

Design Kit

DC Motor Speed Control Circuit

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1. The Simulation of DC Motor Control Circuit

Key simulation models

DC Motor Model

⇒ The model features on transient characteristics of the motor.

LM555 Timer IC Model

⇒ The model features on functions of the IC.

2.1 Manufacturer Specification

MABUCHI MOTOR RS-380PH



- Voltage Range.....12.0 V
- Normal Voltage.....7.2 V
- Normal Load.....9.8 mN·m
- Speed at No Load.....16,400 rpm
- At Normal Load
 - Speed.....14,200 rpm
 - Current.....2.9A

2.2 Torque Constant and Back EMF Constant

- The Torque Constant K_T is obtained as:

$$\text{Torque} = K_T \cdot I_1 \quad (1)$$

RS-380PH at Normal Load:

$$\text{Torque} = 9.8 \text{ mN}\cdot\text{m}$$

$$I_{\text{Normal Load}} = 2.9 \text{ A}$$

$$K_T = 9.8/2.9 = 3.379 \text{ mN}\cdot\text{m/A}$$

- The Back EMF Constant K_E is obtained as:

$$V_{EMF} = K_E \cdot \text{Speed} \quad (2)$$

RS-380PH at No Load:

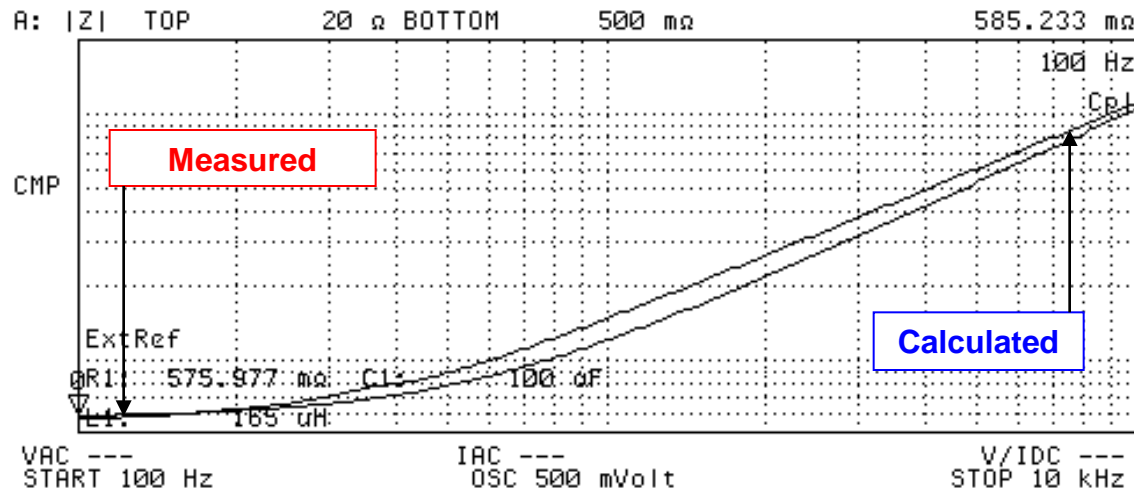
$$\text{Speed} = 16,400 \text{ rpm}$$

$$V_{EMF} = V_{\text{Normal}} - R_M \cdot I_{\text{No Load}} = 7.2 - 0.3456 = 6.8544 \text{ V}$$

$$,R_M = 0.576\Omega \text{ and } I_{\text{No Load}} = 0.6\text{A (measurement data).}$$

$$K_E = 6.8544/16,400 = 0.41795 \text{ mV/rpm}$$

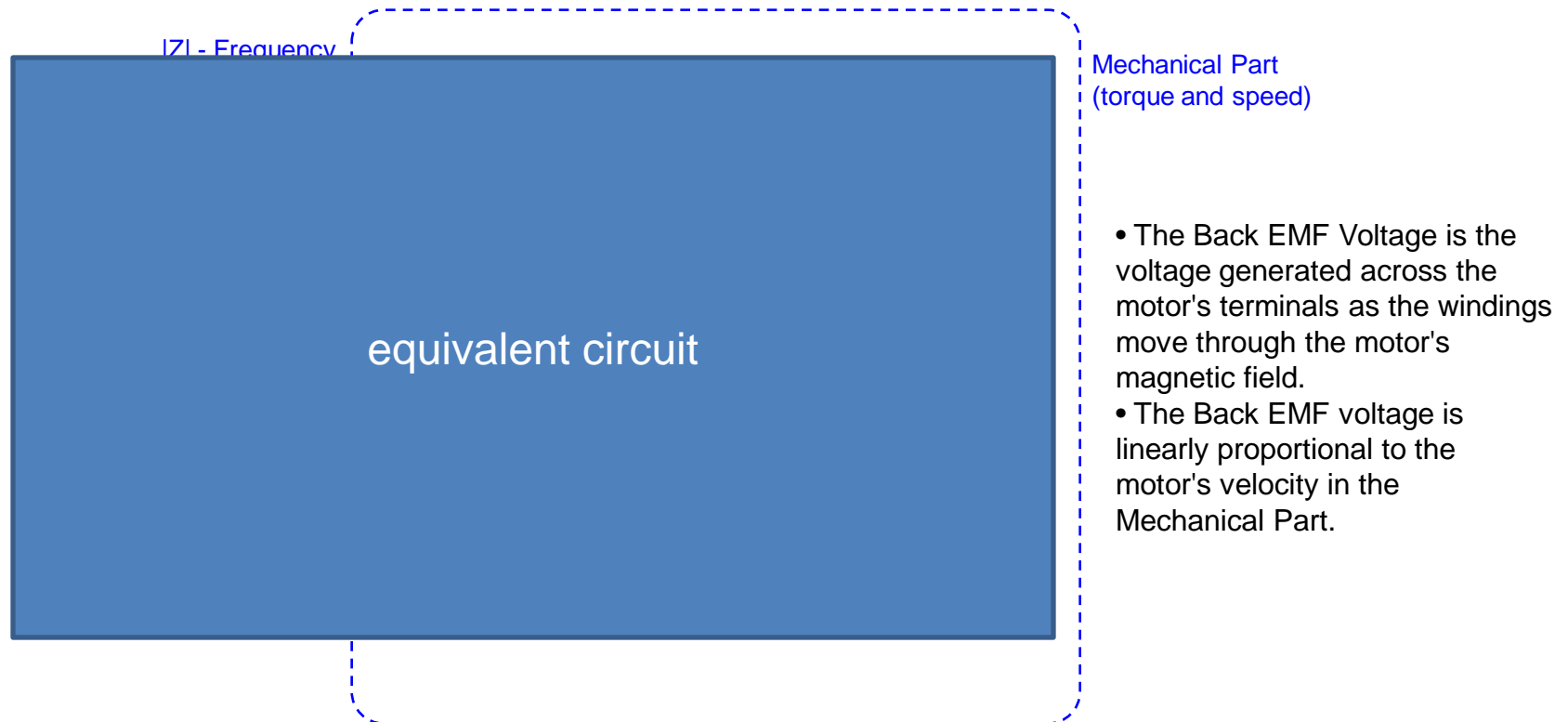
2.3 The Armature Inductance and Resistance



Precision Impedance Analyzer $|Z|$ vs. Frequency measured data.

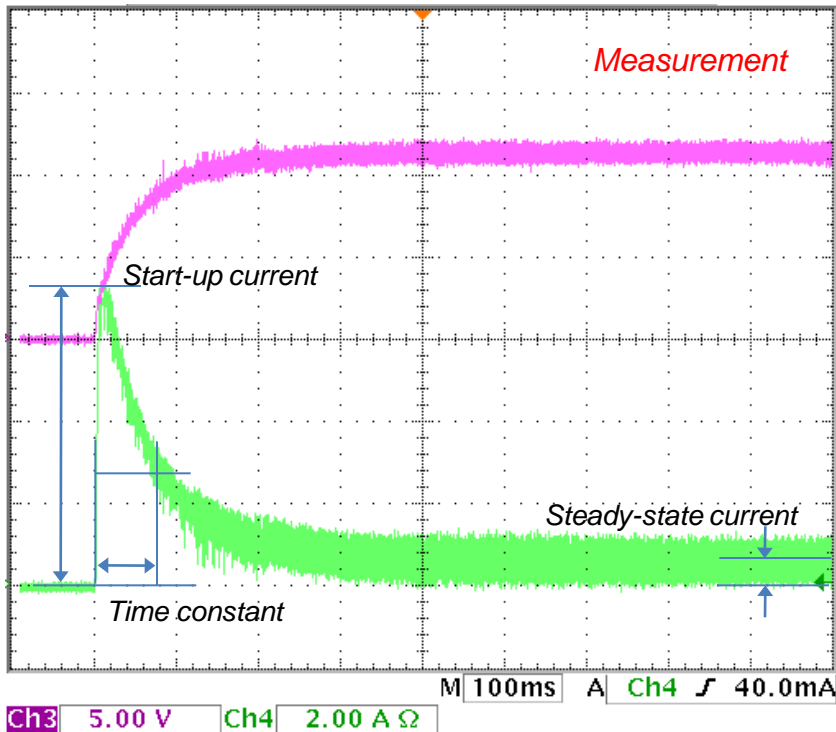
- The Armature Inductance and Resistance are obtained with a Precision Impedance Analyzer (Agilent 4294A)
- $L_S = 165 \mu\text{H}$ and $R_S = 575.977 \text{ m}\Omega$

2.4 The DC Motor Equivalent Circuit



- This figure shows the equivalent circuit of DC motor model that includes the $|Z|$ -frequency part ,Back EMF Voltage part ,and Mechanical part.

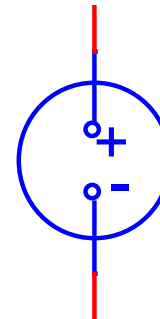
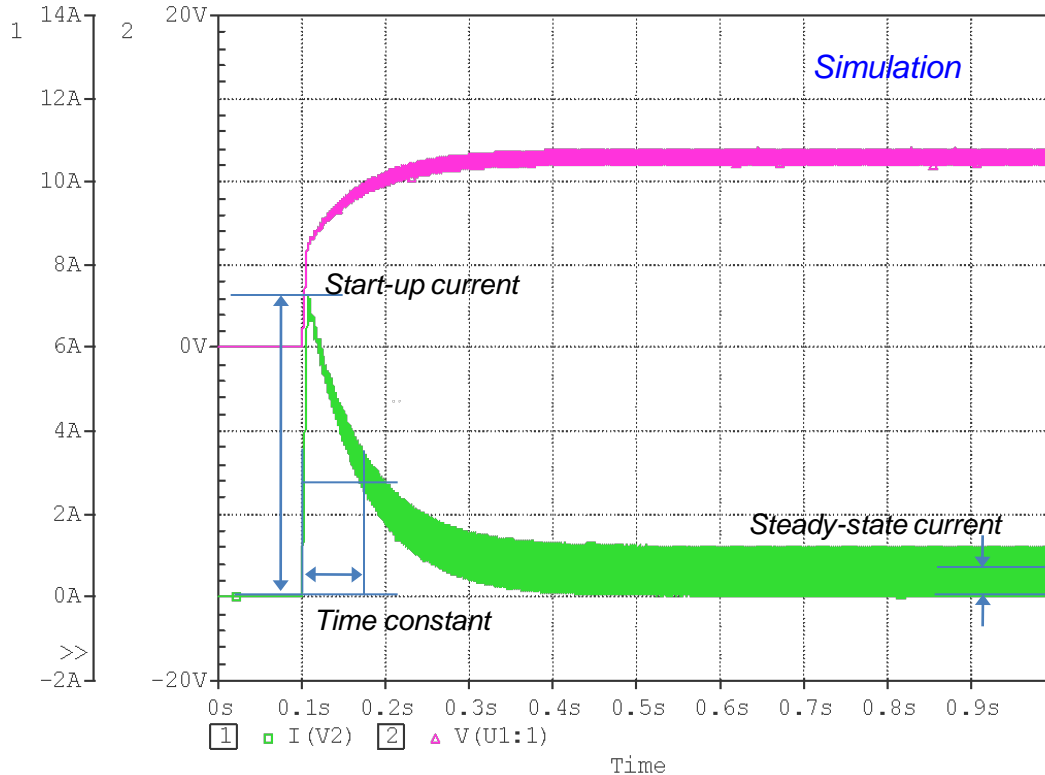
2.5 Transient Response at No Load



This figure is the motor current and voltage at start-up transient (*oscilloscope screen captured*).

- The test setup include 12Vdc source ,series resistor and the motor.
- The result is used to obtain the start-up current and the steady state current.
- The time constant of the current response will be used to determine the parameters that model the motor shaft's inertia.

2.6 Transient Response at No Load (Model)



U1

RS-380PH

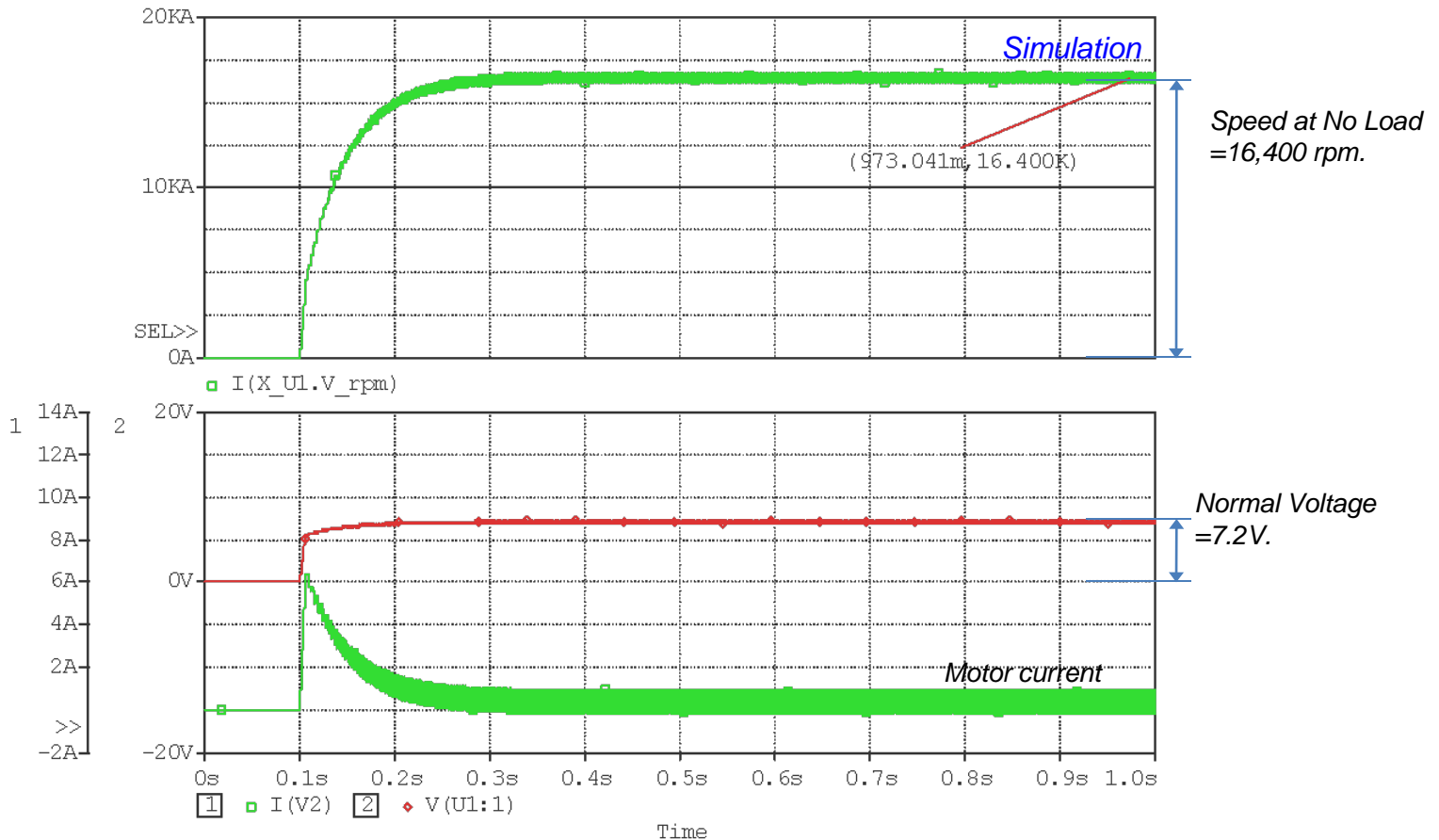
KT = 3.379m

KE = 0.41795m

Torque constant and
back EMF constant.

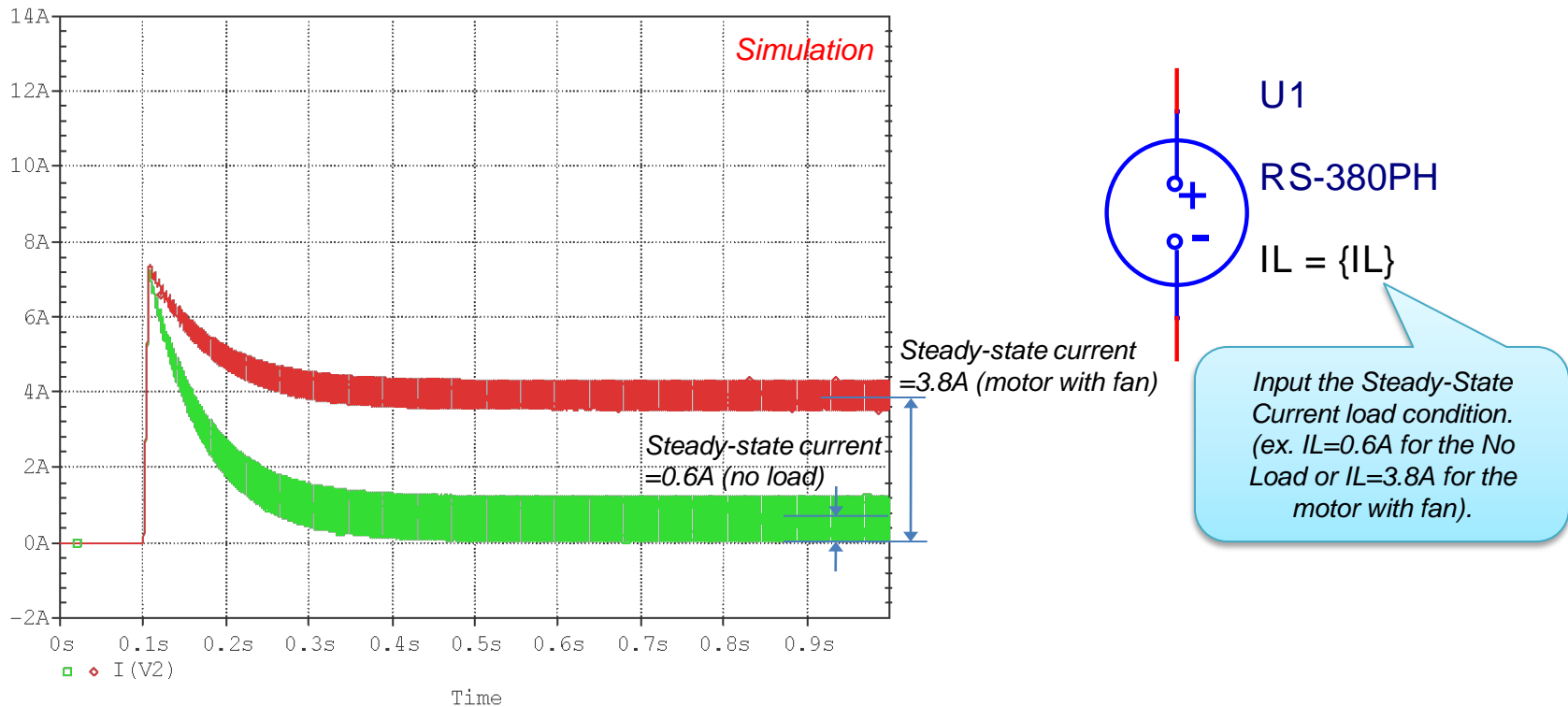
- This figure shows the result of the start-up transient simulation with RS-380PH motor model at condition 12V ,no load.

2.7 Speed at No Load (Model)



- This figure shows the simulated speed at no load (16,400rpm). To monitor the speed ,trace “ I(X_U1.V_rpm) ” inside the model .SUBCKT.
- ✘ Note: for OrCAD 16.0 set "All" for the Currents of the Data Collection Options of the Simulation Settings.

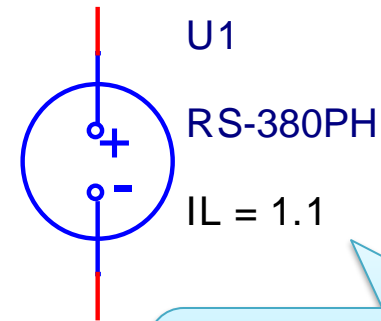
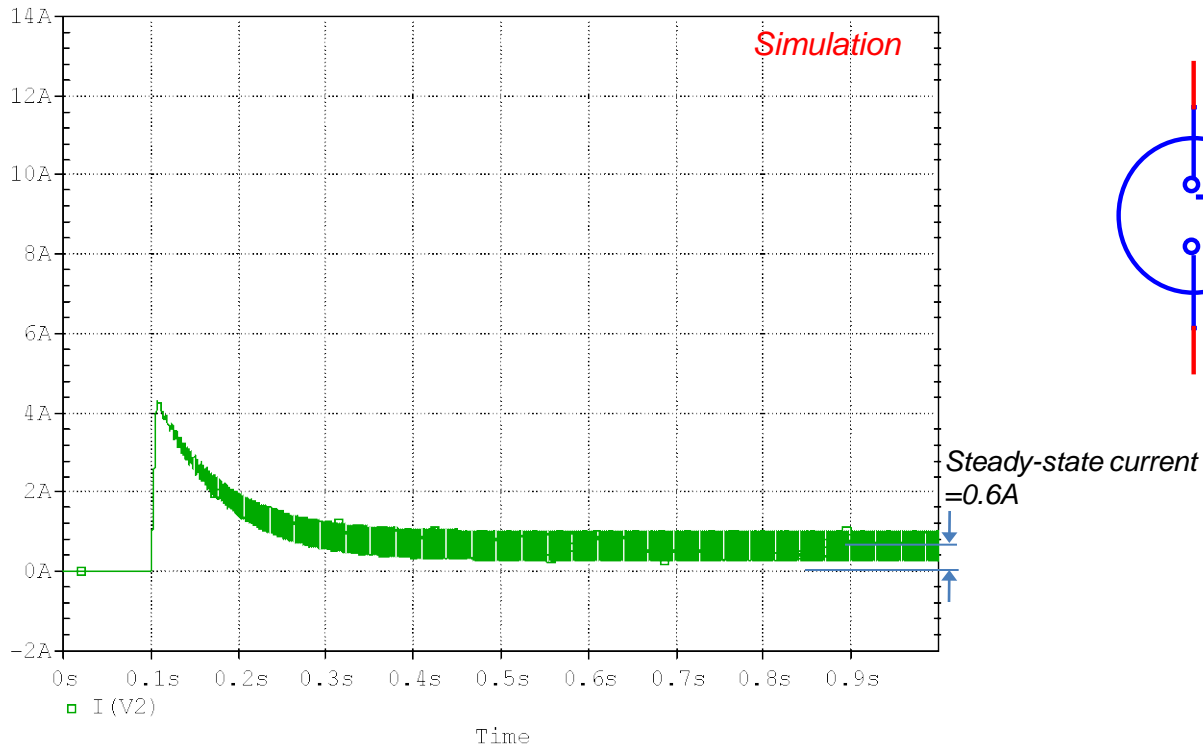
2.8 The Motor Steady-State Current Condition Setting (1/2)



- This figure shows the current waveforms of the motor with the different rated torque load ,that result as the different steady-state current.
- Since the simulations are focused on the electrical world ,the RS-380PH spice model is directly conditioned by input the steady-state current.

2.8 The Motor Steady-State Current Condition Setting (2/2)

- ※ *Steady-state current simulated result will match the model input value “IL” only when the condition Vcc is 12Vdc . In the other case , “IL” value is changed until the desired steady-state current condition is met.*

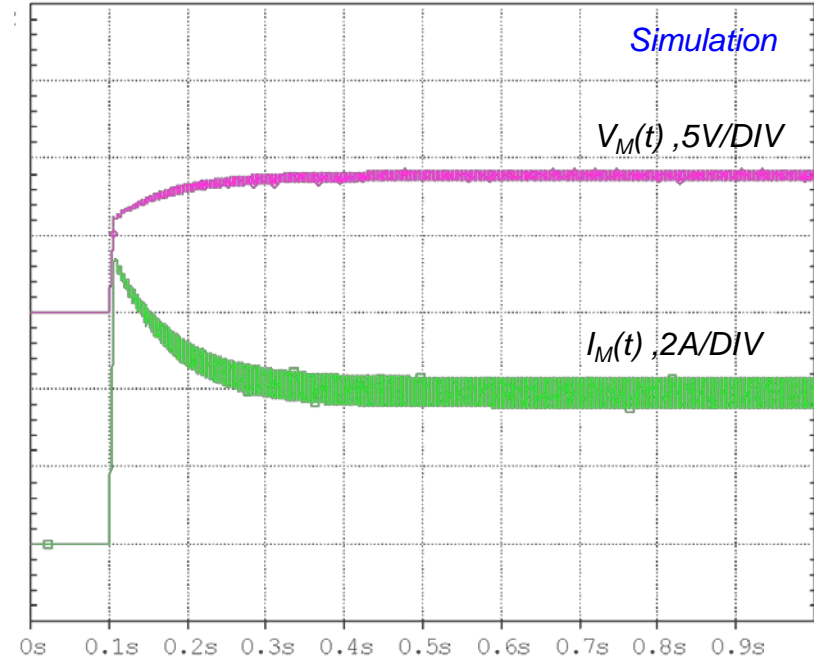
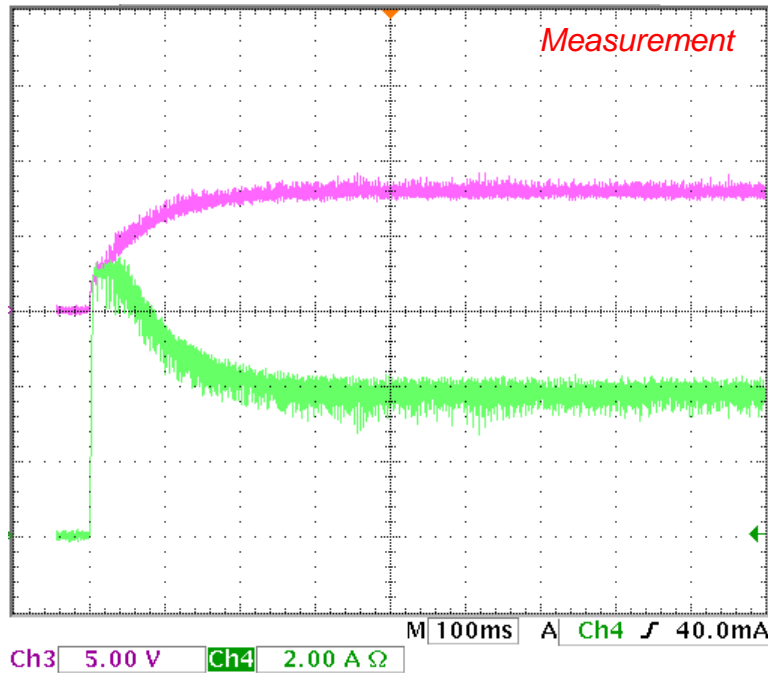


Input the value of “IL”=1.1A for the steady-state current condition 0.6A (the value is not matched).

- This figure shows the unmatched value of the steady-state current condition when Vcc condition is 7.2Vdc (not a 12Vdc).

2.9 Transient Response at Load 3.8A (Measurement vs. Simulation)

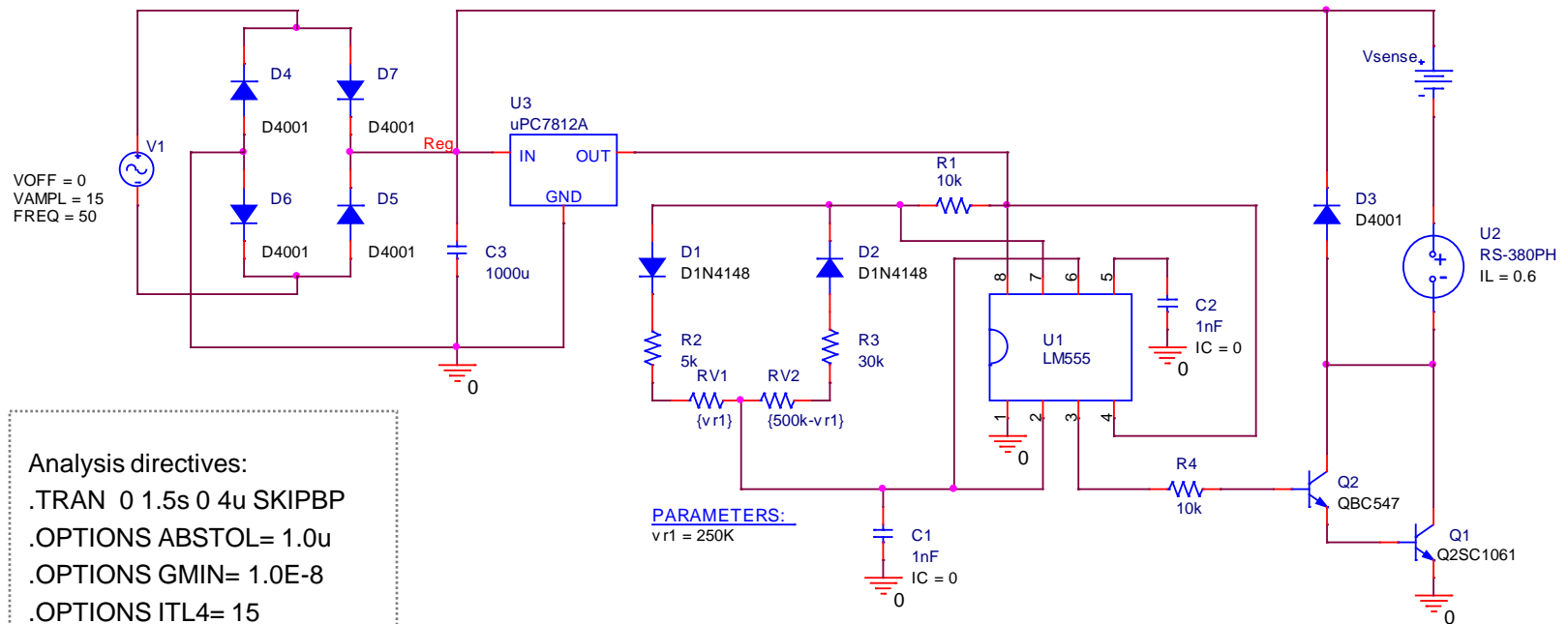
The test setup include 12Vdc source ,0.8 Ω series resistor and the RS-380PH motor with fan.



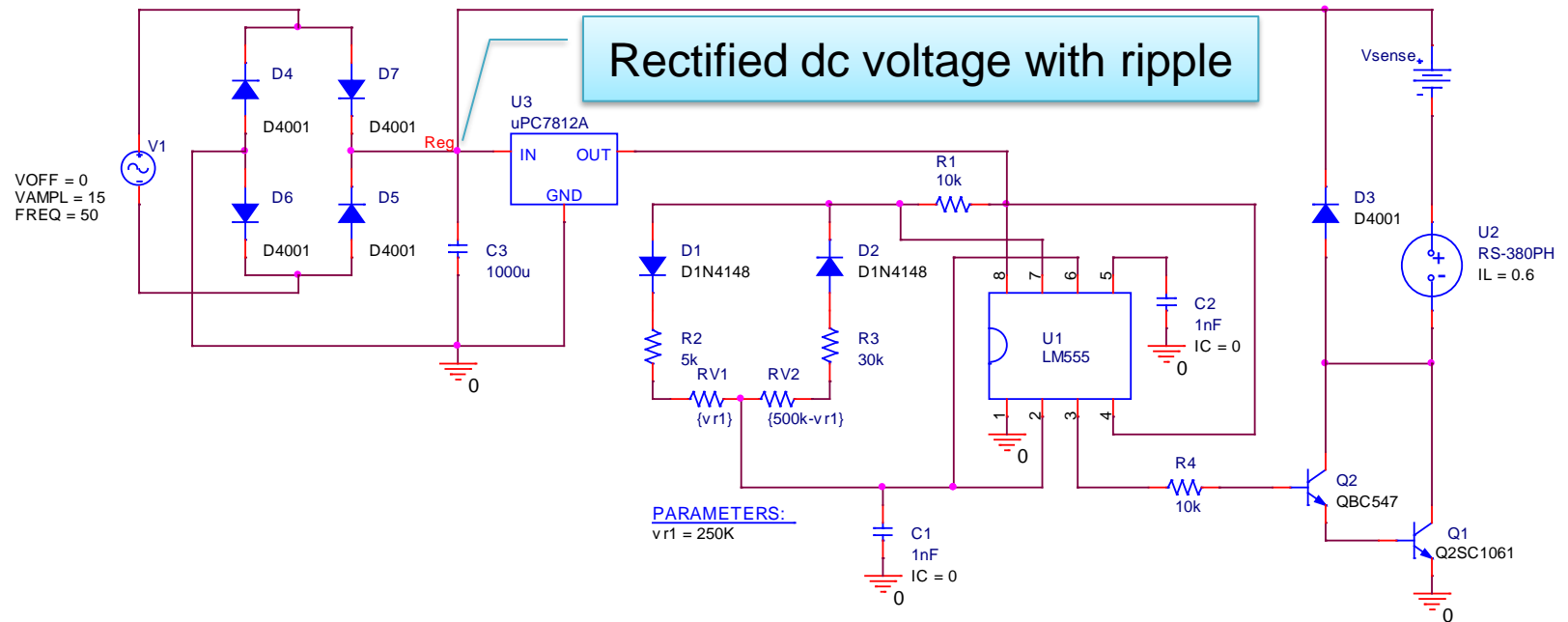
- This figure shows the result of the start-up transient simulation with RS-380PH motor model at condition 12V ,3.8A load.
- The result is compared to the voltage and current waveforms obtained by the oscilloscope.

3. LM555 DC Motor Speed Control Circuit (No Load)

- The circuit is simulated and compared with the measured waveforms from oscilloscope (Tektronix: TDS3054B) to verify the simulation using the RS-380PH model.

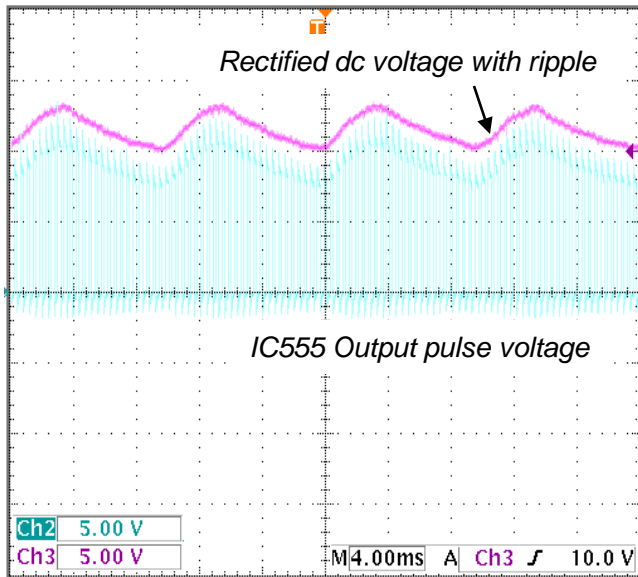


3.1 Rectified dc voltage with ripple

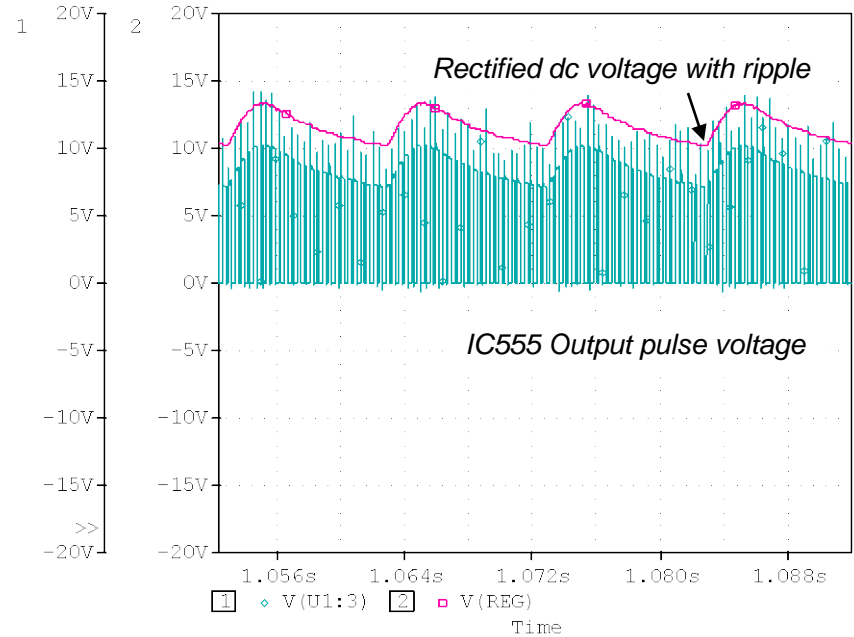


3.1 Rectified dc voltage with ripple

Measurement

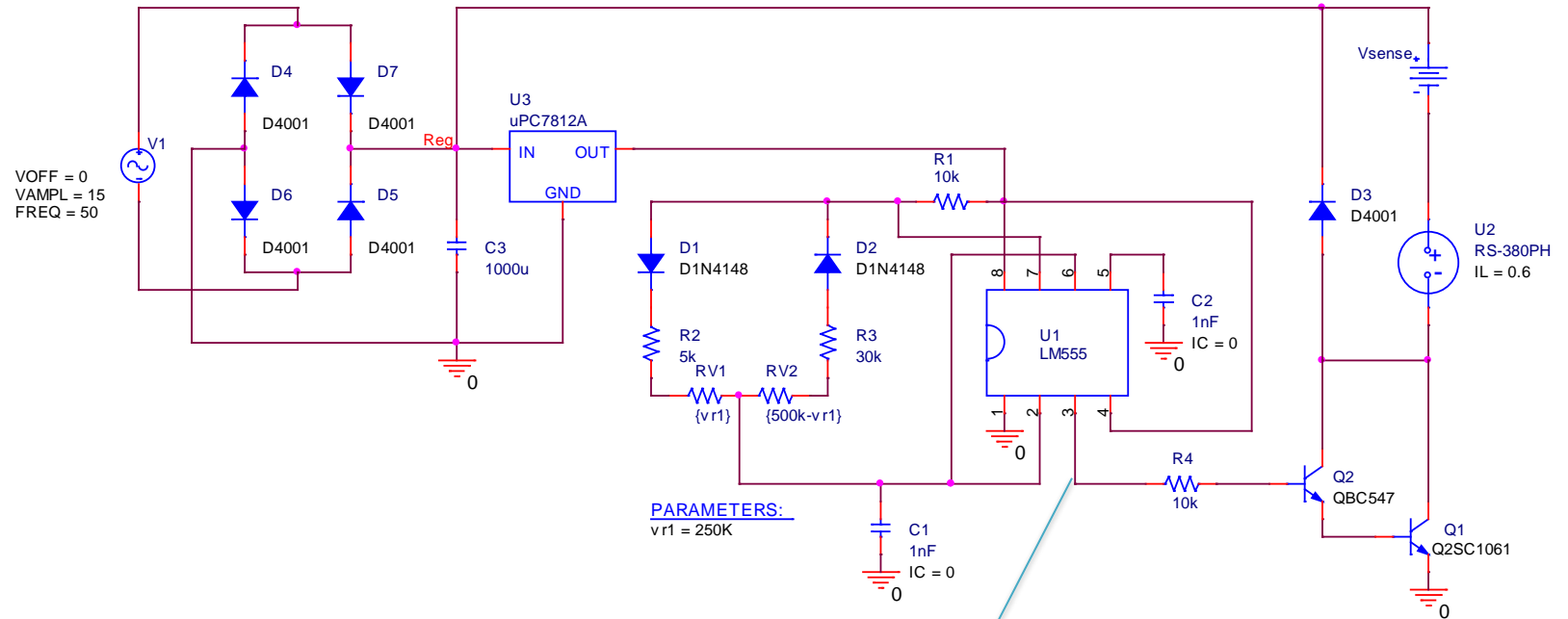


Simulation



Rectified dc voltage with ripple

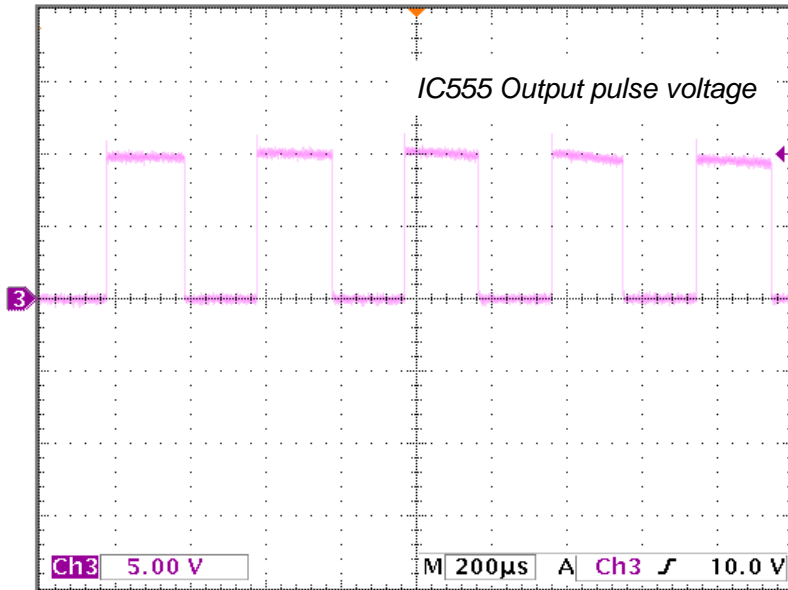
3.2 IC 555 Output Pulse Voltage



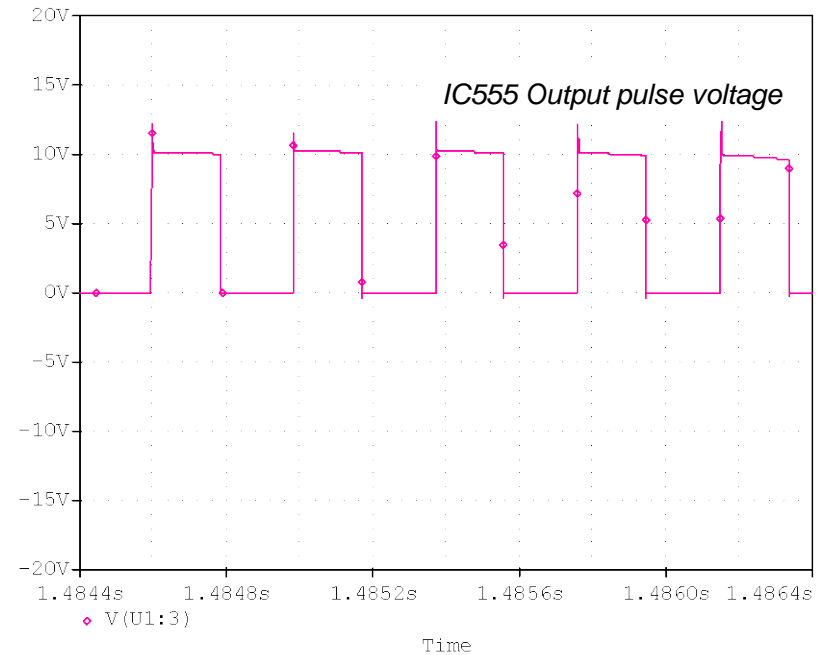
IC 555 Output Pulse Voltage

3.2 IC 555 Output Pulse Voltage

Measurement

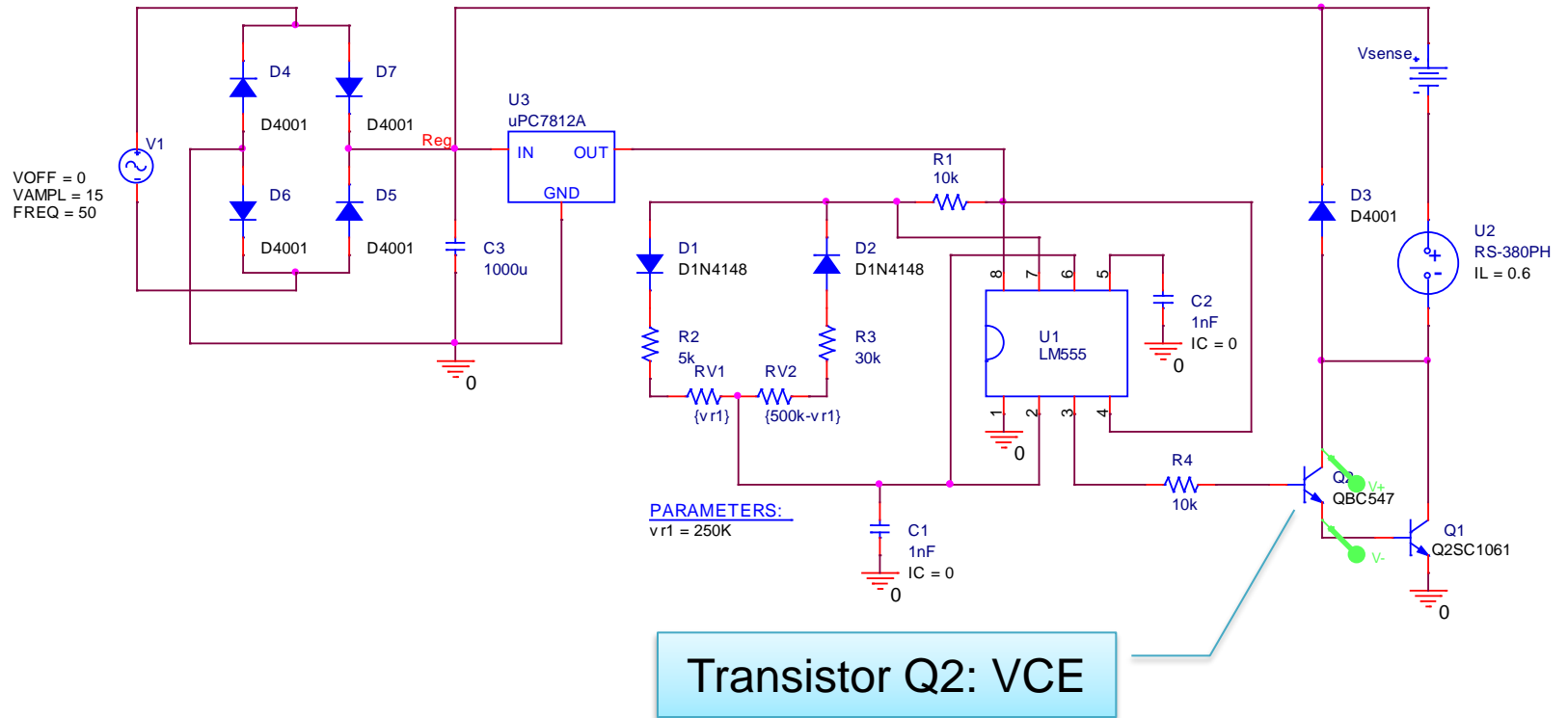


Simulation



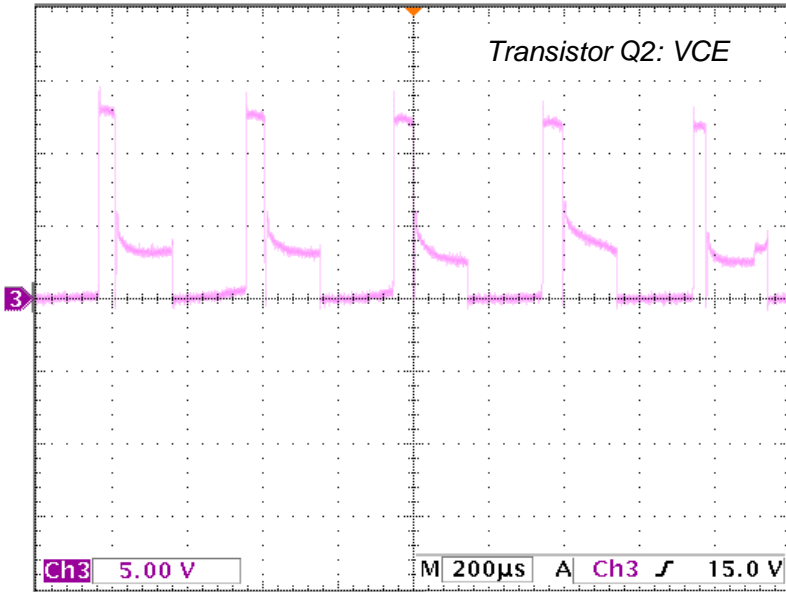
IC 555 Output Pulse Voltage

3.3 Transistor Q2: VCE

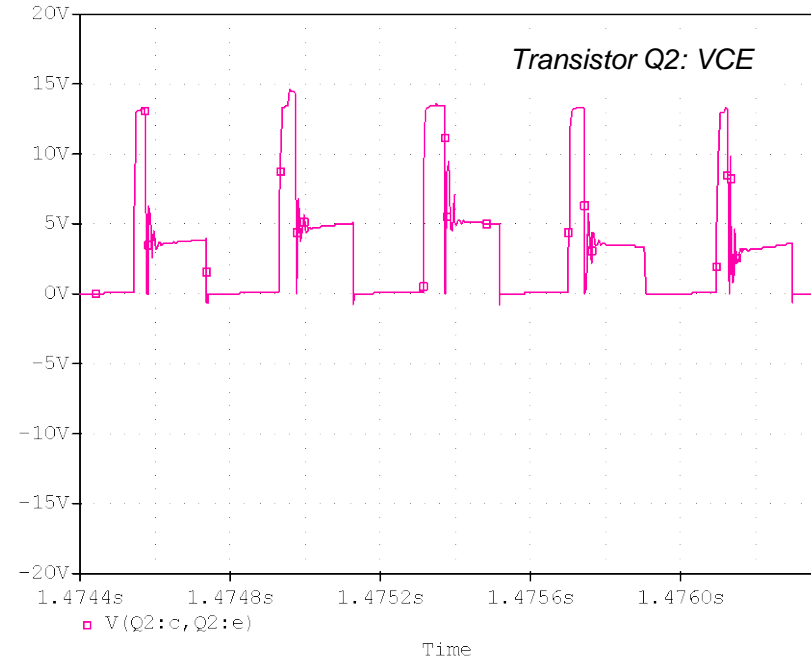


3.3 Transistor Q2: VCE

Measurement

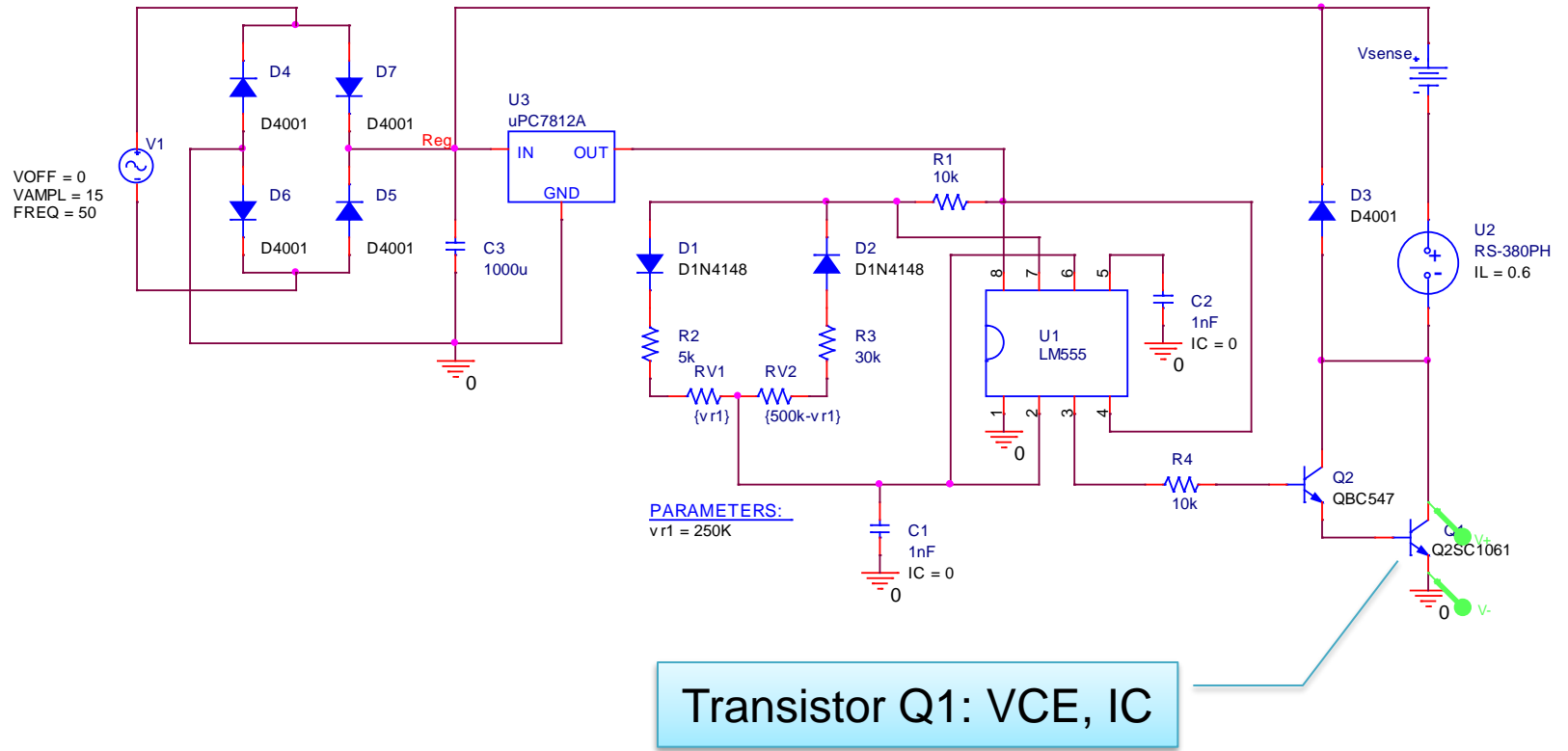


Simulation



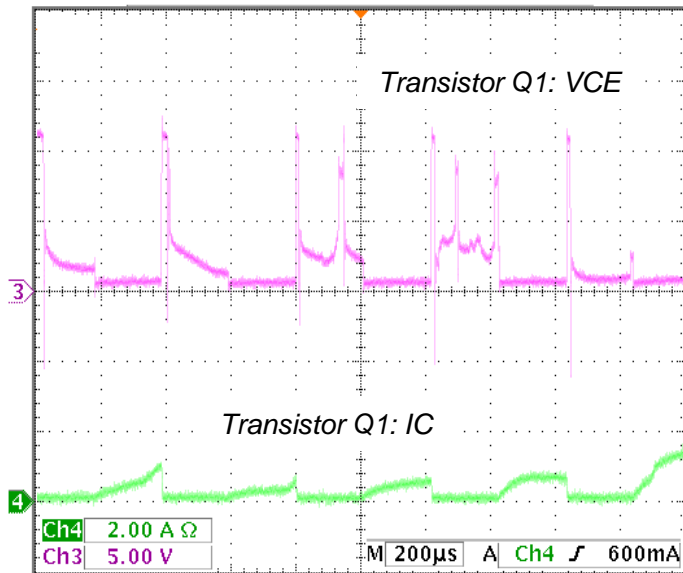
Transistor Q2: VCE

3.4 Transistor Q1: VCE, IC

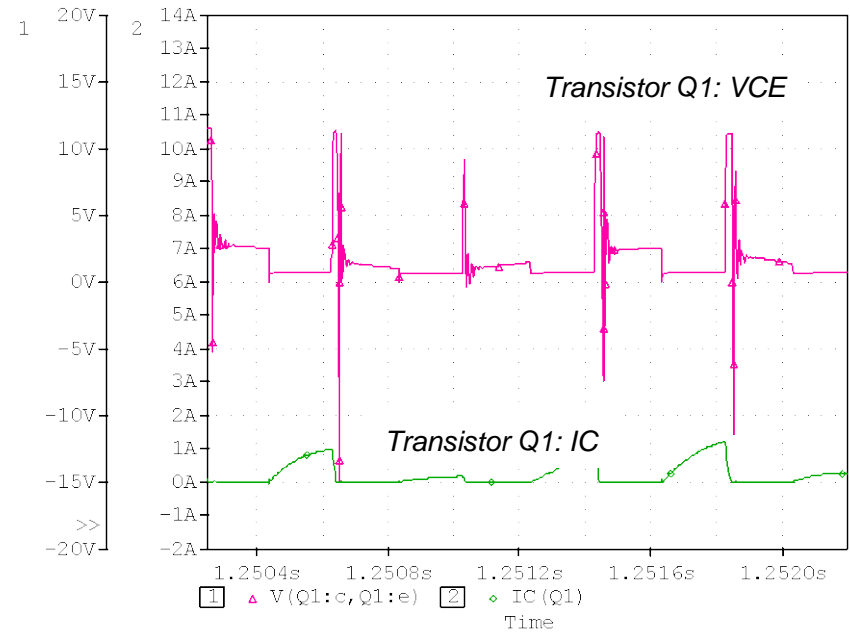


3.4 Transistor Q1: VCE, IC

Measurement

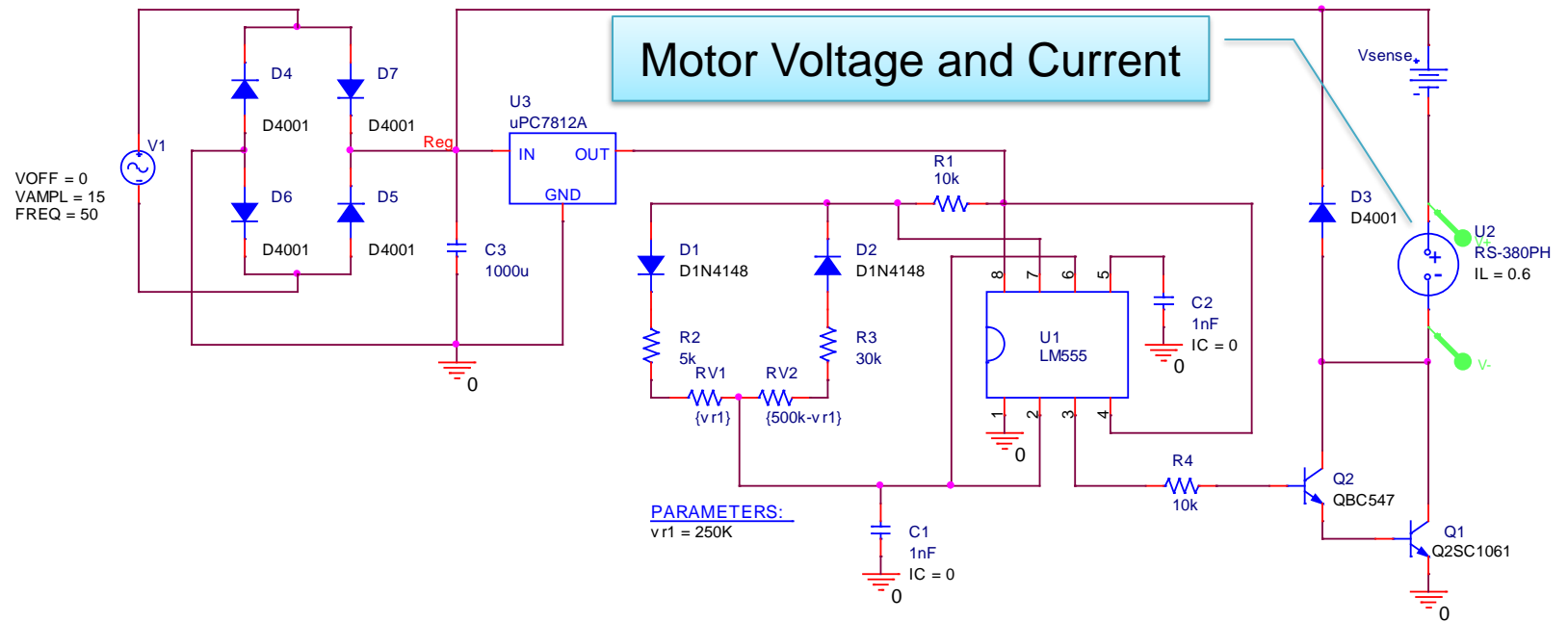


Simulation



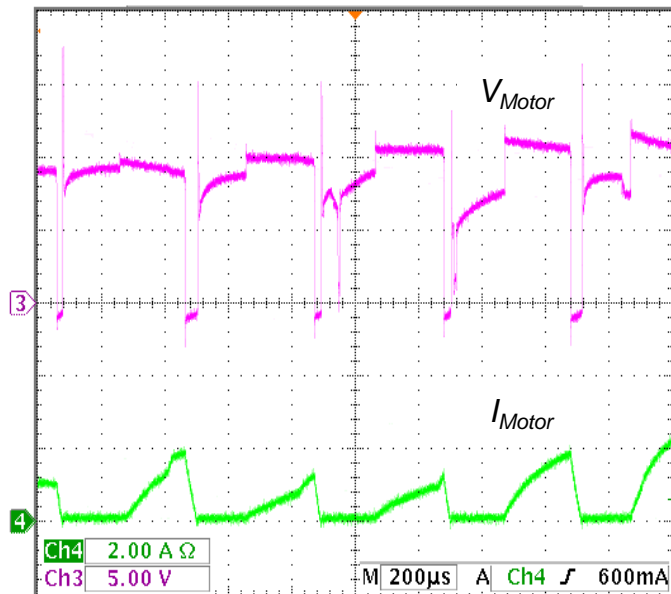
Transistor Q1: VCE, IC

3.5 Motor Voltage and Current

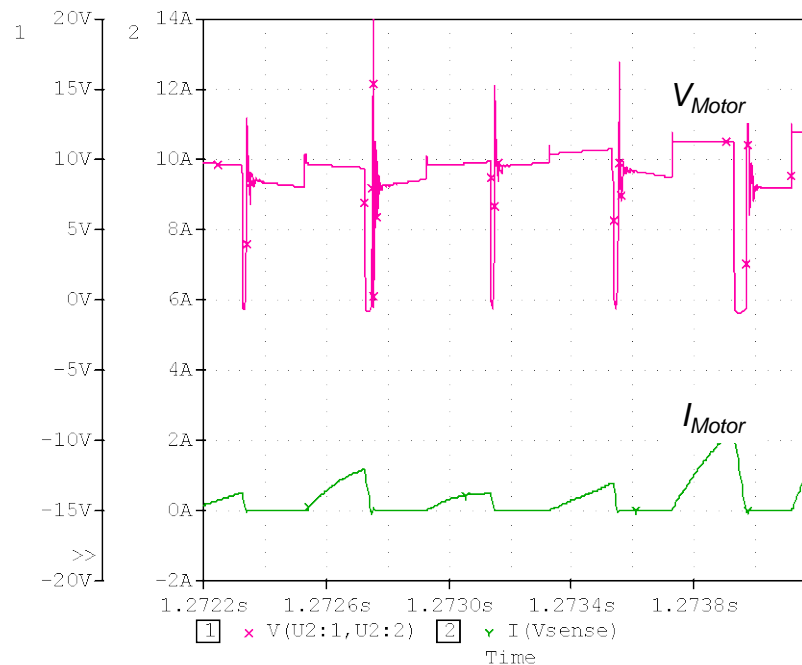


3.5 Motor Voltage and Current

Measurement



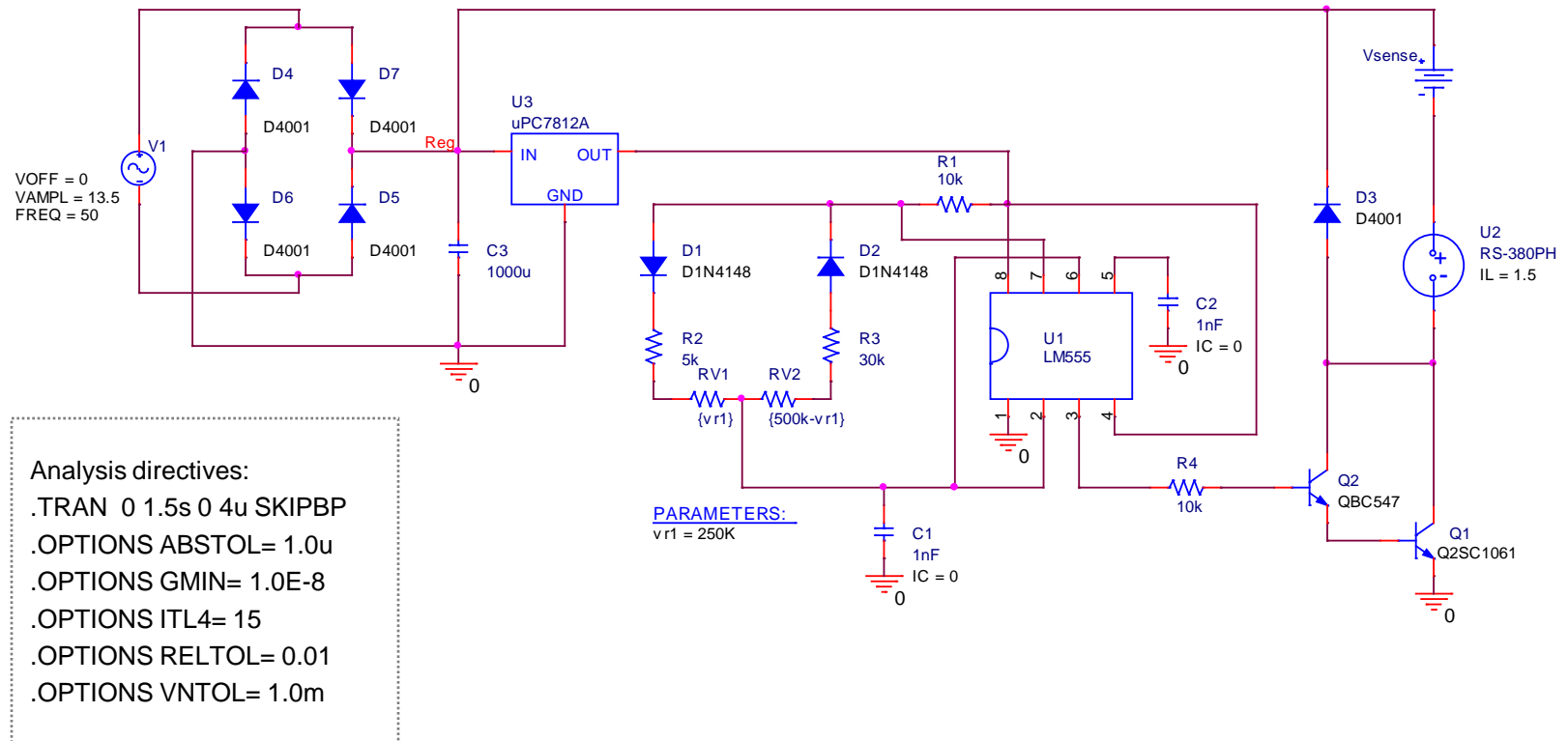
Simulation



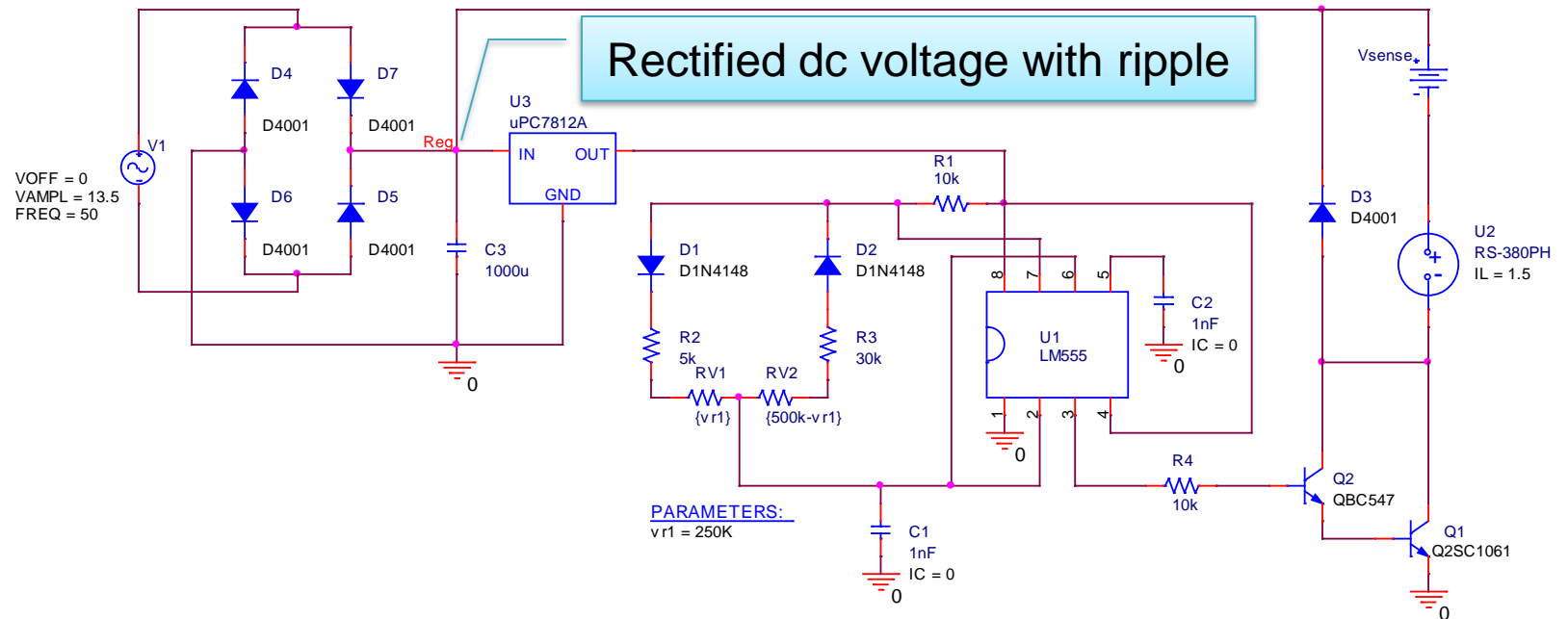
Motor Voltage and Current

4. LM555 DC Motor Speed Control Circuit (Fan Load)

- The circuit is simulated and compared with the measured waveforms from oscilloscope (Tektronix: TDS3054B) to verify the simulation using the RS-380PH model under the different load condition .

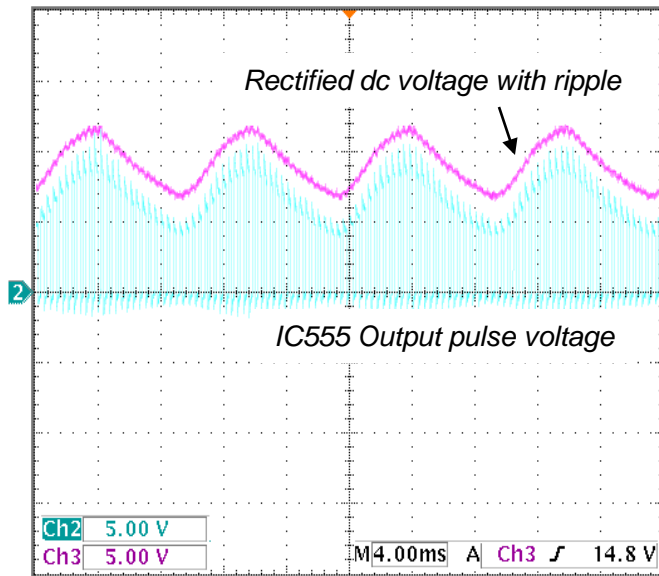


4.1 Rectified dc voltage with ripple

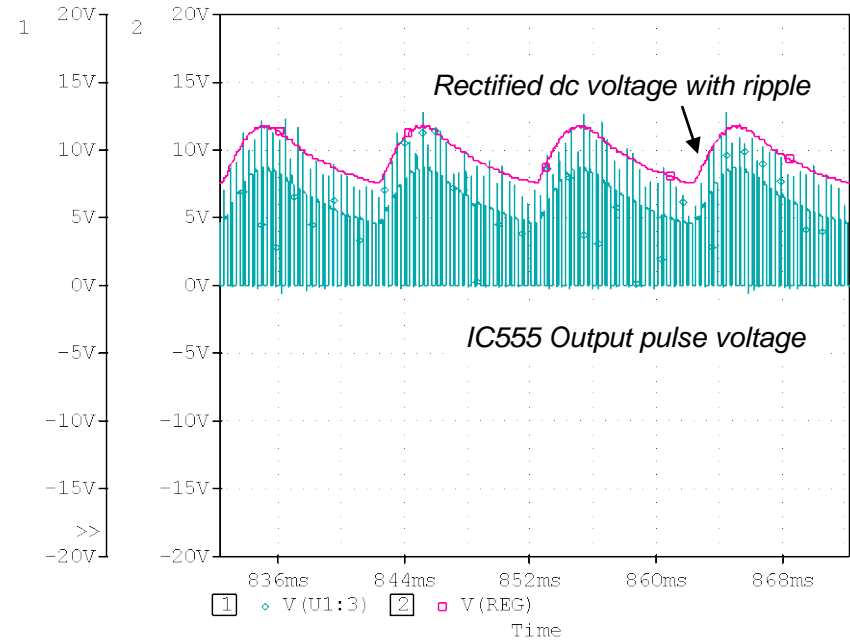


4.1 Rectified dc voltage with ripple

Measurement

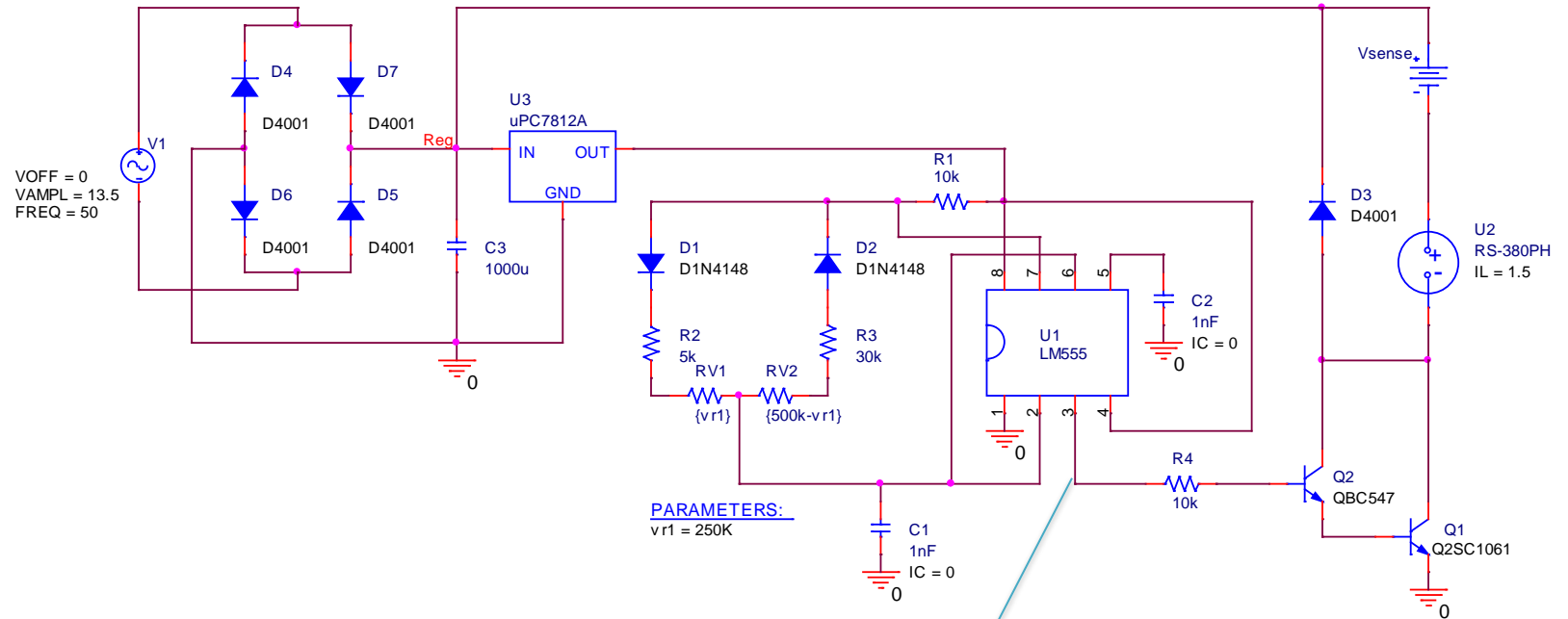


Simulation



Rectified dc voltage with ripple

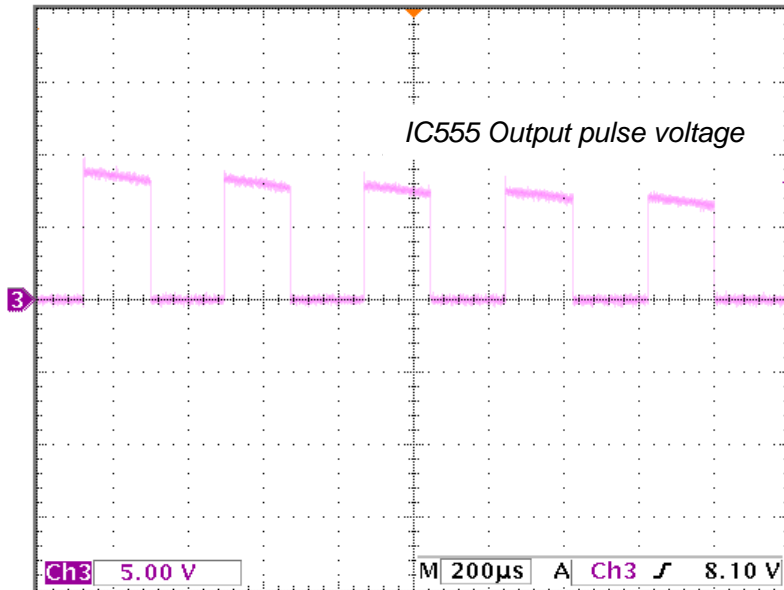
4.2 IC 555 Output Pulse Voltage



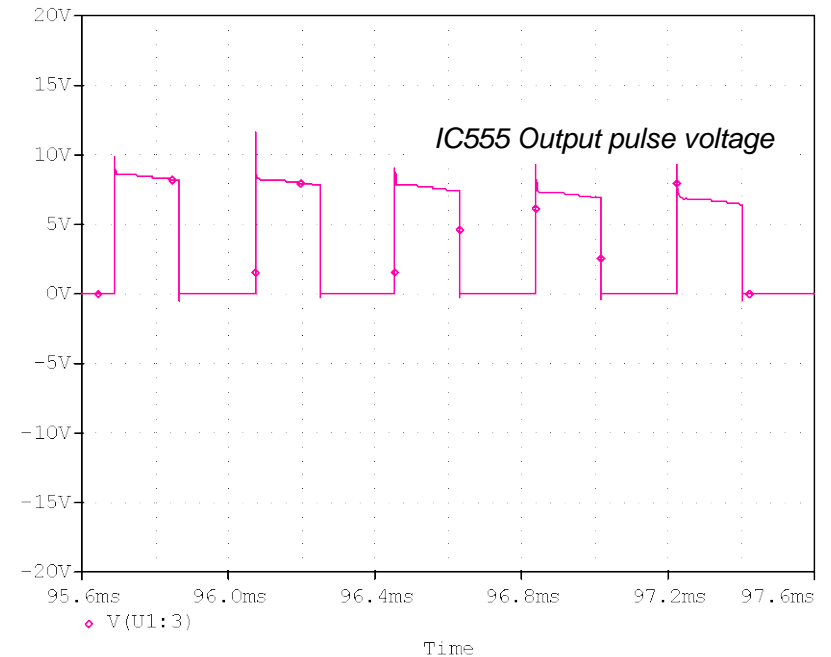
IC 555 Output Pulse Voltage

4.2 IC 555 Output Pulse Voltage

Measurement

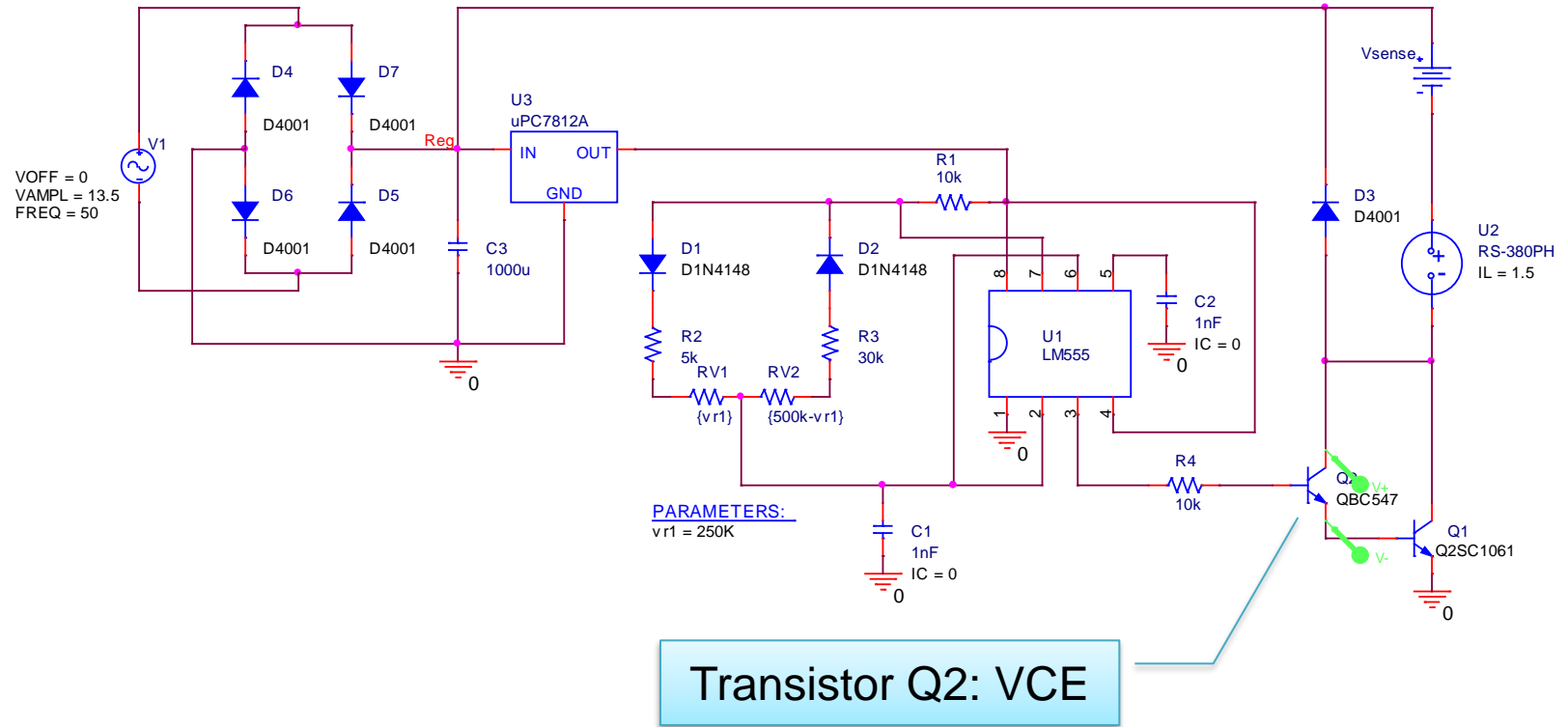


Simulation



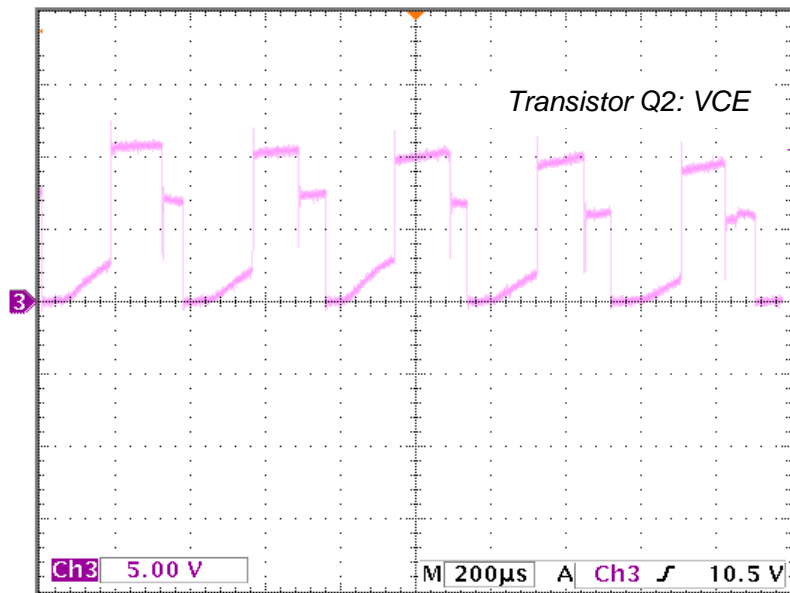
IC 555 Output Pulse Voltage

4.3 Transistor Q2: VCE

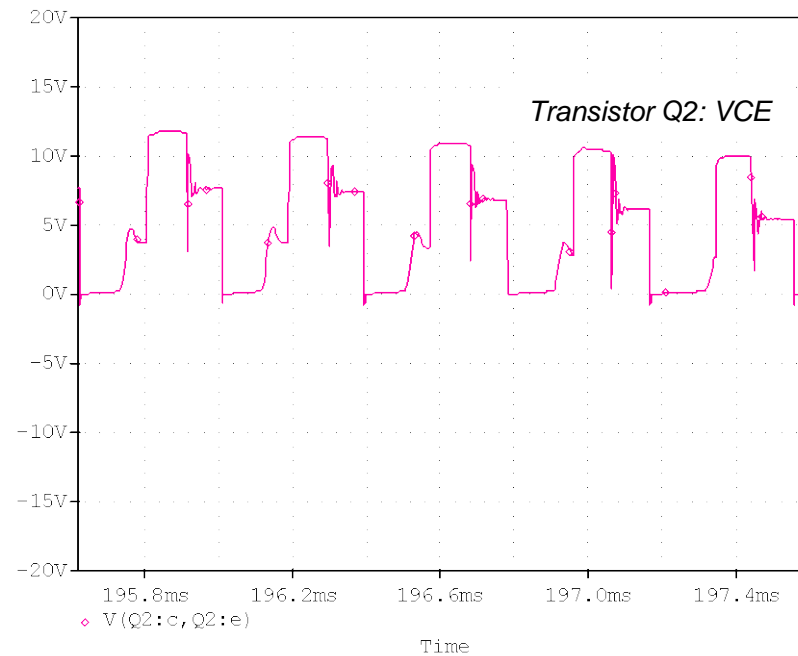


4.3 Transistor Q2: VCE

Measurement

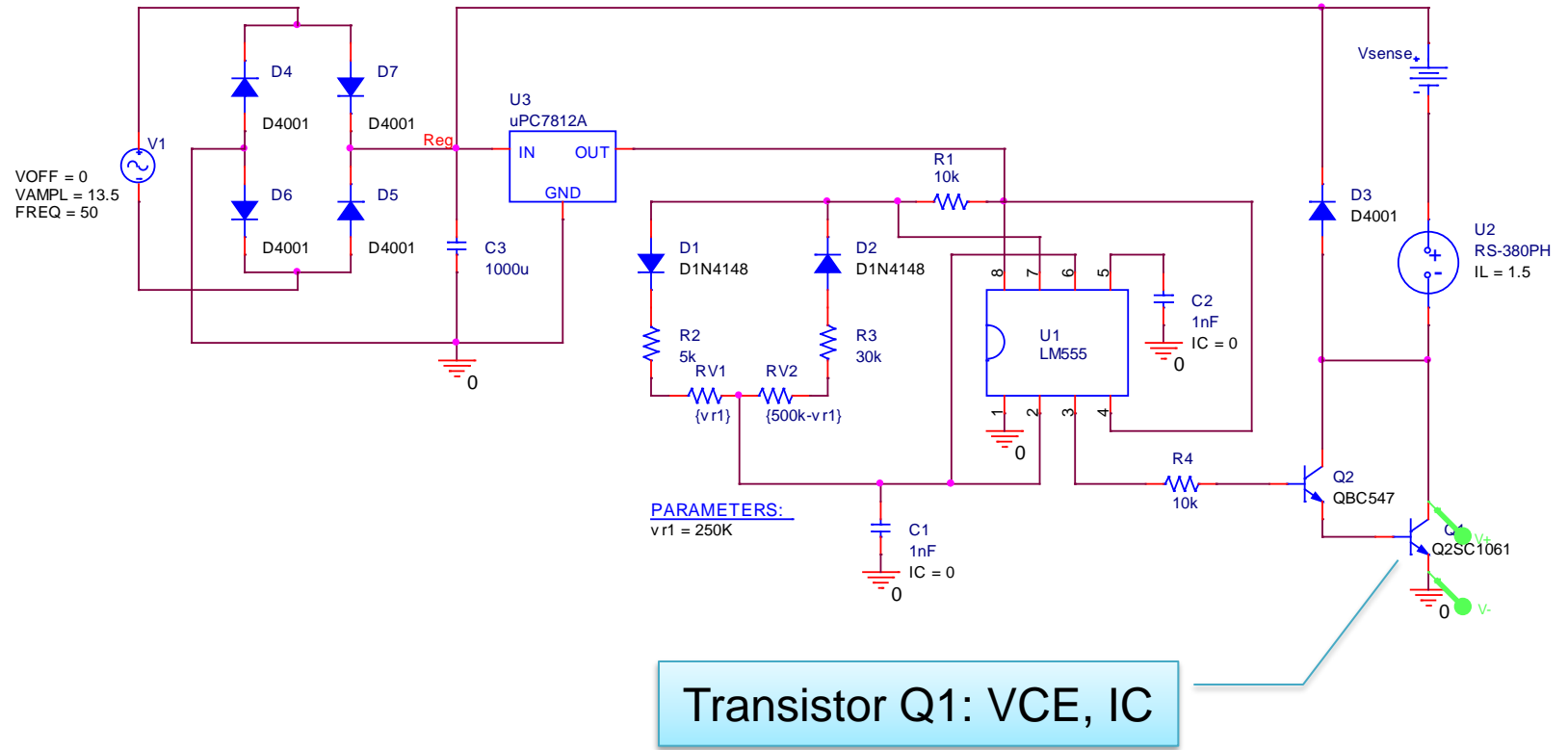


Simulation



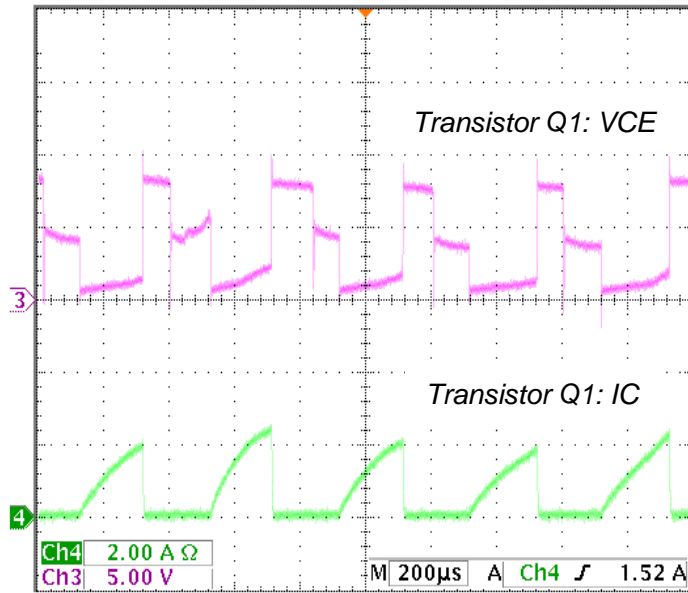
Transistor Q2: VCE

4.4 Transistor Q1: VCE, IC

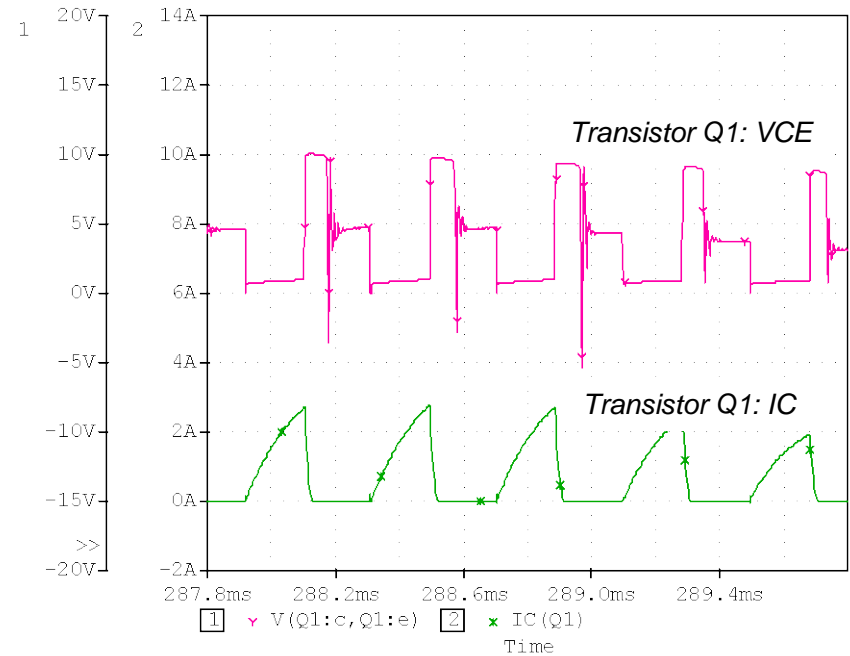


4.4 Transistor Q1: VCE, IC

Measurement

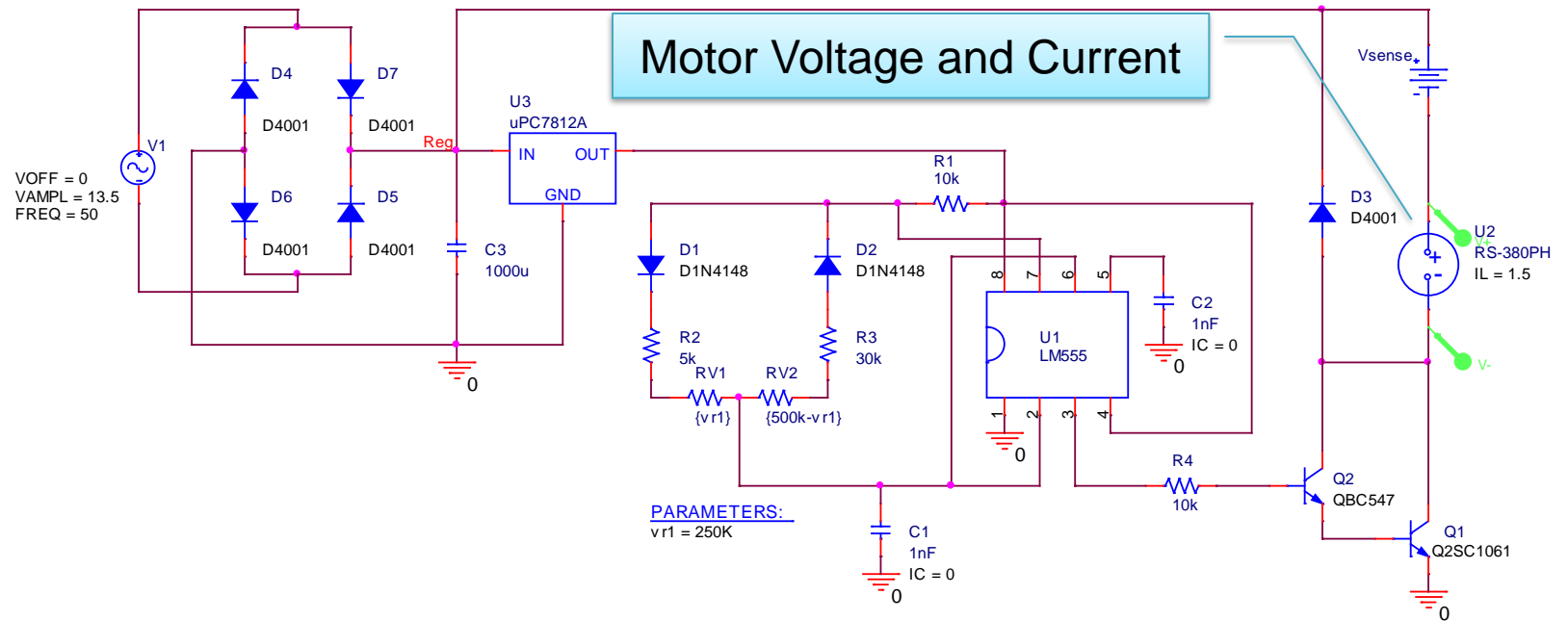


Simulation



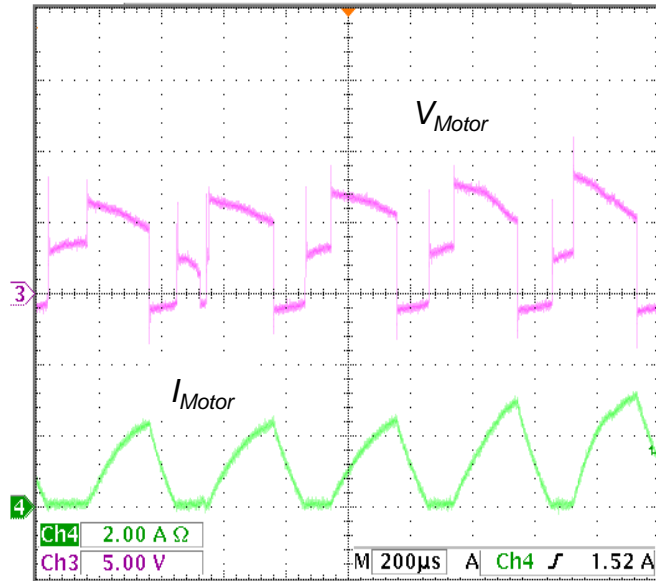
Transistor Q1: VCE, IC

4.5 Motor Voltage and Current

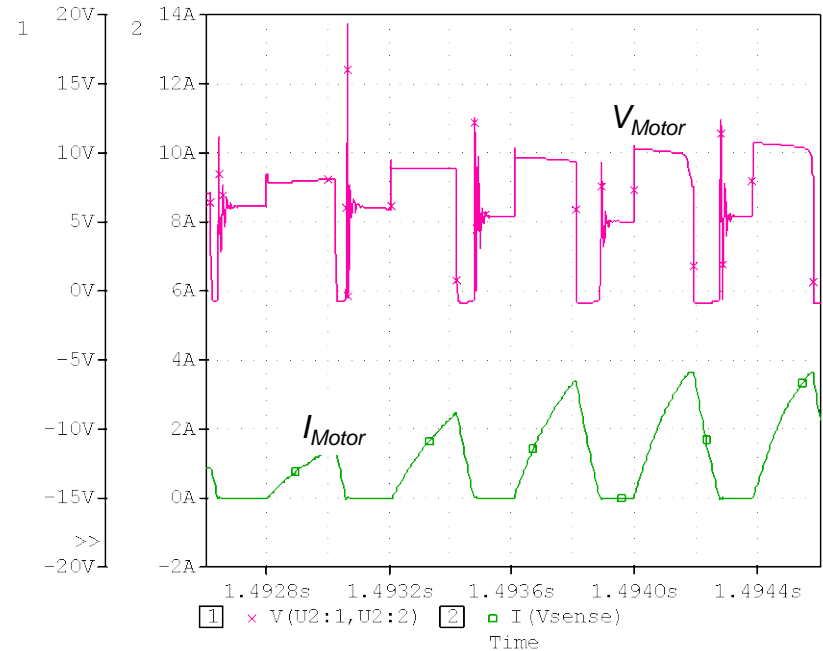


4.5 Motor Voltage and Current

Measurement



Simulation



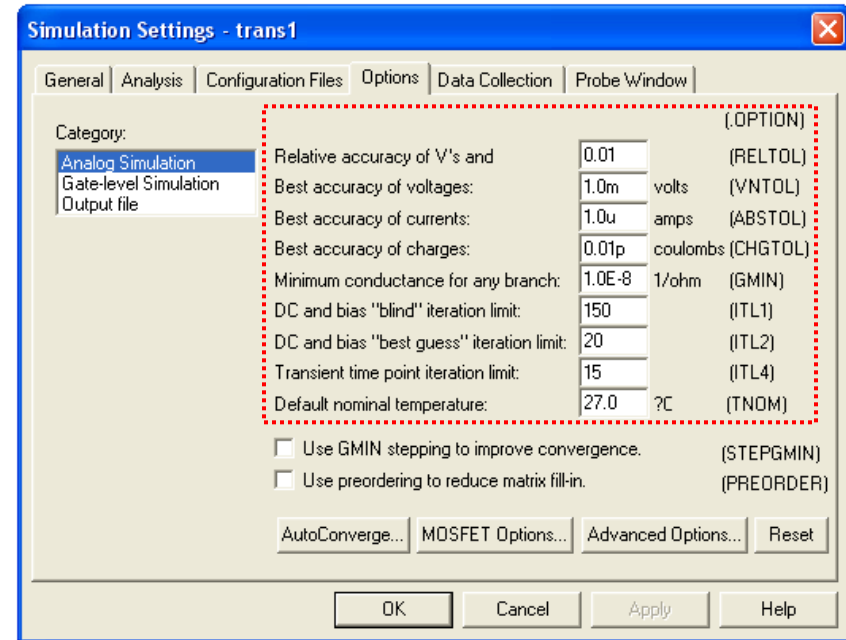
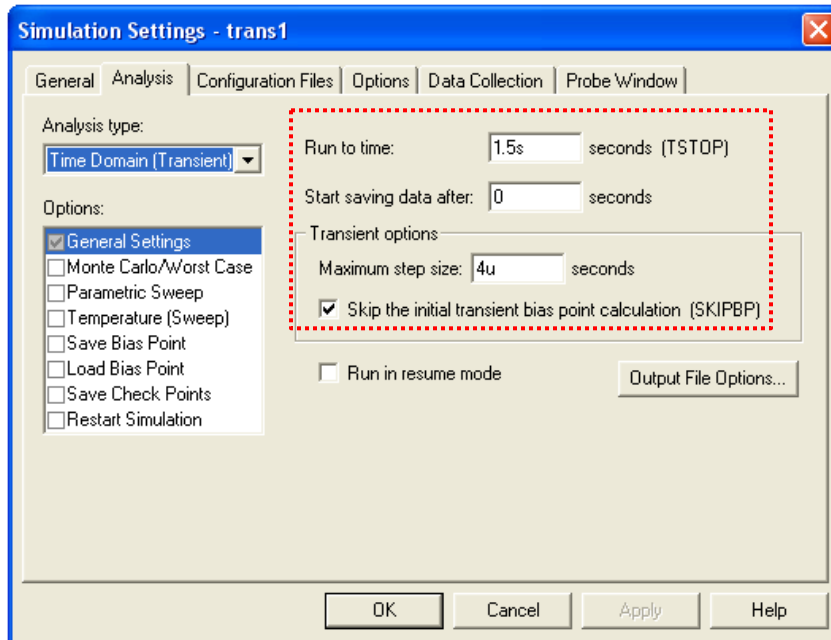
Motor Voltage and Current

Simulations

Folder name

	¥Simulations¥Transient¥Trans_NoLoa
1. Transient Response at No Load (Model).....	d
2. Speed at No Load (Model).....	¥Simulations¥Transient¥Speed_NoLoa
3. The Motor Steady-State Current Condition Setting (1/2).....	d
4. The Motor Steady-State Current Condition Setting (2/2).....	¥Simulations¥Transient¥Steady State
5. Transient Response at Load 3.8A.....	¥Simulations¥Transient¥Trans_1A1
6. LM555 DC Motor Speed Control Circuit (No Load).....	¥Simulations¥Transient¥Trans_3A8
7. LM555 DC Motor Speed Control Circuit (Fan Load).....	¥Simulations¥Trans_NoLoad
	¥Simulations¥Trans_FanLoad

Simulation Settings



Analysis directives:

```
.TRAN 0 1.5s 0 4u SKIPBP  
.OPTIONS ABSTOL= 1.0u  
.OPTIONS GMIN= 1.0E-8  
.OPTIONS ITL4= 15  
.OPTIONS RELTOL= 0.01  
.OPTIONS VNTOL= 1.0m
```