NATIONAL INSTITUTE OF TECHNOLOGY MIZORAM

Laboratory Report

EEP1603
Power Electronics Laboratory

SUBMITTED TO -

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Electrical and Electronics Engineering
IV Year (VIII Semester)
National Institute of Technology Mizoram

Index

Experiment - 1

* **Aim:** Simulation of single-phase half-wave uncontrolled rectifier with R, RL and RLE load by using MATLAB simulink.

* **Requirement:** MATLAB / Simulink

* **Theory:** Single phase uncontrolled half-wave rectifier are the simplest and possibly the most widely used rectification circuit for small power levels as their output is heavily affected by the reactance of the connected load.

For supply voltage V_s, source current i_s, V_D & i_D to be diode voltage and current respectively. V_o and i_o is load and current respectively.

$$V_s = V_m \sin(\omega t)$$

→ In positive half cycle, the diode is forward biased and is turned ON at $\omega t = 0°$.

~~At ωt=0~~ At $\omega t = \pi$, the current through the diode falls to zero, i.e. below zero and simultaneously a reverse voltage appears accross the diode and it turns OFF

→ $0 < \omega t < \pi$

Diode = forward biased (ON)

$V_D = 0V$,

$V_o = V_{ab} = V_m \sin(\omega t)$

$i_o = V_o/R = \dfrac{V_m \sin(\omega t)}{R}$

* Diagram:

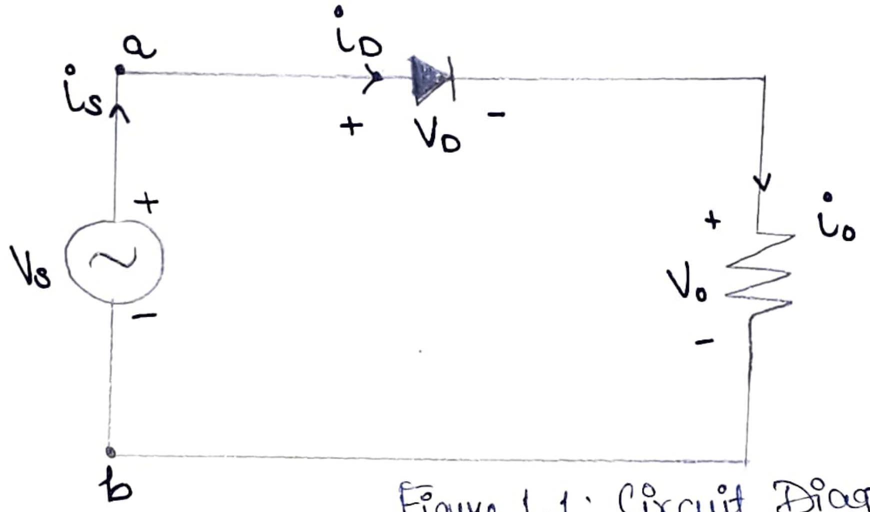


Figure 1.1: Circuit Diagram of 1φ half wave uncontrolled rectifier

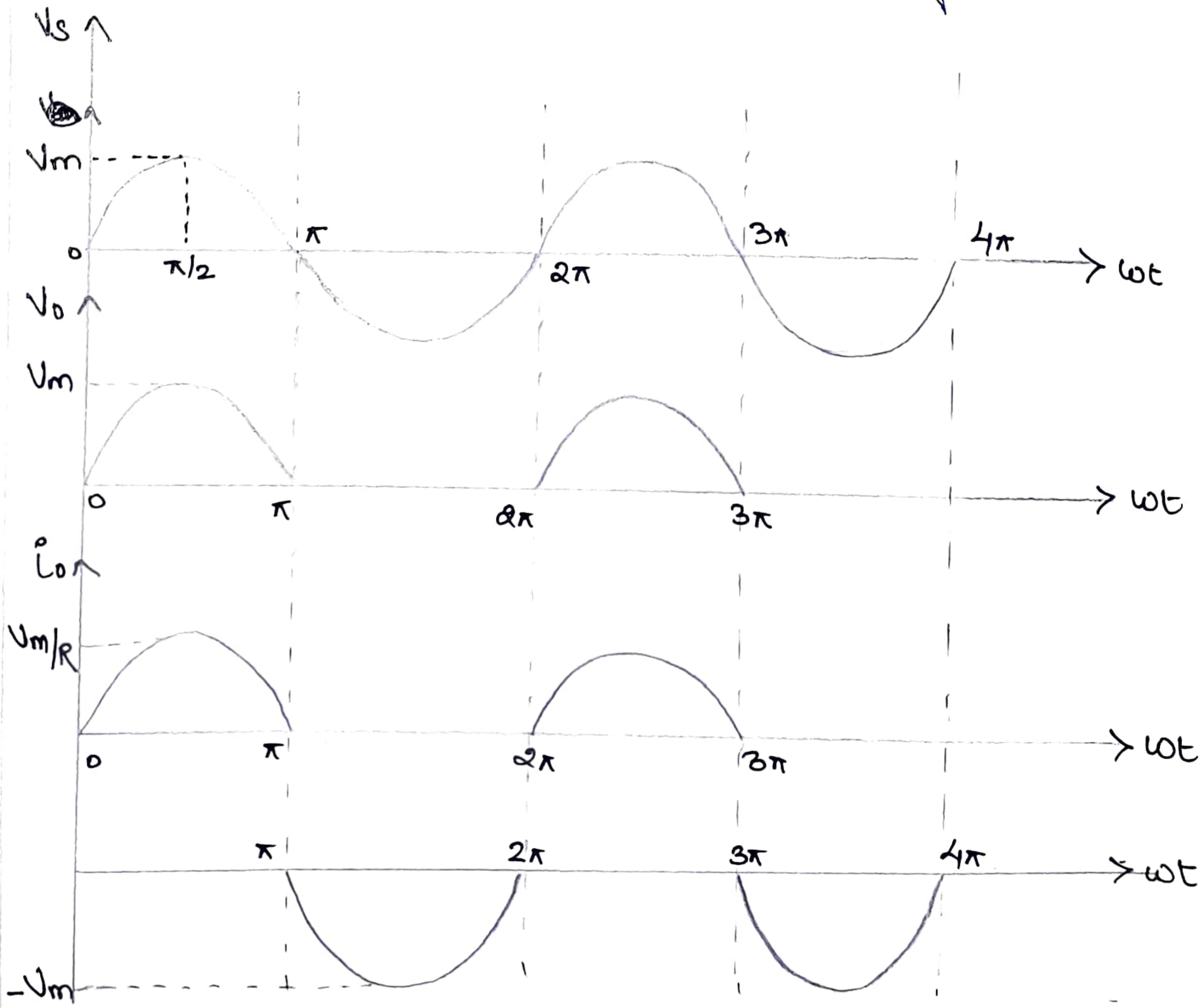


Figure 1.2: Waveform of 1φ half wave uncontrolled rectifier.

→ $\pi < \omega t < 2\pi$

Diode = Reversed bias (off)

$i_o = 0A$

$V_o = 0V$

$V_D = V_{ab} = V_m \sin(\omega t)$

→ $2\pi < \omega t < 3\pi$

Same as $0 < \omega t < \pi$

→ Average values:

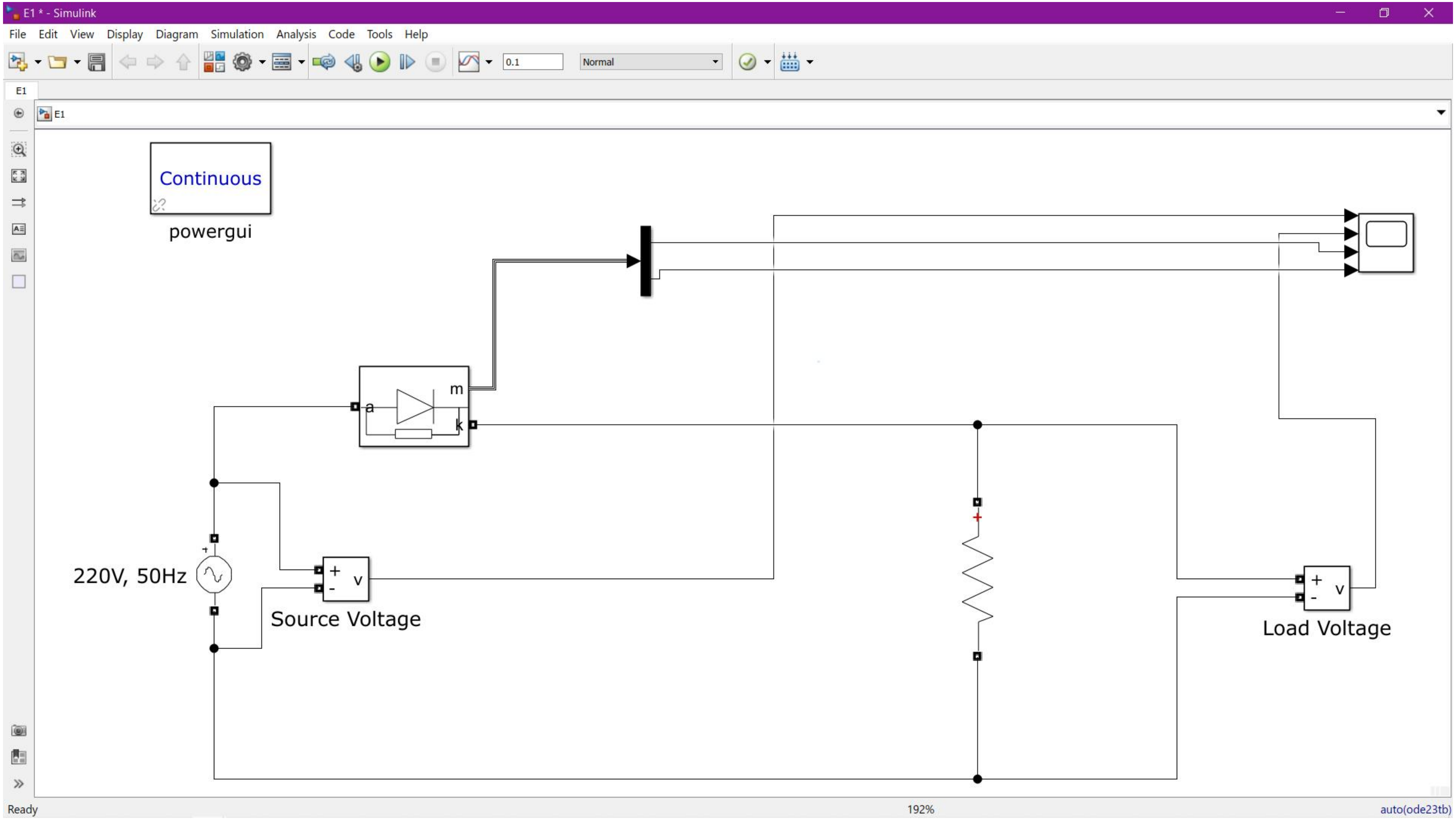
$$V_{o(avg)} = \frac{V_m}{\pi} \qquad I_{o(avg)} = \frac{V_m}{\pi R}$$

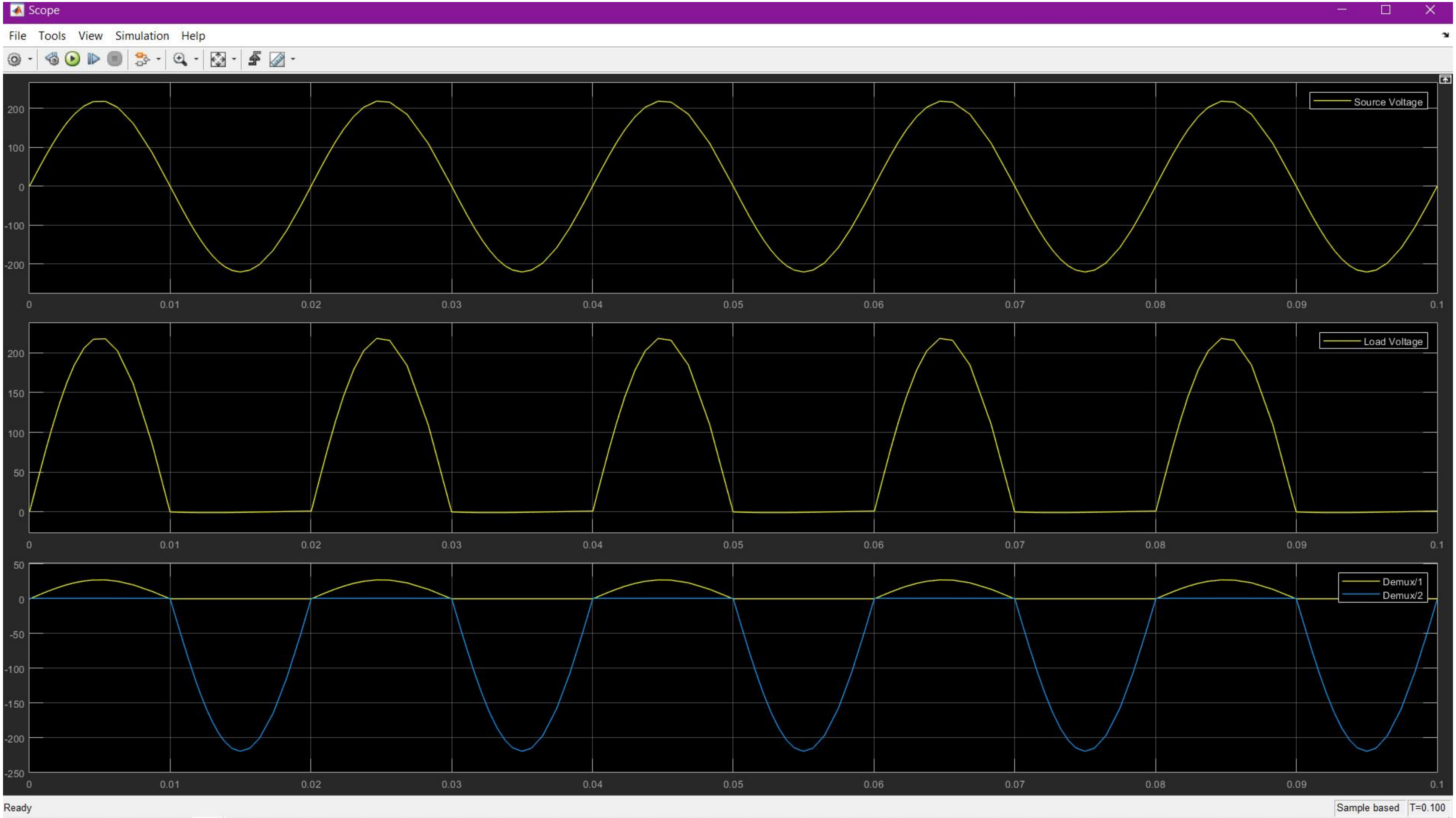
→ RMS values:

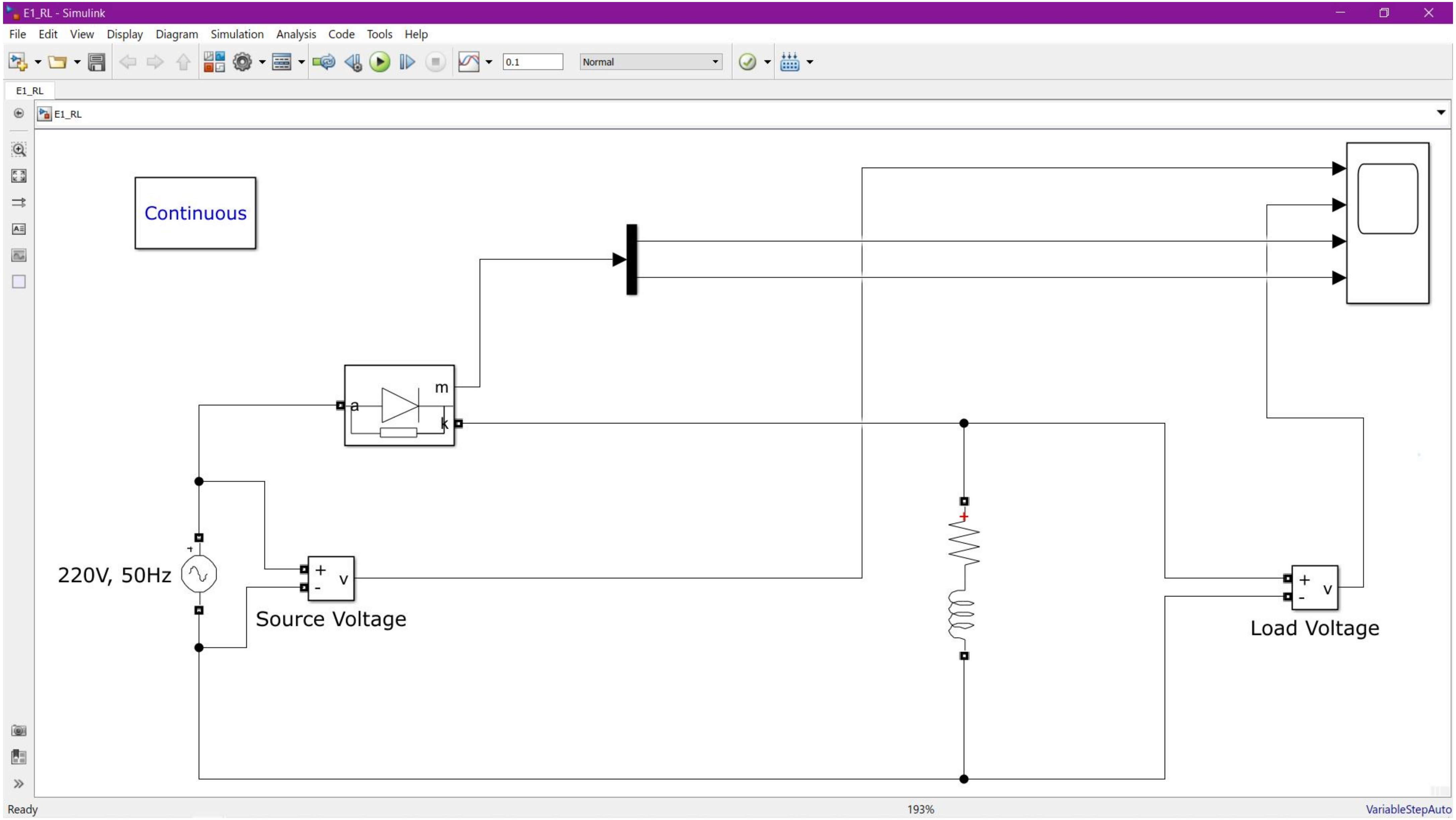
$$I_{o(rms)} = \frac{V_{o(rms)}}{R} \qquad V_{o(rms)} = \sqrt{\frac{1}{2\pi}\int_0^{2\pi}[V_m \sin(\omega t)]^2 d\omega t}$$

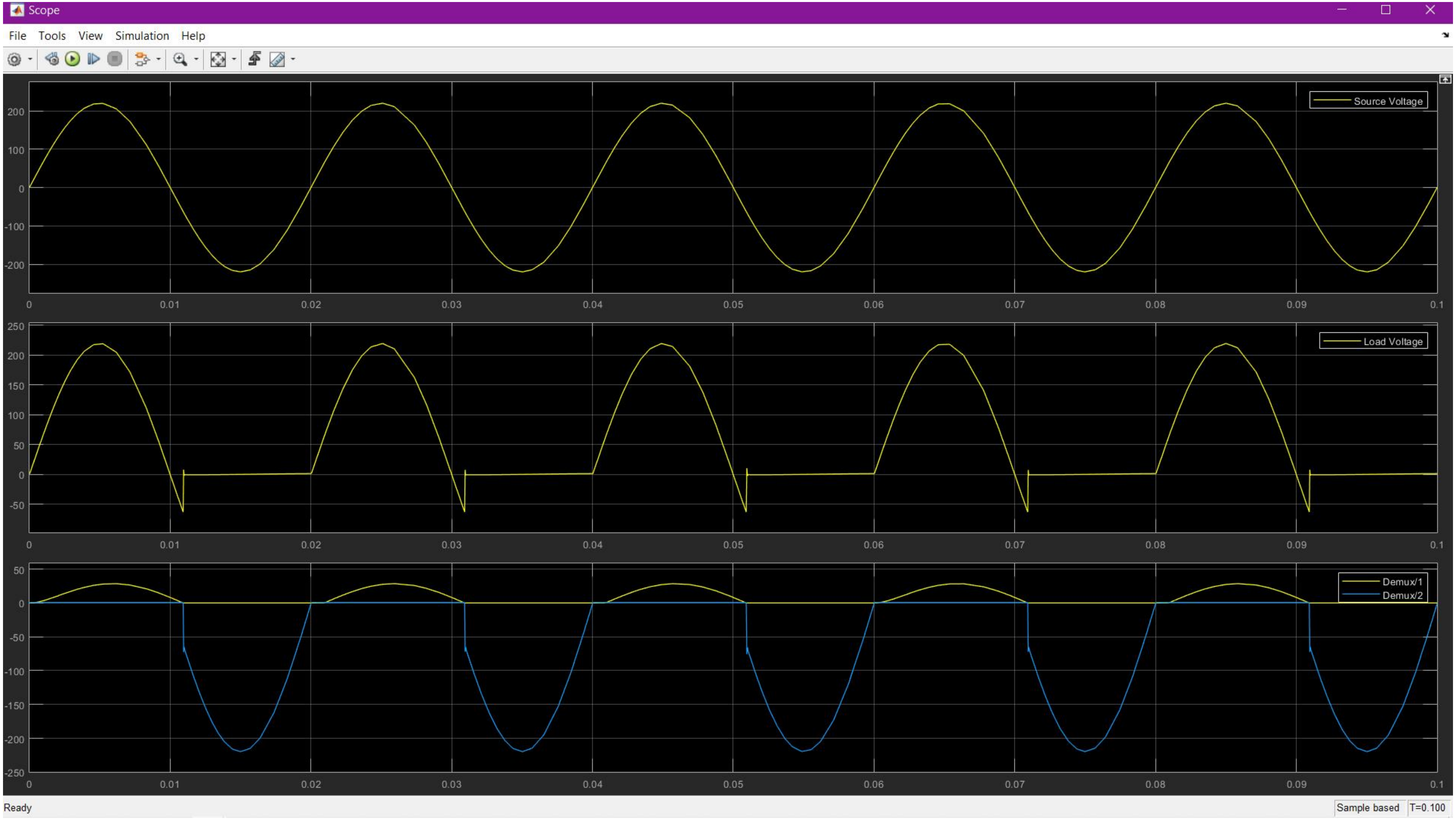
* Procedure:

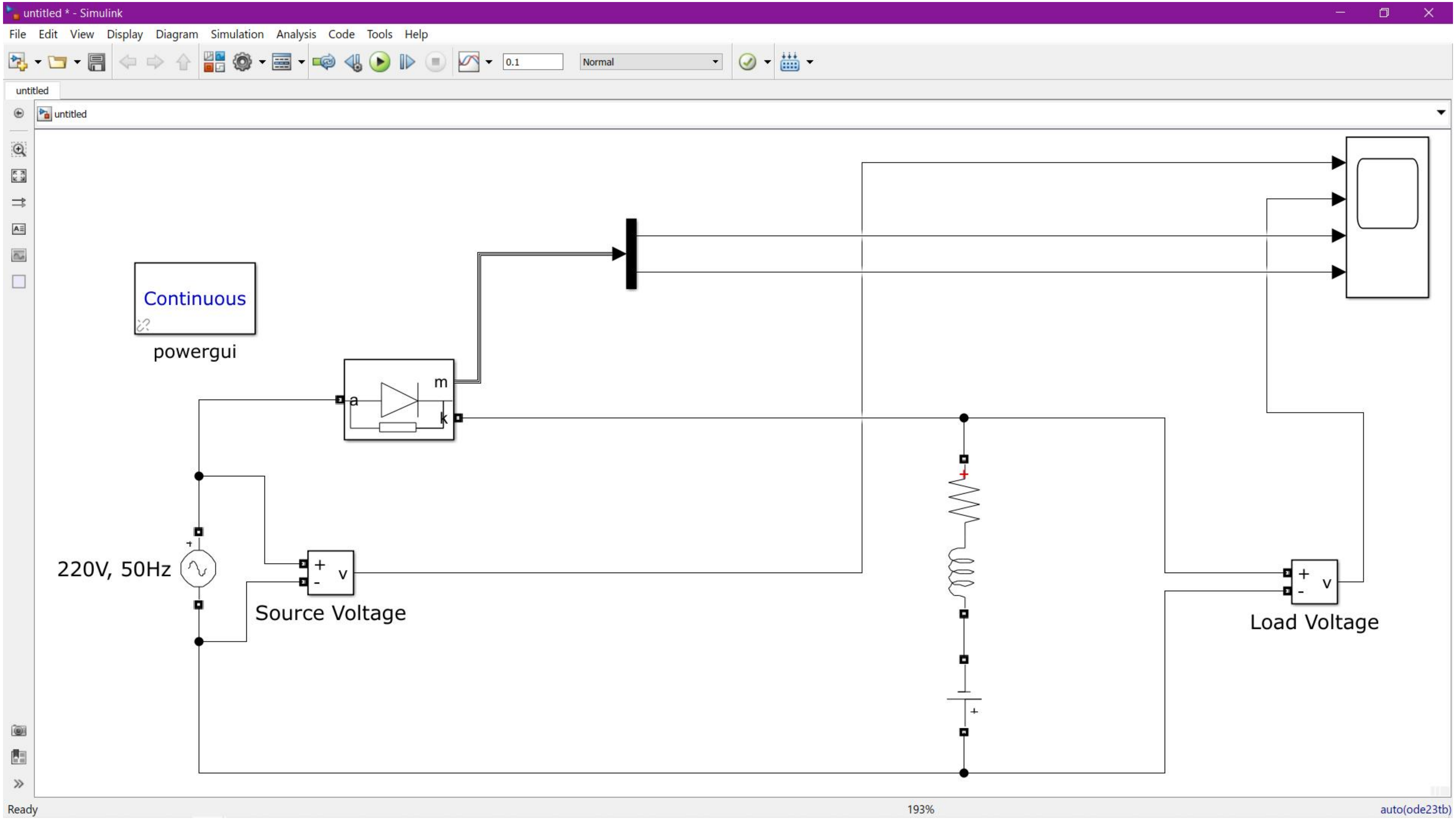
1. Make the required circuit in SIMULINK in MATLAB.
2. Simulate it for 1 ~~seco~~ seconds.
3. Observe the waveform from scope

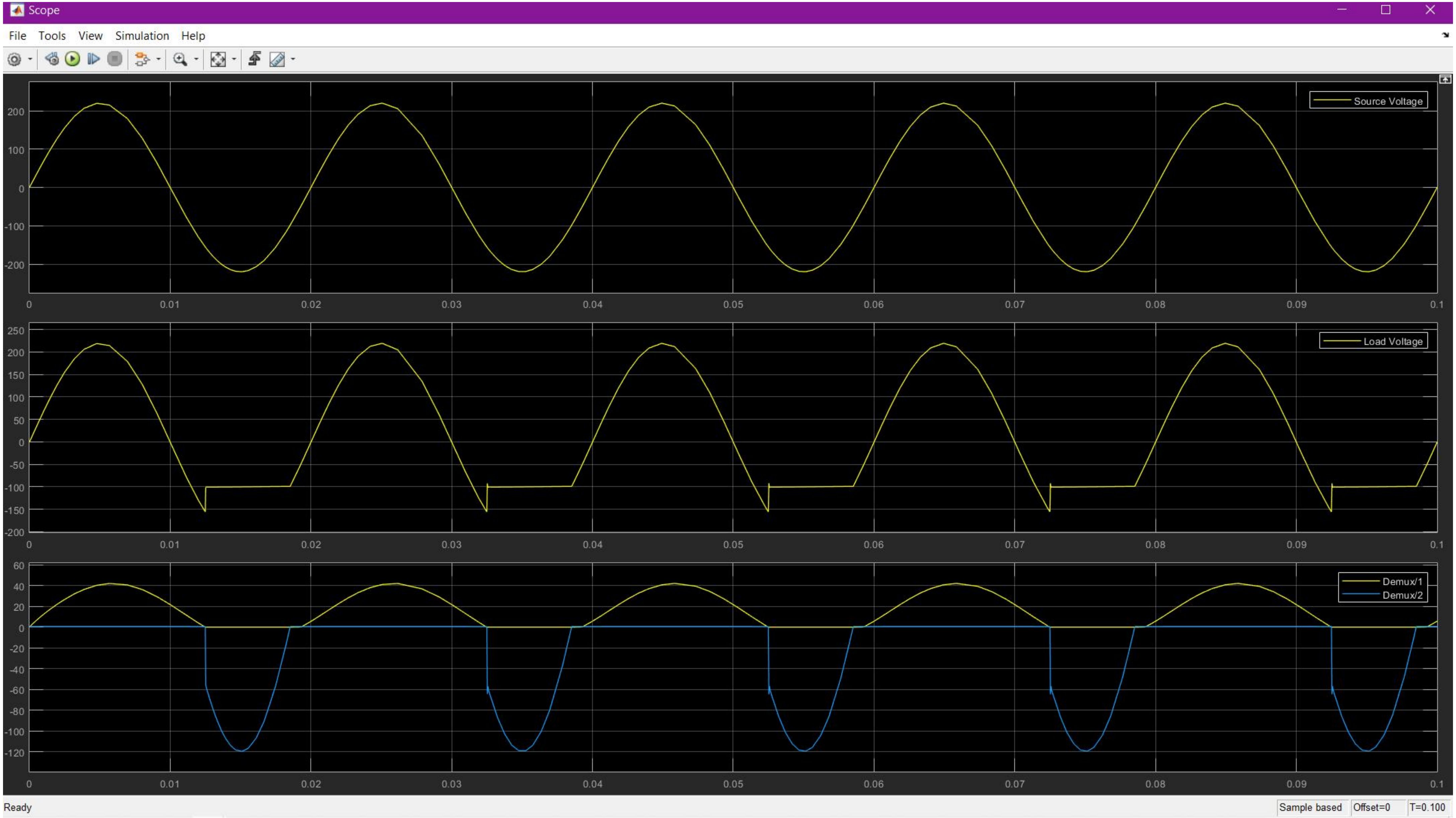

E1 * - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
0.1
Normal
E1
Continuous
powergui
m
a
k
220V, 50Hz
Source Voltage
Load Voltage
Ready
192%
auto(ode23tb)


Scope
File Tools View Simulation Help
Source Voltage
Load Voltage
Demux/1
Demux/2
Ready
Sample based
T=0.100


E1_RL - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
0.1
Normal
E1_RL
E1_RL
Continuous
m
a
k
220V, 50Hz
+
+
-
v
Source Voltage
+
-
v
Load Voltage
Ready
193%
VariableStepAuto


Scope
File Tools View Simulation Help
Source Voltage
Load Voltage
Demux/1
Demux/2
Ready
Sample based
T=0.100


untitled * - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
0.1
Normal
untitled
untitled
Continuous
powergui
m
a
k
220V, 50Hz
Source Voltage
Load Voltage
Ready
193%
auto(ode23tb)


Scope
File Tools View Simulation Help
Source Voltage
Load Voltage
Demux/1
Demux/2
Ready
Sample based
Offset=0
T=0.100

* **Result**: Simulated the single phase half wave uncontrolled rectifier with R, RL and RLE load by using MATLAB simulink.

* **Precautions**:

1. Use powergui to store the equivalent simulink circuit that represents the state-space equation of the model.
2. Always use closed circuit, never leave wire open.
3. MATLAB ~~is~~ takes time to respond, do not give multiple command at once.

Experiment - 2

* **Aim:** To simulate a single phase full wave uncontrolled rectifier with R, RL and RLE load by using MATLAB - simulink.

* **Requirement:** MATLAB - SIMULINK

* **Theory:** Unlike the previous half-wave rectifier, the full-wave rectifier utilise both halves of the input sinusodial waveform to provide a unidirectional output. More efficient than half wave uncontrolled rectifier.

During the positive input half cycle, diode D_1 and D_3 becomes forward biased whereas D_2 and D_4 are reversed bias, and vice versa in other ~~fo~~ half negative cycle.

$$V_s = V_m \sin(\omega t)$$

→ $0 < \omega t < \pi$

Diode D_1 & D_3 = forward bias

$V_o = V_m \sin(\omega t)$

$i_o = V_o / R$

→ $\pi < \omega t < 2\pi$

Diode D_2 & D_4 = forward bias

$V_o = V_m \sin(\omega t)$

$i_o = V_o / R$

* Diagram:

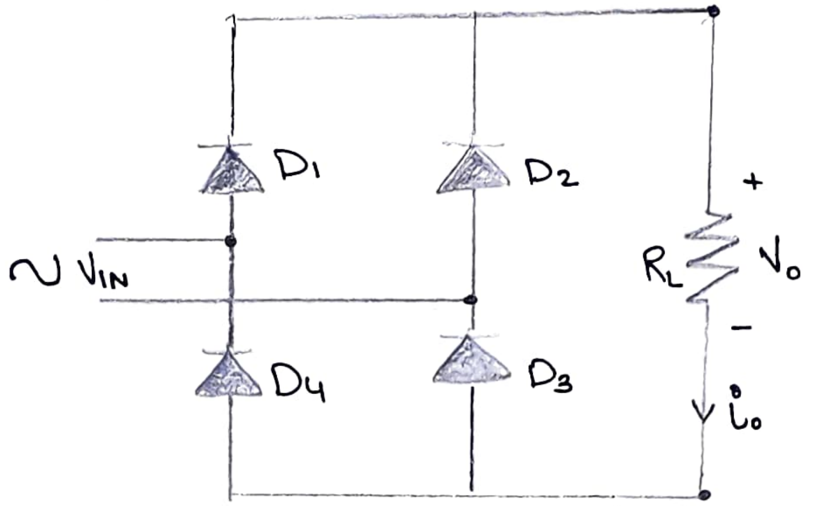


Figure 2.1: circuit diagram of 1Φ full wave uncontrolled rectifier

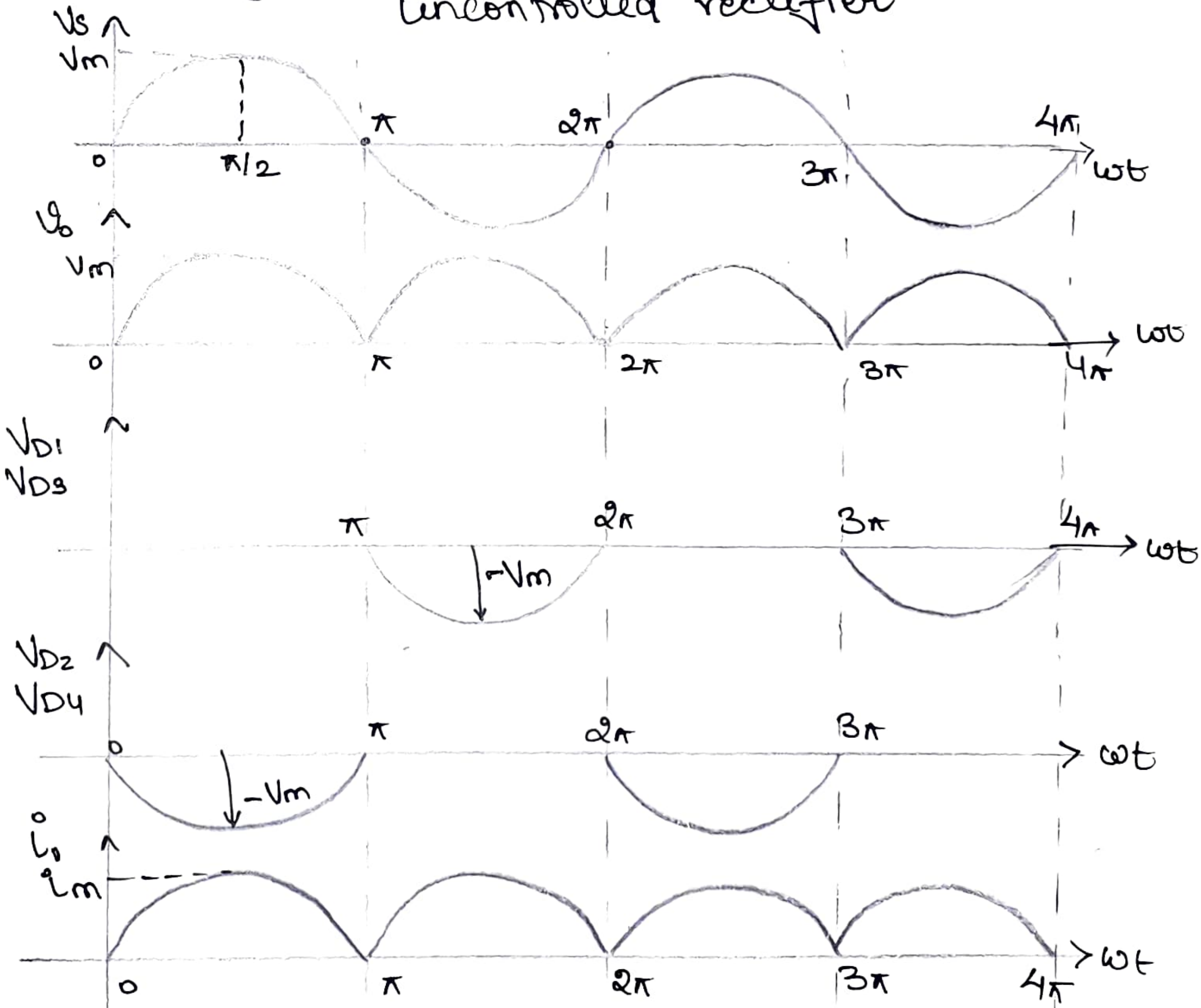


Figure 2.2: Waveform for the circuit

→ Average value

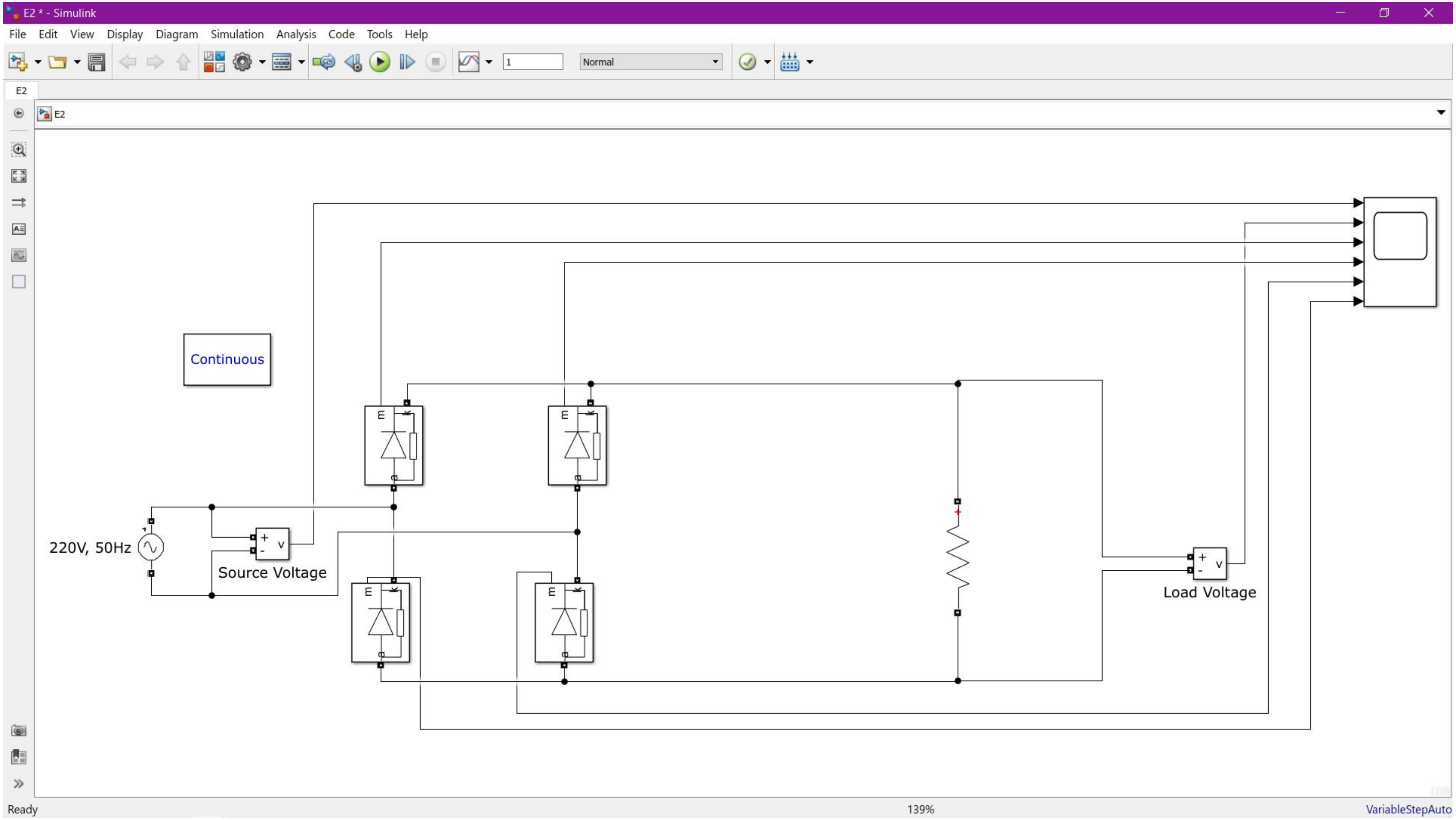
$$V_{o(avg)} = 0.637\, V_m$$

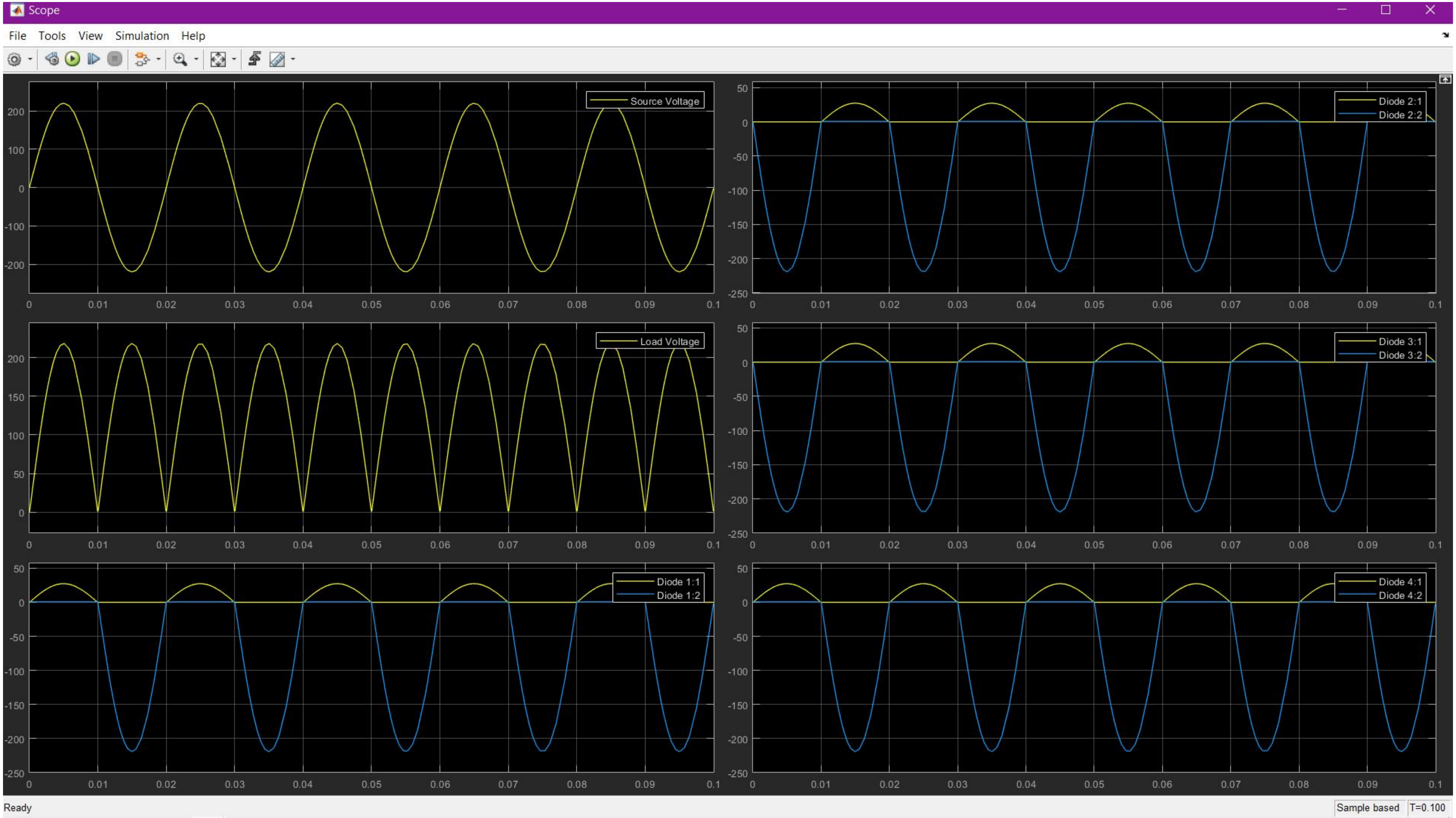
$$I_{o(avg)} = 0.637\, I_m.$$

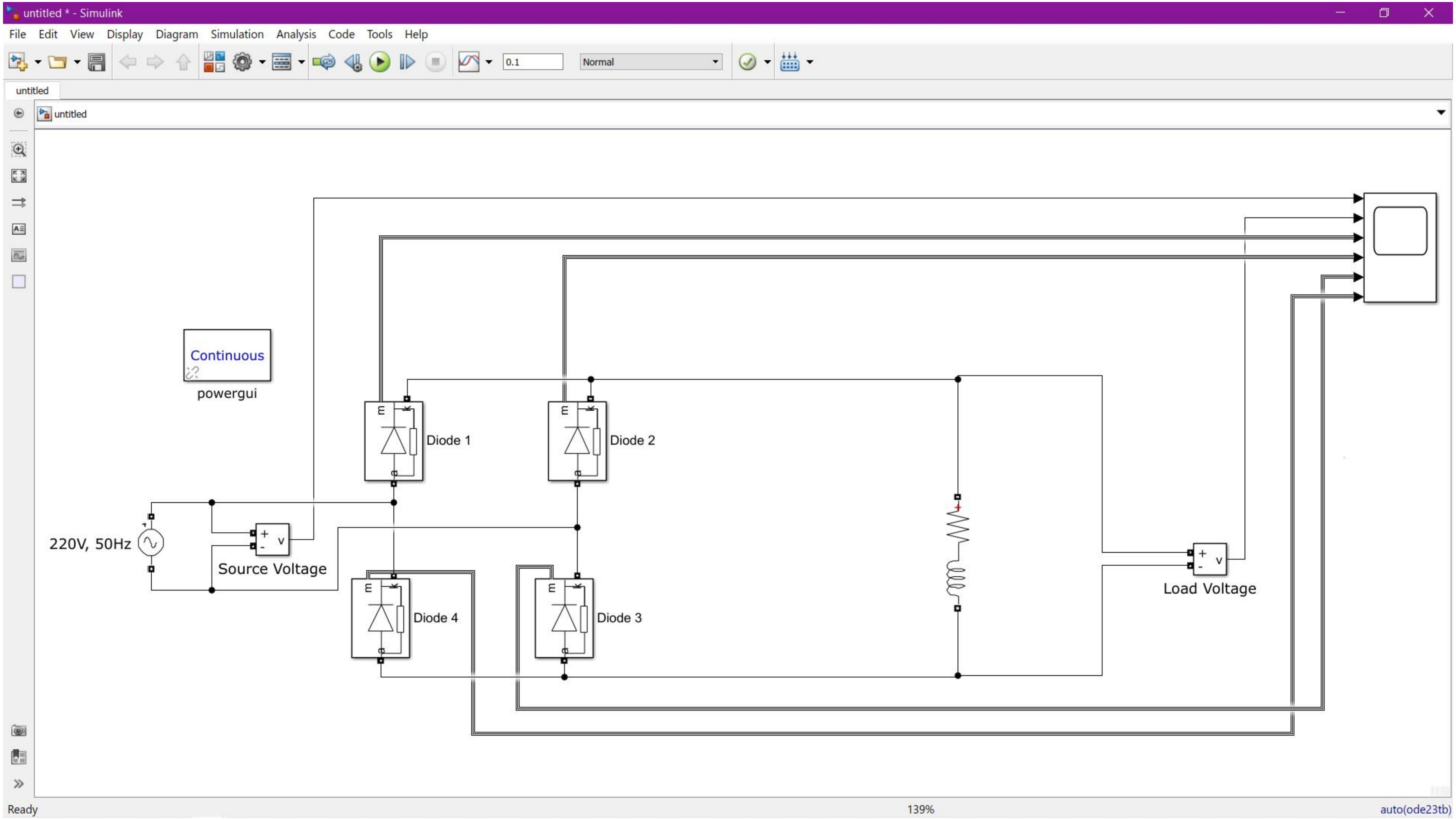
* **Procedure:**

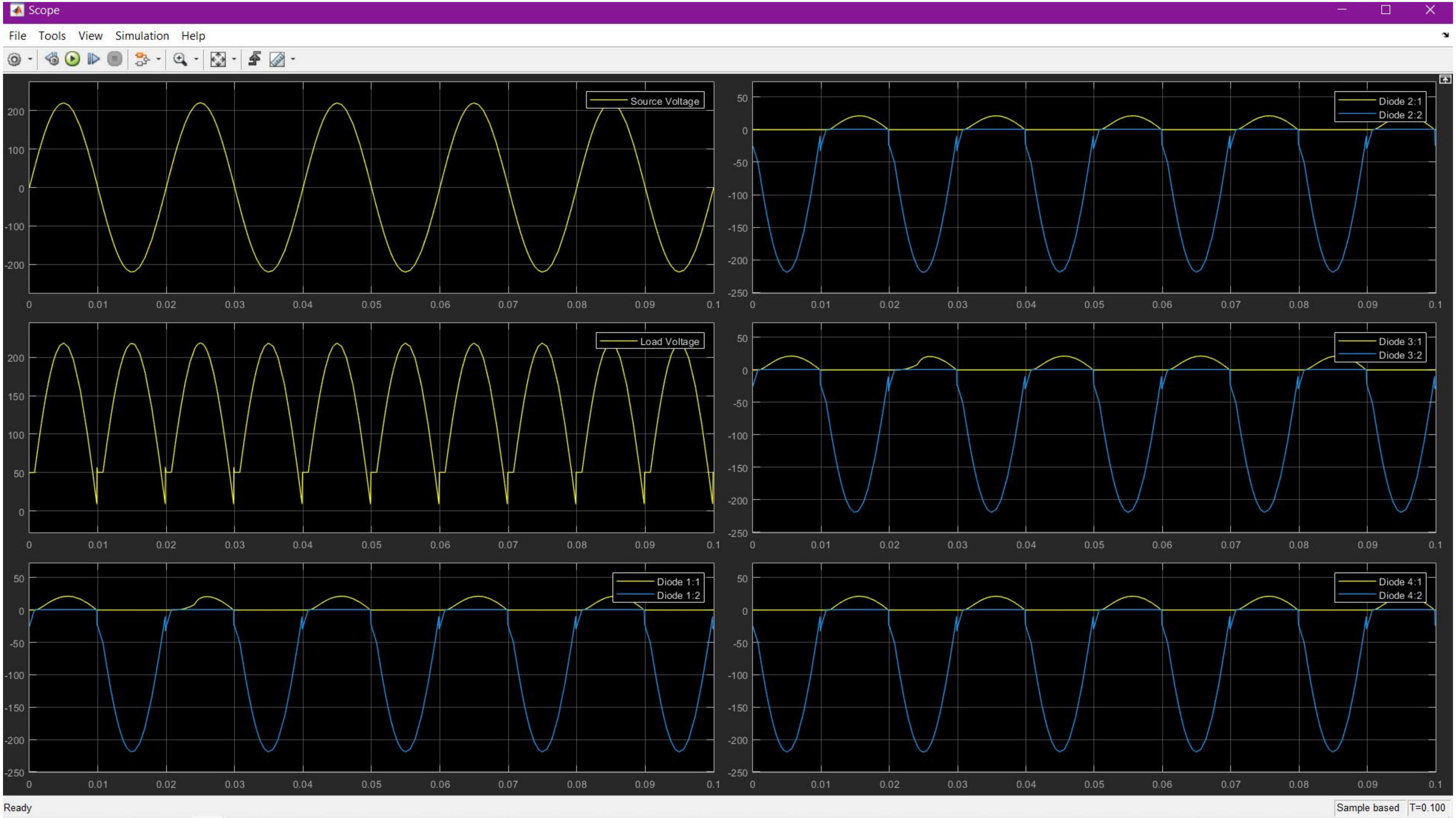
1. Make the required circuit in SIMULINK in MATLAB.
2. Simulate the circuit for 1 second.
3. Observe the waveform from the scope.

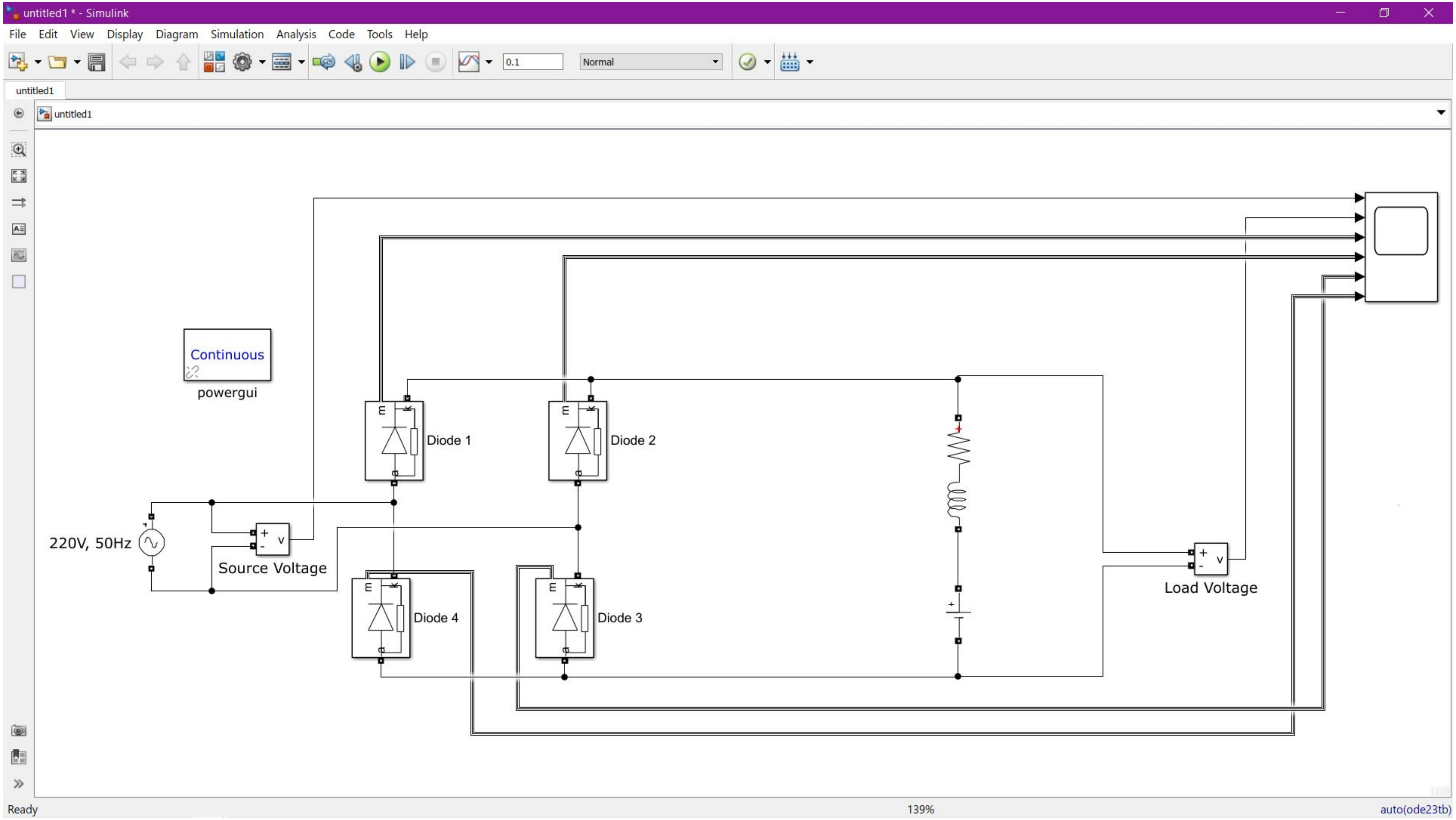
MATLAB Simulation

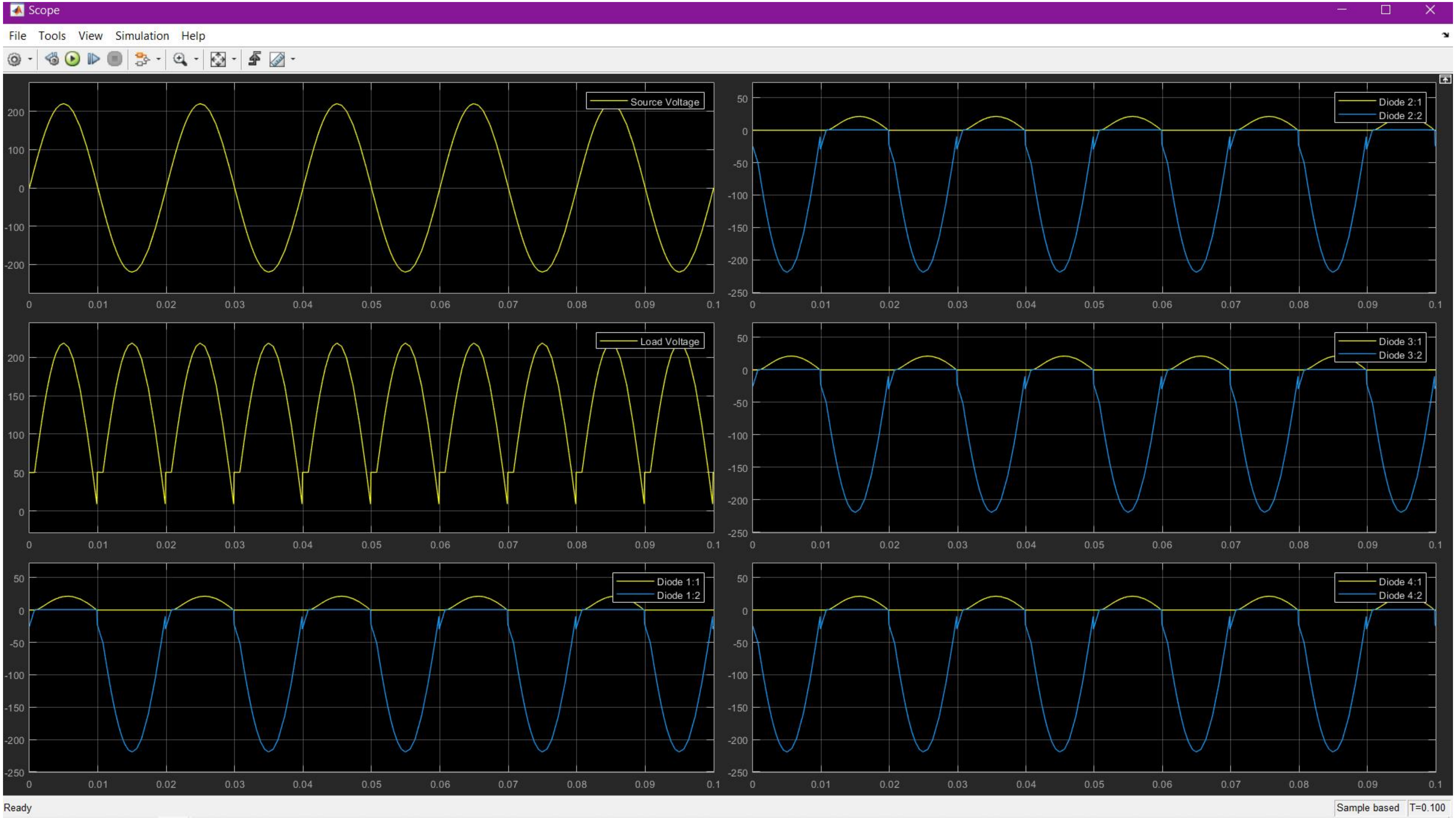



Scope
File Tools View Simulation Help
Source Voltage
Load Voltage
Diode 1:1
Diode 1:2
Diode 2:1
Diode 2:2
Diode 3:1
Diode 3:2
Diode 4:1
Diode 4:2
Ready
Sample based
T=0.100


untitled * - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
0.1
Normal
untitled
untitled
Continuous
powergui
Diode 1
Diode 2
220V, 50Hz
Source Voltage
Diode 4
Diode 3
Load Voltage
Ready
139%
auto(ode23tb)


Scope
File Tools View Simulation Help
Source Voltage
Diode 2:1
Diode 2:2
Load Voltage
Diode 3:1
Diode 3:2
Diode 1:1
Diode 1:2
Diode 4:1
Diode 4:2
Ready
Sample based
T=0.100


untitled1 * - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
0.1
Normal
untitled1
untitled1
Continuous
powergui
Diode 1
Diode 2
Diode 4
Diode 3
220V, 50Hz
Source Voltage
Load Voltage
Ready
139%
auto(ode23tb)


Scope
File Tools View Simulation Help
Source Voltage
Load Voltage
Diode 1:1
Diode 1:2
Diode 2:1
Diode 2:2
Diode 3:1
Diode 3:2
Diode 4:1
Diode 4:2
Ready
Sample based
T=0.100

* **Result**: Simulated the single phase full wave uncontrolled rectifier with R, RL and RLE load by using MATLAB - Simulink.

* **Precautions**:

1. Use powergui to store the equivalent simulink circuit that represents the state-space equation of the Model.
2. Always use closed circuit, never leave wire open.
3. MATLAB takes time to respond, do not give multiple command at once.

Experiment - 3

* **Aim:** To simulate a three phase full wave uncontrolled rectifier in MATLAB Simulink with R, RL and RLE load

* **Requirement:** MATLAB Simulink

* **Theory:** A three phase full wave diode rectifier with ~~R~~ load uses diode to provide an average output voltage of fixed value relative to the value of the input AC voltage. Its commonly used in industry to produce a dc voltage and current for large loads.

$V_{an} = V_m \sin(\omega t)$ $\quad$ $V_{bn} = V_m \sin(\omega t - 2\pi/3)$

$V_{cn} = V_m \sin(\omega t - 4\pi/3)$

$V_{ab} = V_{an} - V_{bn} = \sqrt{3}\, V_m \sin(\omega t + \pi/6)$

$V_{bc} = V_{bn} - V_{cn} = \sqrt{3}\, V_m \sin(\omega t - \pi/2)$

$V_{ca} = V_{cn} - V_{an} = \sqrt{3}\, V_m \sin(\omega t - 7\pi/6)$

$V_{dc} = \dfrac{3\sqrt{3}\, V_m}{\pi} = 1.654\, V_m$ $\quad$ $V_{rms} = 1.655\, V_m$

$I_{dc} = 1.654 \dfrac{V_m}{R}$ $\quad$ $I_{rms} = 0.78\, I_m$

$I_{D(rms)} = 0.552\, I_m$

where, $I_m = 1.73\, V_m/R$

Average Power

$P_{dc} = V_{dc} I_{dc}$.

* Diagram:

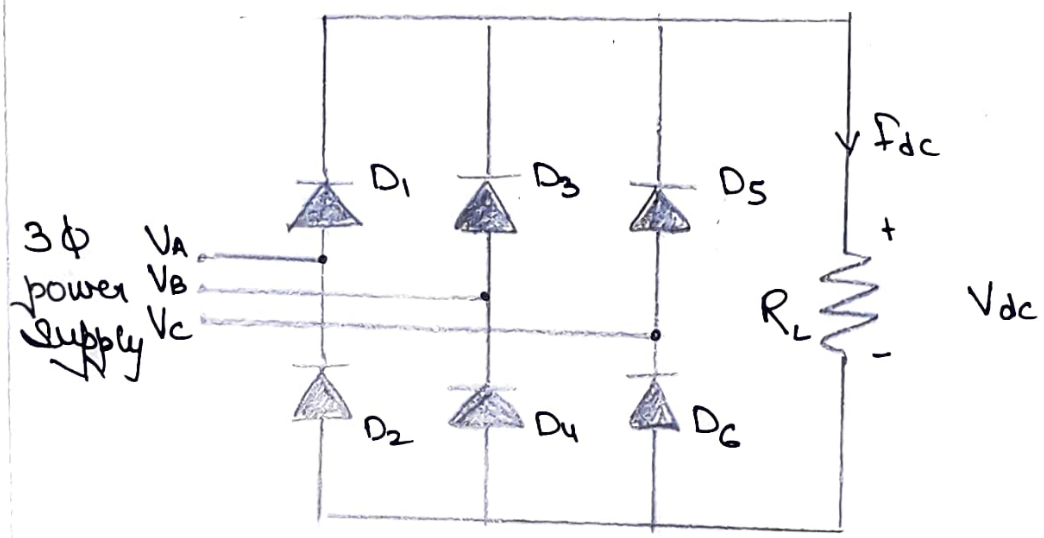
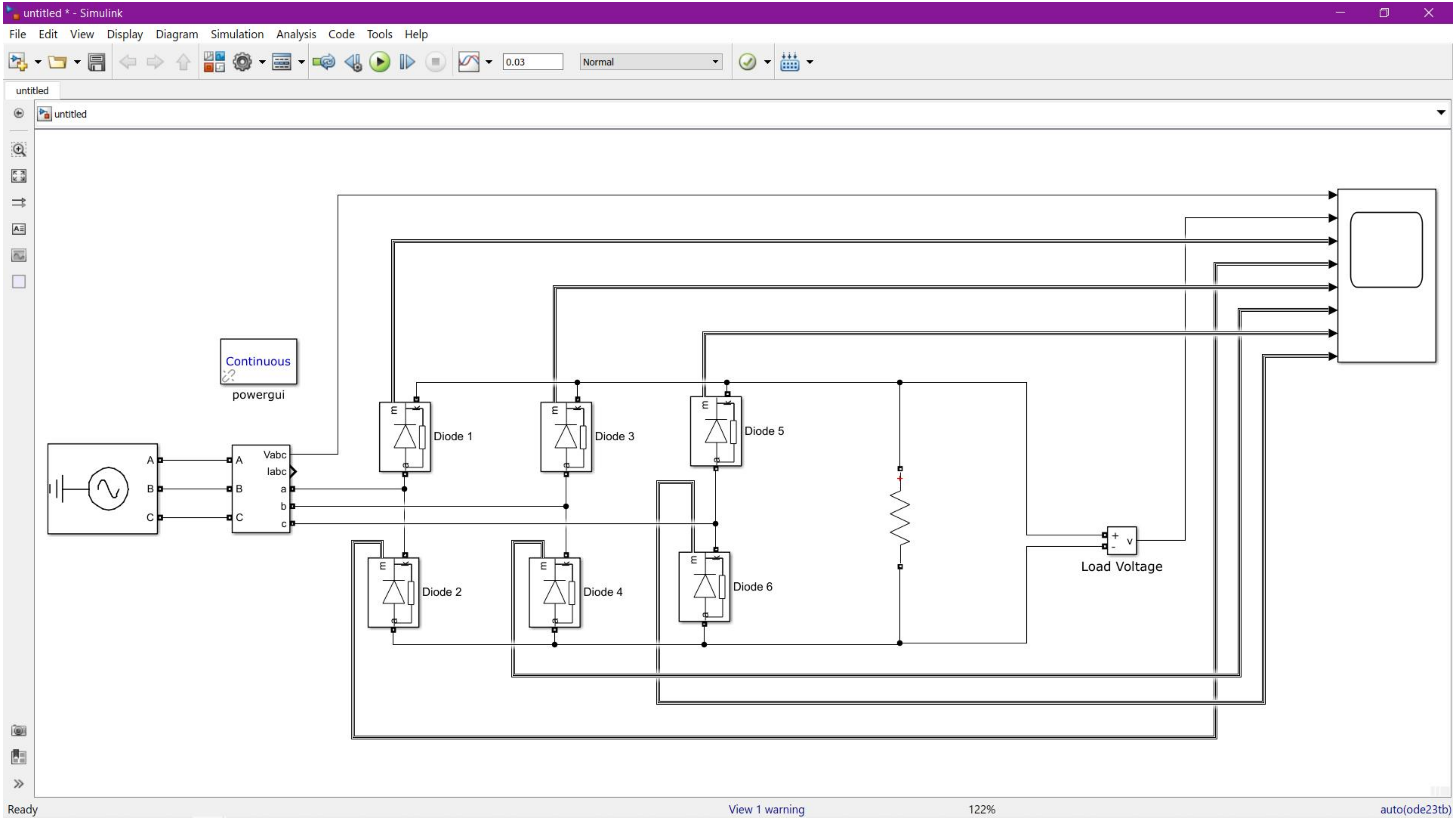
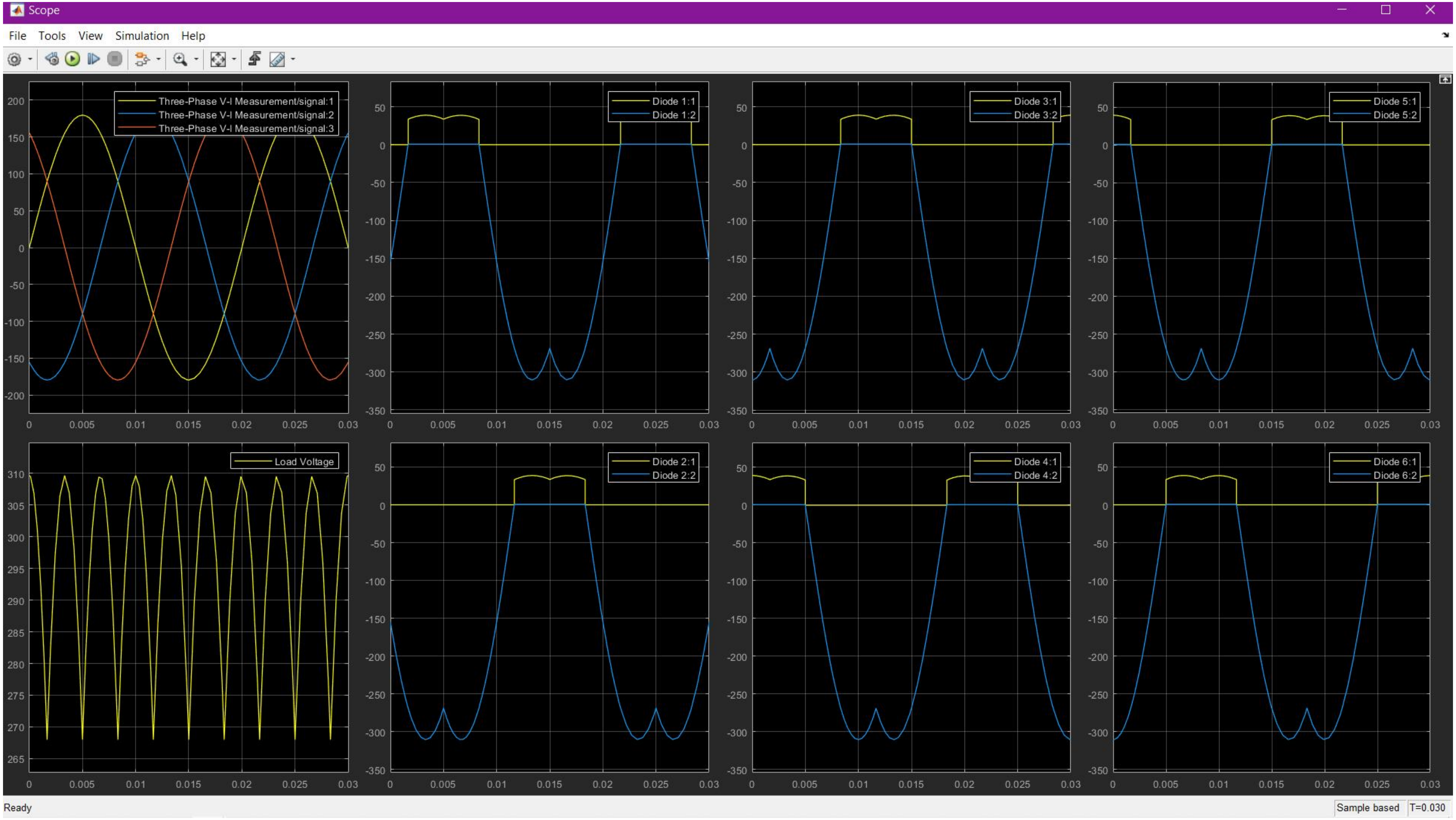


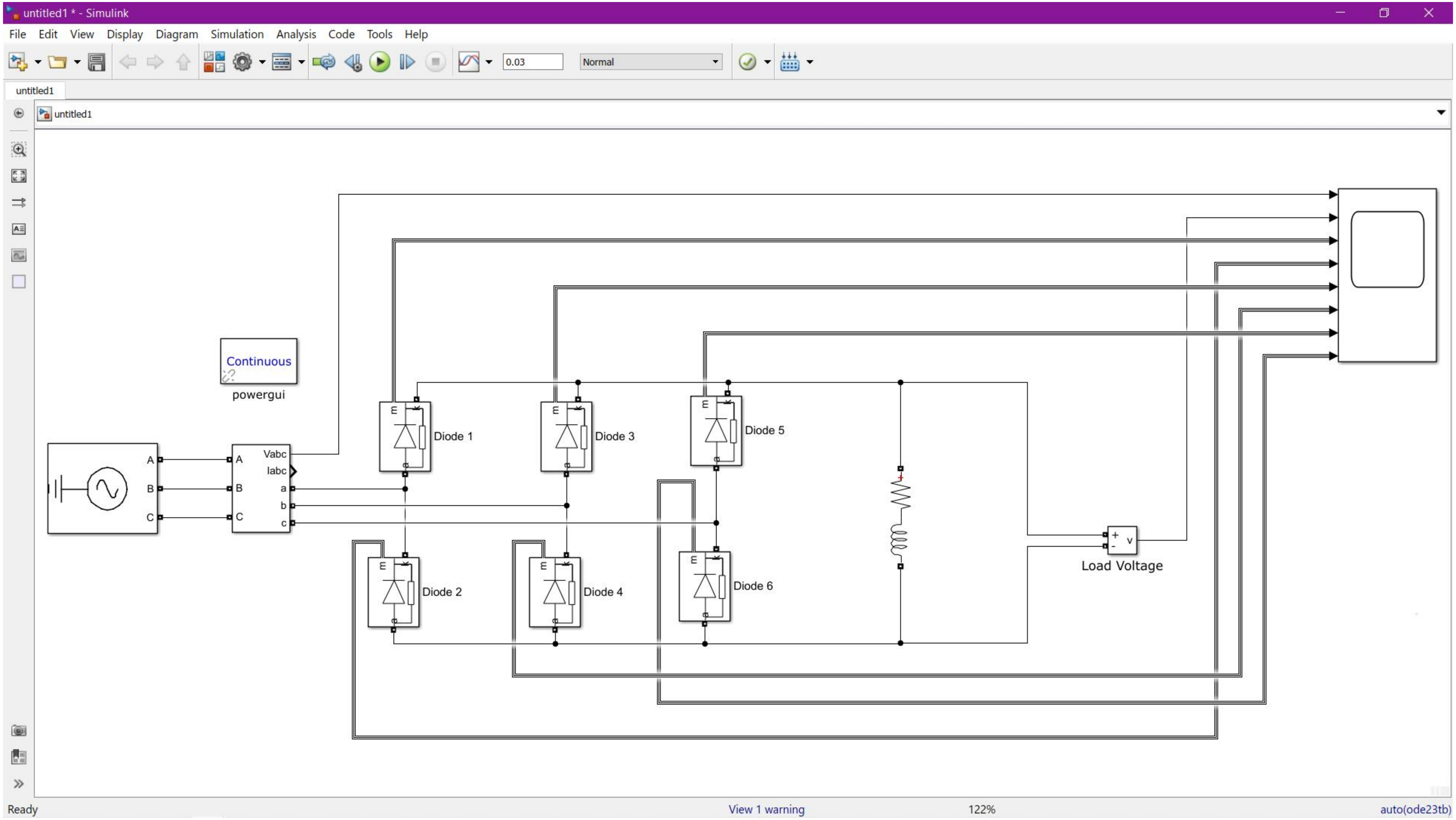
Figure 3.1: Circuit diagram for 3φ full wave uncontrolled rectifier.

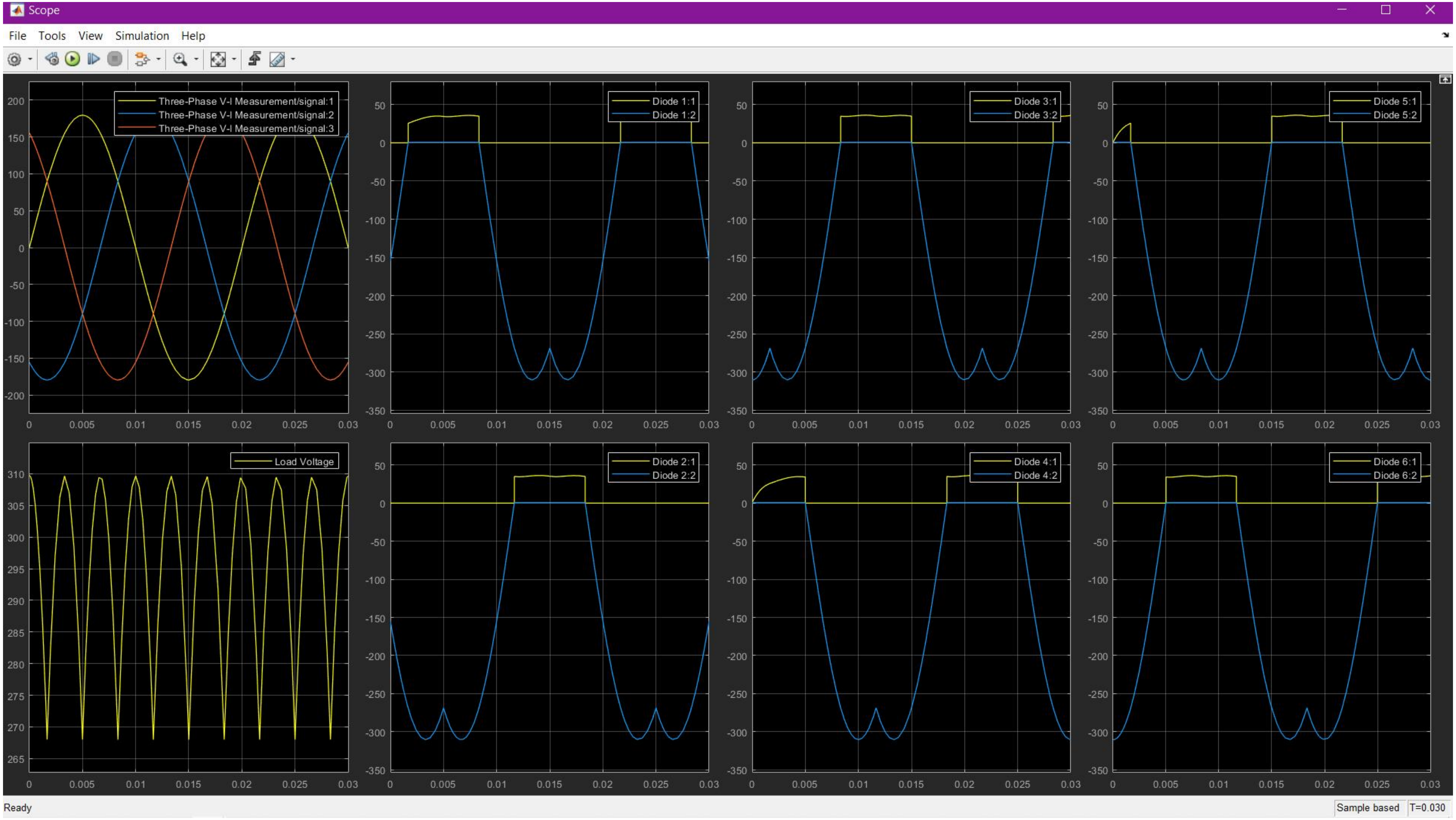
MATLAB Simulation

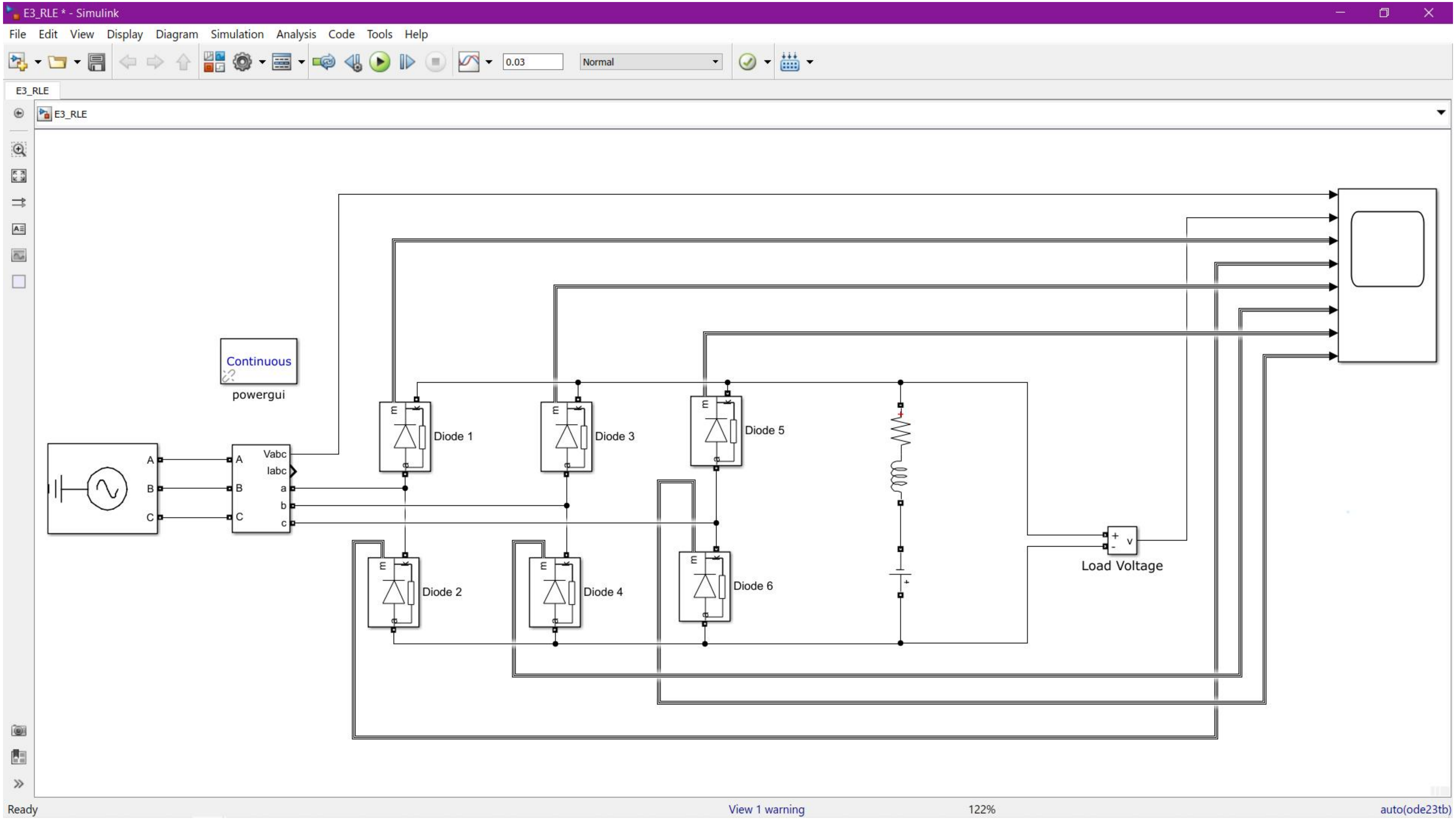


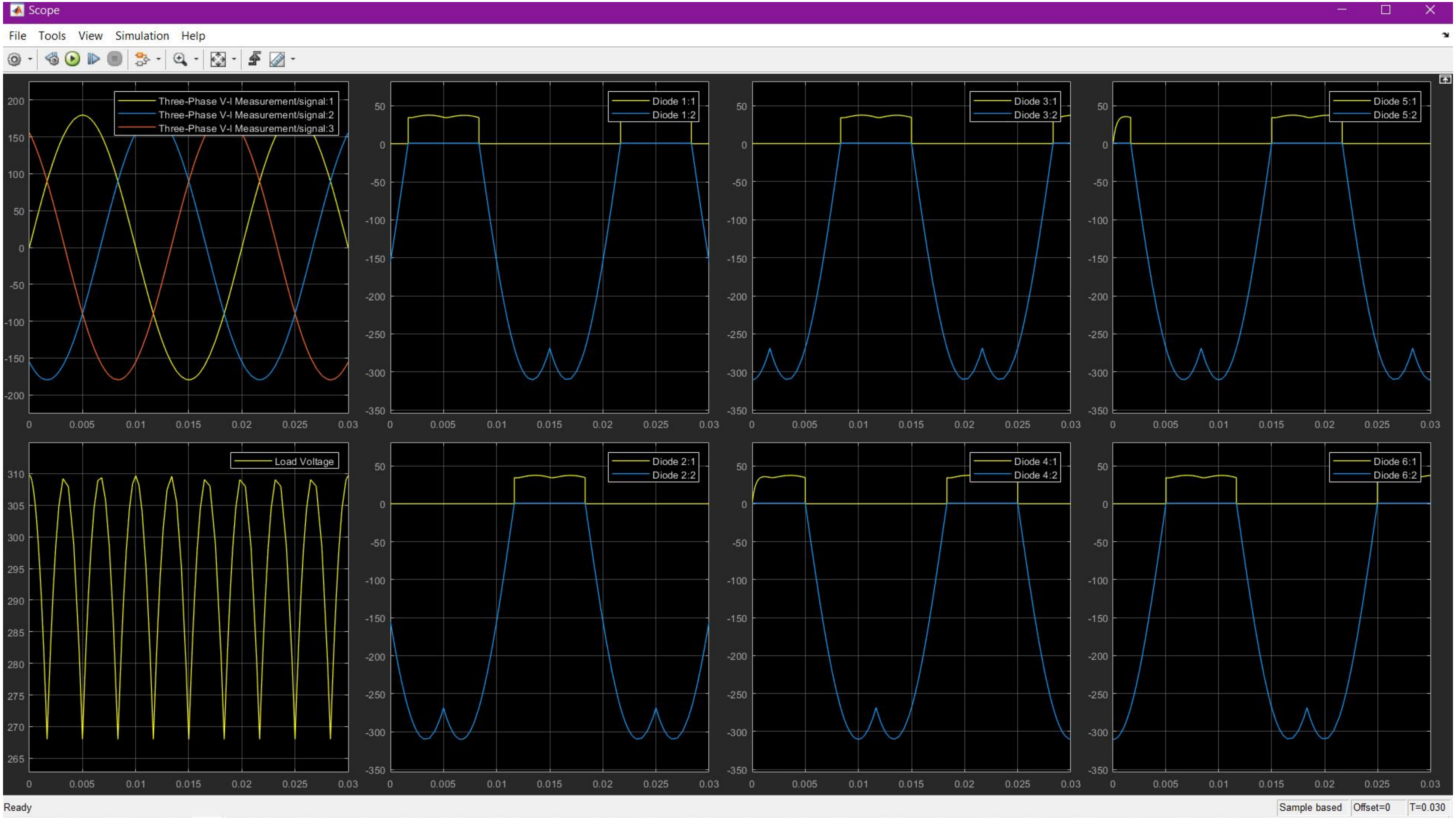


Scope
File Tools View Simulation Help
Three-Phase V-I Measurement/signal:1
Three-Phase V-I Measurement/signal:2
Three-Phase V-I Measurement/signal:3
Diode 1:1
Diode 1:2
Diode 3:1
Diode 3:2
Diode 5:1
Diode 5:2
Load Voltage
Diode 2:1
Diode 2:2
Diode 4:1
Diode 4:2
Diode 6:1
Diode 6:2
Ready
Sample based
T=0.030


untitled1 * - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
0.03
Normal
untitled1
Continuous
powergui
A
B
C
Vabc
Iabc
a
b
c
Diode 1
Diode 2
Diode 3
Diode 4
Diode 5
Diode 6
Load Voltage
Ready
View 1 warning
122%
auto(ode23tb)


Scope
File Tools View Simulation Help
Three-Phase V-I Measurement/signal:1
Three-Phase V-I Measurement/signal:2
Three-Phase V-I Measurement/signal:3
Diode 1:1
Diode 1:2
Diode 3:1
Diode 3:2
Diode 5:1
Diode 5:2
Load Voltage
Diode 2:1
Diode 2:2
Diode 4:1
Diode 4:2
Diode 6:1
Diode 6:2
Ready
Sample based
T=0.030


E3_RLE * - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
0.03
Normal
E3_RLE
Continuous
powergui
A
B
C
Vabc
Iabc
a
b
c
Diode 1
Diode 2
Diode 3
Diode 4
Diode 5
Diode 6
Load Voltage
Ready
View 1 warning
122%
auto(ode23tb)


Scope
File Tools View Simulation Help
Three-Phase V-I Measurement/signal:1
Three-Phase V-I Measurement/signal:2
Three-Phase V-I Measurement/signal:3
Diode 1:1
Diode 1:2
Diode 3:1
Diode 3:2
Diode 5:1
Diode 5:2
Load Voltage
Diode 2:1
Diode 2:2
Diode 4:1
Diode 4:2
Diode 6:1
Diode 6:2
Ready
Sample based
Offset=0
T=0.030

* **Procedure:**

1. Make the required circuit in SIMULINK in MATLAB.
2. Simulate the model for 1 seconds.
3. Observe the waveform from the scope.

* **Result:** Simulated a three phase full wave uncontrolled rectifier in MATLAB Simulink with R, RL and RLE load.

* **Precautions:**

1. Use power gui to store the equipment simulink circuit that represents the sate-space equation of the model.
2. Always use closed circuit, never leave wire open.
4. MATLB takes time to respond, do not give multiple command at once.

Experiment - 4

* **Aim:** To simulate of single-phase half wave controlled rectifier for R, RL, RLE and also use free wheeling diode by using MATLAB-simulink.

* **Requirement:** MATLAB- Simulink.

* **Theory:** A single phase half wave controlled rectifier circuit of SCR/ thyristor, an AC voltage source and load. The load may be purely resistive, Inductive or a combination of resistance and inductance. For load output voltage V_o, load current i_o and voltage across the thyristor V_T.

$$V_s = V_m \sin(\omega t)$$

Let us go ahead, assume that thyristor T is fired at a firing angle of α. This means when $\omega t = \alpha$, gate signal will be applied and SCR will start conducting. Thyristor T is forward bias for the positive half cycle of supply voltage. The load output voltage is zero till SCR is fired. At α, SCR ~~stra~~ starts conducting. At $\omega t = \pi$, voltage become zero, and after $\omega t = \pi$ SCR is reversed biased. till next firing ~~SCR~~ thyristor will remain OFF.

$$V_o = V_m \sin(\omega t) \qquad \text{for } \alpha \le \omega t \le \pi$$

$$i_o = \frac{V_m \sin(\omega t)}{R} \qquad \text{for } \alpha \le \omega t \le \pi$$

* Diagram:

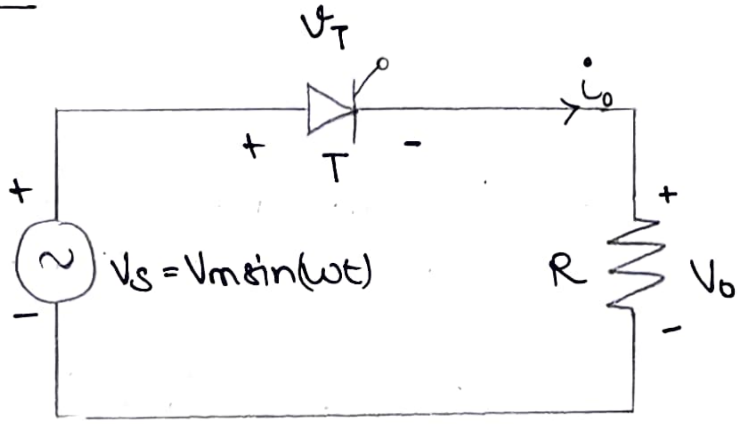


Figure 4.1: Circuit Diagram of 1φ half wave controlled rectifier.

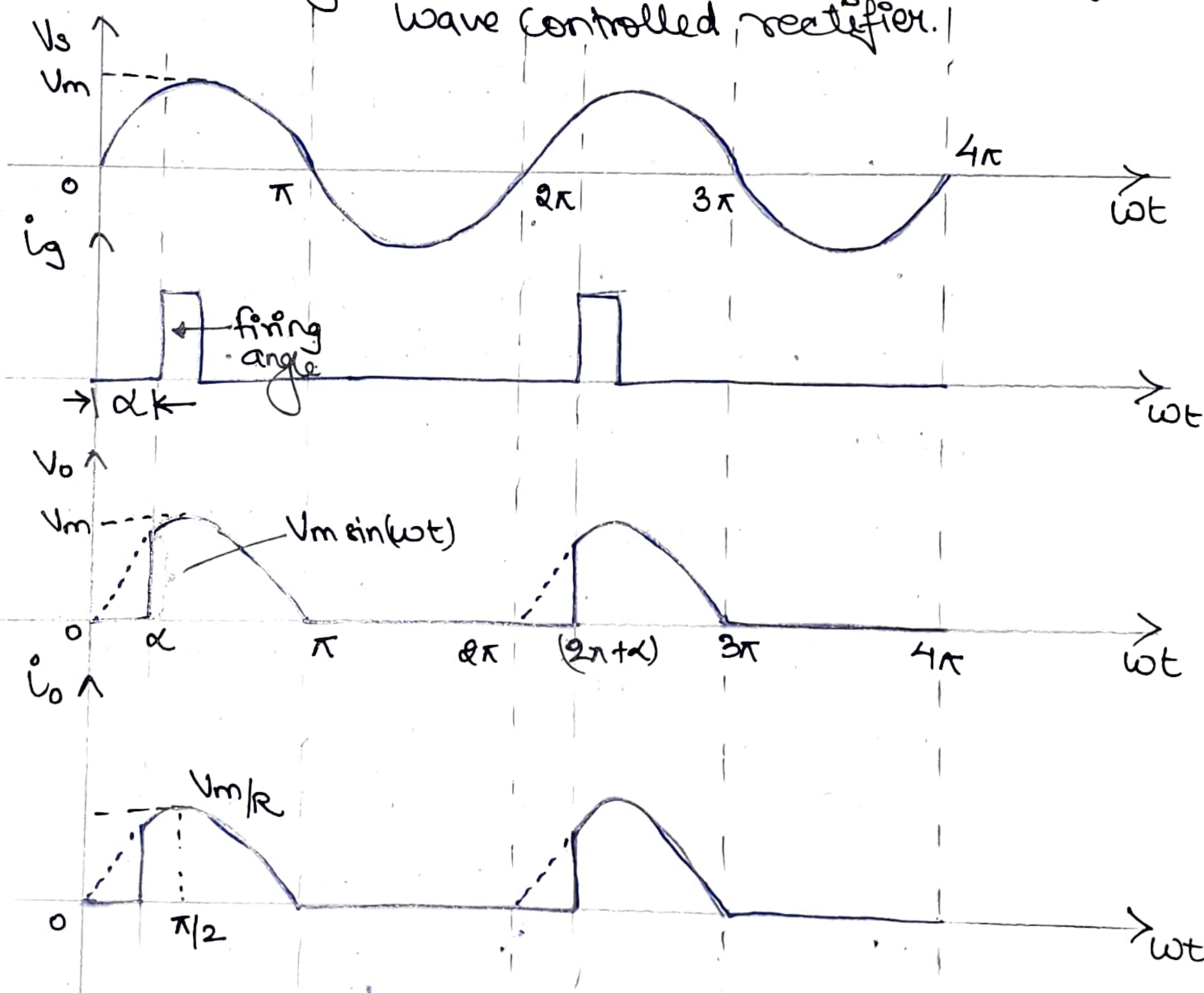


Figure 4.2: Waveform of 1φ half wave controlled rectifier.

→ Average value

$$V_{o(avg)} = \left(\frac{V_m}{2\pi}\right)[1+\cos\alpha]$$

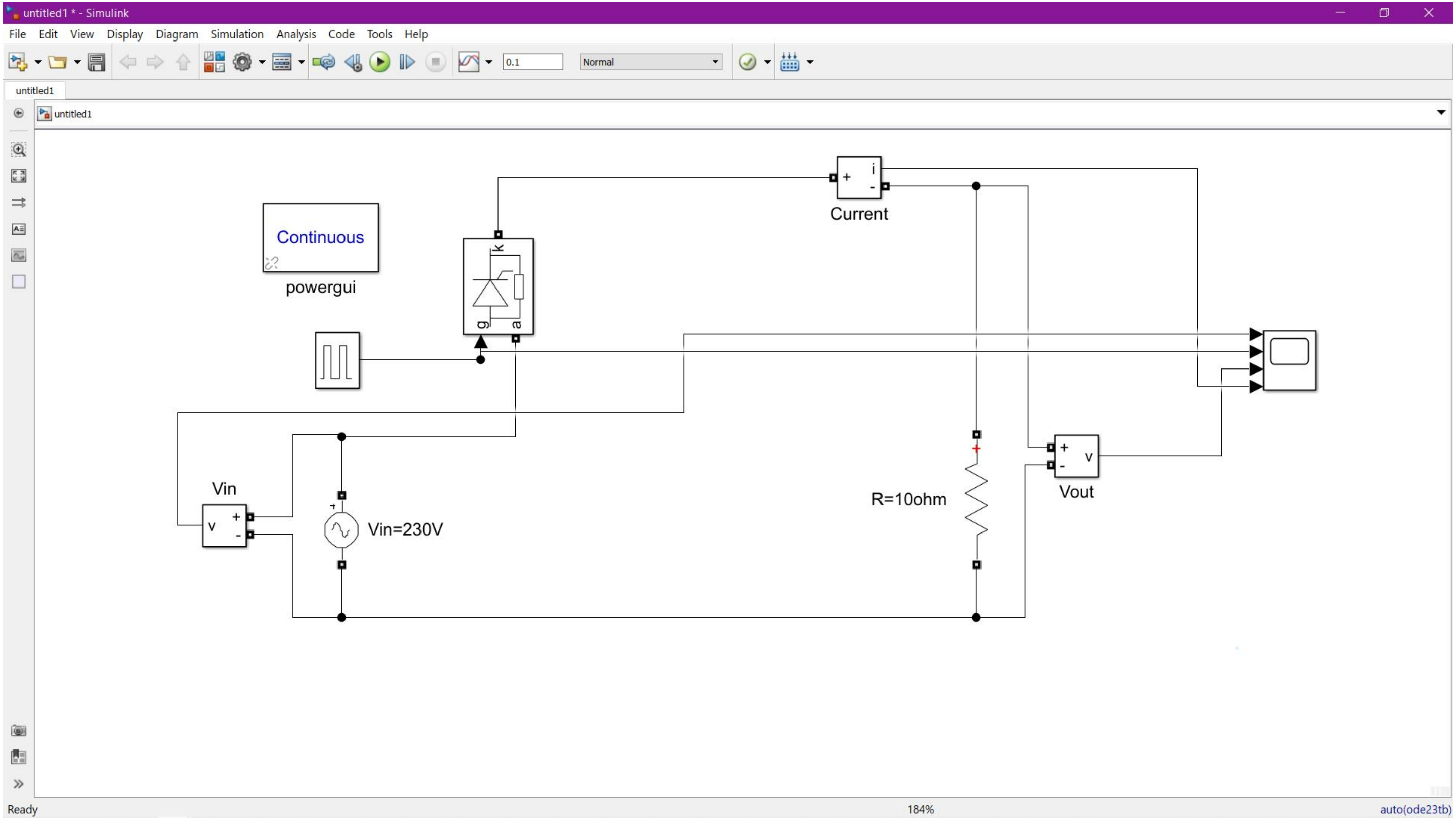
→ RMS value

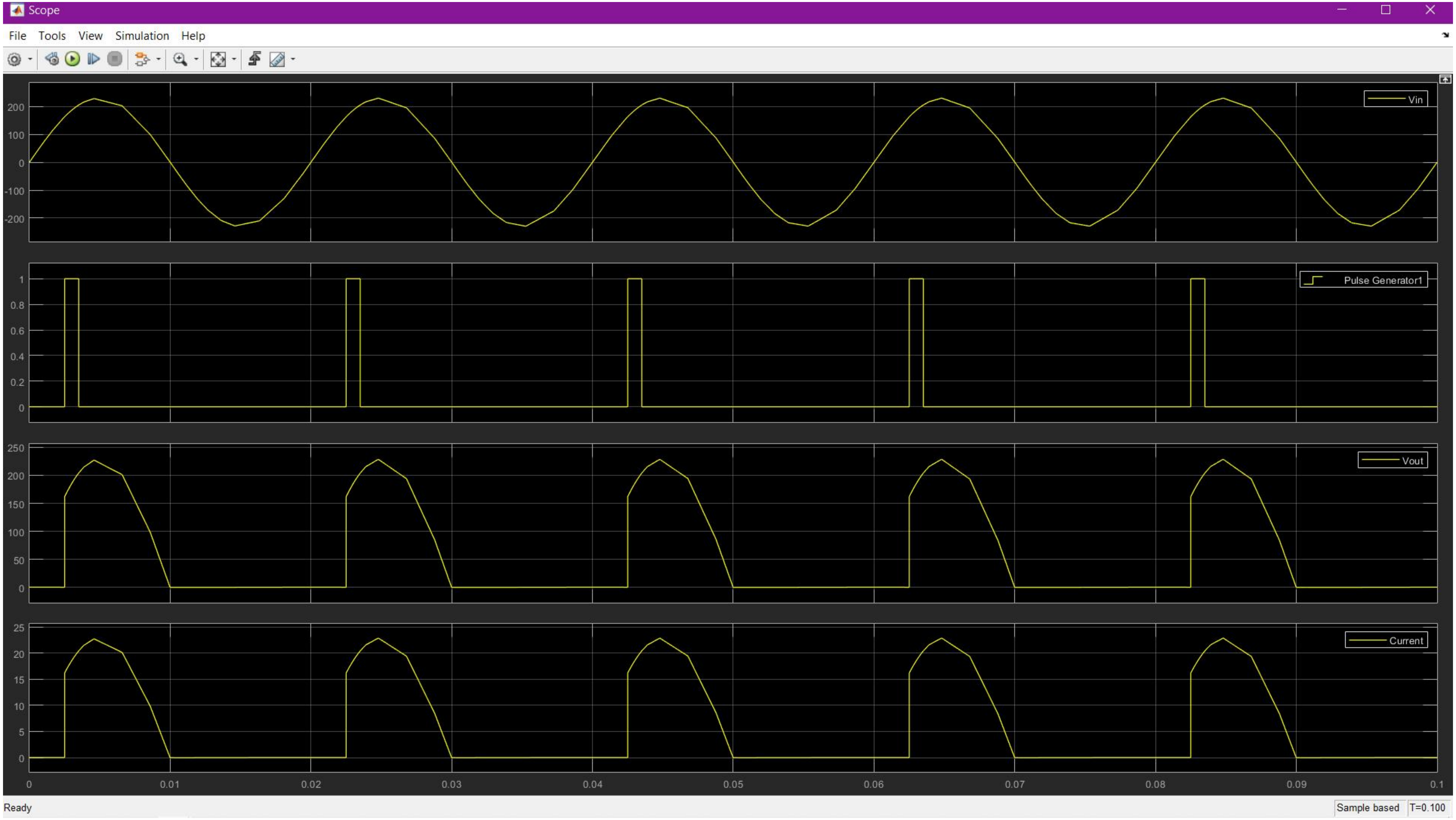
$$V_{o(rms)} = \frac{V_m}{2\sqrt{\pi}}\sqrt{(\pi-\alpha)+\frac{\sin 2\alpha}{2}}$$

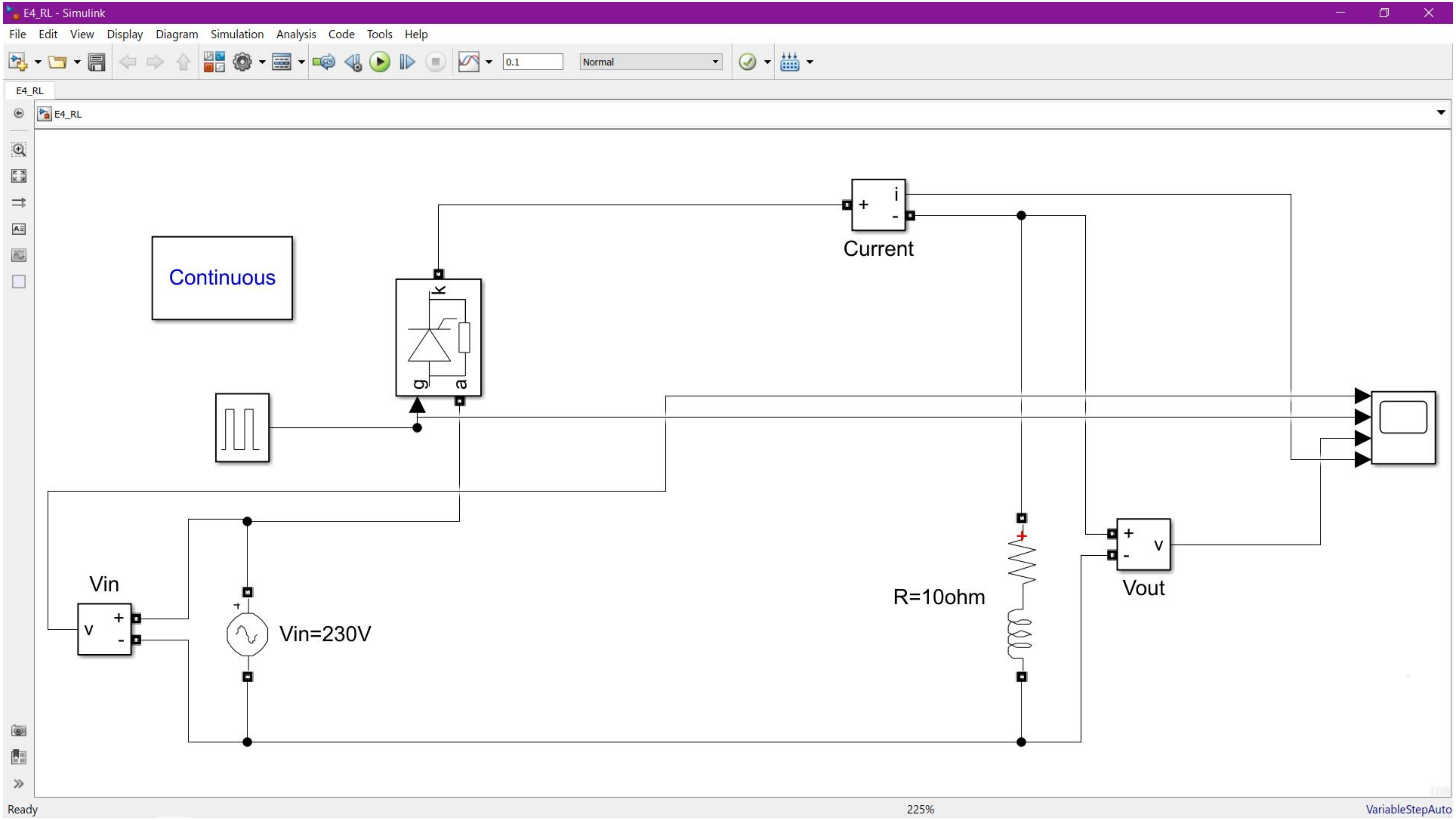
* Procedure:

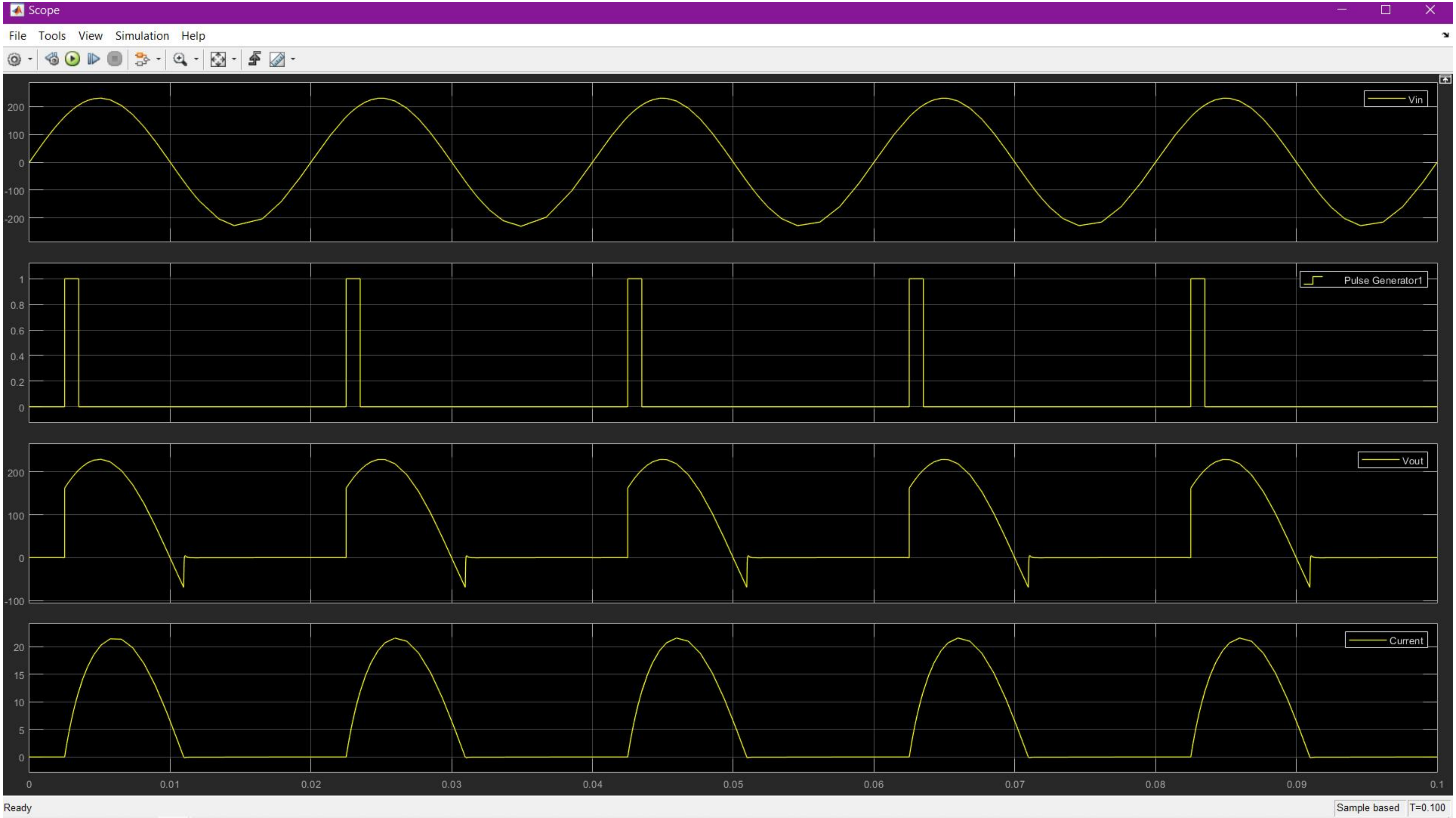
1. Make the required circuit in SIMULINK in MATLAB.
2. Simulate the circuit for 1 seconds.
3. Observe the waveform form scope.

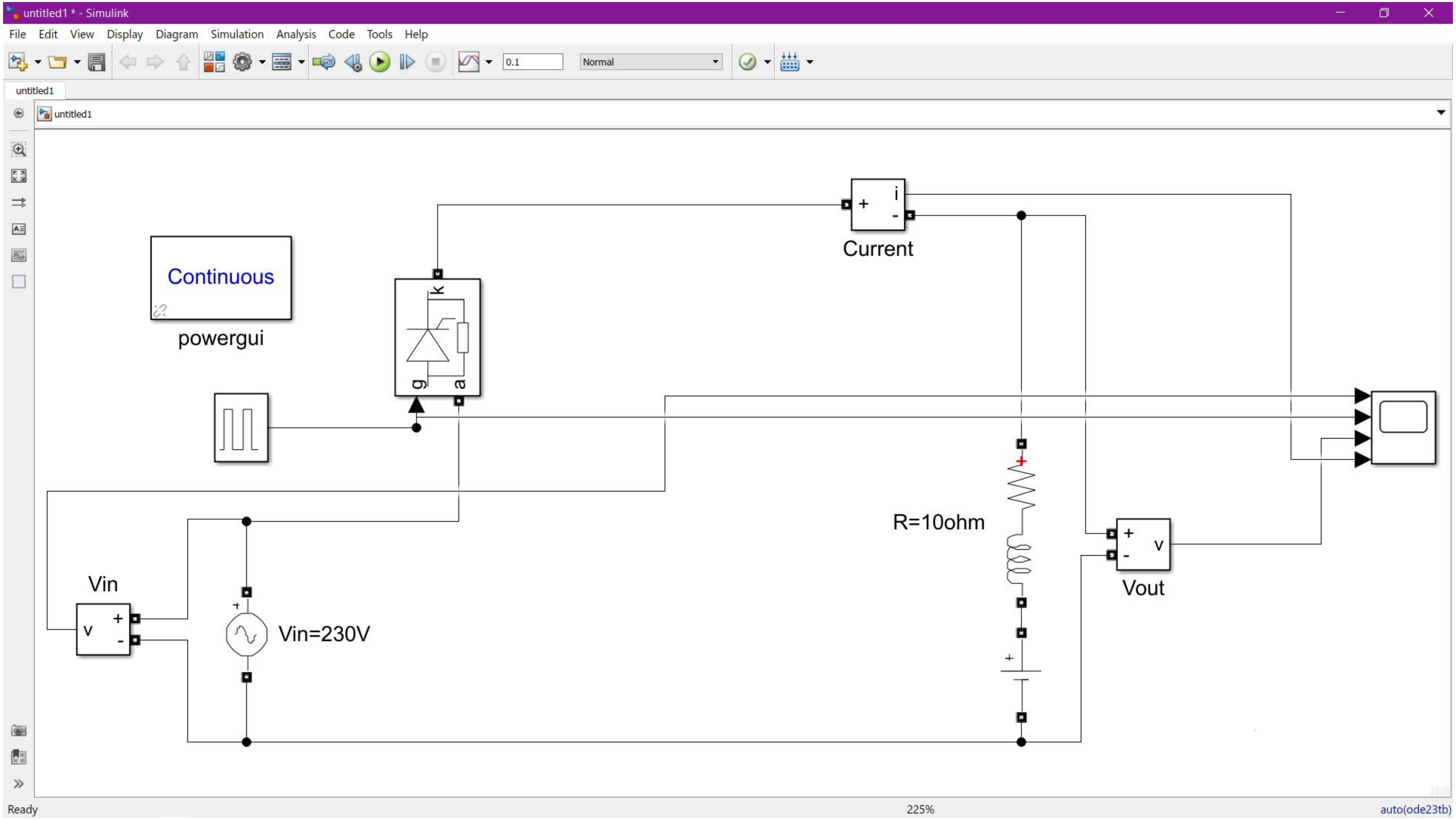
MATLAB Simulation

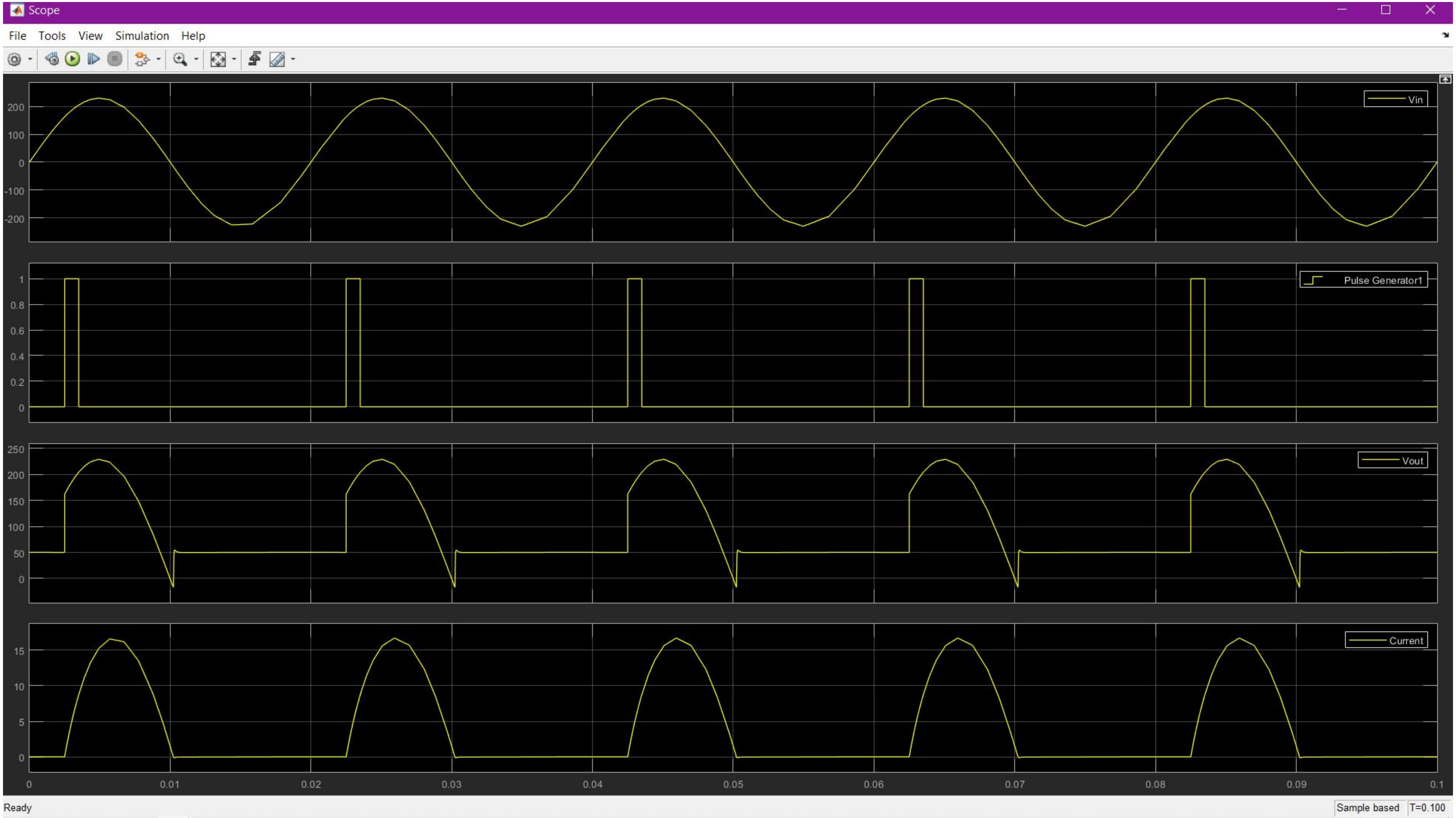


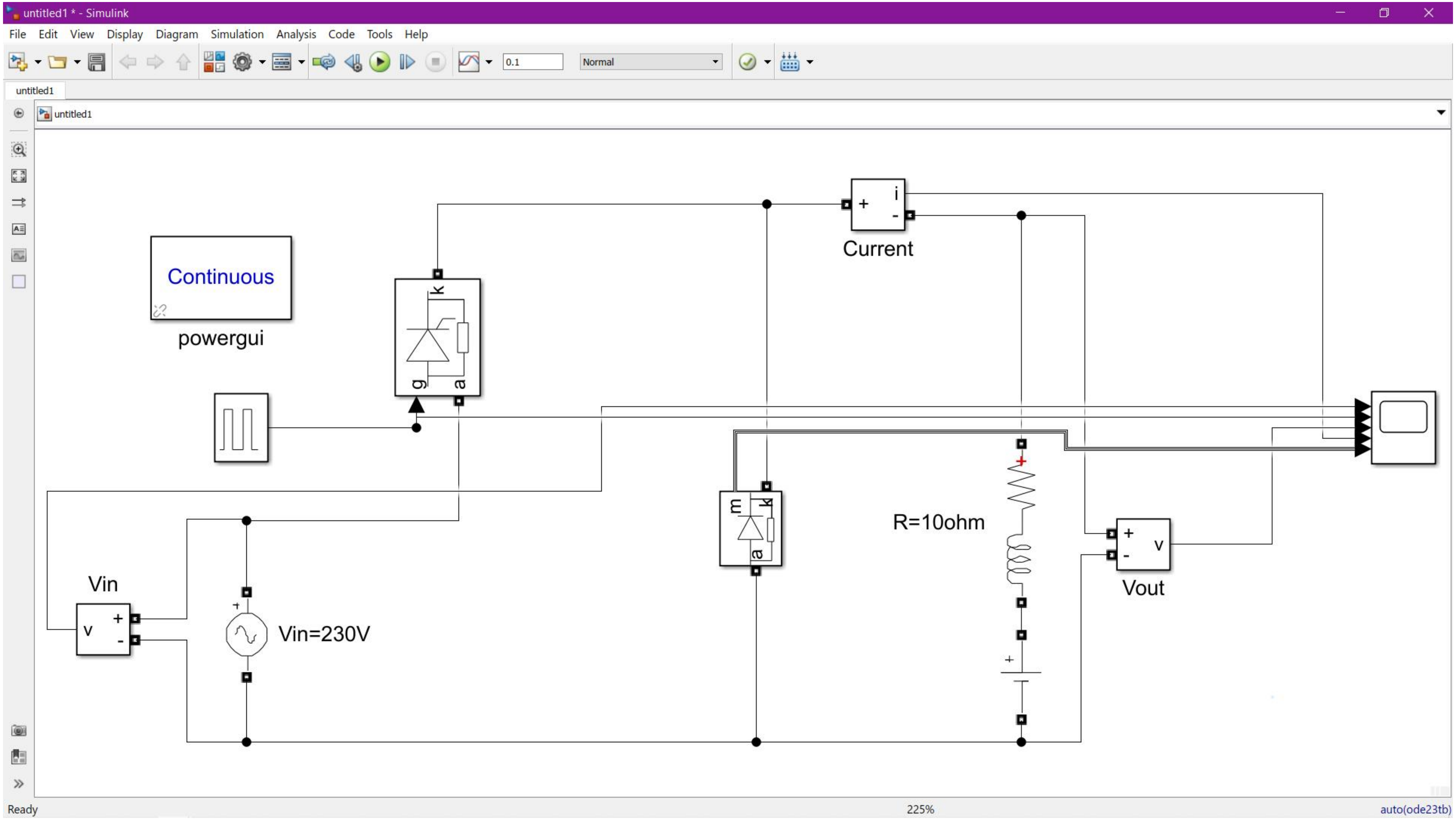

Scope
File Tools View Simulation Help
Vin
Pulse Generator1
Vout
Current
200
100
0
-100
-200
1
0.8
0.6
0.4
0.2
0
250
200
150
100
50
0
25
20
15
10
5
0
0 0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09 0.1
Ready
Sample based T=0.100

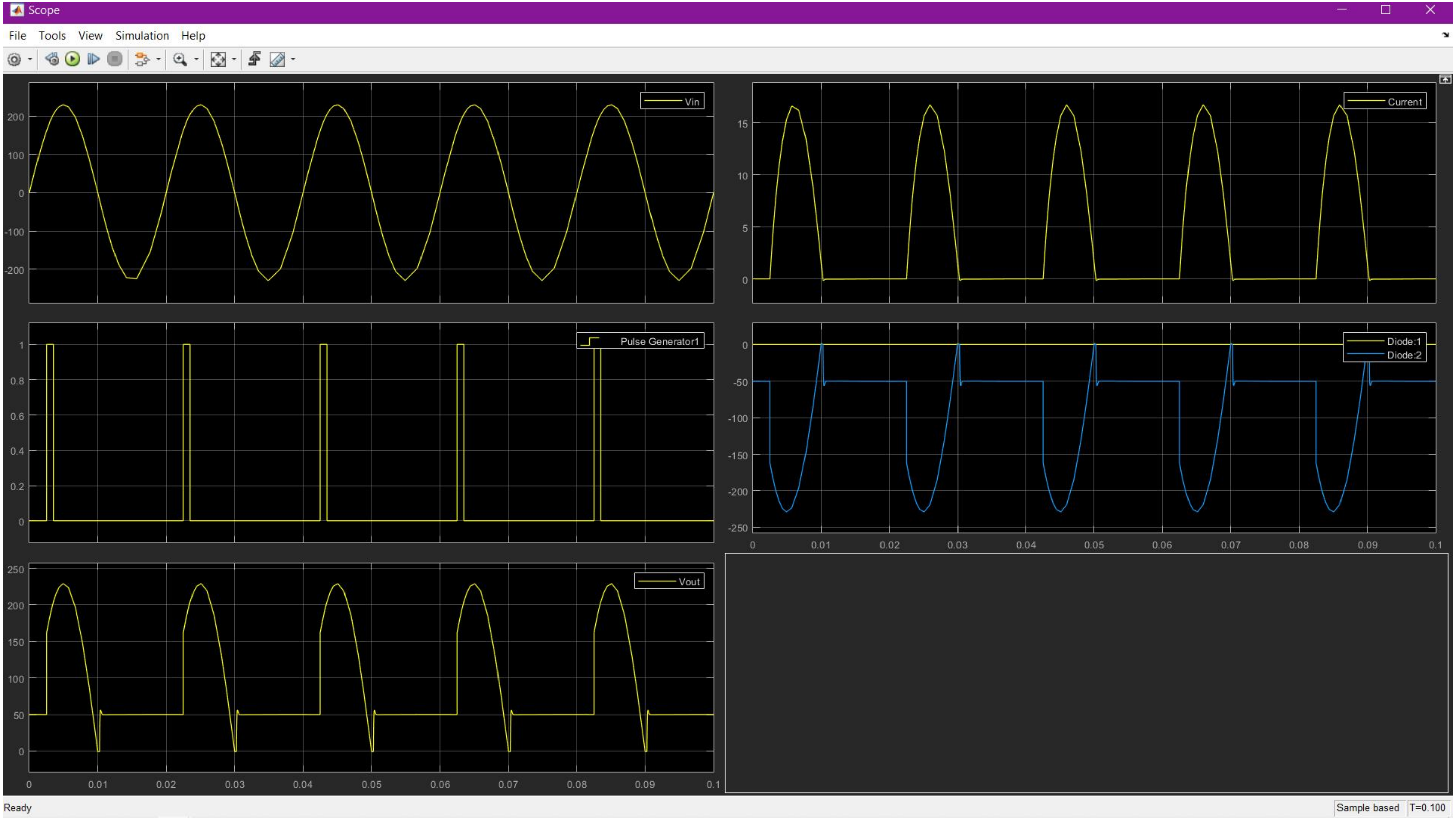

E4_RL - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
0.1
Normal
E4_RL
Continuous
Current
k
g
a
Vin
Vin=230V
R=10ohm
Vout
Ready
225%
VariableStepAuto


Scope
File Tools View Simulation Help
Vin
Pulse Generator1
Vout
Current
Ready
Sample based
T=0.100


untitled1 * - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
0.1
Normal
untitled1
untitled1
Continuous
powergui
Current
R=10ohm
Vout
Vin
Vin=230V
Ready
225%
auto(ode23tb)


Scope
File Tools View Simulation Help
Vin
Pulse Generator1
Vout
Current
Ready
Sample based
T=0.100


untitled1 * - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
0.1
Normal
untitled1
untitled1
Continuous
powergui
k
g
a
Current
i
m
k
a
R=10ohm
Vin
v
Vin=230V
Vout
v
Ready
225%
auto(ode23tb)


Scope
File Tools View Simulation Help
Vin
Current
Pulse Generator1
Diode:1
Diode:2
Vout
Ready
Sample based
T=0.100

* **Result**: Simulated the single-phase half wave controlled rectifier for Ri, RL, RLE and with free wheeling diode by using MATLAB SIMULINK.

* **Precautions**:

1. Use powergui to store the equipment equivalent simulink circuit that represents the state-space equations of the model.
2. Always use closed circuit, never leave wire open.
3. MATLAB takes time to respond, do not give multiple command at once.

Experiment - 5

* **Aim:** Simulate of single phase full wave controlled rectifier for R, RL, RLE and also use freewheeling diode by using MATLAB - Simulink.

* **Requirement:** MATLAB - Simulink

* **Theory:**

The figure shows a fully controlled bridge rectifier, which uses four thyristors to control the average load voltage.
Thyristors T_1 & T_2 must be fired simultaneously during the positive half wave of the source voltage V_s to allow conduction of current. To ensure simultaneous firing, thyristors T_1 & T_2 use the same firing signal.
Alternatively, thyristors T_3 and T_4 must be fired simultaneously during the negative half wave of the source voltage.

- Average values.

$$V_{dc} = V_o = \frac{1}{\pi}\int_{\alpha}^{\pi} V_m \sin(\omega t)\, d(\omega t)$$

$$= \frac{V_m}{\pi}(1+\cos\alpha)$$

$$I_{dc} = \frac{V_{dc}}{R} = \frac{V_m}{\pi R}(1+\cos\alpha)$$

- RMS Values

$$V_{rms} = \sqrt{\frac{1}{\pi}\int_{\alpha}^{\pi}(V_m \sin\omega t)^2 d\omega t}$$

* Diagram:

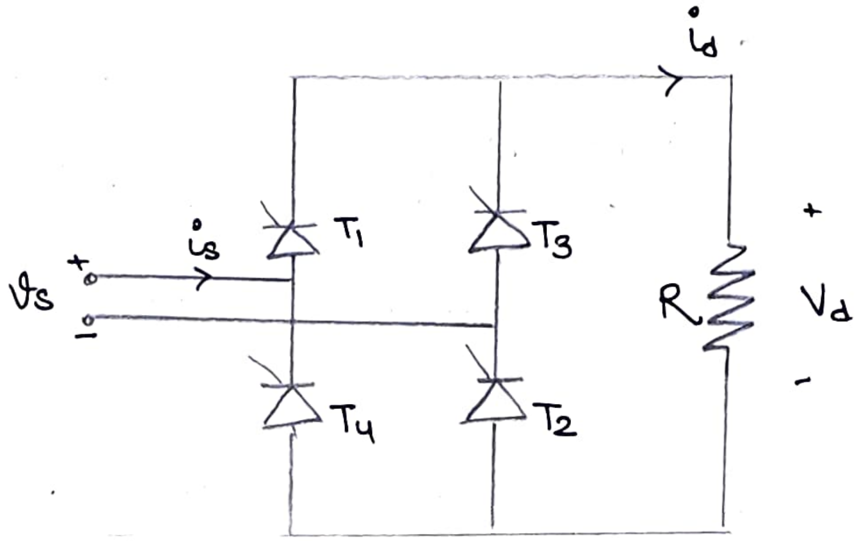


Figure 5.1: Circuit diagram of 1ϕ full wave controlled rectifier.

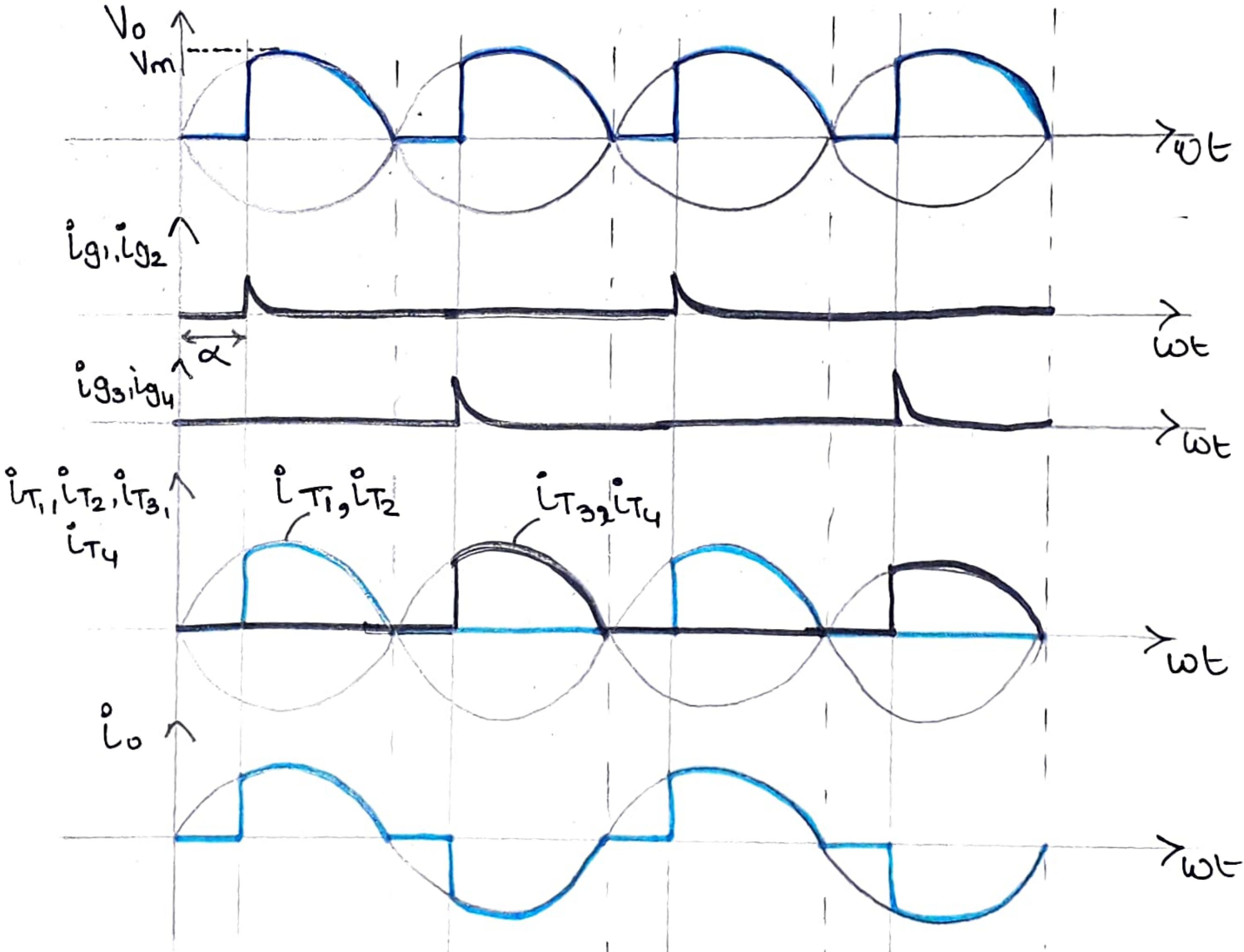


Figure 5.2: Waveform of 1ϕ full wave controlled rectifier.

$$= V_m \sqrt{\frac{1}{2} - \frac{\alpha}{2\pi} + \frac{\sin(2\alpha)}{4\pi}}$$

$$I_{rms} = \frac{V_{rms}}{R} = \frac{V_m}{R} \sqrt{\frac{1}{2} - \frac{\alpha}{2\pi} + \frac{\sin(2\alpha)}{4\pi}}$$

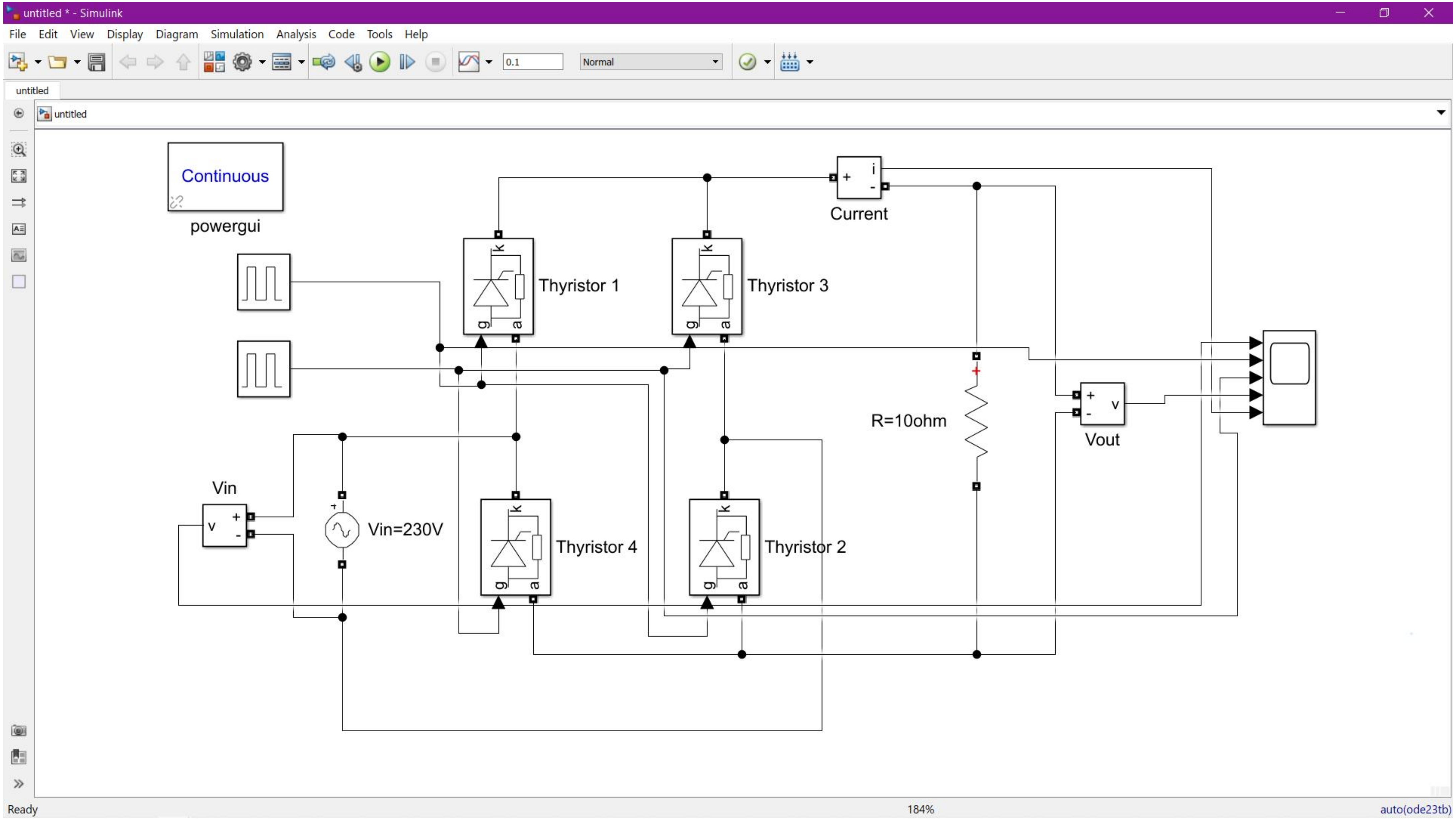
— Power delivered

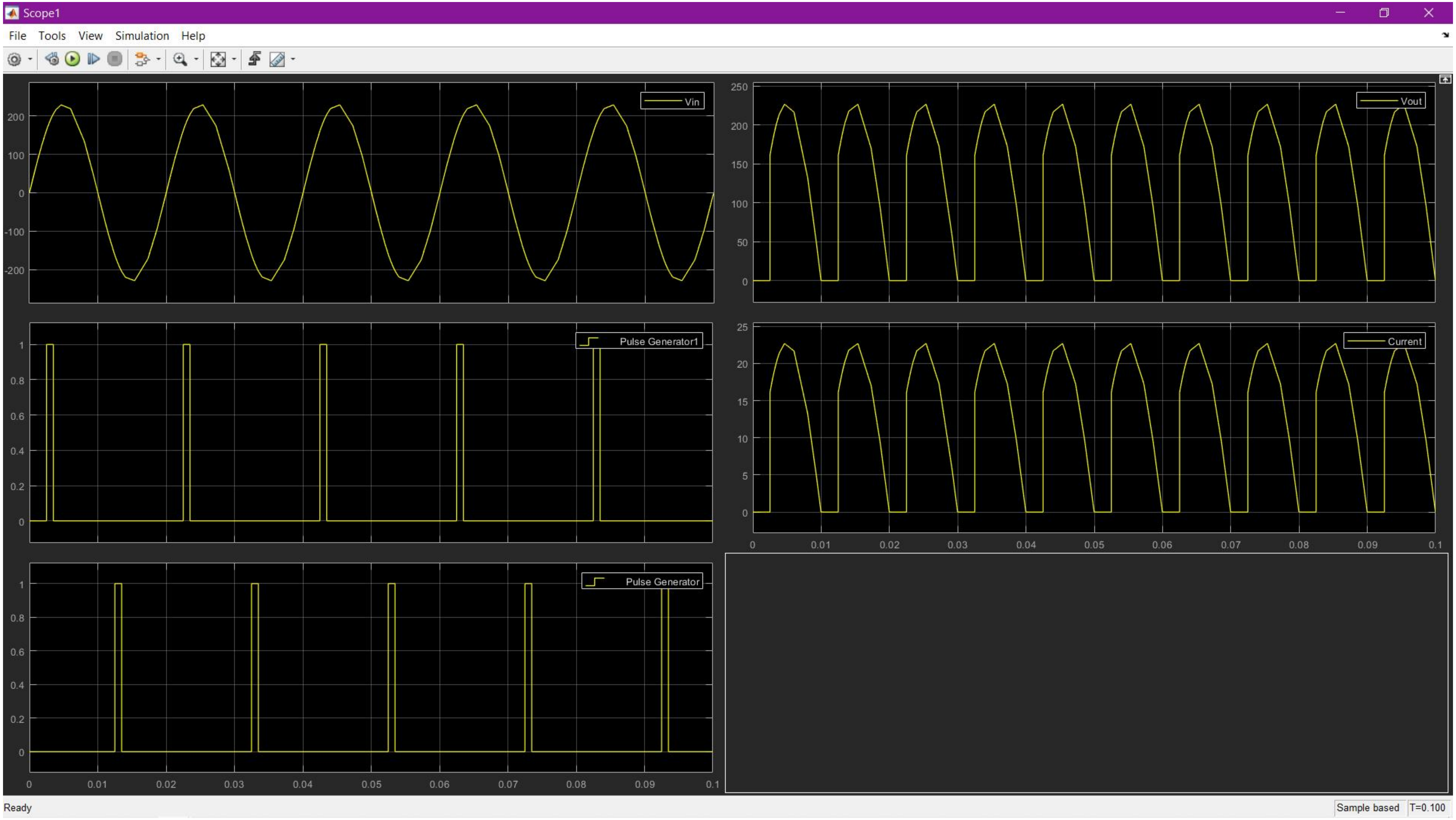
$$P = I_{rms}^2 R$$

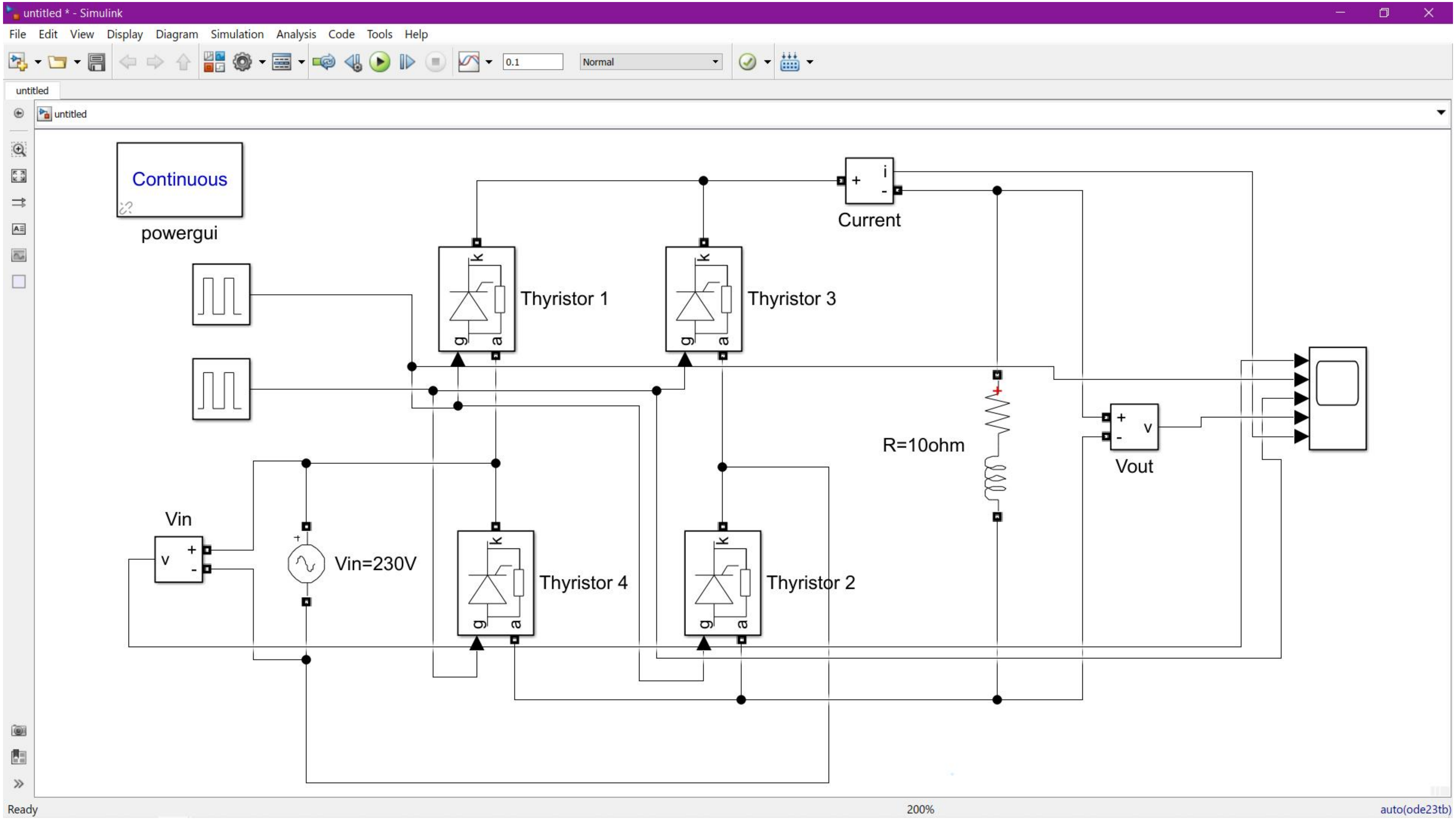
* <u>Procedure</u>:

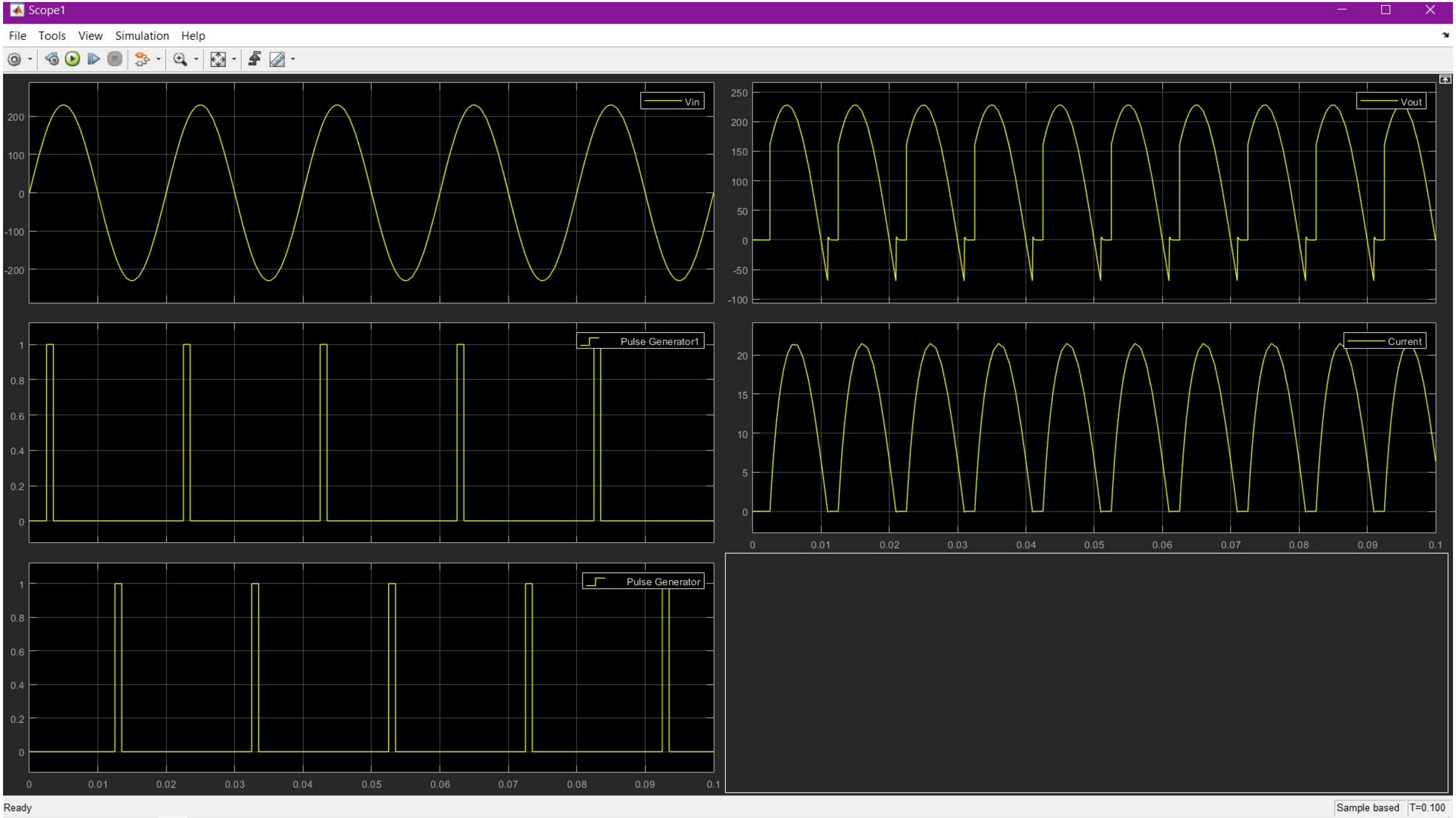
1. Make the required circuit in SIMULINK in MATLAB.
2. Simulate the circuit for 1 seconds.
3. Observe the waveform from the scope.

MATLAB Simulation

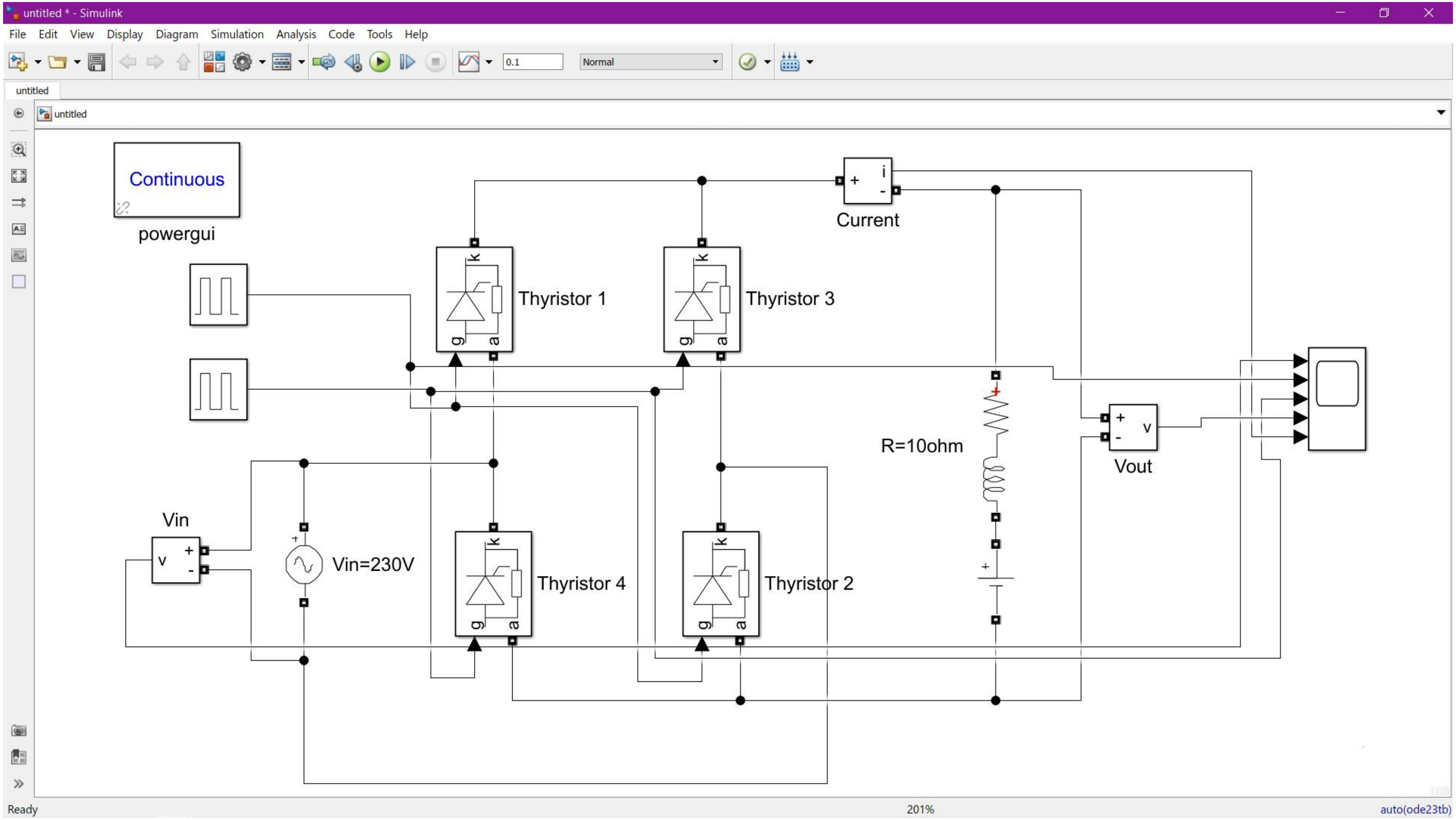


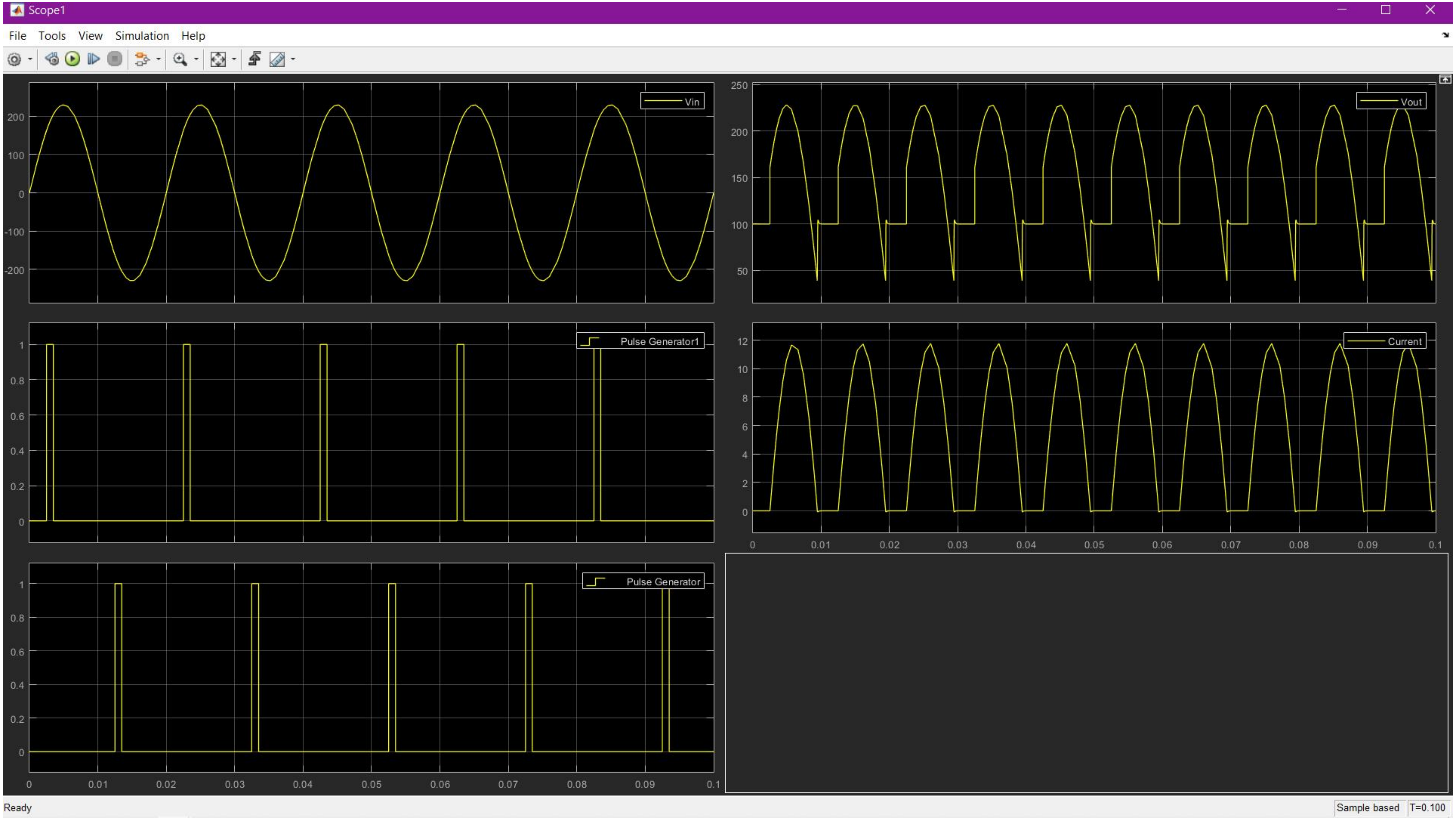

Scope1
File Tools View Simulation Help
Vin
Vout
Pulse Generator1
Current
Pulse Generator
Ready
Sample based
T=0.100

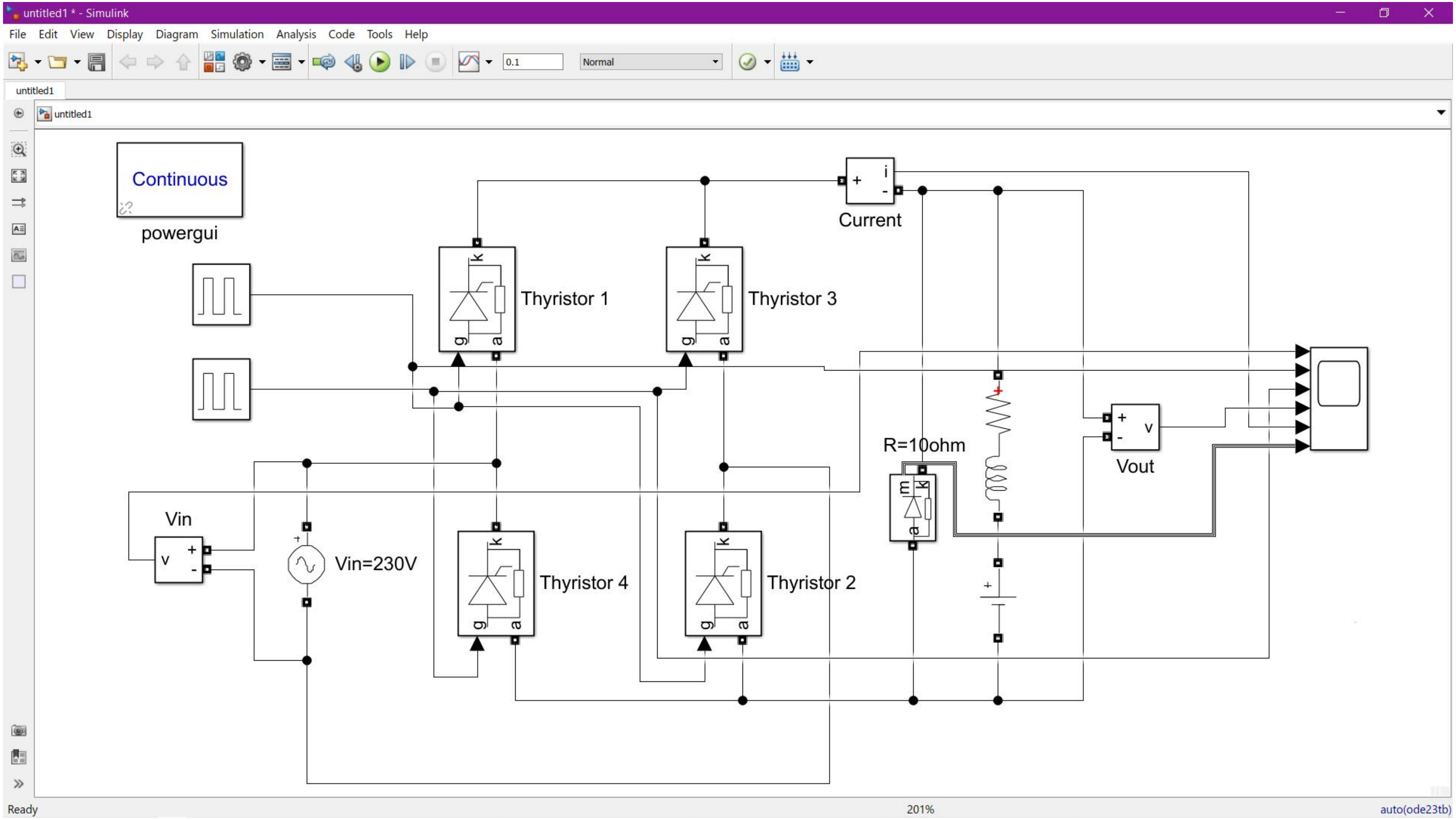

untitled * - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
0.1
Normal
untitled
untitled
Continuous
powergui
Thyristor 1
Thyristor 3
Current
Thyristor 4
Thyristor 2
Vin
Vin=230V
R=10ohm
Vout
Ready
200%
auto(ode23tb)

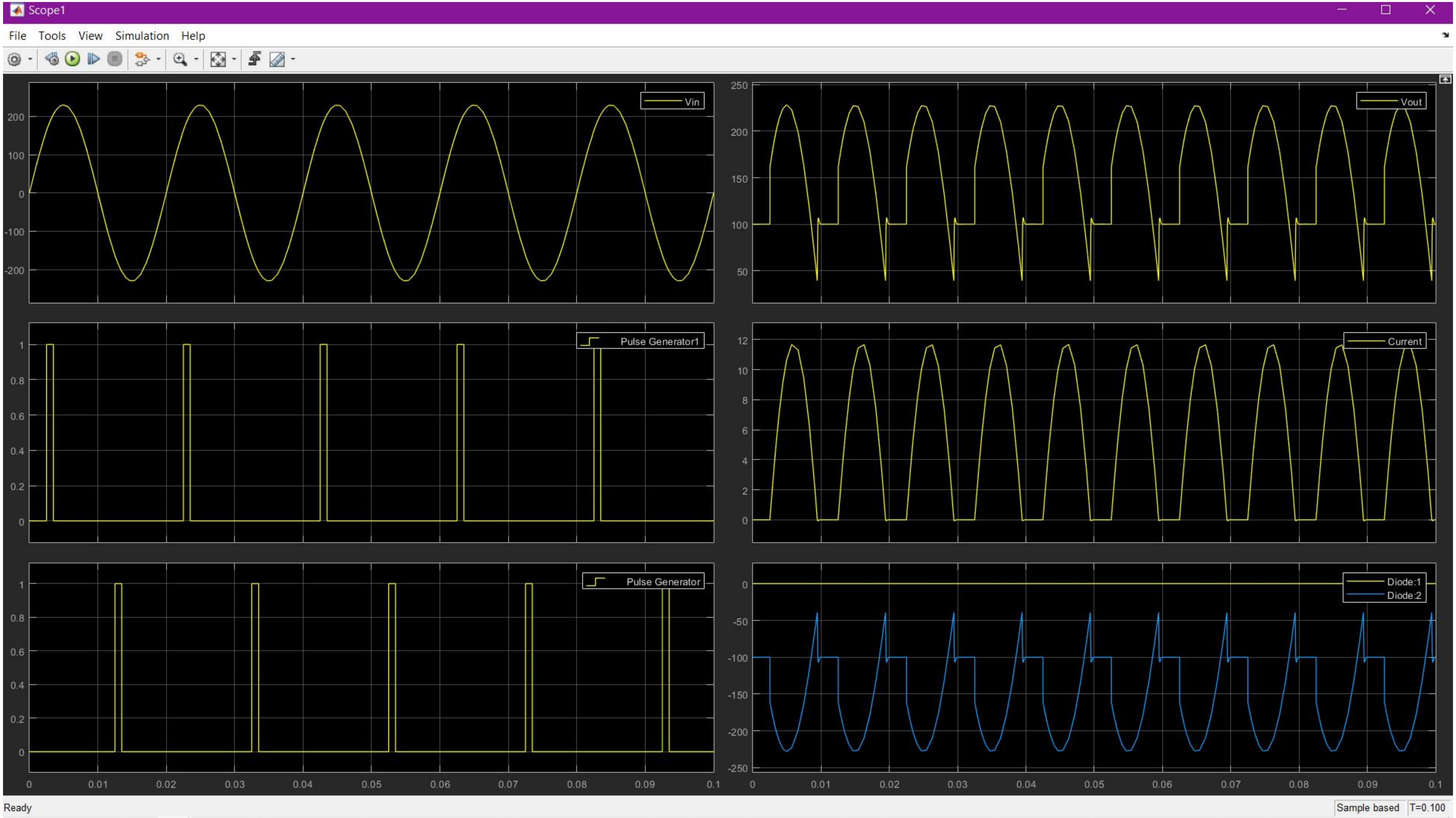


Scope1
File Tools View Simulation Help
Vin
Vout
Pulse Generator1
Current
Pulse Generator
Ready
Sample based
T=0.100


untitled * - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
0.1
Normal
untitled
Continuous
powergui
Current
Thyristor 1
Thyristor 3
Thyristor 4
Thyristor 2
R=10ohm
Vout
Vin
Vin=230V
Ready
201%
auto(ode23tb)


Scope1
File Tools View Simulation Help
Vin
Vout
Pulse Generator1
Current
Pulse Generator
Ready
Sample based
T=0.100


untitled1 * - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
0.1
Normal
untitled1
untitled1
Continuous
powergui
Current
Thyristor 1
Thyristor 3
Thyristor 4
Thyristor 2
Vin
Vin=230V
R=10ohm
Vout
Ready
201%
auto(ode23tb)



Scope1
File Tools View Simulation Help
Vin
Vout
Pulse Generator1
Current
Pulse Generator
Diode:1
Diode:2
Ready
Sample based
T=0.100

* **Result**: Simulated single phase full wave controlled rectifier for R, RL RLE and free wheeling diode by using MATLAB- simulink.

* Precautions:

1. Use powergui to store the equivalent simulink circuit that represents the state-space equation of the model.
2. Always use closed circuit, never leave wire open.
3. MATLAB takes time to respond, do not give multiple command at once.

Experiment - 6

* **Aim:** To simulate the three phase full-wave controlled rectifier for R, RL, RLE and use free wheeling diode by using MATLAB- Simulink.

* **Requirement:** MATLAB - Simulink

* **Theory:** Three phase full wave controlled rectifier is fully controlled bridge controlled rectifier using six thyristors connected in the form of a full wave bridge configuration. All the six thyristor are controlled switches which are turned on at a appropriate times by applying suitable gate trigger signals.

- Three ~~ty~~ thyristors T_1, T_3 and T_5 & T_2, T_4 and T_6 will not work together at the same time.
- Each thyristor is triggered at an interval of $2\pi/3$.
- Each pair T_1 & T_6, T_1 & T_2, T_2 & T_3, T_3 & T_4, T_4 & T_5, T_5 & T_6 is triggered at an interval of $\pi/3$.
- T is triggered at

$T_1 = 30+\alpha$ $\qquad$ $T_2 = 30+\alpha+240+180$

$T_3 = 30+\alpha+120$ $\qquad$ $T_4 = 30+\alpha+180$

$T_5 = 30+\alpha+240$ $\qquad$ $T_6 = 30+\alpha+120+180$

* Diagram:

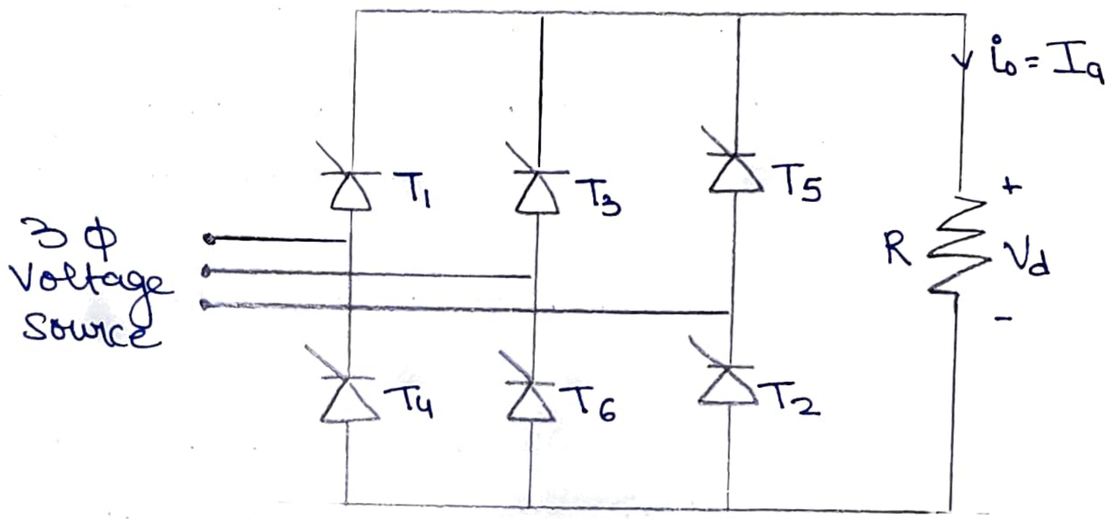


Figure 6.1: Circuit diagram of 3ϕ full wave rectifier.

- Average value

$$V_{an} = V_m \sin(\omega t)$$
$$V_{bn} = V_m \sin(\omega t - 2\pi/3)$$
$$V_{cn} = V_m \sin(\omega t - 4\pi/3)$$

$$\Rightarrow V_{ab} = \sqrt{3}\, V_m \sin\left(\omega t + \frac{\pi}{6}\right)$$
$$V_{bc} = \sqrt{3}\, V_m \sin\left(\omega t - \frac{\pi}{2}\right)$$
$$V_{ca} = \sqrt{3}\, V_m \sin\left(\omega t - \frac{7\pi}{6}\right)$$

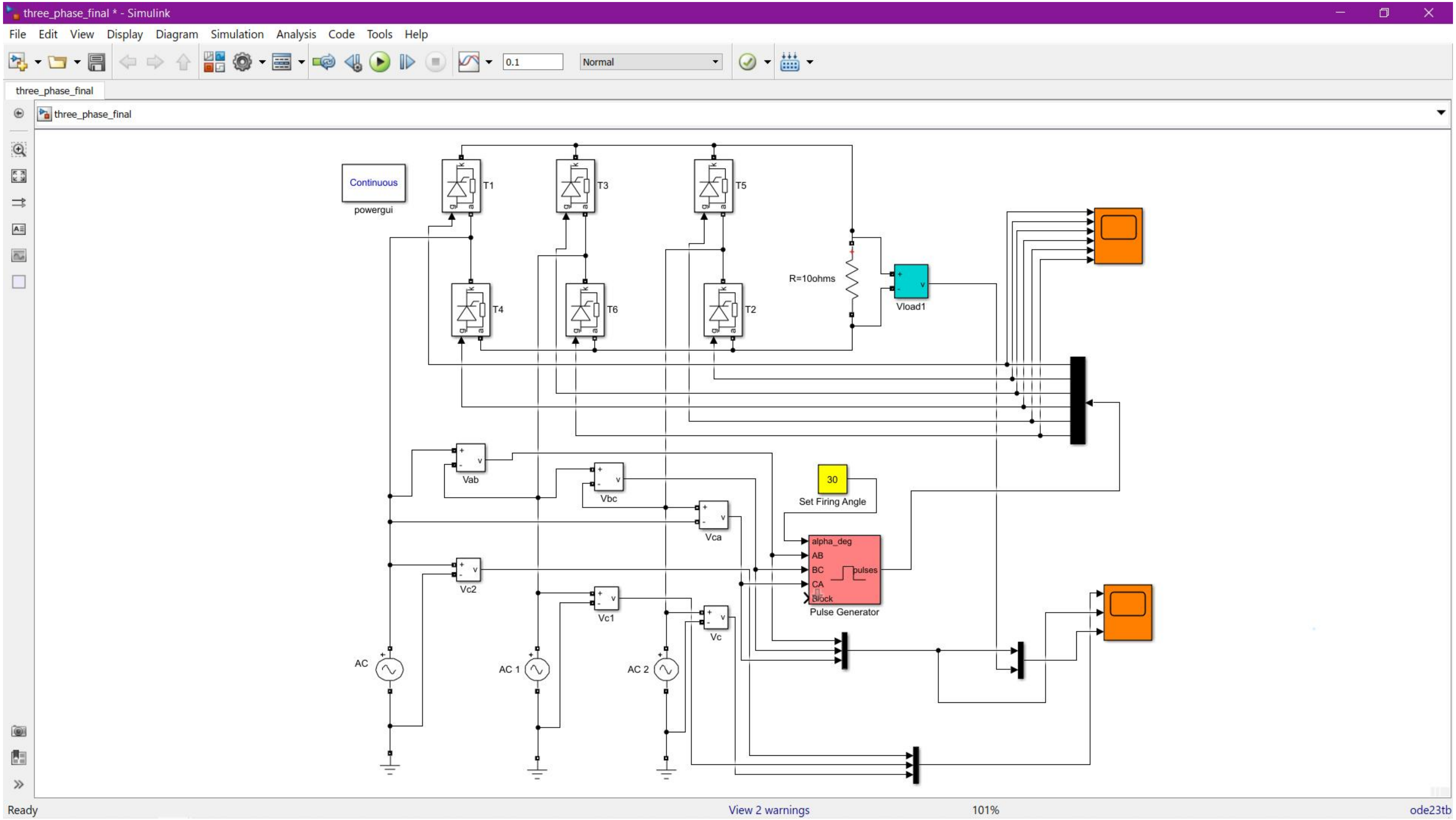
$$V_{dc} = \frac{3\sqrt{3}\, V_m}{\pi} \cos\alpha$$
$$I_{dc} = \frac{3\sqrt{3}\, V_m}{\pi R} \cos\alpha$$

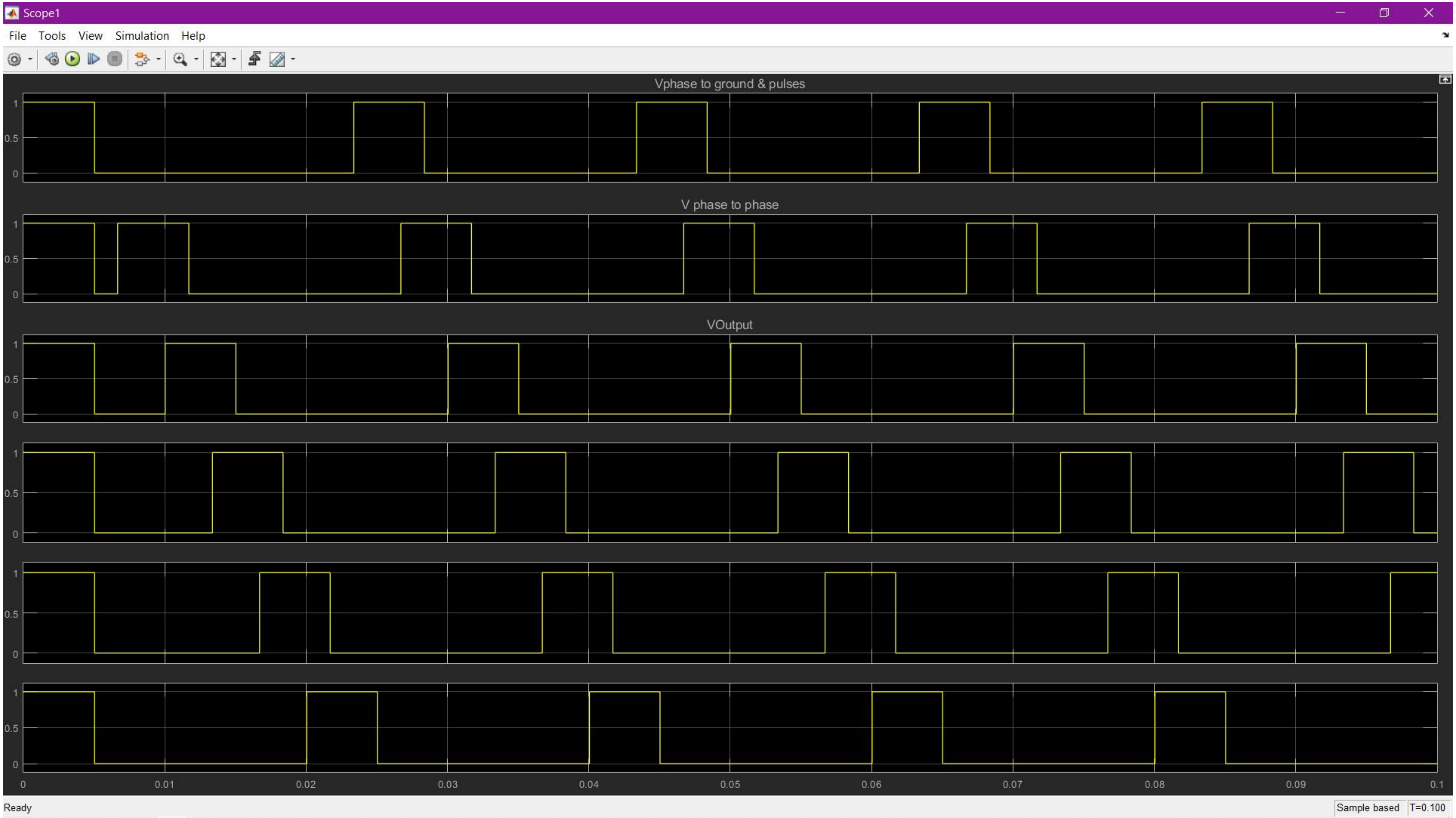
- RMS Value

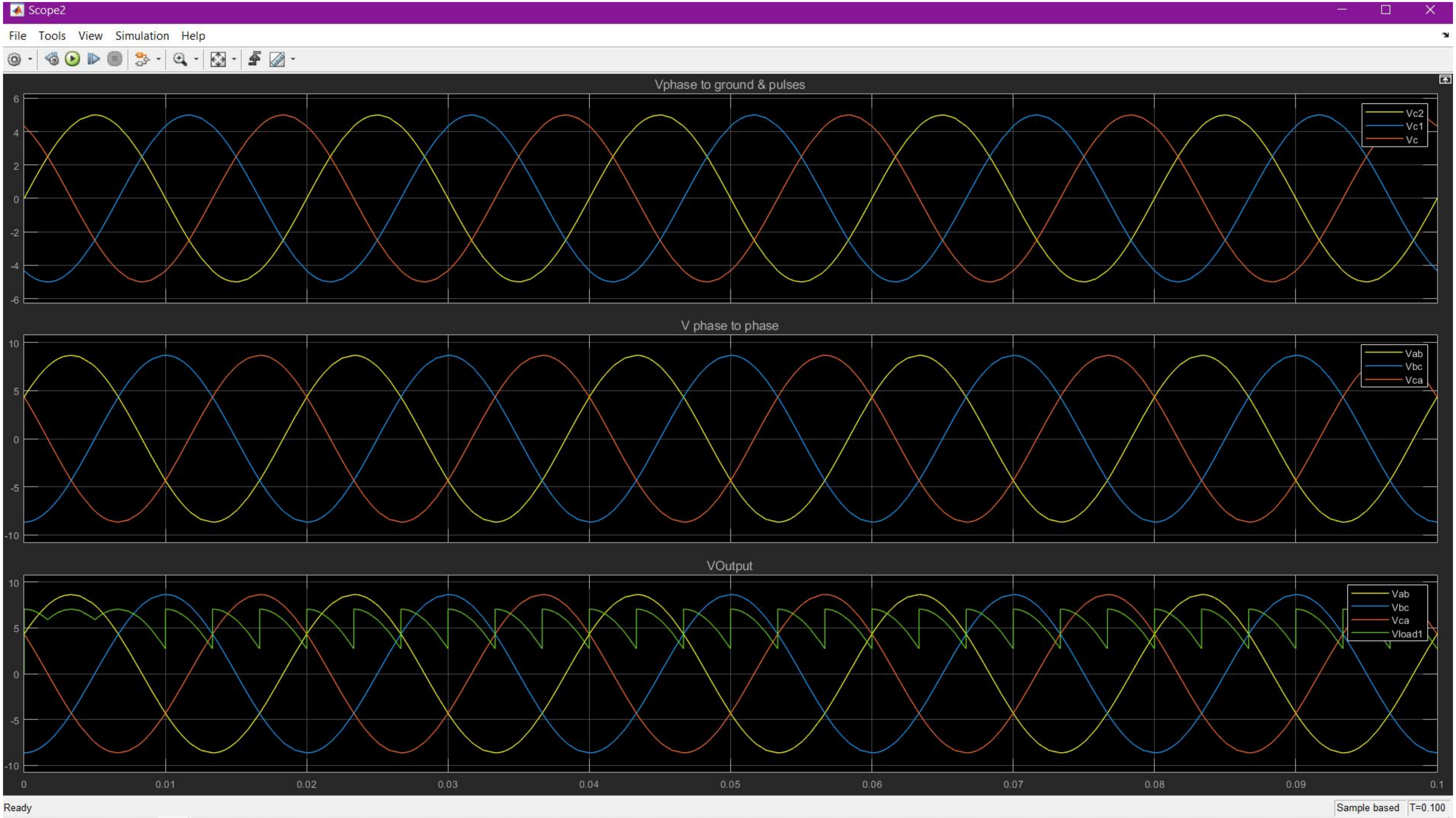
$$V_{rms} = \sqrt{3}\, V_m \sqrt{\frac{1}{2} + \frac{3\sqrt{3}}{4\pi} \cos 2\alpha}$$
$$I_{rms} = \frac{V_{rms}}{\sqrt{R^2 + (\omega L)^2}}$$

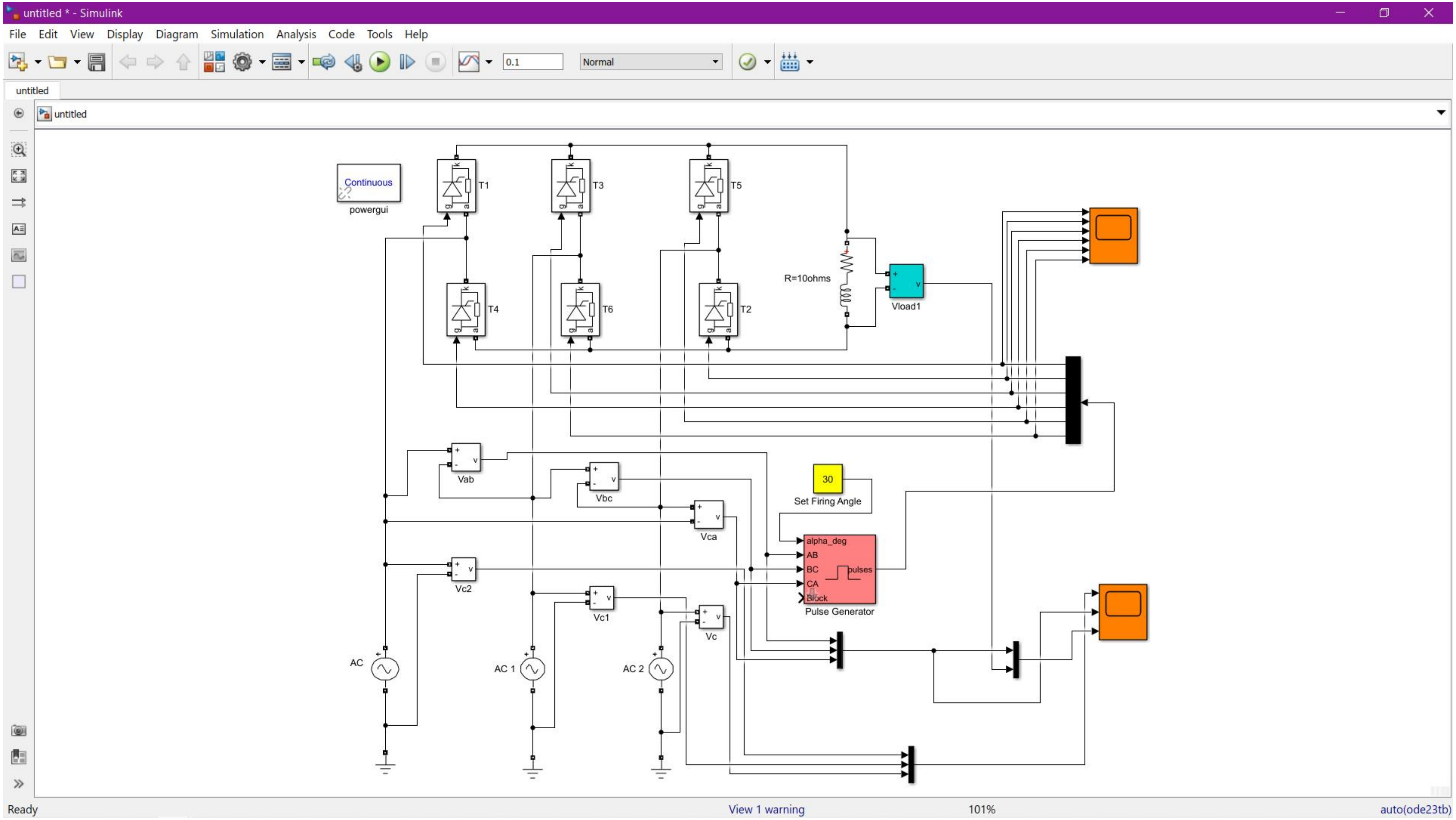
* **Procedure:**

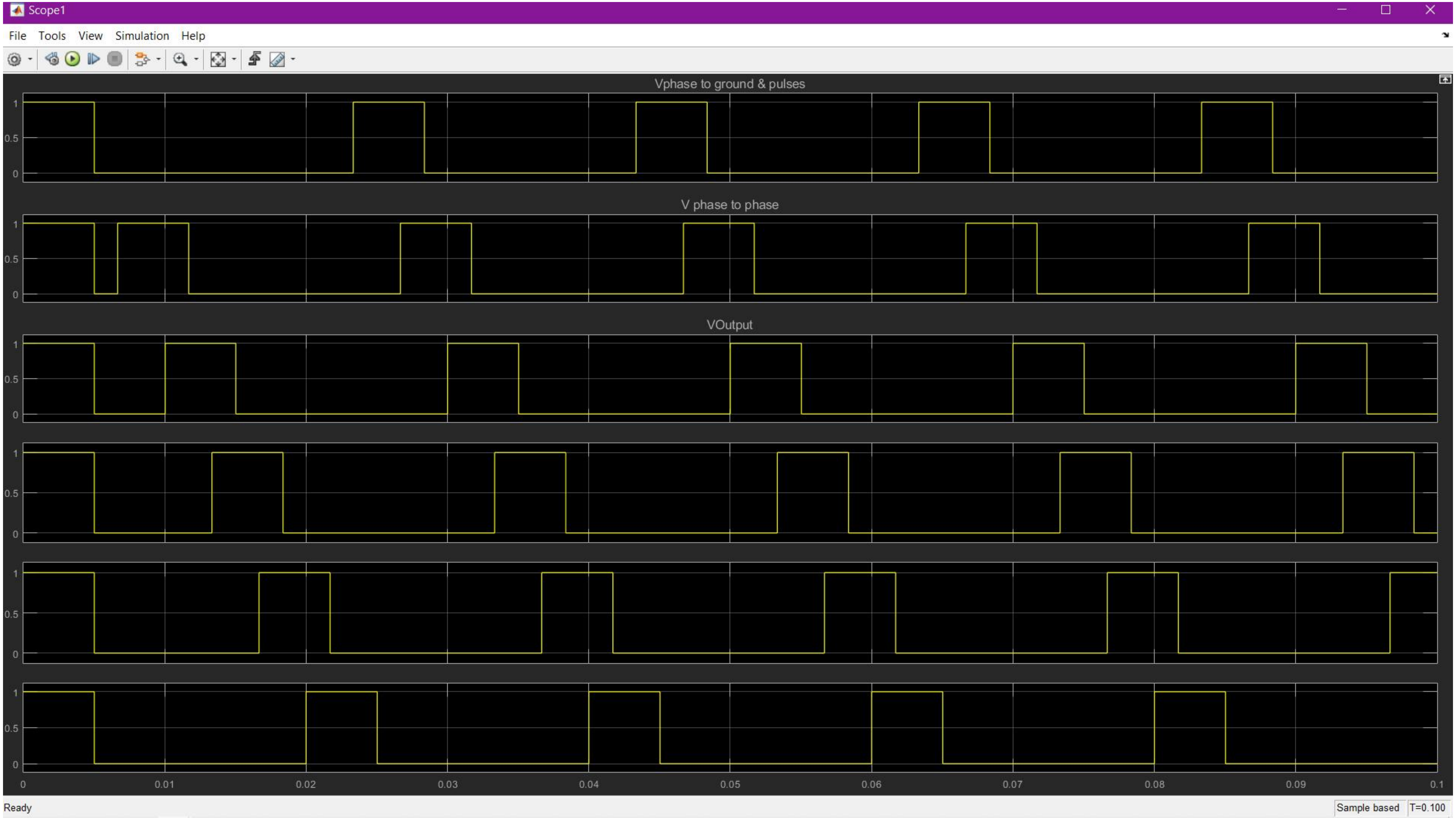
1. Make the required circuit in SIMULINK in MATLAB.
2. Simulate the circuit for 1 second.
3. Observe the waveform from the scope.

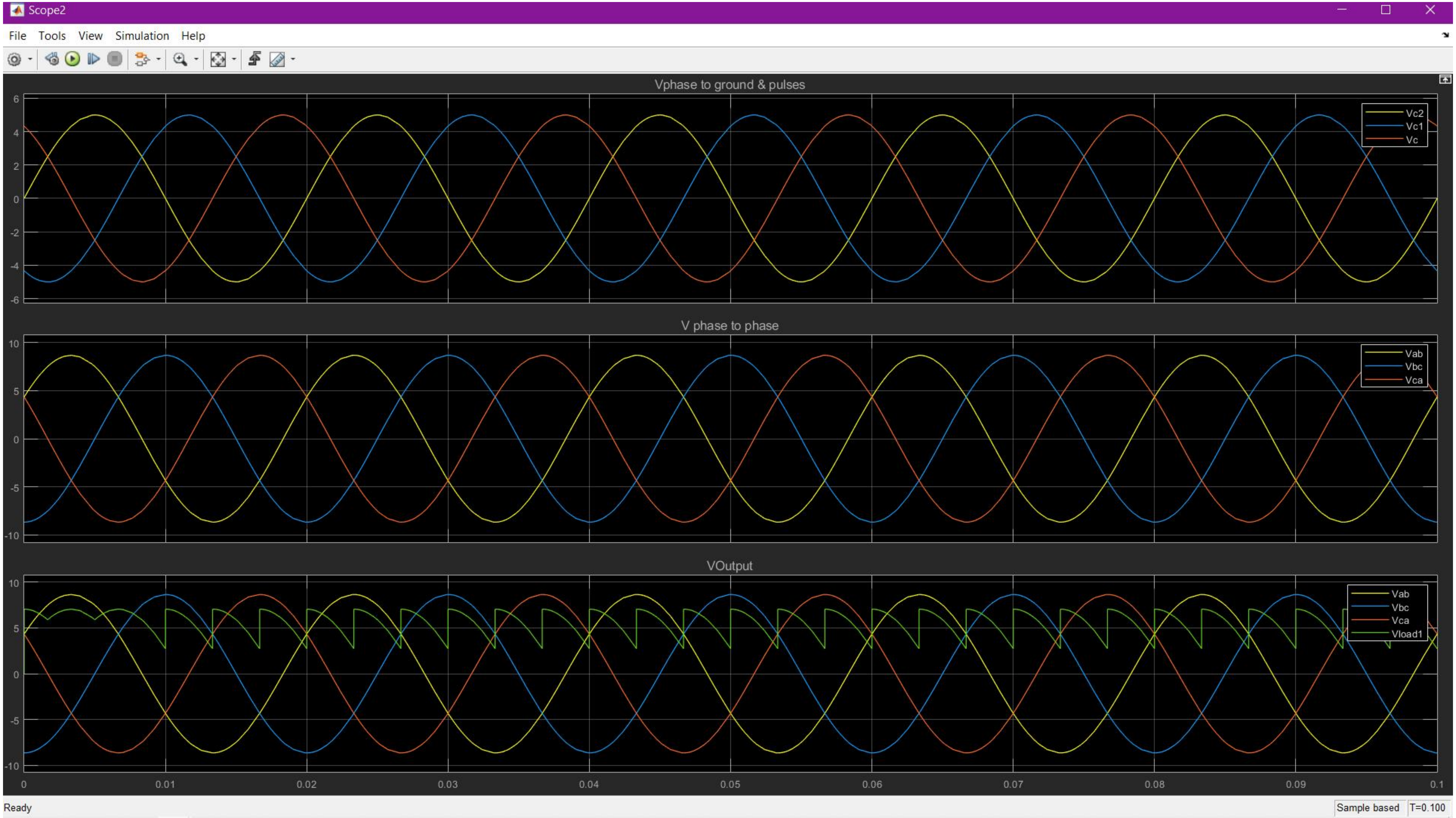

three_phase_final * - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
0.1
Normal
three_phase_final
Continuous
powergui
T1
T3
T5
T4
T6
T2
R=10ohms
Vload1
Vab
Vbc
Vca
Vc2
Vc1
Vc
30
Set Firing Angle
alpha_deg
AB
BC
CA
Block
pulses
Pulse Generator
AC
AC 1
AC 2
Ready
View 2 warnings
101%
ode23tb

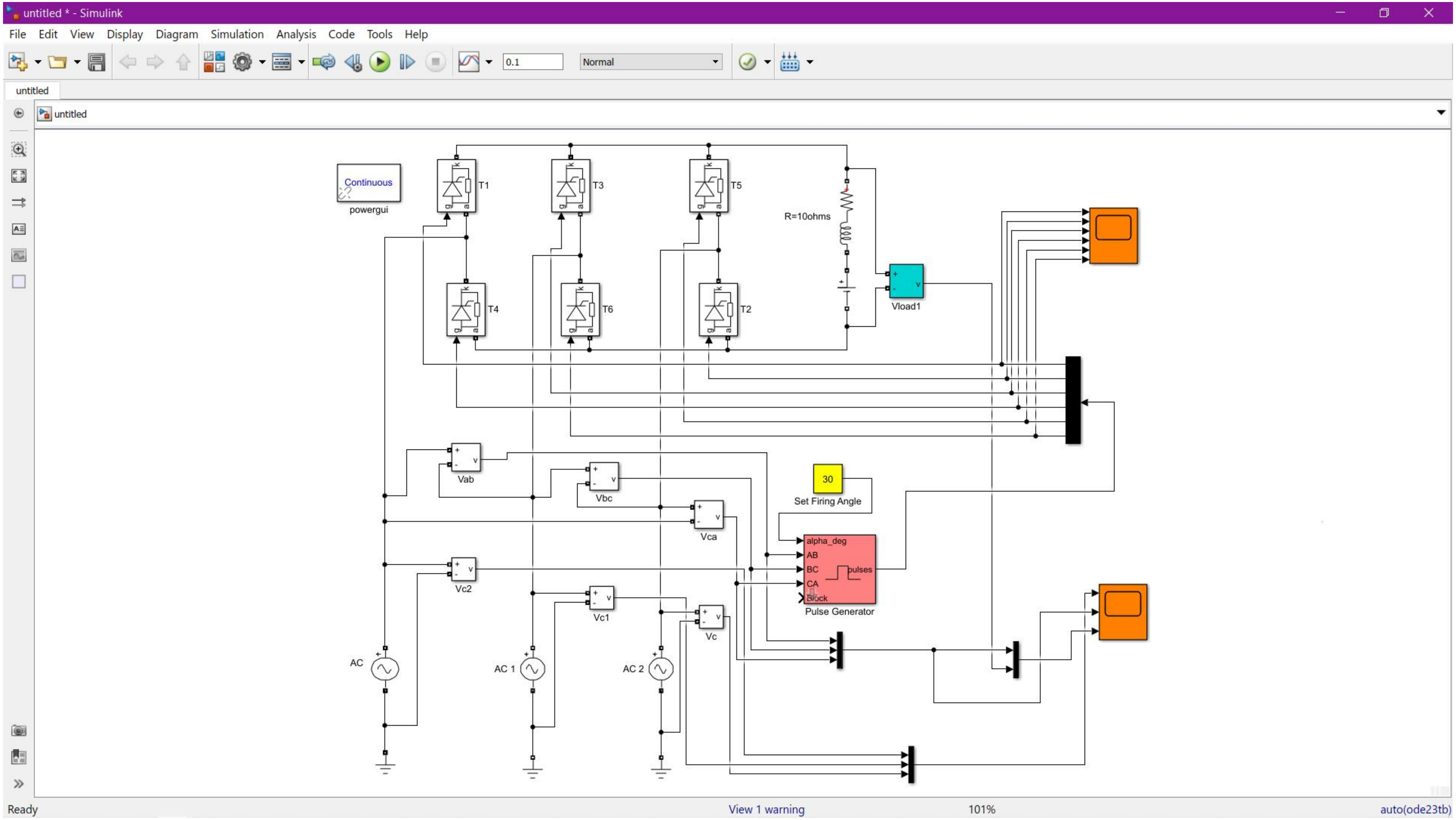

Scope1
File Tools View Simulation Help
Vphase to ground & pulses
V phase to phase
VOutput
1
0.5
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
Ready
Sample based
T=0.100

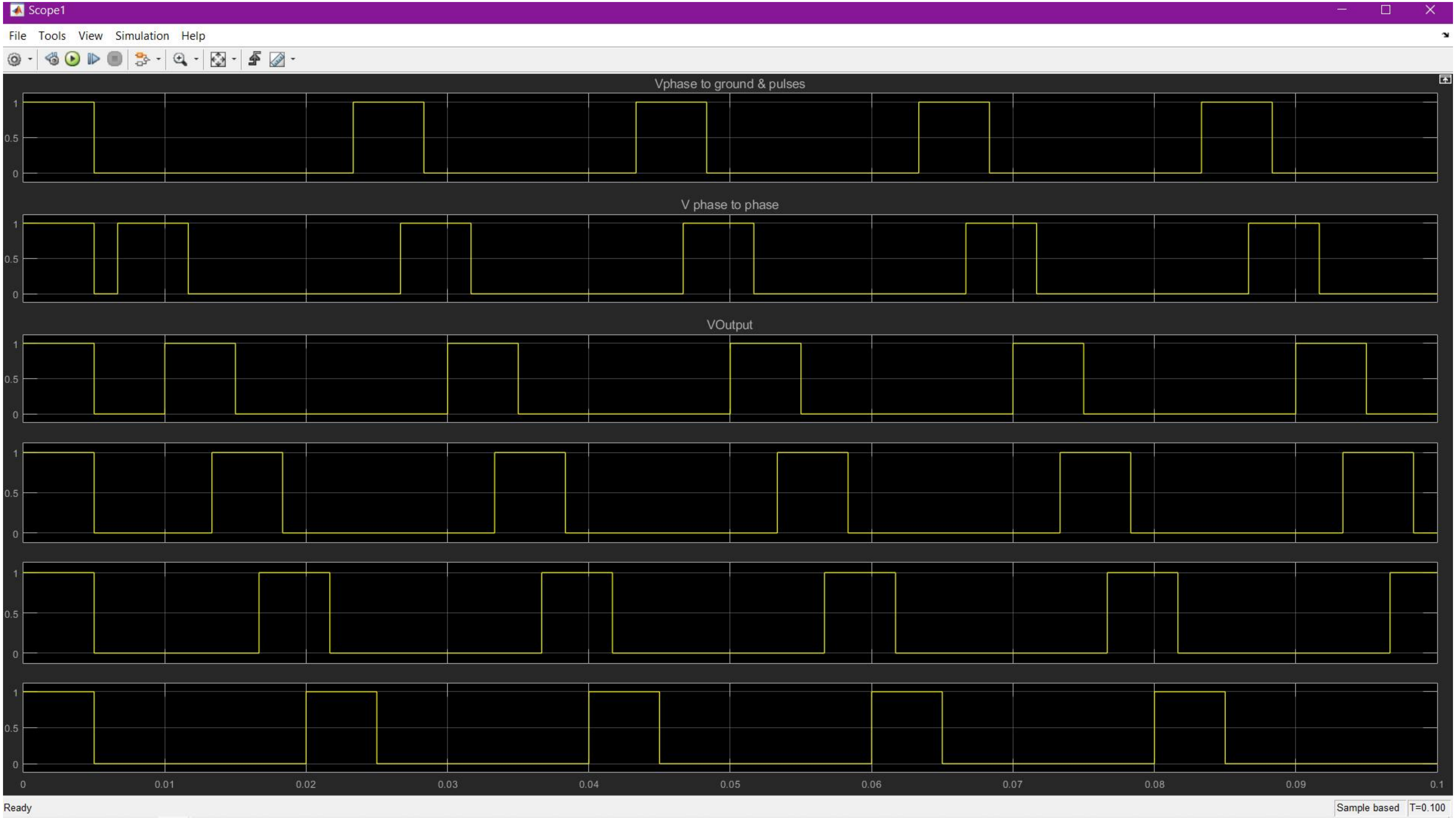

Scope2
File Tools View Simulation Help
Vphase to ground & pulses
Vc2
Vc1
Vc
V phase to phase
Vab
Vbc
Vca
VOutput
Vab
Vbc
Vca
Vload1
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
Ready
Sample based
T=0.100

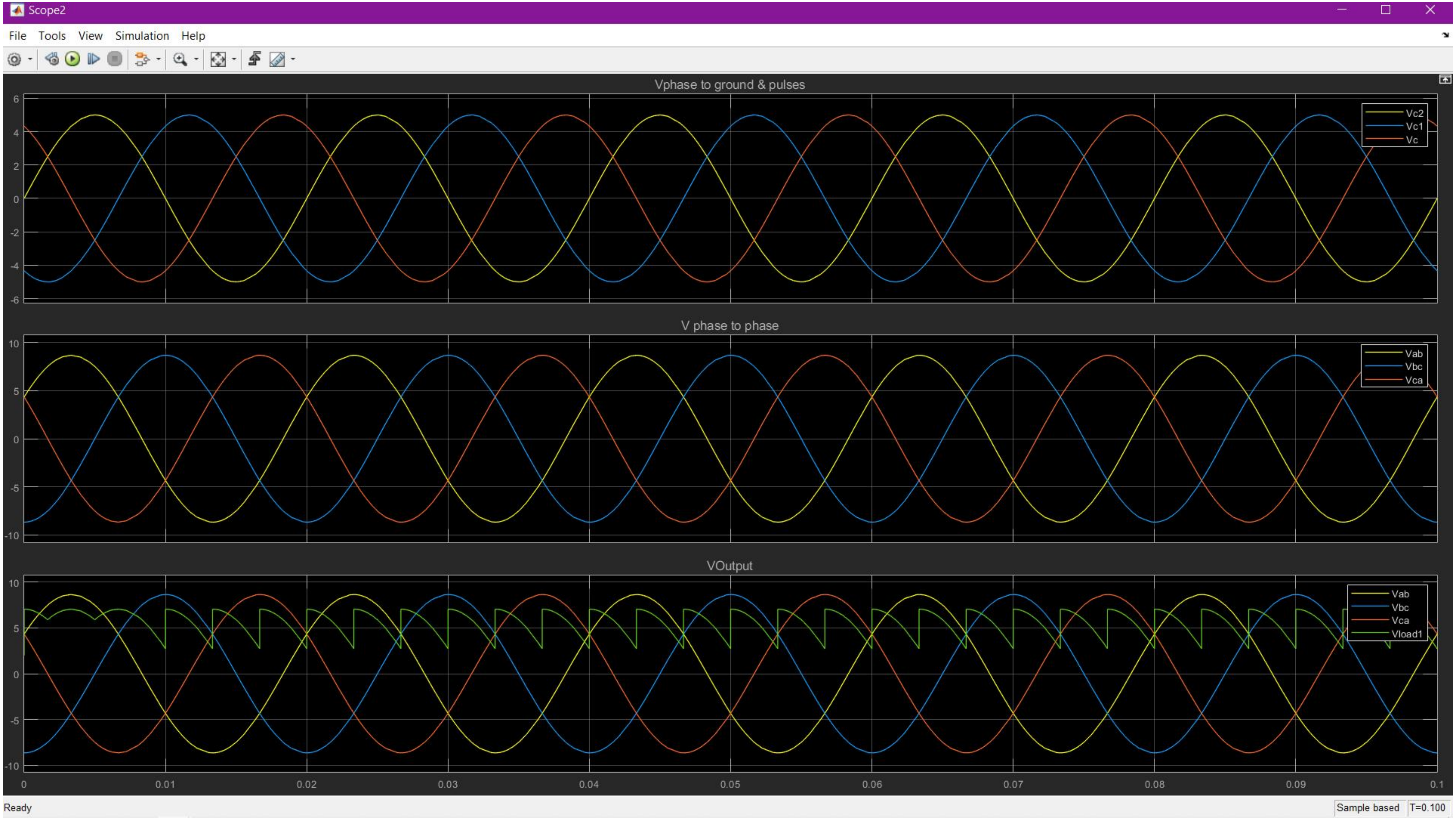

untitled * - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
0.1
Normal
untitled
untitled
Continuous
powergui
T1
T3
T5
T4
T6
T2
R=10ohms
Vload1
Vab
Vbc
Vca
30
Set Firing Angle
alpha_deg
AB
BC
CA
Block
pulses
Pulse Generator
Vc2
Vc1
Vc
AC
AC 1
AC 2
Ready
View 1 warning
101%
auto(ode23tb)

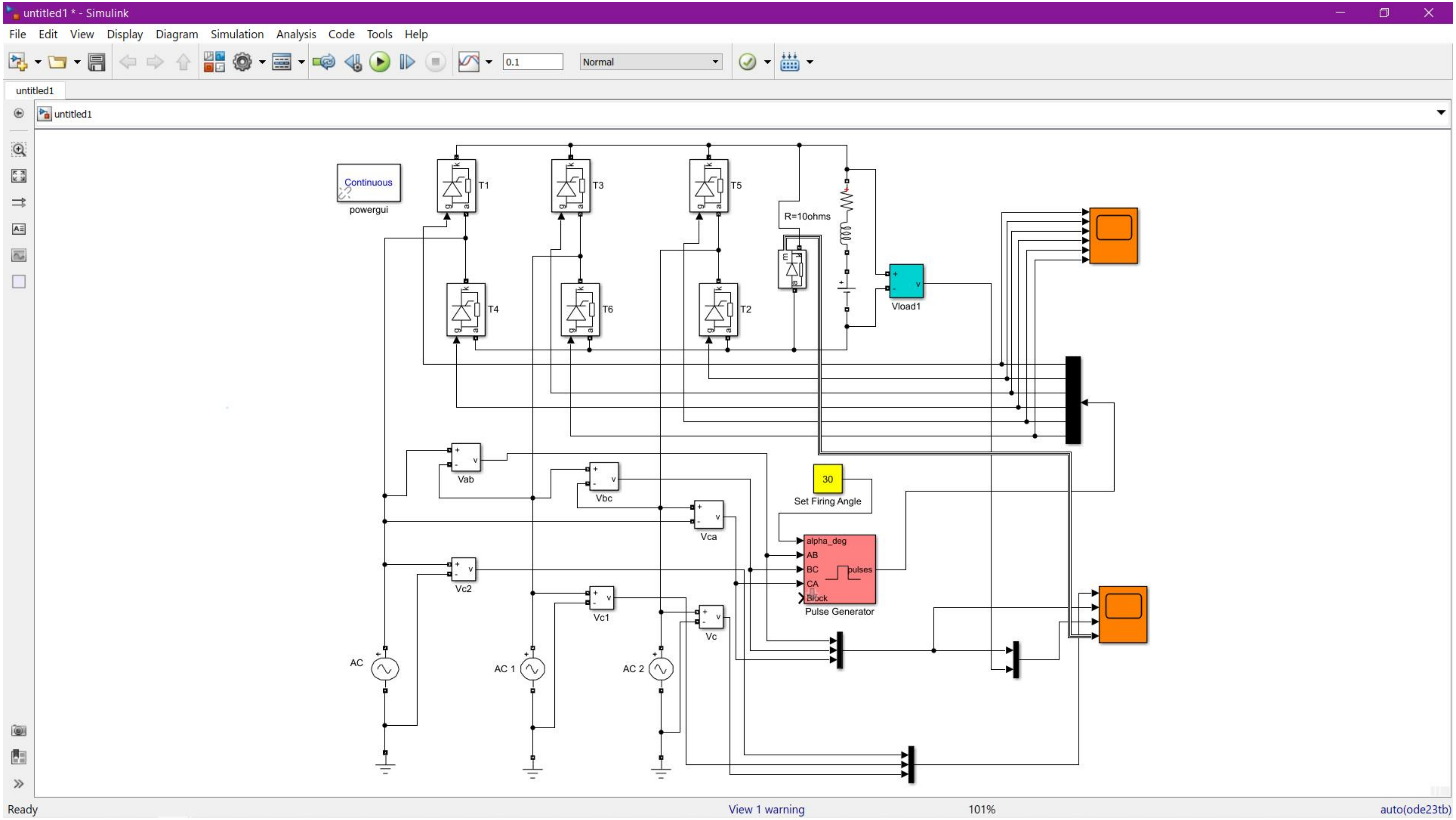

Scope1
File Tools View Simulation Help
Vphase to ground & pulses
V phase to phase
VOutput
1
0.5
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
Ready
Sample based
T=0.100

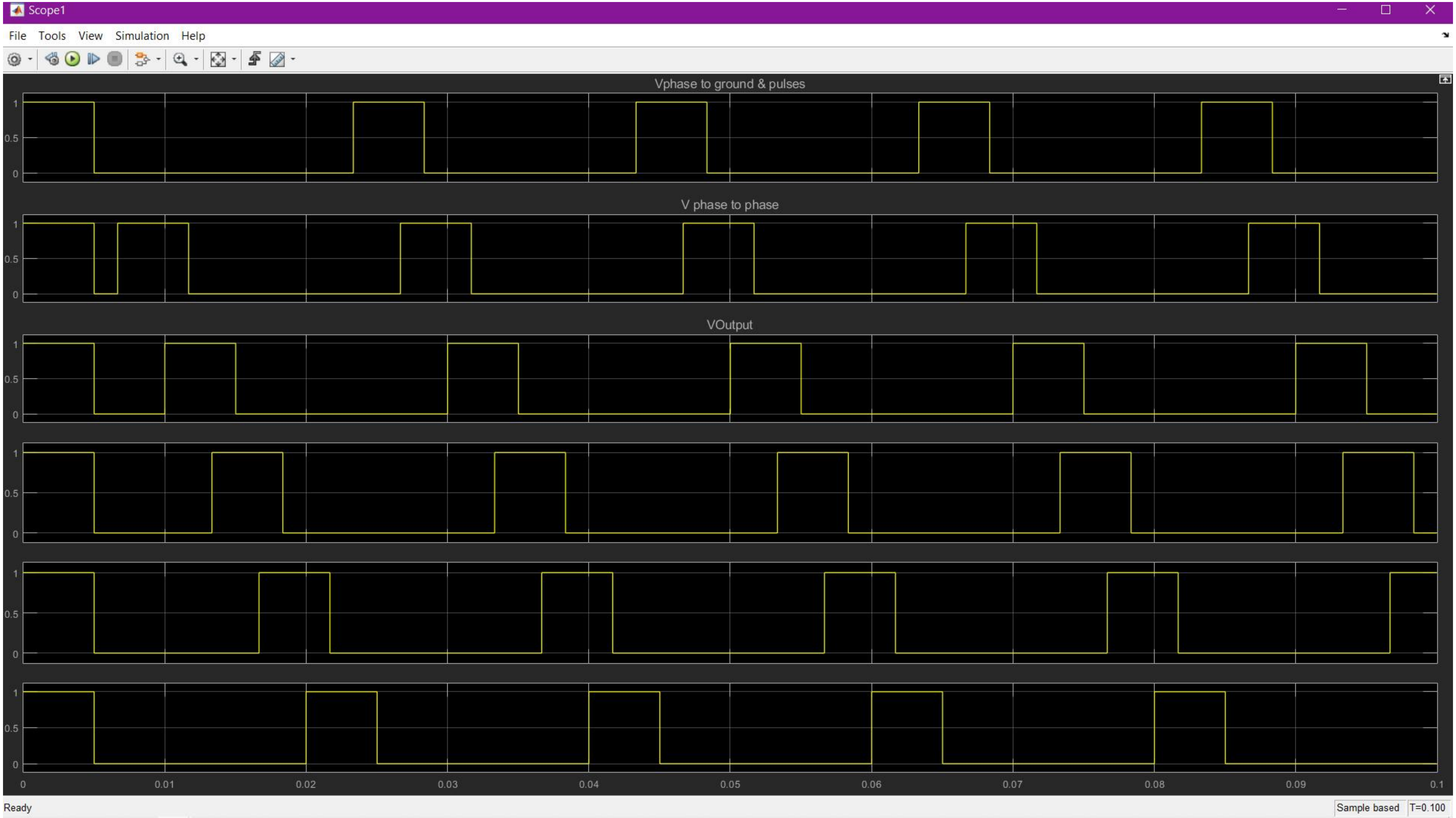

Scope2
File Tools View Simulation Help
Vphase to ground & pulses
Vc2
Vc1
Vc
V phase to phase
Vab
Vbc
Vca
VOutput
Vab
Vbc
Vca
Vload1
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
Ready
Sample based
T=0.100

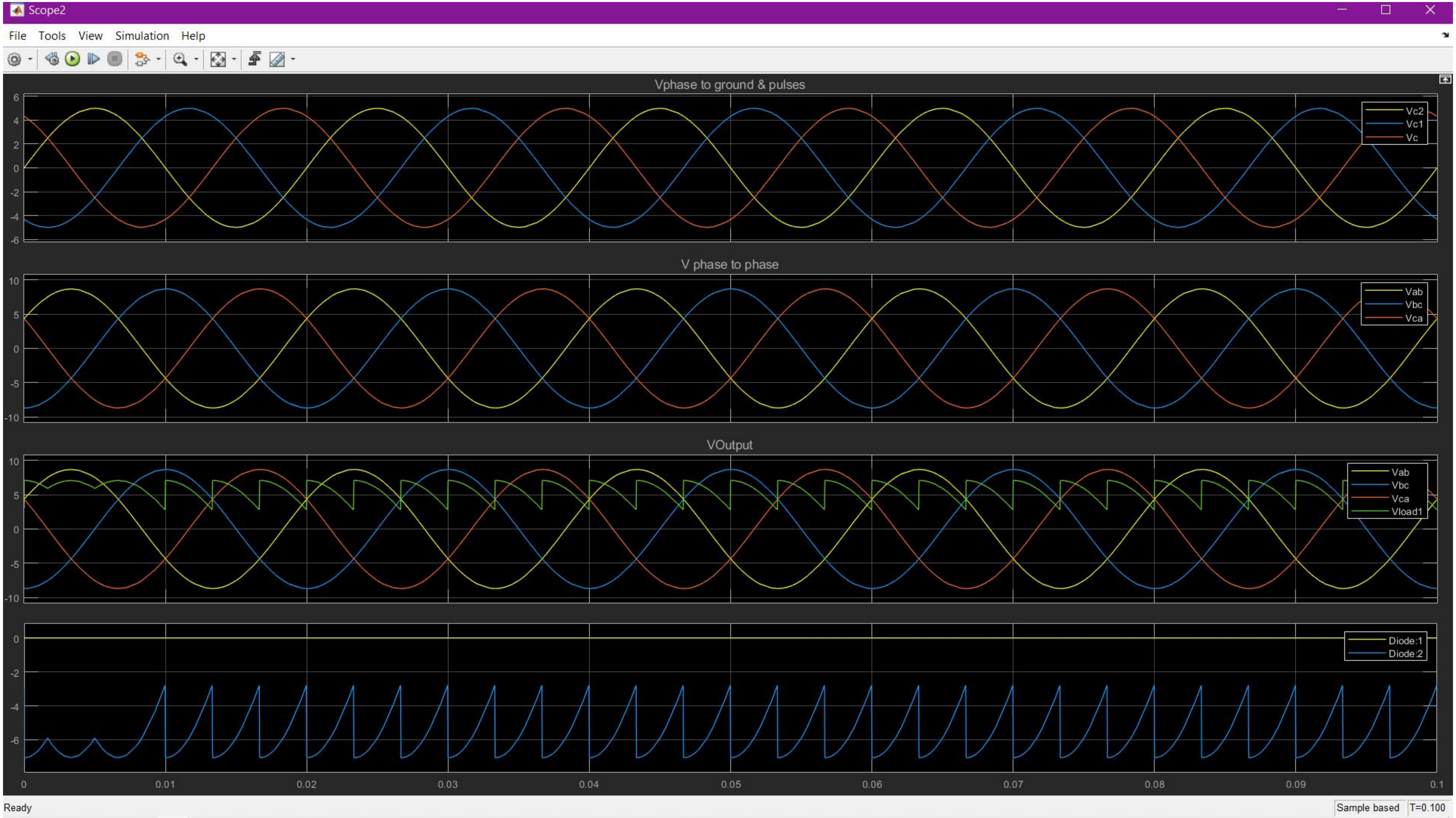

untitled * - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
0.1
Normal
untitled
Continuous
powergui
T1
T3
T5
T4
T6
T2
R=10ohms
Vload1
Vab
Vbc
Vca
Vc2
Vc1
Vc
30
Set Firing Angle
alpha_deg
AB
BC
CA
Block
pulses
Pulse Generator
AC
AC 1
AC 2
Ready
View 1 warning
101%
auto(ode23tb)


Scope1
File Tools View Simulation Help
Vphase to ground & pulses
V phase to phase
VOutput
1
0.5
0
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
Ready
Sample based
T=0.100


Scope2
File Tools View Simulation Help
Vphase to ground & pulses
Vc2
Vc1
Vc
V phase to phase
Vab
Vbc
Vca
VOutput
Vab
Vbc
Vca
Vload1
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
Ready
Sample based
T=0.100


untitled1 * - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
0.1
Normal
untitled1
Continuous
powergui
T1
T3
T5
T4
T6
T2
R=10ohms
Vload1
Vab
Vbc
Vca
Vc2
Vc1
Vc
30
Set Firing Angle
alpha_deg
AB
BC
CA
Block
pulses
Pulse Generator
AC
AC 1
AC 2
Ready
View 1 warning
101%
auto(ode23tb)


Scope1
File Tools View Simulation Help
Vphase to ground & pulses
V phase to phase
VOutput
1
0.5
0
0 0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09 0.1
Ready
Sample based
T=0.100


Scope2
File Tools View Simulation Help
Vphase to ground & pulses
Vc2
Vc1
Vc
V phase to phase
Vab
Vbc
Vca
VOutput
Vab
Vbc
Vca
Vload1
Diode:1
Diode:2
0 0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09 0.1
Ready
Sample based
T=0.100

* **Result:** Simulated the three phase full-wave controlled rectifier for R, RL, RLE and use free wheeling diode by using MATLAB-simulink.

* **Precautions:**

1. Use powergui to store the equivalent simulink circuit that represents the state-space equation of the model.
2. Always use closed circuit, never leave wire open.
3. MATLAB takes time to respond, do not give multiple command at once.

Experiment - 7

* **Aim:** Simulate step up and step down ~~c~~ Chopper for R, RL and RLE load by using MATLAB simulink.

* **Requirement:** MATLAB - Simulink

* **Theory:** A chopper uses high speed to connect and disconnect from a source load. A fixed DC voltage is applied intermittently to the source load by continuously triggering the power switch ON/OFF.

— Step up Chopper

Also known as Boost Converter. ~~A~~ The average voltage (V_o) in a step up chopper is greater than the voltage input (V_s). The figure below shows a configuration of a step ~~up~~ up chopper.

— The average output voltage is positive when chopper is switched ON and negative when the chopper is OFF.

T_{ON} - time interval when chopper is ON

T_{OFF} - time interval when chopper is OFF

V_L - Load voltage

V_s - source voltage

T - chopping time period = $T_{ON} + T_{OFF}$

* Diagram:

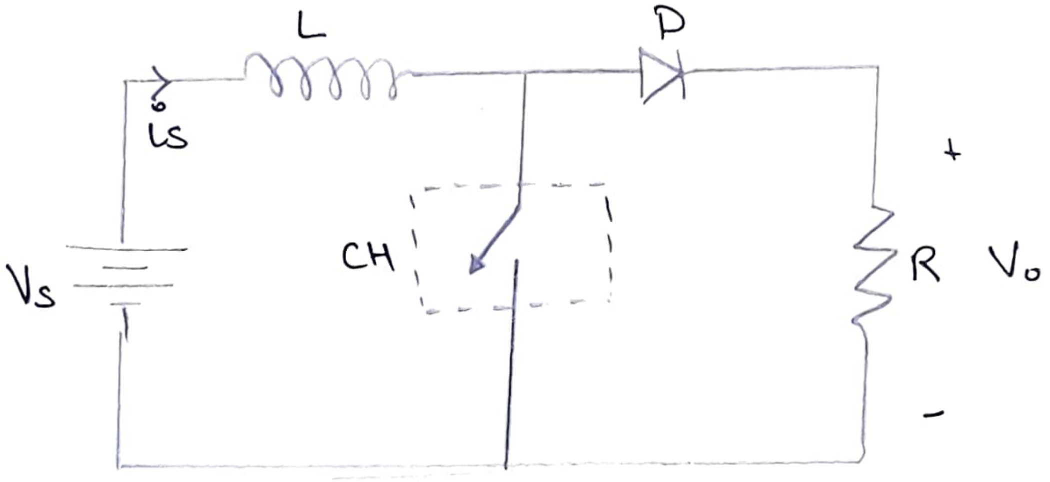


Figure 7.1: Circuit diagram of step-up Chopper

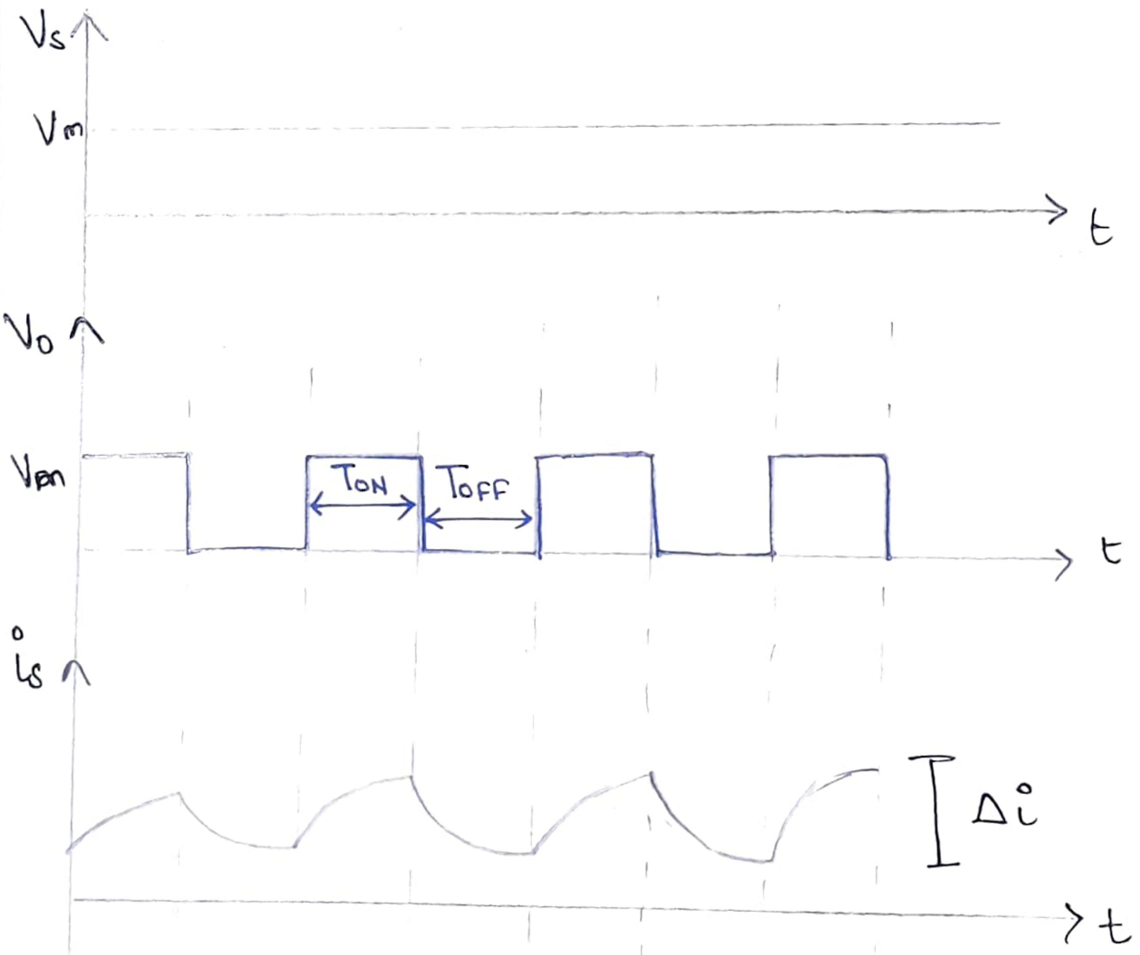


Figure 7.2: Wave form of Step up chopper

- Average voltage output

$$V_o = \frac{V_s}{1-D} \qquad D = \frac{T+T_{ON}}{T}$$

The equation proves that the output voltage will always be more than the voltage ~~of~~ input and hence, it boosts up or increases the voltage level.

- Step down Chopper

Also known as buck converter. In this, the average voltage output V_o is less than the input voltage V_s. When Chopper is ON, $V_o = V_s$ and when the chopper is off, $V_o = 0$.

when chopper is ON

$$V_s = (V_L + V_o) \qquad L\frac{di}{dt} = V_s - V_o$$

$$V_L = V_s - V_o \qquad L\frac{\Delta i}{T_{ON}} = V_s + V_o$$

Thus, peak-to-peak current load is given by

$$\Delta i = \frac{V_s - V_o}{L} T_{ON}$$

Where FD is free-wheel diode, when chopper is OFF, polarity reversal and discharging occurs at the inductor.

- Average voltage output

$$V_o = DV_s \qquad D = \frac{T_{ON}}{T}$$

* Diagram:

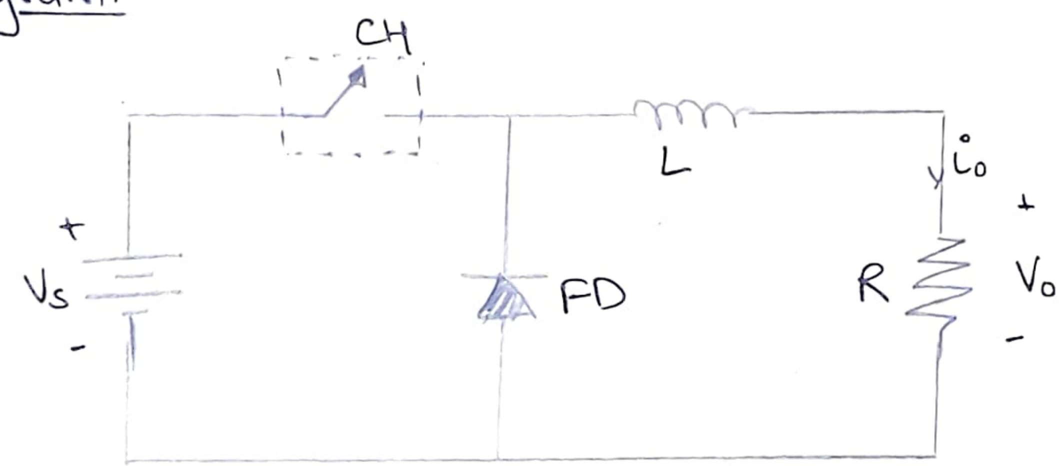


Figure 7.3: Circuit diagram of step down chopper.

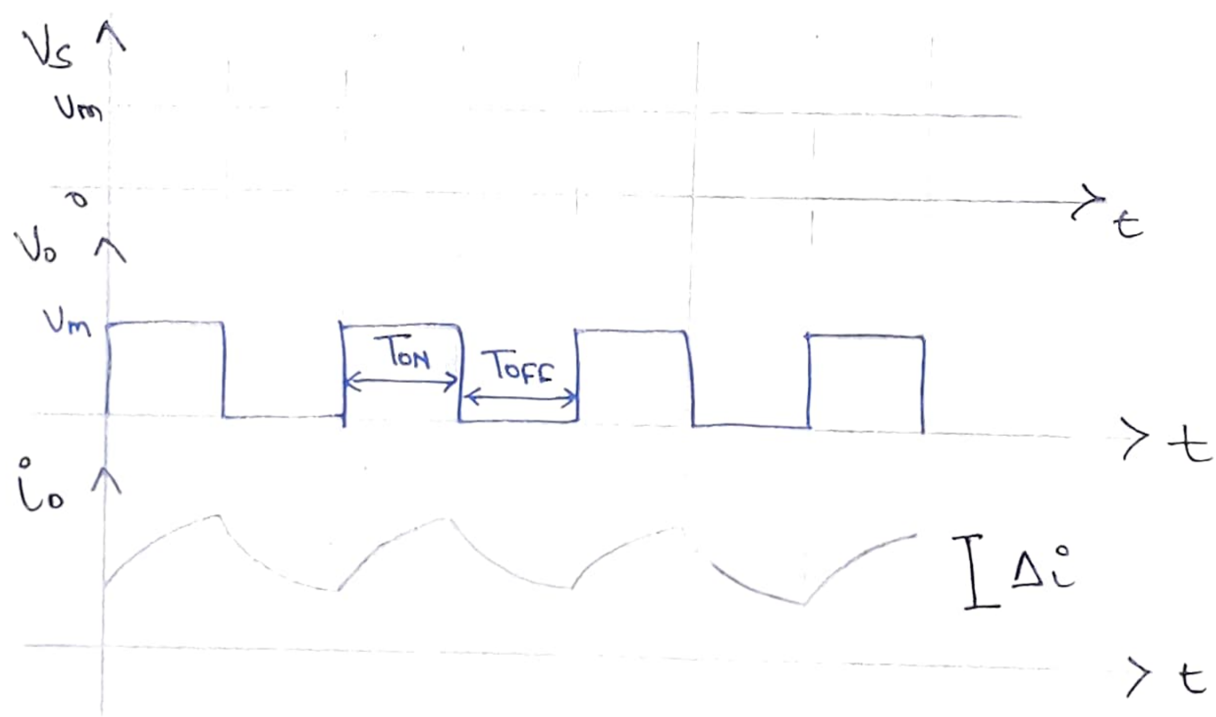


Figure 7.4: Waveform of step down chopper

$$\Delta i = \frac{V_s-(1-D)D}{Lf} \qquad D = \frac{T_{ON}}{T} \ \& \ f = \frac{1}{T}$$

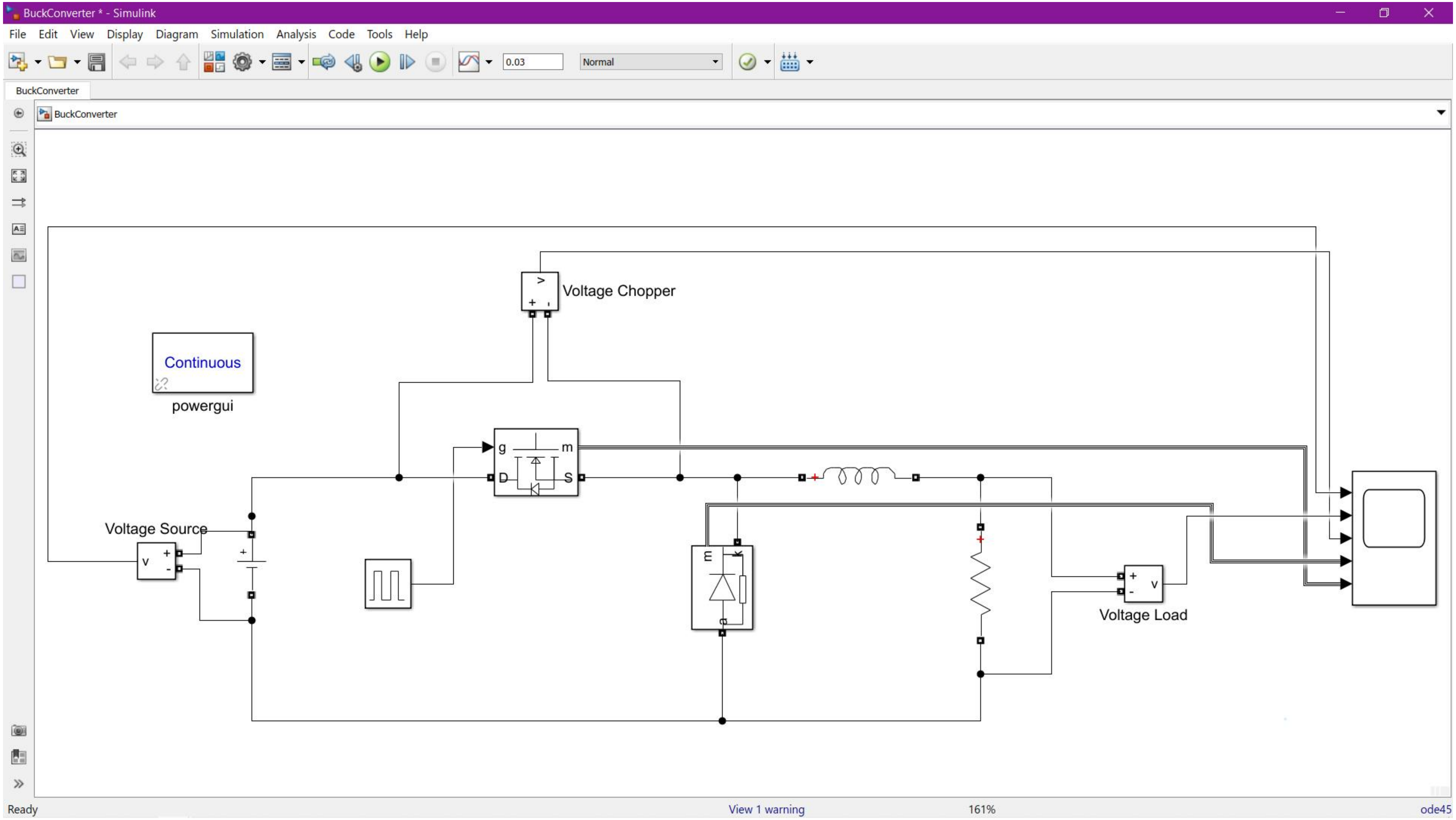
where, Δi is the inductor peak to peak current.

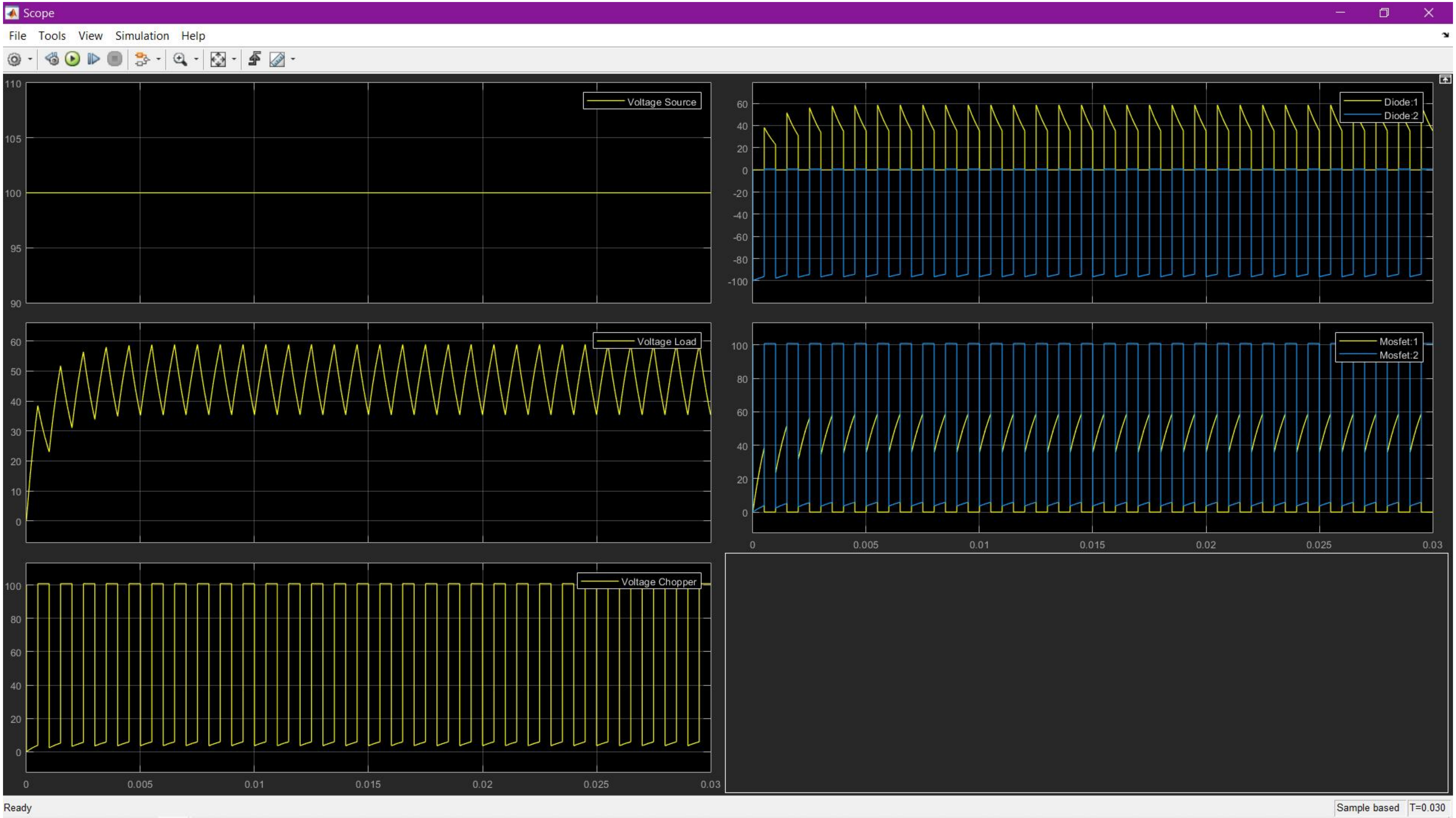
For step down chopper the voltage output is always less than the voltage input.

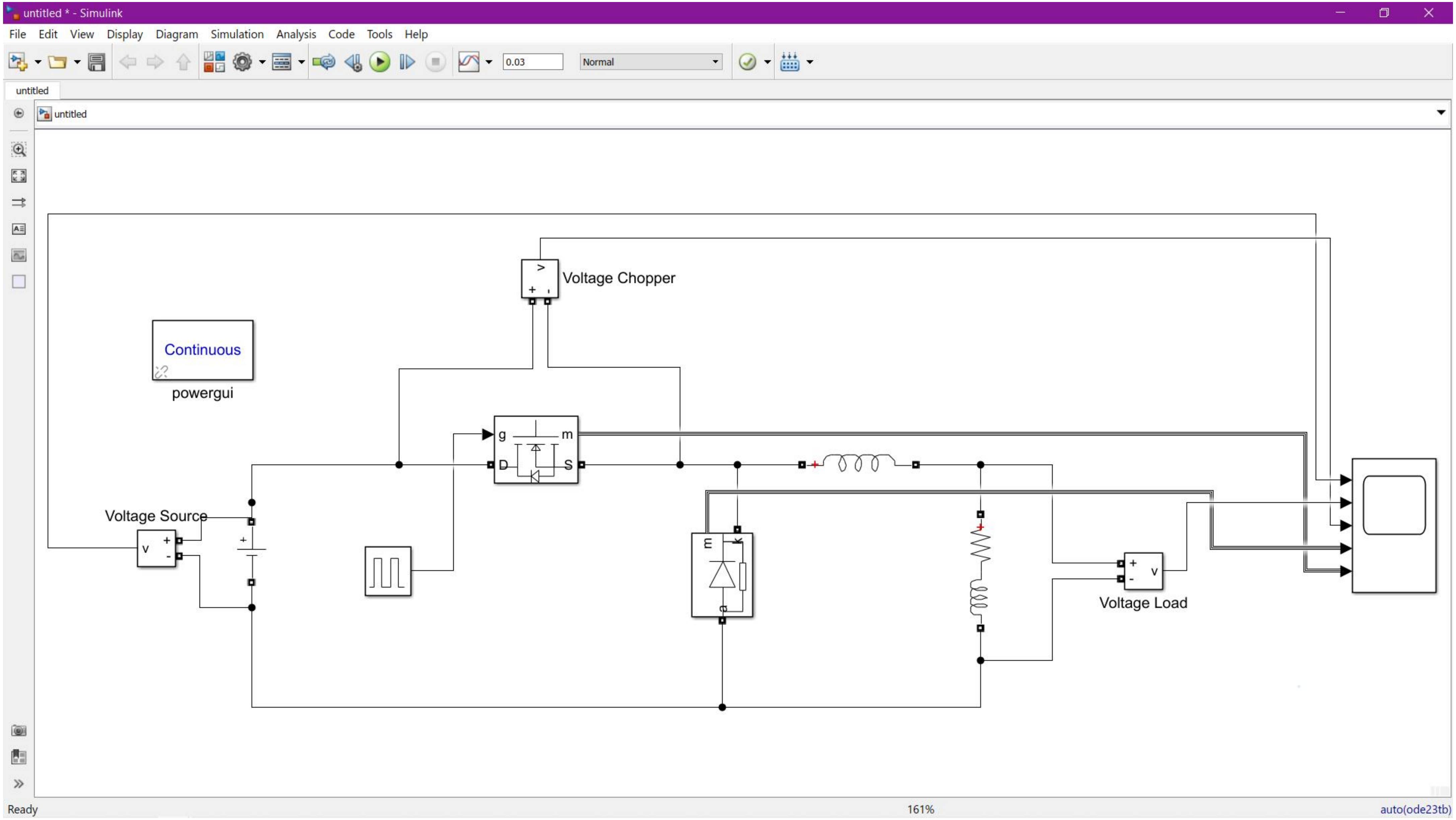
* Procedure:

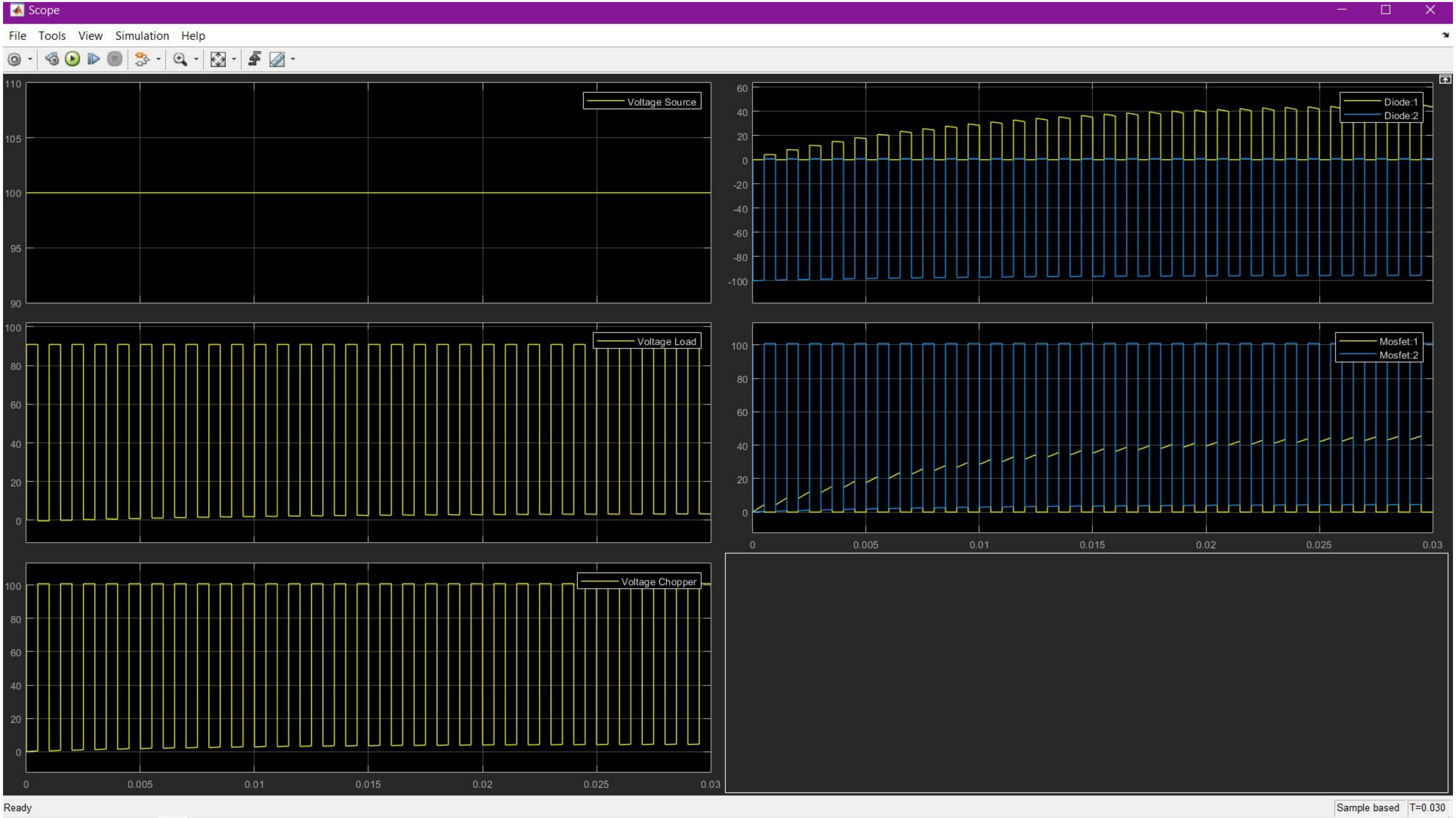
1. Make the required circuit in SIMULINK in MATLAB for step up chopper.
2. Simulate the circuit for 1 second.
3. Observe the waveform from the scope.
4. Now repeat the procedure for step down chopper.

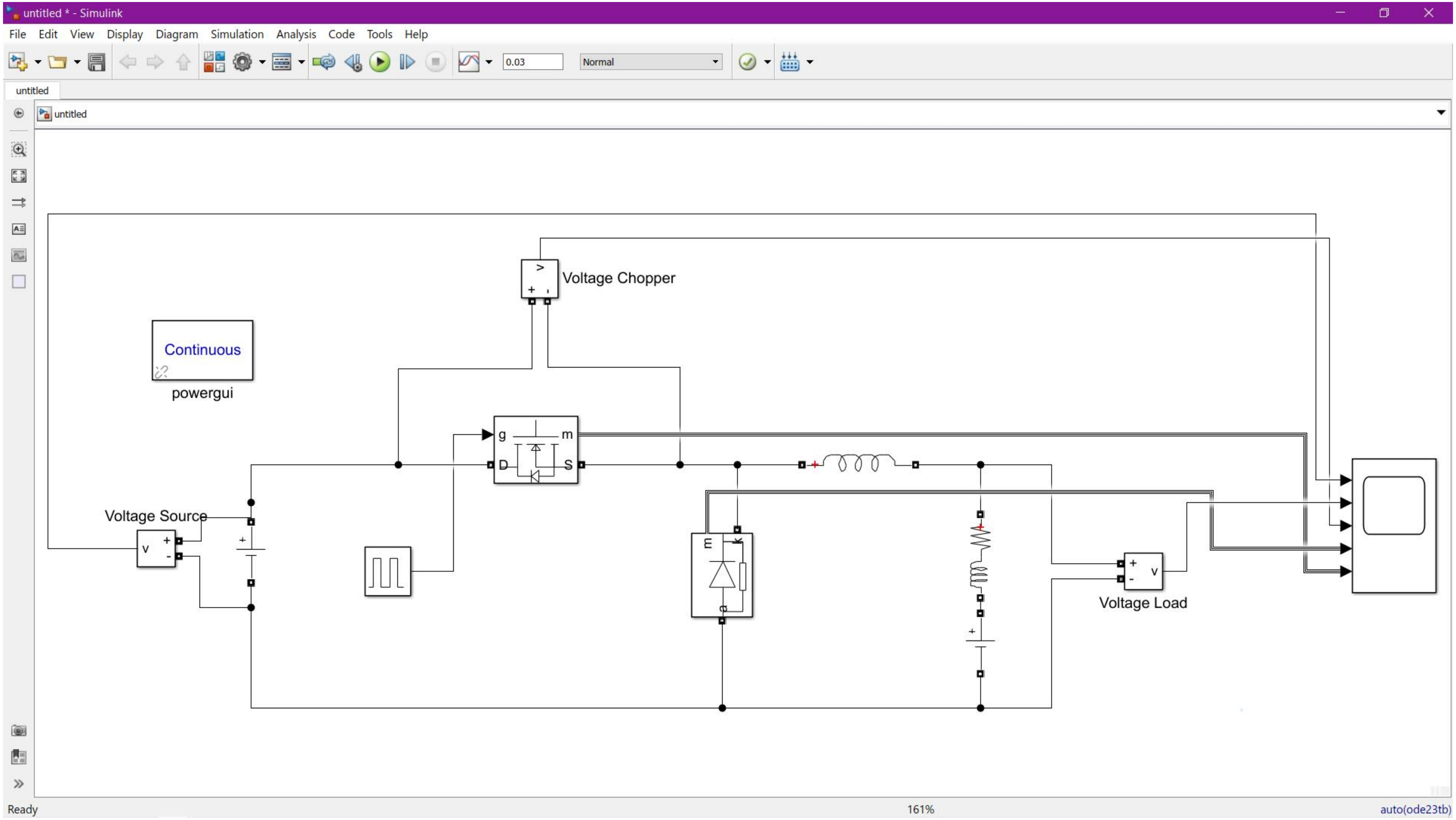
MATLAB Simulation

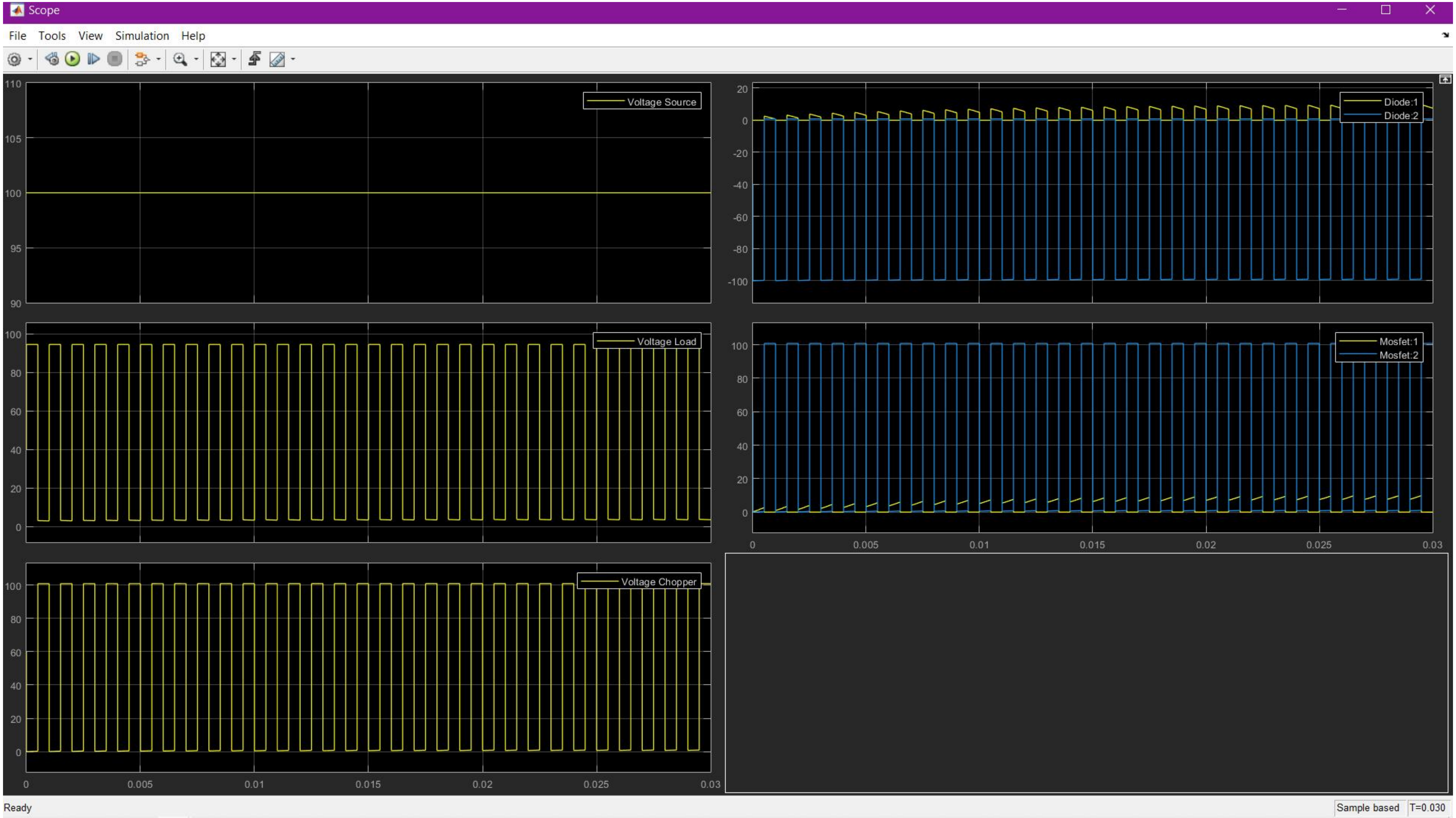


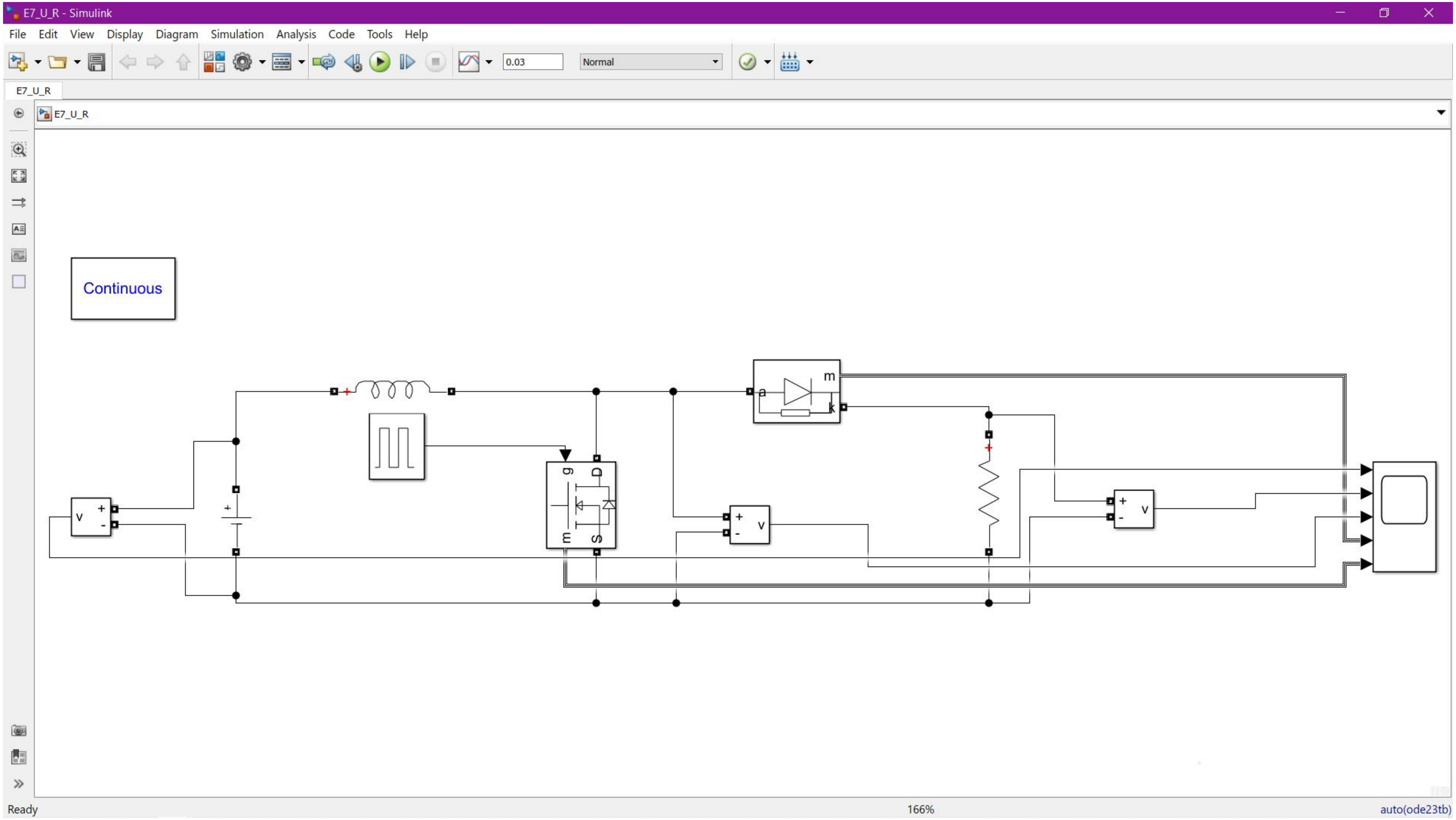

Scope
File Tools View Simulation Help
Voltage Source
Diode:1
Diode:2
Voltage Load
Mosfet:1
Mosfet:2
Voltage Chopper
Ready
Sample based
T=0.030

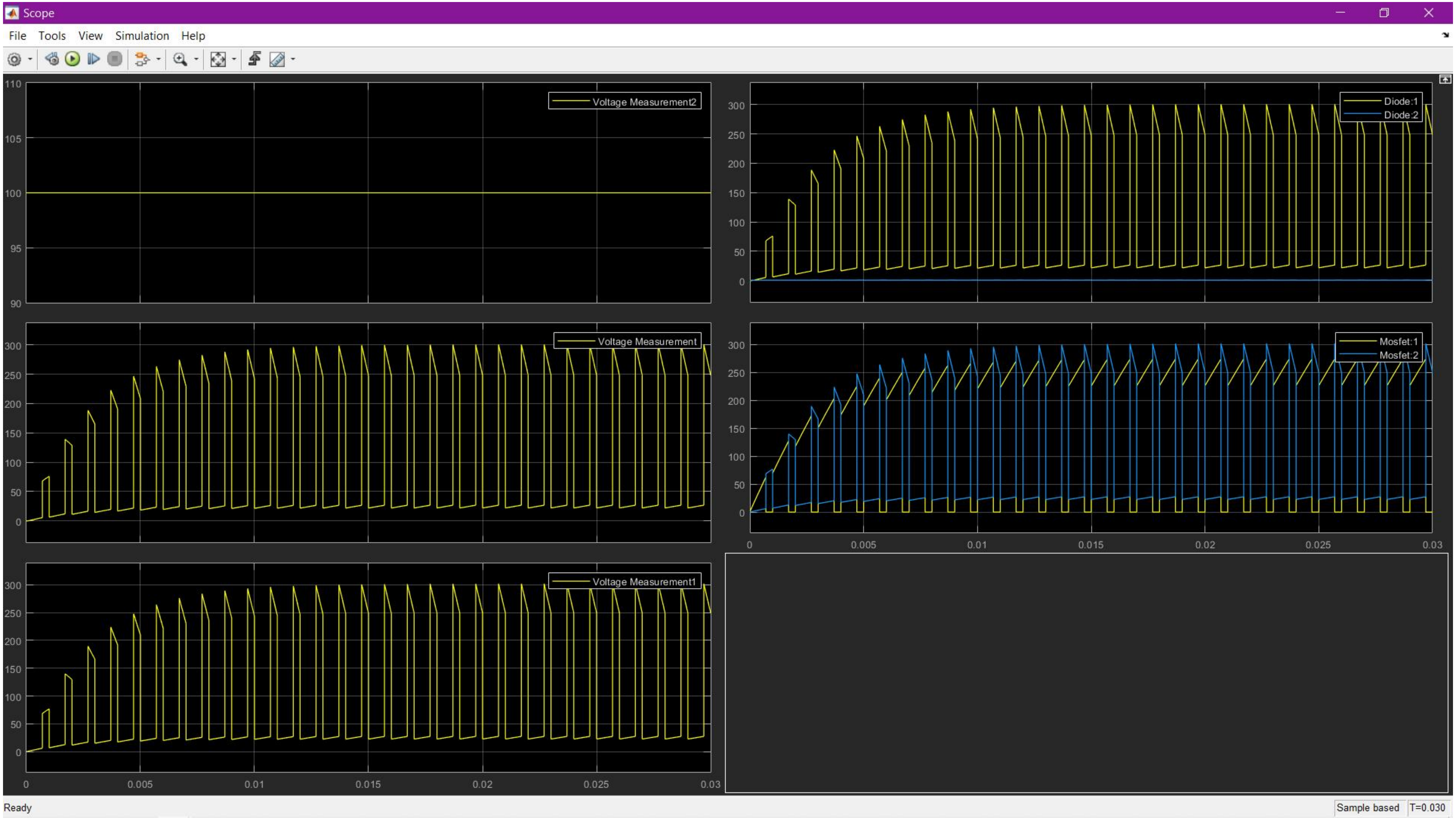

untitled * - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
0.03
Normal
untitled
Voltage Chopper
Continuous
powergui
Voltage Source
Voltage Load
Ready
161%
auto(ode23tb)

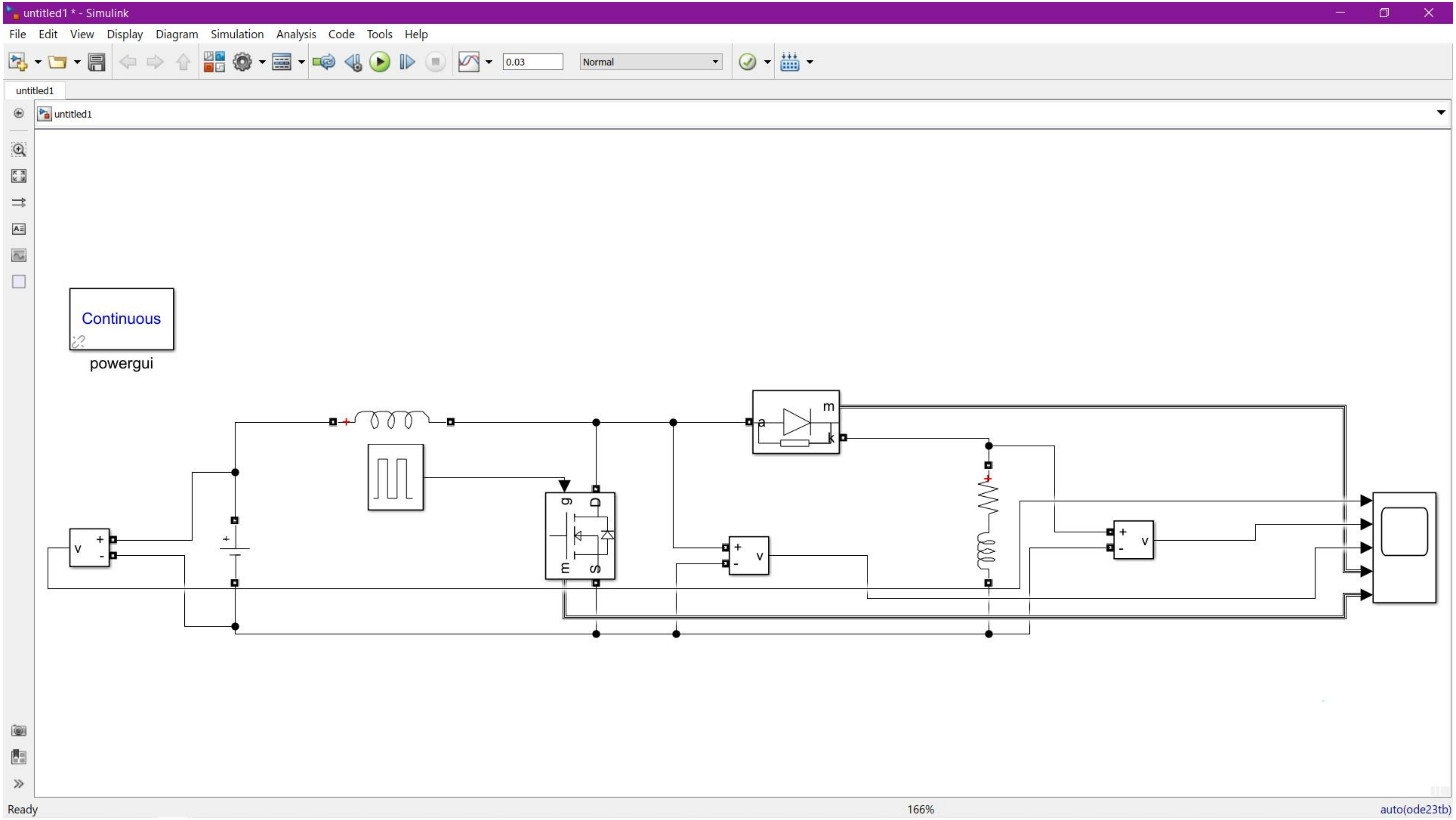

Scope
File Tools View Simulation Help
Voltage Source
Voltage Load
Voltage Chopper
Diode:1
Diode:2
Mosfet:1
Mosfet:2
Ready
Sample based
T=0.030

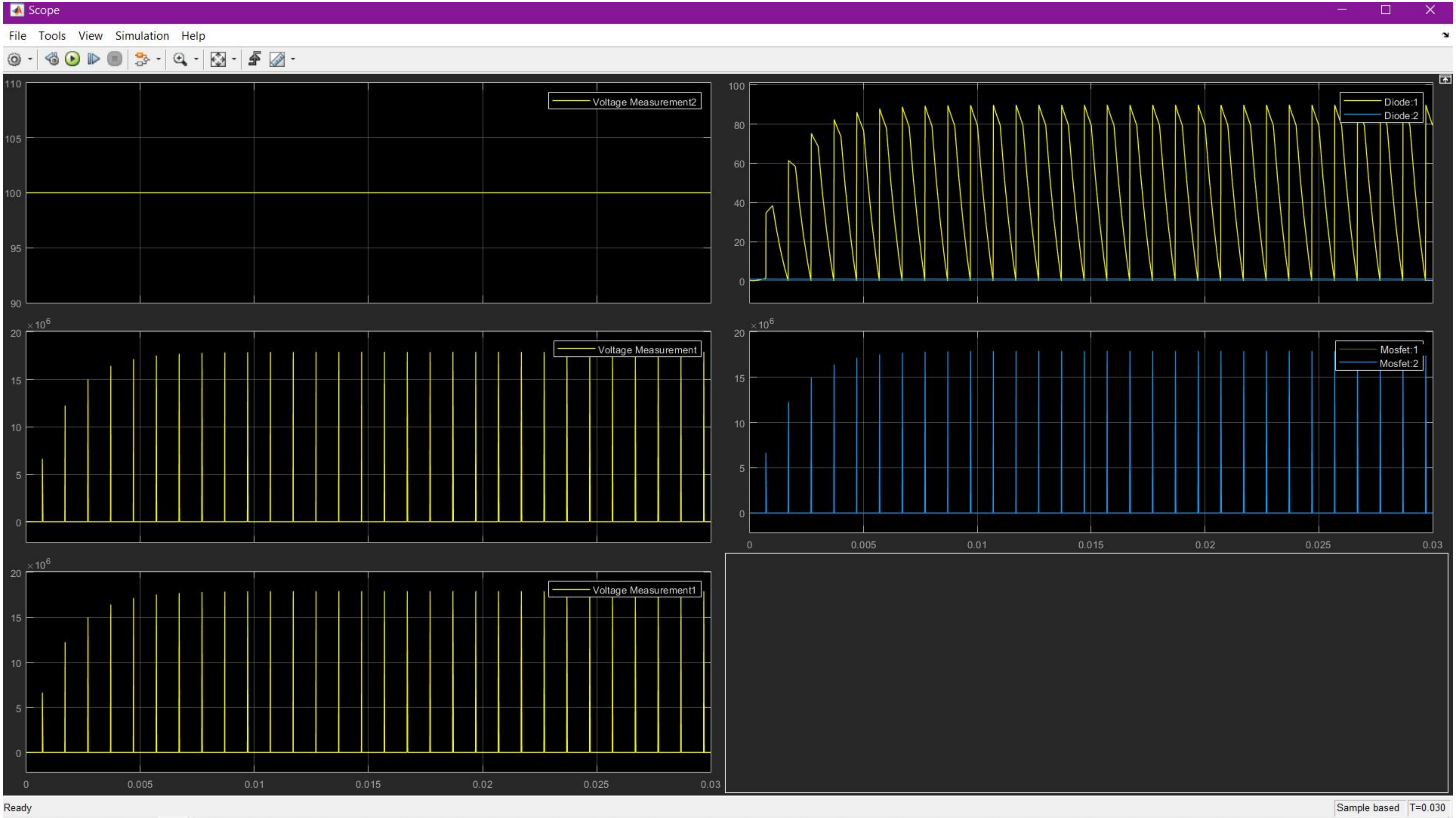

untitled * - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
0.03
Normal
untitled
Voltage Chopper
Continuous
powergui
Voltage Source
Voltage Load
Ready
161%
auto(ode23tb)

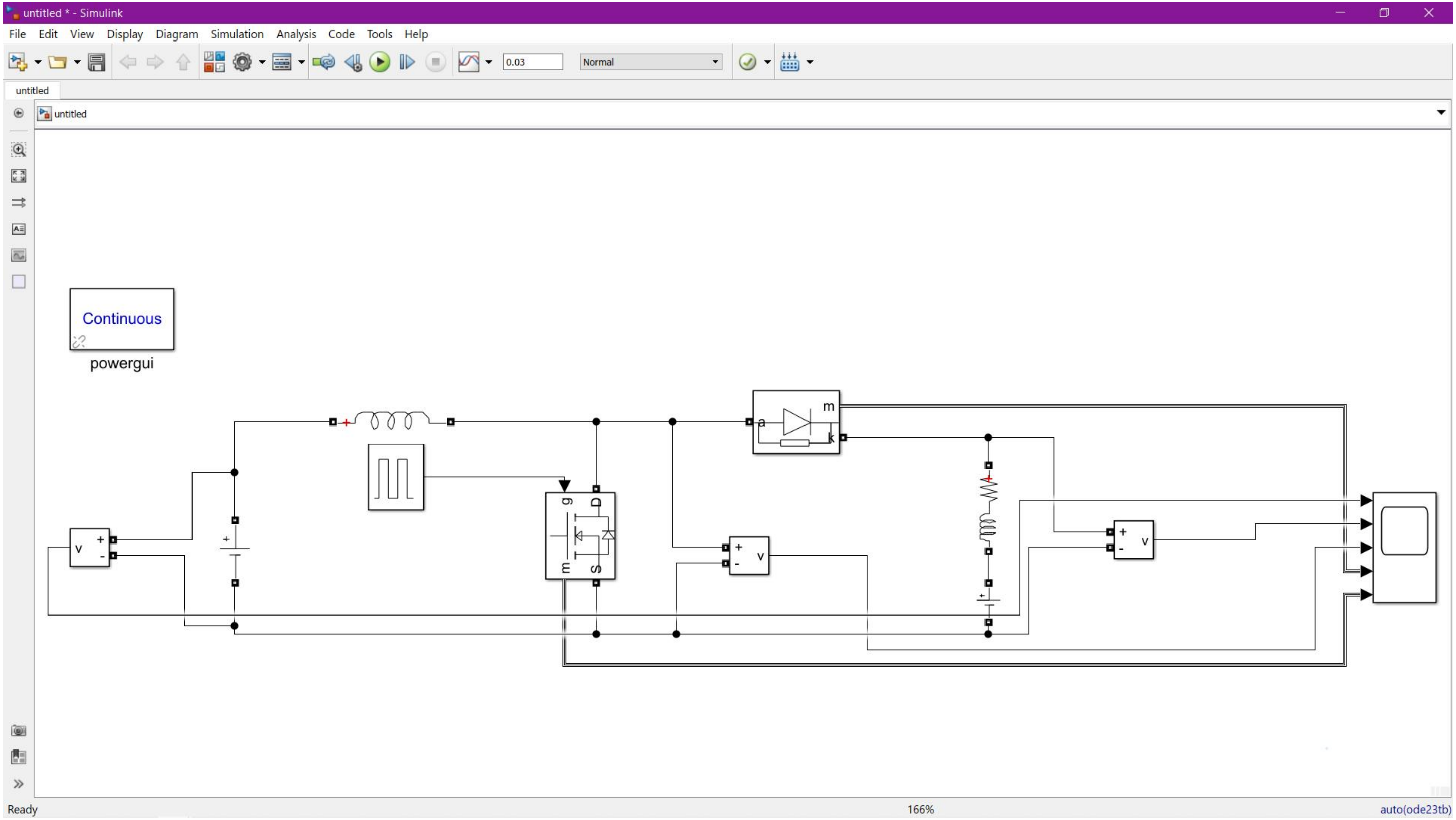

Scope
File Tools View Simulation Help
Voltage Source
Voltage Load
Voltage Chopper
Diode:1
Diode:2
Mosfet:1
Mosfet:2
0 0.005 0.01 0.015 0.02 0.025 0.03
Ready
Sample based
T=0.030

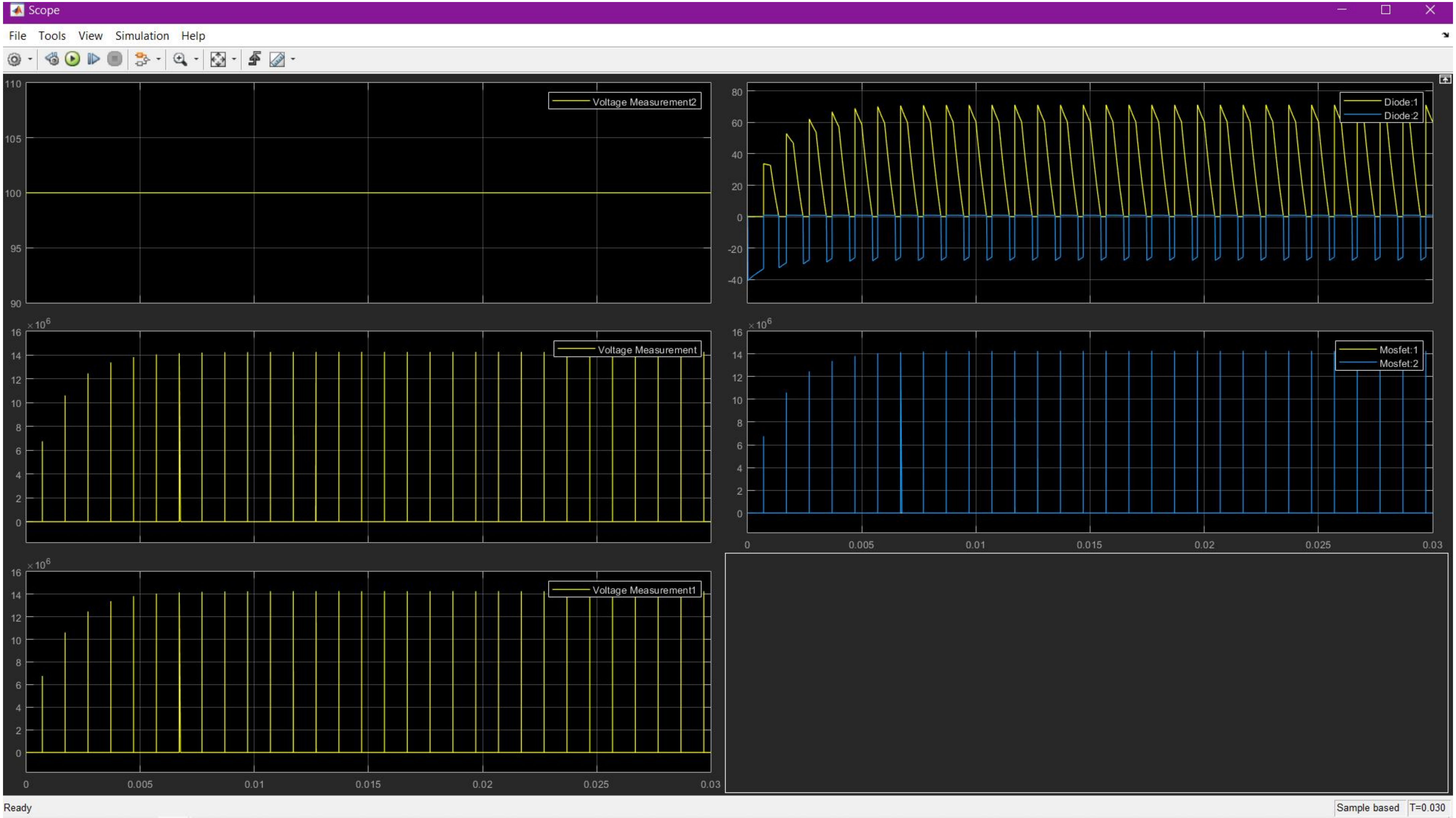

E7_U_R - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
0.03
Normal
E7_U_R
E7_U_R
Continuous
m
a
k
g
D
m
S
v
v
v
Ready
166%
auto(ode23tb)


Scope
File Tools View Simulation Help
Voltage Measurement2
Diode:1
Diode:2
Voltage Measurement
Mosfet:1
Mosfet:2
Voltage Measurement1
Ready
Sample based
T=0.030


untitled1 * - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
0.03
Normal
untitled1
Continuous
powergui
Ready
166%
auto(ode23tb)


Scope
File Tools View Simulation Help
Voltage Measurement2
Diode:1
Diode:2
Voltage Measurement
Mosfet:1
Mosfet:2
Voltage Measurement1
Ready
Sample based
T=0.030


untitled * - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
0.03
Normal
untitled
untitled
Continuous
powergui
m
a
k
g
D
m
S
v
v
v
Ready
166%
auto(ode23tb)


Scope
File Tools View Simulation Help
Voltage Measurement2
Diode:1
Diode:2
Voltage Measurement
Mosfet:1
Mosfet:2
Voltage Measurement1
Ready
Sample based
T=0.030

* **Result:** Simulated the step up and step down chopper for R, RL and RLE load using MATLAB simulink

* **Precautions:**

1. Use powergui to store the equivalent simulink circuit that represents the state-space equation of the model.
2. Always keep the circuit closed.
3. MATLAB takes time to respond, do not give multiple command at once.

Experiment - 8

* **Aim:** To simulate the three phase bridge voltage source inverter (180° & 120° modes) with R & RL load using MATLAB Simulink.

* **Requirement:** MATLAB Simulink

* **Theory:** A three phase inverter converts DC input into a three phase AC output. Its three arms are normally delayed by an angle of 120° so as to generate a three phase AC supply. There are two types of Inverter.

— 180° Mode of conduction

In this mode of conduction, every device is in conduction state of 180°, where they are switched ON at 60° intervals.

Firing scheme in this mode is:

Interval	Conducting Device	Incoming	Outgoing
I	5,6,1	1	4
II	6,1,2	2	5
III	1,2,3	3	6
IV	2,3,4	4	1
V	3,4,5	5	2
VI	4,5,6	6	3

* Diagram:

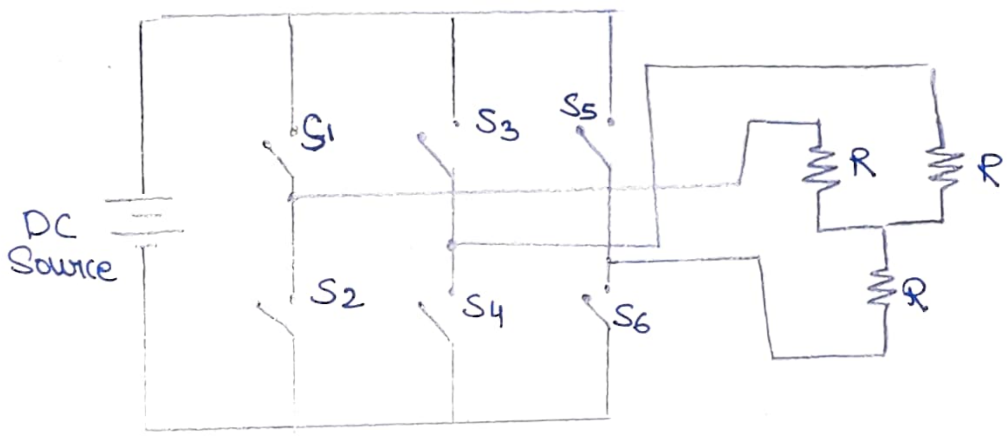


Fig 8.1 : Circuit diagram of VSI

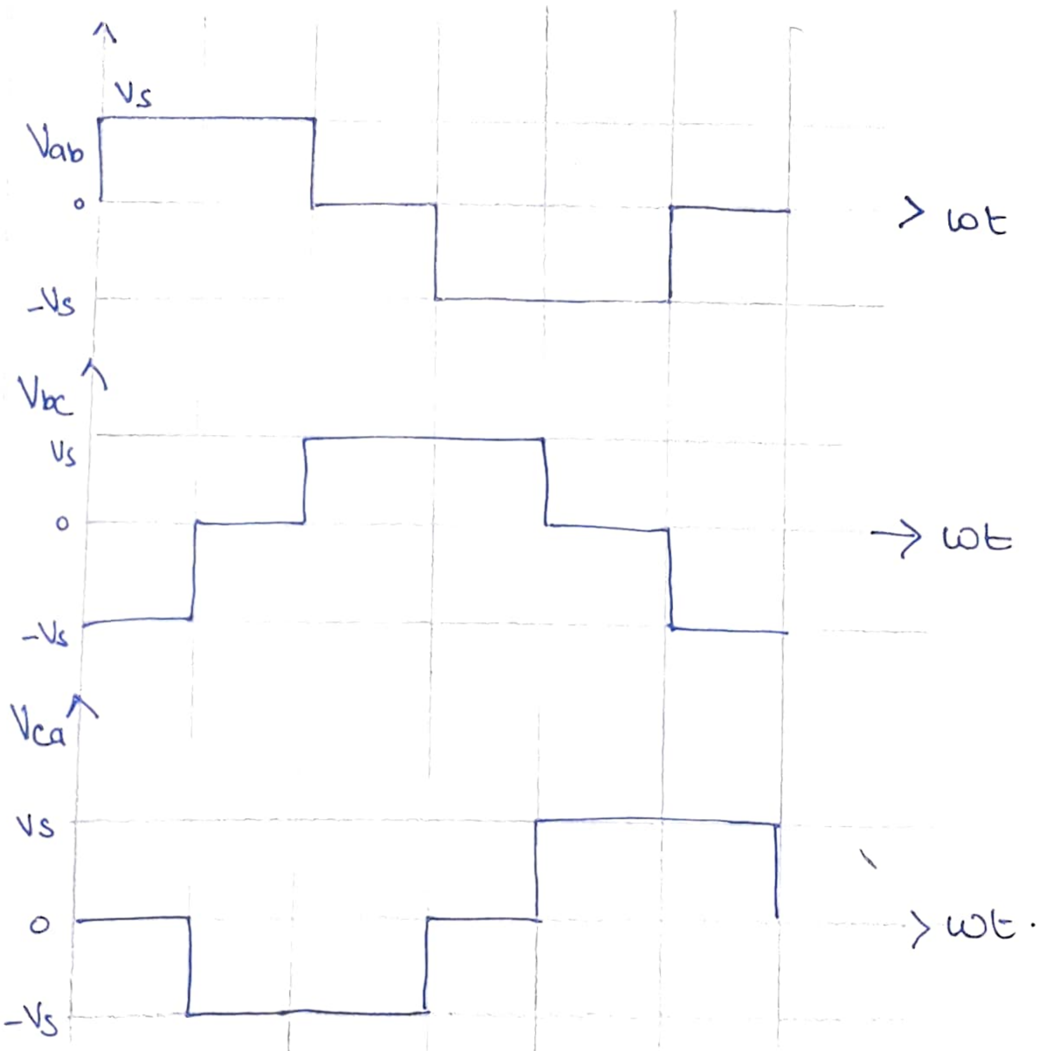


Fig 8.2: Wave form of 180° mode. (phase-to phase)

Interval I

$R_{eq} = \frac{3R}{2}$ $\qquad V_{an} = V_{cn} = \frac{IR}{2} = \frac{V_{dc}}{3}$

$I = \frac{2V_{dc}}{3R}$ $\qquad V_{bn} = -IR = -\frac{2V_{dc}}{3}$

$\therefore V_{ab} = V_{dc}$

$V_{bc} = -V_{dc}$

$V_{ca} = 0$

$\therefore$ the phase to phase ~~vol~~ and line voltage are:

Interval	V_{an}	V_{bn}	V_{cn}	V_{ab}	V_{bc}	V_{ca}
I	$V_{dc}/3$	$-2V_{dc}/3$	$V_{dc}/3$	V_{dc}	$-V_{dc}$	0
II	$2V_{dc}/3$	$-V_{dc}/3$	$-V_{dc}/3$	V_{dc}	0	$-V_{dc}$
III	$V_{dc}/3$	$V_{dc}/3$	$-2V_{dc}/3$	0	V_{dc}	$-V_{dc}$
IV	$-V_{dc}/3$	$2V_{dc}/3$	$-V_{dc}/3$	$-V_{dc}$	V_{dc}	0
V	$-2V_{dc}/3$	$V_{dc}/3$	$V_{dc}/3$	$-V_{dc}$	0	V_{dc}
VI	$-V_{dc}/3$	$-V_{dc}/3$	$2V_{dc}/3$	0	$-V_{dc}$	V_{dc}

— 120° Mode of Conduction

In this mode, each device is in conduction ~~mode~~ state of 120°. It is most suitable for a delta ~~connect~~ connection in a load because it results in a six step type of waveform.

Firing scheme ~~a~~ in this mode is:

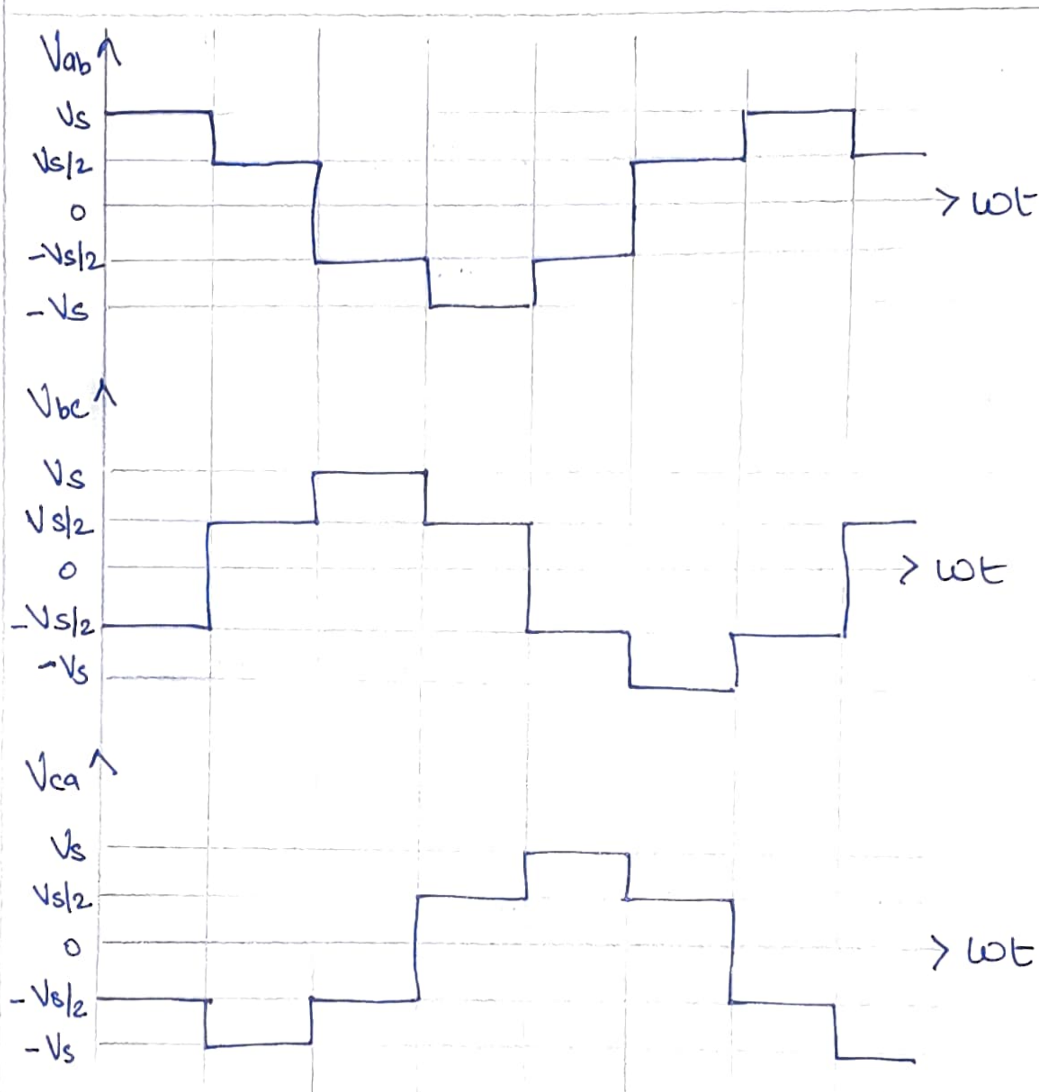


Fig 8.3: Waveform of 120° mode.

Interval	Conducting Device	Incoming	Outgoing
I	6, 1	1	6
II	1, 2	2	1
III	2, 3	3	2
IV	3, 4	4	3
V	4, 5	5	4
VI	5, 6	6	5

Interval I

$$i_o = \frac{V_{dc}}{R+R} = \frac{V_{dc}}{2R}$$

$$V_{an} = \frac{V_{dc}}{2} \qquad V_{bn} = \frac{-V_{dc}}{2} \qquad V_{cn} = 0$$

$$V_{AB} = V_{dc}$$

$$V_{BC} = -\frac{V_{dc}}{2}$$

$$V_{ca} = -\frac{V_{dc}}{2}$$

$\therefore$ the phase and line to line voltage are:

Interval	V_{an}	V_{bn}	V_{cn}	V_{ab}	V_{bc}	V_{ca}
I	$V_{dc}/2$	$-V_{dc}/2$	0	V_{dc}	$-V_{dc}/2$	$-V_{dc}/2$
II	$V_{dc}/2$	0	$-V_{dc}/2$	$V_{dc}/2$	$V_{dc}/2$	$-V_{dc}$
III	0	$V_{dc}/2$	$-V_{dc}/2$	$-V_{dc}/2$	V_{dc}	$-V_{dc}/2$
IV	$-V_{dc}/2$	$V_{dc}/2$	0	$-V_{dc}$	$V_{dc}/2$	$V_{dc}/2$

V	$-V_{dc}/2$	0	$V_{dc}/2$	$-V_{dc}/2$	$-V_{dc}/2$	$-V_{dc}$
VI	0	$-V_d/2$	$V_{dc}/2$	$V_{dc}/2$	V_{dc}	$V_{dc}/2$

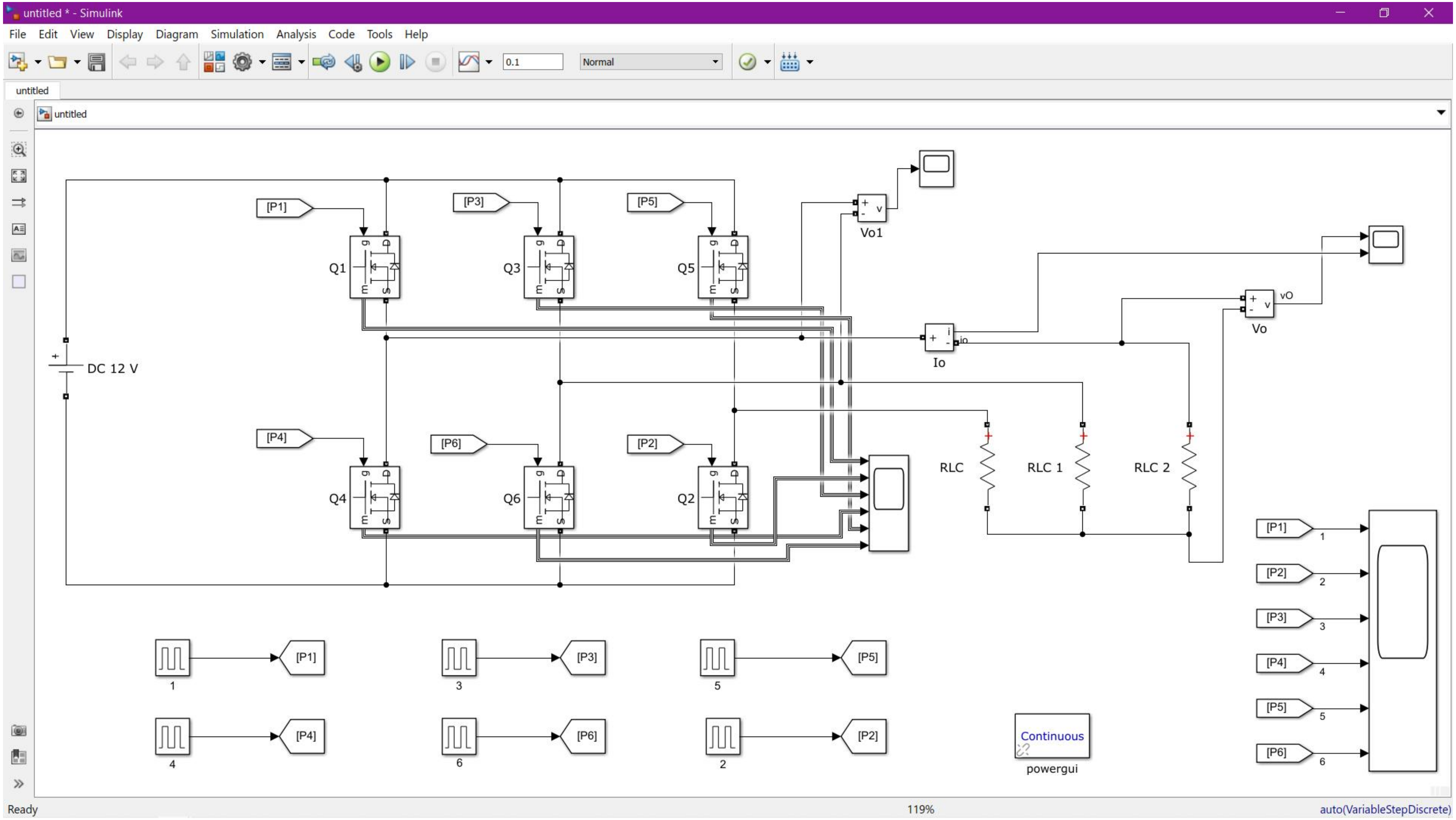
* Procedure:

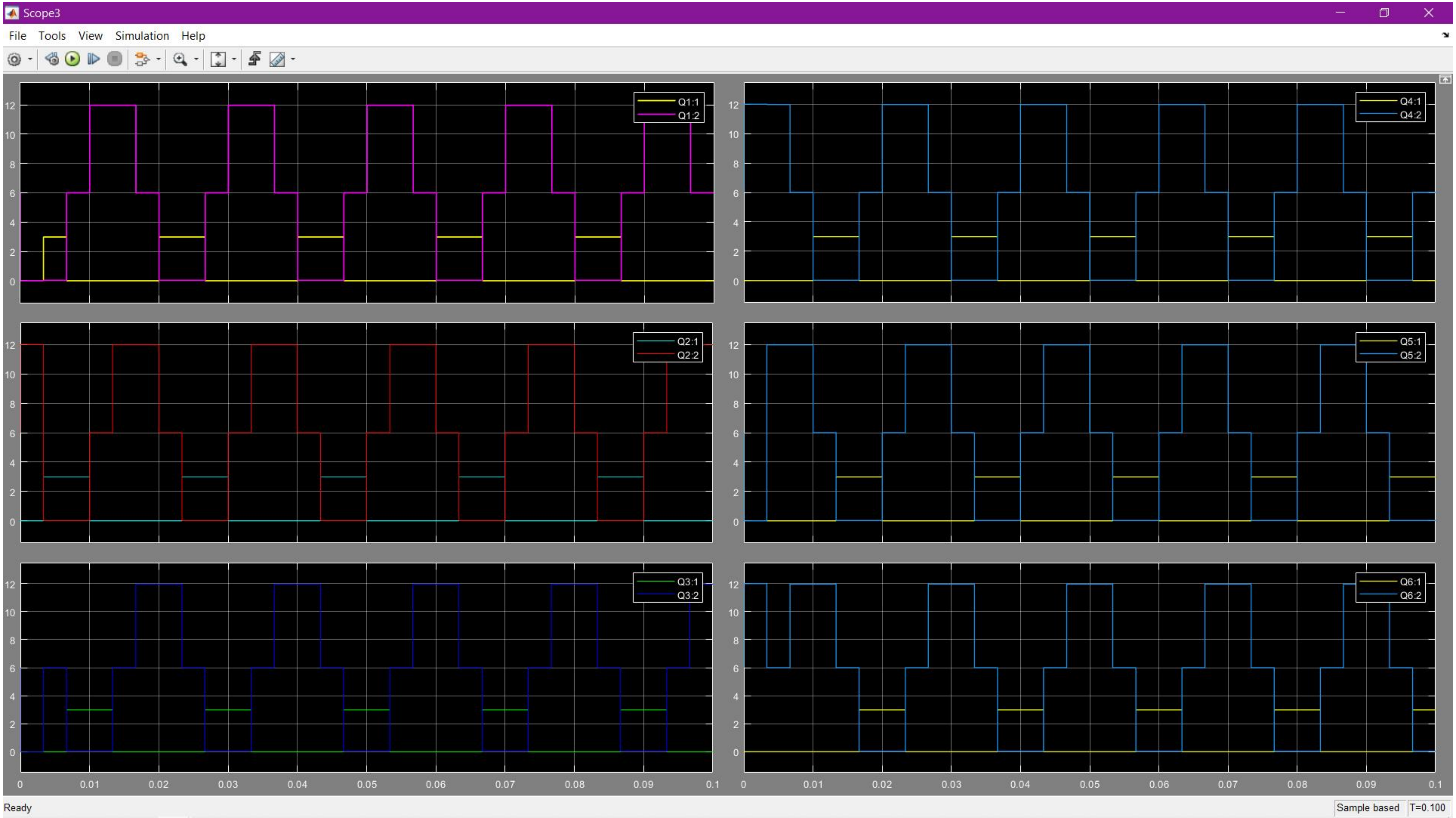
1. Make the required circuit in SIMULINK in MATLAB for 120° mode of VSI

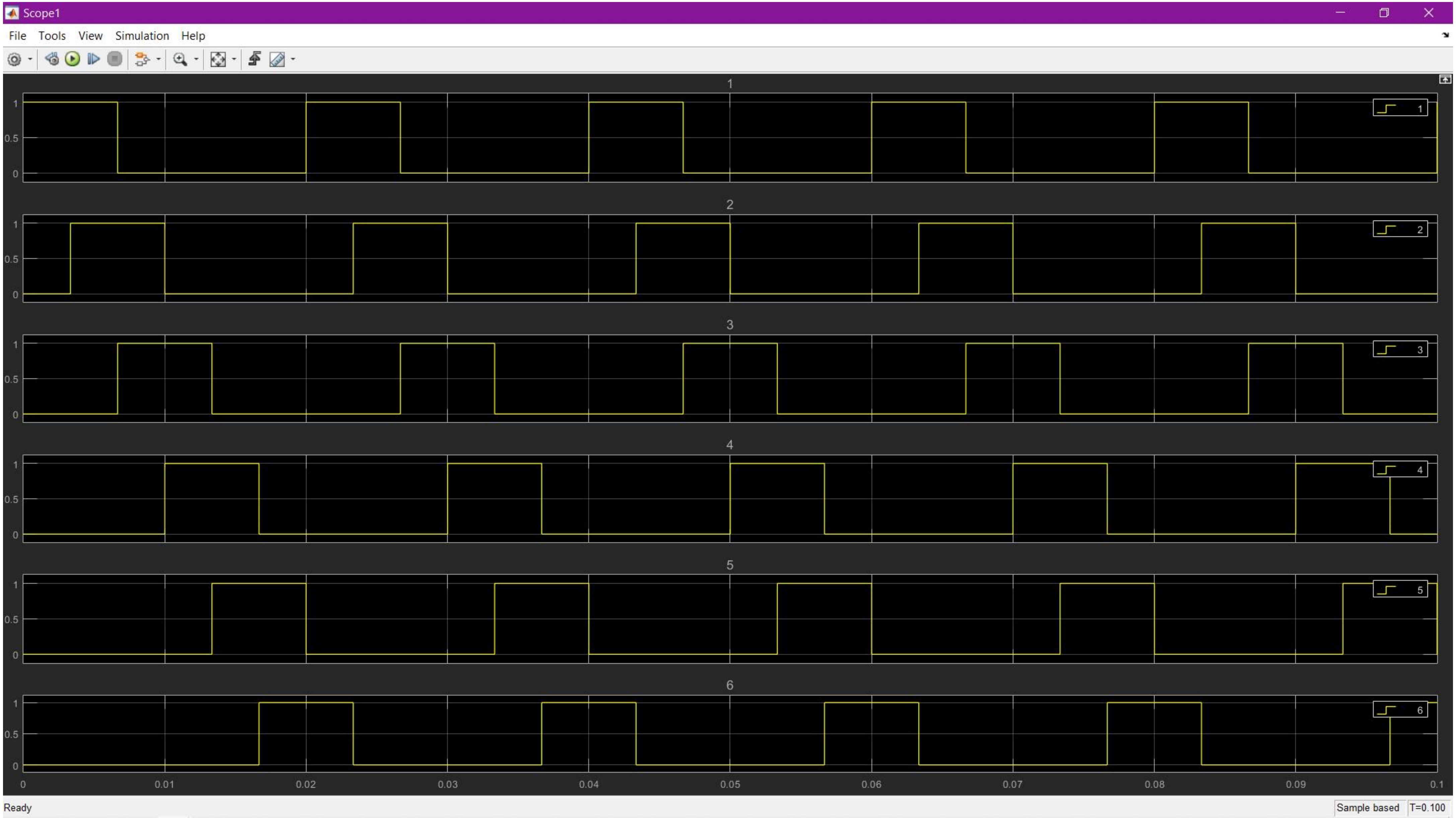
2. Simulate the model.

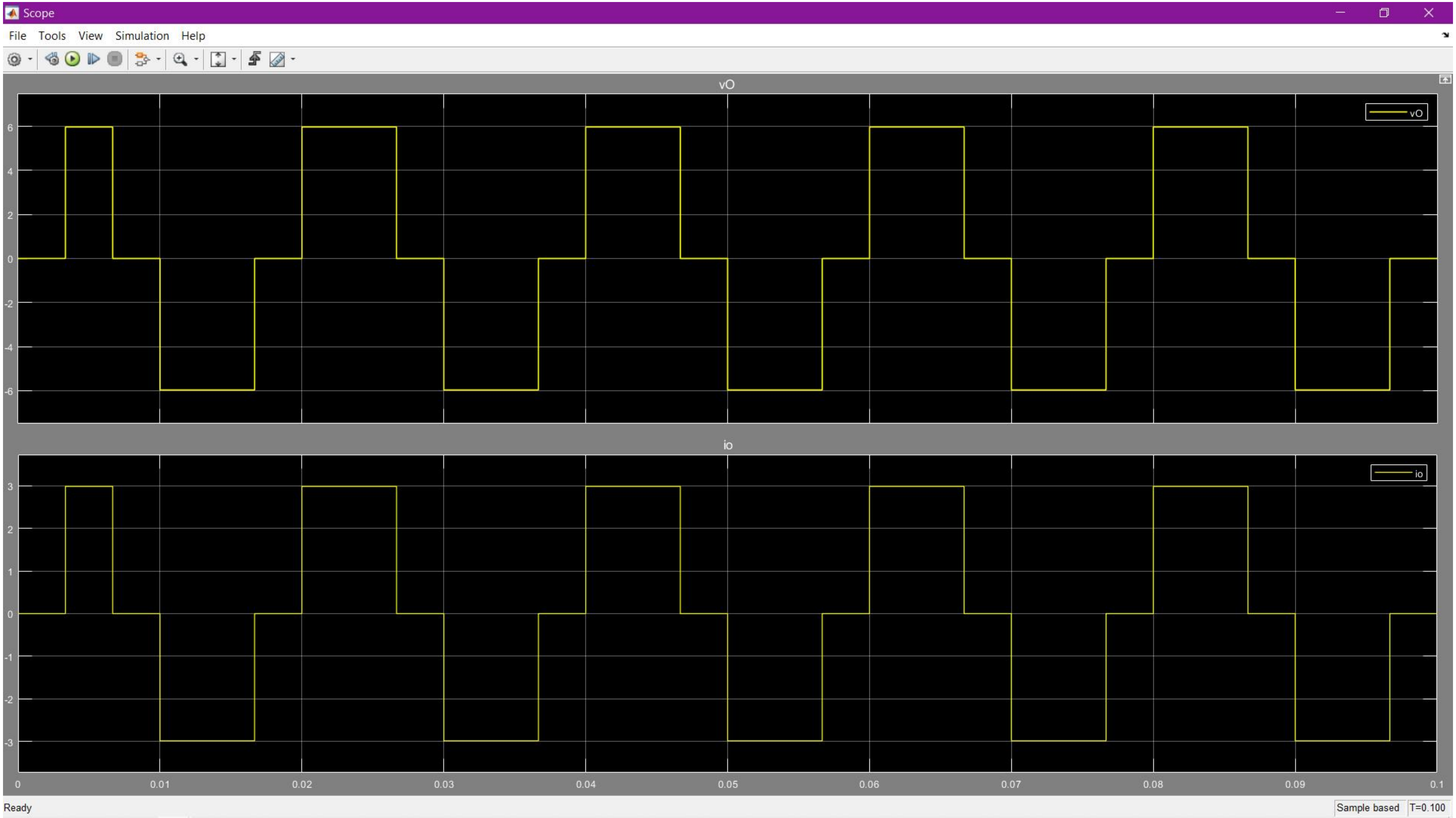
3. Observe the waveform from the slope

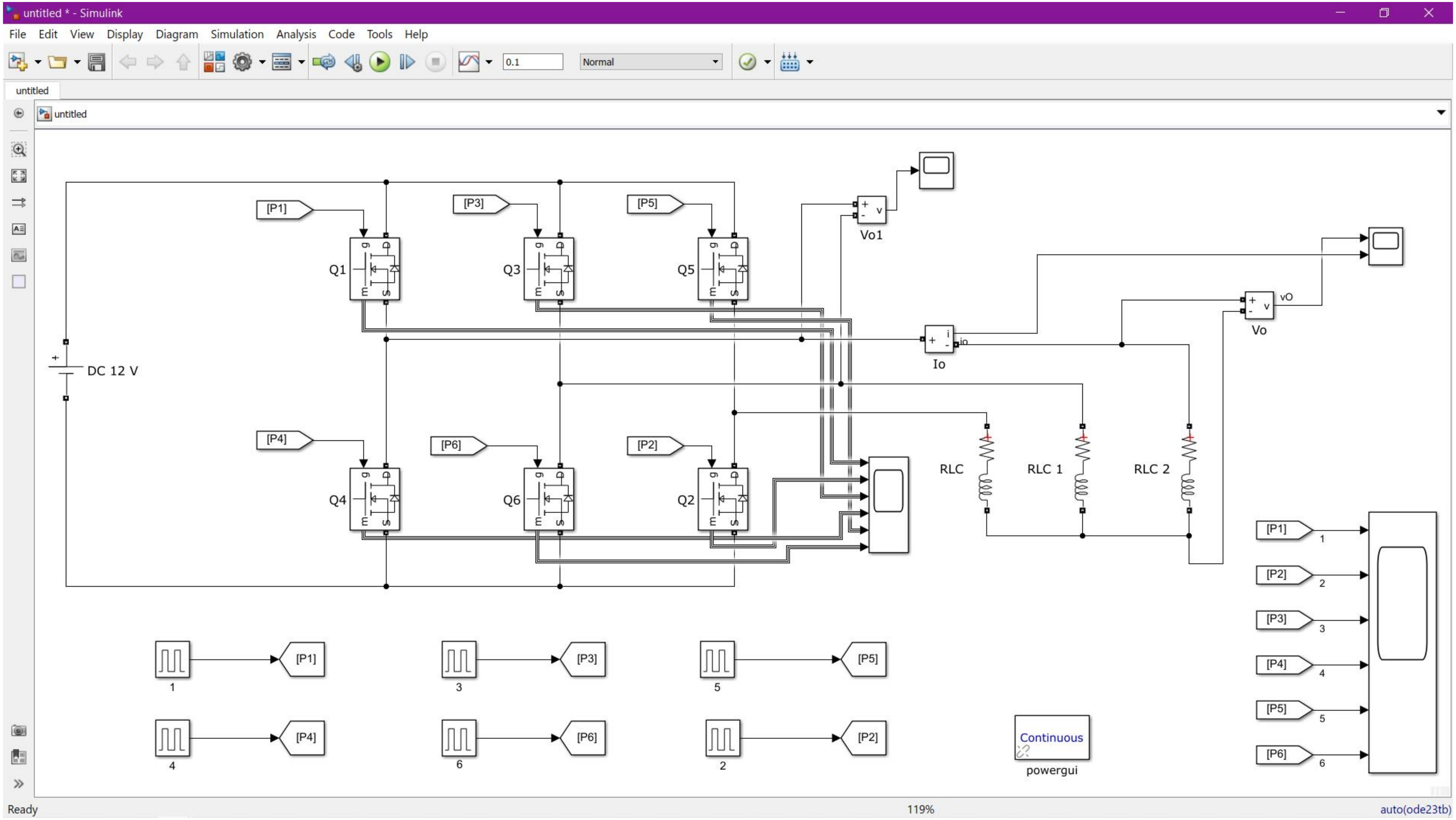
4. Now, repeat the process for ~~step~~ 180° mode of VSI.

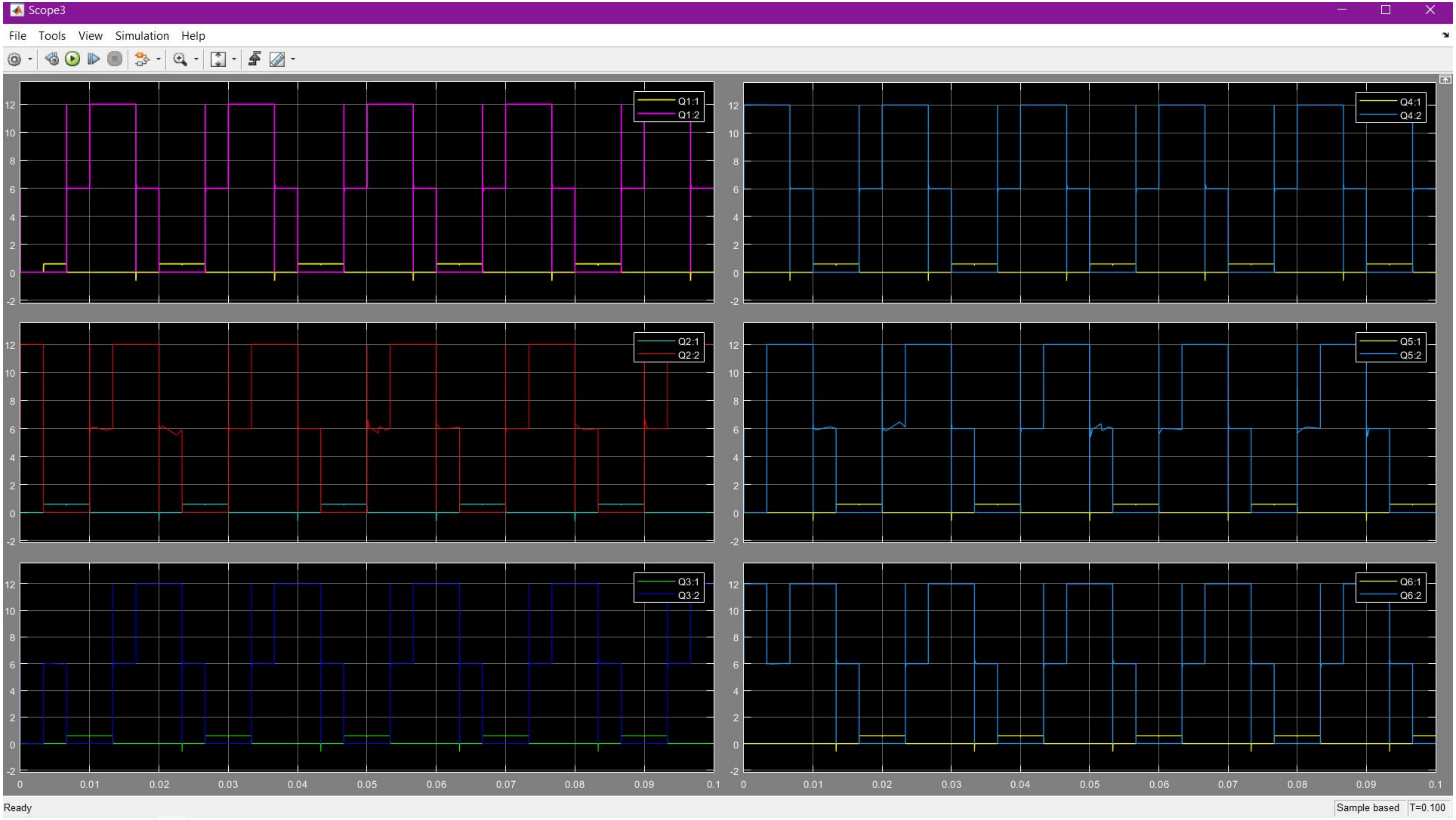

untitled * - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
0.1
Normal
untitled
untitled
[P1]
[P3]
[P5]
Q1
Q3
Q5
Vo1
DC 12 V
Io
Vo
vO
[P4]
[P6]
[P2]
Q4
Q6
Q2
RLC
RLC 1
RLC 2
1
3
5
4
6
2
Continuous
powergui
Ready
119%
auto(VariableStepDiscrete)

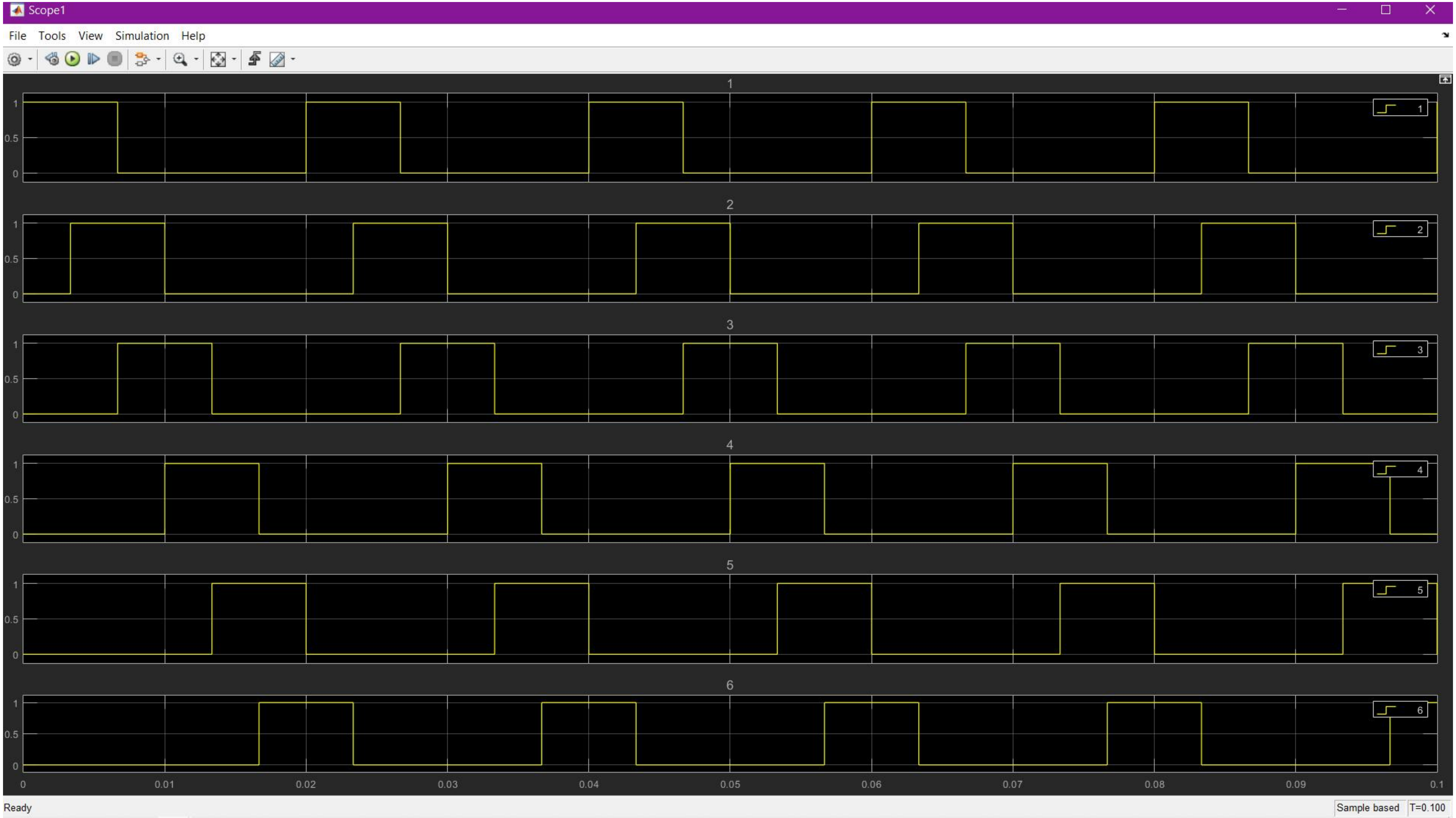

Scope3
File Tools View Simulation Help
Q1:1
Q1:2
Q2:1
Q2:2
Q3:1
Q3:2
Q4:1
Q4:2
Q5:1
Q5:2
Q6:1
Q6:2
Ready
Sample based
T=0.100

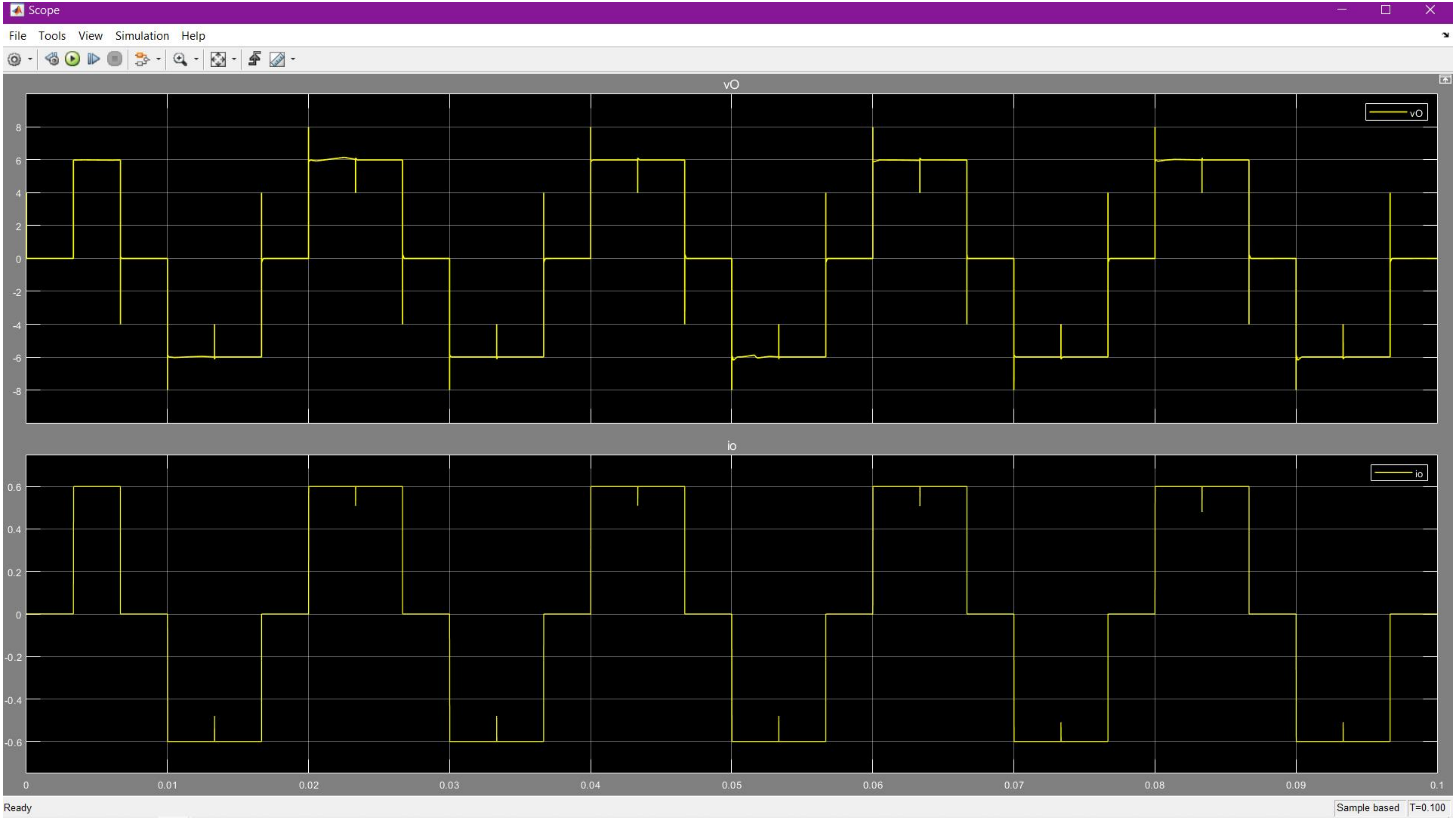

Scope1
File Tools View Simulation Help
1
2
3
4
5
6
0 0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09 0.1
Ready
Sample based
T=0.100

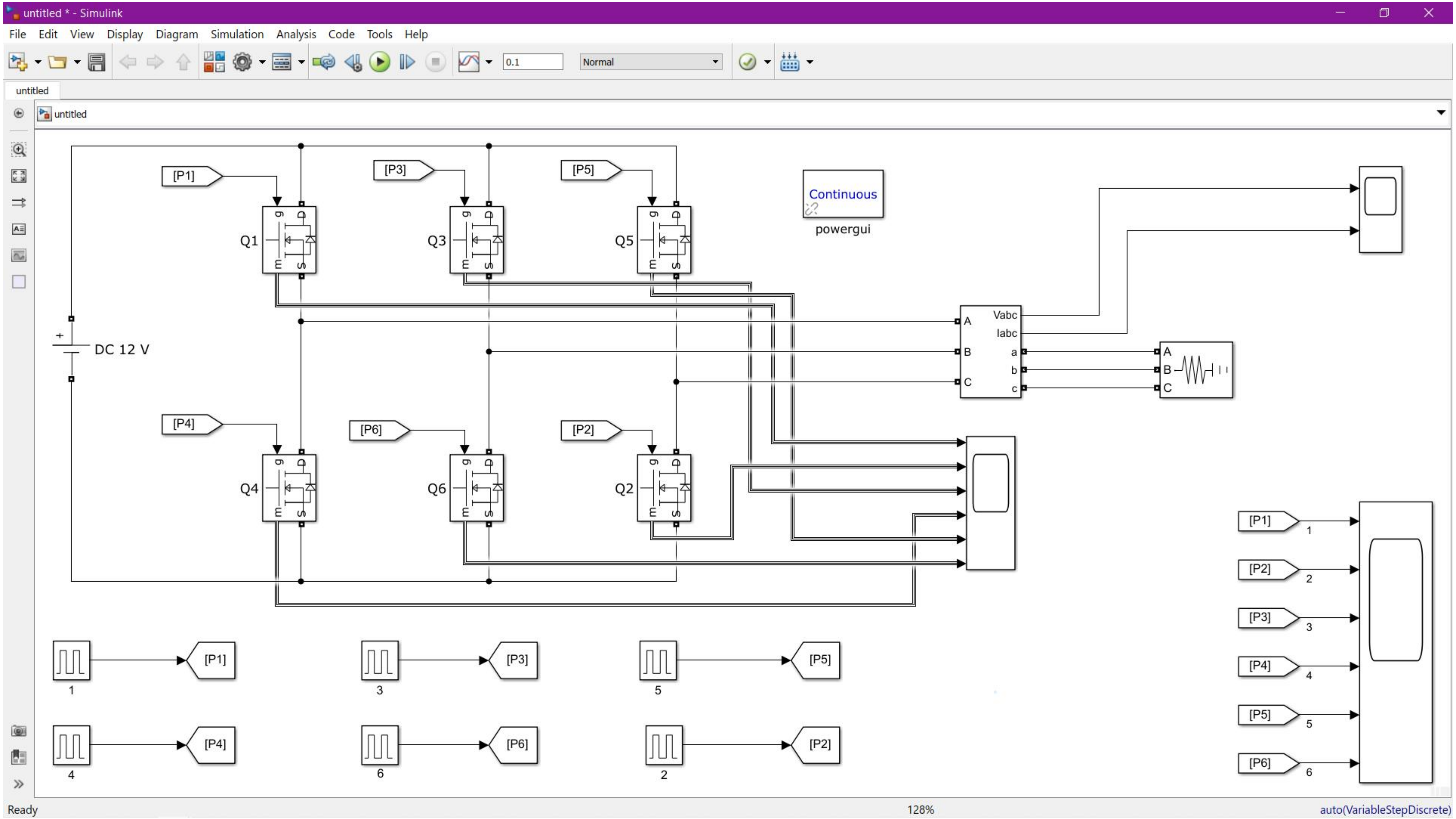

Scope
File Tools View Simulation Help
vO
vO
io
io
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
Ready
Sample based
T=0.100


untitled * - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
0.1
Normal
untitled
DC 12 V
[P1]
[P3]
[P5]
[P4]
[P6]
[P2]
Q1
Q3
Q5
Q4
Q6
Q2
Vo1
Io
Vo
vO
RLC
RLC 1
RLC 2
Continuous
powergui
Ready
119%
auto(ode23tb)

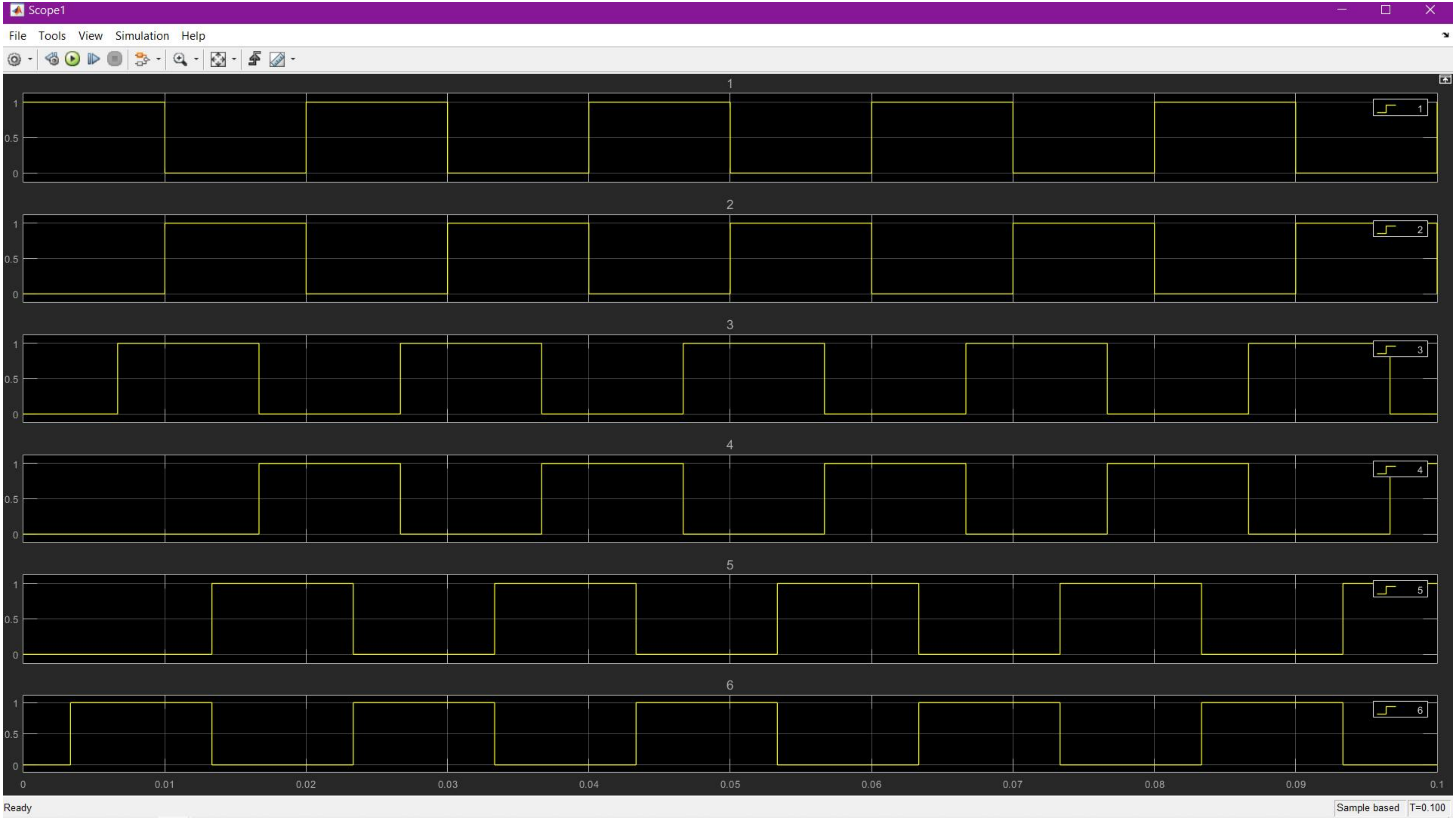

Scope3
File Tools View Simulation Help
Q1:1
Q1:2
Q2:1
Q2:2
Q3:1
Q3:2
Q4:1
Q4:2
Q5:1
Q5:2
Q6:1
Q6:2
Ready
Sample based
T=0.100

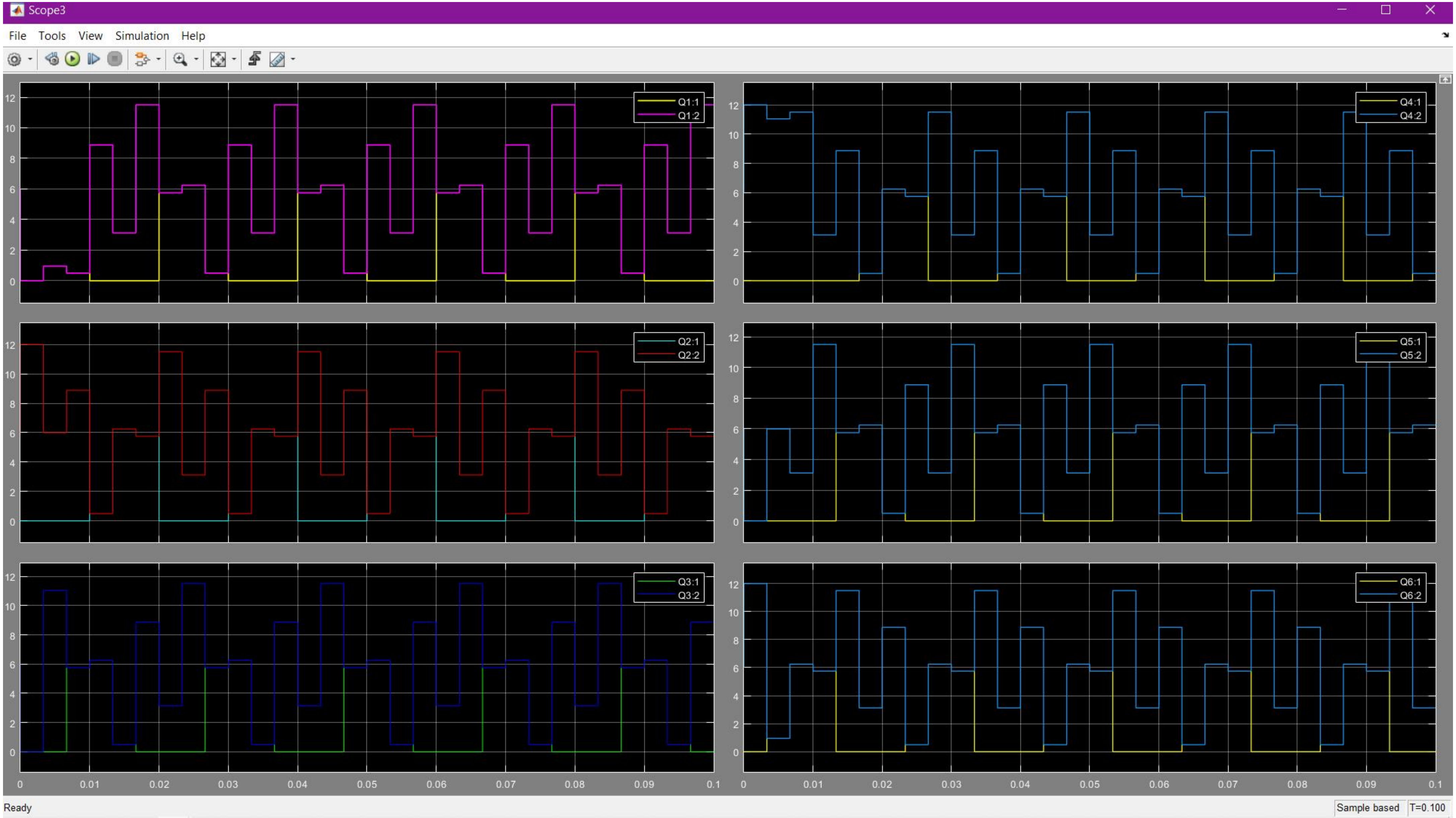

Scope1
File Tools View Simulation Help
1
2
3
4
5
6
0 0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09 0.1
Ready
Sample based T=0.100


Scope
File Tools View Simulation Help
vO
vO
8
6
4
2
0
-2
-4
-6
-8
io
io
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
Ready
Sample based
T=0.100

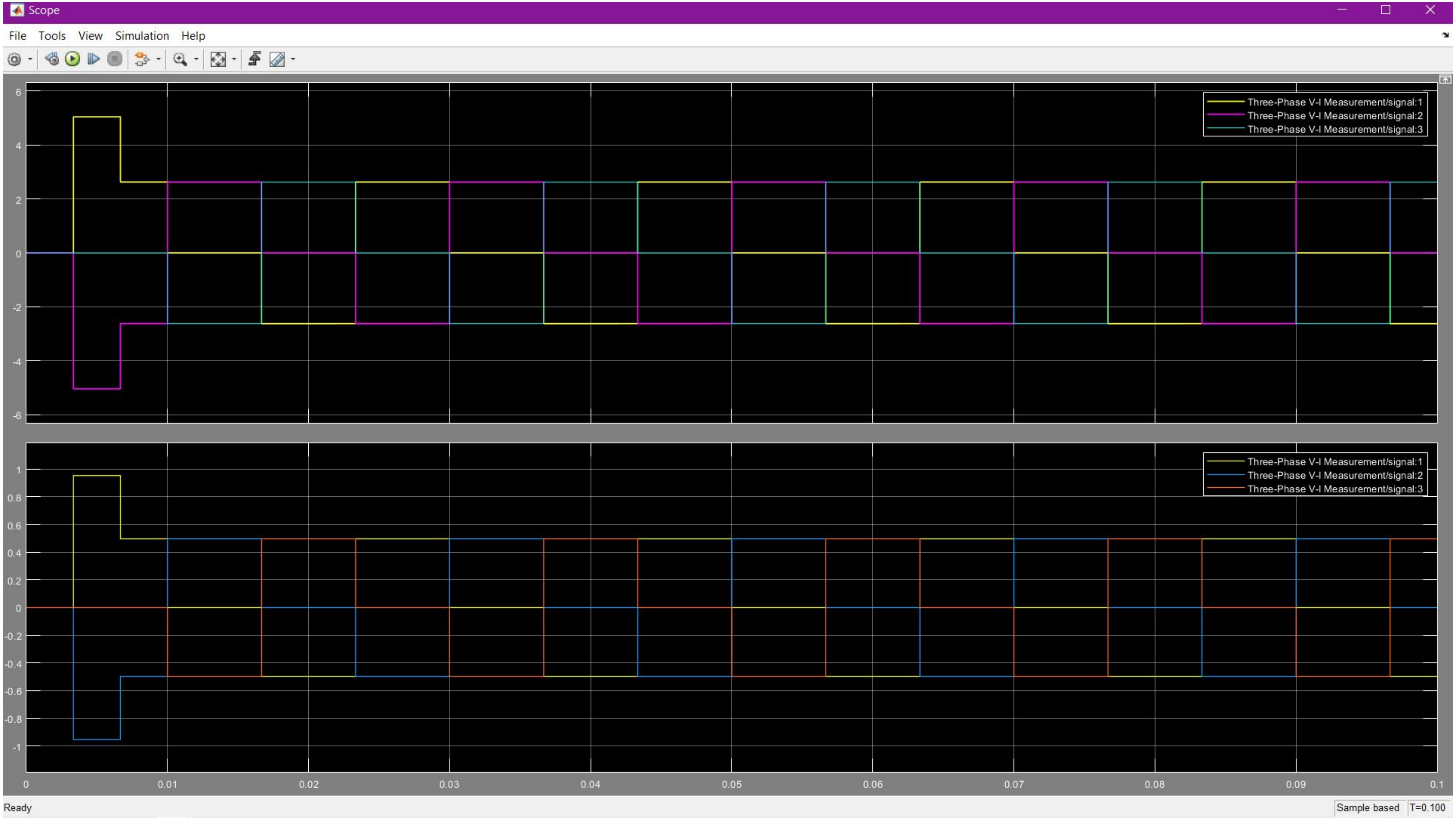


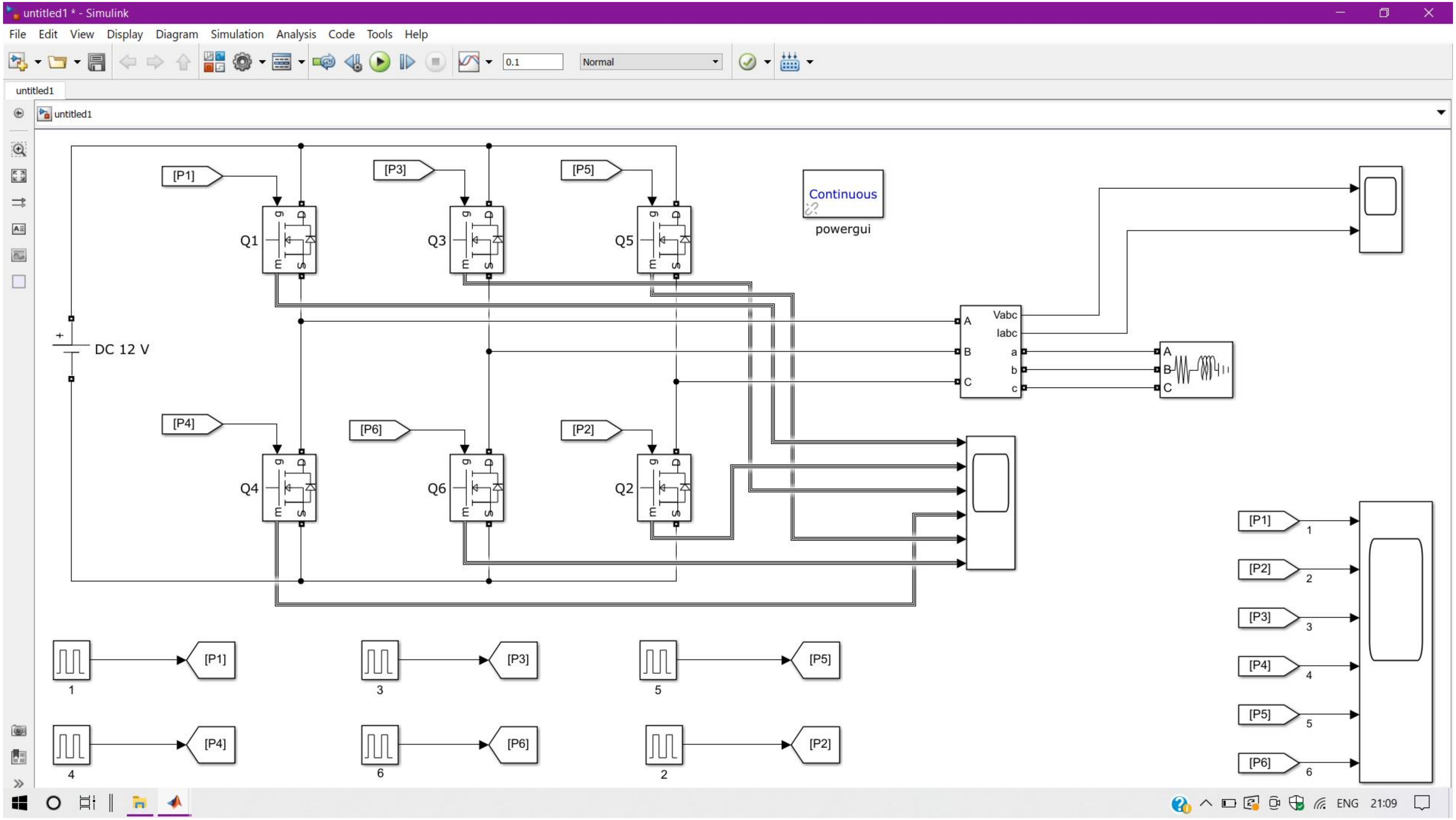
untitled * - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
Normal
untitled
[P1]
[P3]
[P5]
Q1
Q3
Q5
Continuous
powergui
DC 12 V
Vabc
Iabc
[P4]
[P6]
[P2]
Q4
Q6
Q2
Ready
128%
auto(VariableStepDiscrete)

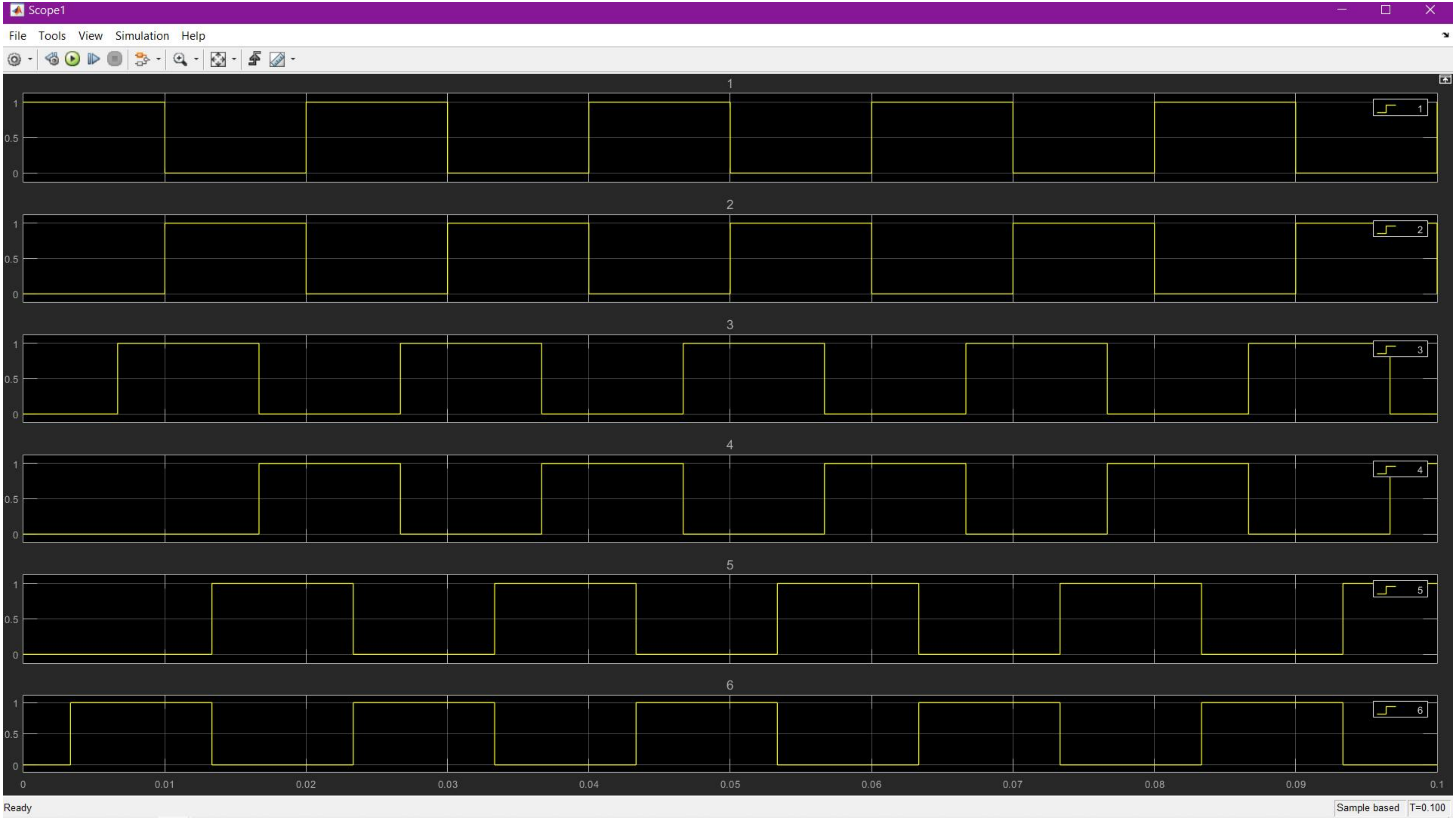

Scope1
File Tools View Simulation Help
1
2
3
4
5
6
1
0.5
0
0 0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09 0.1
Ready
Sample based T=0.100

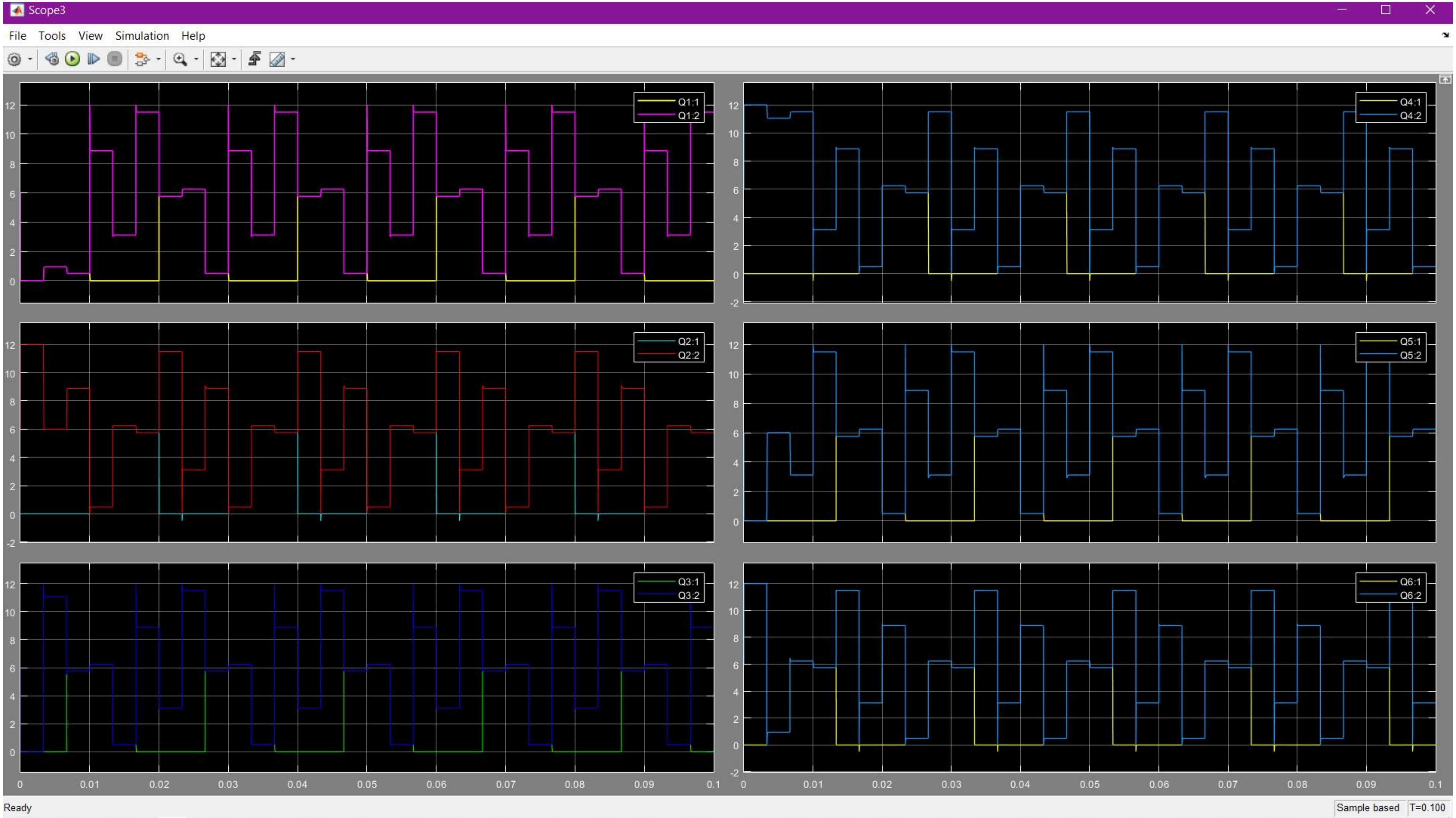


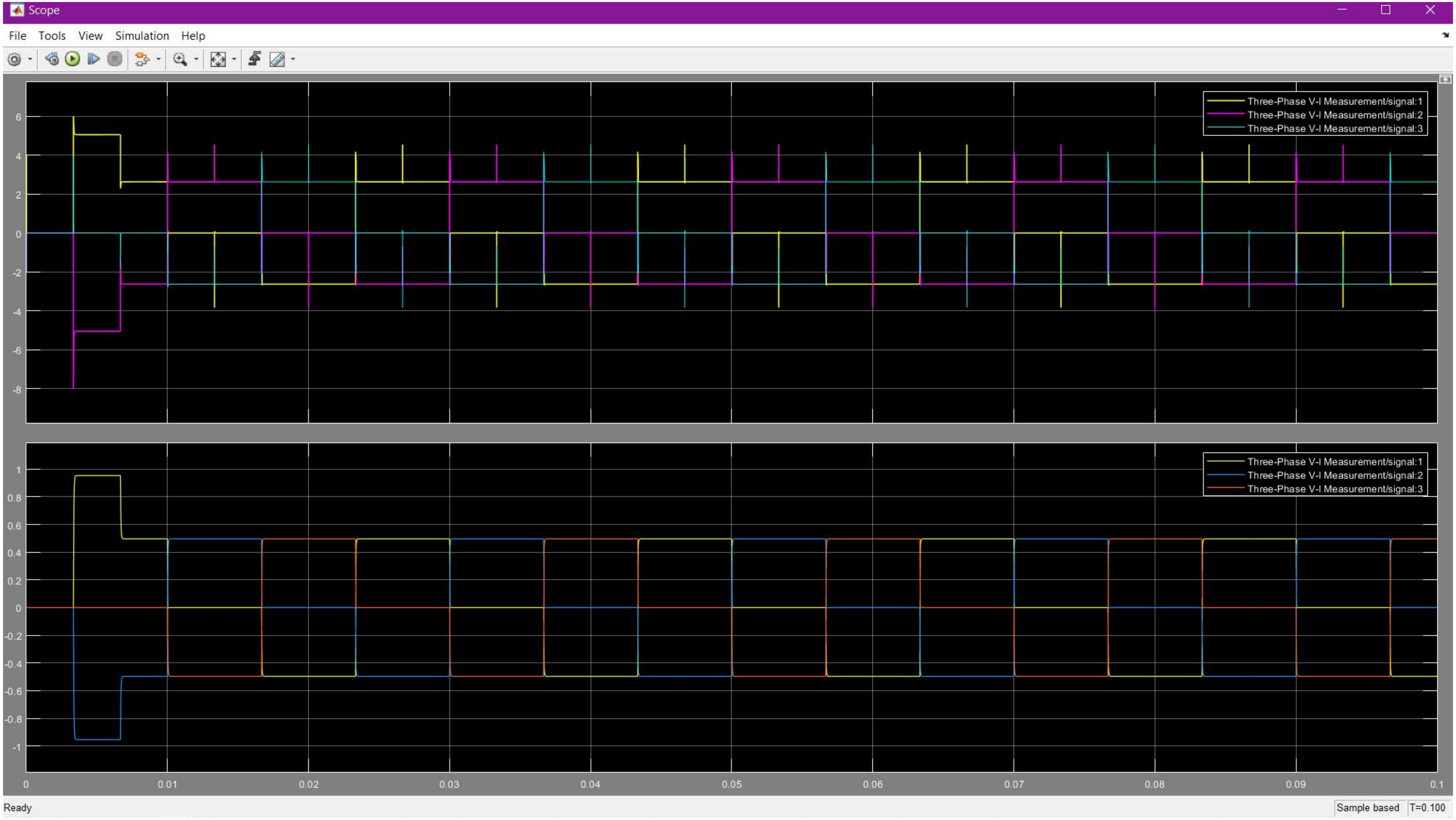
Scope3
File Tools View Simulation Help
Q1:1
Q1:2
Q2:1
Q2:2
Q3:1
Q3:2
Q4:1
Q4:2
Q5:1
Q5:2
Q6:1
Q6:2
0 0.01 0.02 0.03 0.04 0.05 0.06 0.07 0.08 0.09 0.1
Ready
Sample based
T=0.100


Scope
File Tools View Simulation Help
Three-Phase V-I Measurement/signal:1
Three-Phase V-I Measurement/signal:2
Three-Phase V-I Measurement/signal:3
Three-Phase V-I Measurement/signal:1
Three-Phase V-I Measurement/signal:2
Three-Phase V-I Measurement/signal:3
Ready
Sample based
T=0.100


untitled1 * - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
0.1
Normal
untitled1
Continuous
powergui
DC 12 V
[P1]
[P3]
[P5]
[P4]
[P6]
[P2]
Q1
Q3
Q5
Q4
Q6
Q2
Vabc
Iabc
A
B
C
a
b
c
1
2
3
4
5
6
ENG
21:09


Scope1
File Tools View Simulation Help
1
2
3
4
5
6
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
Ready
Sample based
T=0.100


Scope3
File Tools View Simulation Help
Q1:1
Q1:2
Q2:1
Q2:2
Q3:1
Q3:2
Q4:1
Q4:2
Q5:1
Q5:2
Q6:1
Q6:2
Ready
Sample based
T=0.100


Scope
File Tools View Simulation Help
Three-Phase V-I Measurement/signal:1
Three-Phase V-I Measurement/signal:2
Three-Phase V-I Measurement/signal:3
Three-Phase V-I Measurement/signal:1
Three-Phase V-I Measurement/signal:2
Three-Phase V-I Measurement/signal:3
Ready
Sample based T=0.100

* Result : Simulated the 180° & 120° mode of conduction, voltage source inverter in R & RL load.

* Precautions:

1. Use powergui to store the equivalent simulink circuit that represents the state-space equation of the model.
2. Always keep the circuit closed.
3. MATLAB takes time to respond, do not give multiple ~~all~~ command at once.

Experiment - 9

* Aim: To study and plot V-I characteristics of BJT using MATLAB.

* Requirement: MATLAB software: SIMULINK

* Theory: A BJT (bipolar junction transistor) is a three terminal semiconductor device consisting of two p-n junction which are able to amplify or magnify a signal. It is a current controlled device. The three terminals of BJT are base, collector and emitter.

NPN BJT:

In a npn transistor, one p-type semiconductor resides between two n-type semiconductors. I_E, I_C is emitter current & collect current resp. V_{EB} and V_{CB} are emitter base & collector base ~~et~~ voltage resp.

PNP BJT:

In a pnp transistor, one n-type semiconductor resides between two p-type semiconductor. Current enters into the transistor through the emitter terminal.

* <u>Diagram:</u>

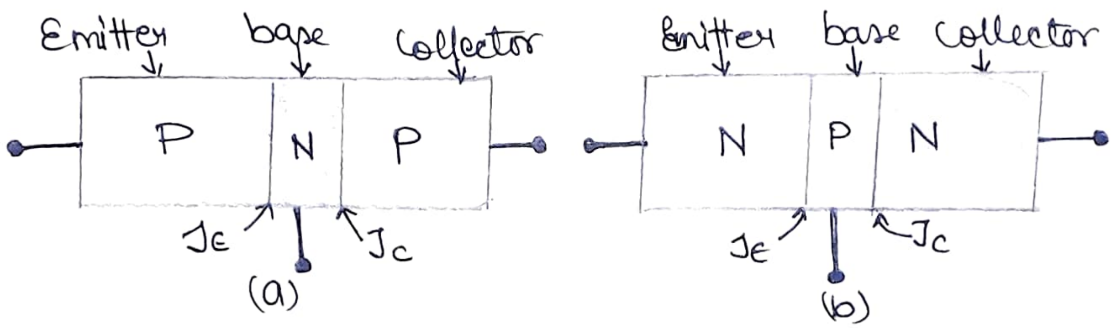


Fig 9.1: Diagram of BJT: (a) pnp & (b) npn

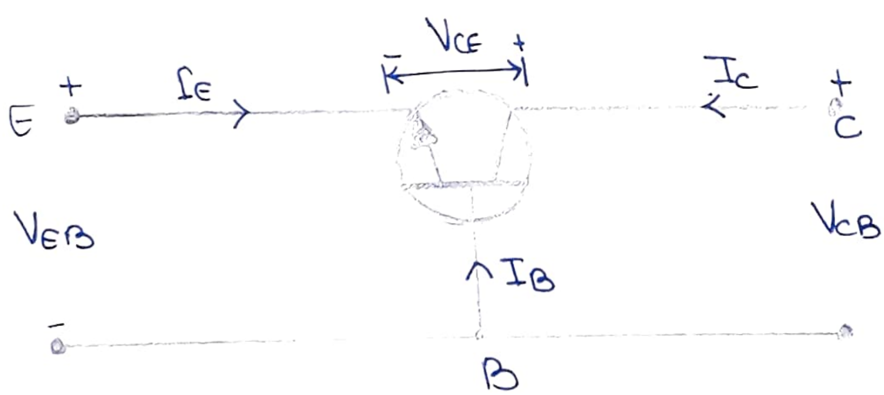


Fig 9.2: NPN BJT circuit

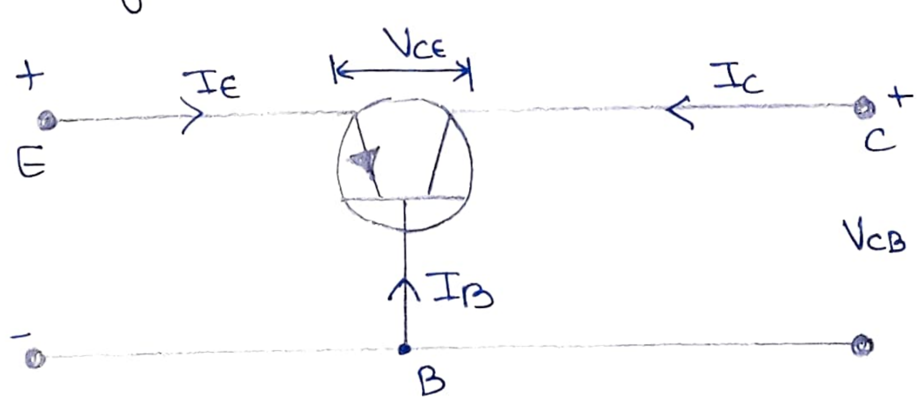
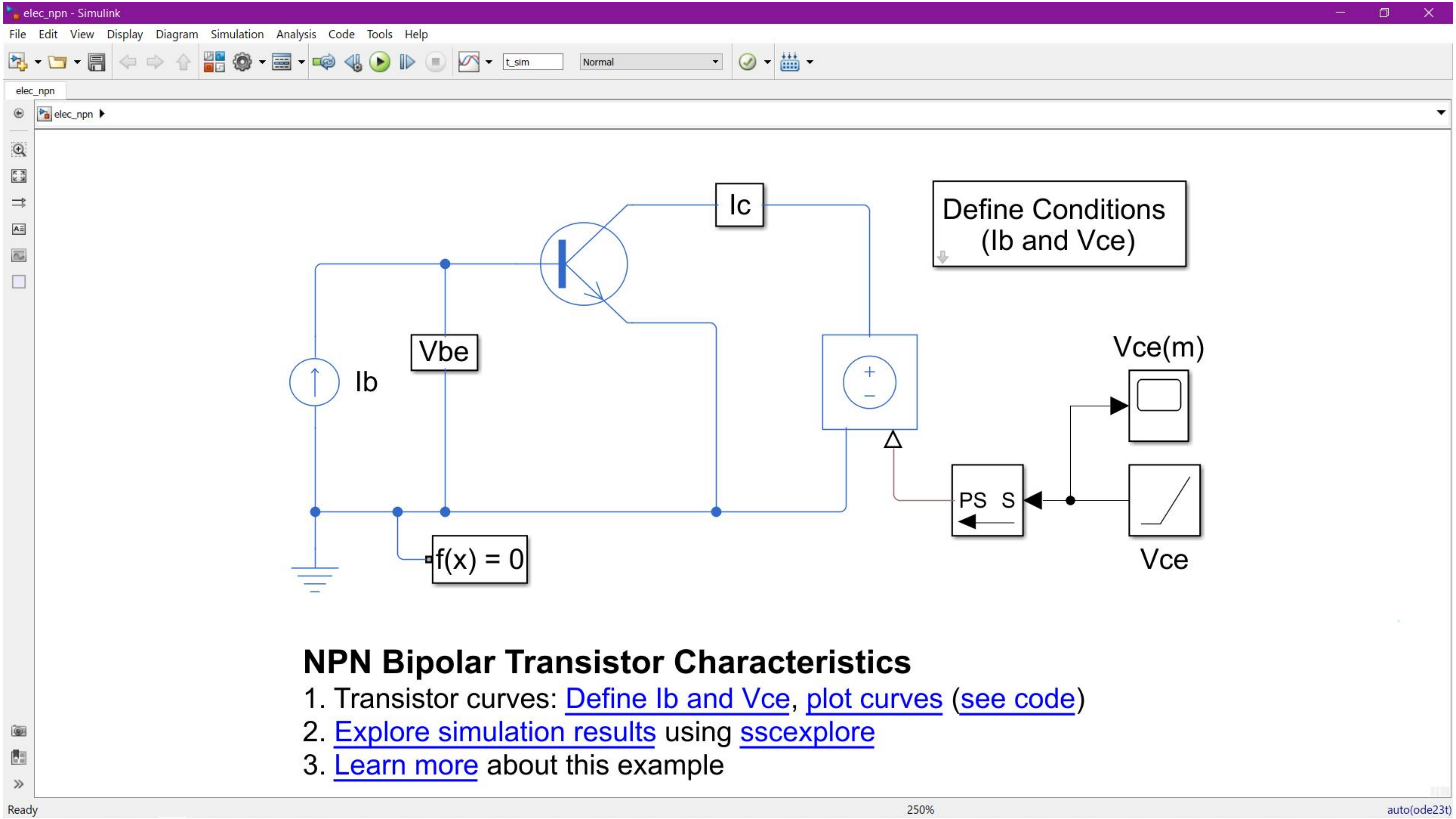
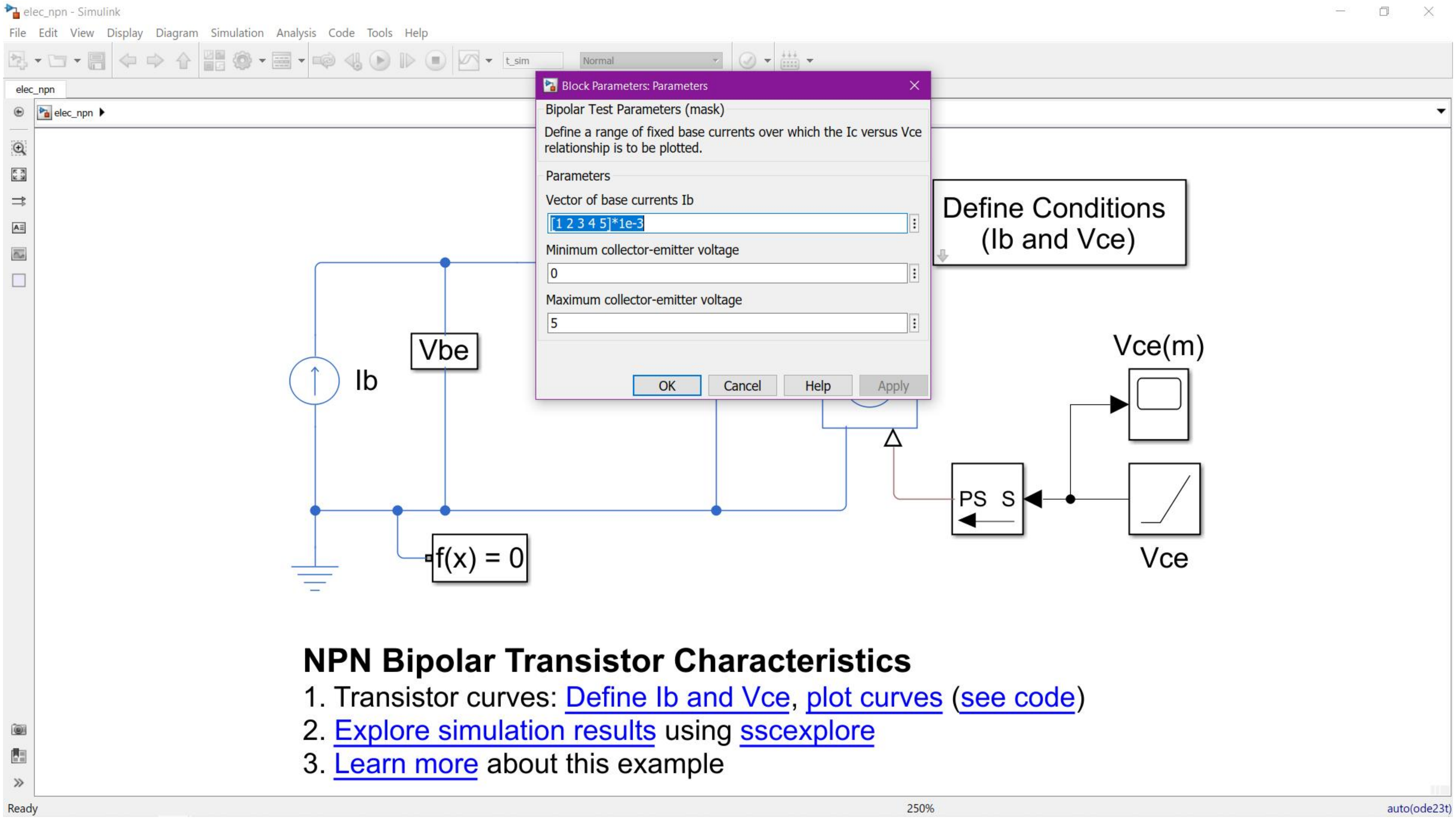


Fig 9.3: PNP BJT circuit

MATLAB Simulation




elec_npn - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
t_sim
Normal
elec_npn
Block Parameters: Parameters
Bipolar Test Parameters (mask)
Define a range of fixed base currents over which the Ic versus Vce relationship is to be plotted.
Parameters
Vector of base currents Ib
[1 2 3 4 5]*1e-3
Minimum collector-emitter voltage
0
Maximum collector-emitter voltage
5
OK
Cancel
Help
Apply
Define Conditions
(Ib and Vce)
Vbe
Ib
Vce(m)
PS S
Vce
f(x) = 0
NPN Bipolar Transistor Characteristics
1. Transistor curves: Define Ib and Vce, plot curves (see code)
2. Explore simulation results using sscexplore
3. Learn more about this example
Ready
250%
auto(ode23t)

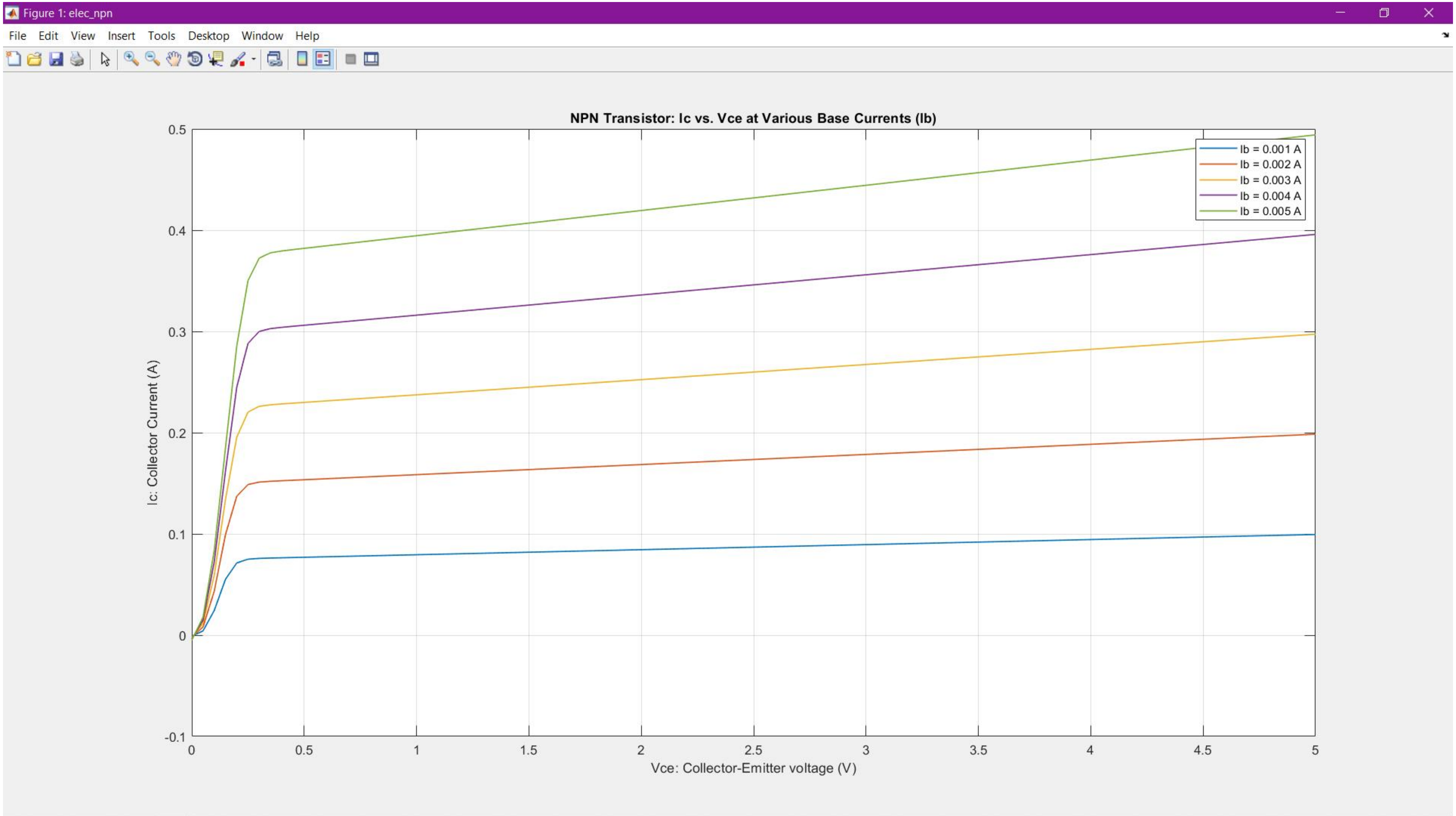
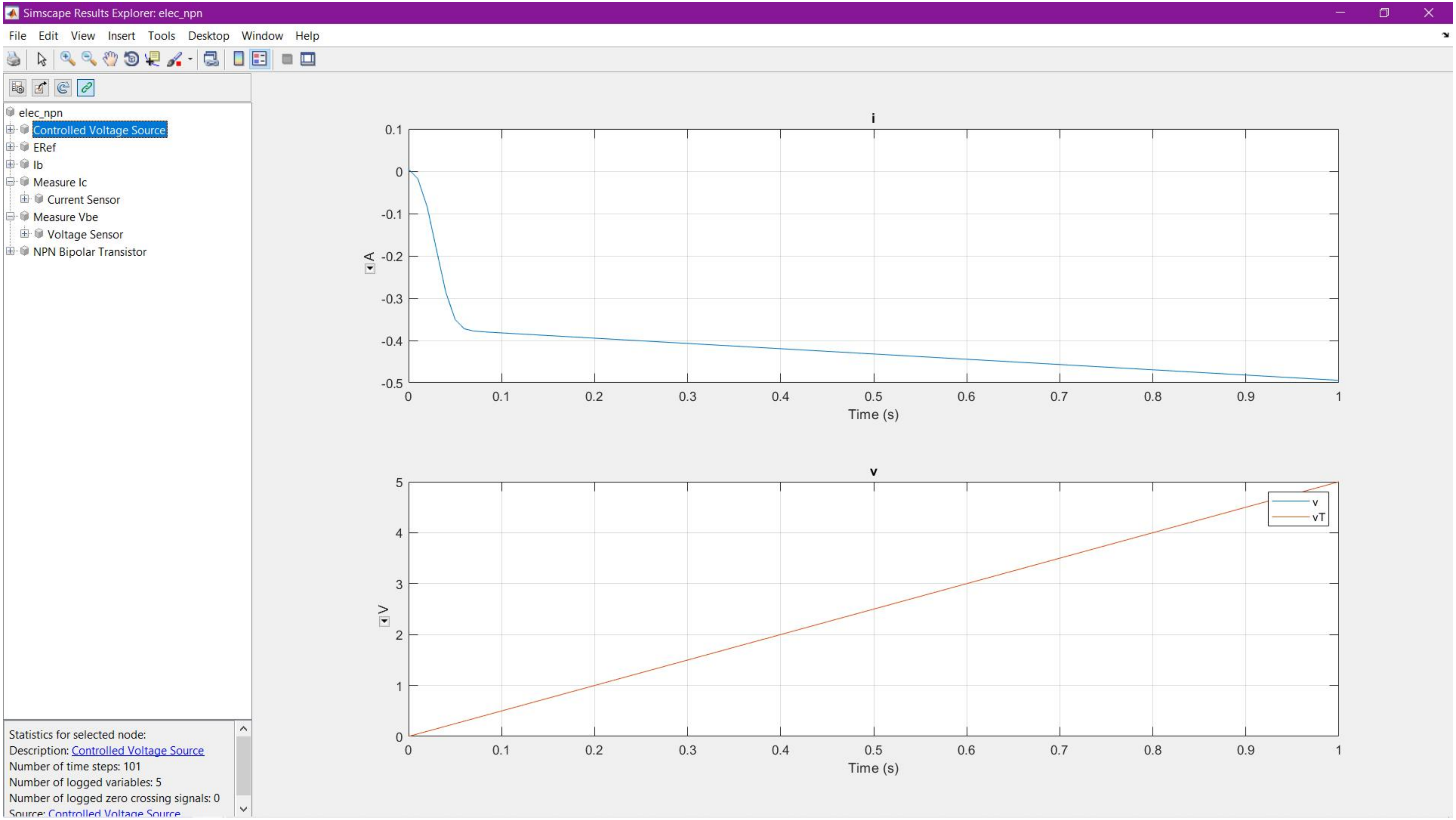
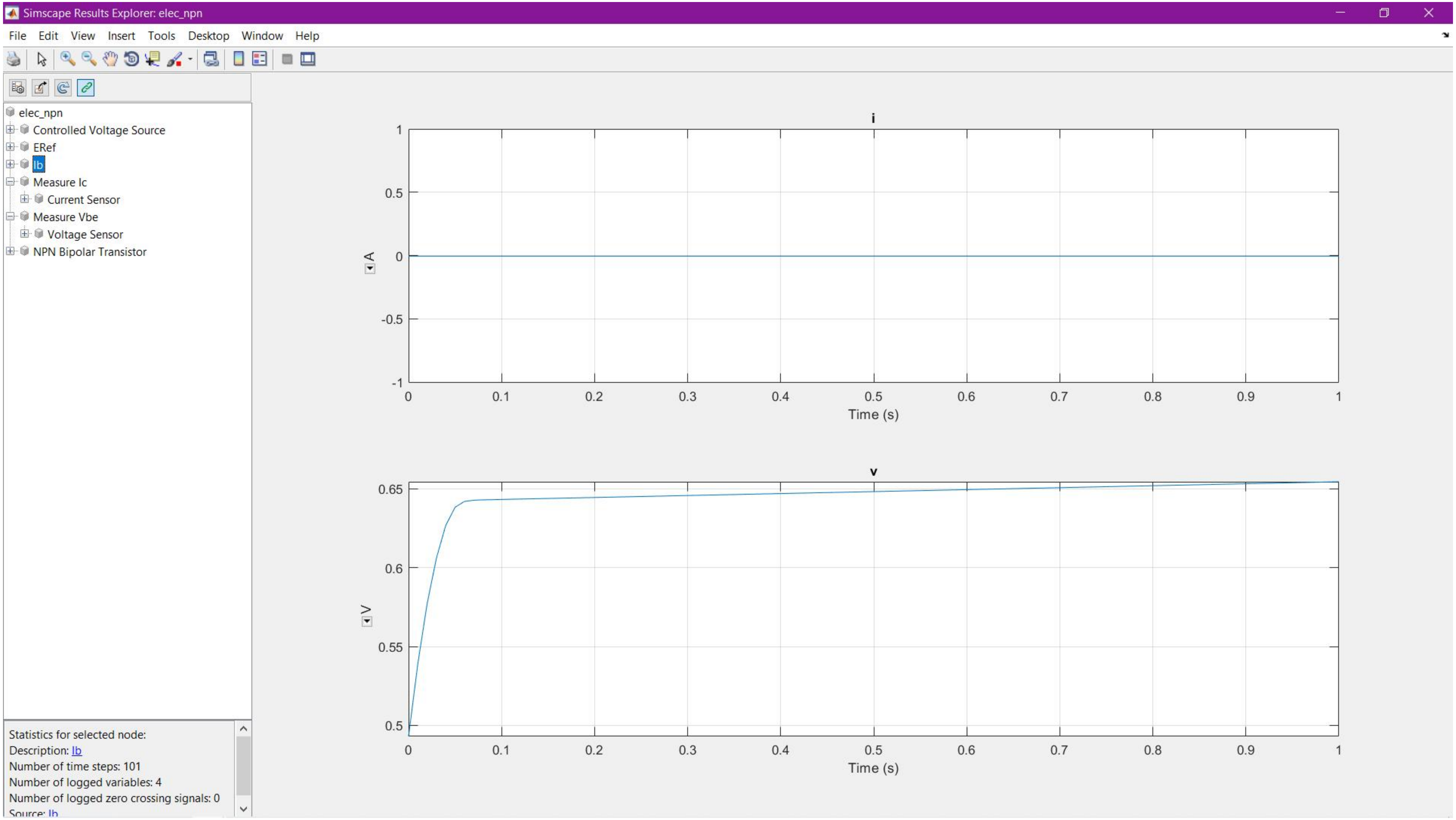
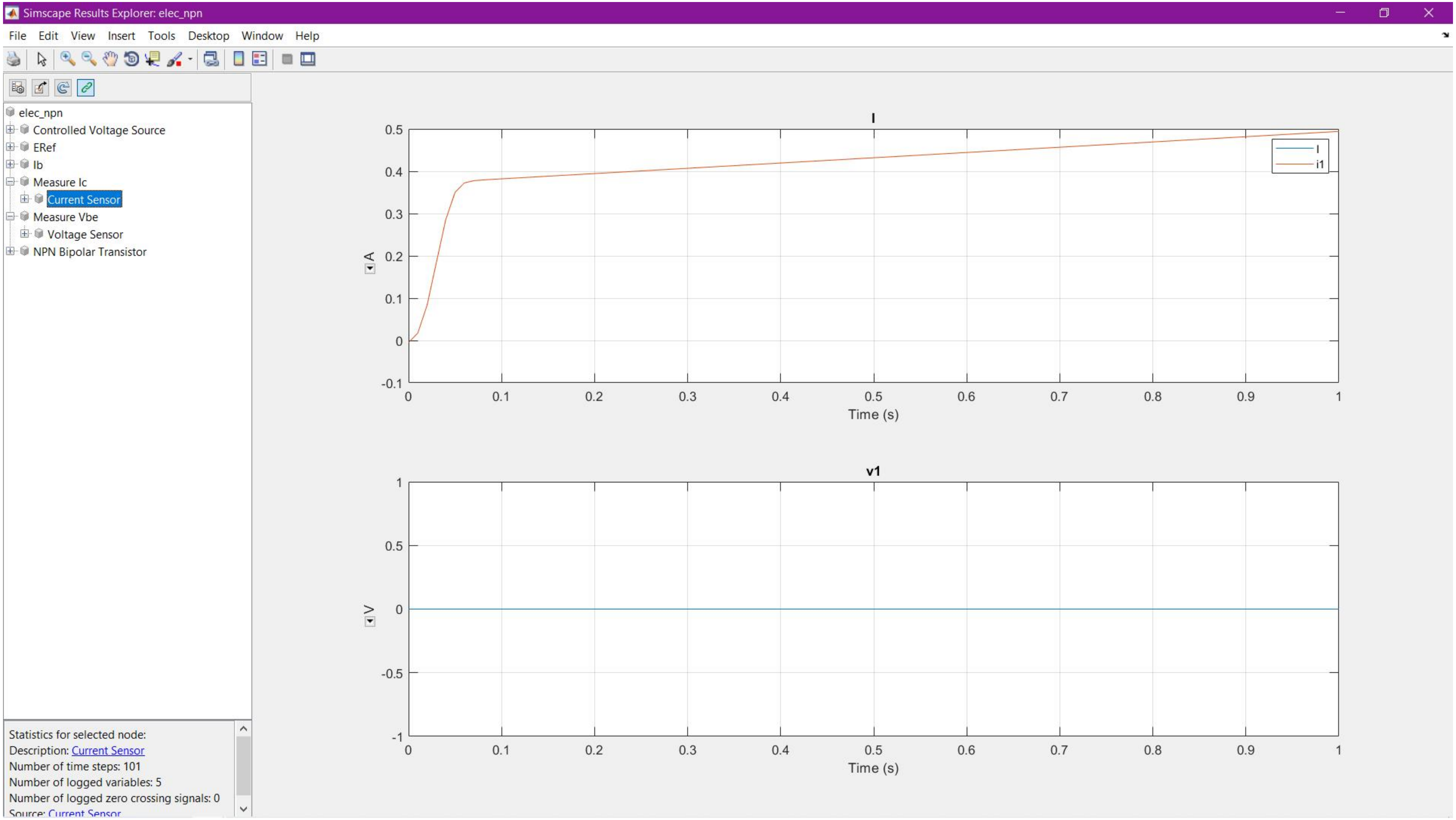
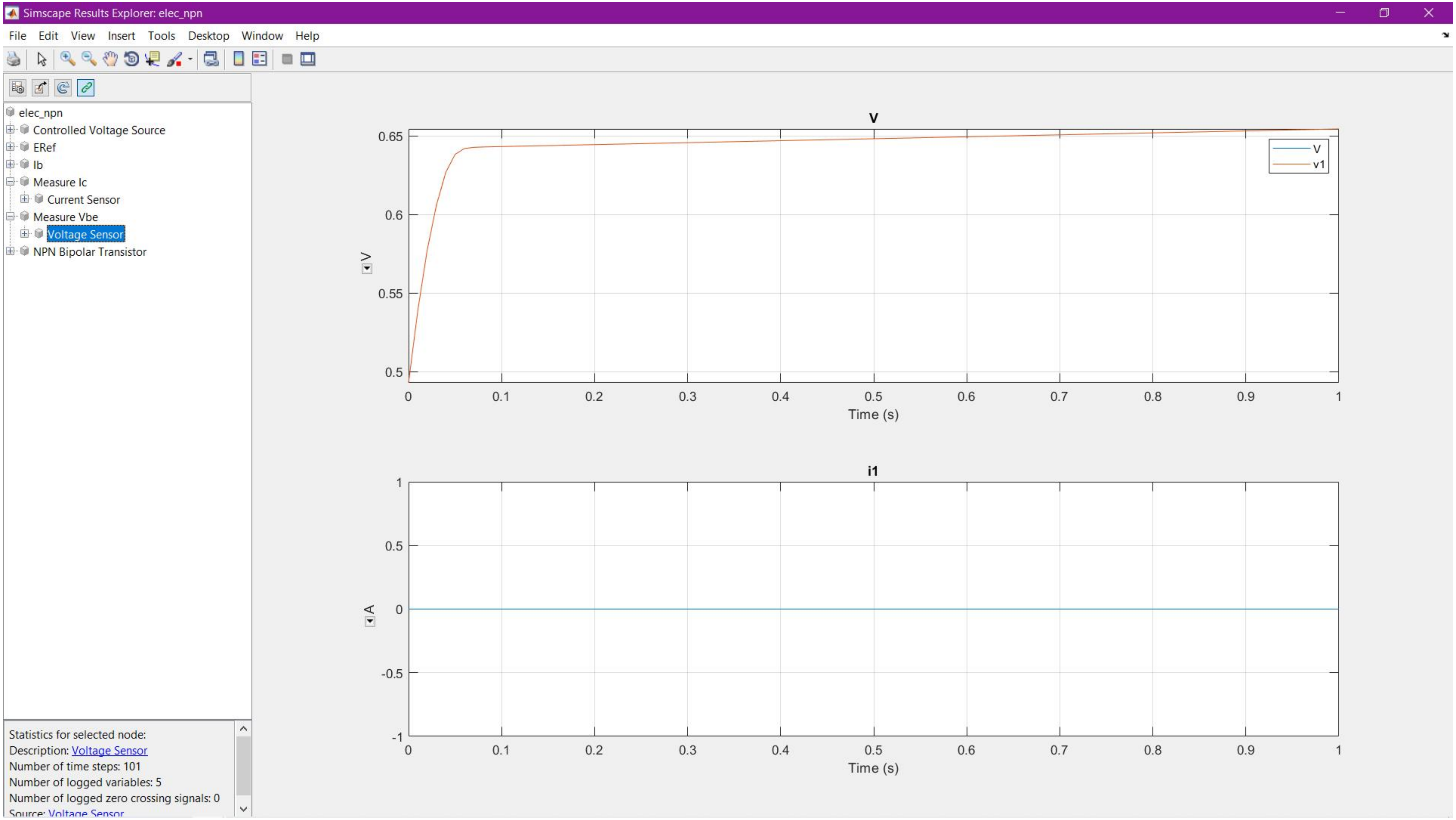


Figure 1: elec_npn
File Edit View Insert Tools Desktop Window Help
NPN Transistor: Ic vs. Vce at Various Base Currents (Ib)
Ib = 0.001 A
Ib = 0.002 A
Ib = 0.003 A
Ib = 0.004 A
Ib = 0.005 A
Ic: Collector Current (A)
Vce: Collector-Emitter voltage (V)
0.5
0.4
0.3
0.2
0.1
0
-0.1
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5

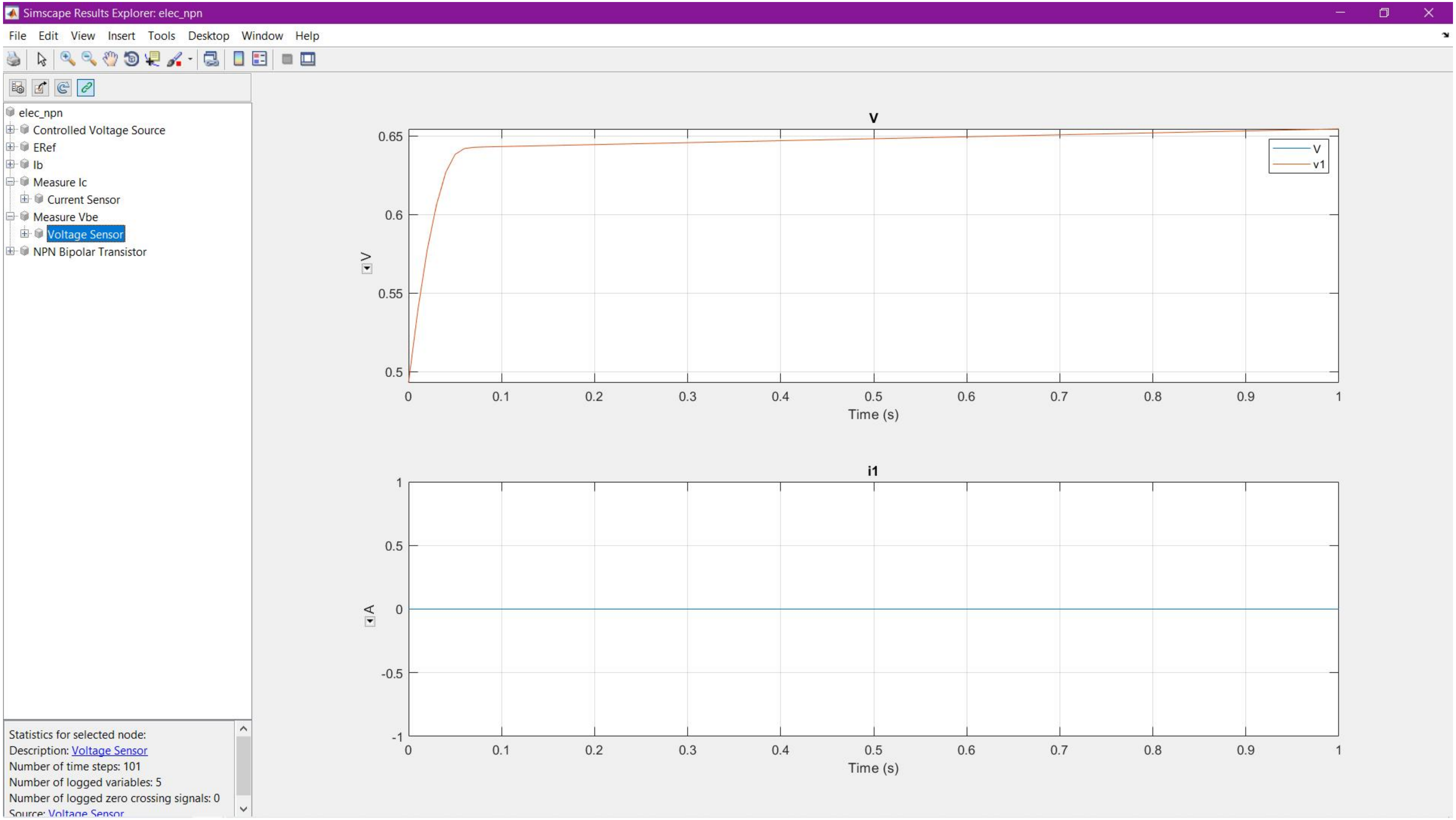

Simscape Results Explorer: elec_npn
File Edit View Insert Tools Desktop Window Help
elec_npn
Controlled Voltage Source
ERef
Ib
Measure Ic
Current Sensor
Measure Vbe
Voltage Sensor
NPN Bipolar Transistor
Statistics for selected node:
Description: Controlled Voltage Source
Number of time steps: 101
Number of logged variables: 5
Number of logged zero crossing signals: 0
i
A
Time (s)
v
V
vT
Time (s)

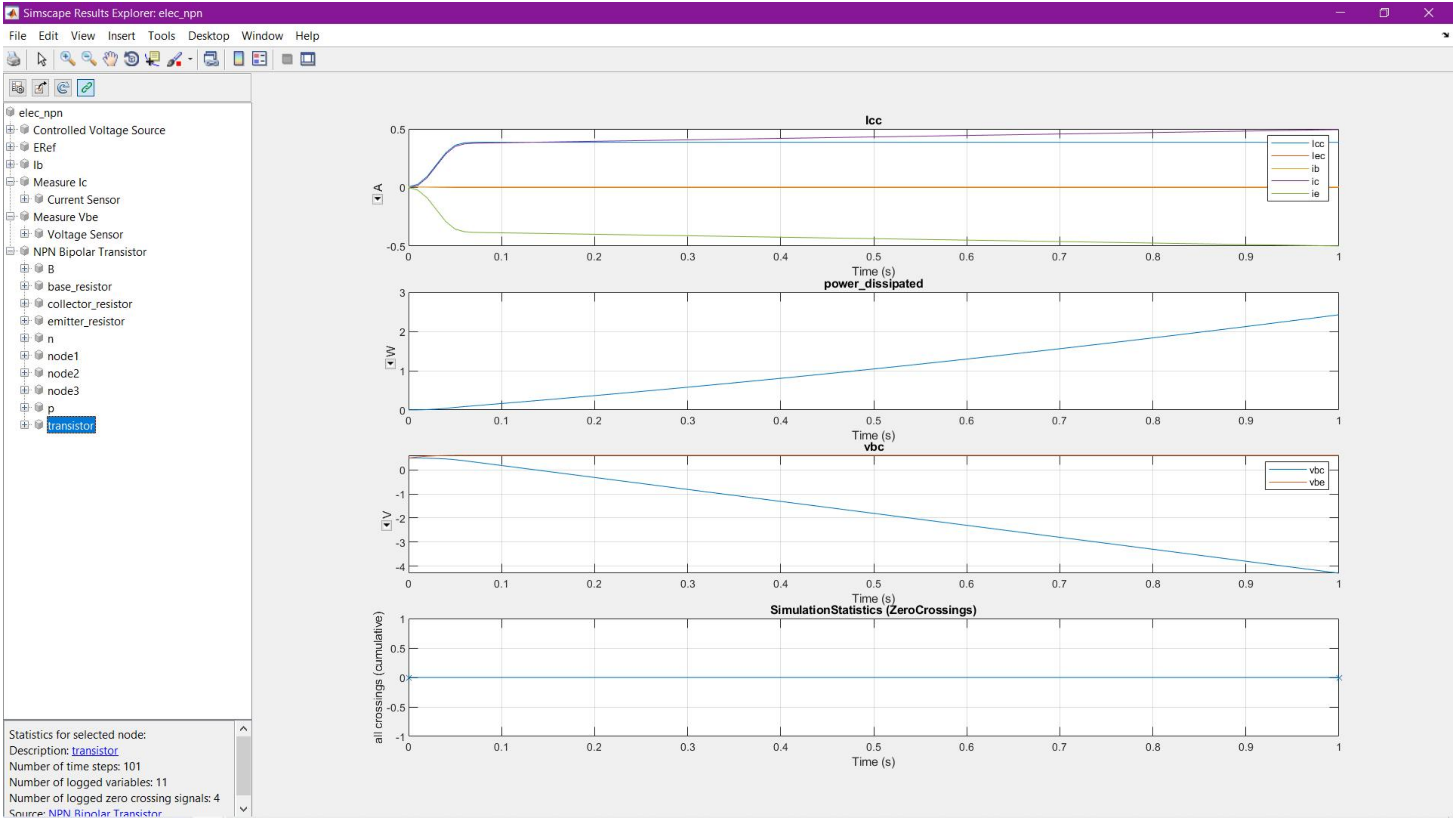

Simscape Results Explorer: elec_npn
File Edit View Insert Tools Desktop Window Help
elec_npn
Controlled Voltage Source
ERef
Ib
Measure Ic
Current Sensor
Measure Vbe
Voltage Sensor
NPN Bipolar Transistor
Statistics for selected node:
Description: Ib
Number of time steps: 101
Number of logged variables: 4
Number of logged zero crossing signals: 0
Source: Ib
i
A
Time (s)
v
V
Time (s)

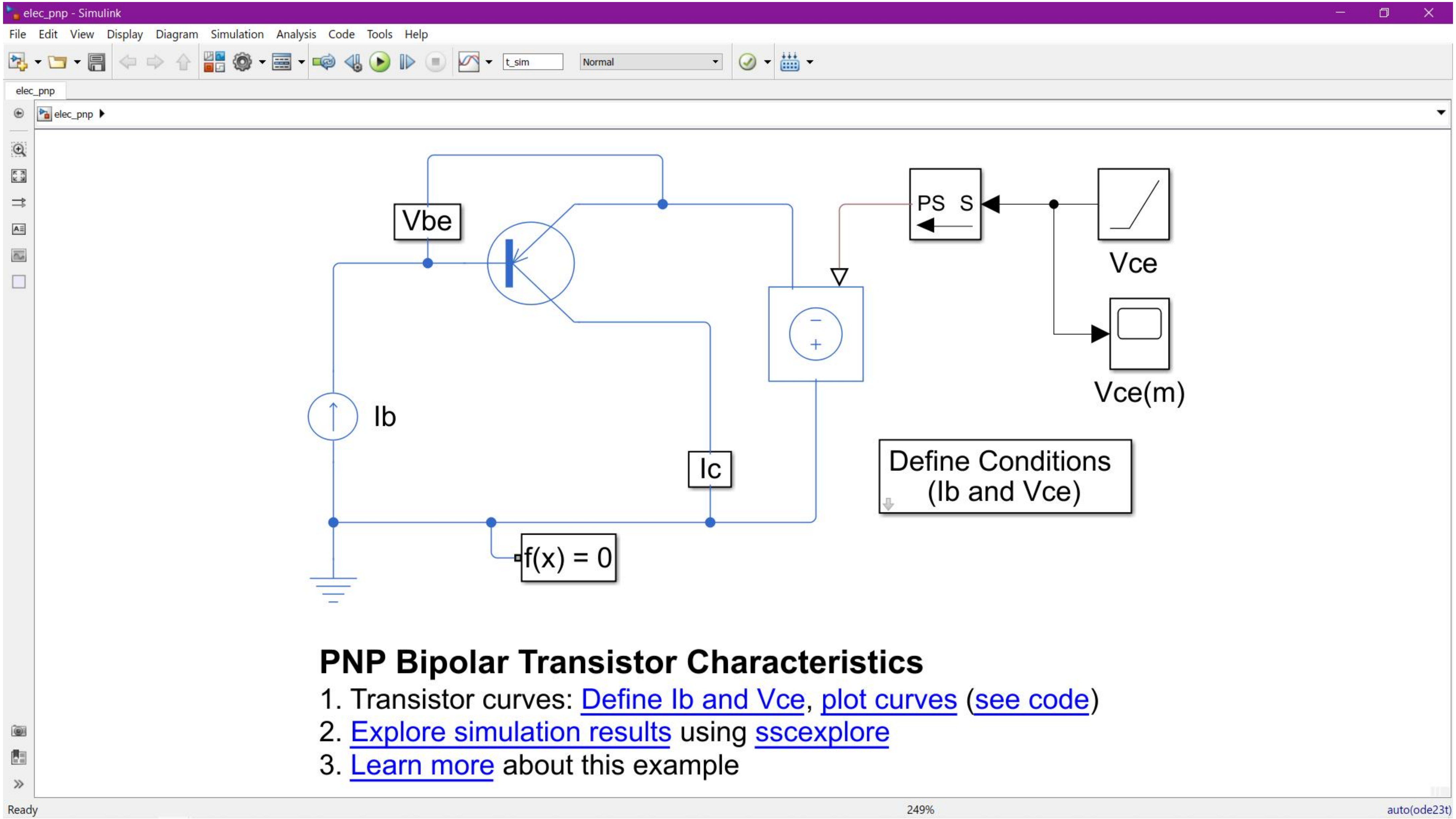

Simscape Results Explorer: elec_npn
File Edit View Insert Tools Desktop Window Help
elec_npn
Controlled Voltage Source
ERef
Ib
Measure Ic
Current Sensor
Measure Vbe
Voltage Sensor
NPN Bipolar Transistor
Statistics for selected node:
Description: Current Sensor
Number of time steps: 101
Number of logged variables: 5
Number of logged zero crossing signals: 0
I
A
Time (s)
i1
v1
V
Time (s)

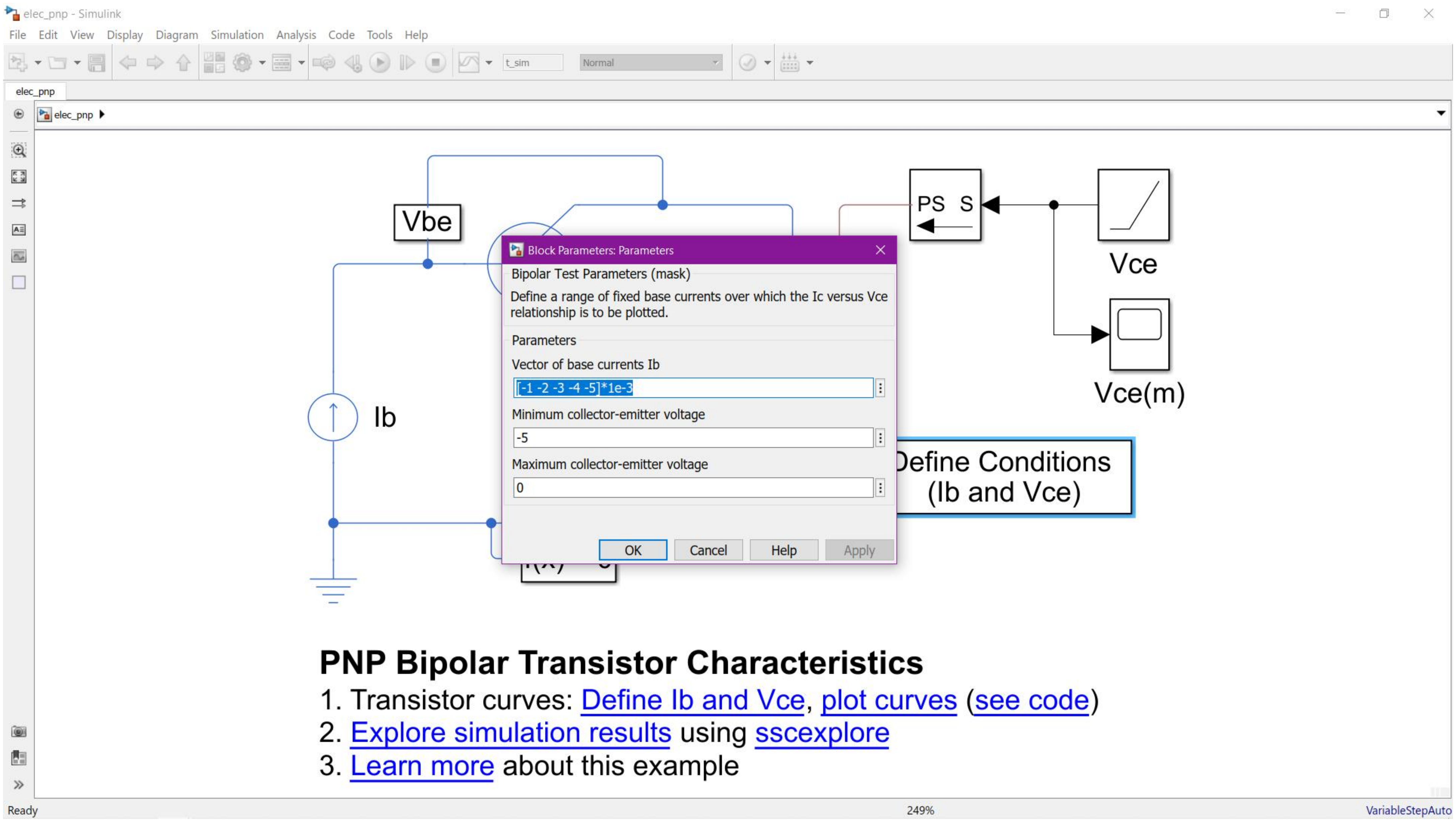


Simscape Results Explorer: elec_npn
File Edit View Insert Tools Desktop Window Help
elec_npn
Controlled Voltage Source
ERef
Ib
Measure Ic
Current Sensor
Measure Vbe
Voltage Sensor
NPN Bipolar Transistor
Statistics for selected node:
Description: Voltage Sensor
Number of time steps: 101
Number of logged variables: 5
Number of logged zero crossing signals: 0
Source: Voltage Sensor
V
V
v1
Time (s)
i1
A
Time (s)


Simscape Results Explorer: elec_npn
File Edit View Insert Tools Desktop Window Help
elec_npn
Controlled Voltage Source
ERef
Ib
Measure Ic
Current Sensor
Measure Vbe
Voltage Sensor
NPN Bipolar Transistor
Statistics for selected node:
Description: Voltage Sensor
Number of time steps: 101
Number of logged variables: 5
Number of logged zero crossing signals: 0
V
V
v1
0.65
0.6
0.55
0.5
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Time (s)
i1
A
1
0.5
0
-0.5
-1
Time (s)


Simscape Results Explorer: elec_npn
File Edit View Insert Tools Desktop Window Help
elec_npn
Controlled Voltage Source
ERef
Ib
Measure Ic
Current Sensor
Measure Vbe
Voltage Sensor
NPN Bipolar Transistor
B
base_resistor
collector_resistor
emitter_resistor
n
node1
node2
node3
p
transistor
Statistics for selected node:
Description: transistor
Number of time steps: 101
Number of logged variables: 11
Number of logged zero crossing signals: 4
Source: NPN Bipolar Transistor
Icc
A
Time (s)
Icc
Iec
ib
ic
ie
power_dissipated
W
Time (s)
vbc
V
Time (s)
vbc
vbe
SimulationStatistics (ZeroCrossings)
all crossings (cumulative)
Time (s)


elec_pnp - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
t_sim
Normal
elec_pnp
elec_pnp
Vbe
PS S
Vce
Vce(m)
Ib
Ic
Define Conditions
(Ib and Vce)
f(x) = 0
PNP Bipolar Transistor Characteristics
1. Transistor curves: Define Ib and Vce, plot curves (see code)
2. Explore simulation results using sscexplore
3. Learn more about this example
Ready
249%
auto(ode23t)


elec_pnp - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
t_sim
Normal
elec_pnp
elec_pnp
Vbe
PS S
Vce
Vce(m)
Ib
Block Parameters: Parameters
Bipolar Test Parameters (mask)
Define a range of fixed base currents over which the Ic versus Vce relationship is to be plotted.
Parameters
Vector of base currents Ib
[-1 -2 -3 -4 -5]*1e-3
Minimum collector-emitter voltage
-5
Maximum collector-emitter voltage
0
OK
Cancel
Help
Apply
Define Conditions (Ib and Vce)
PNP Bipolar Transistor Characteristics
1. Transistor curves: Define Ib and Vce, plot curves (see code)
2. Explore simulation results using sscexplore
3. Learn more about this example
Ready
249%
VariableStepAuto

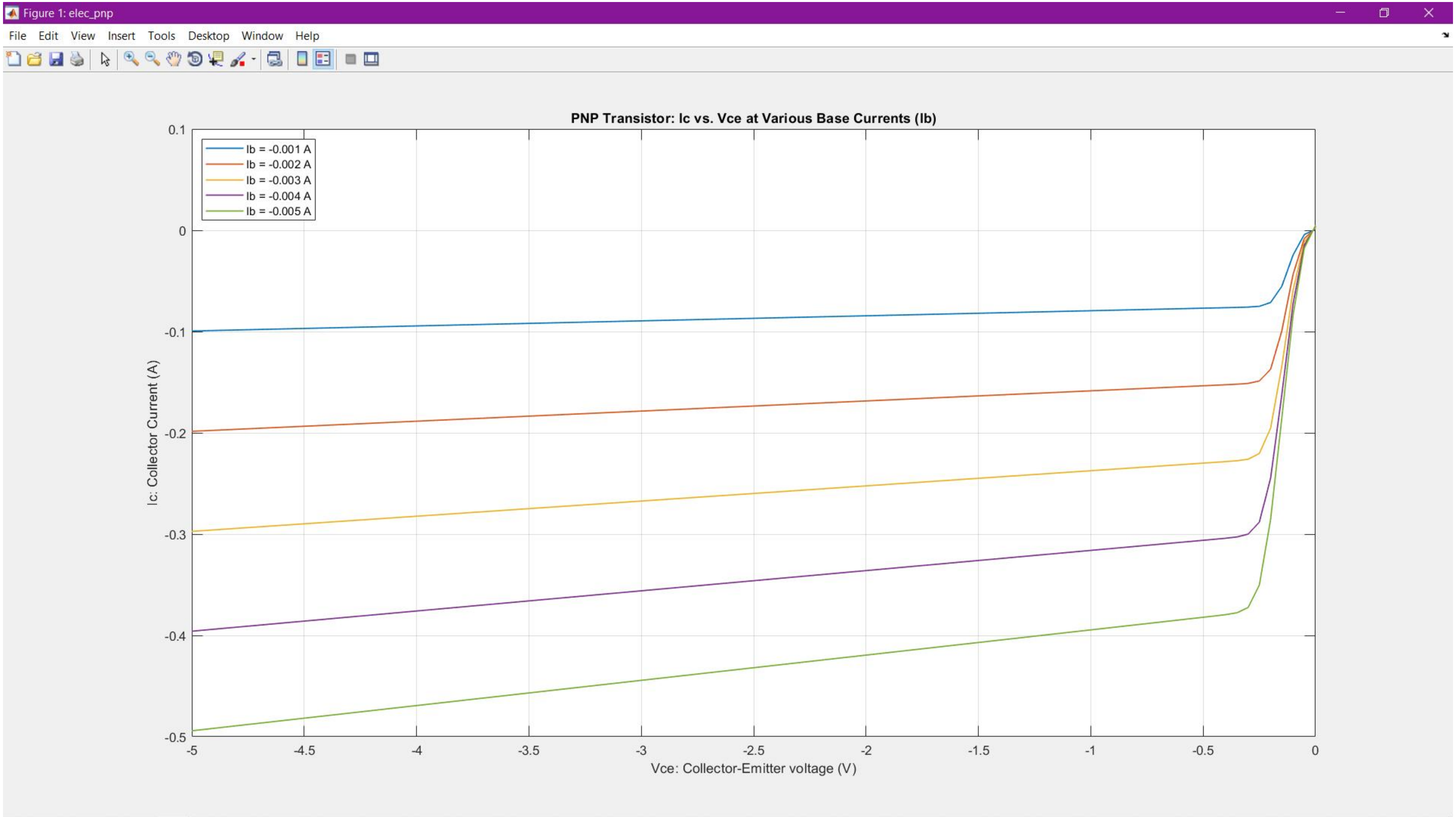
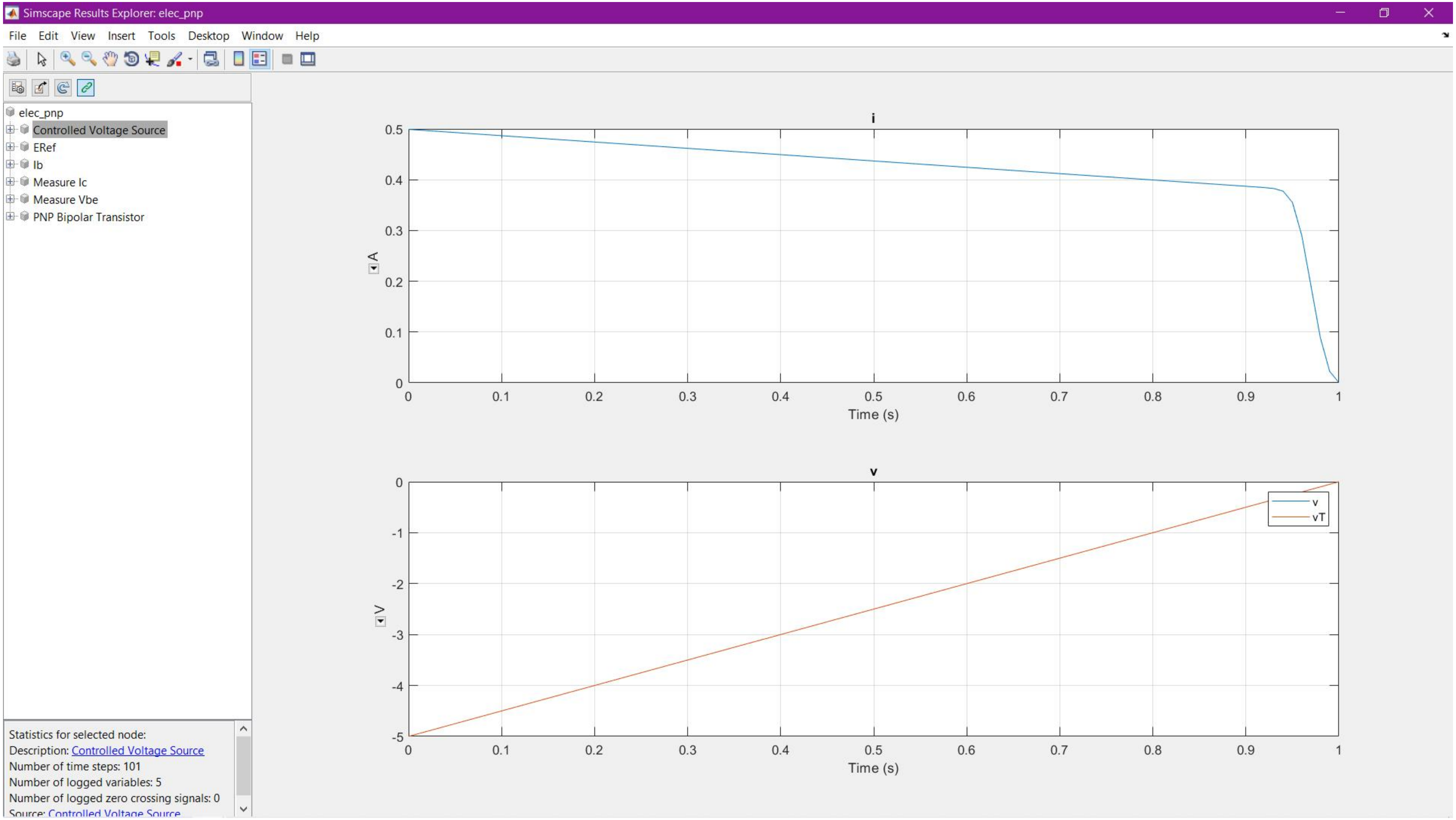
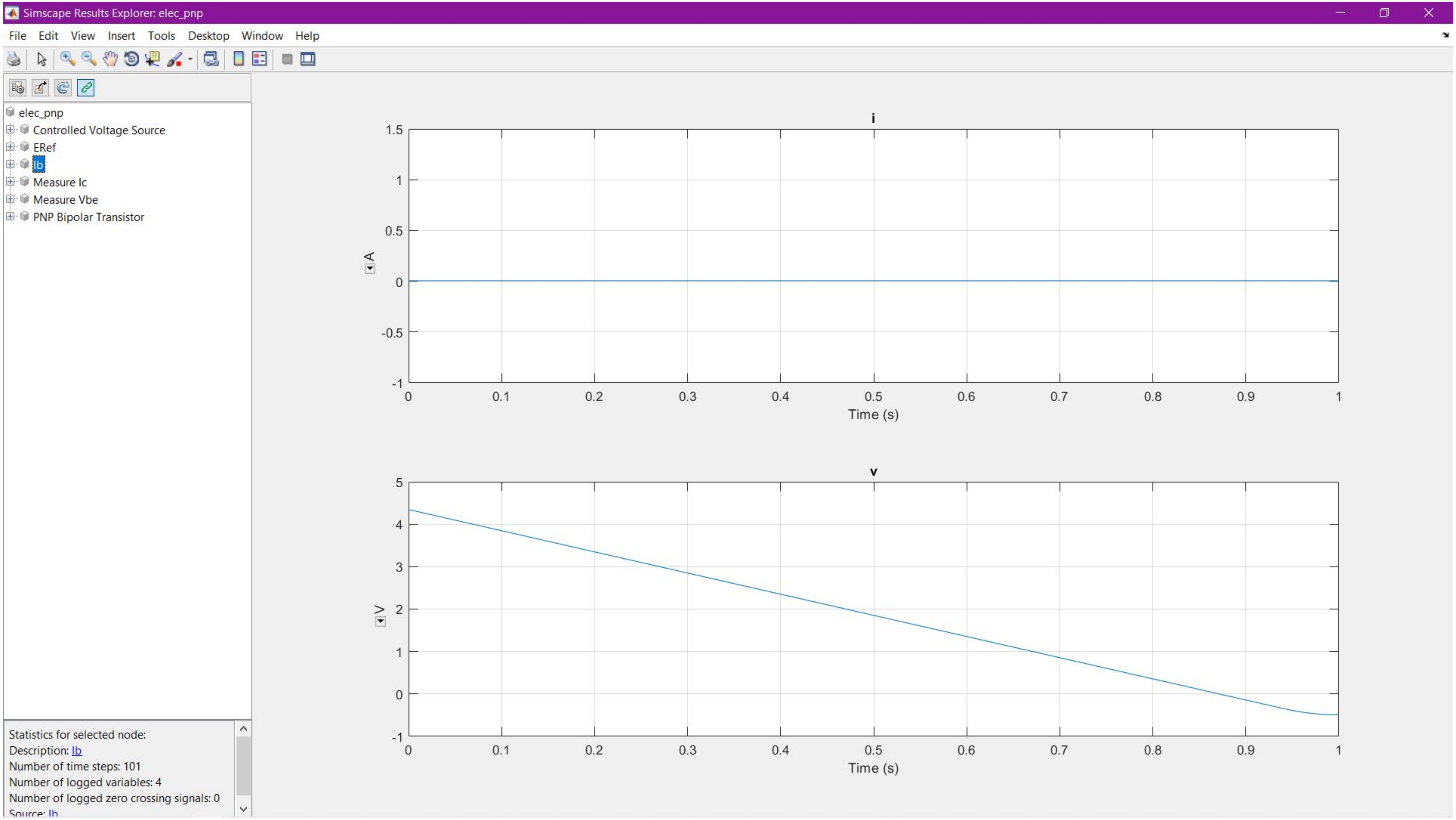
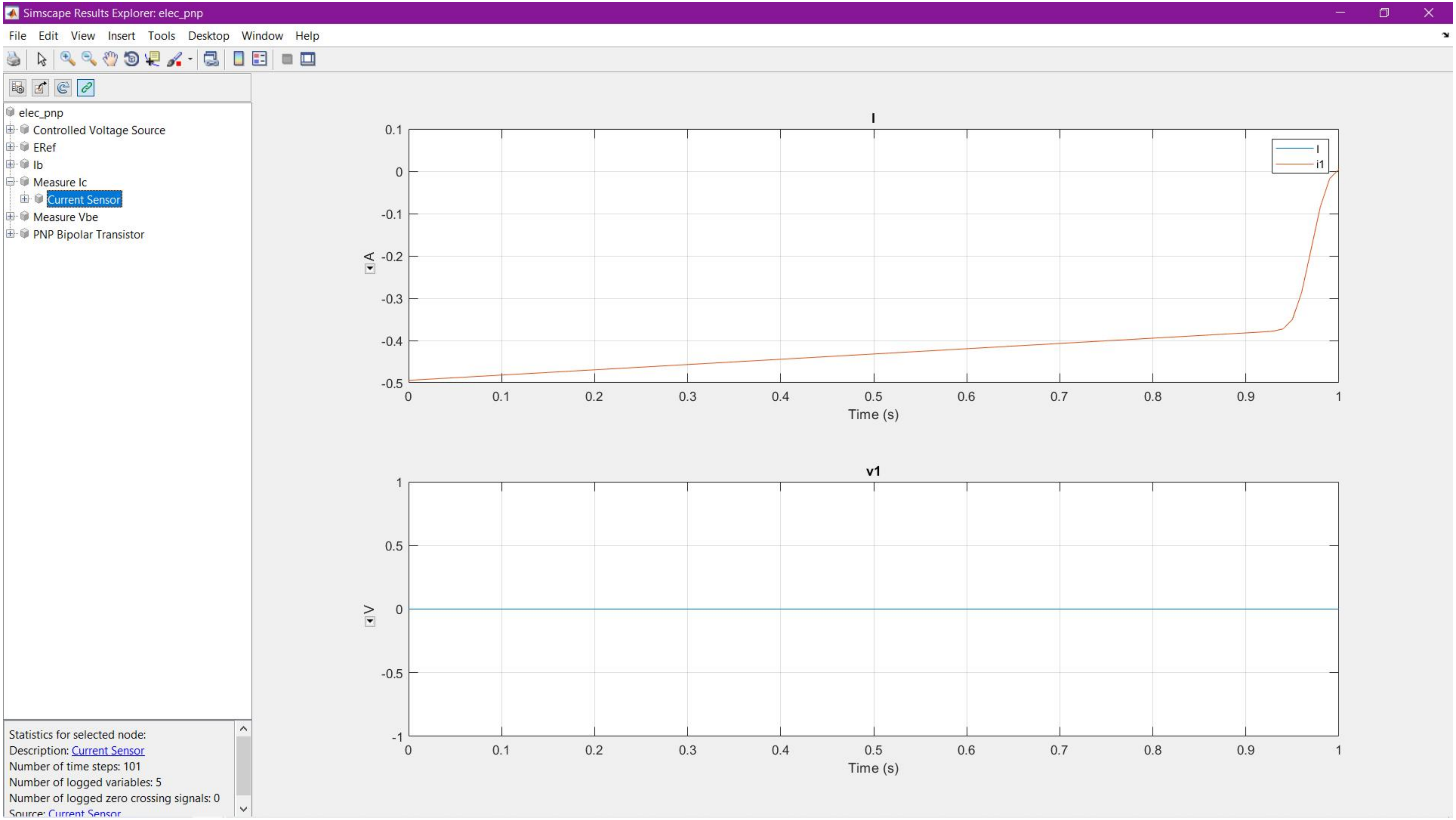
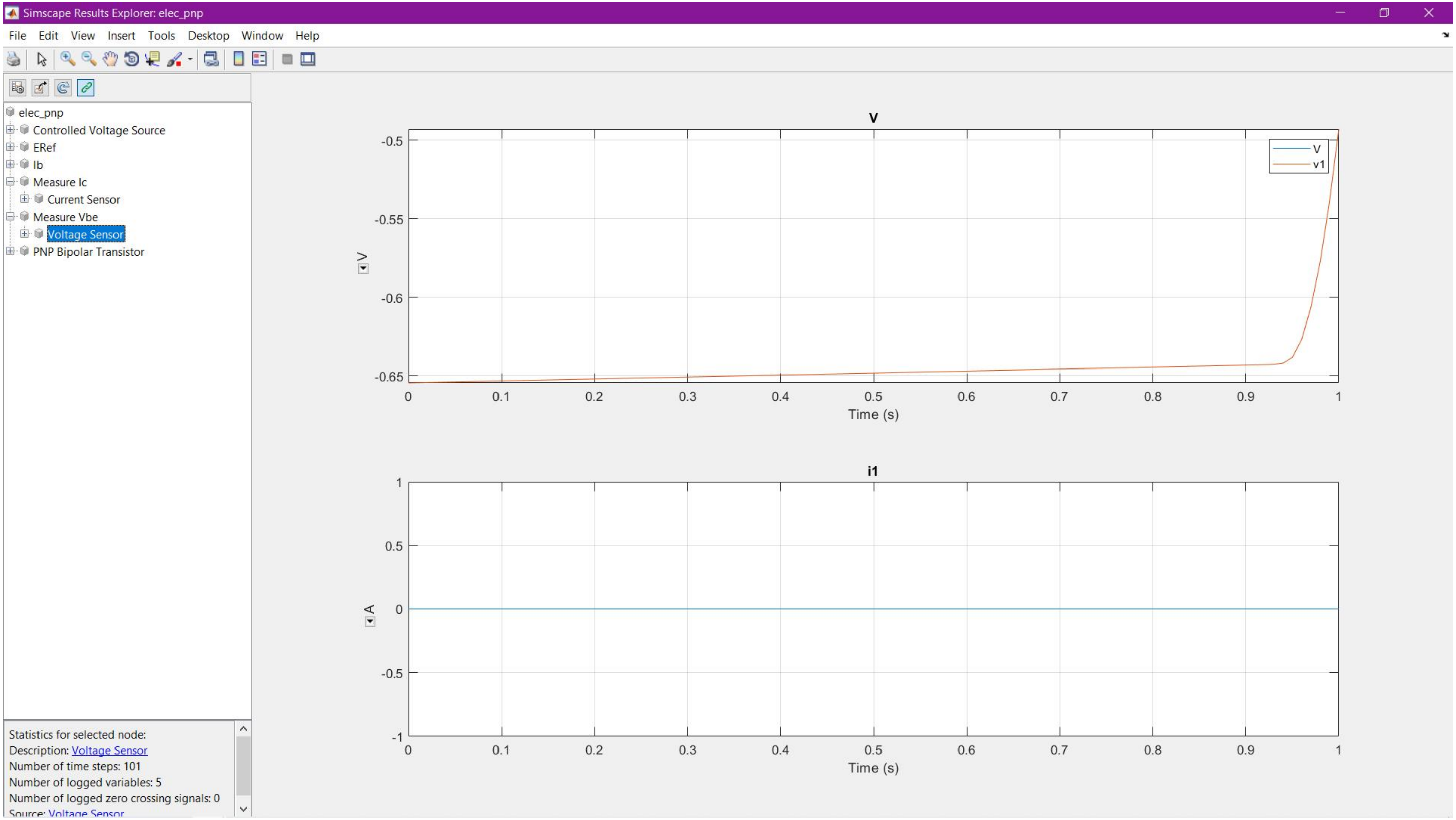


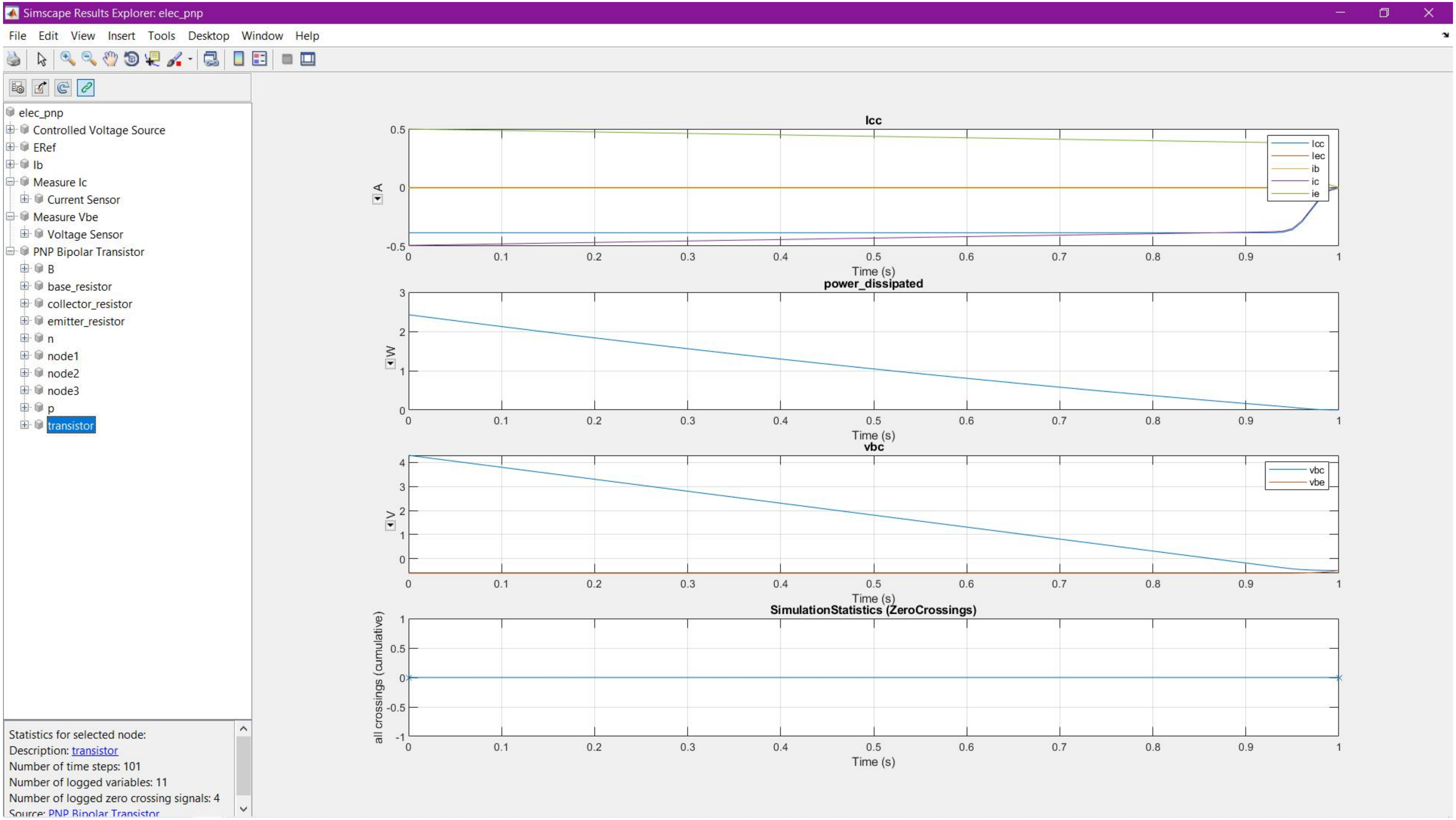
Figure 1: elec_pnp
File Edit View Insert Tools Desktop Window Help
PNP Transistor: Ic vs. Vce at Various Base Currents (Ib)
Ib = -0.001 A
Ib = -0.002 A
Ib = -0.003 A
Ib = -0.004 A
Ib = -0.005 A
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
Ic: Collector Current (A)
-5
-4.5
-4
-3.5
-3
-2.5
-2
-1.5
-1
-0.5
0
Vce: Collector-Emitter voltage (V)


Simscape Results Explorer: elec_pnp
File Edit View Insert Tools Desktop Window Help
elec_pnp
Controlled Voltage Source
ERef
Ib
Measure Ic
Measure Vbe
PNP Bipolar Transistor
Statistics for selected node:
Description: Controlled Voltage Source
Number of time steps: 101
Number of logged variables: 5
Number of logged zero crossing signals: 0
i
A
Time (s)
v
V
v
vT
Time (s)


Simscape Results Explorer: elec_pnp
File Edit View Insert Tools Desktop Window Help
elec_pnp
Controlled Voltage Source
ERef
Ib
Measure Ic
Measure Vbe
PNP Bipolar Transistor
Statistics for selected node:
Description: Ib
Number of time steps: 101
Number of logged variables: 4
Number of logged zero crossing signals: 0
i
A
Time (s)
v
V
Time (s)


Simscape Results Explorer: elec_pnp
File Edit View Insert Tools Desktop Window Help
elec_pnp
Controlled Voltage Source
ERef
Ib
Measure Ic
Current Sensor
Measure Vbe
PNP Bipolar Transistor
Statistics for selected node:
Description: Current Sensor
Number of time steps: 101
Number of logged variables: 5
Number of logged zero crossing signals: 0
I
A
Time (s)
i1
v1
V
Time (s)


Simscape Results Explorer: elec_pnp
File Edit View Insert Tools Desktop Window Help
elec_pnp
Controlled Voltage Source
ERef
Ib
Measure Ic
Current Sensor
Measure Vbe
Voltage Sensor
PNP Bipolar Transistor
Statistics for selected node:
Description: Voltage Sensor
Number of time steps: 101
Number of logged variables: 5
Number of logged zero crossing signals: 0
V
V
v1
-0.5
-0.55
-0.6
-0.65
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
Time (s)
i1
A
1
0.5
0
-0.5
-1
Time (s)


Simscape Results Explorer: elec_pnp
File Edit View Insert Tools Desktop Window Help
elec_pnp
Controlled Voltage Source
ERef
Ib
Measure Ic
Current Sensor
Measure Vbe
Voltage Sensor
PNP Bipolar Transistor
B
base_resistor
collector_resistor
emitter_resistor
n
node1
node2
node3
p
transistor
Statistics for selected node:
Description: transistor
Number of time steps: 101
Number of logged variables: 11
Number of logged zero crossing signals: 4
Source: PNP Bipolar Transistor
Icc
A
Time (s)
Icc
Iec
ib
ic
ie
power_dissipated
W
vbc
V
vbc
vbe
SimulationStatistics (ZeroCrossings)
all crossings (cumulative)

* Procedure:

1. Open MATLAB and in command window write: "elec_npn" (for npn bjt) and press enter.
2. A simulation circuit will appear; (change the values if required) and run the simulation.
3. ~~You will~~ After simulation, click on plot curve and observe the characteristics graph.
4. For more observation click on Explore simulation results.
5. Repeate it for pnp bjt with code "elec_pnp".

* Result:

Studied and observed VI characteristics of npn & pnp BJT transister. using MATLAB simulink.

* Precautions:

1. Don't give multiple command at a time.
2. Do not change the circuit until required of the file as its inbuilt example.

Experiment -10

* **Aim:** To study the VI characteristics of MOSFET

* **Requirement:** Software : MATLAB - Simulink.

* **Theory:**

Mosfet are tri- terminal, unipolar, voltage controlled high input impedance device. MOSFET i.e. metal oxide semiconductor field effect transistor. In general Mosfet is seen to exhibit three operating regions

1. Cut-off region : OFF; as there is no current flow. Mosfet behave like an open switch and is thus used when they are required to function as electronic switches.
2. Ohmic | Linear region: current I_{DS} increases with an increase value of V_{DS}. In this region it acts as an amplifiers
3. Saturation region: I_{DS} become constant inspite of increase in V_{DS}, V_{DS} exceeds the value of pinch-off voltage V_p. Now it will acts as closed switch

* Diagram :

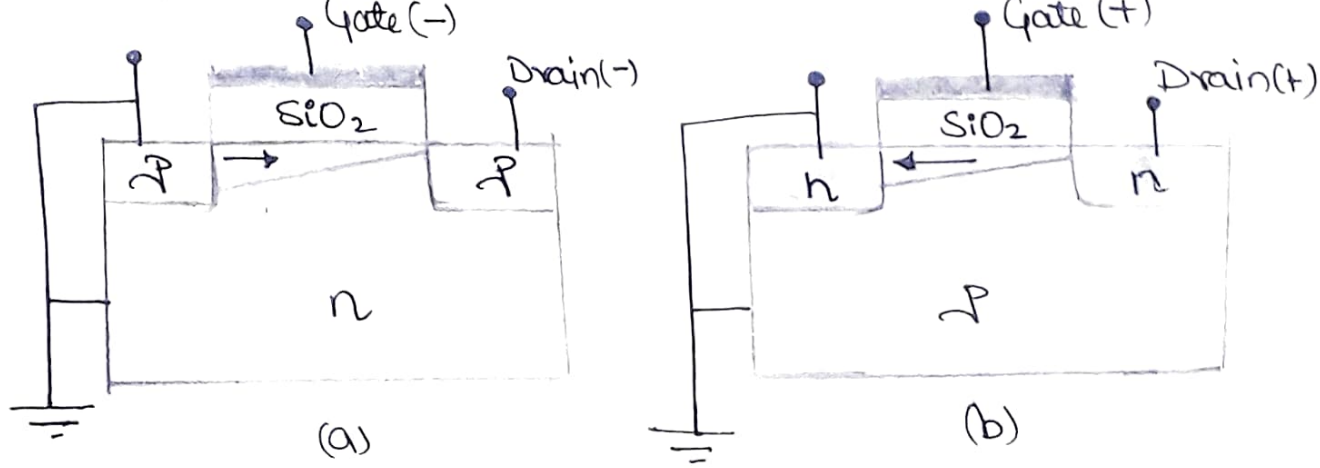
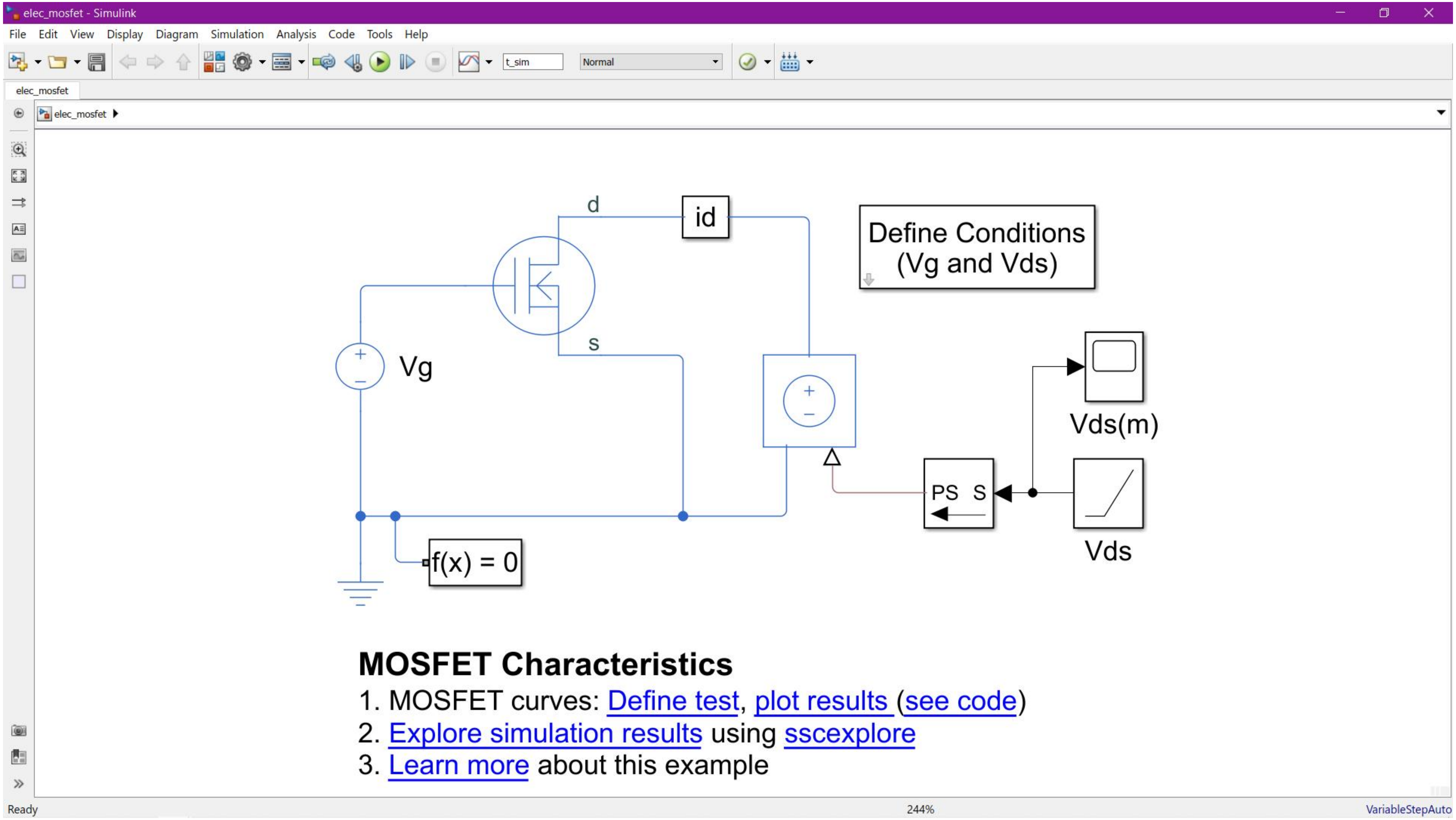
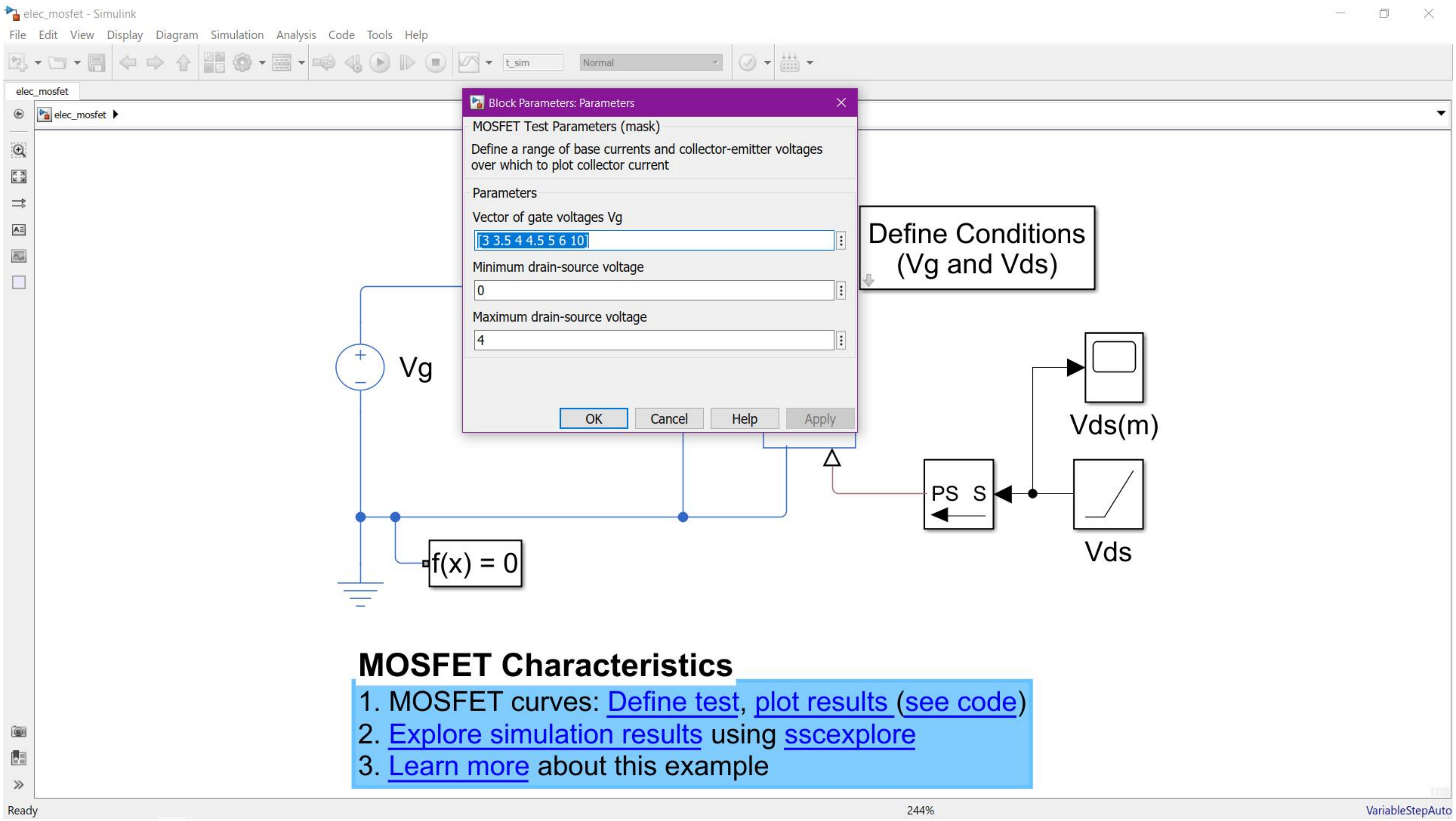


fig 10.1 : Mosfet diagram : (a) p-Channel enhancement mosfet (b) n-Channel enhancement mosfet

MATLAB Simulation




elec_mosfet - Simulink
File Edit View Display Diagram Simulation Analysis Code Tools Help
t_sim
Normal
elec_mosfet
elec_mosfet
Block Parameters: Parameters
MOSFET Test Parameters (mask)
Define a range of base currents and collector-emitter voltages over which to plot collector current
Parameters
Vector of gate voltages Vg
[3 3.5 4 4.5 5 6 10]
Minimum drain-source voltage
0
Maximum drain-source voltage
4
OK
Cancel
Help
Apply
Define Conditions (Vg and Vds)
Vg
Vds(m)
PS S
Vds
f(x) = 0
MOSFET Characteristics
1. MOSFET curves: Define test, plot results (see code)
2. Explore simulation results using sscexplore
3. Learn more about this example
Ready
244%
VariableStepAuto

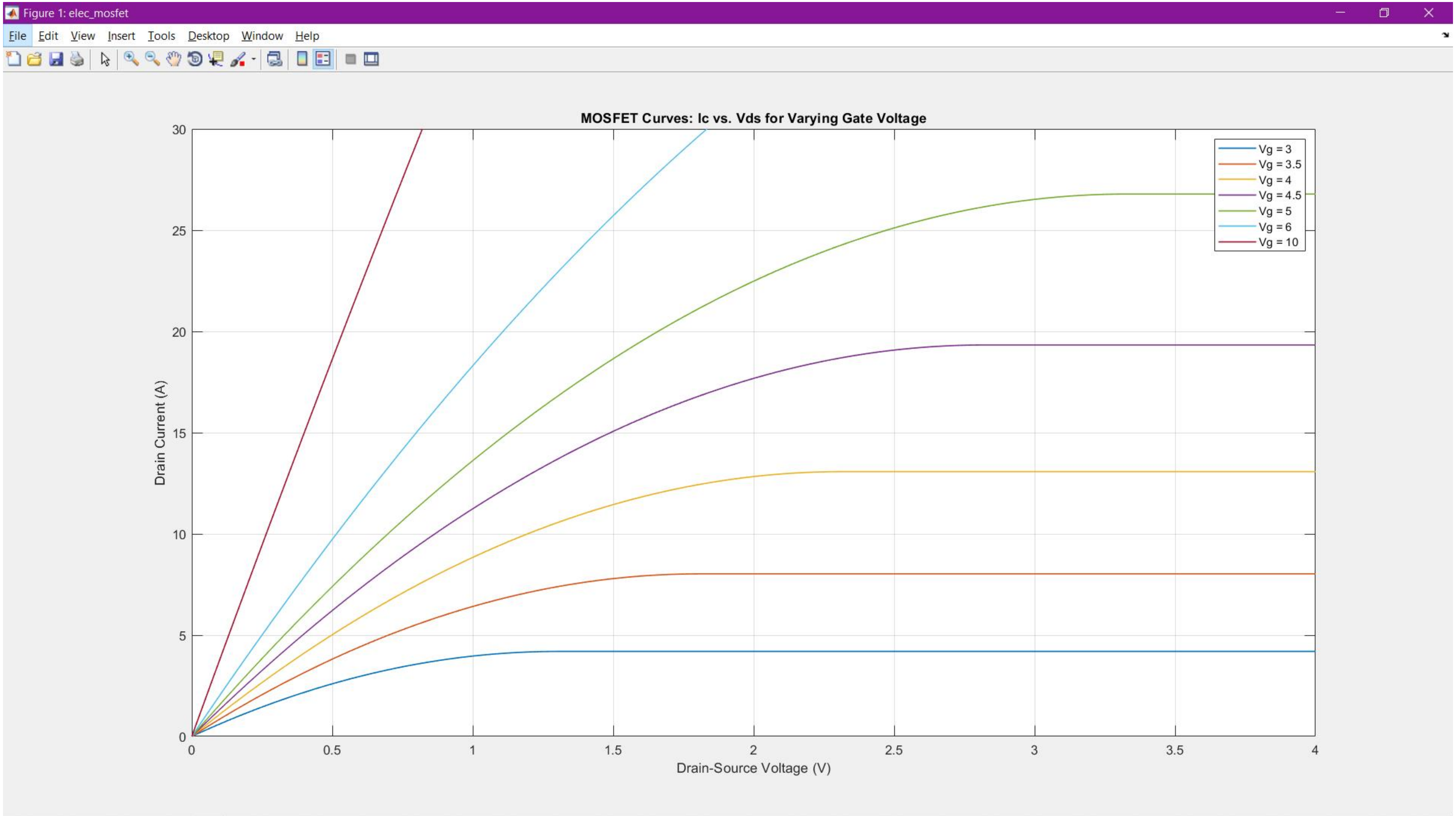
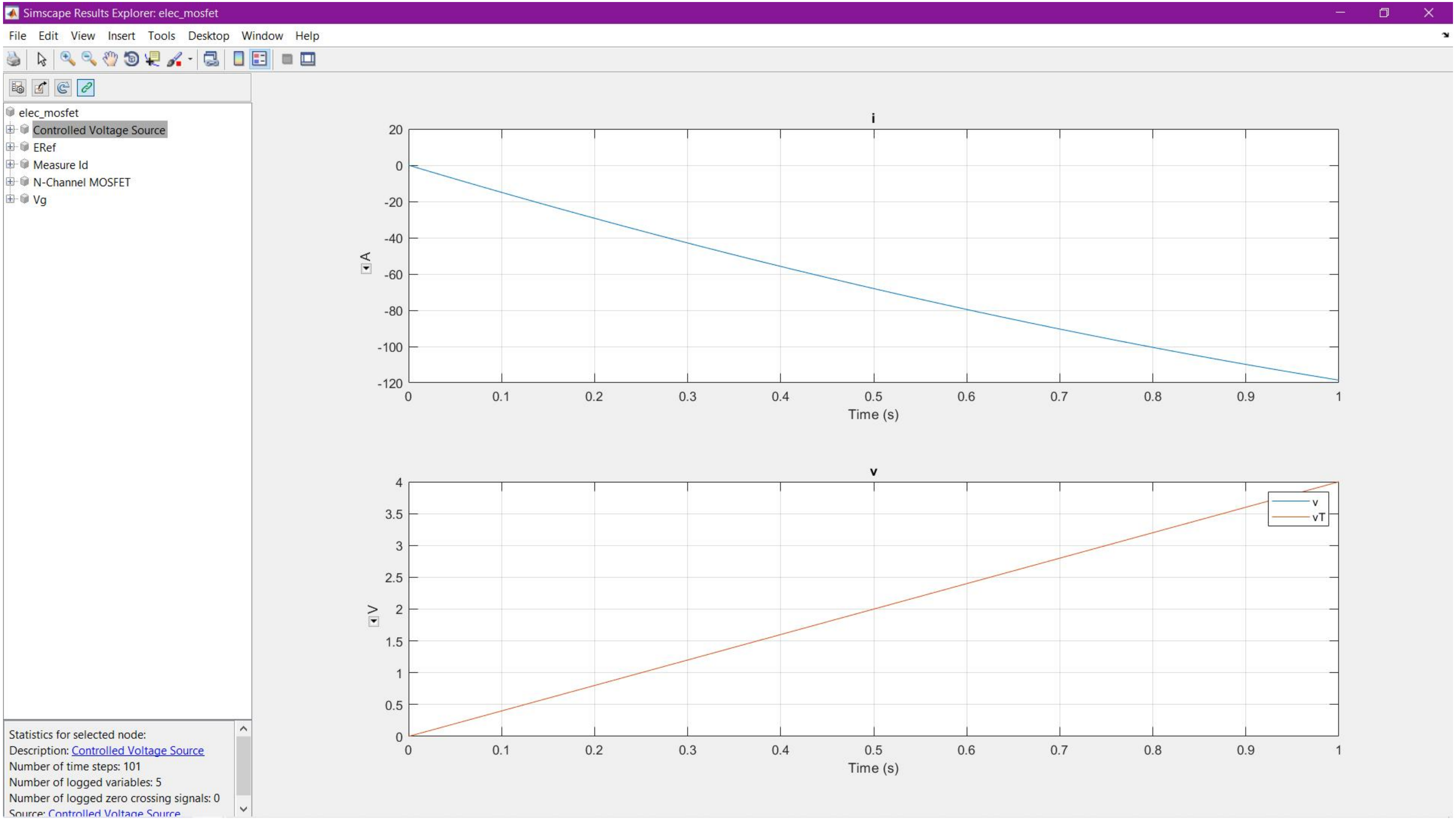
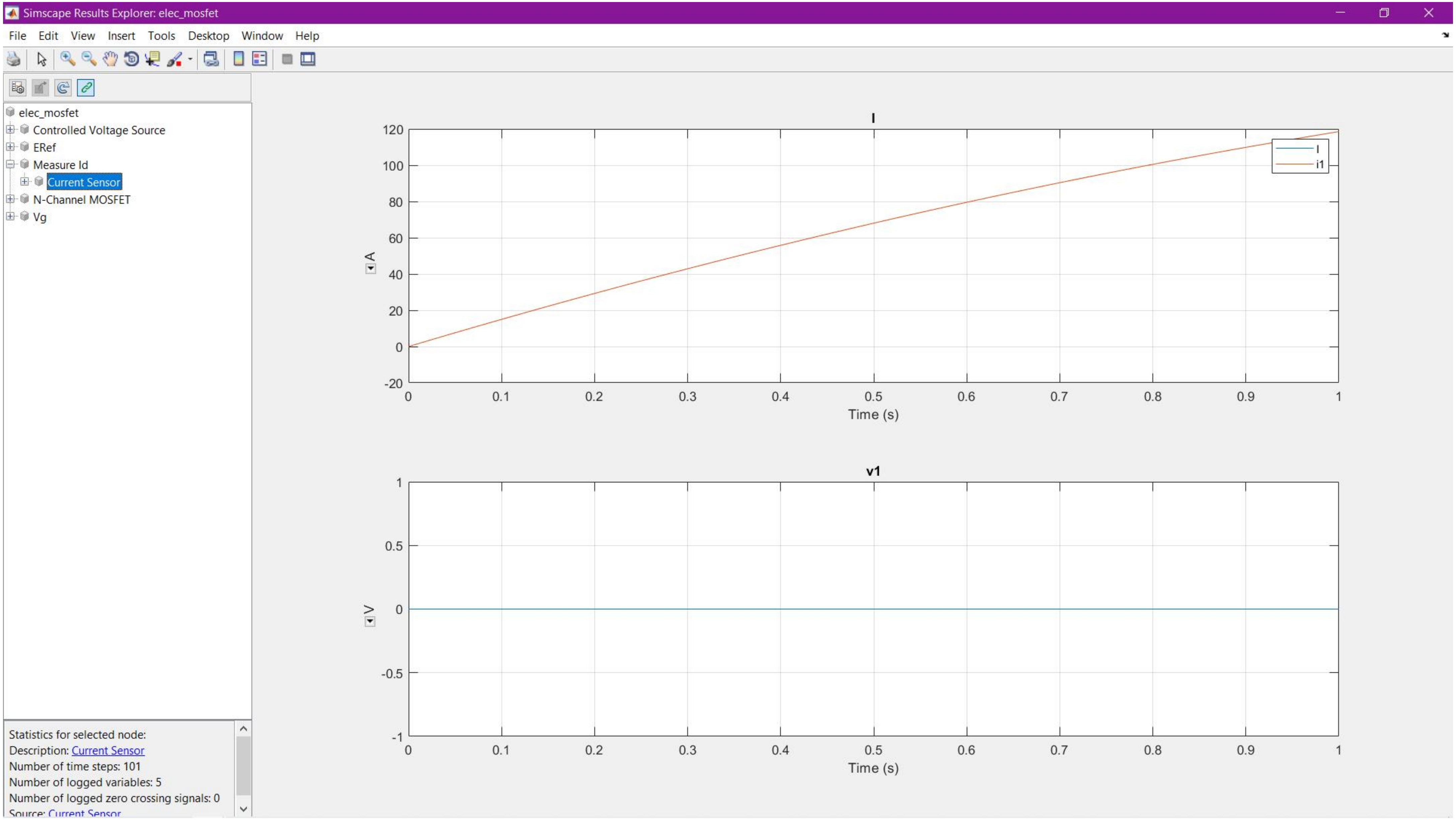
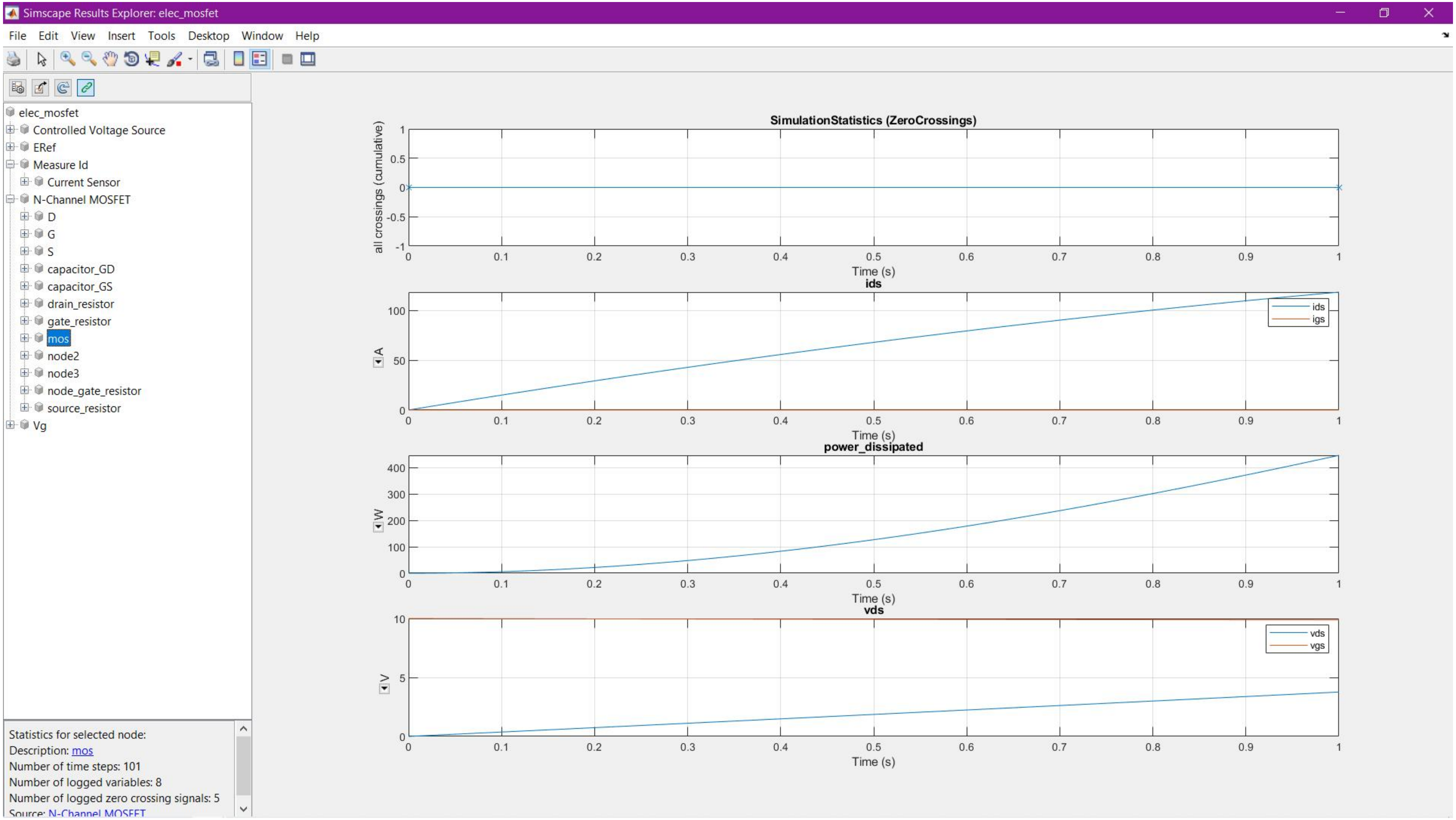


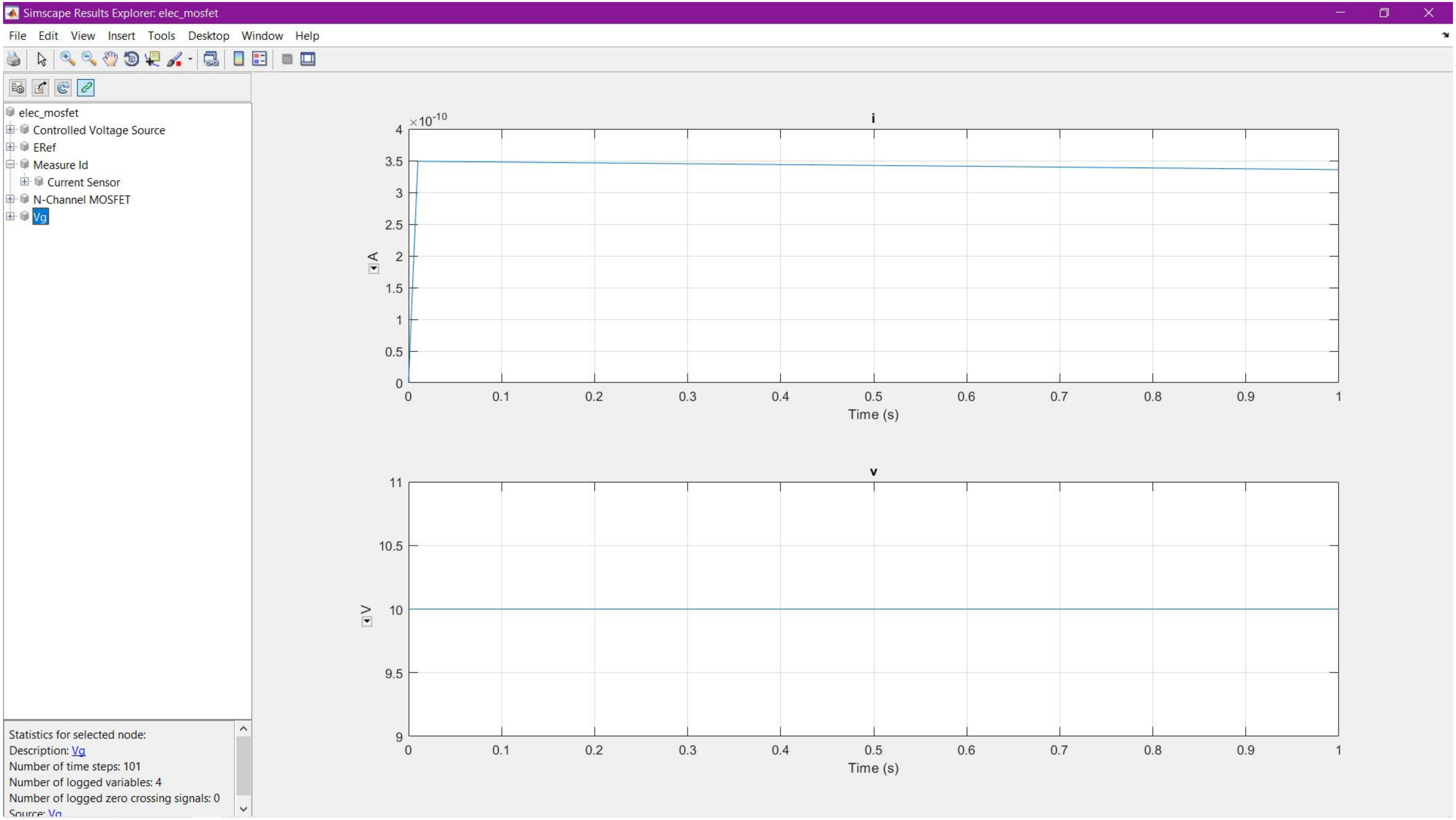
Figure 1: elec_mosfet
File Edit View Insert Tools Desktop Window Help
MOSFET Curves: Ic vs. Vds for Varying Gate Voltage
Drain Current (A)
Drain-Source Voltage (V)
0
5
10
15
20
25
30
0
0.5
1
1.5
2
2.5
3
3.5
4
Vg = 3
Vg = 3.5
Vg = 4
Vg = 4.5
Vg = 5
Vg = 6
Vg = 10


Simscape Results Explorer: elec_mosfet
File Edit View Insert Tools Desktop Window Help
elec_mosfet
Controlled Voltage Source
ERef
Measure Id
N-Channel MOSFET
Vg
Statistics for selected node:
Description: Controlled Voltage Source
Number of time steps: 101
Number of logged variables: 5
Number of logged zero crossing signals: 0
i
A
Time (s)
v
V
v
vT
Time (s)



Simscape Results Explorer: elec_mosfet
File Edit View Insert Tools Desktop Window Help
elec_mosfet
Controlled Voltage Source
ERef
Measure Id
Current Sensor
N-Channel MOSFET
Vg
Statistics for selected node:
Description: Current Sensor
Number of time steps: 101
Number of logged variables: 5
Number of logged zero crossing signals: 0
Source: Current Sensor
I
A
Time (s)
v1
V
Time (s)


Simscape Results Explorer: elec_mosfet
File Edit View Insert Tools Desktop Window Help
elec_mosfet
Controlled Voltage Source
ERef
Measure Id
Current Sensor
N-Channel MOSFET
D
G
S
capacitor_GD
capacitor_GS
drain_resistor
gate_resistor
mos
node2
node3
node_gate_resistor
source_resistor
Vg
Statistics for selected node:
Description: mos
Number of time steps: 101
Number of logged variables: 8
Number of logged zero crossing signals: 5
Source: N-Channel MOSFET
SimulationStatistics (ZeroCrossings)
all crossings (cumulative)
Time (s)
ids
A
ids
igs
power_dissipated
W
vds
V
vds
vgs


Simscape Results Explorer: elec_mosfet
File Edit View Insert Tools Desktop Window Help
elec_mosfet
Controlled Voltage Source
ERef
Measure Id
Current Sensor
N-Channel MOSFET
Vg
Statistics for selected node:
Description: Vg
Number of time steps: 101
Number of logged variables: 4
Number of logged zero crossing signals: 0
i
×10^-10
A
Time (s)
v
V
Time (s)

* Procedure:

1. Open MATLAB and in command window write: "elec_mosfet" and press enter.
2. A simulation circuit will apper; (change the values if required) and run the simulation.
3. After simulation, click on plot curve and observe the characteristics graph.
4. For more observation click on Explore simulation results.

* Result: Studied and observed VI characterstics of mosfet using MATLAB simulink.

* Precautions:

1. Don't give multiple command at a time.
2. Do not change the circuit until required of the file as its inbuilt example.

Experiment - 11

* Aim: To study and plot V-I characteristics of SCR

* Equipment required:

  1. NV6530 SCR characteristics trainer
  2. 2mm patch coards

* Theory:

A SCR is a four layered PNPN device, its prominent member of thyristor family. It consists of three diodes connected back in back with gate connections or two complementary transistors connected back to back.

It is widely used as a switching device in power control applications. It can switch ON for variable length of time and delivers amount of power to load.

It can control by the switching current Off and ON upto many thousand time a second. Hence, it posses arrays of RHEOSTAT and a switch with none of their advantages

* **Diagram:**

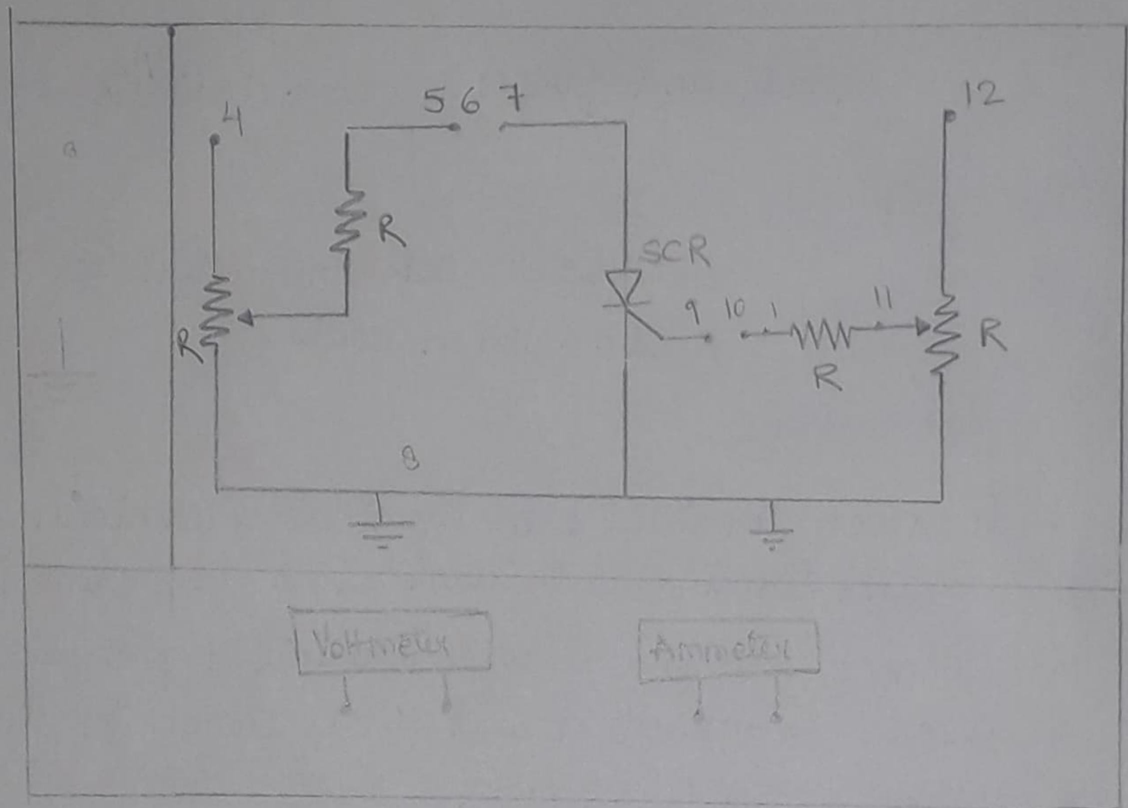


Fig 11.1 : Circuit diagram connection of SCR

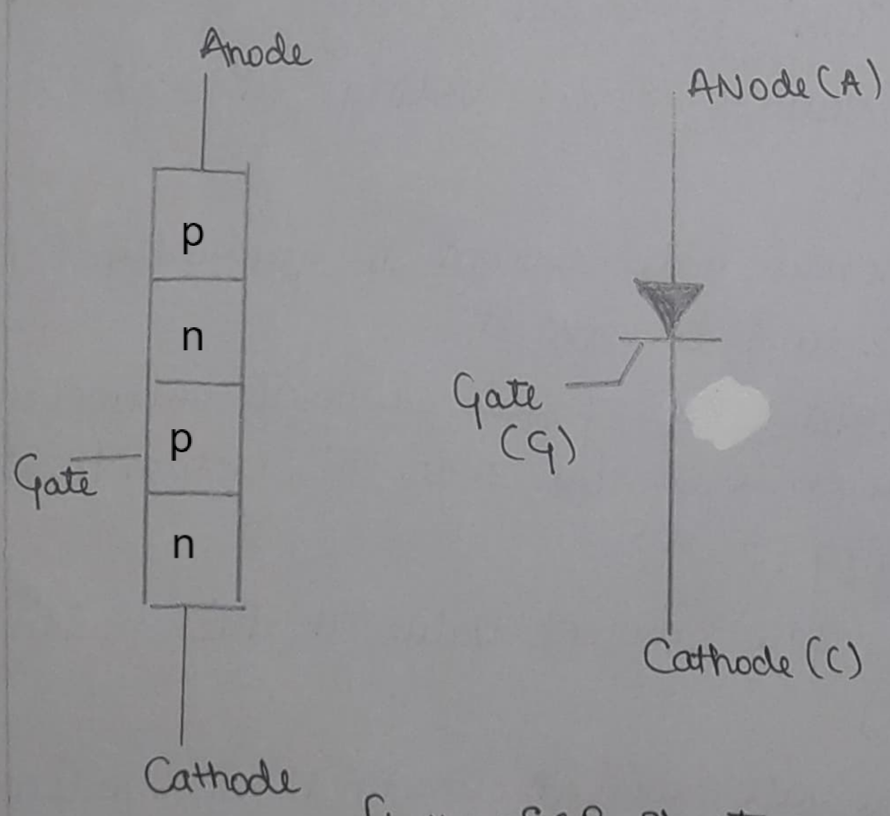


Fig 11.2 : SCR structure & symbol

* Procedure:

1. Connect terminal 1 to terminal 4, terminal 2 to terminal 8 and terminal 3 to terminal 12 as shown in figure.
2. Connect voltmeter across terminal 7 $ 8 and Ammeter across terminal 9 and 10 as shown in figure
3. Make short terminals 5 $ 6.
4. Rotate the knob P1 $ P2 fully in counter clockwise.
5. Switch "ON" the power supply.
6. Set the value of Anode Voltage at 35V by using the knob P1.
7. Now, Increase gate current Ig gradually by varying knob P2 and observe it.
8. At certain value of gate current, voltmeter reading falls down to almost zero. This action indicates the firing of SCR.
9. Note the gate current value at this position (firing of SCR).
10. Keep the gate current constant by shorting terminal 9 with 10 and connect Ammeter to the ~~terminal~~ terminal

5 and 6 (as in figure).

11. Rotate the potentiometer P1 fully in counter clockwise.

12. Rotate knob P1 (from initial position to its maximum limit) gradually and record Anode current for respective value of anode voltages.

13. Plot the graph between anode voltage Va and anode current Ia.

* Observation Table:

Sl. No.	Anode Voltage Va (V)	Anode current Ia (mA)
1.	0	0
2.	0.5	0
3.	1.3	1
4.	7.4	0.2
5.	11.6	0.2
6.	13.5	8.5
7.	0.7	11.8
8.	0.7	21.2
9.	0.7	35.4
10.	0.7	39.5

* Graph:

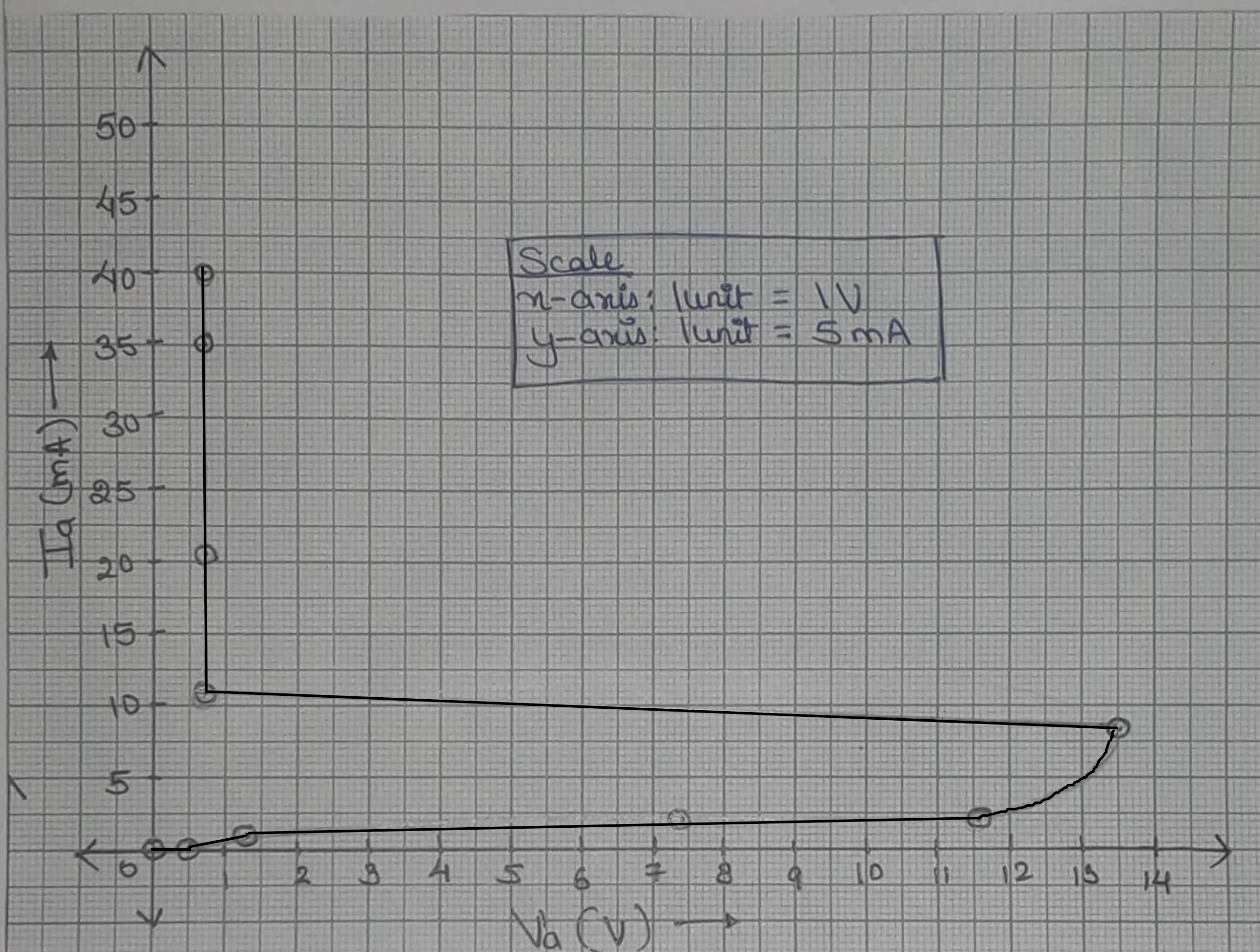


Fig 11.3: Ia Vs Va characterstics of SCR

* **Result** : Studied and ploted V-I characteristecs of SCR.

* **Precautions :**

1. Connect the circuit carefully as per the given circuit diagram.
2. Verify the circuit before giving power suppy
3. Switch off the power supply after the experiment and remove the connections.

Experiment - 12

* **Aim:** Study of the half-wave controlled rectifier with resistive load.

* **Equipments Needed:**

1. Power Electronics board, Scientech 2708
2. Oscilloscope - Scientech 803/831, or equivalent
3. 2mm patch cords
4. Multimeter

* **Procedure:**

Make sure that there should not be any connections by patch cord on the board.

1. Rotate the firing control pot in full clockwise directions
2. Switch 'On' the power.
3. Measure the ac voltage (Vrms) by voltmeter between point 0V-15V and calculate Em by:

$$E_m = 1.414 \times V_{rms}$$

4. Switch 'Off' the power.
5. Connects the circuit of half-wave rectifier as ~~sto~~ shown figure 8 using 2 mm patch cords
6. Switch 'On' the power supply
7. Connect the oscilloscope and voltmeter across the load.

* Circuit Diagram:

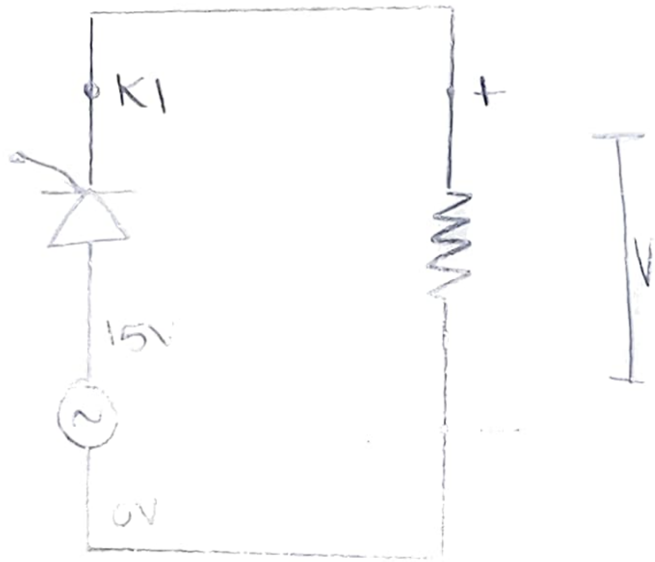


Fig 12.1: The circuit diagram of basic half-wave controlled rectifier circuit diagram.

8. Vary the firing control pot and set on 30°, 60°, 90°, 120° and 150° firing angles using equations (11).
9. Observe the output waveforms and note the reading of voltage across load on different firing angles.
10. Observe the waveforms ~~and~~ across the SCR, when firing angle is 90°.
11. Calculate the average load current and power P_{dc} from measured load voltage V_o.
12. Plot the input signal, gate pulse and drop signal across SCR and output waveform when firing angle is 90°.

* Observation table

$V_s = 15\ V\ (ac) \Rightarrow V_m = \sqrt{2} \times V_s = 21.21\ V$

α (degree)	Practical O/P Voltage (V)	Practical O/P Current (mA)	Practical Power (W)	Theoritical O/P Voltage (V)	Theoritical O/P Current (mA)	Theoritical Power (W)	% Error
0	6.42	6.42	0.041	6.75	6.75	0.045	4.88%
30	6.09	6.09	0.037	6.30	6.30	0.039	3.33%
36	5.912	5.912	0.349	6.1	6.1	0.037	3.08%
45	5.62	5.62	0.315	5.76	5.76	0.033	2.43%
60	4.86	4.86	0.0236	5.06	5.06	0.0256	3.95%
90	3.59	3.59	0.0128	3.37	3.37	0.0113	6.5%
108	2.25	2.25	0.005	2.33	2.33	0.0054	3.43%
126	1.39	1.39	0.0019	1.391	1.391	0.0019	0.07%

$$V_o = \frac{V_m}{2\pi}(1+\cos\alpha)\ ;\ R = 1\times10^3\,\Omega$$

* Calculation:

1. $\alpha = 0°,\ V_o = 6.42\,V$

Practical: $I_o = \frac{V_o}{R} = \frac{6.42}{1\times10^3} = 6.42\,mA$

$$P_o = \frac{V_o^2}{R} = \frac{6.42^2}{10^3} = 0.041\,W.$$

Theoritical:

$$V_o = \frac{21.21}{2\pi}(1+\cos 0°) = 6.75\,V$$

$$I_o = \frac{6.75}{10^3} = 6.75\,mA\ ;\ P_o = \frac{6.75^2}{10^3} = 0.045\,W$$

2. $\alpha = 30°\ ;\ V_o = 6.09\,V$

Practical: $I_o = \frac{6.09}{10^3} = 6.09\,mA \quad P_o = \frac{6.09^2}{10^3} = 0.037\,W$

Theoritical: $V_o = \frac{21.21}{2\pi}(1+\cos(30°)) = 6.30\,V$

$$I_o = \frac{6.30}{10^3} = 6.3\,mA \quad P_o = \frac{6.3^2}{10^3} = 0.039\,W.$$

3. $\alpha = 36°;\ V_o = 5.912\,V$

Practical: $I_o = \frac{5.912}{10^3} = 5.912\,mA\ ;\ P_o = \frac{5.912^2}{10^3} = 0.349\,W$

theoritical: $V_o = \frac{21.21}{2\pi}(1+\cos 36°) = 6.1\,V$

$$I_o = 6.1\,mA \quad P_o = \frac{6.1^2}{10^3} = 0.037\,W$$

4. $\alpha = 45°;\ V_o = 5.62\,V$

Practical: $I_o = 5.62\,mA\ ;\ P_o = 0.0315\,W$

Theoritical: $V_o = \frac{21.21}{2\pi}(1+\cos 45°) = 5.76\,V$

$$I_o = 5.76\,mA \quad P_o = \frac{5.76^2}{10^3} = 0.033\,W.$$

5. $\alpha = 60^\circ$; $V_o = 4.86$ V

Practical : $I_o = 4.86$ mA $\quad P_o = \frac{4.86^2}{10^3} = 0.0236$ W

Theoritical : $V_o = \frac{21.21}{2\pi}(1+\cos 60^\circ) = 5.06$ V

$I_o = 5.06$ mA $\quad P_o = \frac{5.06^2}{10^3} = 0.0256$ W

6. $\alpha = 90^\circ$; $V_o = 3.59$ V

Practical : $I_o = 3.59$ mA $\quad P_o = \frac{3.59^2}{10^3} = 0.0128$ W

Theoritical : $V_o = \frac{21.21}{2\pi}(1+\cos 90^\circ) = 3.37$ V

$I_o = 3.37$ mA $\quad P_o = \frac{3.37^2}{10^3} = 0.0113$ W

7. $\alpha = 108^\circ$; $V_o = 2.25$ V

Practical : $I_o = 2.25$ mA $\quad P_o = \frac{2.25^2}{10^3} = 0.005$ W

Theoritical : $V_o = \frac{21.21}{2\pi}(1+\cos(108)) = 2.33$ V

$I_o = 2.33$ mA $\quad P_o = \frac{2.33^2}{10^3} = 0.0054$ W

8. $\alpha = 126^\circ$; $V_o = 1.39$ V

Practical : $I_o = 1.39$ mA $\quad P_o = \frac{1.39^2}{10^3} = 0.0019$ W

Theoritical : $V_o = \frac{21.21}{2\pi}(1+\cos(126^\circ)) = 1.391$ V

$I_o = 1.391$ mA $\quad P_o = \frac{1.391^2}{10^3} = 0.0019$ W

* % Error

1 → $\frac{|6.42 - 6.75|}{6.75} \times 100 = 4.88\%$ $\quad$ 5 → $\frac{|4.86 - 5.06|}{5.06} \times 100 = 3.95\%$

2 → $\frac{|6.09 - 6.30|}{6.30} \times 100 = 3.33\%$ $\quad$ 6 → $\frac{|3.59 - 3.37|}{3.37} \times 100 = 6.5\%$

3 → $\frac{|5.912 - 6.1|}{6.1} \times 100 = 3.08\%$ $\quad$ 7 → $\frac{|2.25 - 2.33|}{2.33} \times 100 = 3.43\%$

4 → $\frac{|5.62 - 5.76|}{5.76} \times 100 = 2.43\%$ $\quad$ 8 → $\frac{|1.39 - 1.391|}{1.391} \times 100 = 0.07\%$

* ~~[illegible]~~ Waveform:

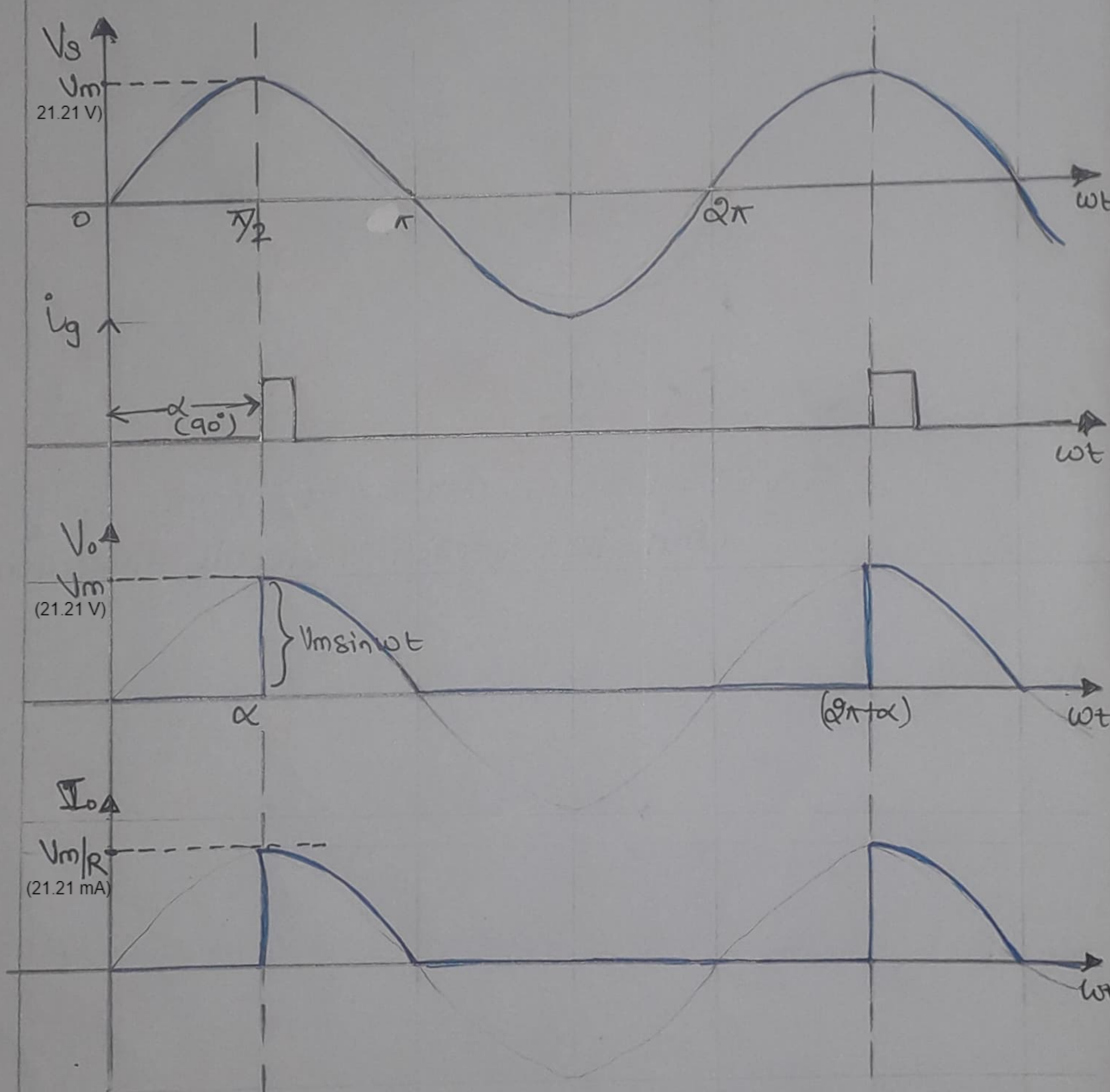


Fig12.2: Waveform of half wave controlled rectifier for $\alpha = 90°$.

* **Result**: Studied and observed the waveform of the half wave controlled rectifier with resistive load using trainer kit.

* **Precautions**:

1. Make the connection tight.
2. Do not power on the supply until the connection is verified.