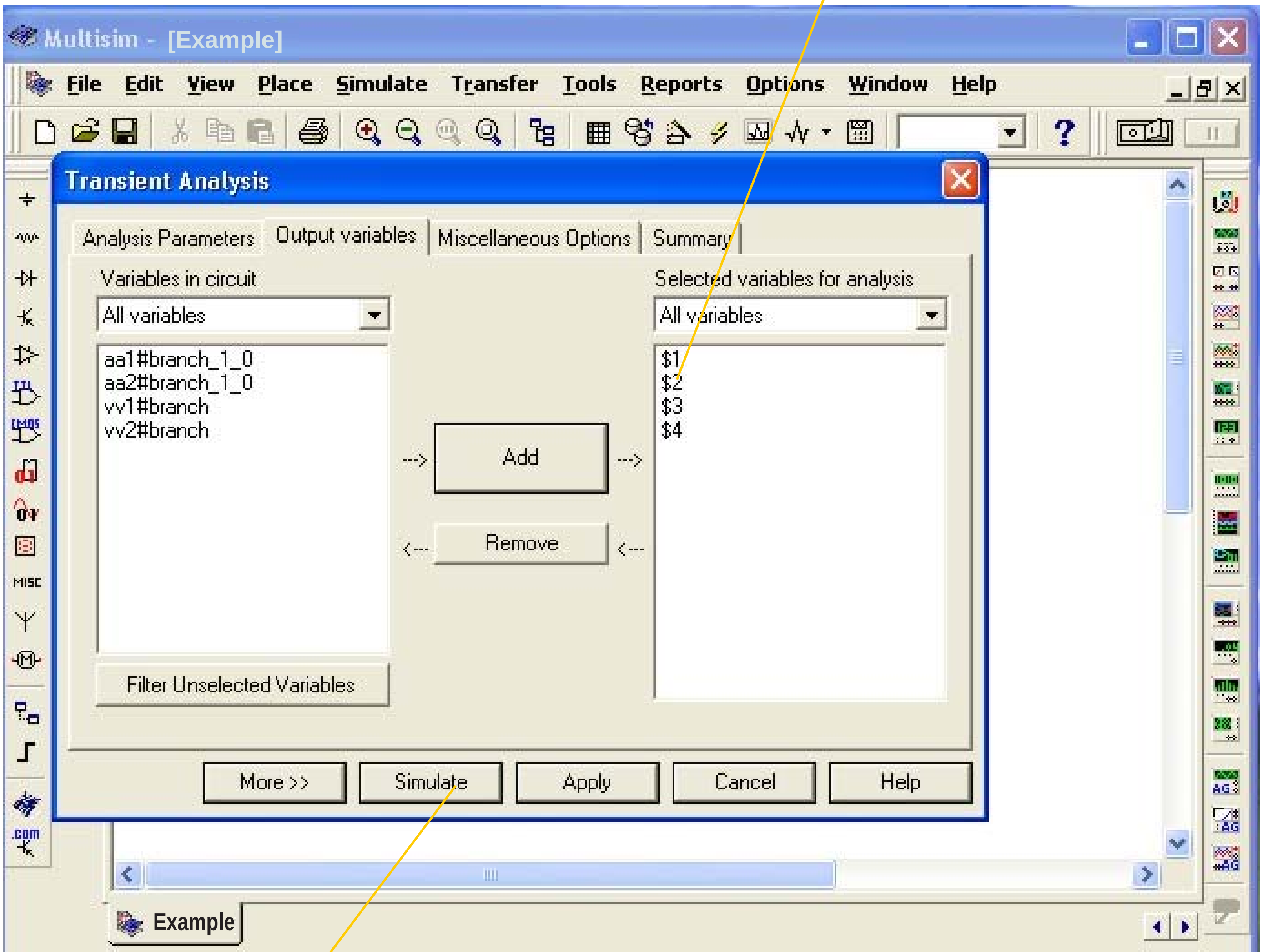




Looking at the circuit, the nodes of interest are:

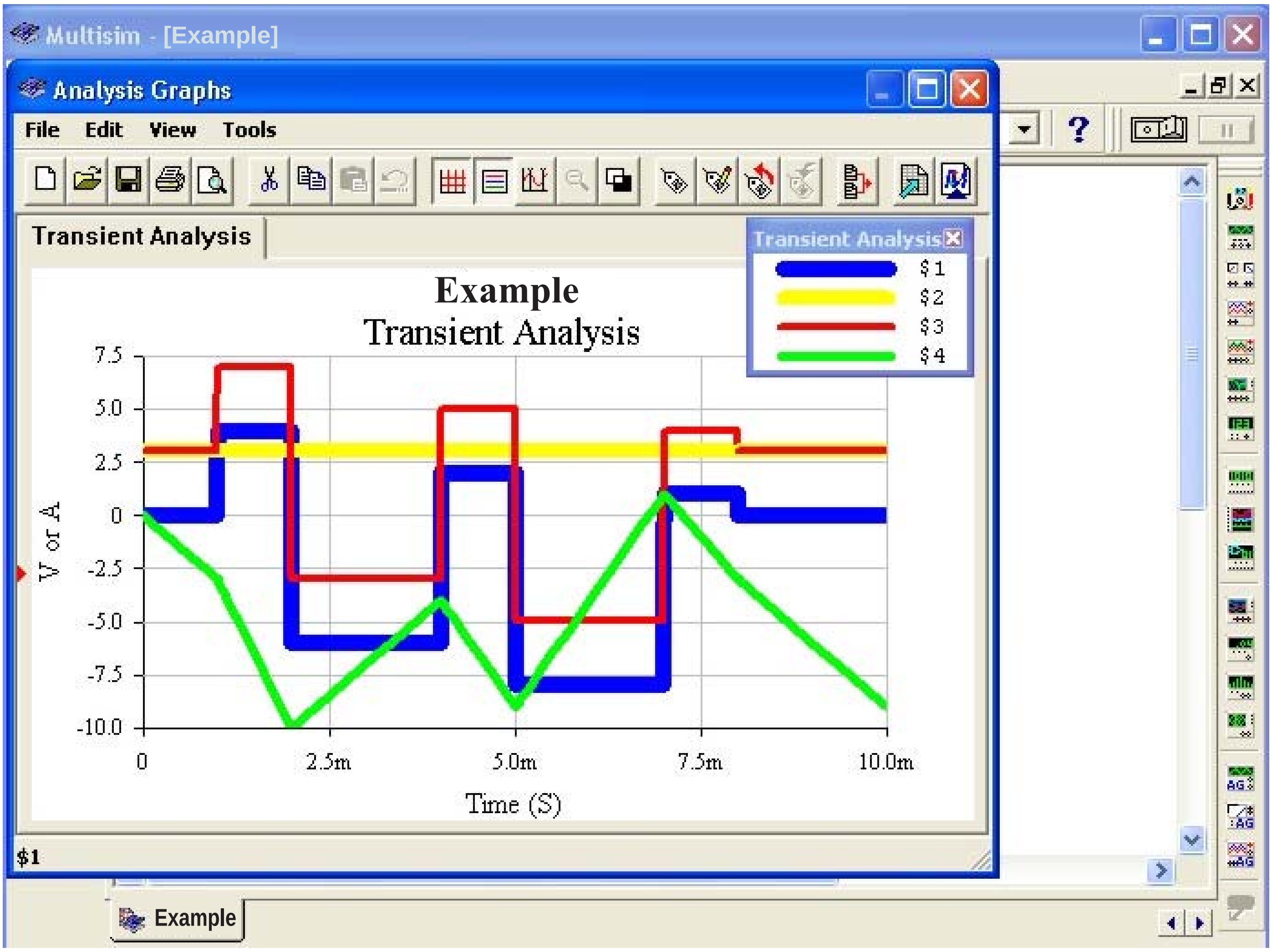
node 1: Signal of the Input Interface.
node 2: Signal of the Set Point.
node 3: Summer output.
node 4: Output of the Integral Controller.

In the **Selected variables** list we have the nodes 1, 2, 3 and 4 selected.



To observe the signals of the selected nodes, click on **Simulate**

Presentation of the Integral Controller's signals



For the legend of the Transient Analysis:

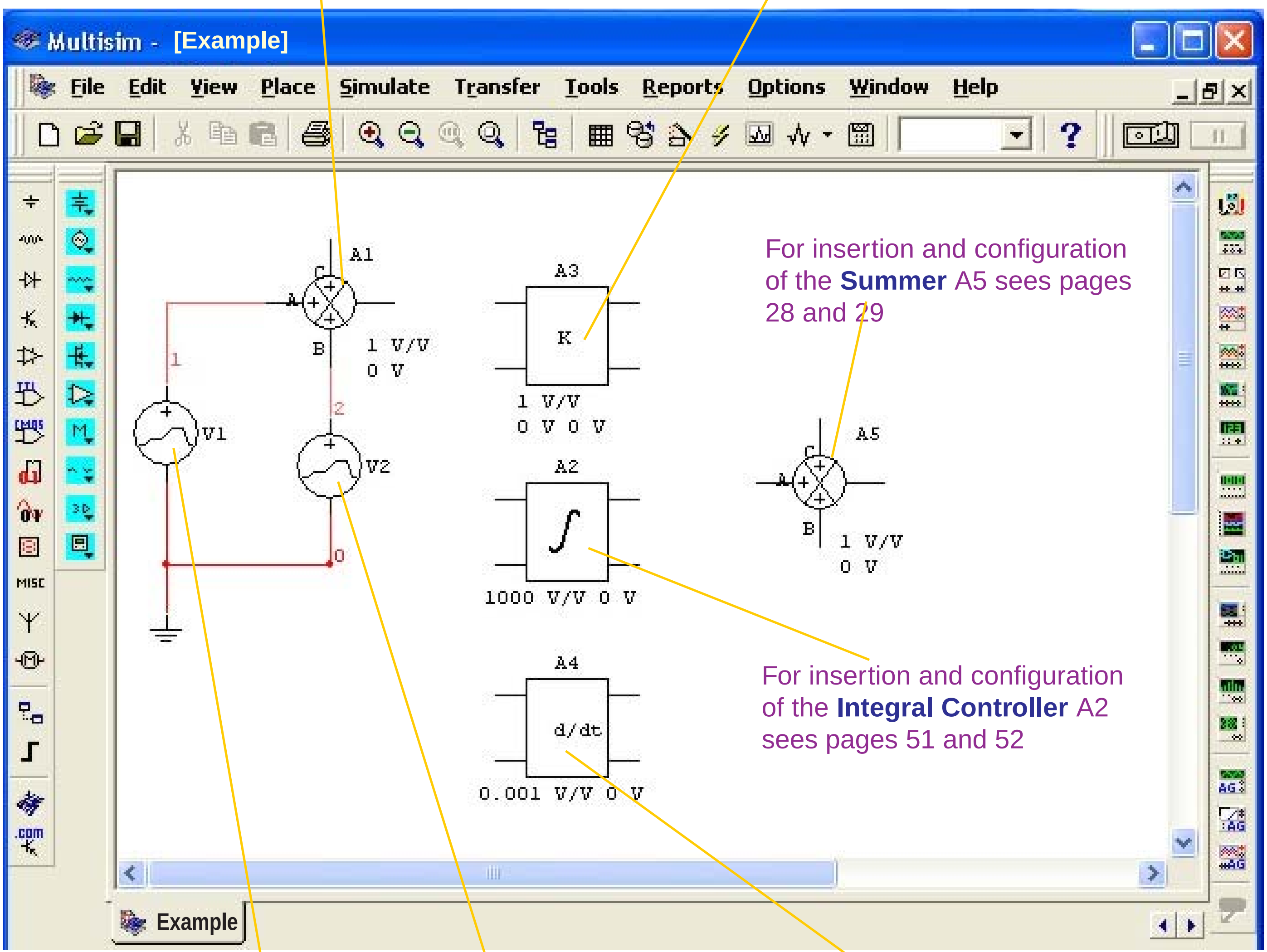
The **blue** color (node 1) corresponds to the signal of the **Input Interface.**
The **yellow** color (node 2) corresponds to the signal of the **Set Point.**
The **red** color (node 3) corresponds to the output signal of the **Summer**.
The **green** color (node 4) corresponds to the output signal of the **Integral Controller**.

For the width and color of the signals, see pages 39, 40 and 41.

The Proportional- Integral-Derivative Controller (PID). (according to the example of page 20).

For insertion and configuration of the **Summer** A1 sees pages 28 and 29

For insertion and configuration of the **Proportional Controller** A3 sees pages 30 and 31



For insertion and configuration of the **Summer** A5 sees pages 28 and 29

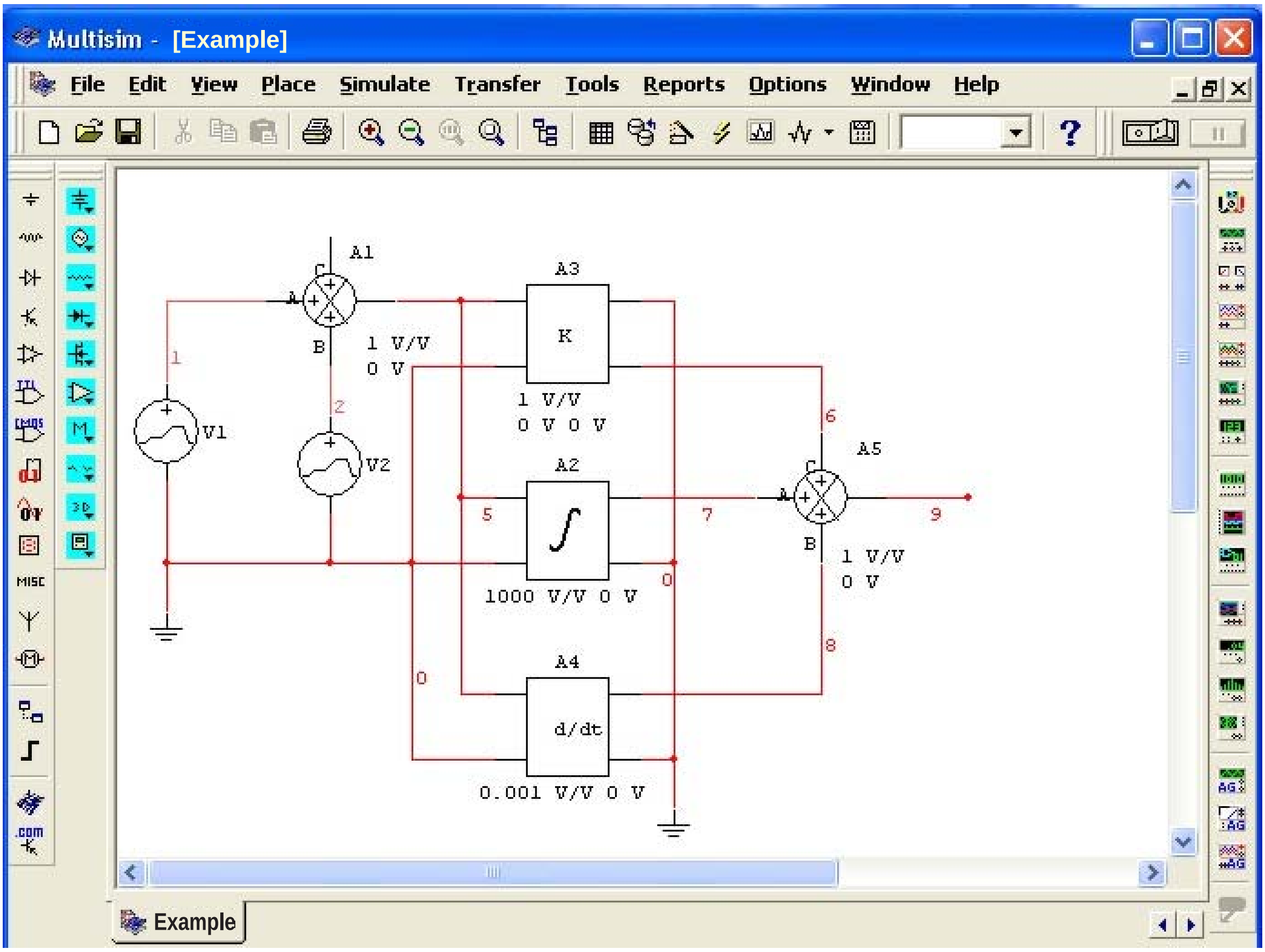
For insertion and configuration of the **Integral Controller** A2 sees pages 51 and 52

For tabulation and insertion of the Input **Interface signal** V1: see pages 22, 24, and 25

For tabulation and insertion of the **Set Point** signal V2: see pages 23, 26 and 27

For insertion and configuration of the **Derivative Controller** A4 sees pages 43 and 44

Determination of the PID Controller's nodes

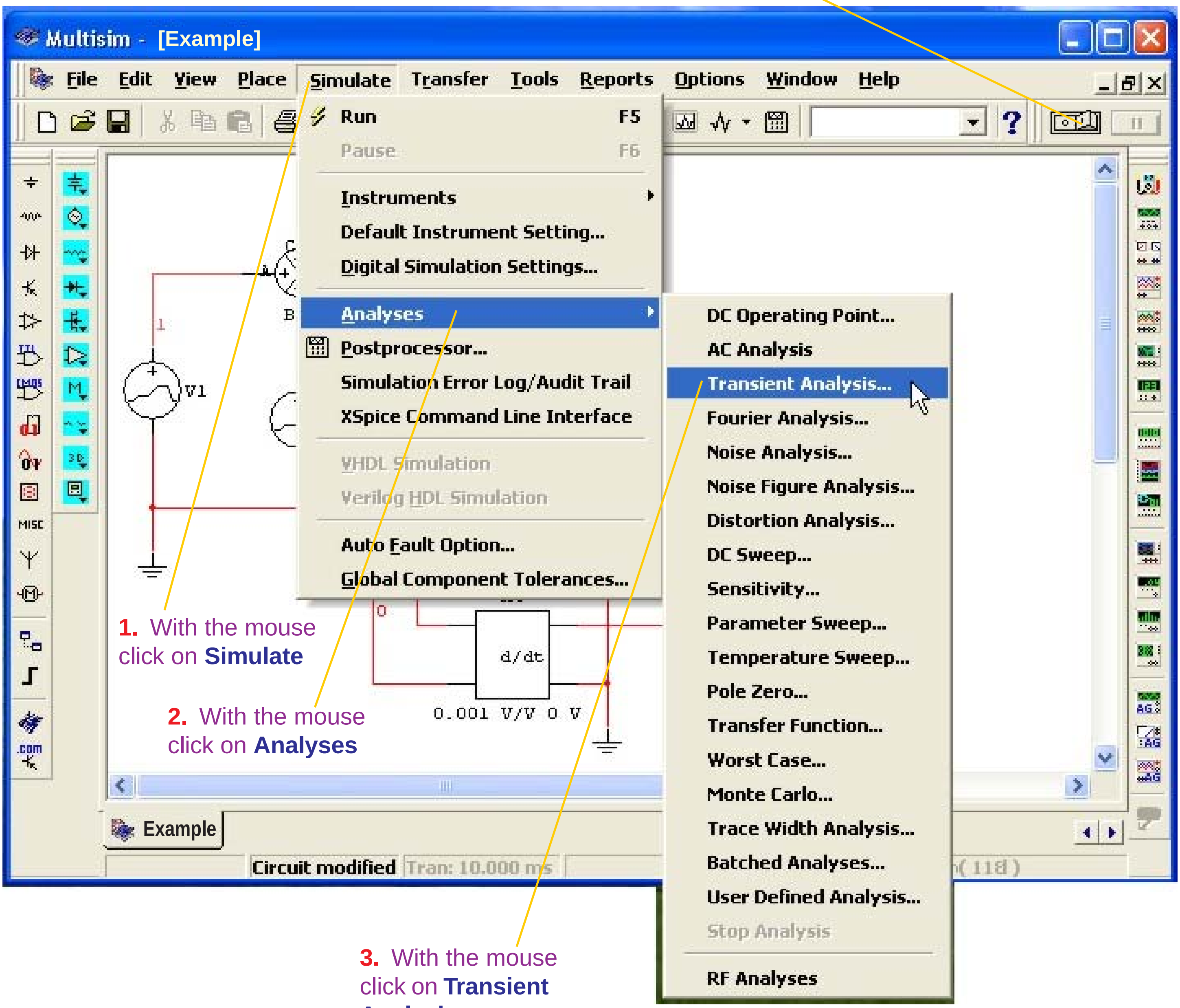


In the circuit, we will take the outputs of the Proportional Controller (**node 6**), Integral Controller (**node 7**), Derivative Controller (**node 8**) and Proportional-Integral- Derivative Controller PID (**node 9**).

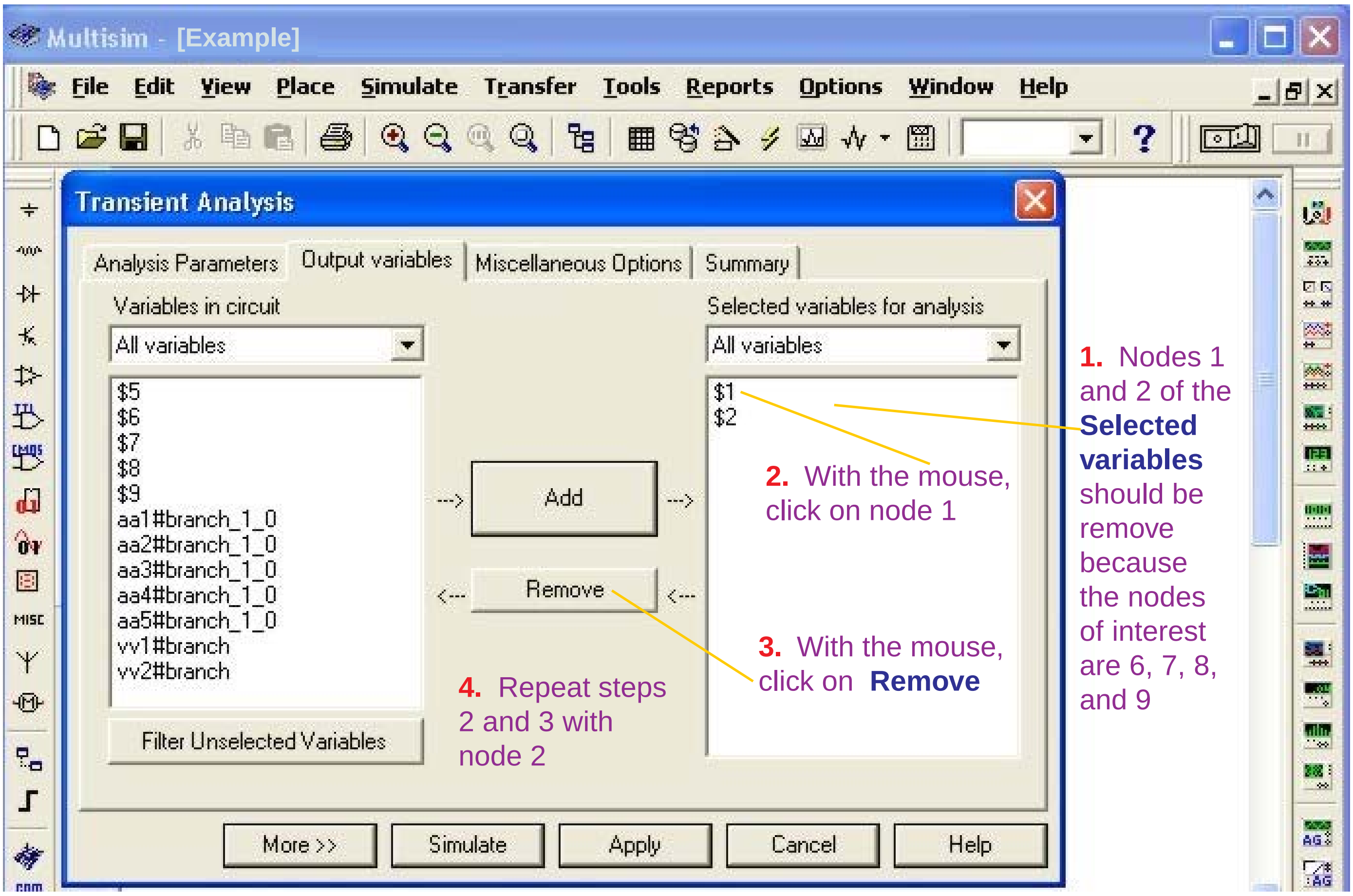
Transient Analysis Configuration of the Proportional-Integral- Derivative Controller (PID).

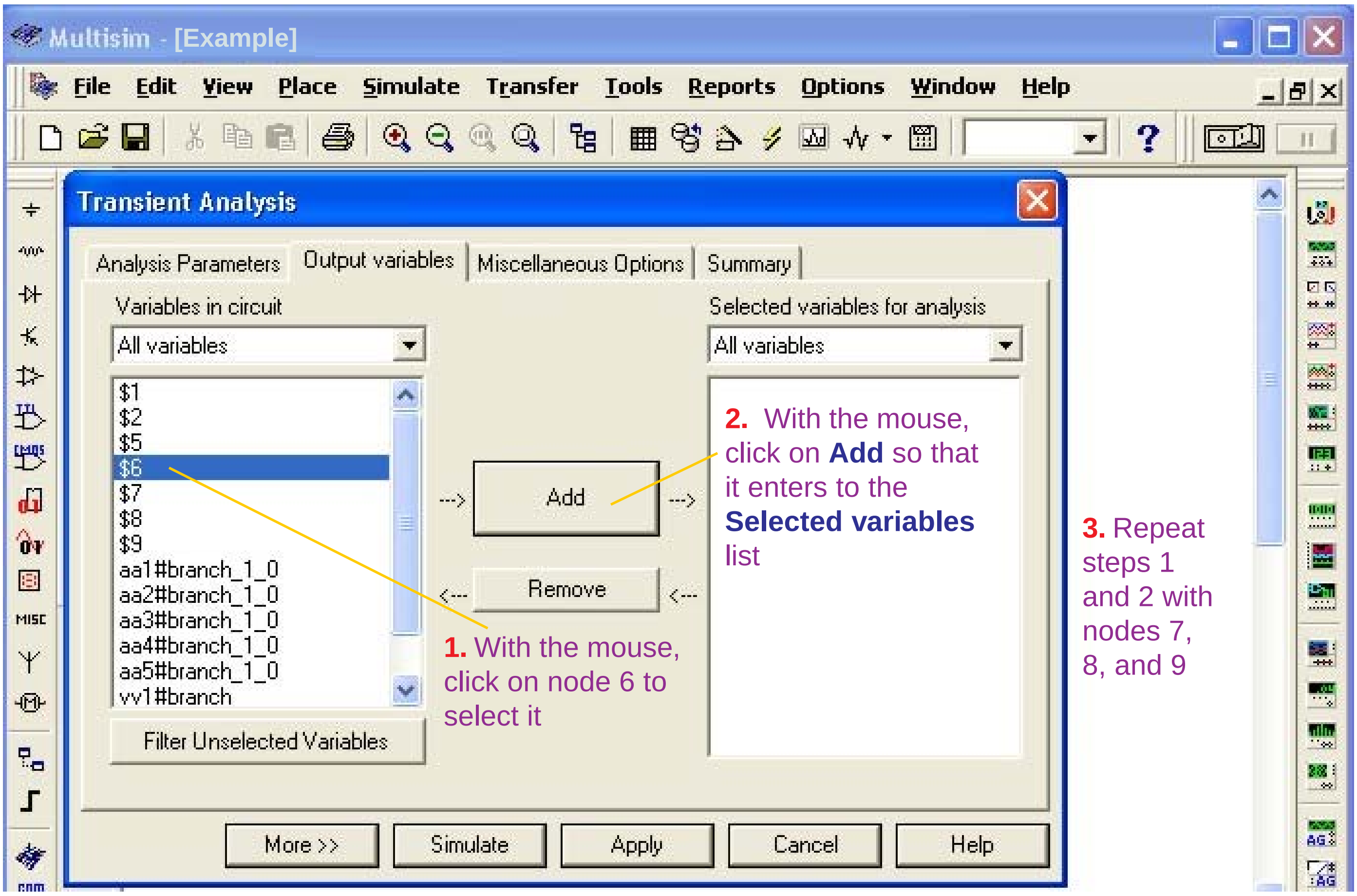
DON'T TURN ON THE SWITCH of Multisim.

Follow the following procedure:

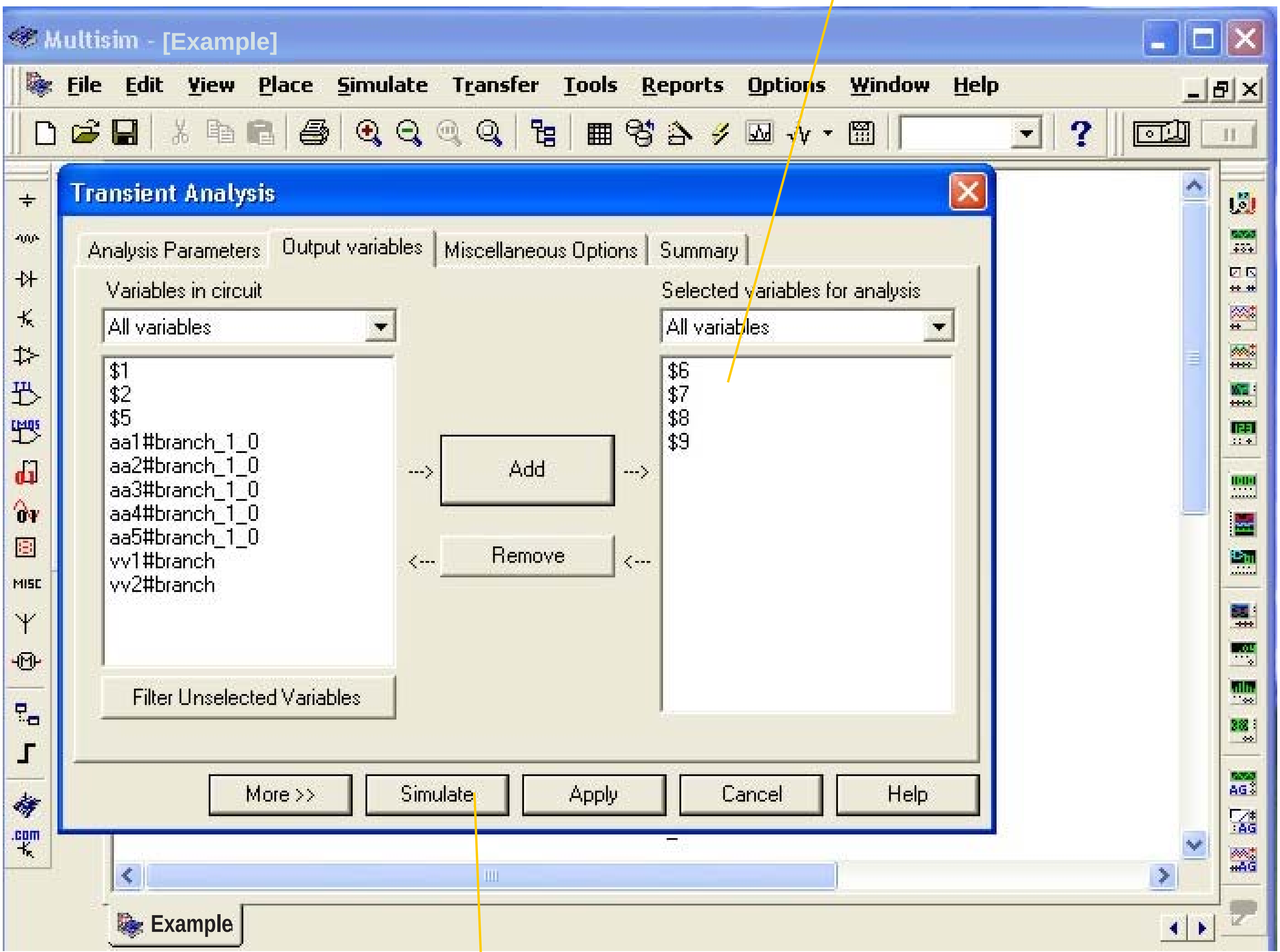


3. With the mouse click on **Transient Analysis**


Multisim - [Example]
Transient Analysis
Analysis Parameters
Output variables
Miscellaneous Options
Summary
Variables in circuit
Selected variables for analysis
All variables
$5
$6
$7
$8
$9
aa1#branch_1_0
aa2#branch_1_0
aa3#branch_1_0
aa4#branch_1_0
aa5#branch_1_0
vv1#branch
vv2#branch
$1
$2
Add
Remove
Filter Unselected Variables
More >>
Simulate
Apply
Cancel
Help
1. Nodes 1 and 2 of the Selected variables should be remove because the nodes of interest are 6, 7, 8, and 9
2. With the mouse, click on node 1
3. With the mouse, click on Remove
4. Repeat steps 2 and 3 with node 2

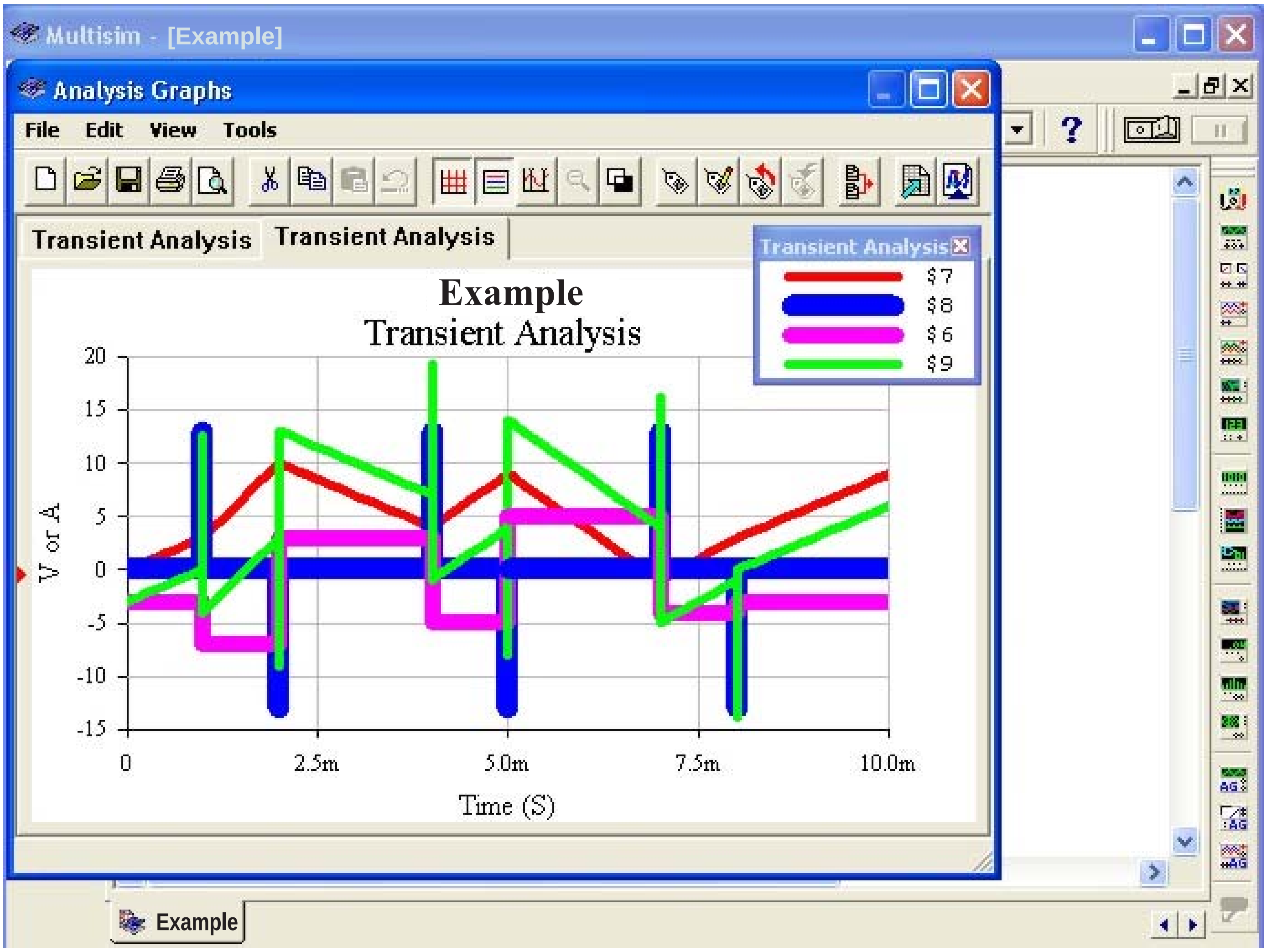

Multisim - [Example]
Transient Analysis
Analysis Parameters
Output variables
Miscellaneous Options
Summary
Variables in circuit
Selected variables for analysis
All variables
$1
$2
$5
$6
$7
$8
$9
aa1#branch_1_0
aa2#branch_1_0
aa3#branch_1_0
aa4#branch_1_0
aa5#branch_1_0
vv1#branch
Add
Remove
Filter Unselected Variables
More >>
Simulate
Apply
Cancel
Help
1. With the mouse, click on node 6 to select it
2. With the mouse, click on Add so that it enters to the Selected variables list
3. Repeat steps 1 and 2 with nodes 7, 8, and 9

In the **Selected variables** list we have the nodes 6, 7, 8 and 9 selected.



To observe the signals of the selected nodes, with the mouse click on **Simulate**

Presentation of the Proportional-Integral- Derivative Controller‘s signals (PID).



For the legend of the Transient Analysis:

The **red** color (node 7) corresponds to the output signal of the **Integral Controller**.
The **blue** color (node 8) corresponds to the output signal of the **Derivative Controller.**
The color **fuchsia** (node 6) corresponds to the output signal of the **Proportional Controller**.
The **green** color (node 9) corresponds to the output signal of the **Proportional-Integral- Derivative Controller (PID).**

For the width and color of the signals, see pages 39, 40 and 41.