University of North Carolina at Charlotte  
Department of Electrical and Computer Engineering

Junior Design Lab 2-1

**H-Bridge DC-to-AC Inverter**

Lab 2-1

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**Objective:**

The objective of this lab was to design, model, and simulate an H-bridge AC-to-DC Inverter using four MOSFETs, amongst other design parameters, to provide AC voltage over a load with less than 1% ripple and provide a current through the inductor with less than 10% ripple.

**Relevant Theory:**

One of the primary advantages of an H-bridge DC-to-AC (DC/AC) inverter is its ability to produce bipolar output voltages. This means it can switch between positive and negative voltage levels, allowing for a true AC waveform. The H-bridge is composed of 4 MOSFETs, a PWM generator, and an output filter that transfers a given DC input voltage () to a load (. The resultant AC voltage signal () in a true inverter will be 180° out of phase with the input voltage.

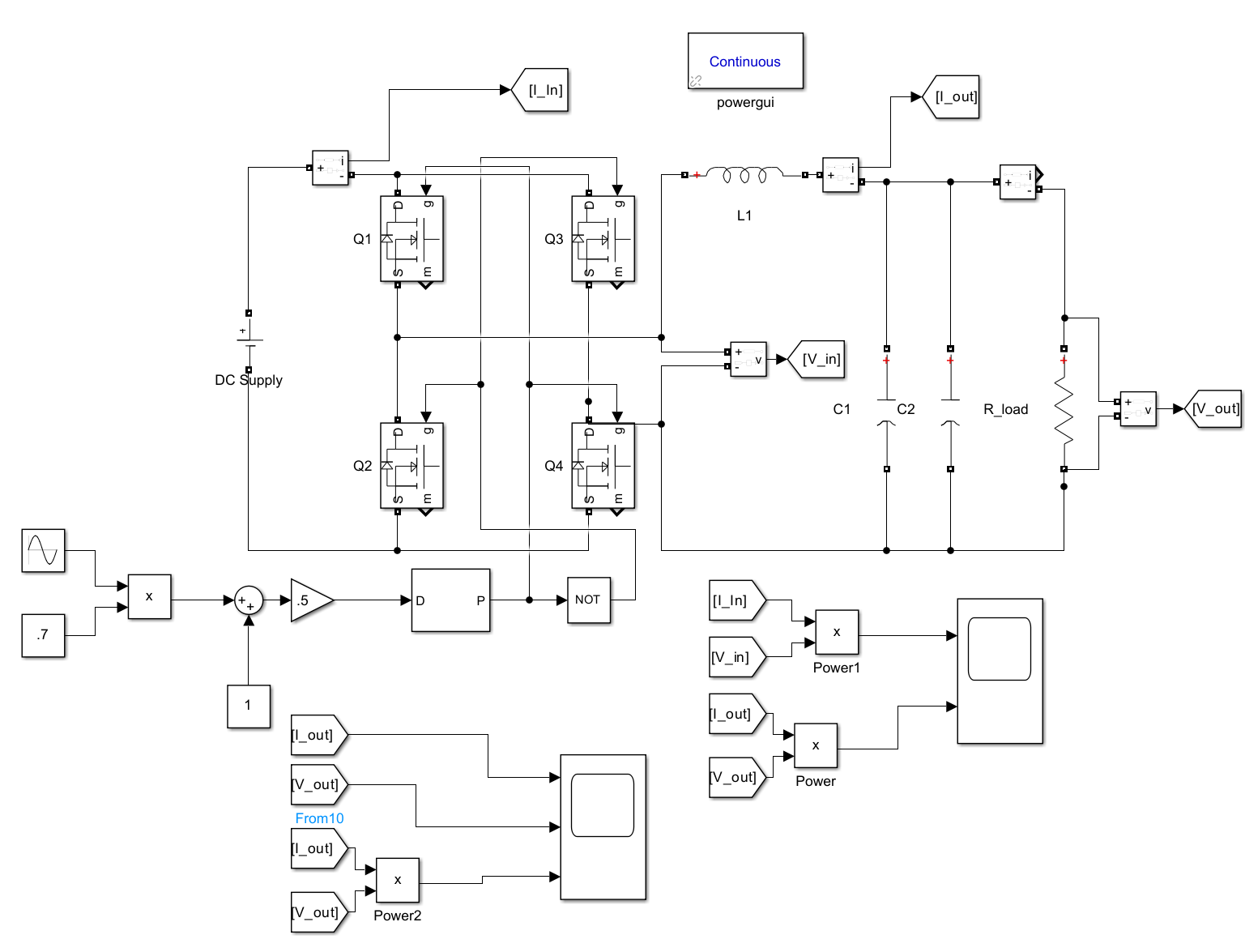
In the United States, the typical AC voltage frequency supplied to homes is 60 Hz, which we identify as our output frequency ￼￼) values in our DC/AC inverter circuit. A true inverter shifts the phase of the input voltage by 180 degrees. To accomplish this, the natural frequency () of the second-order LC filter should be . Natural frequency of the ￼ filter is given as:

**Design Parameters:**

* Power rating: 200W- 400W
* DC voltage supply (input): 30V-40V
* Switching frequency: 10kHz – 50kHz
* Duty Cycle: 70% - 85%
* Current ripple in the inductor: less than 10% of the max current
* Output voltage ripple measured at the load: less than 1% at the max load

**Design Elements:**

* (4) MOSFETS
* 520 µH Inductor
* (2) 68 µF Capacitors
* 1.96 Ω Resistor
* DC Voltage Supply (Capable of 40V)
* PWM Generator
* Other elements needed to run the simulation (not essential in the converter operation)

** Schematic:**

**Questions:**

1. **Define your nominal operating conditions and specifications, i.e., switching frequency, input voltage, duty cycle, load resistance value, inductor and capacitor values, etc. Provide a justification on how to pick your inductor and capacitor values. Use standard values for capacitor values. I suggest using ceramic capacitors for filtering, voltage rating of about 100VAC. If you need a bigger capacitance for filtering, you can use Film capacitors.**

|  |  |
| --- | --- |
| **Design Specifications** | **Values** |
| Switching Frequency (*f)* | 10 kHz |
| DC Input Voltage (V­in) | 40 Volts |
| Duty Cycle (D) | 70% |
| Power Rating (P) | 400W |
| Load Resistance value () | 1.96 Ω |
| Inductor () | 520 µH |
| Capacitor (C) | 136 µF |

**Load Resistance:** To accommodate the maximum power rating specified in our design parameters, we opted for a power rating of 400 Watts for our system.

Solving for and in the equation for , we get the following equations for inductance and capacitance:

**Inductor:**

**Capacitor:**

1. **Provide the theoretical input-output voltage relationship. This is sometimes called conversion ratio. With your simulation, include a plot showing the input and output voltage. Does it follow the theoretical (calculated) value?**

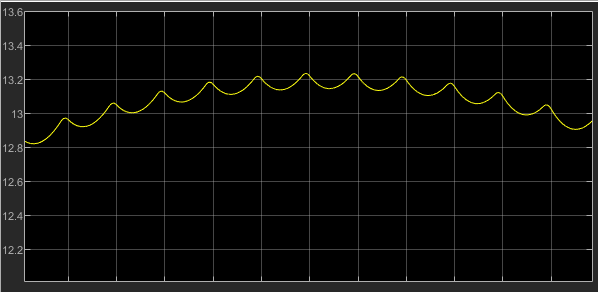
**Load Voltage:** Toaccount for low quality MOSFETS, we chose a Duty Cycle of 70%.

1. **At different instances (three or more), measure the current ripple in the inductor and voltage ripple across the output (capacitor) at your nominal operating point? With your simulation include a plot with your measurements.**

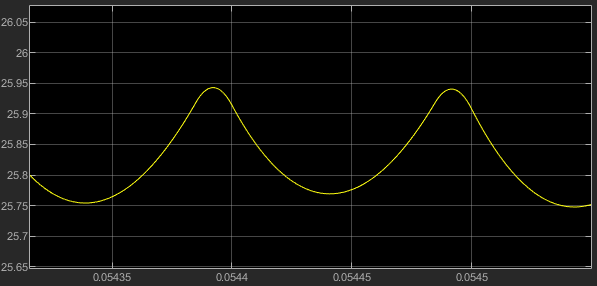
**Voltage Ripple:**

**Maximum Output Current:**

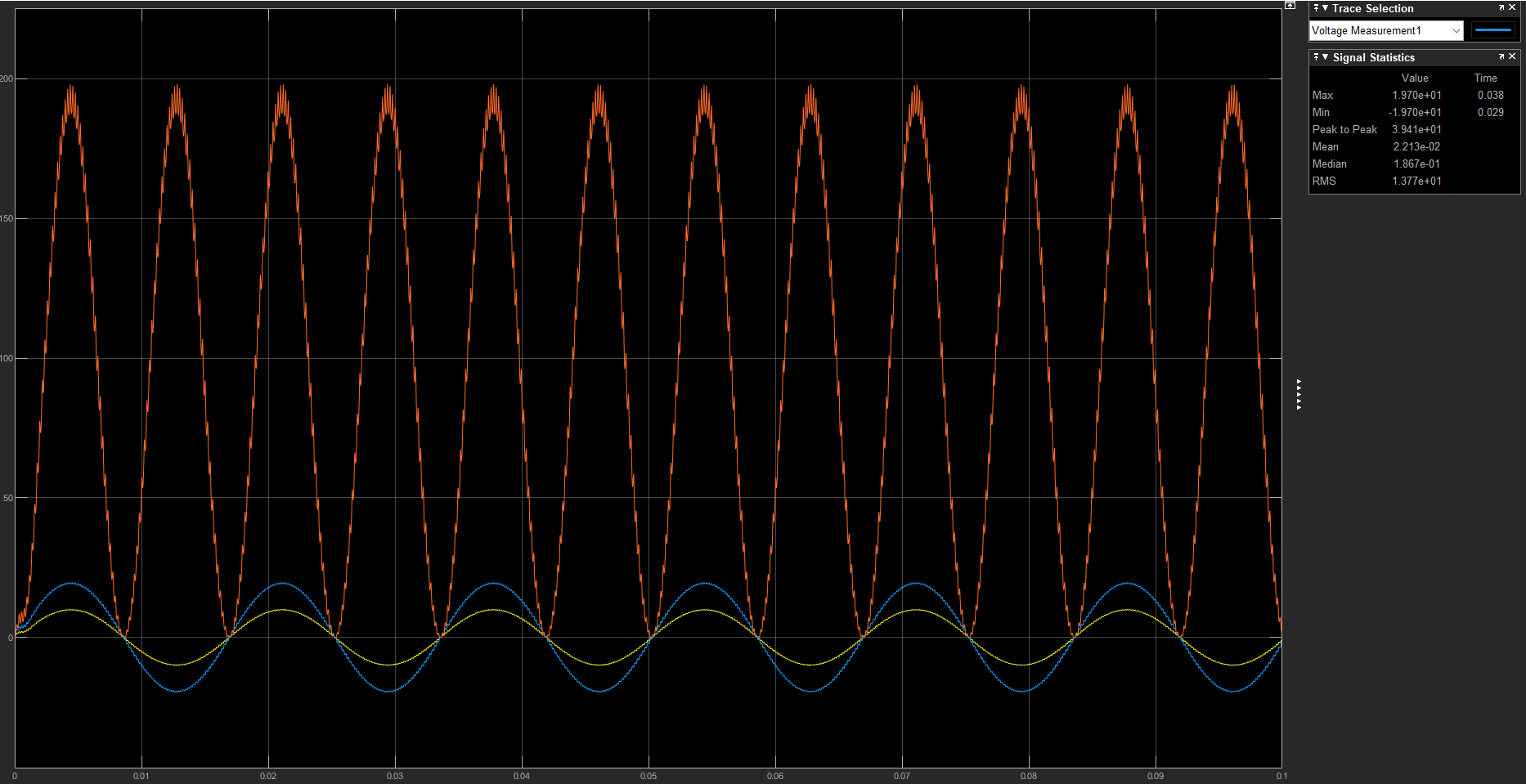
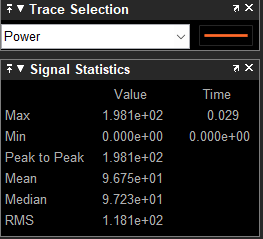
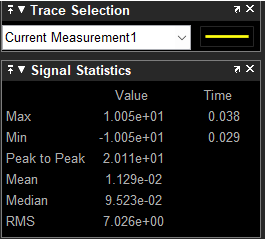
**Ripple Current:**

**Current Ripple: less than 10%**

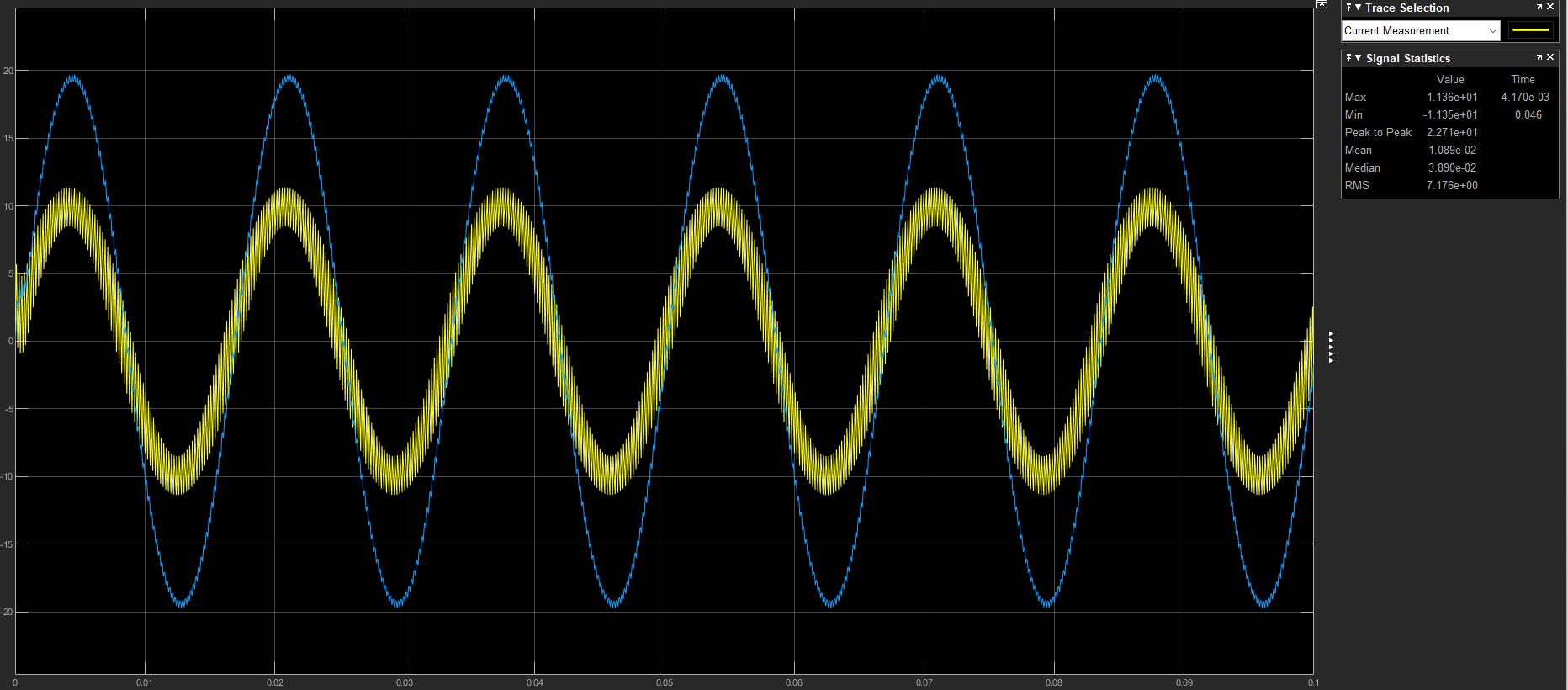
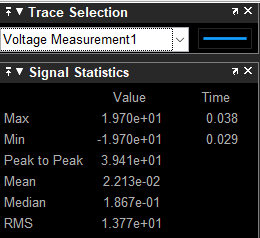
**Voltage Ripple: less than 1%**

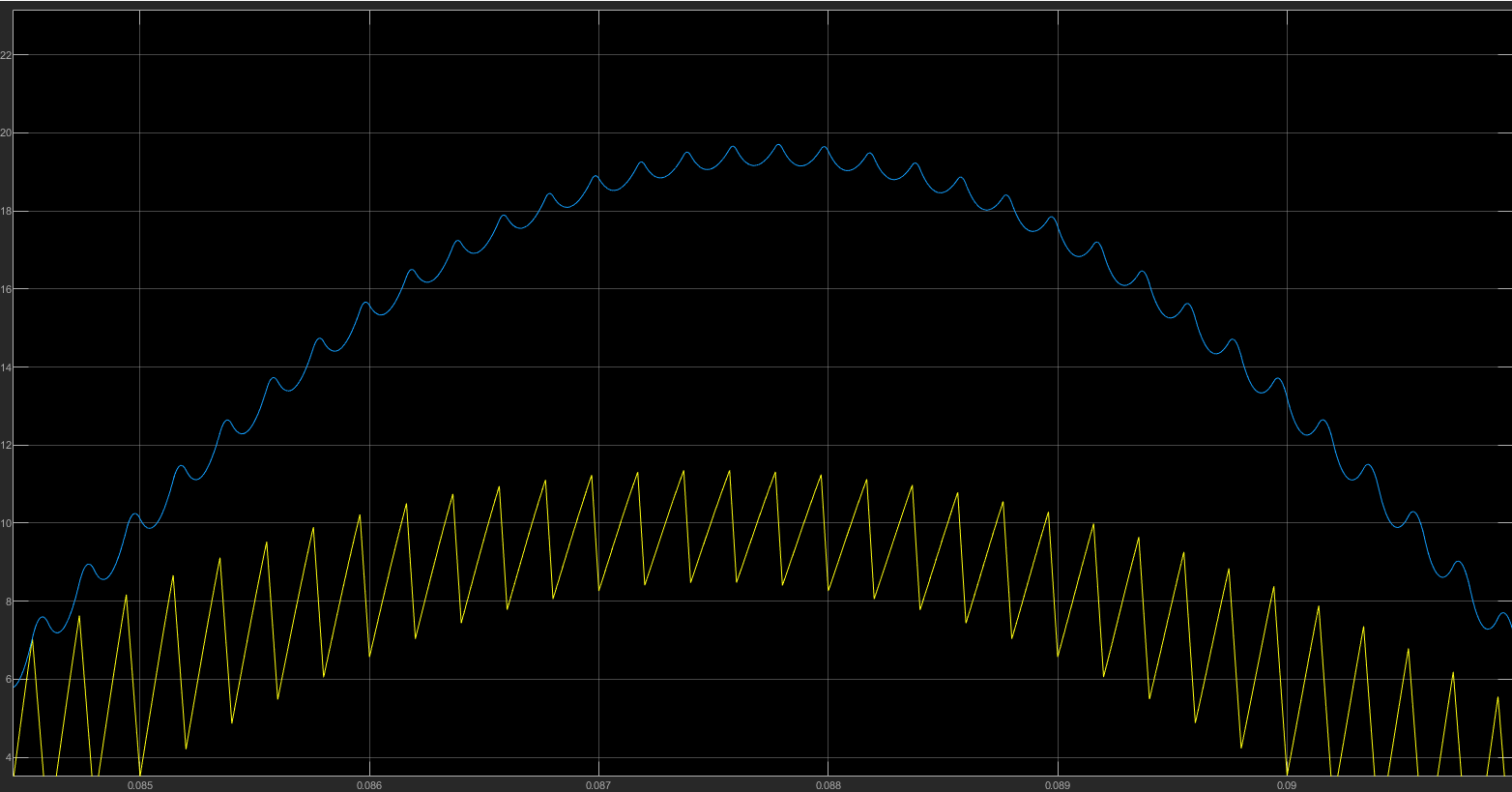
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1. **Change the input voltage ±10V and run your simulation.**
   1. **In one plot, measure the output voltage, output current, and output power.**

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* 1. **In another plot, show the inductor current and output voltage. Measure the inductor current ripple and output voltage ripple at different instances. Compare them with your nominal operating point.**

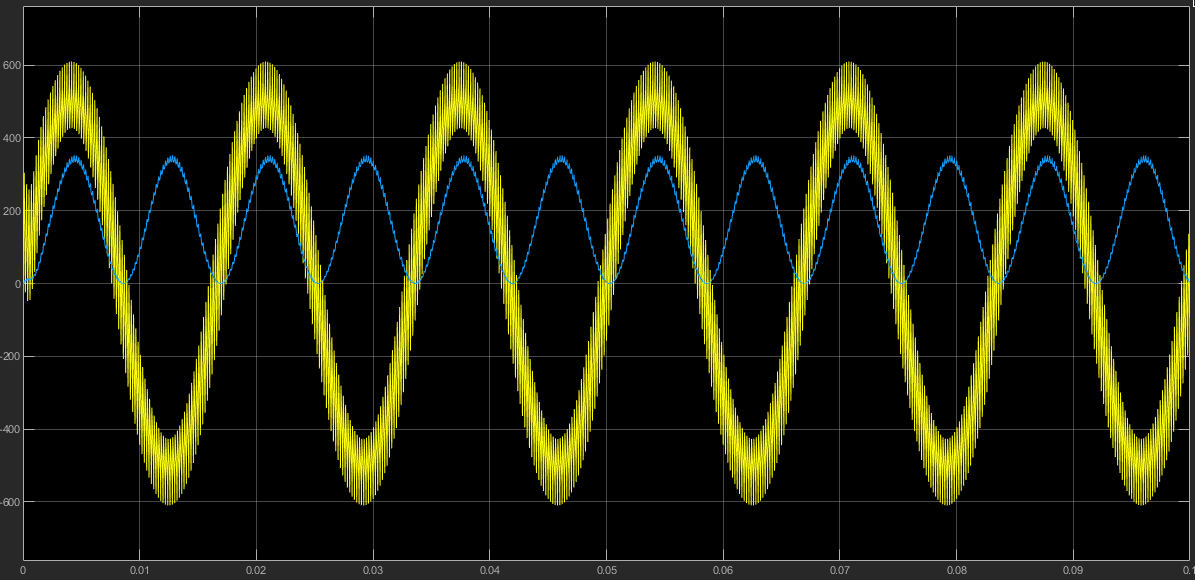
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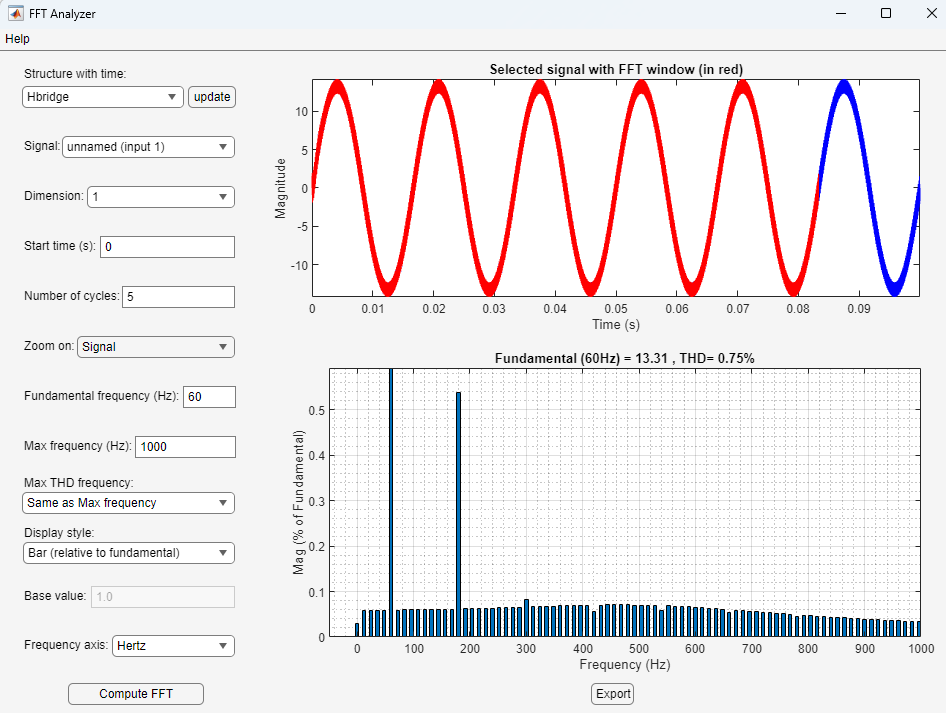
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The voltage ripple is ~ 0.48-0.55 Volts.

The current ripple is ~ 2.4-2.6 Amps.

1. **Capture the input and output power by multiplying the respective current by voltage.**

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1. **Measure the total harmonic distortion (THD) of the output current. Make sure it is less then 5%. If not, you need to change your filter values. You can use the FFT tools available in MATLAB/Simulink, Simscape library. You can use find the “FFT Analysis” under “Tools” tab in Powergui block. To use the FFT Analysis Tools, you need to log the data: open the Scope when you capture the measurements. Under “view”, Configuration Properties, Logging, check “Log data to workspace”. Assign a name for the “Variable name” and change the save format to “Structure With Time”.**

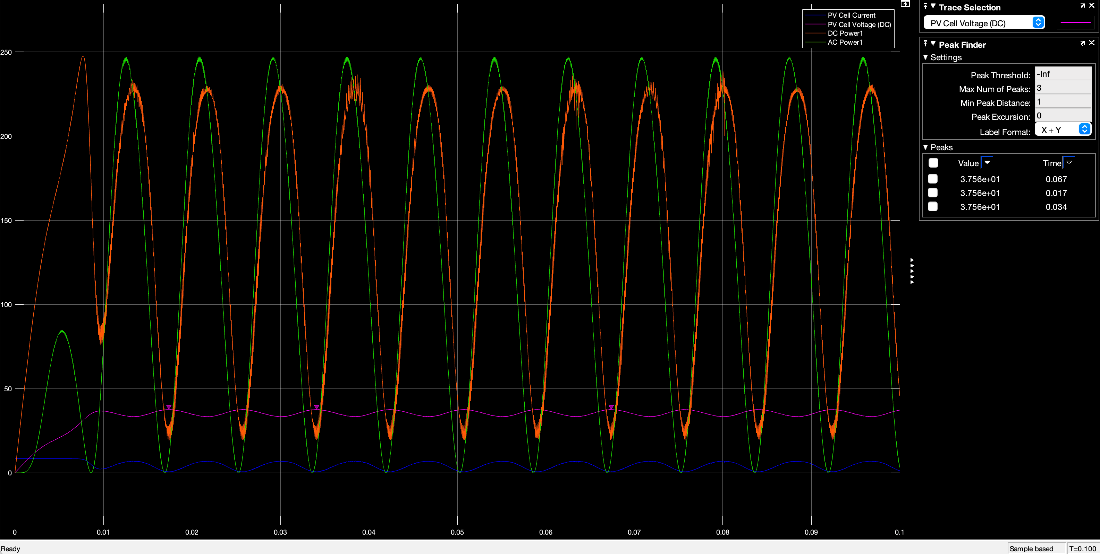
**EXERCISE 2: Simulation of H-bridge DC/AC Inverter with PV**

**Objectives:**

- Getting familiar with how a PV source operates when interfaced with an H-bridge PV Inverter.

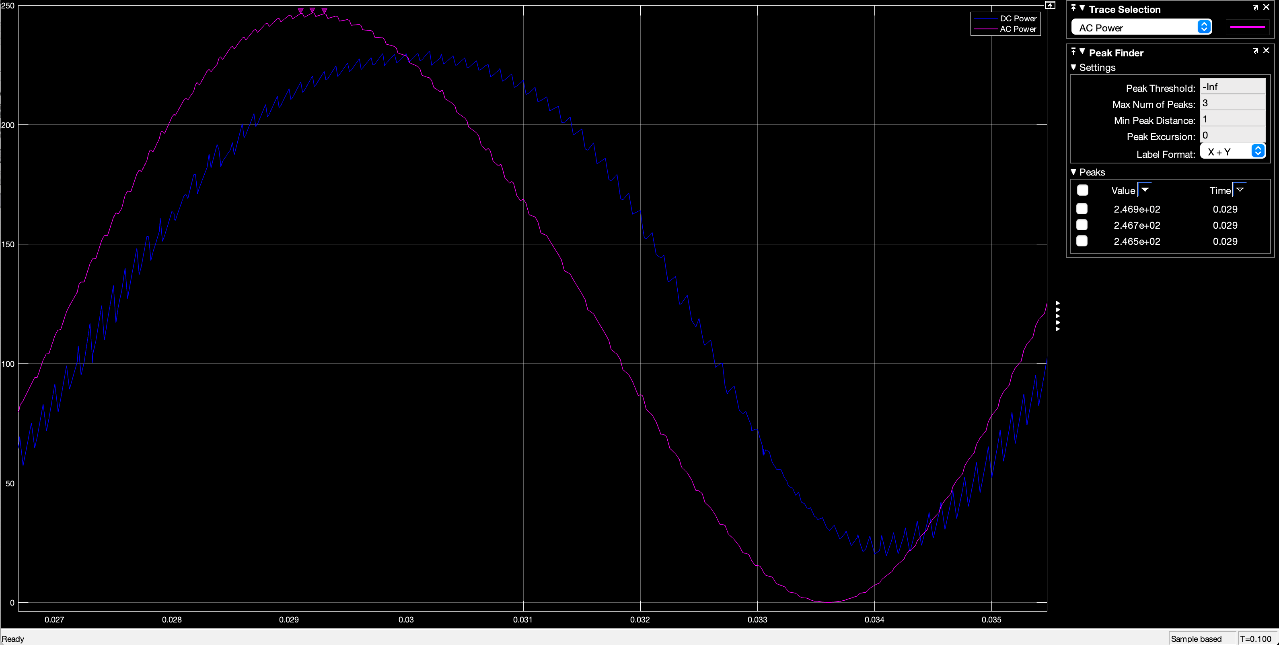
**You need to take the “PV Array” block from the Simulink Library. Choose the SolarWorld Sunmodule Plus SW 250 mono Black from the Module data drop-down list. We use only one panel throughout the lab. First, consider the nominal operating points defined in the PV panel datasheet (mentioned in the Simulink interface too). Use the nominal parameters you have chosen in Exercise 1. You need to consider a DC link capacitor in parallel to the PV panel.**

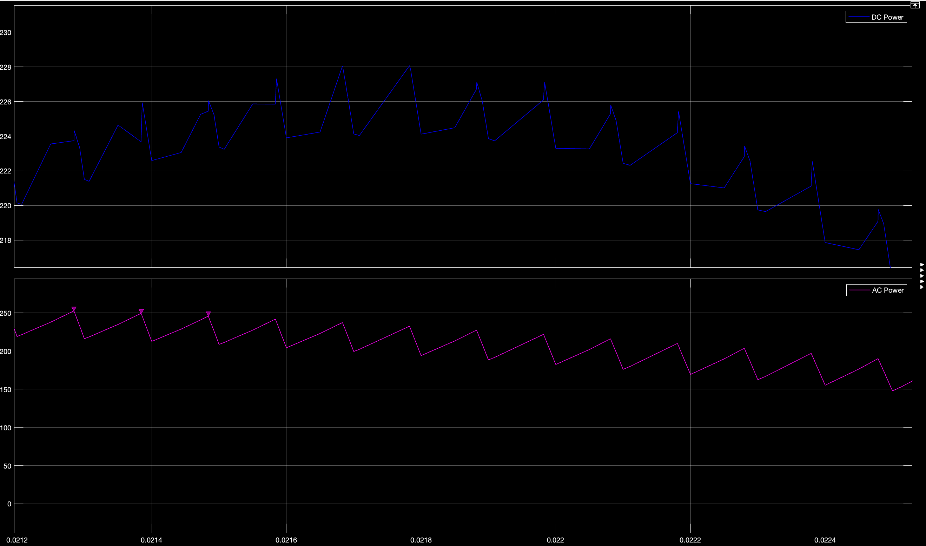
1. **Capture the PV outputs: voltage, current and power. In the same plot, capture the output (AC) power, load resistor. Choose a small value for the capacitor, i.e. 10e-6 F. Can you measure the DC link voltage ripple?**



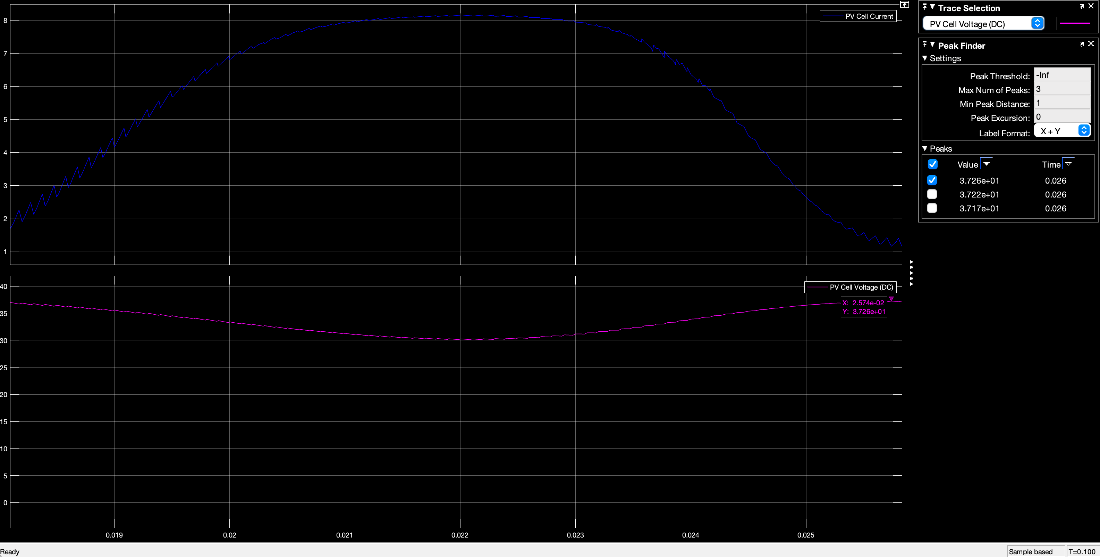
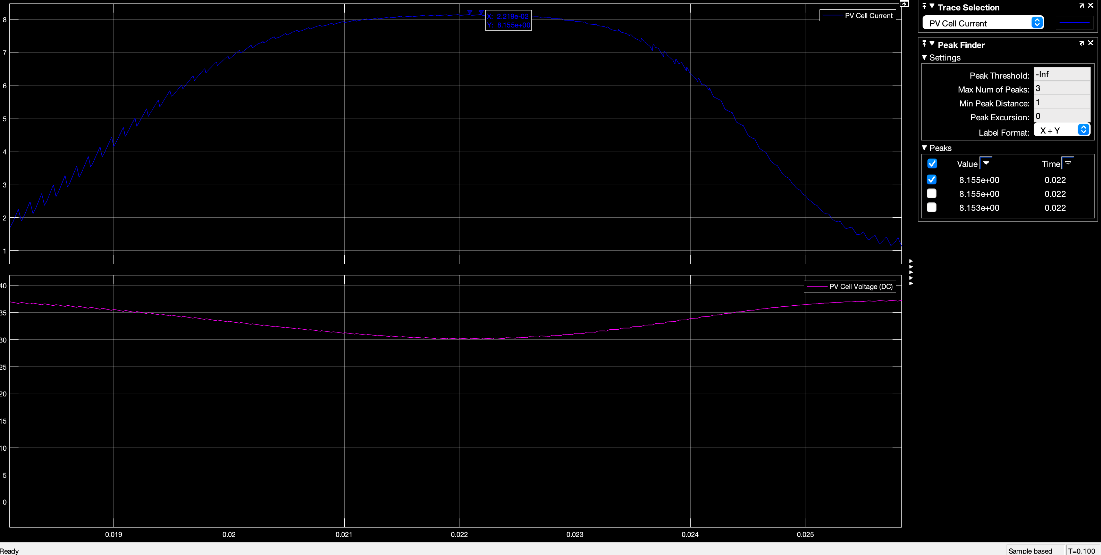
* 1. The DC link voltage ripple was measured at when using a capacitance of 10 µF

1. **Increase the value of the capacitor such that the PV voltage (DC link voltage) ripple is than two volts. Report on the final value for the capacitor with your voltage ripple measurement. You may need to increase your simulation time to reach a steady state condition.**
   1. The capacitance value used to produce a ripple of less than 2 is 1.5mF
2. **With the new DC link capacitor value, capture the DC and AC power. Is it the max. power available from the PV? How much is the ripple in the DC power measured at the PV panel?**
   1. The PV panel (SolarWorld Sunmodule Plus SW 250 mono black) is rated for max 250.355 W of power. The AC Power is transferring the maximum energy potential from the PV panel to the load. The DC power ripple is approximately 4 Watts or ~1.6%.

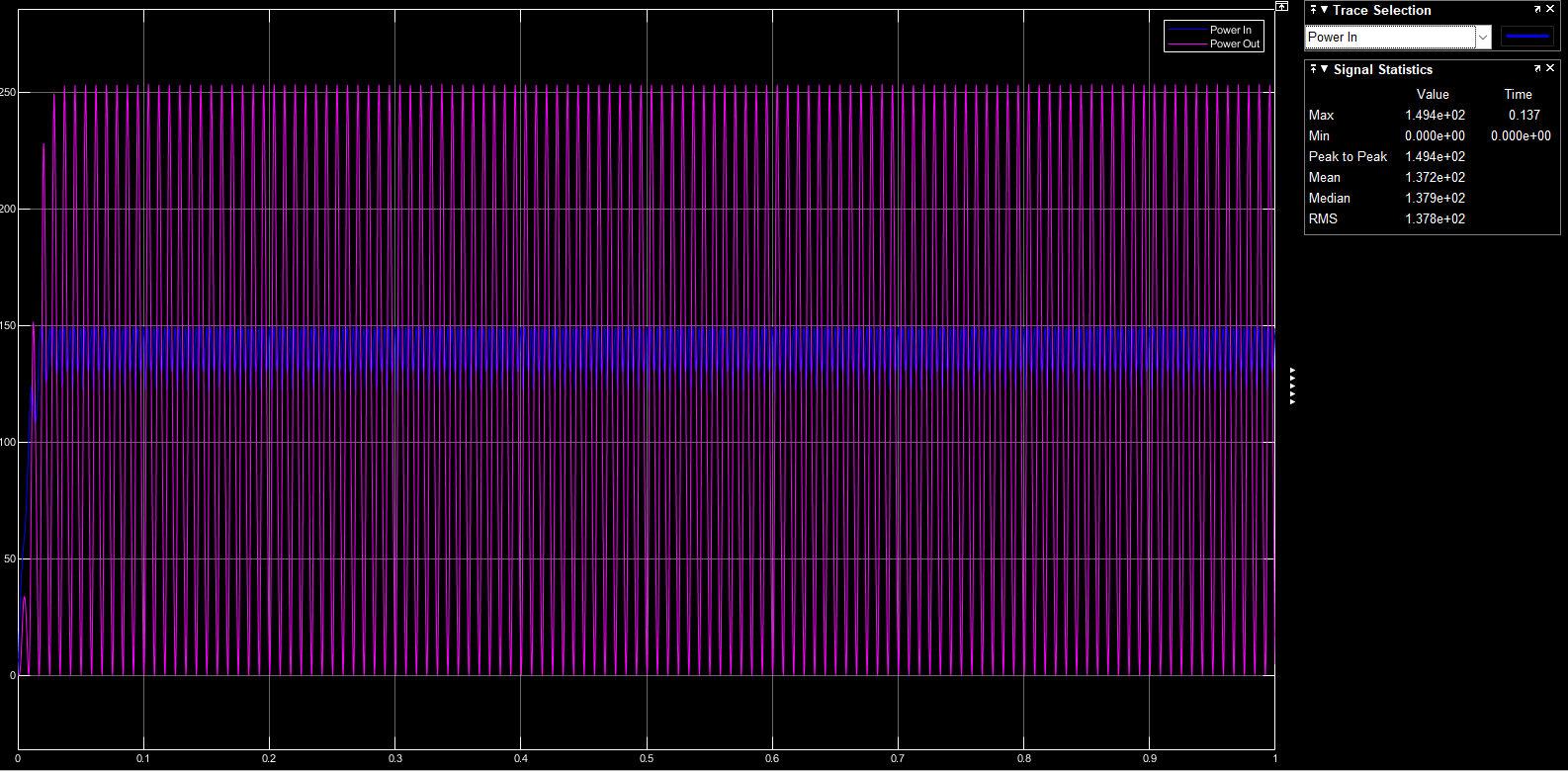
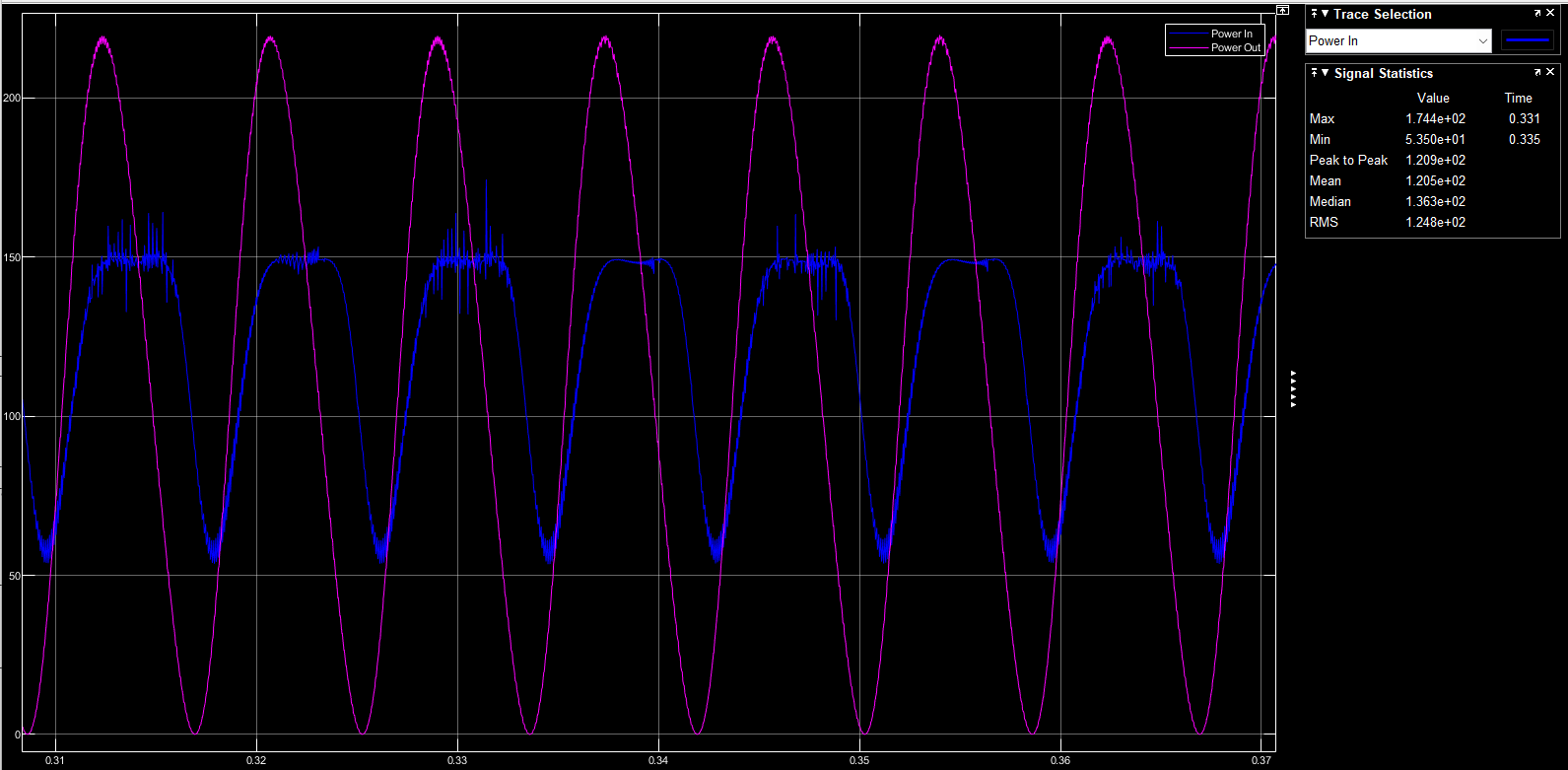
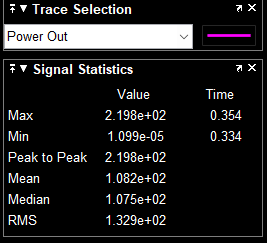
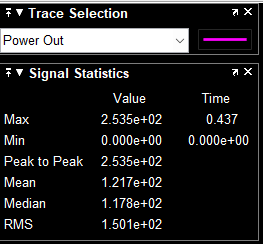




1. **Alter the load resistance value and/or duty cycle to capture the maximum power available in the SolarWorld PV panel. You will have oscillations. Record and report the values. Record the DC voltage and current and compare them with the datasheet.**
   1. The load resistance for maximum power is 1.96. A duty cycle of 85% results in a max AC power output of 330W and 70% duty cycle results in a 265W output. These are the max and minimum bounds of the duty cycle parameters given for the lab. To maximize efficiency, the PV cell can only supply a maximum power of 250.355W. So, to capture the maximum power of the PV cell a duty cycle of 70% is sufficient.
   2. The max voltage we receive from the PV cell is 37.26V and max current from the cell is 8.16A. Maximum open circuit voltage and short circuit current from the datasheet of the SolarWorld Sunmodule Plus SW 250 mono black is 37.8V and 8.28A, respectively.

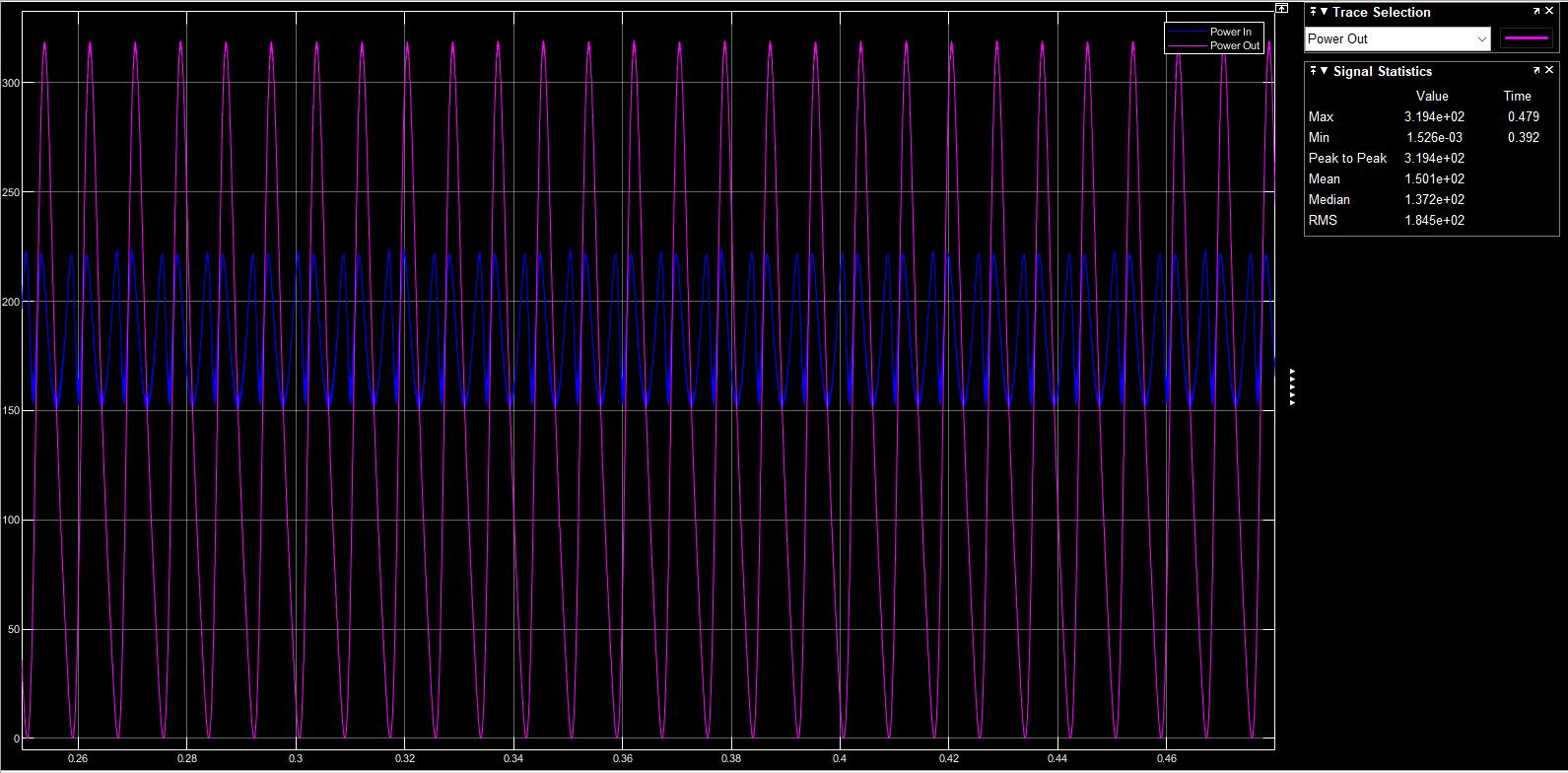


1. **Change the irradiance level to 600 W/m2. Measure the input and output power. Alter the load resistance to maximize the output power. What is the PV voltage? Compare it with the voltage recorded in the previous problem.**

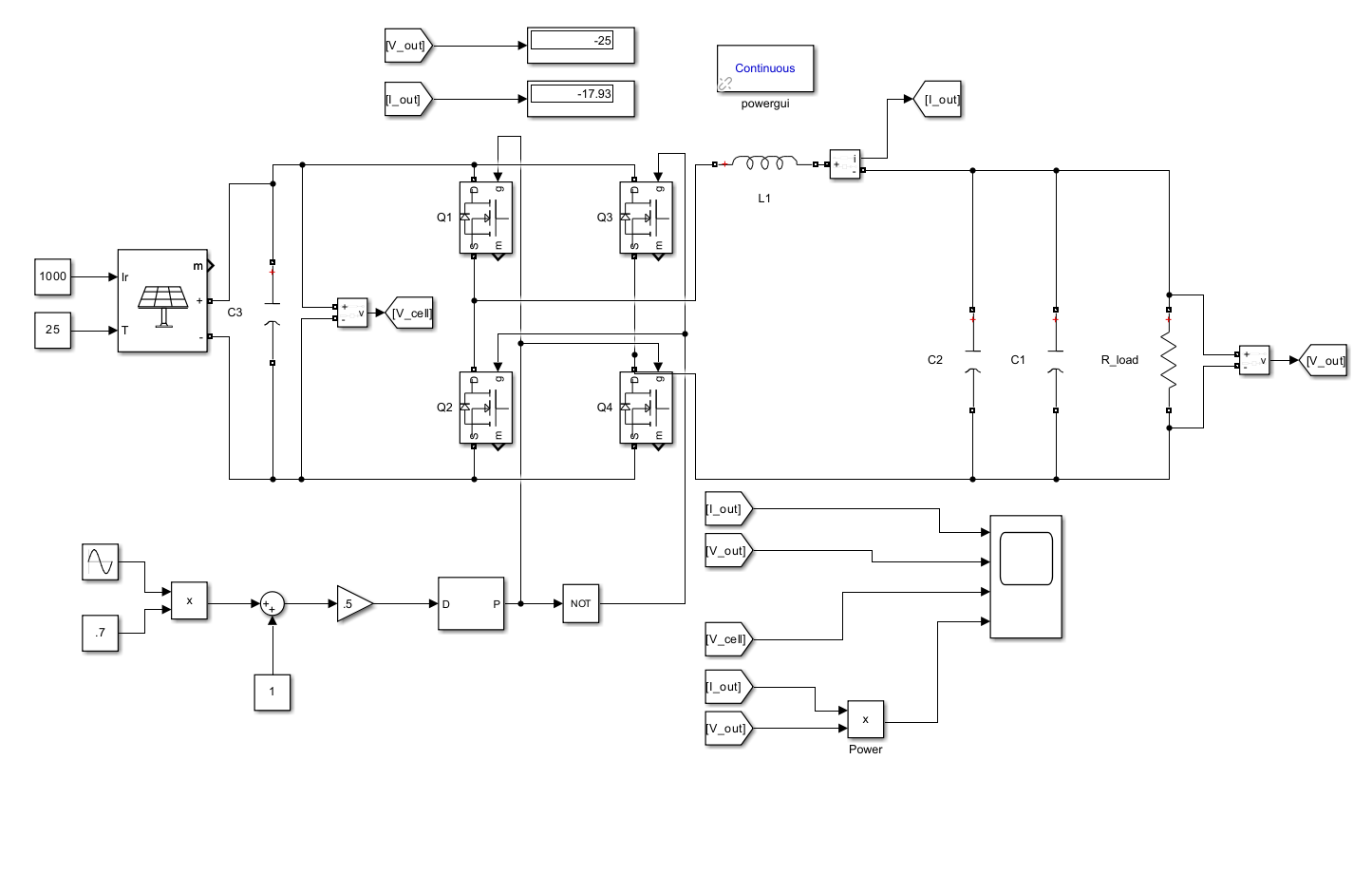
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Maximum power was achieved at around 1.4Ω with a voltage of 26.9. PV voltage is lower at an irradiance level of 600 W/ in comparison to the nominal 1000 W/

1. **Use the nominal irradiance level of 1000 W/ but now at 50-degree C. Repeat the simulation. Alter the load resistance to maximize the output power. What is the PV voltage? Compare it with the voltage recorded under nominal operating points.**



The output voltage peaked at 32.8 when subjected to a 0.6Ω load. This voltage, although lower than what's observed under nominal conditions, remains higher than the value recorded at 600 W/ and 25°C.

**Schematic:**

**Conclusion:**

This study aimed to meticulously design, implement, and evaluate an H-bridge DC to AC inverter. The results confirmed the successful conversion of a direct voltage to an alternating voltage output. The H-bridge did not merely function correctly but exhibited outstanding consistency and reliability throughout rigorous tests. The waveforms measured with the oscilloscope closely matched our theoretical expectations, outputting a clear sinusoidal wave with a 180° phase shift in reference to the input, confirming the functional operation of the H-bridge inverter. The robust performance and versatility of the H-bridge make it advantageous for renewable energy systems.

A subsequent enhancement in our experimentation involved the substitution of the original DC source with a high-caliber SolarWorld Sunmodule Plus Photovoltaic cell array, paired in tandem with a capacitor. This modification was instrumental in emulating real-world scenarios. Our revamped circuit demonstrated exemplary efficiency, transferring the maximum power output from the PV cell panel, under conditions mimicking peak solar irradiance (1000 W/m^2 at 25°C), to our predetermined load with an AC power ripple of 1.2% and voltage ripple of <1%.

**Appendix:**

GitHub:[**https://github.com/RocketDan11/JuniorDesign**](https://github.com/RocketDan11/JuniorDesign)