Circuit Design for Electromagnetic Energy Harvesting

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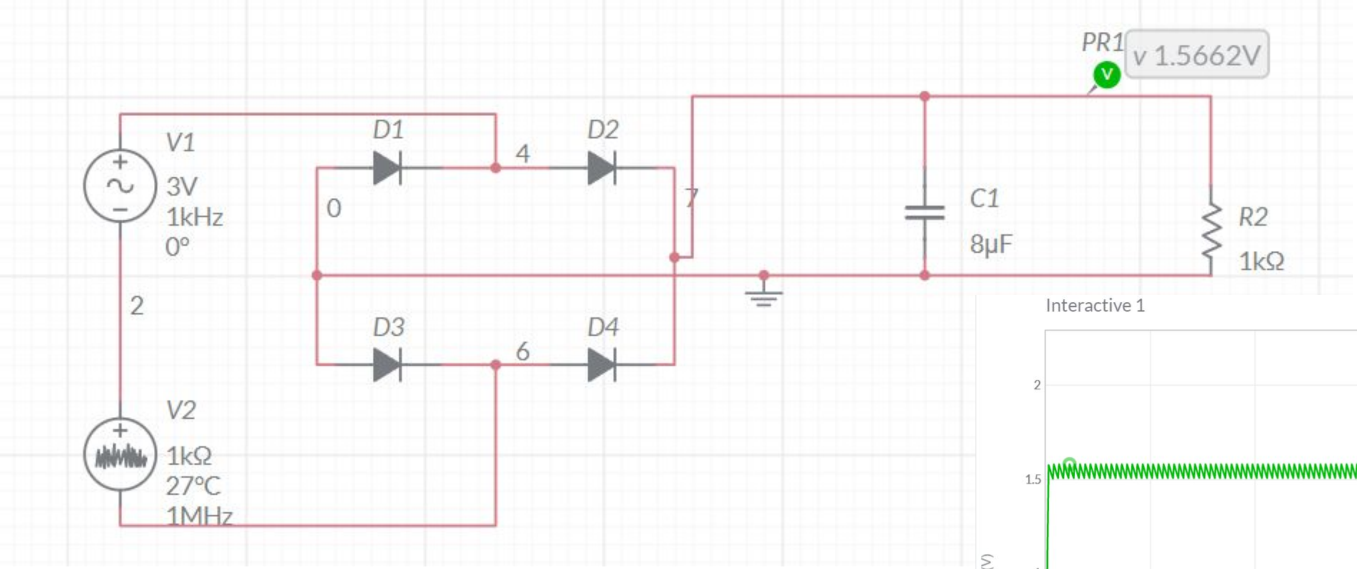
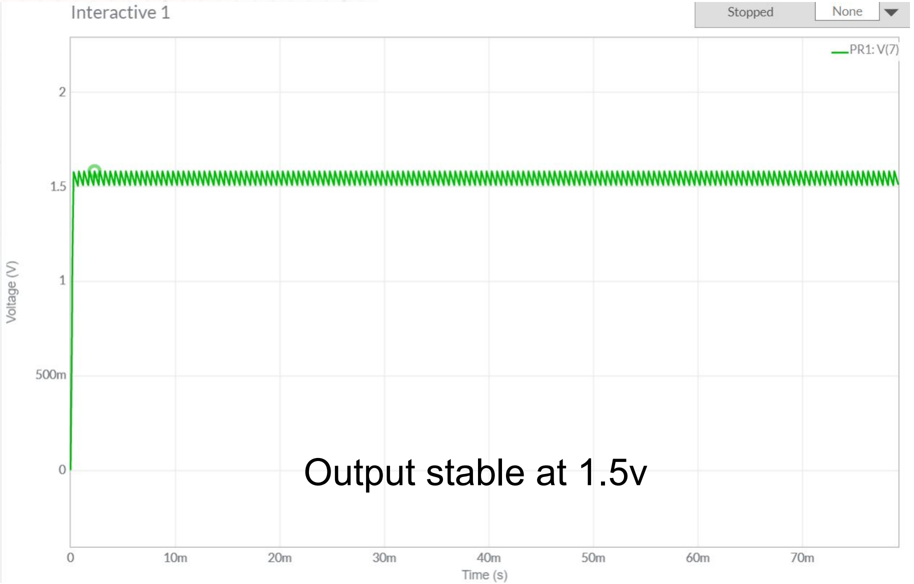
Simple EMEH Circuit Design

We model the EMEH as a noisy sinusoid. We will choose the resistance and inductance value to match with the impedance of the EMEH for maximum power transfer *However the method of impedance matching is old and has low conversion efficiency*

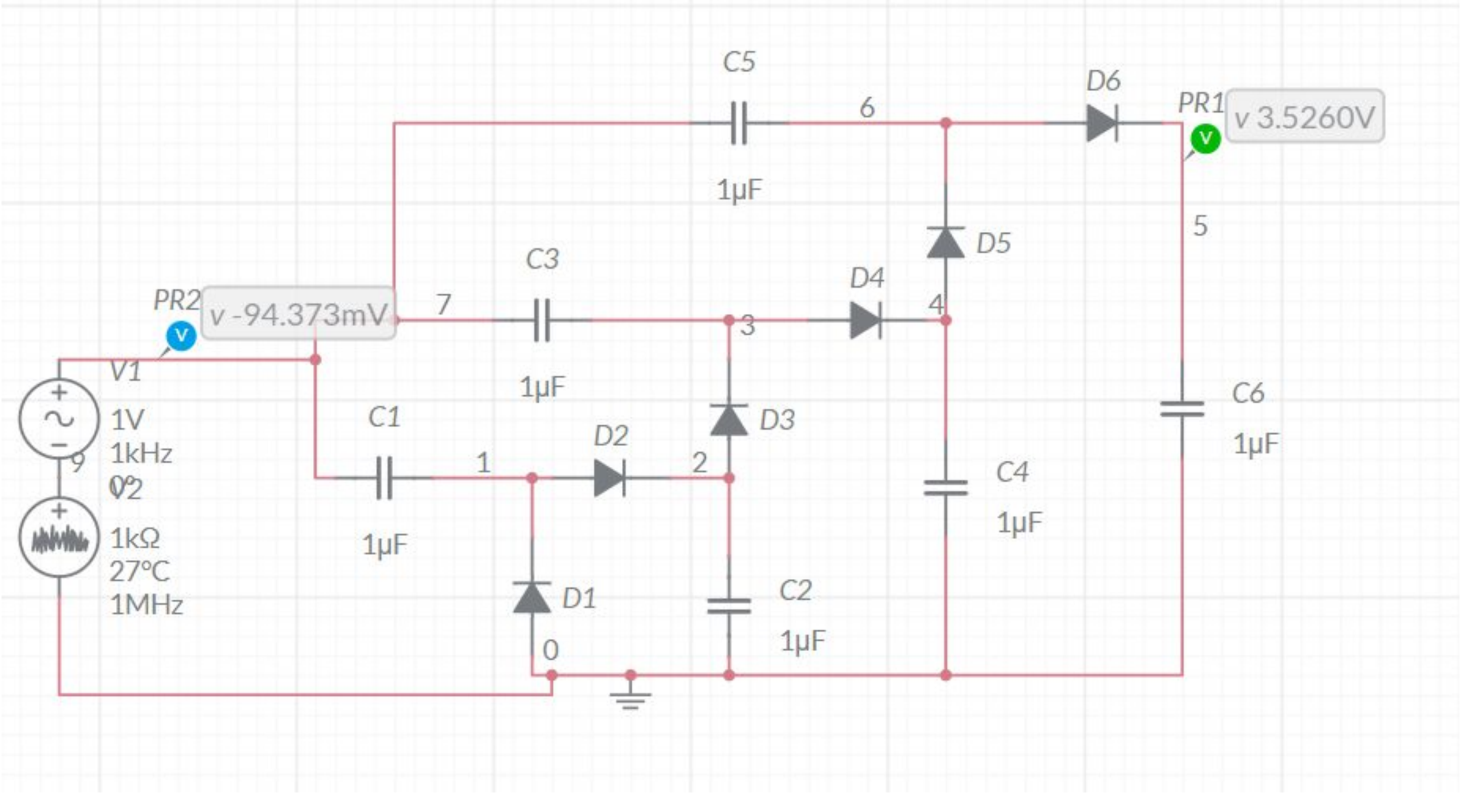


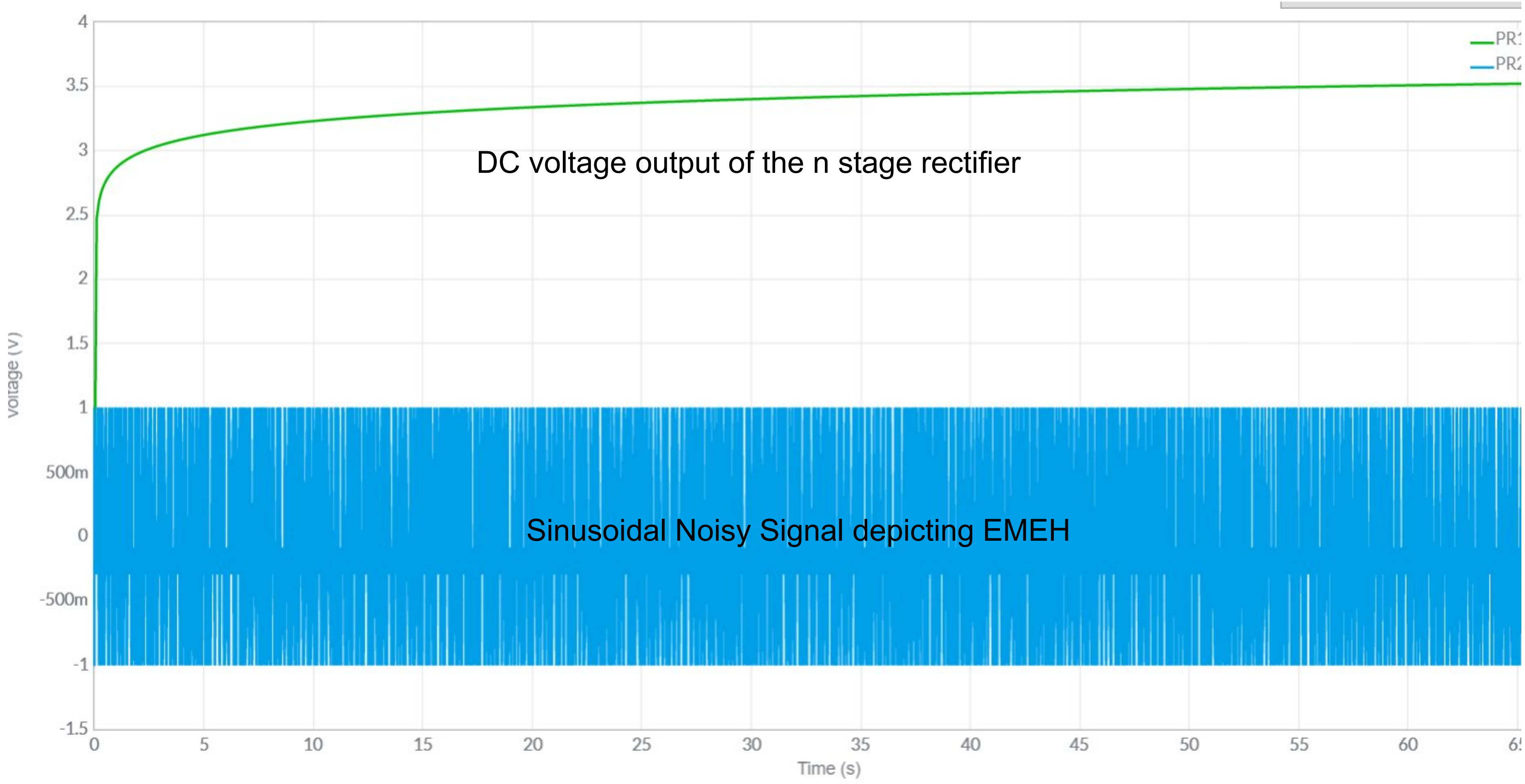
Rectifier converts AC to DC. The capacitive filter is used to filter out the noise.



Output stable at 1.5v

In some studies I came across n stage rectifiers are used



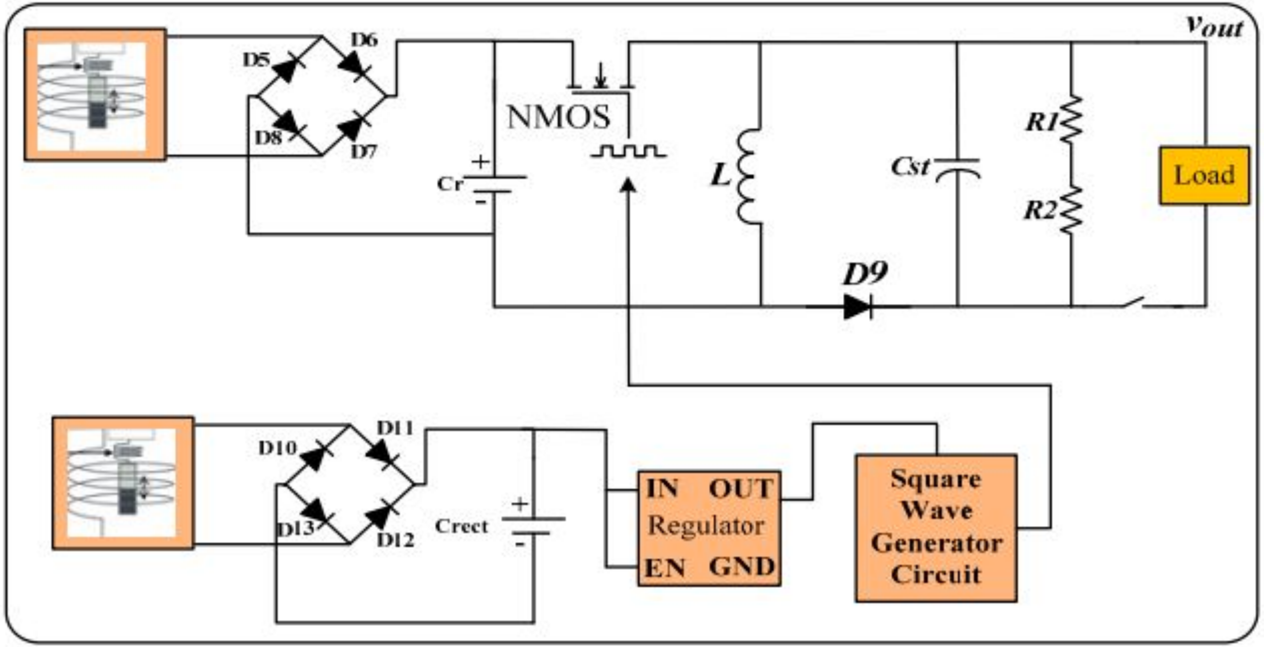


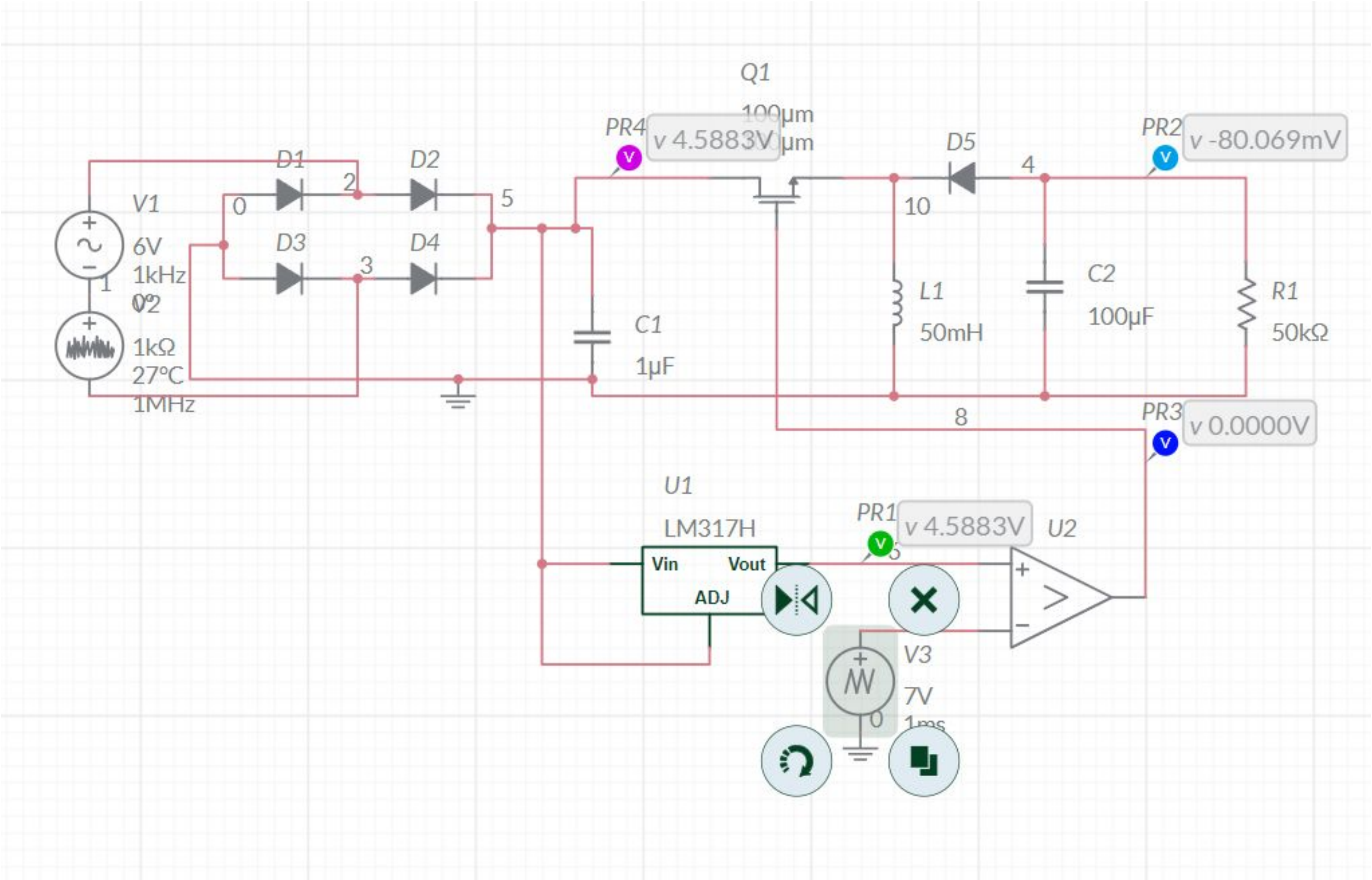
PR1
PR2
DC voltage output of the n stage rectifier
Sinusoidal Noisy Signal depicting EMEH
voltage (V)
Time (s)
4
3.5
3
2.5
2
1.5
1
500m
0
-500m
-1
-1.5
0
5
10
15
20
25
30
35
40
45
50
55
60

Buck Boost Converter Design

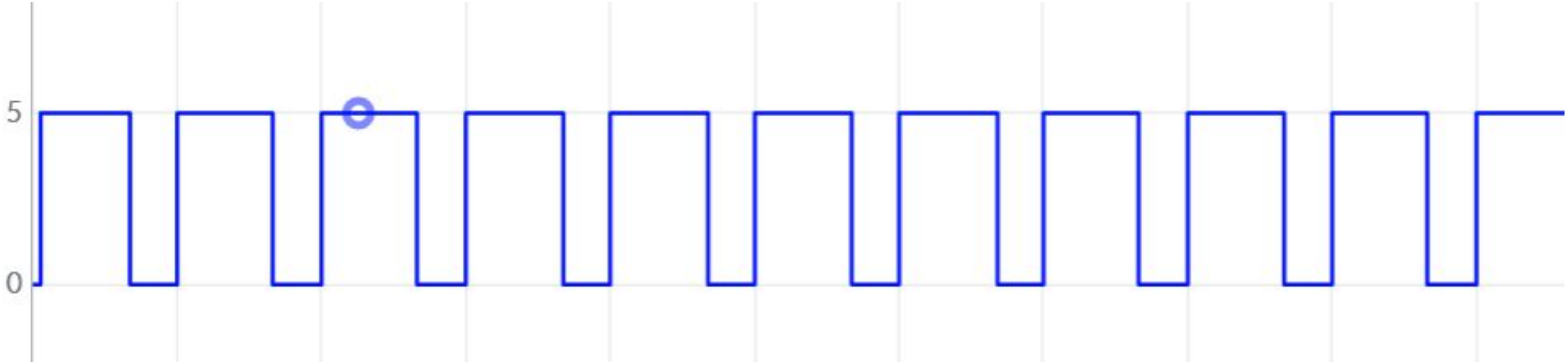
Synchronous switch harvesting on inductor (SSHI) technique

Synchronous switch harvesting on inductor (SSHI) technique



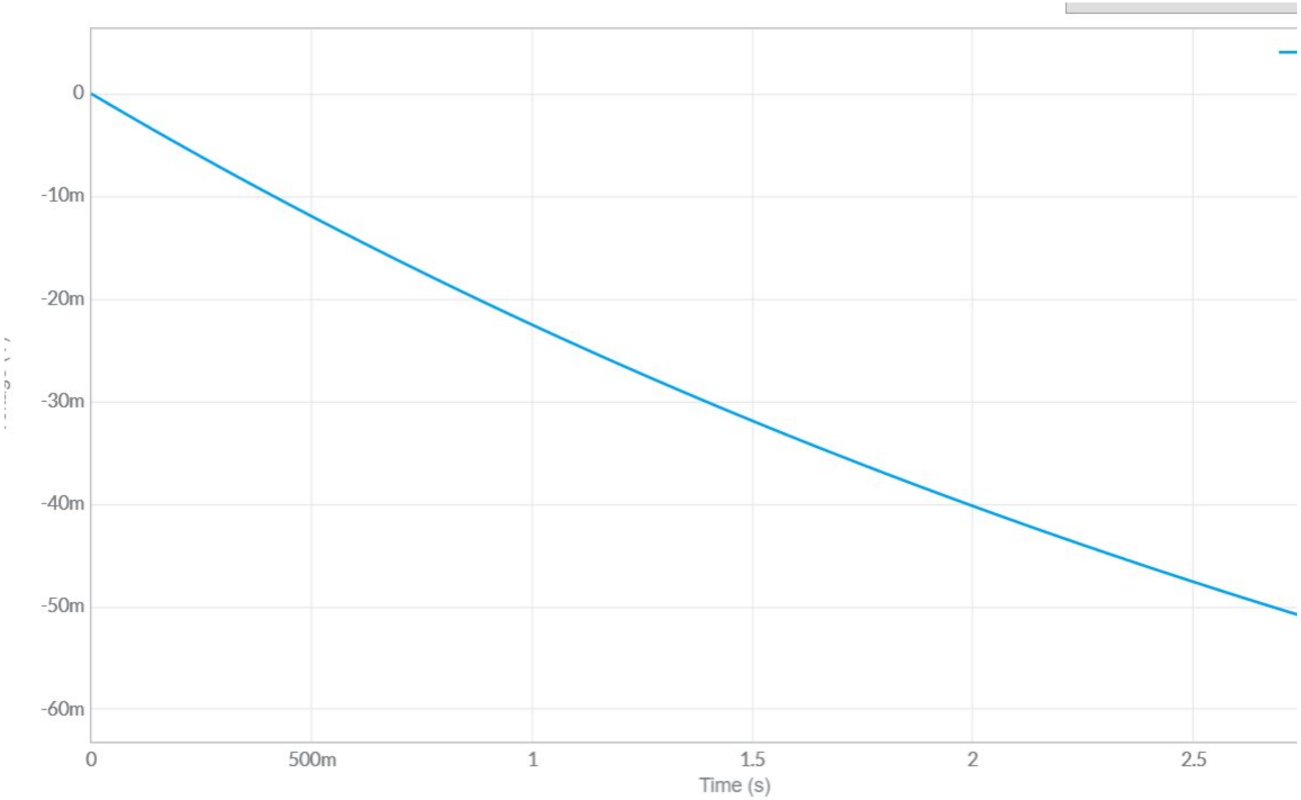

Q1
100µm
PR4
v 4.5883V
D5
PR2
v -80.069mV
D1
D2
V1
6V
1kHz
V2
1kΩ
27°C
1MHz
D3
D4
C1
1µF
L1
50mH
C2
100µF
R1
50kΩ
PR3
v 0.0000V
U1
LM317H
PR1
v 4.5883V
U2
Vin
Vout
ADJ
V3
7V
1ms

Voltage after rectification



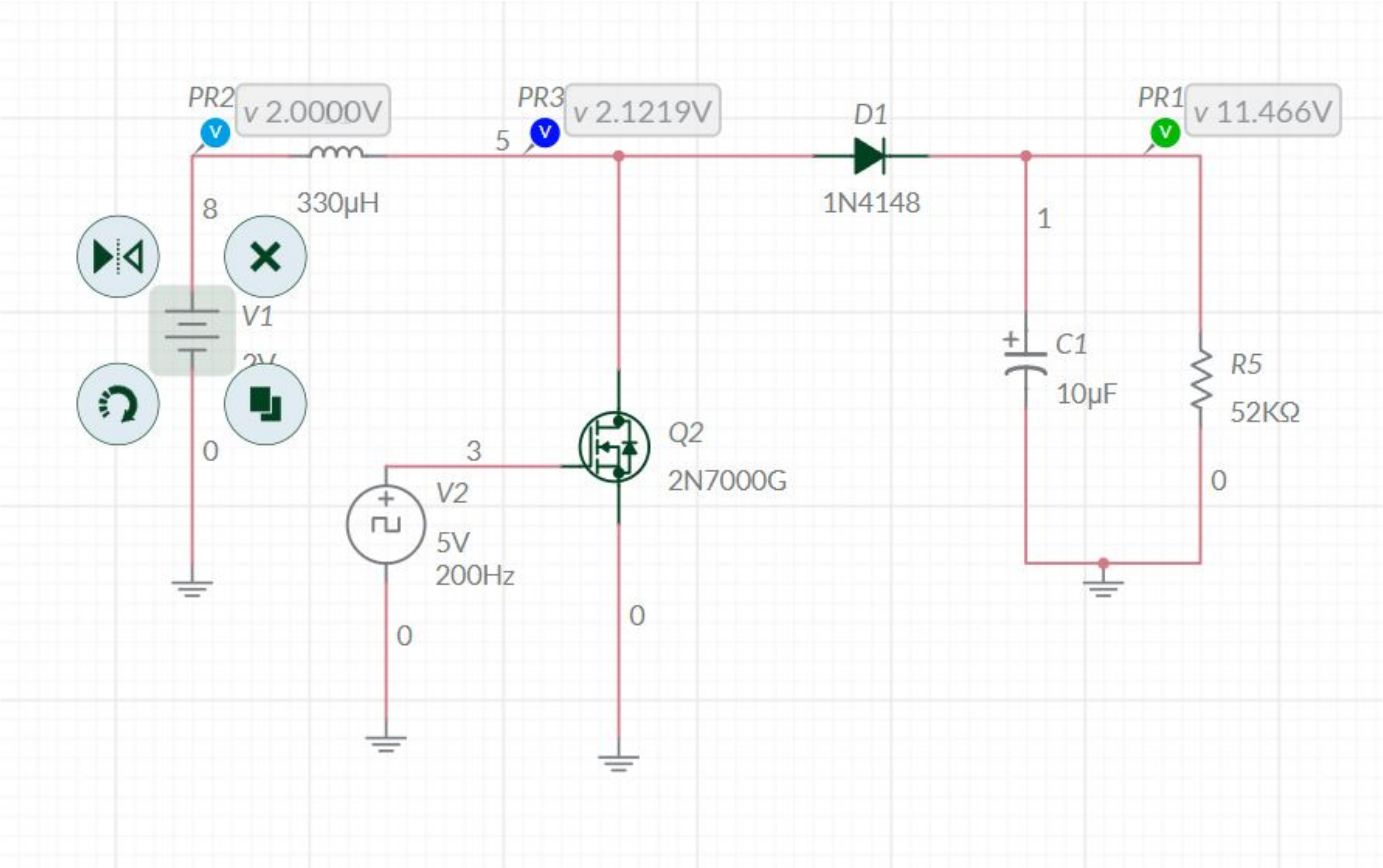
This is the PWM generated using the saw tooth wave and the rectified signal as reference.

Buck Boost Converters have inverted output voltage. The simulation output looks like this :

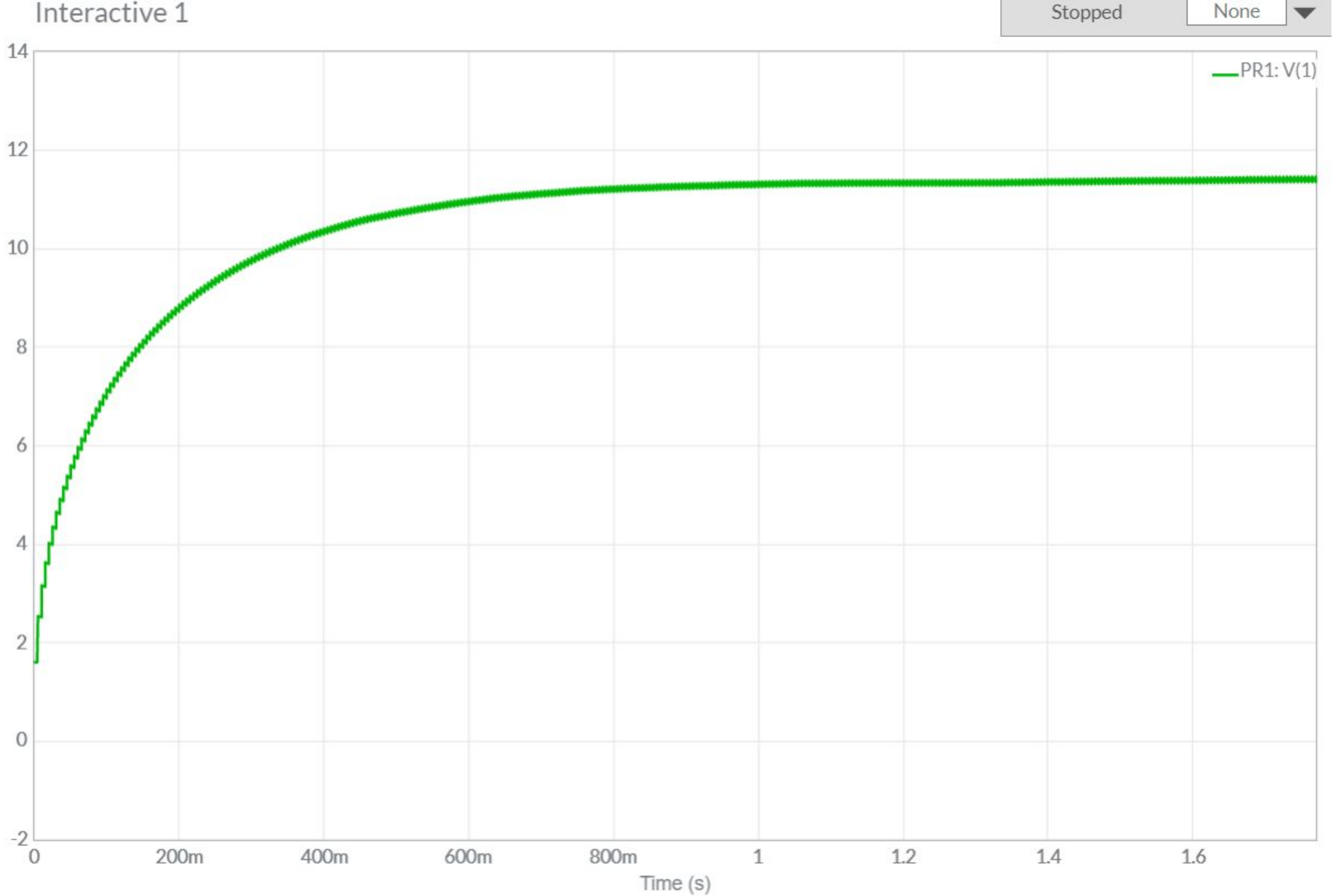


Boost Converter Circuit

Boost Converter Circuit for EMEH



As most of the papers we being able to produce a maximum voltage of 2V so I have given 2V as input



Output Graph

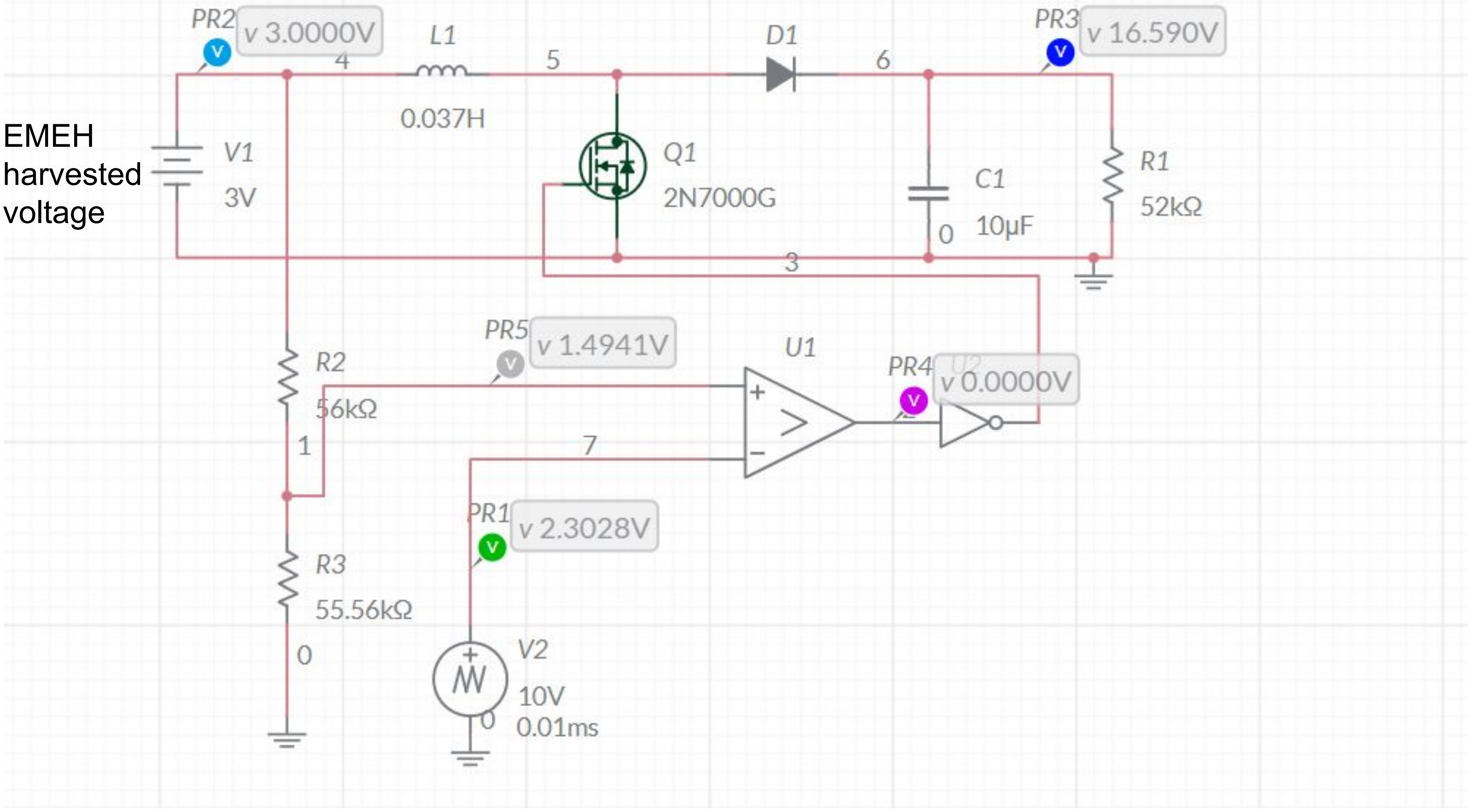
I have consulted these two papers to make modifications in the DC-DC boost converter

Feedforward control of DC-DC PWM boost converter

Electromagnetic Energy Harvesting Circuit with Feedforward and Feedback

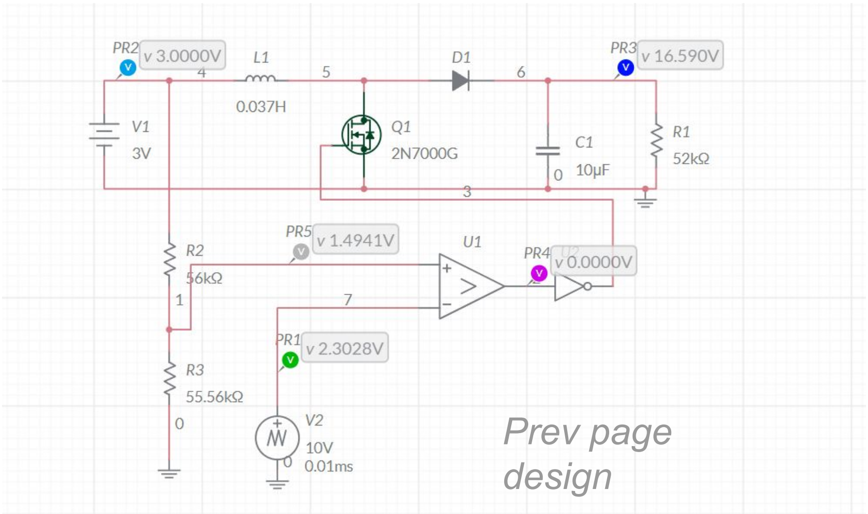
DC-DC PWM Boost Converter for Vibration Power Generator System

Boost converter with feedforward

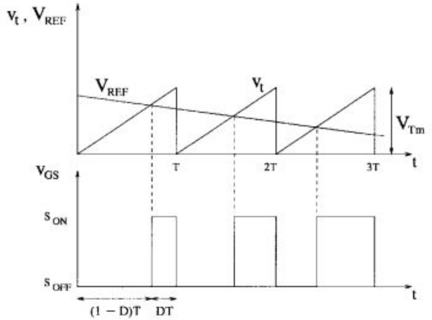


DC-DC boost converter with feedforward circuit

In PWM dc-dc power converters operated in CCM and without any control, the dc output voltage is almost independent of the output current (or load resistance), but is directly proportional to the dc input voltage. Therefore, it is difficult to achieve good line regulation in these converters. So we will introduce a feed forward circuit.



When the reference voltage at the comparator inverting input is higher than the sawtooth voltage at the noninverting input, the gate-to-source voltage goes low, turning the power transistor OFF. On the other hand, when the reference voltage is lower than the sawtooth voltage , the voltage goes high, turning the power transistor ON. Therefore, the on-duty cycle of the power transistor increases as the converter dc input voltage decreases



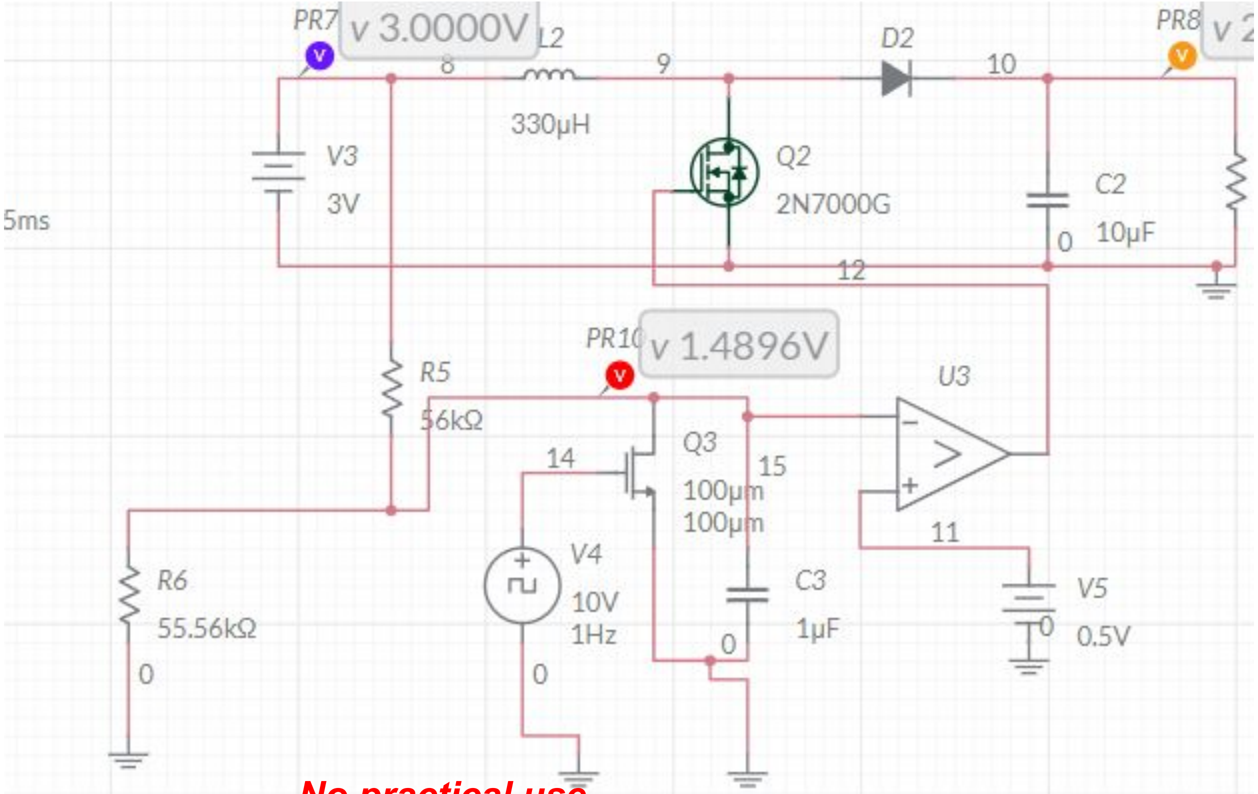
$$V_O = \frac{1}{1-D}V_I.$$

$$V_O = \frac{V_{Tm}}{\alpha} = \left(\frac{R_1}{R_2}+1\right)V_{Tm}.$$

Vo becoming independent of Vi

Boost converter with Amplitude modulated Sawtooth

We can also change the duty cycle by changing the magnitude of the sawtooth wave and giving a fixed vref instead of a variable one as in the previous example

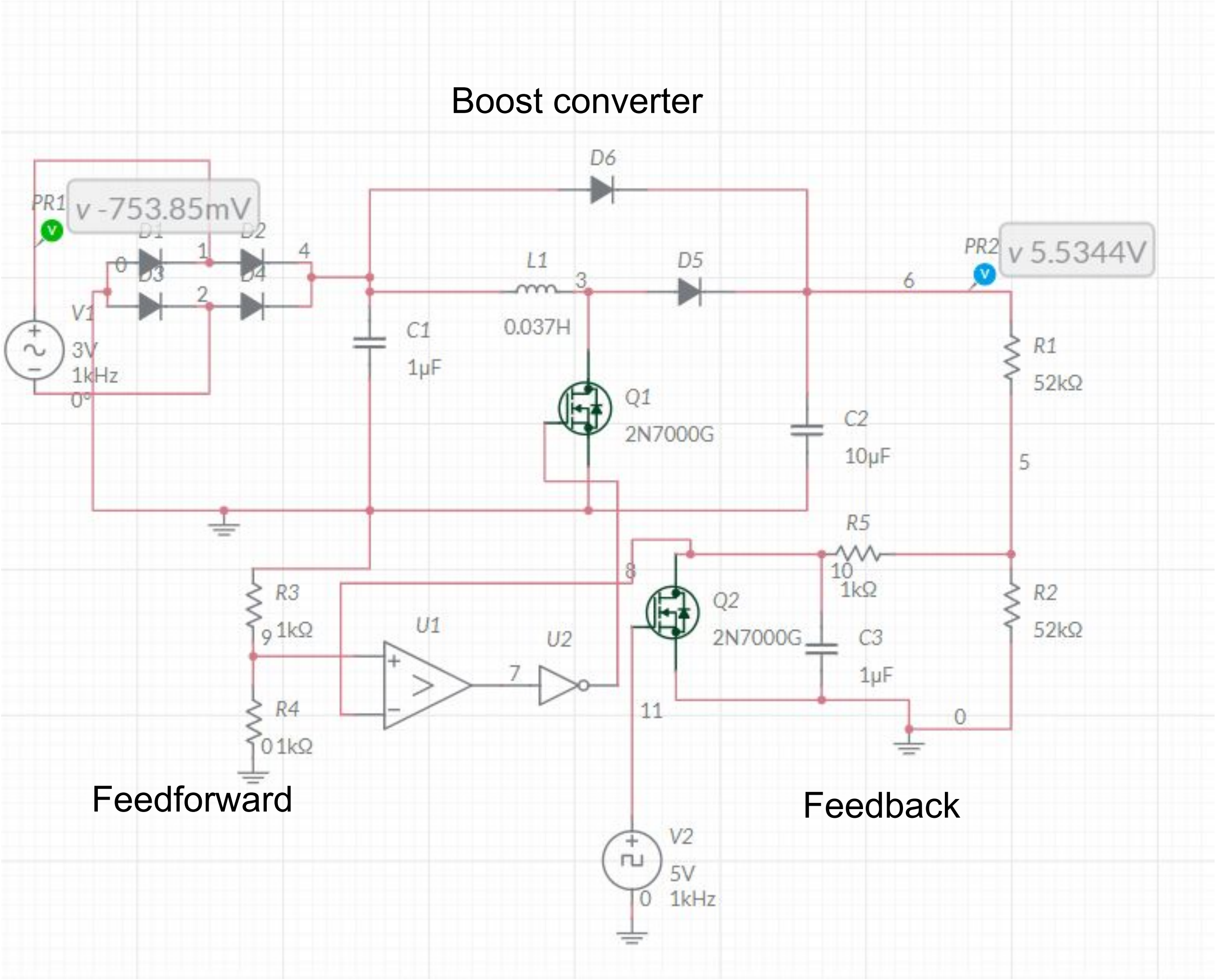


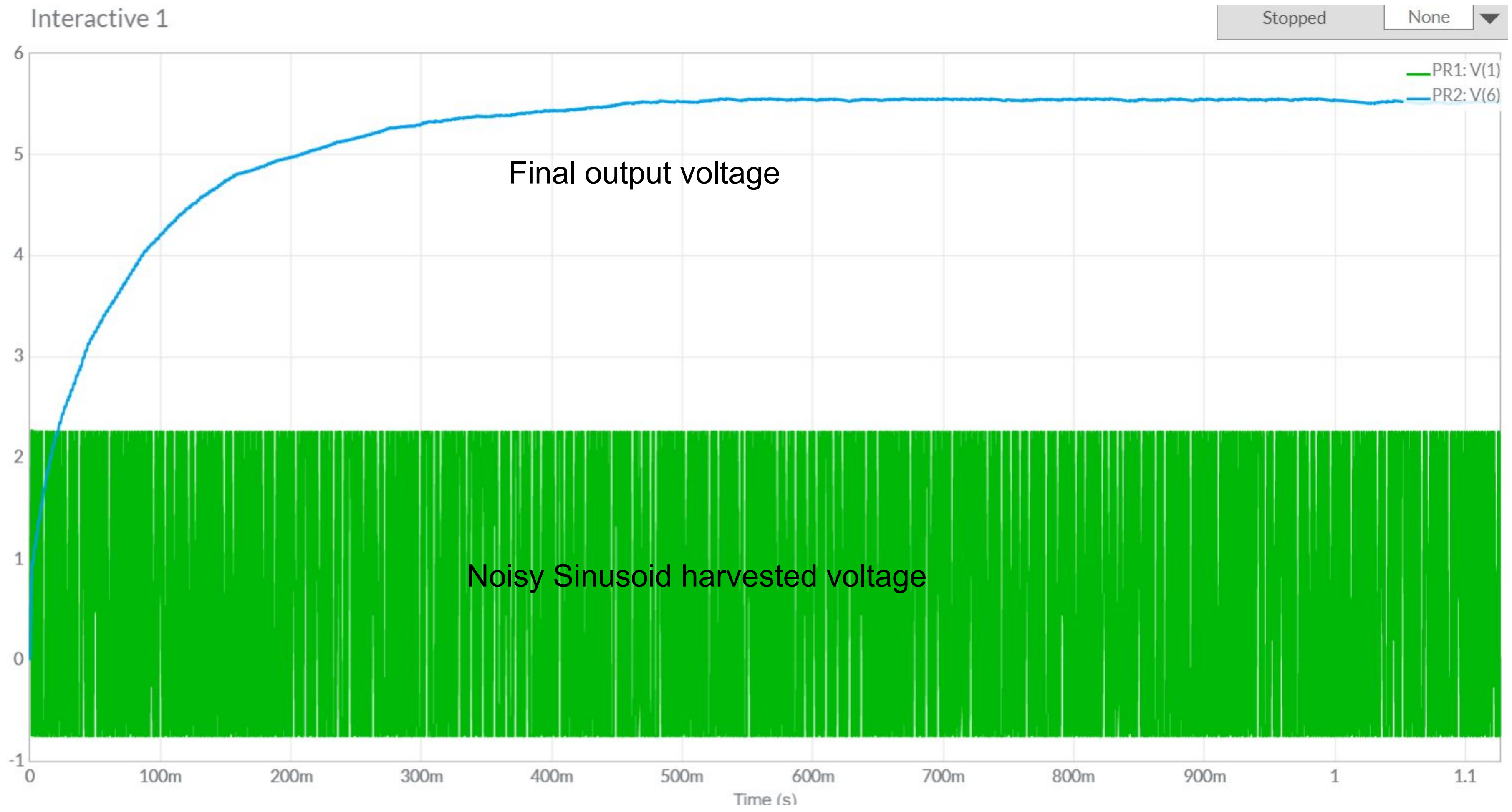
No practical use

$$V_O = \frac{V_I}{1 - D} = \frac{V_I}{1 - \frac{\tau_C V_{\mathrm{REF}}}{\alpha T V_I}}.$$

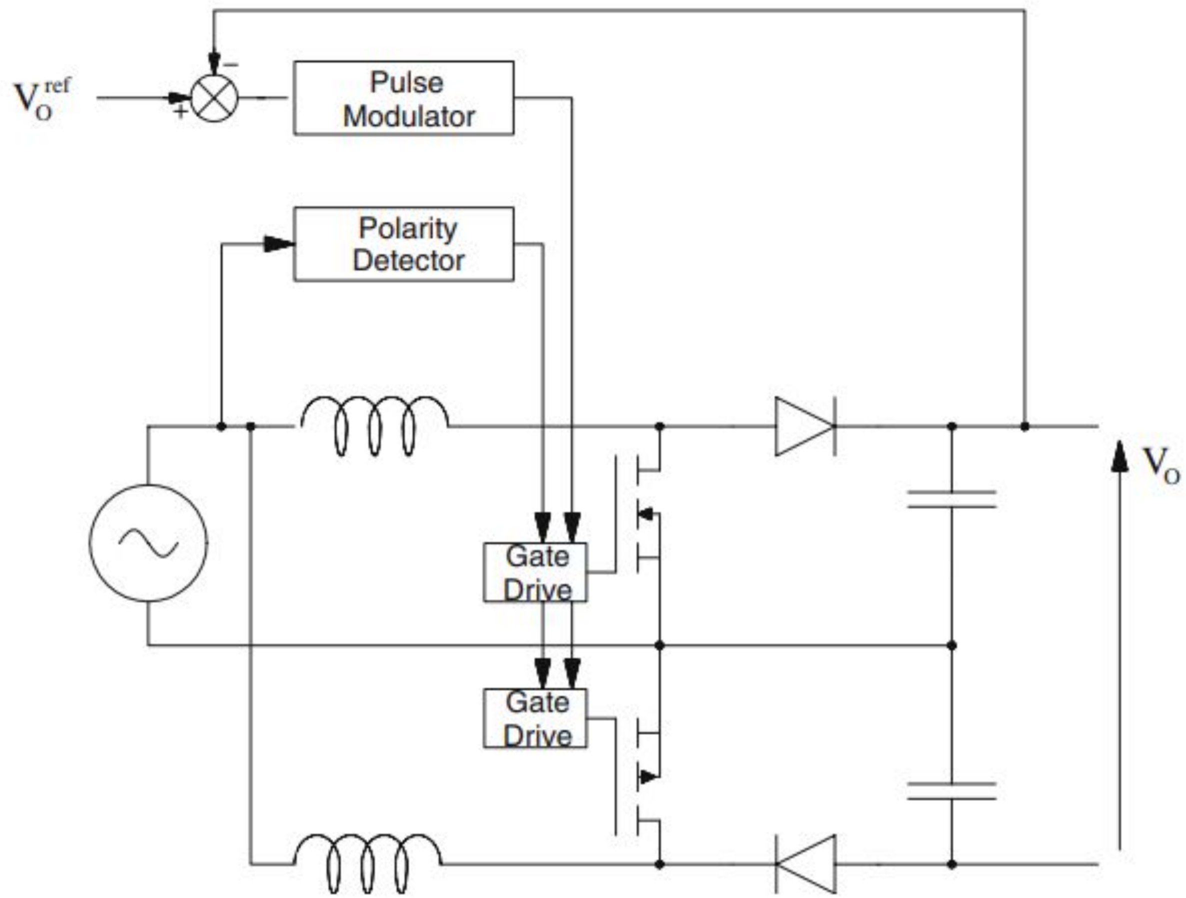
However the output becomes highly dependent on the input so this circuit has no practical values

Boost converter with both feedforward and feedback


Boost converter
D6
PR1
v -753.85mV
D1
D2
D3
D4
L1
D5
PR2
v 5.5344V
V1
3V
1kHz
0°
C1
1µF
0.037H
Q1
2N7000G
C2
10µF
R1
52kΩ
R5
1kΩ
R2
52kΩ
R3
1kΩ
R4
1kΩ
U1
U2
Q2
2N7000G
C3
1µF
V2
5V
1kHz
Feedforward
Feedback


Interactive 1
Stopped
None
PR1: V(1)
PR2: V(6)
Final output voltage
Noisy Sinusoid harvested voltage
6
5
4
3
2
1
0
-1
0
100m
200m
300m
400m
500m
600m
700m
800m
900m
1
1.1
Time (s)

Dual polarity Boost Converter



Design proposed in a paper

Isolated and Non isolated DC - DC converters

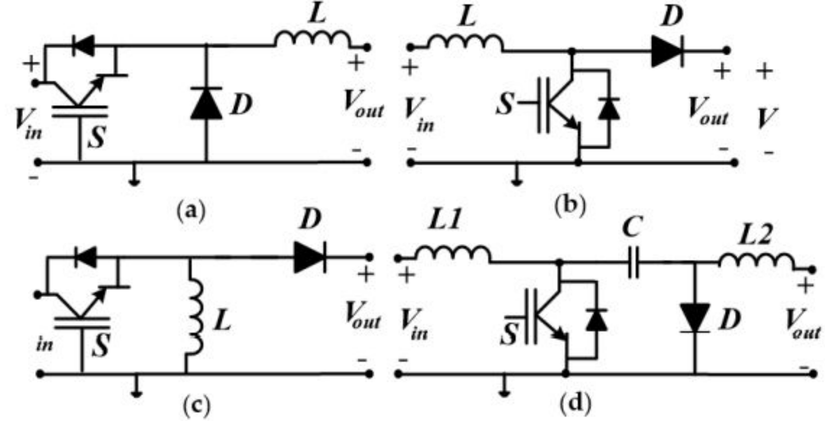


Figure 30. Numerous conventional non-isolated DC-DC converters: (**a**) buck, (**b**) boost, (**c**) buck–boost, and (**d**) Cuk [134].

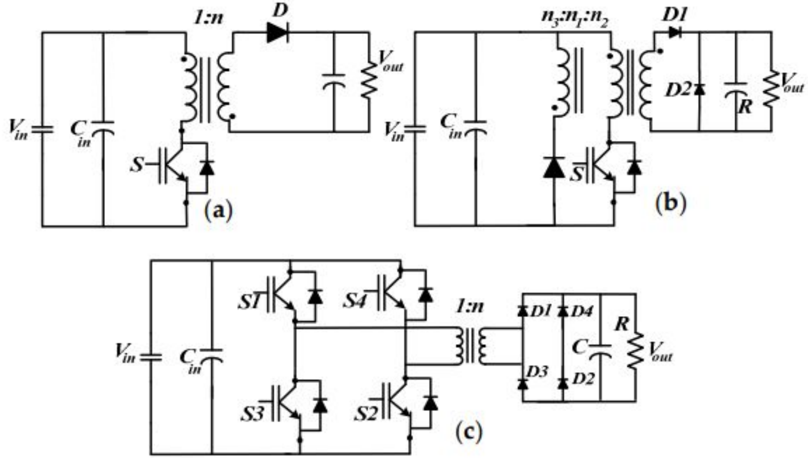


Figure 31. Isolated DC-DC converter: (**a**) flyback converter, (**b**) forward converter, and (**c**) full-bridge converter [134].