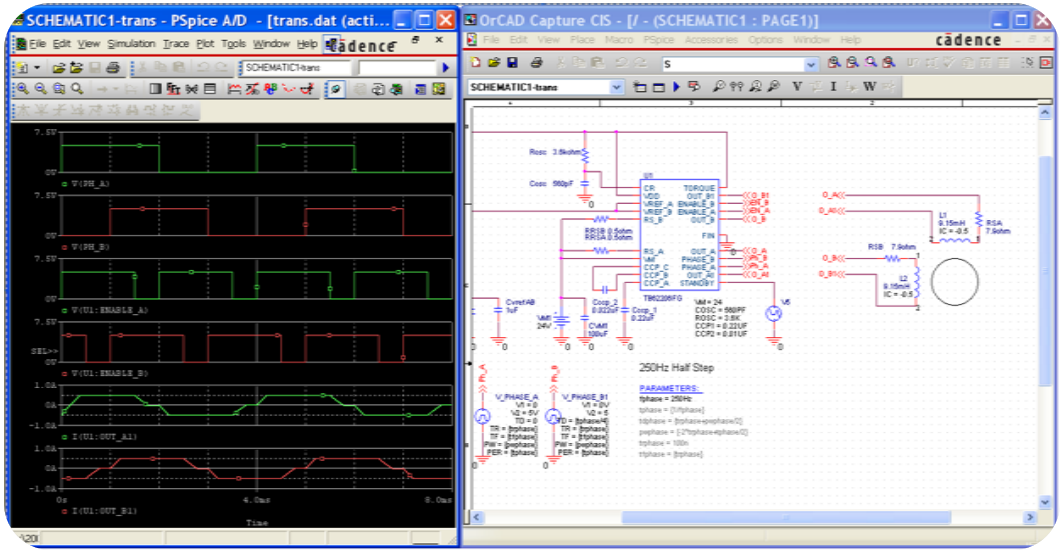


Design Kit

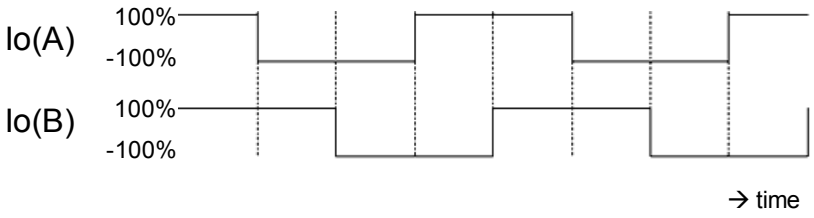
2-Phase Bipolar Stepping Motor Driver Using TB62206FG

Contents

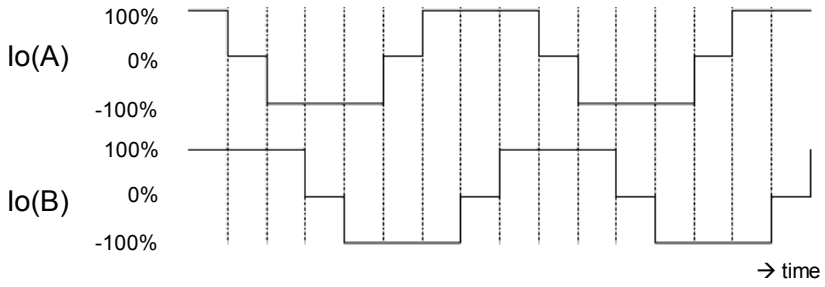
1.1 Bipolar Stepping Motors

- There are two winding with no center taps.
- The drive circuitry requires an H-bridge control circuit for each winding, as the drive circuit need to change the polarity of each pair of motor poles.
- The current sequences are shown below.

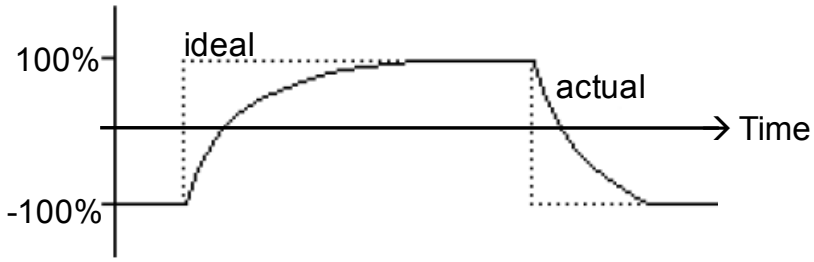
- Full Step

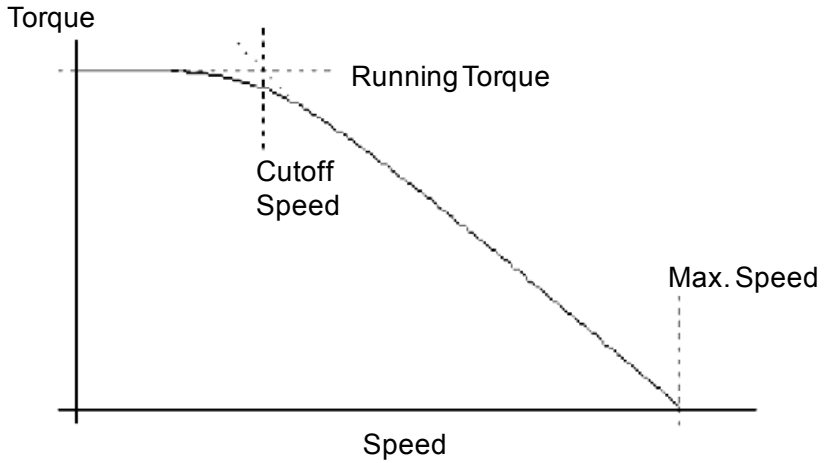


- Half Step



1.2 Torque vs. Speed

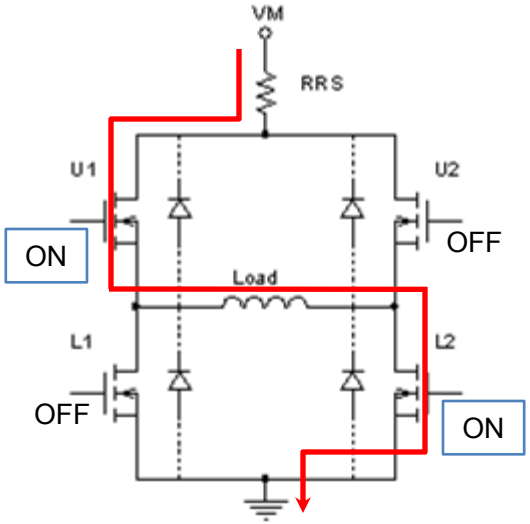




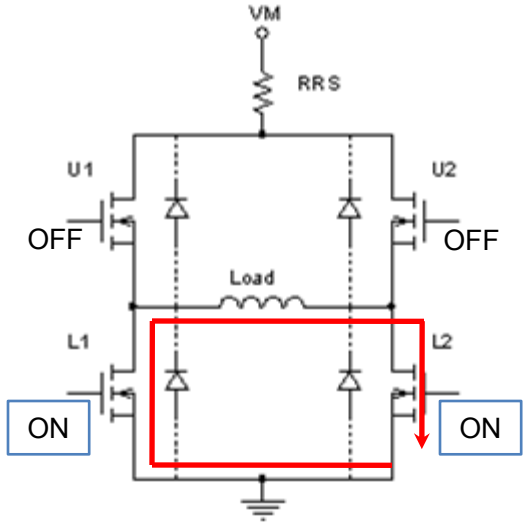
- The inductance of the motor winding determines the rise and fall time of the current through the winding.
- The current-vs-time function through each winding depend on the drive circuitry and the motor characteristics.
- The rise time is determined by the drive voltage, while the fall time depends on the circuitry used to dissipate the stored energy in the motor winding (fast or slow decay).
- The effect of the inductance of the motor windings is to reduce the available torque, as shown in the Torque-vs-Speed curve.

1.3 Bipolar Operating Mode

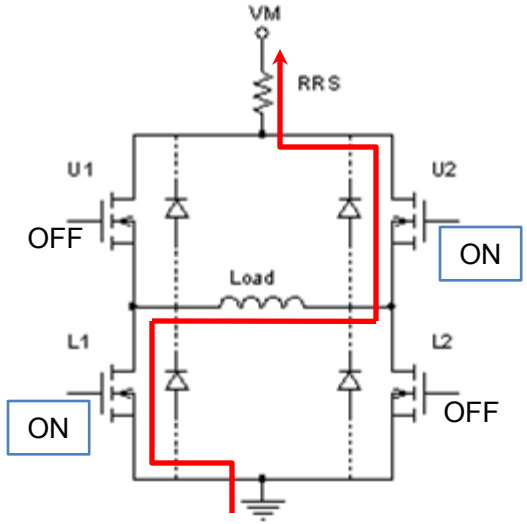
Charge mode



Slow decay mode



Fast decay mode



- These figure show how TB62206FG switches the current in each motor winding on and off, and controlling its direction, in three different modes.

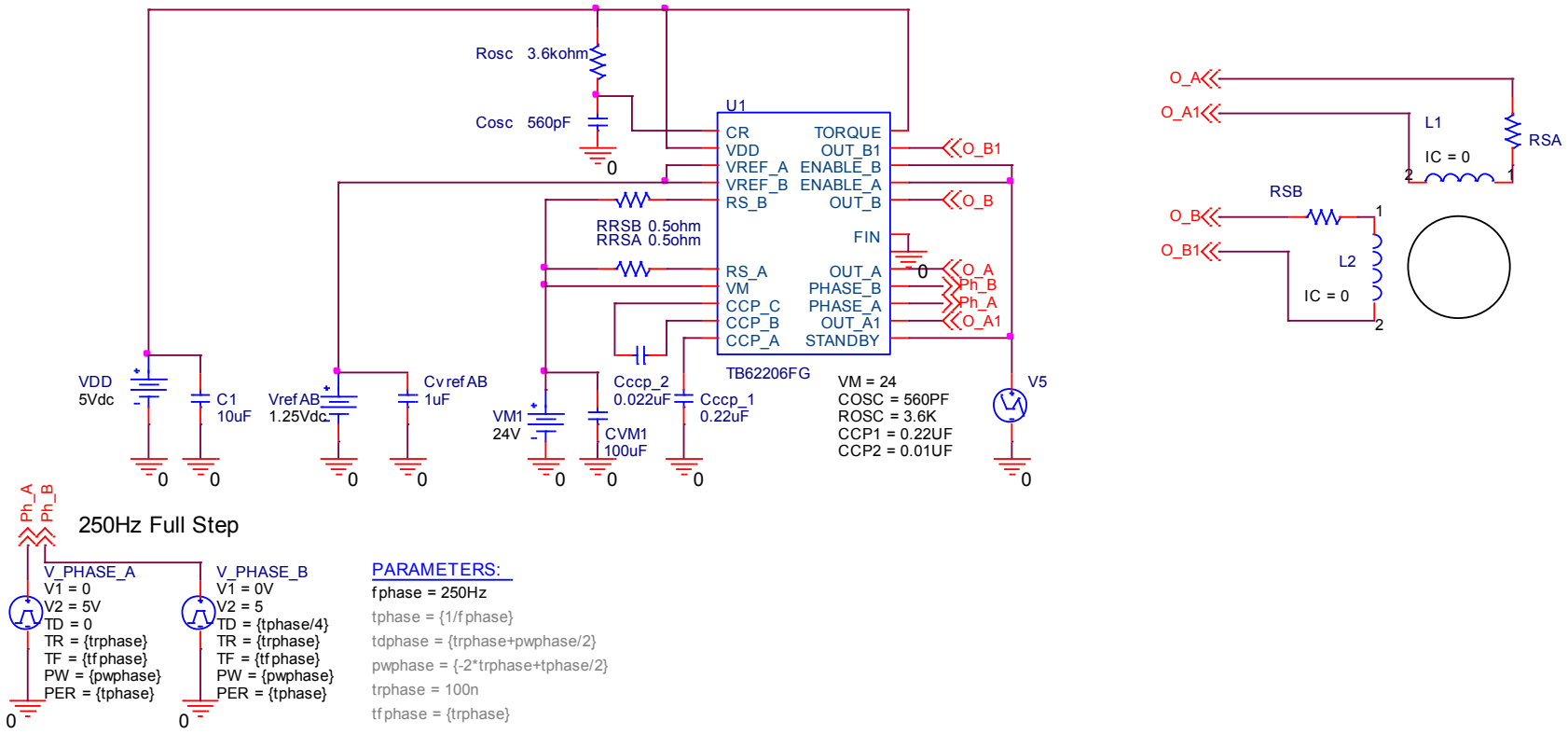
1.3 Bipolar Operating Mode

- Charge mode, the H-bridge forward state to allow current to flow from the supply through the motor winding and onward to ground.
- Slow decay mode, in this mode, winding current is re-circulated by enabling both of the low-side FETs in the bridge.
- Fast decay mode, the H-bridge reverses state to allow winding current to flow in a reverse direction.

	U1	U2	L1	L2
Charge	ON	OFF	OFF	ON
Slow	OFF	OFF	ON	ON
Fast	OFF	ON	ON	OFF

- In TB62206FG, three modes as shown above are automatically switched to control the constant current

2. Application Circuit

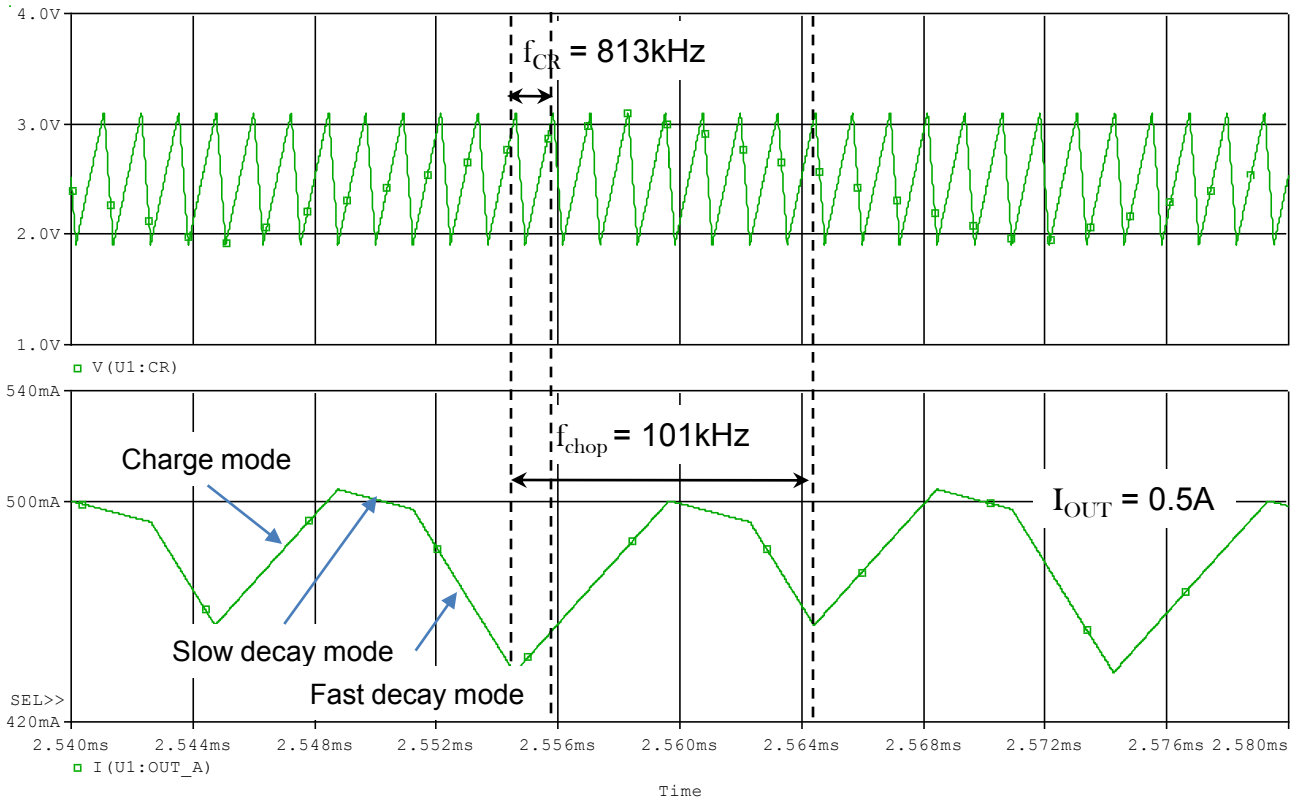


2.1 Specification

Operating Conditions

Characteristics	Symbol	Value	Unit
Power supply voltage	V_{DD}	5	V
Motor supply voltage	V_M	24	V
Reference voltage	V_{REF}	1.25	V
Logic input voltage	V_{IN}	5	V
Output current	I_{OUT}	0.5	A
Phase signal input frequency	f_{PHASE}	250	Hz
Chopping frequency	f_{chop}	101	kHz
Oscillation frequency	f_{CR}	813	kHz

2.1 Specification



- This figure shows the output current I_{OUT} ,the oscillation frequency f_{CR} ,and the chopping frequency f_{chop}.

2.2 Calculating Equations

- The output current value (set current value) can be determined by setting the sensing resistor (R_{RS}) and reference voltage (V_{ref}).

$$I_{OUT} = \frac{1}{5} \times Vref \times \frac{Torque_{(Torque=100,71\%)}}{R_{RS} \times 100\%} \quad (1)$$

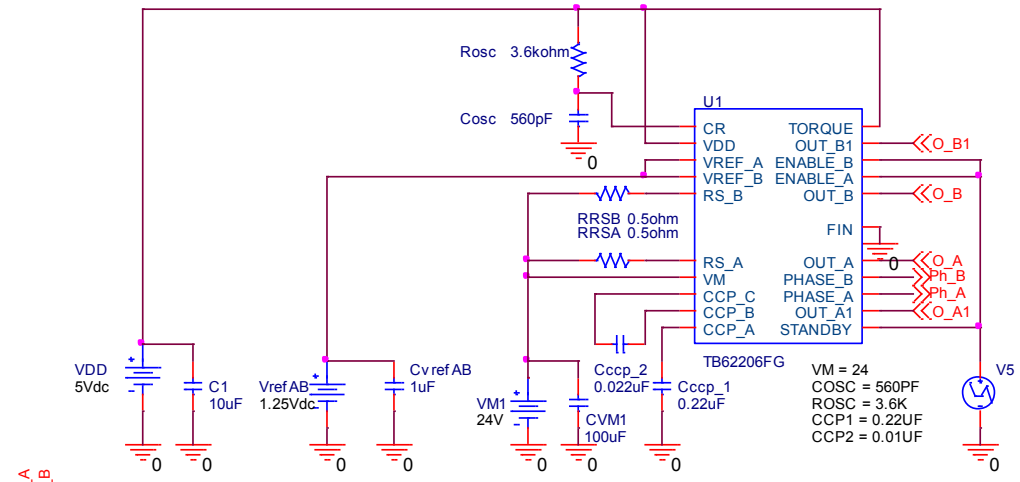
- The oscillation frequency is calculated as follows:

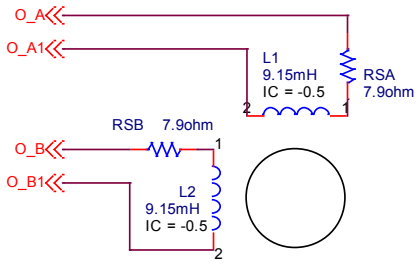
$$f_{CR} = \frac{1}{0.523 \times (C_{OSC} \times R_{OSC} + 600 \times C)} \quad (2)$$

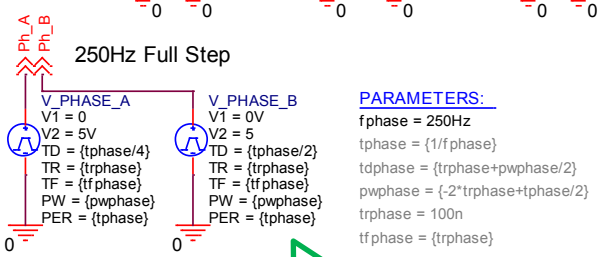
- The chopping frequency fchop is calculated as follows:

$$f_{CR} = \frac{f_{chop}}{8} \quad (3)$$

3.1 Full Step Switching Sequence





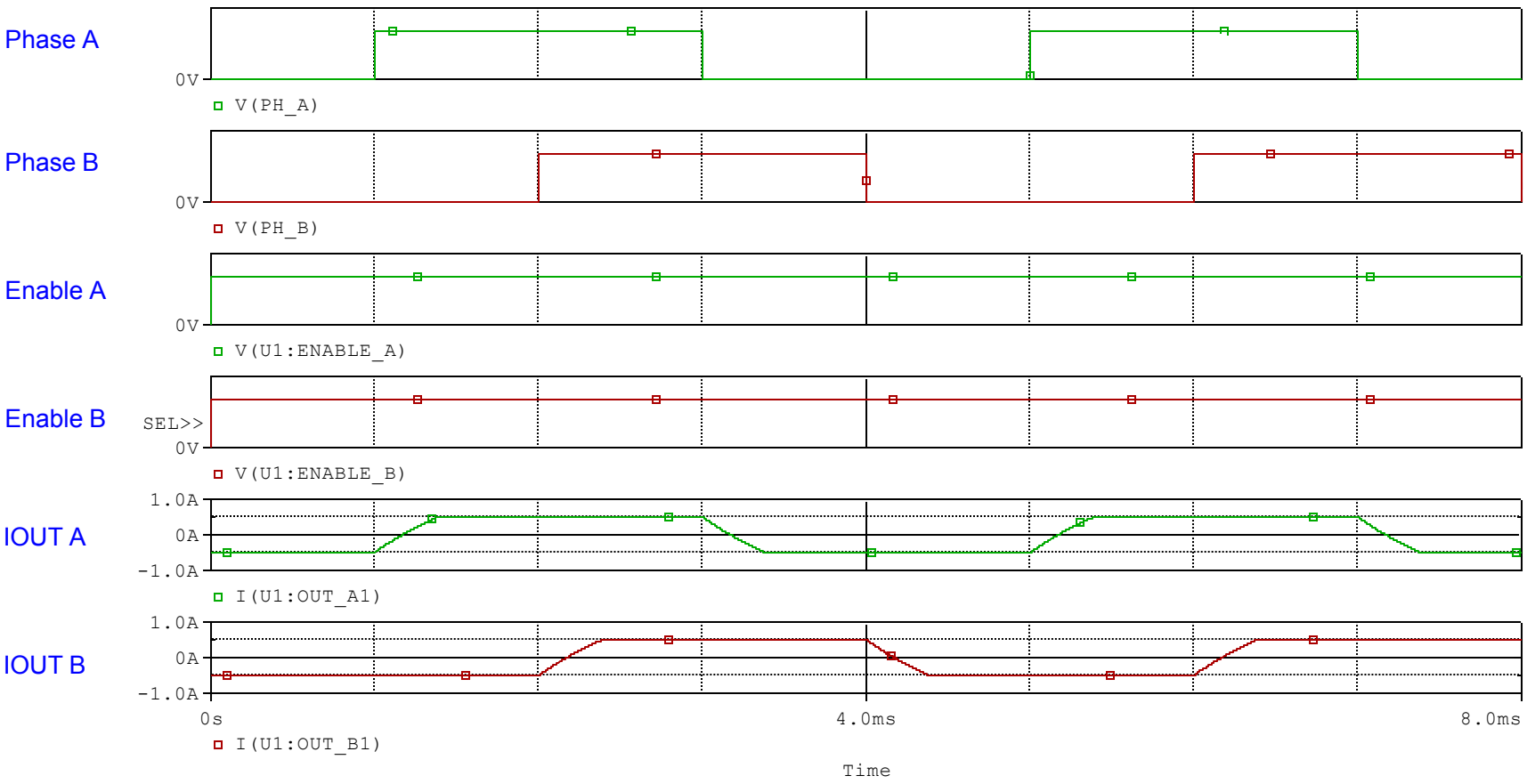


Full-step sequences control signals

Analysis
Time Domain (Transient)
Run to time: 8ms
Start saving data after: 0ms
Maximum step size: -

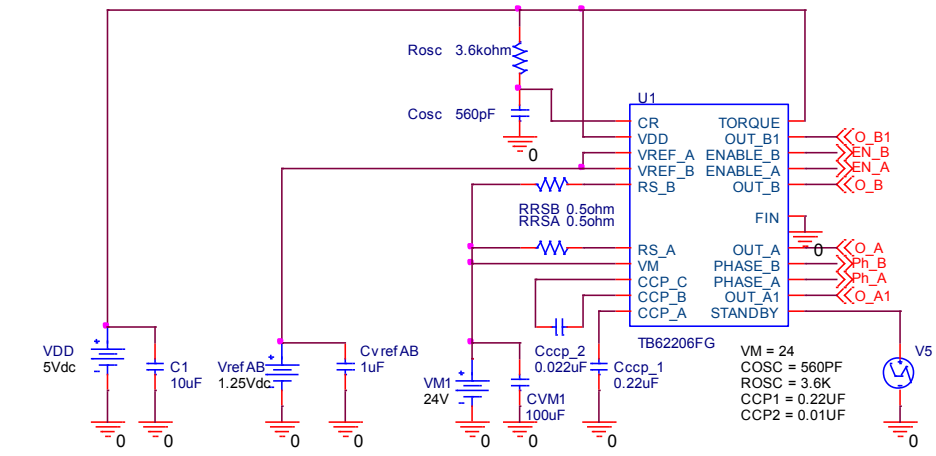
.Options
RELTOL: 0.01
VNTOL: 1.0m
ABSTOL: 1.0n
CHGTOL: 1p
GMIN: 1.0E-12
ITL1: 500
ITL2: 200
ITL4: 100

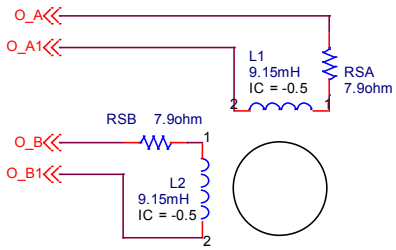
3.1 Full Step Switching Sequence

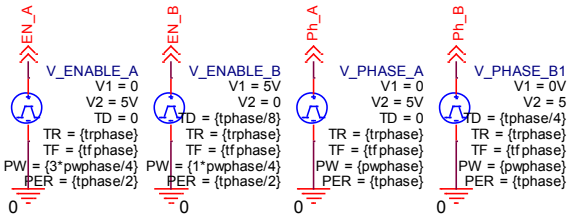


- This figure shows the simulation result of the circuit with Full-step switching sequence.

3.2 Half Step Switching Sequence







250Hz Half Step

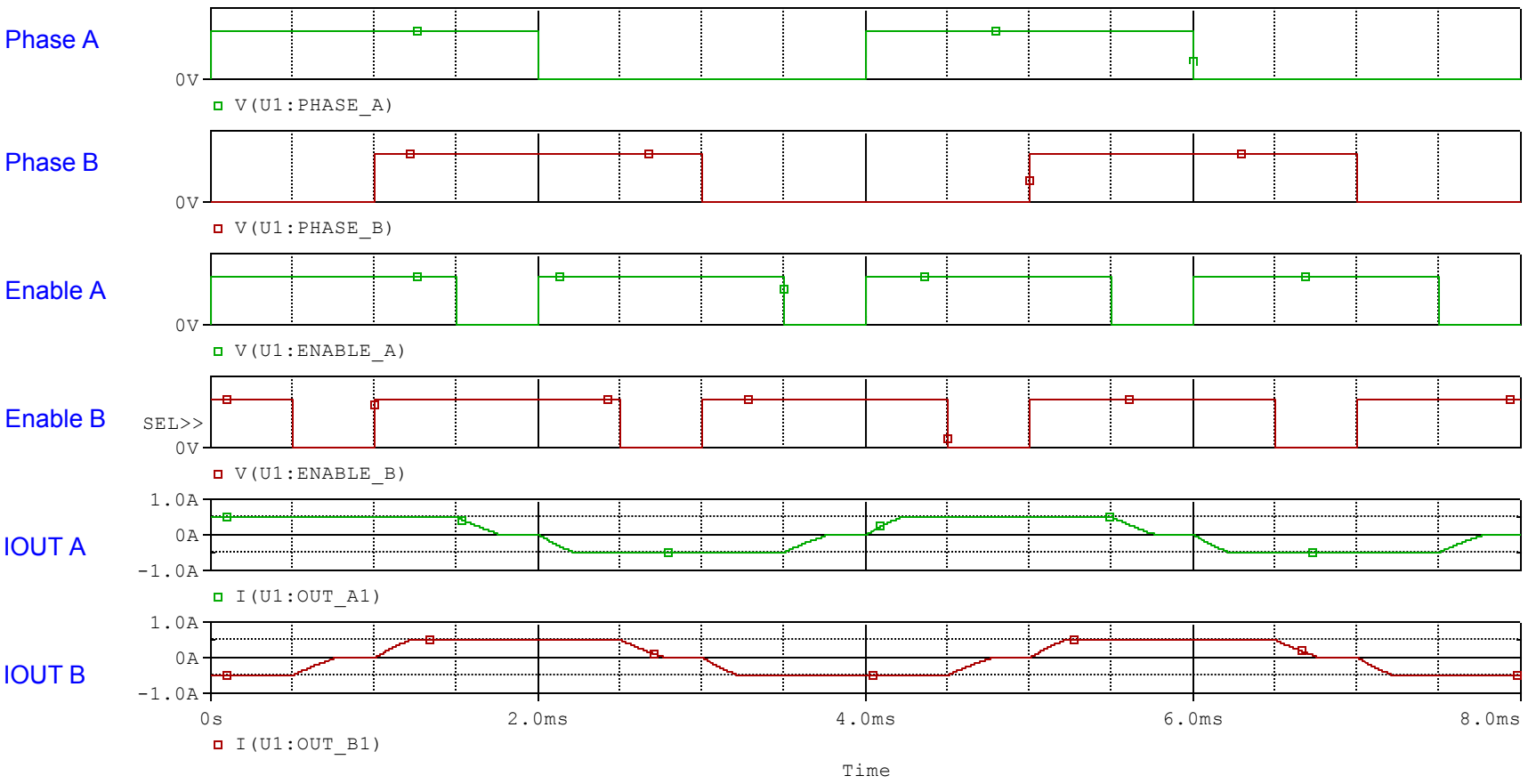
PARAMETERS:
fphase = 250Hz
tphase = {1/fphase}
tdphase = {trphase+pwphase/2}
pwphase = {-2*trphase+tphase/2}
trphase = 100n
tfphase = {trphase}

Half-step sequences control signals

Analysis
Time Domain (Transient)
Run to time: 8ms
Start saving data after: 0ms
Maximum step size: -

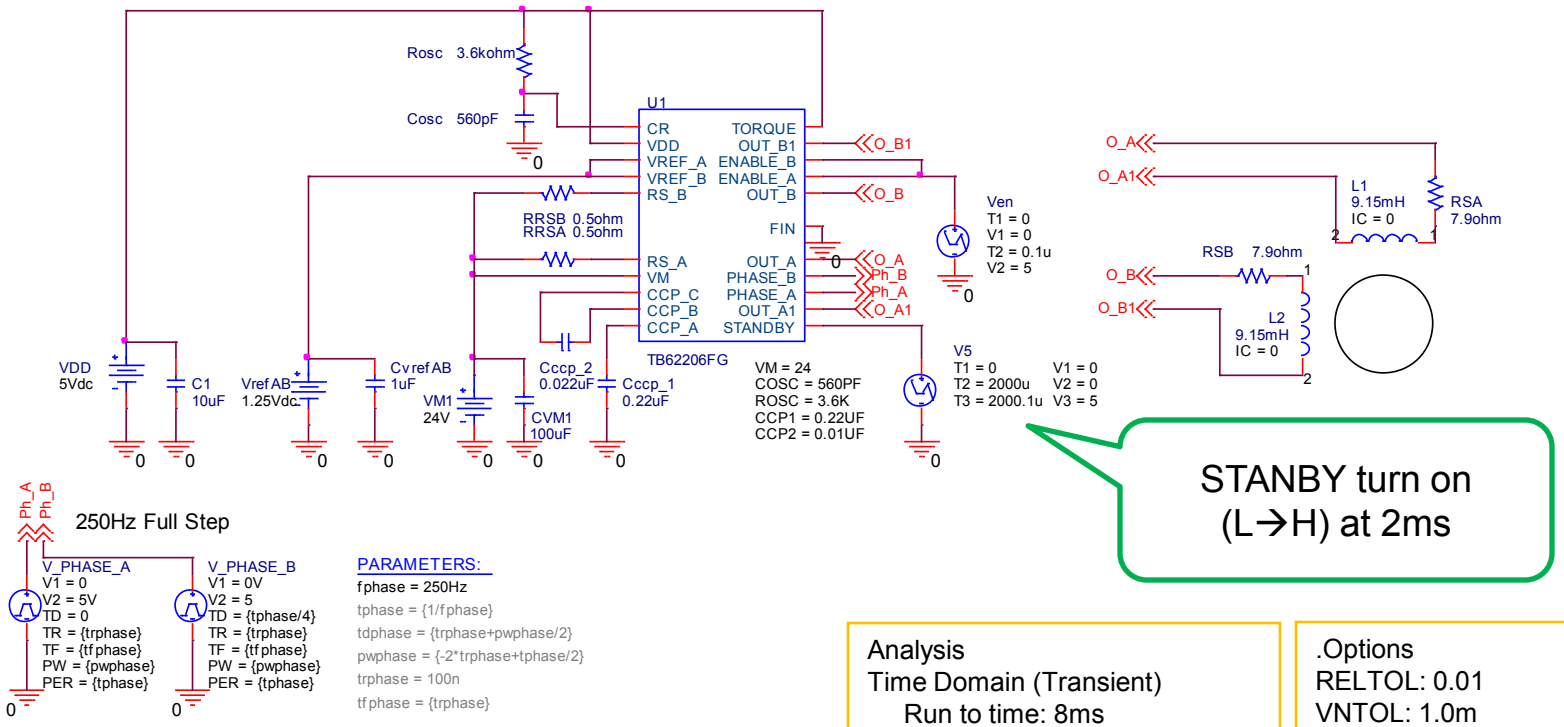
.Options
RELTOL: 0.01
VNTOL: 1.0m
ABSTOL: 1.0n
CHGTOL: 1p
GMIN: 1.0E-12
ITL1: 500
ITL2: 200
ITL4: 100

3.2 Half Step Switching Sequence



- This figure shows the simulation result of the circuit with Half-step switching sequence.

4.1 STANDBY

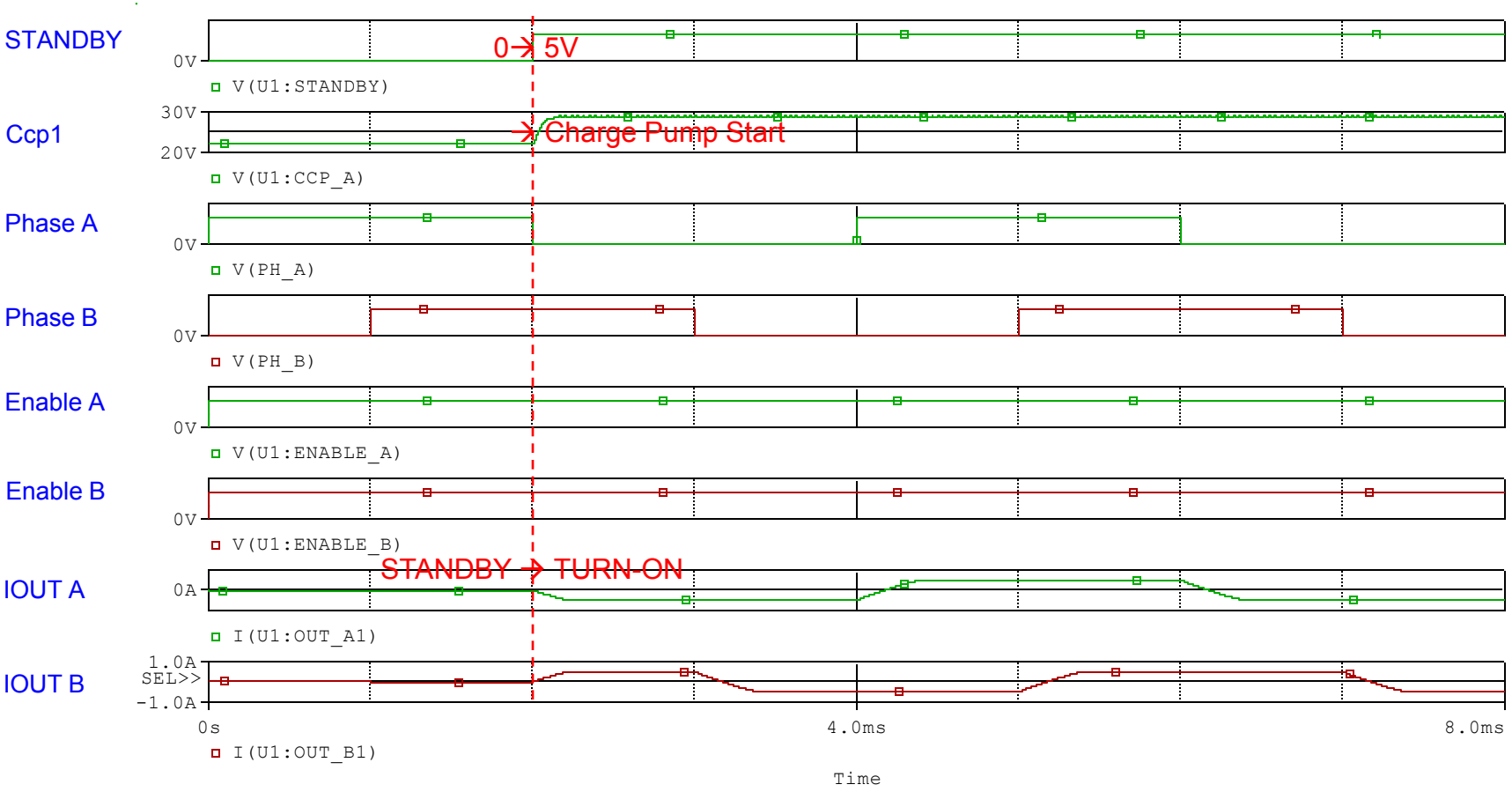


STANBY turn on
(L→H) at 2ms

Analysis
Time Domain (Transient)
Run to time: 8ms
Start saving data after: 0ms
Maximum step size: -

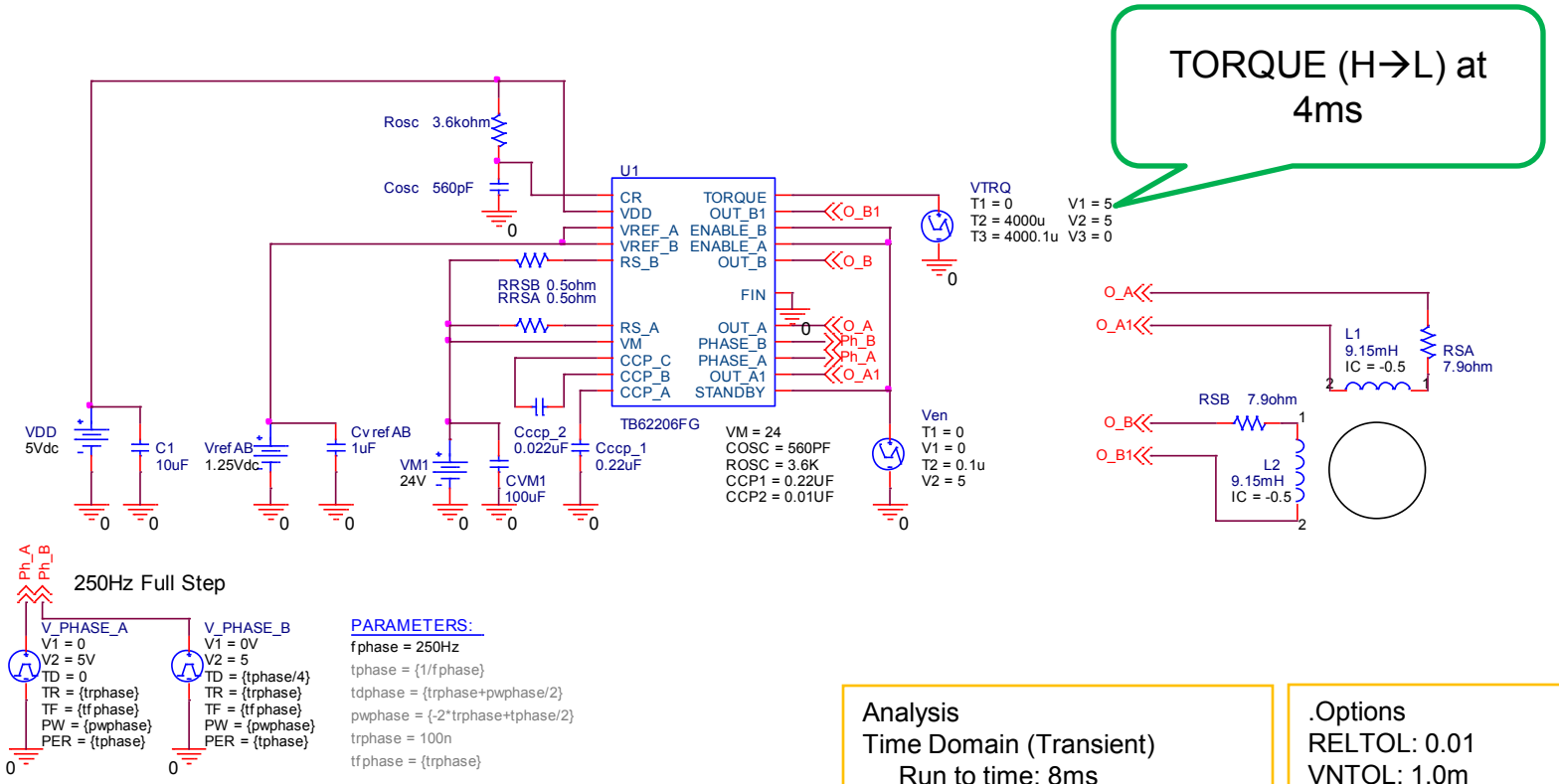
.Options
RELTOL: 0.01
VNTOL: 1.0m
ABSTOL: 1.0n
CHGTOL: 10p
GMIN: 1.0E-12
ITL1: 500
ITL2: 200
ITL4: 100

4.1 STANDBY



- This figure shows the simulation result of the circuit when V(STANDBY) changes from L→H.

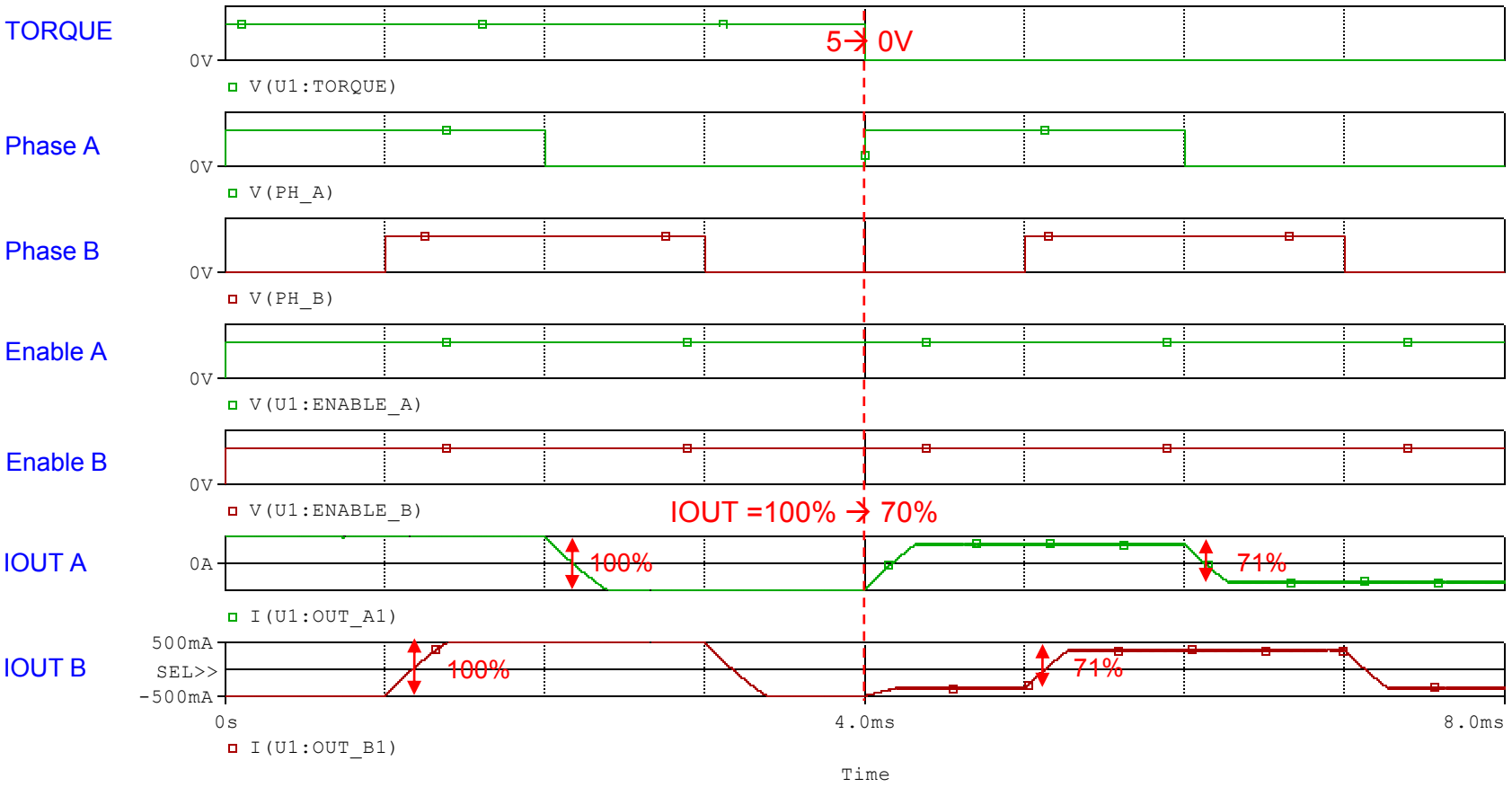
4.2 TORQUE



Analysis
Time Domain (Transient)
Run to time: 8ms
Start saving data after: 0ms
Maximum step size: -

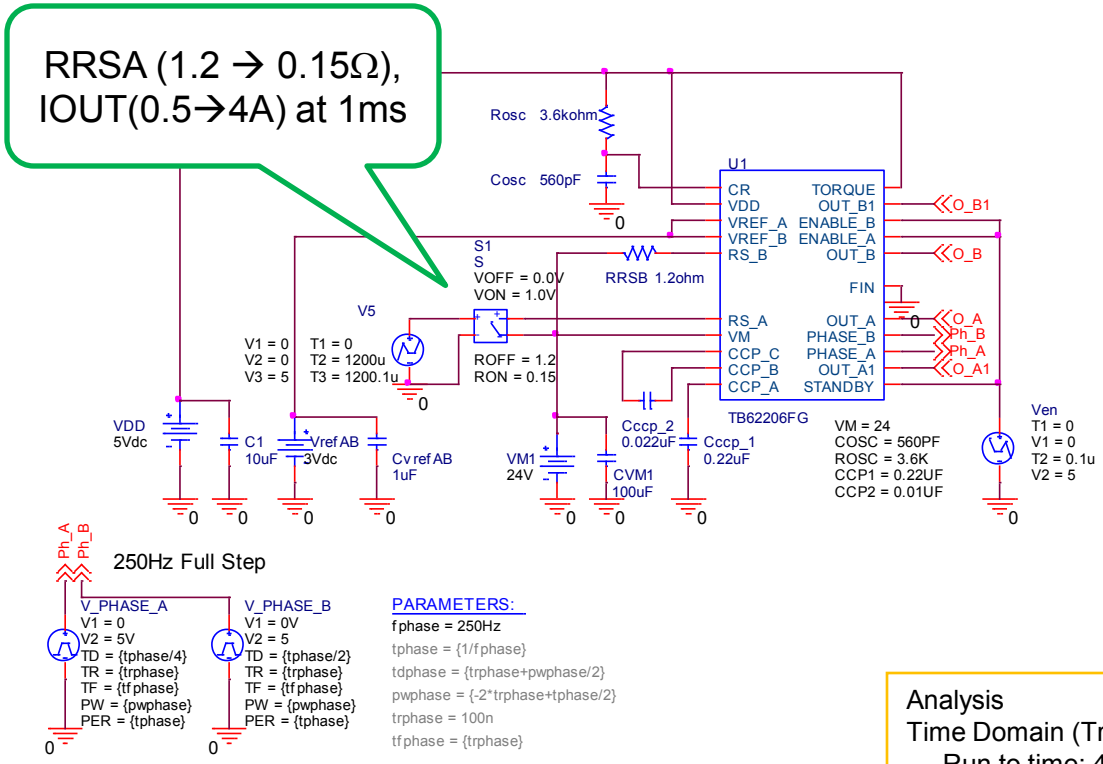
.Options
RELTOL: 0.01
VNTOL: 1.0m
ABSTOL: 1.0n
CHGTOL: 1p
GMIN: 1.0E-12
ITL1: 500
ITL2: 200
ITL4: 100

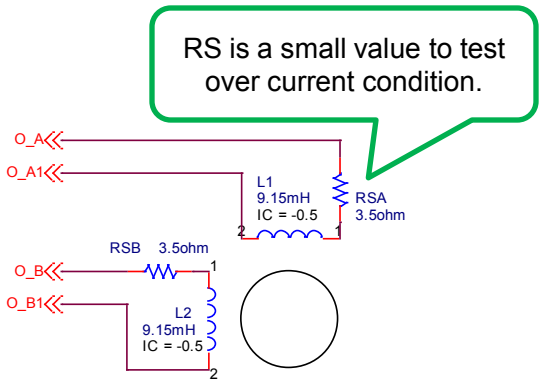
4.2 TORQUE



- This figure shows the simulation result of the circuit when V(TORQUE) changes from H→L ,then the output current changes from 100% to 71%.

4.3 Phase A Over-current Protection

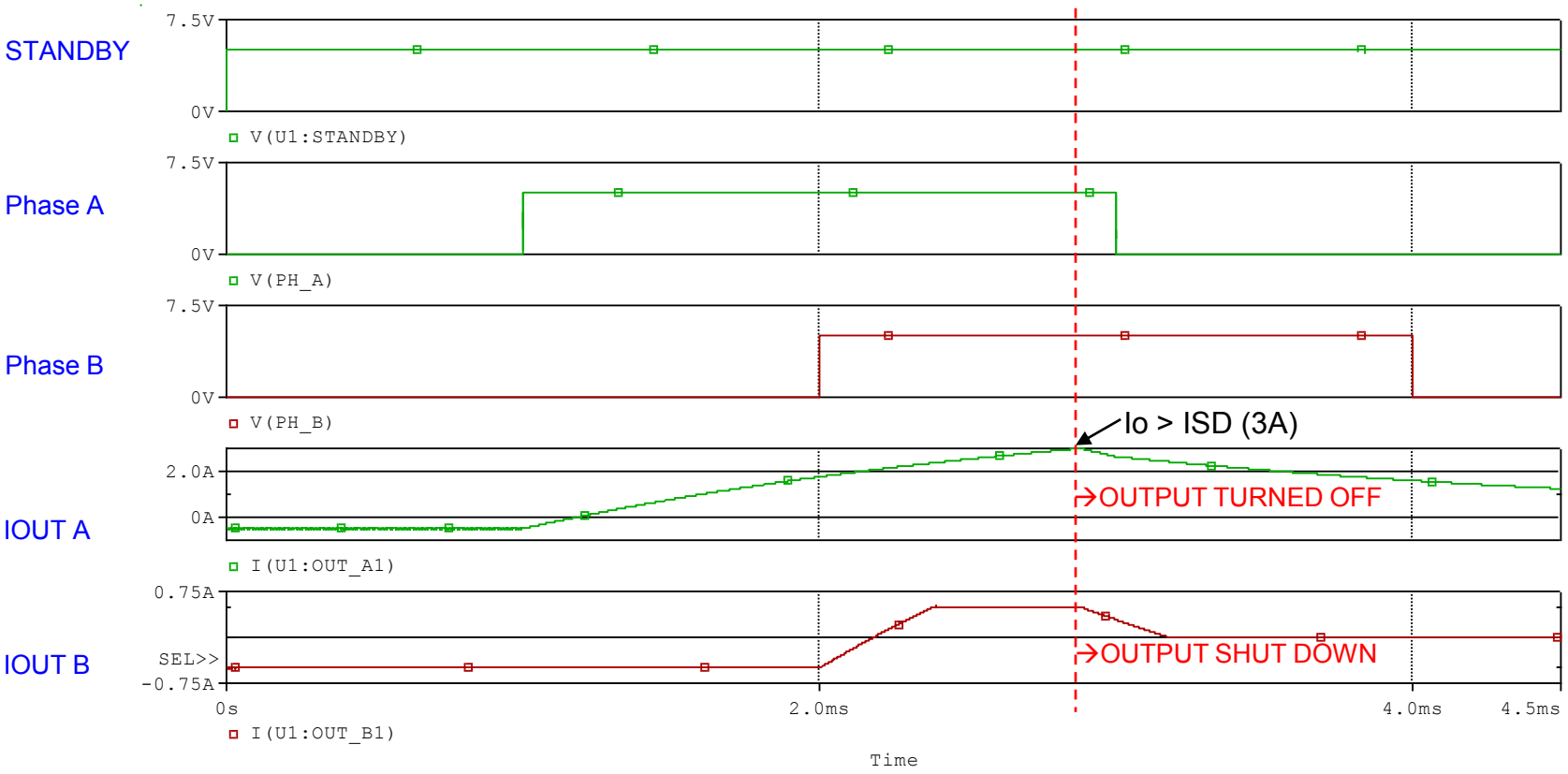




Analysis
Time Domain (Transient)
Run to time: 4.5ms
Start saving data after: 0ms
Maximum step size: -

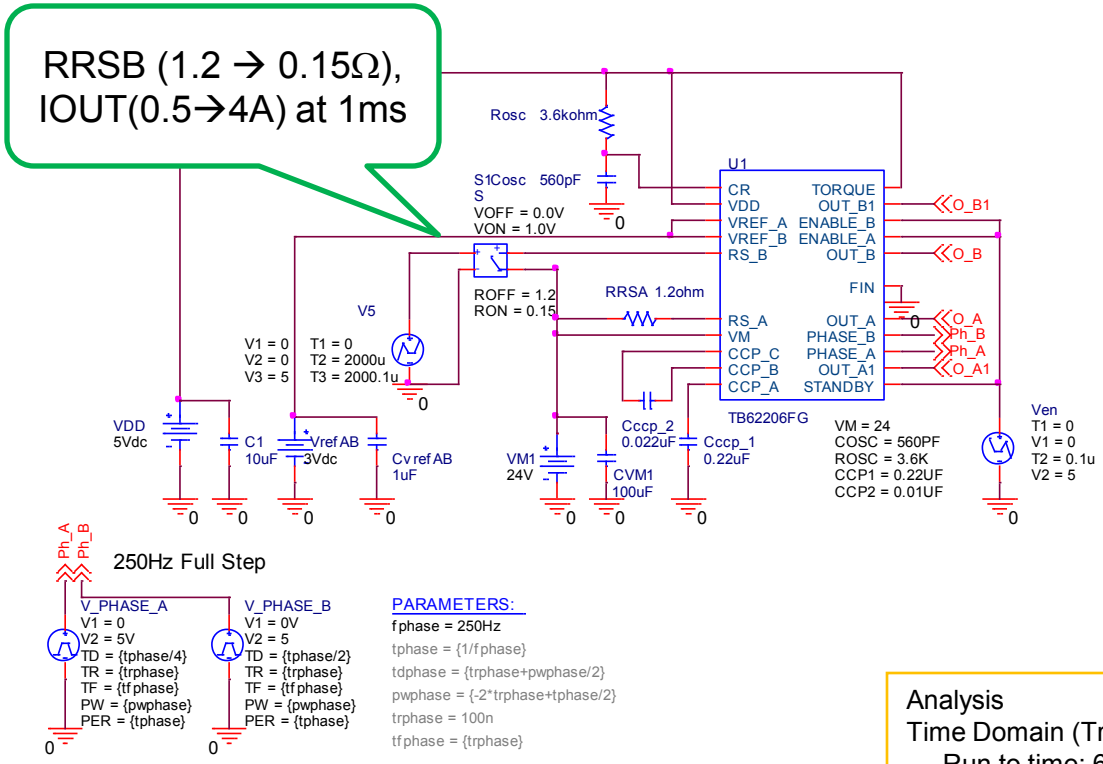
.Options
RELTOL: 0.01
VNTOL: 1.0m
ABSTOL: 1.0n
CHGTOL: 1p
GMIN: 1.0E-12
ITL1: 500
ITL2: 200
ITL4: 100

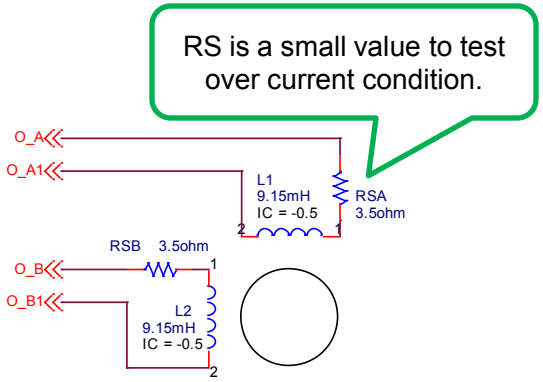
4.3 Phase A Over-current Protection



- This figure shows the simulation result of the circuit when Phase A output current exceeds the ISD(3A), then OCP shutdowns the output.

4.4 Phase B Over-current Protection

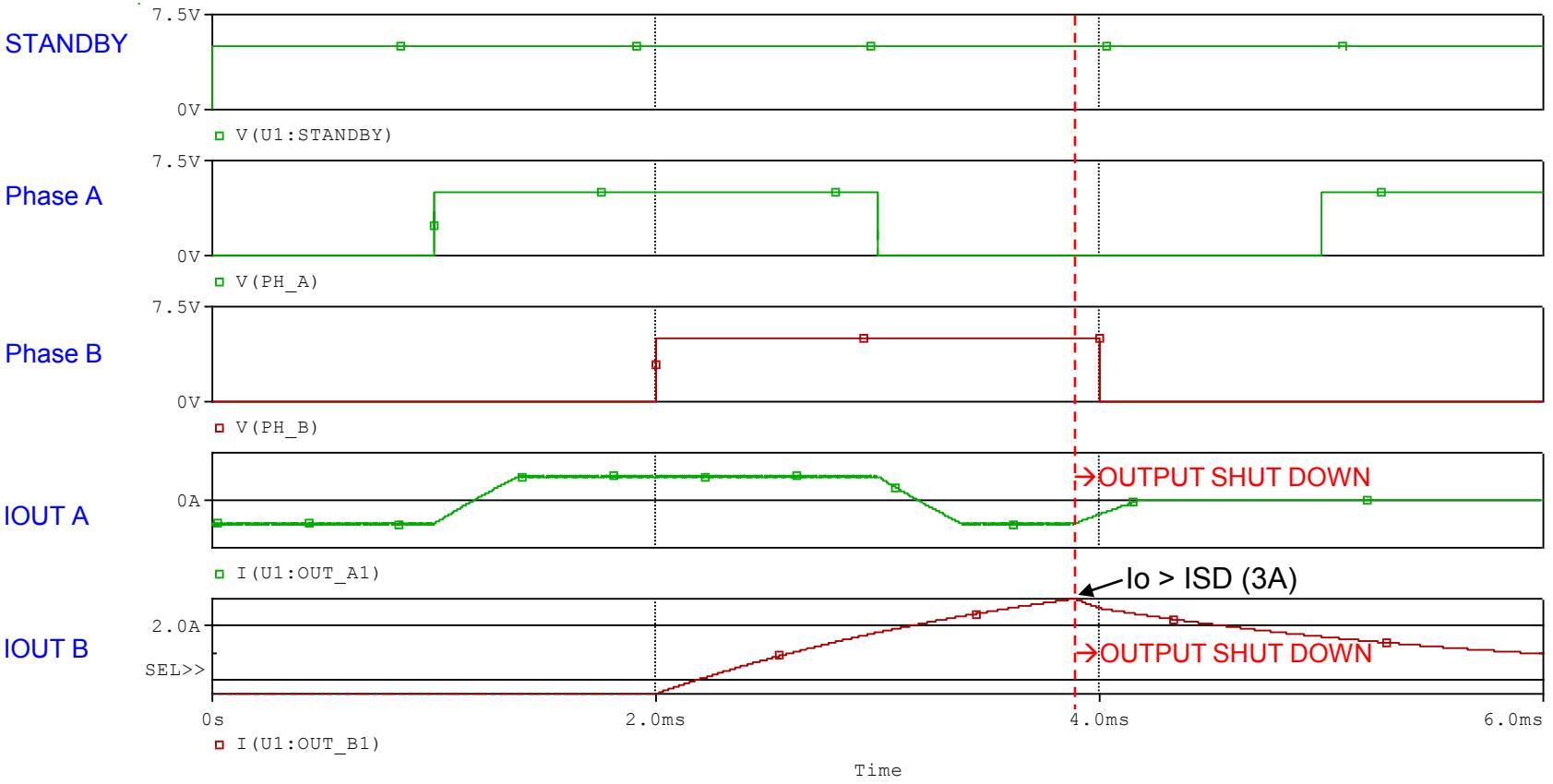




Analysis
Time Domain (Transient)
Run to time: 6ms
Start saving data after: 0ms
Maximum step size: -

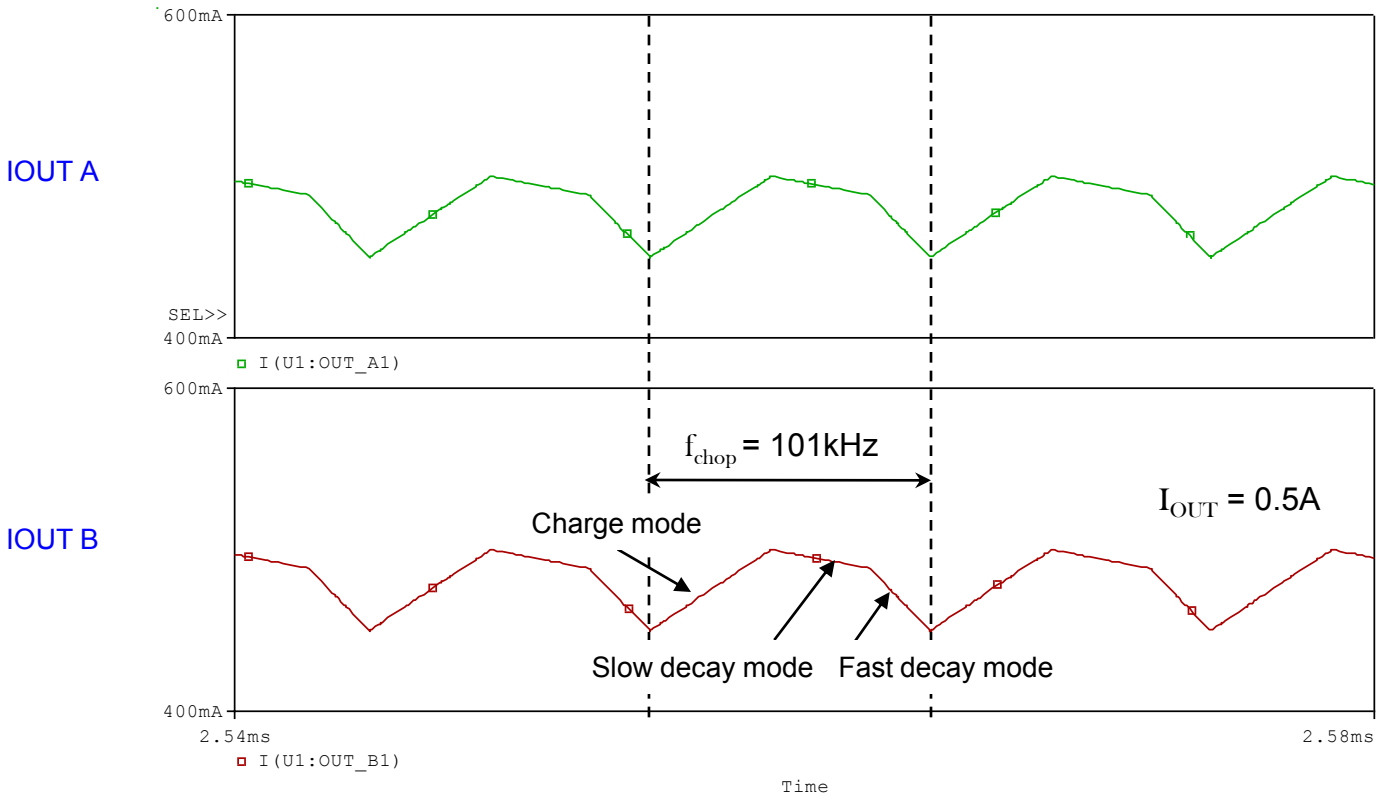
.Options
RELTOL: 0.01
VNTOL: 1.0m
ABSTOL: 1.0n
CHGTOL: 1p
GMIN: 1.0E-12
ITL1: 500
ITL2: 200
ITL4: 100

4.4 Phase B Over-current Protection



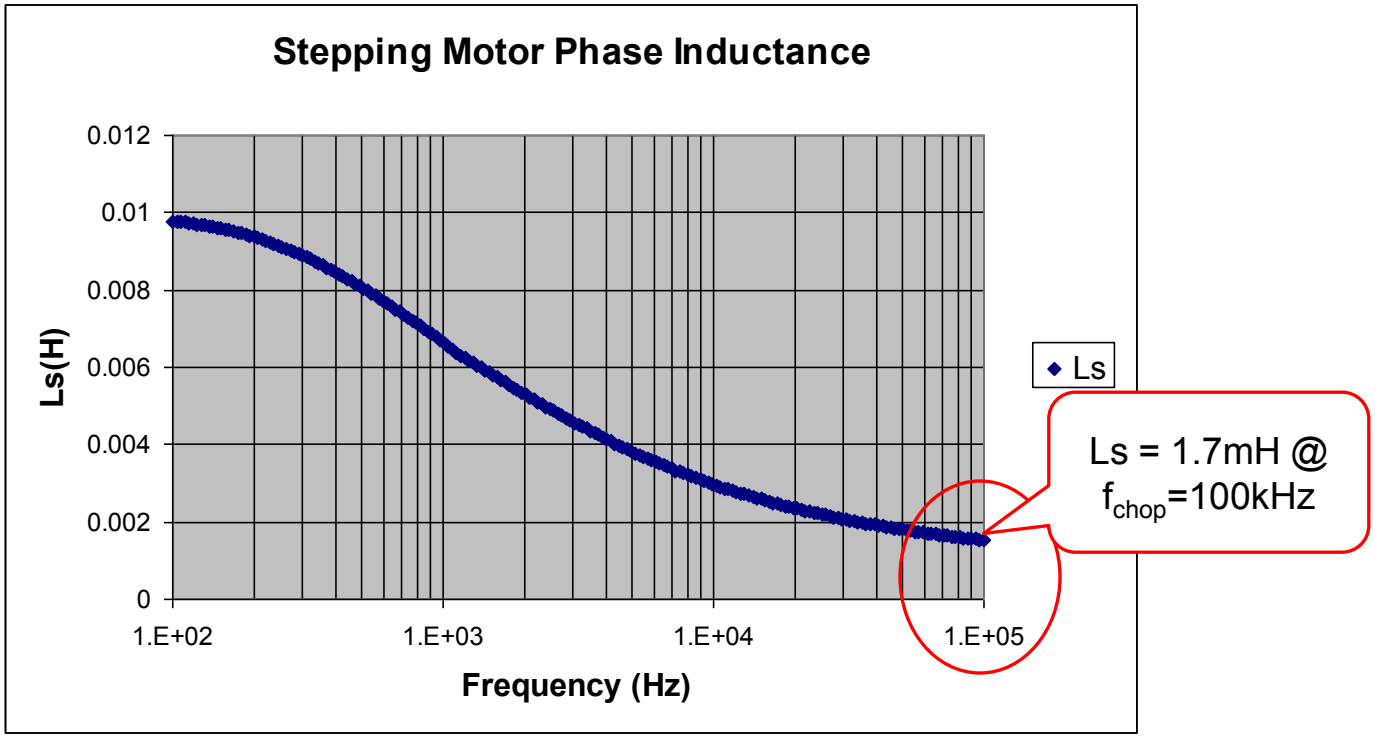
- This figure shows the simulation result of the circuit when Phase B output current exceeds the ISD(3A), then OCP shutdowns the output.

5 Output Ripple Current



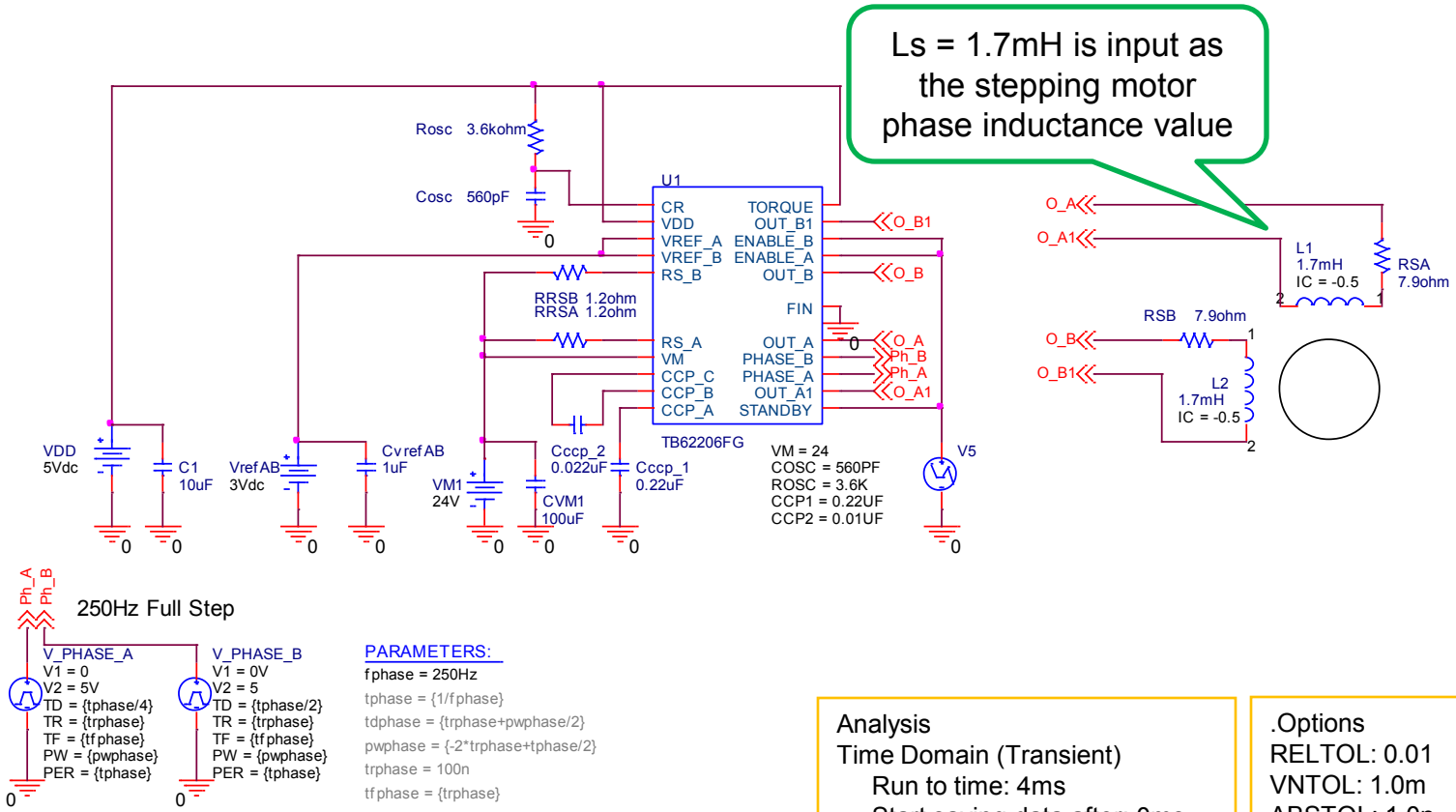
- This figure shows the output ripple current of the Mixed Decay Mode ,which consist of Charge ,Slow decay ,and Fast decay mode ,with 101kHz chopping frequency.

5.1 Stepping Motor Phase Inductance at The Chopping Frequency



- Ls(H) vs. Frequency(Hz) is shown in figure above. Ls value at the chopping frequency (approximately 100kHz) will be used as stepping motor phase inductance.

5.2 Ripple Current Simulation

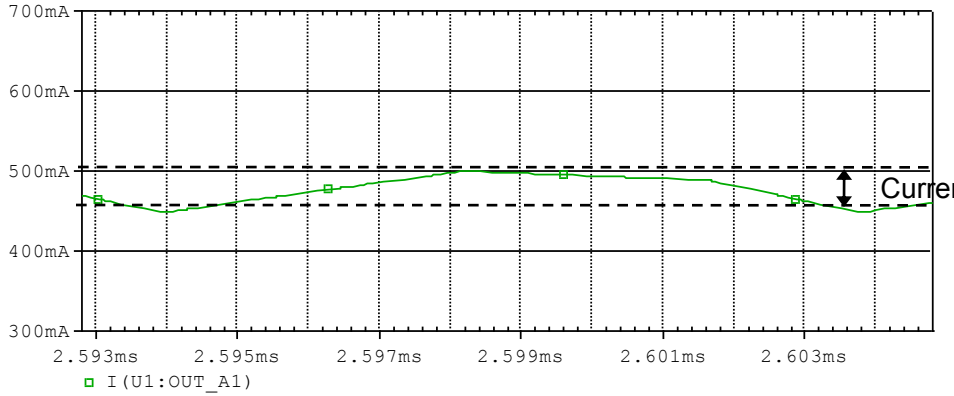


Analysis
Time Domain (Transient)
Run to time: 4ms
Start saving data after: 0ms
Maximum step size: -

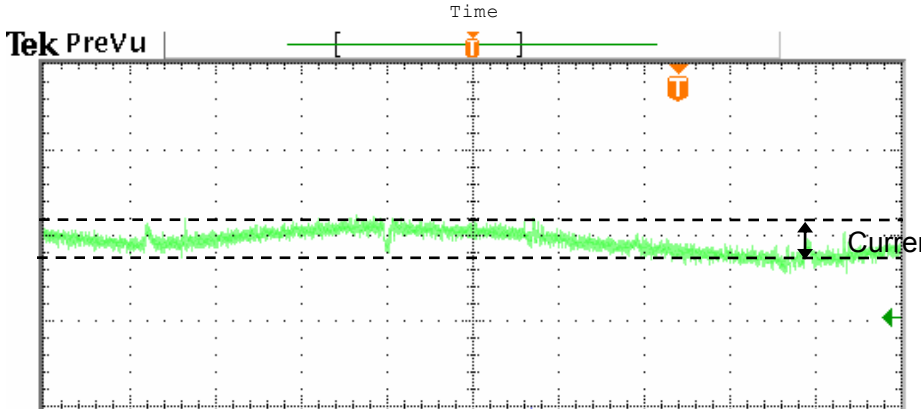
.Options
RELTOL: 0.01
VNTOL: 1.0m
ABSTOL: 1.0n
CHGTOL: 1p
GMIN: 1.0E-12
ITL1: 500
ITL2: 200
ITL4: 100

5.2 Ripple Current Simulation

Simulation

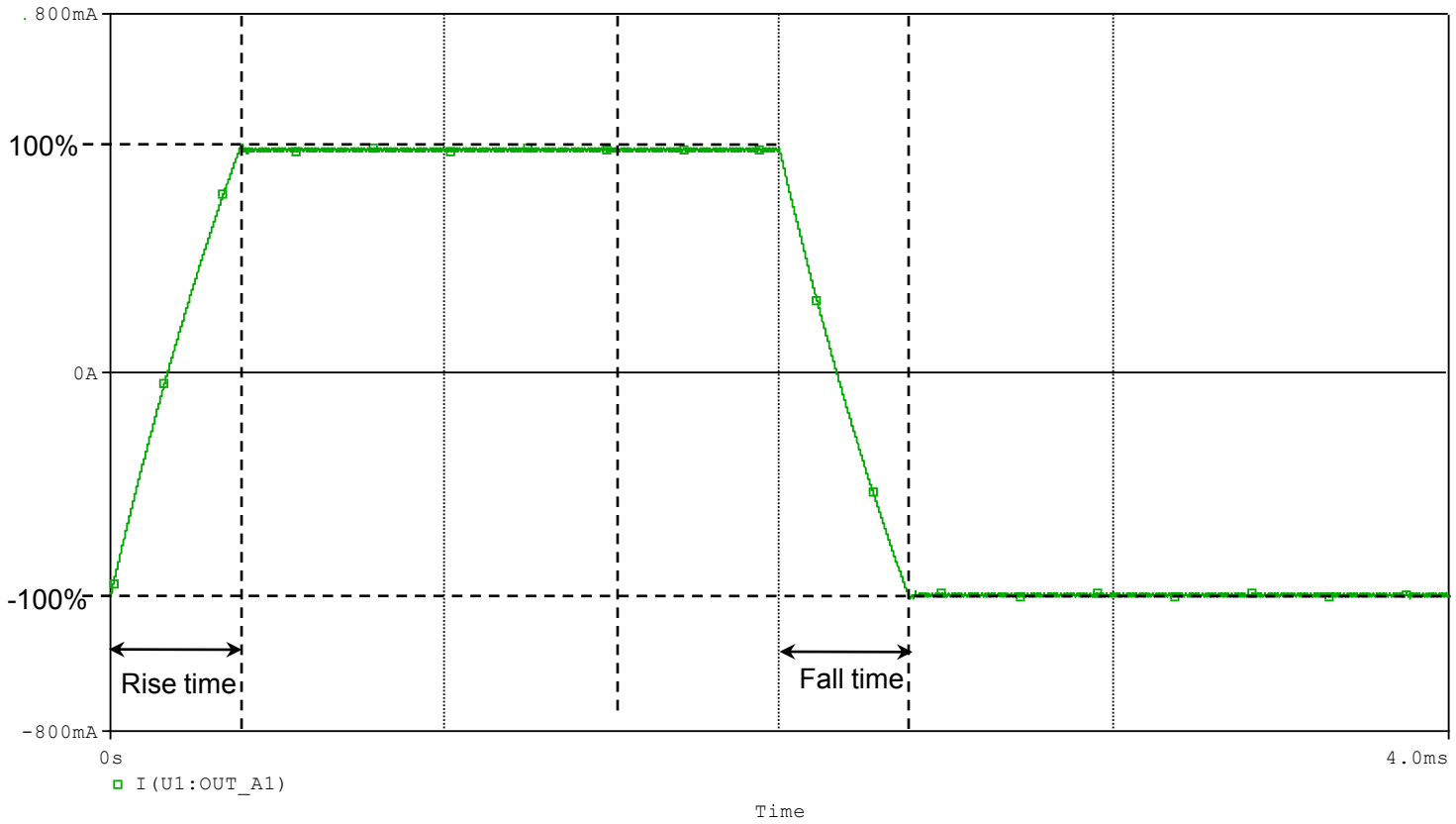


Measurement



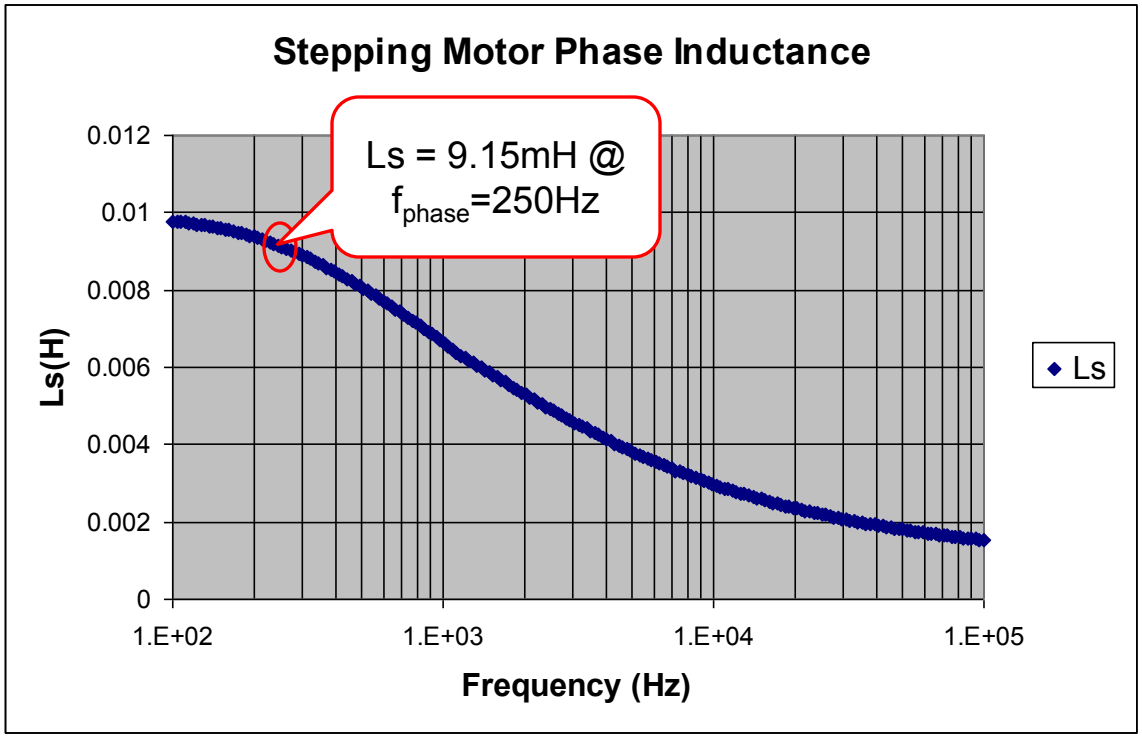
- The simulation result shows the current ripple that agrees to the measurement data.

6. The Current Changing Rate



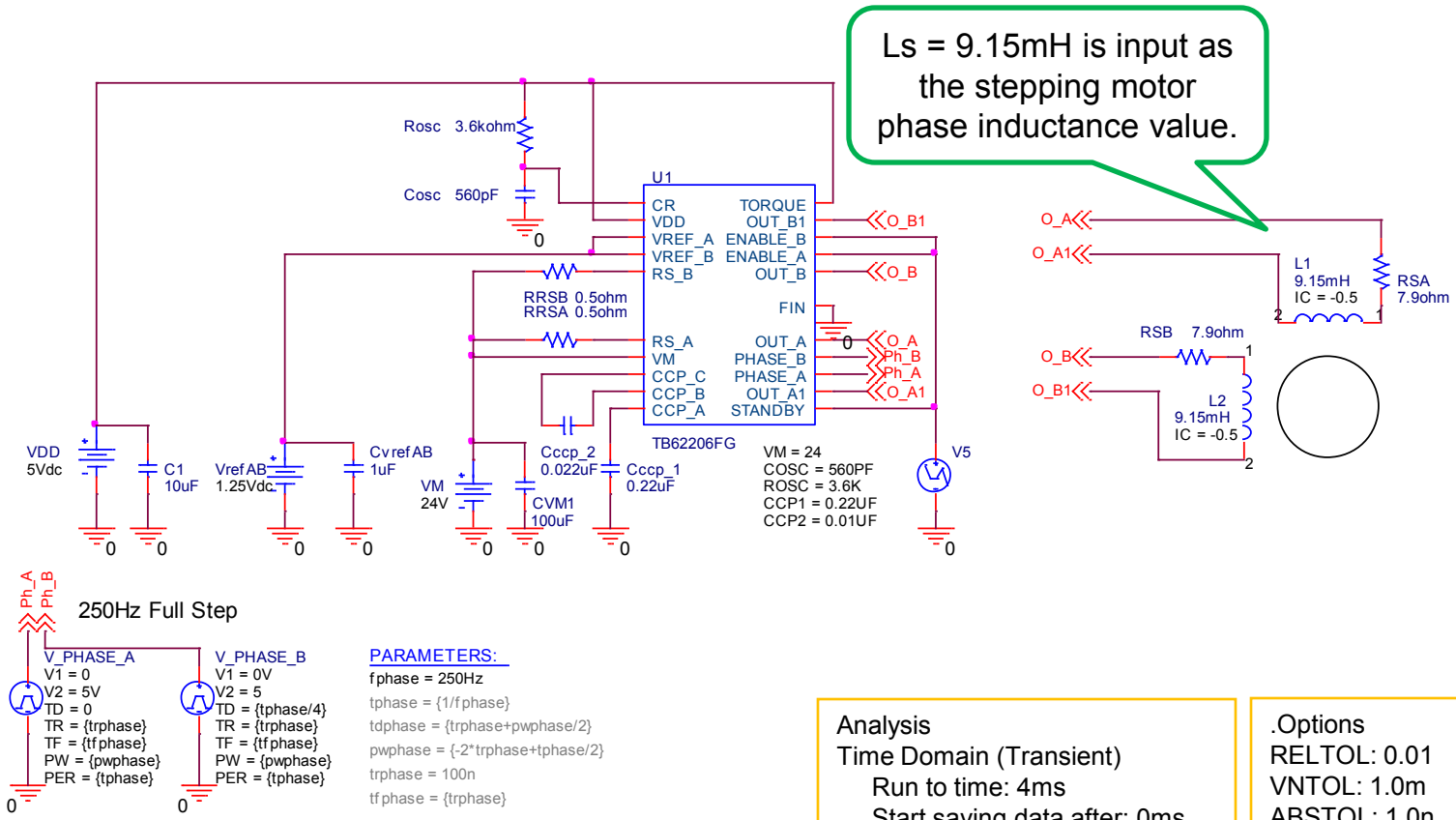
- This figure shows the current changing rate (rise and fall time) that is determined by the phase inductance value.

6.1 Stepping Motor Phase Inductance at The Phase Frequency



- Ls(H) vs. Frequency(Hz) is shown in figure above. Ls value at the phase frequency (250 Hz) will be used as stepping motor phase inductance.

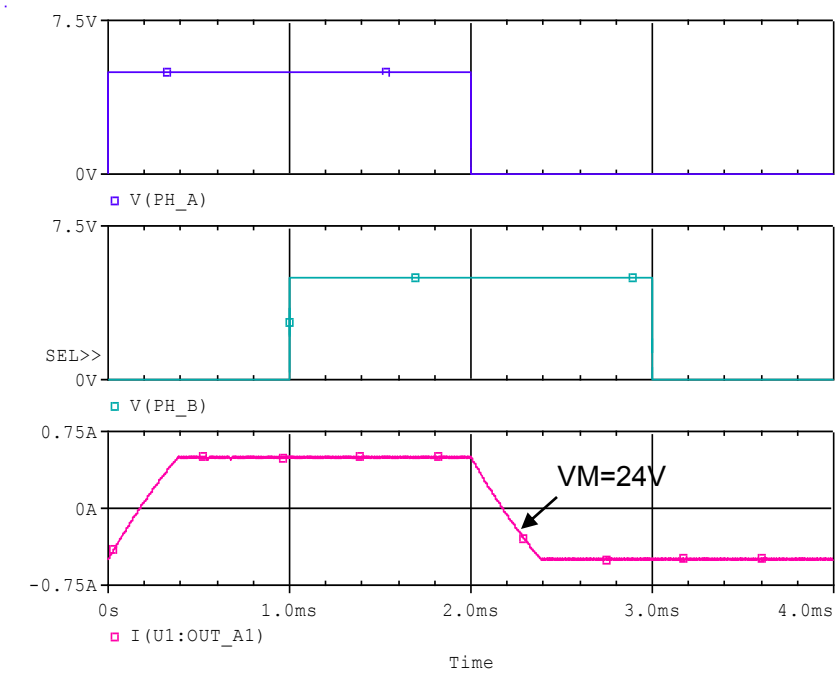
6.2 Current Changing Rate Simulation

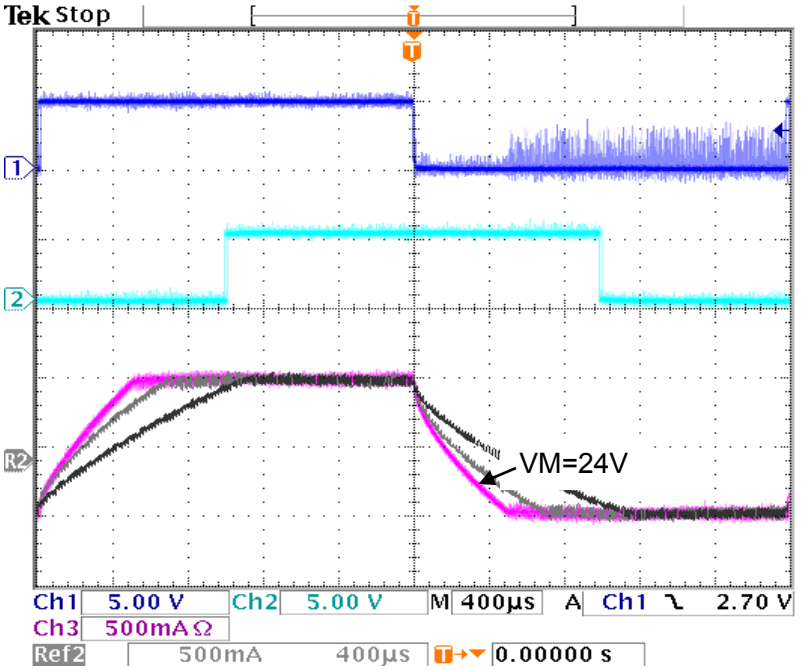


Analysis
Time Domain (Transient)
Run to time: 4ms
Start saving data after: 0ms
Maximum step size: -

.Options
RELTOL: 0.01
VNTOL: 1.0m
ABSTOL: 1.0n
CHGTOL: 1p
GMIN: 1.0E-12
ITL1: 500
ITL2: 200
ITL4: 100

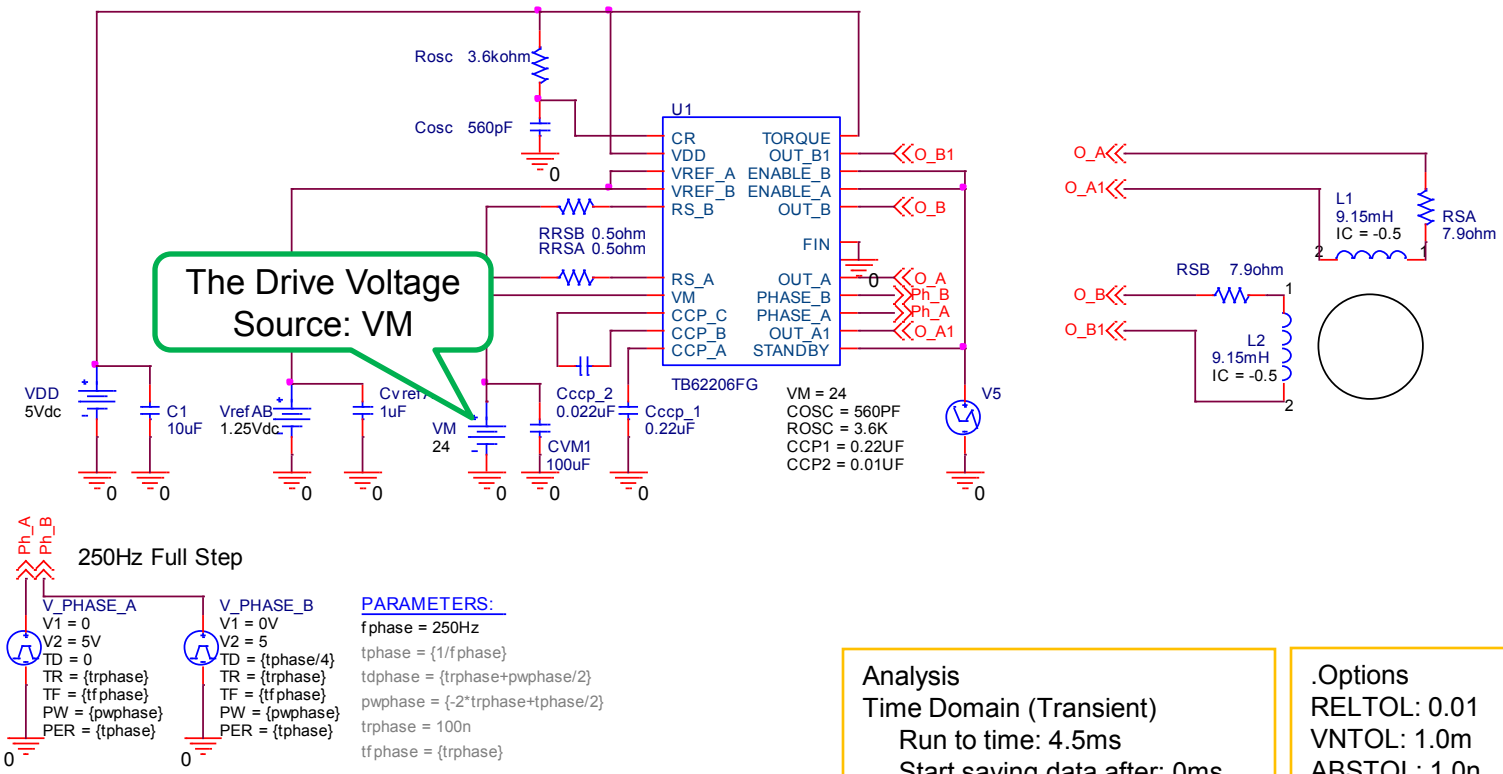
6.2 Current Changing Rate Simulation





- The simulation result shows the current changing rate (rise and fall time) that agrees to the measurement data.

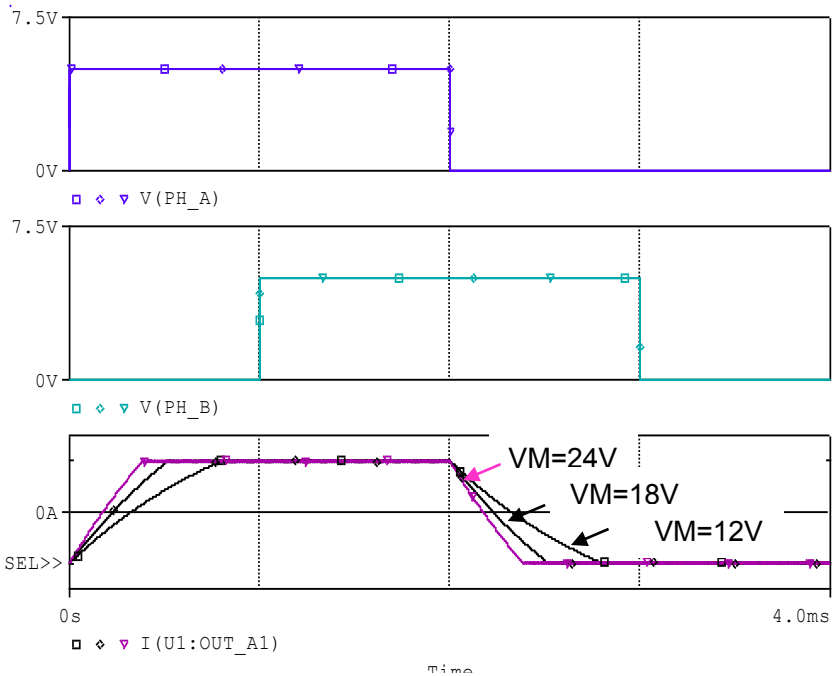
7. Optimization of The Drive Voltage VM

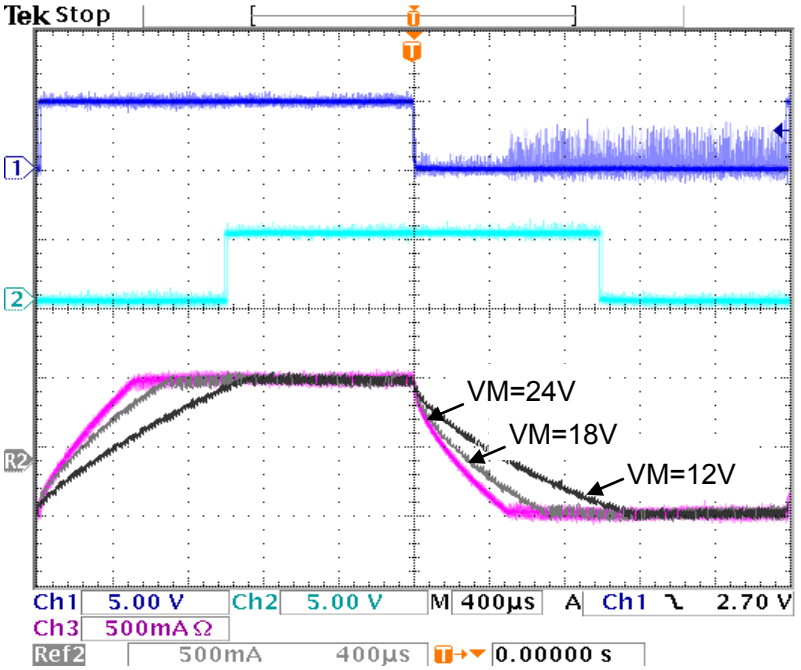


Analysis
Time Domain (Transient)
Run to time: 4.5ms
Start saving data after: 0ms
Maximum step size: 1u
☑ (SKIPBP)
Parametric Sweep
◉ Voltage source
Name: VM
◉ Value list: 12, 18, 24

.Options
RELTOL: 0.01
VNTOL: 1.0m
ABSTOL: 1.0n
CHGTOL: 10p
GMIN: 1.0E-12
ITL1: 500
ITL2: 200
ITL4: 100

7. Optimization of The Drive Voltage VM





- These figures show that the current changing rates (rise and fall time) depend on the drive voltage (VM). The higher current changing rate means higher phase frequency is available.

Simulations index

Simulations	Folder name
1. Full Step Switching Sequence.....	Full-Step
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4. TORQUE.....	TORQUE
5. Phase A Over-current Protection.....	OCP_A
6. Phase B Over-current Protection.....	OCP_B
7. Ripple Current Simulation.....	RIPPLE
8. Current Changing Rate Simulation.....	I_Step
9. Optimization of The Drive Voltage VM.....	VM