Lab #3

Is the load connected?

Yes, the load is connected.

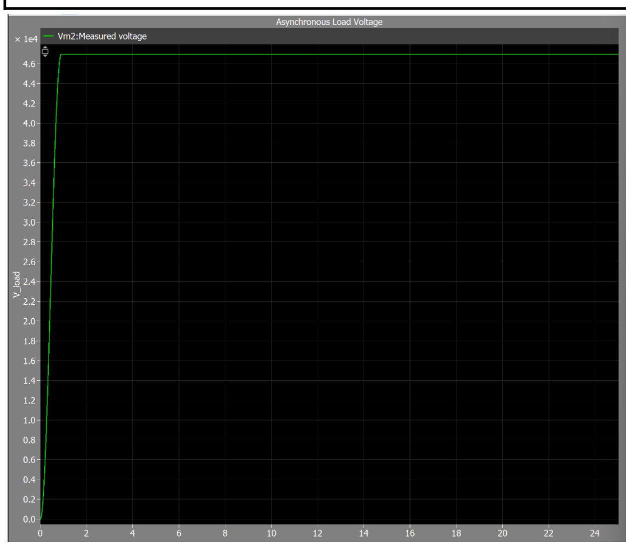
In an unloaded asynchronous boost converter, the output voltage will increase unbounded. Does this matter if you operate your synchronous boost converter? Why/Why not? (5 pts).

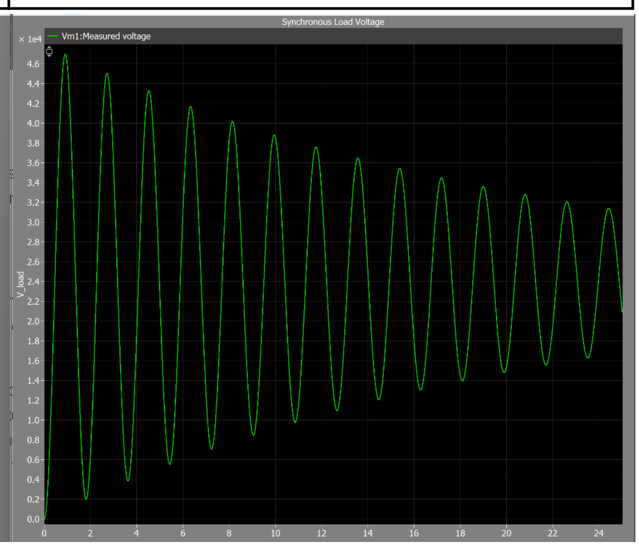
For an asynchronous boost converter, we use a combination of a Diode and a MOSFET. Because current can only flow unidirectionally (i.e., one way) through the Diode, the capacitor on the load side will be able to charge, however, it will not have the ability to discharge through the Diode. As a result, the voltage will increase unbounded.

For a synchronous boost converter composed of two MOSFETs switching in a complimentary manner, the current will be able to flow bidirectionally (i.e., both ways) through the MOSFET connected to the load. As such, the capacitor is able to discharge through the MOSFET. This means the voltage will not increase unbounded. It is also important to note that there is no DCM (Discontinuous Conduction Mode) operation for the synchronous boost converter.

Below is a PLECS screenshot depicting this phenomenon:

Nonsynchronous	Synchronous



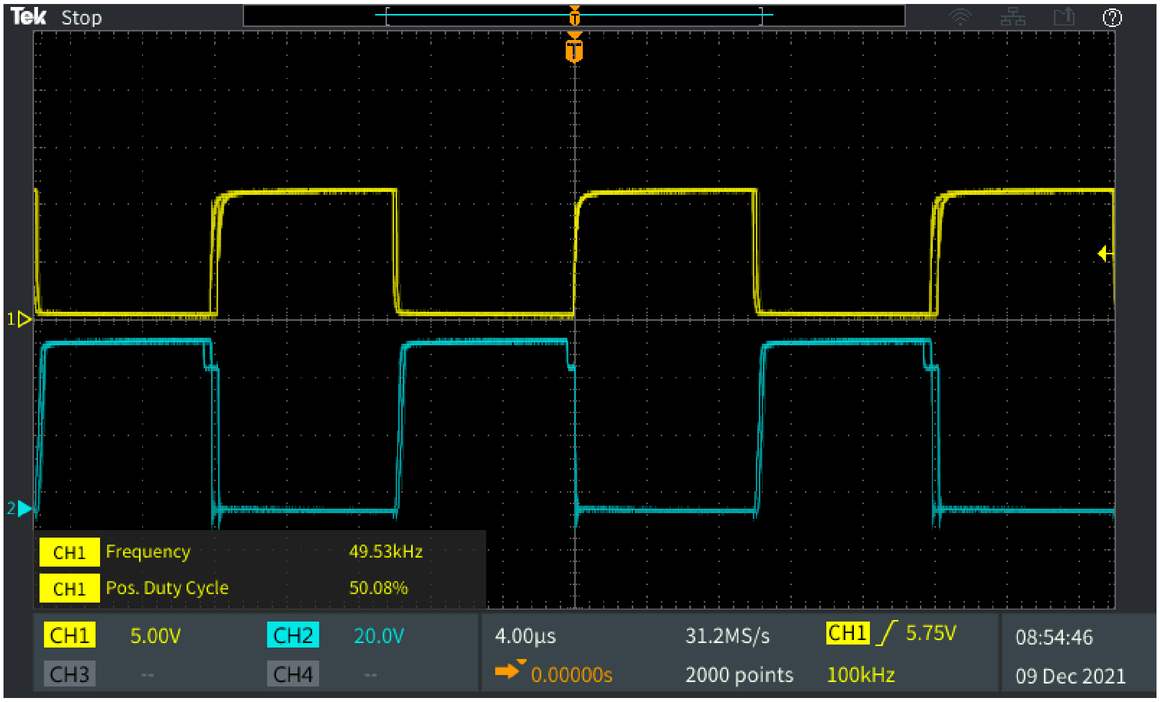


Make a table of the power stage components and experimental conditions. This should include the inductor, power MOSFETS, input and voltage levels, corresponding load levels and expected currents (5 pts).

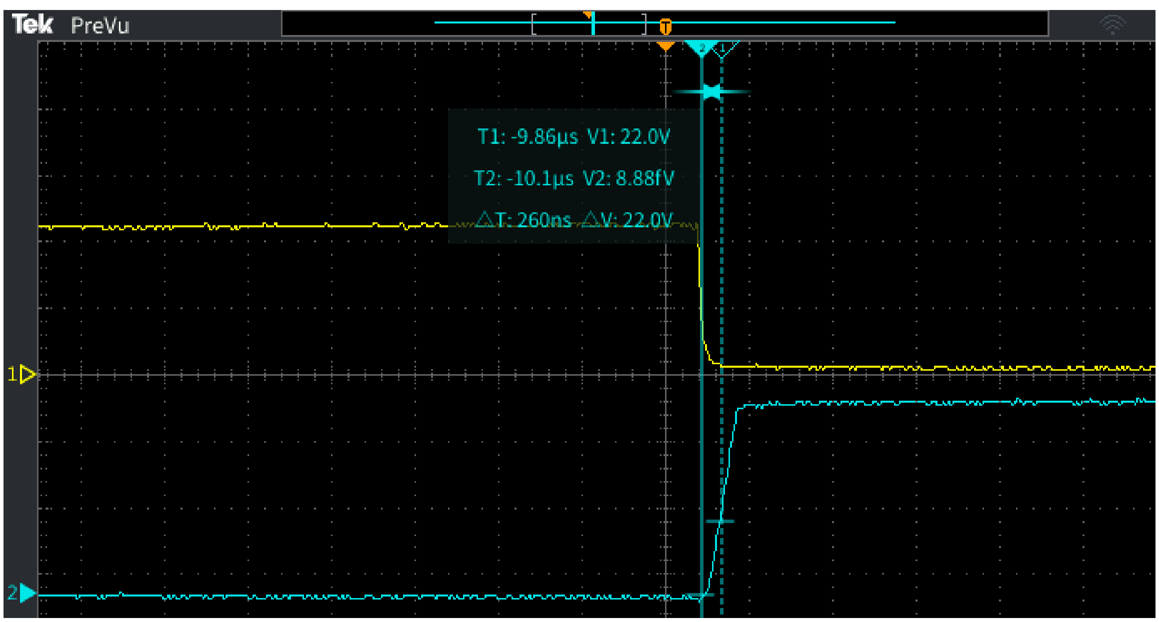
Inductor	*Expected:* L = 200 μH || R = 40 mΩ
	Actual: L = 270 μH || R = 35 mΩ
MOSFETs *(for both power MOSFETs)*	CSD19535KCS
Electrolytic Capacitor	8AX200MEFC6.3X7
TVS Diode *(Transient Voltage Suppression Diode)*	1.5KE75A
MOV *(Metal Oxide Varistor)*	V100ZA15P
Voltage	*Input:* $V_{in} = 24\,V$
	Output: $V_{out} = 48\,V$
Loads	*Load #1*: R_{LOAD} = 100 Ω, I_{LOAD} = 0.48 A
	Load #2: R_{LOAD} = 200 Ω, I_{LOAD} = 0.24 A
	Load #3: R_{LOAD} = 300 Ω, I_{LOAD} = 0.16 A
	Load #4: R_{LOAD} = 400 Ω, I_{LOAD} = 0.12 A

Capture 1: HO and LO of gate driver. User cursors to find the deadtime and compare with deadtime given in the datasheet. (10pts)

No deadtime present; this is probably due to power-stage components



Blue → HO || Yellow → LO



Blue → HO || Yellow → LO

Capture 2: (EE452 optional) Voltage waveform across bootstrap capacitance. This is a floating voltage, so make sure only 1 probe is connected to the oscilloscope. (10 pts)

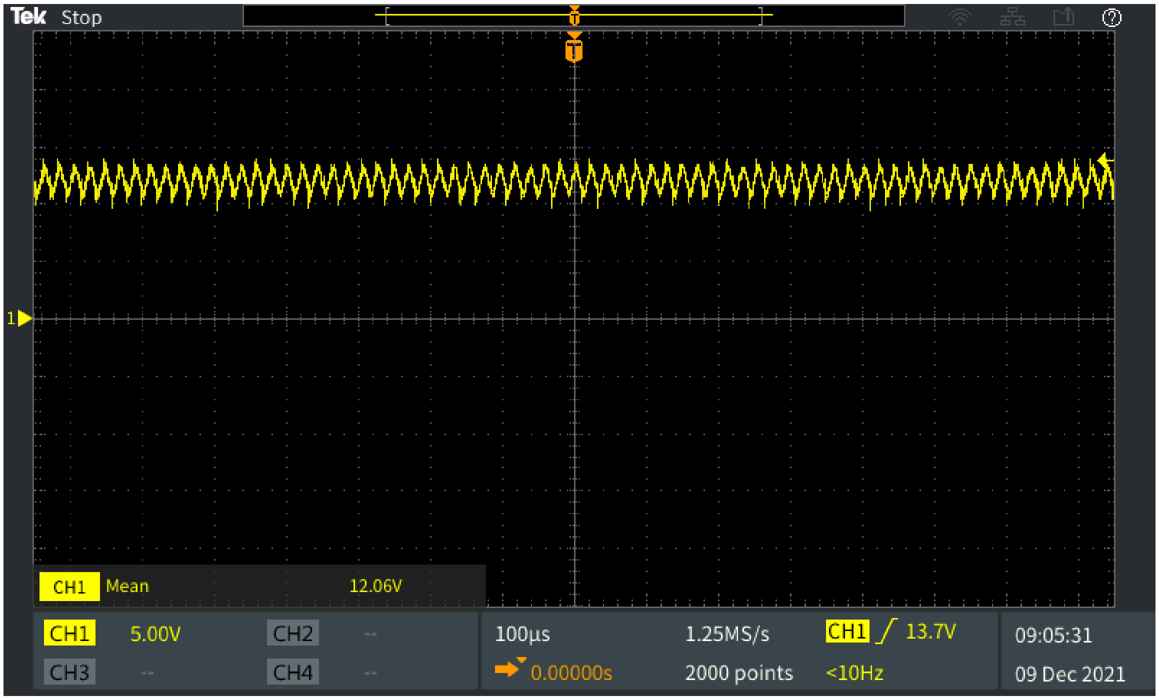


Figure: Bootstrap Capacitance Waveform

Take a photograph of your setup and annotate the image by labeling the each module: drive circuit, power stage, auxiliary power supply, etc.(15 pts).

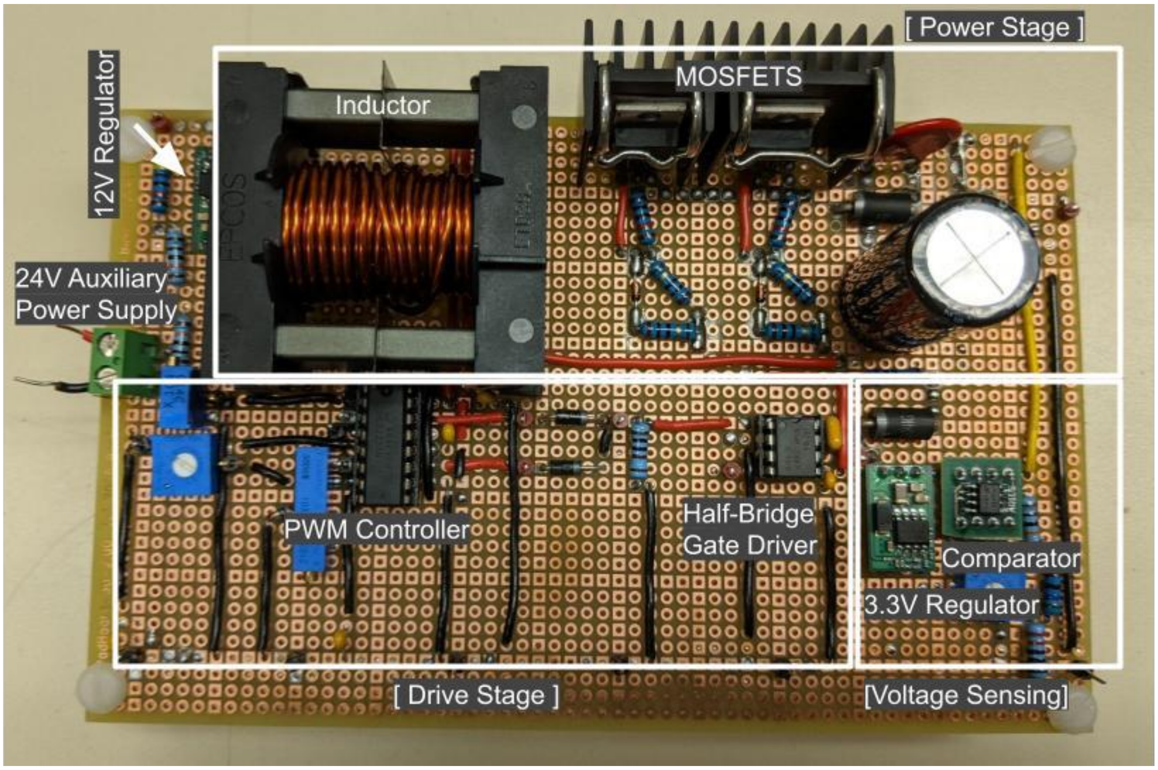


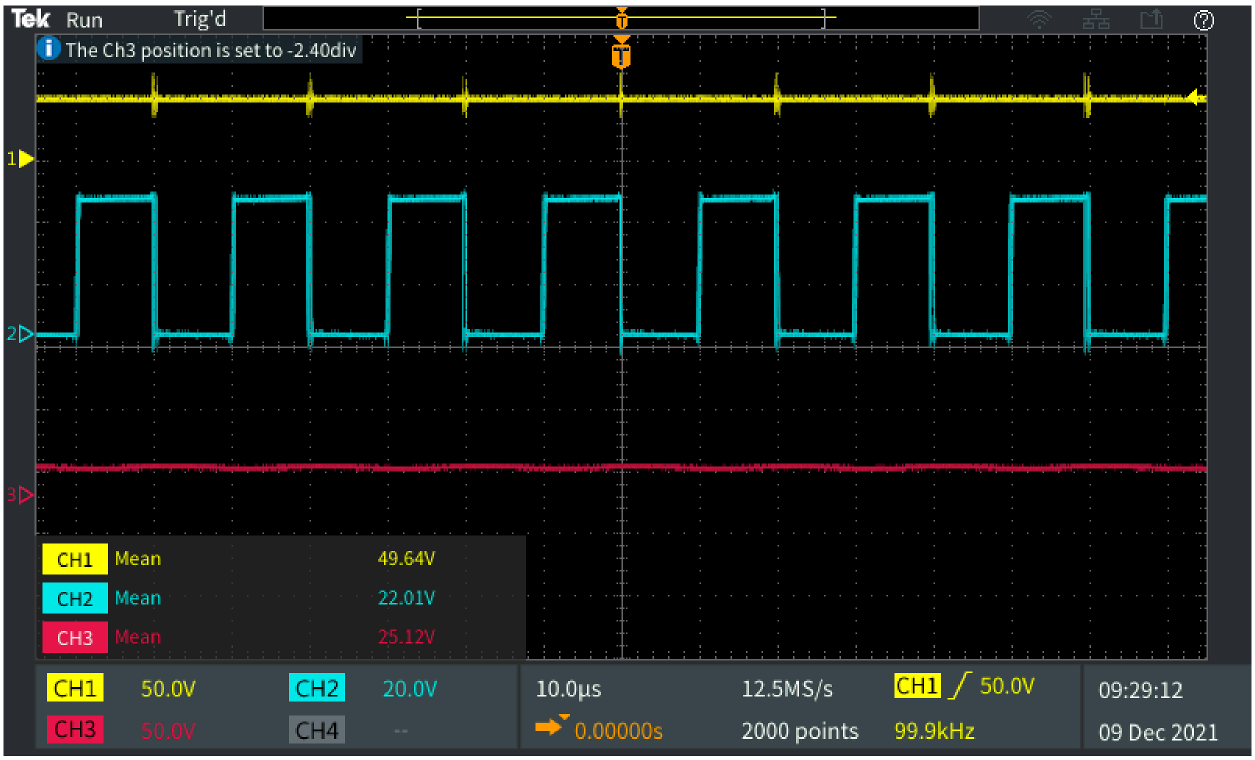
Figure: Labeled Setup

Following the same startup procedure explained in the previous paragraph, record the following waveforms/quantities for 4 different power levels (different load resistances) (Vin=24V, Vout=48V).

Note that a significant noise bias (1-5 V) was present in our oscilloscope DCV measurements at the Volts/Div and Probe Attenuation settings that we used, thus oscilloscope captures for input/output voltages below are for illustrative purposes only. Input/Output data used for calculations were measured with the Keysight and Keithley Digital Multimeters (see appendix for details).

- **R_{LOAD} = 100 Ω**

Load R_{LOAD}	**Input**		**Output**	
	V_{in} *(Volts)*	**I_{in} *(Amps)***	**V_{out} *(Volts)***	**I_{out} *(Amps)***
100 Ω	24	0.98729	46.3015	0.46544

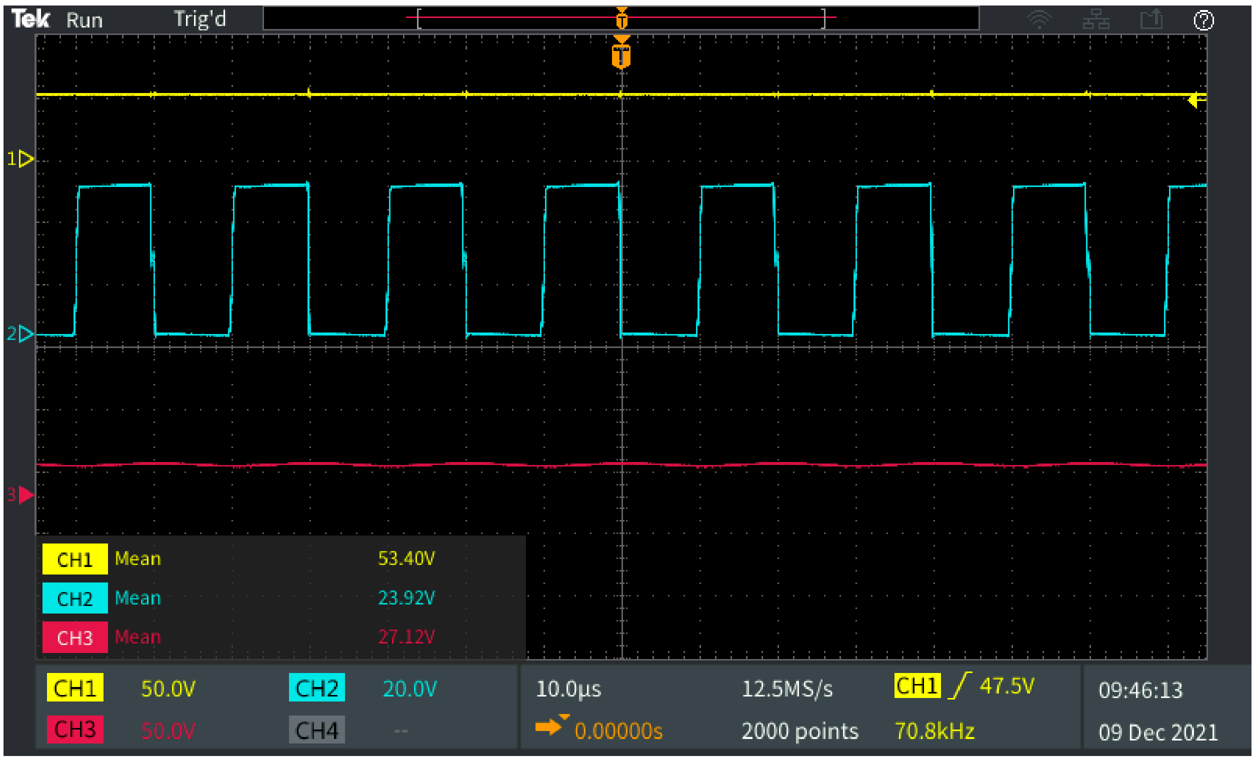


Pink → Input Voltage || Yellow → Output Voltage || Blue → Switch Node Voltage (i.e., across bottom MOSFET)

Output Voltage Multimeter Reading

- R_{LOAD} = 200 Ω

Load R_{LOAD}	Input		Output	
	V_{in} *(Volts)*	I_{in} *(Amps)*	V_{out} *(Volts)*	I_{out} *(Amps)*
200 Ω	24	0.5343	47.775	0.2402

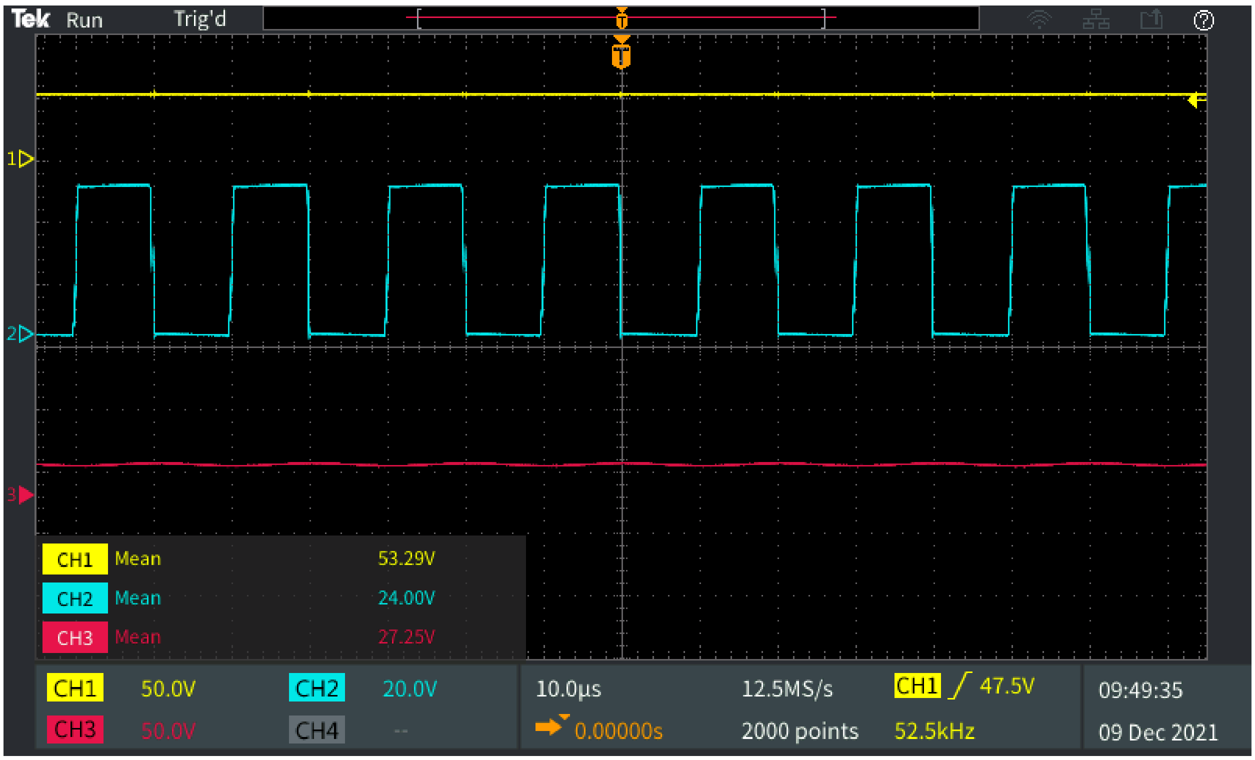


Pink → Input Voltage || Yellow → Output Voltage || Blue → Switch Node Voltage (i.e., across bottom MOSFET)

Output Voltage Multimeter Reading

- **R_{LOAD} = 300 Ω**

Load R_{LOAD}	**Input**		**Output**	
	V_{in} (Volts)	***I_{in} (Amps)***	***V_{out} (Volts)***	***I_{out} (Amps)***
300 Ω	24	0.36925	48.4848	0.16171

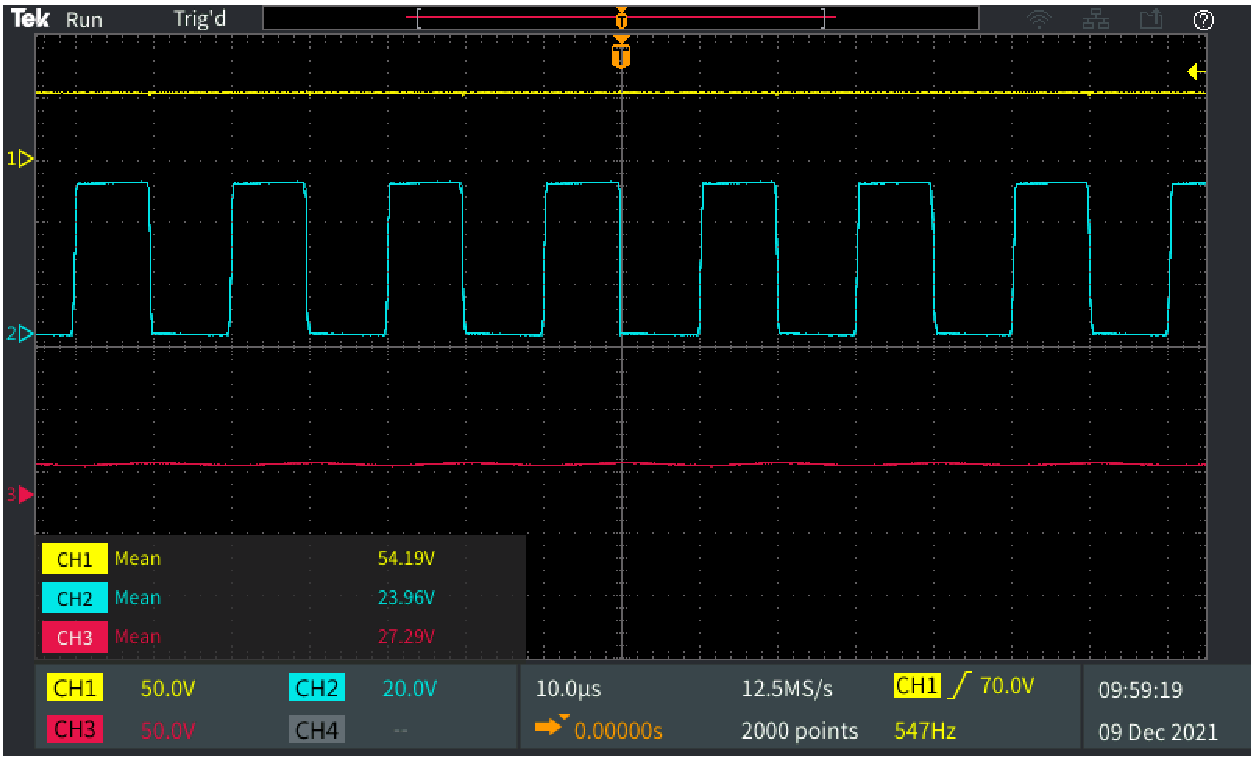


Pink → Input Voltage || Yellow → Output Voltage || Blue → Switch Node Voltage (i.e., across bottom MOSFET)

Output Voltage Multimeter Reading

- **R_{LOAD} = 400 Ω**

Load R_{LOAD}	**Input**		**Output**	
	V_{in} *(Volts)*	**I_{in} *(Amps)***	**V_{out} *(Volts)***	**I_{out} *(Amps)***
400 Ω	24	0.29594	48.1769	0.12301



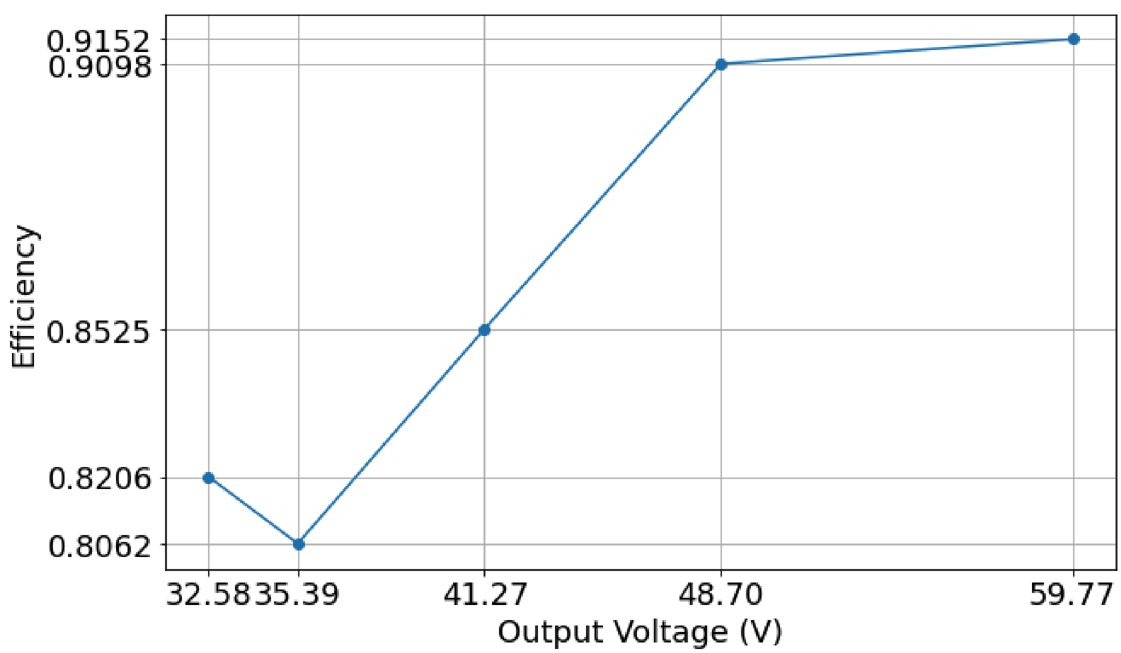
Pink → Input Voltage || Yellow → Output Voltage || Blue → Switch Node Voltage (i.e., across bottom MOSFET)

Output Voltage Multimeter Reading

Duty sweep: For one load level vary the duty cycle of the boost converter, note down the output voltage levels and draw up a graph of the measured efficiencies with voltage level. Do not exceed 55V (40 pts)

$$\eta = \frac{P_{out}}{P_{in}} = \frac{V_{out} I_{out}}{V_{in} I_{in}}$$

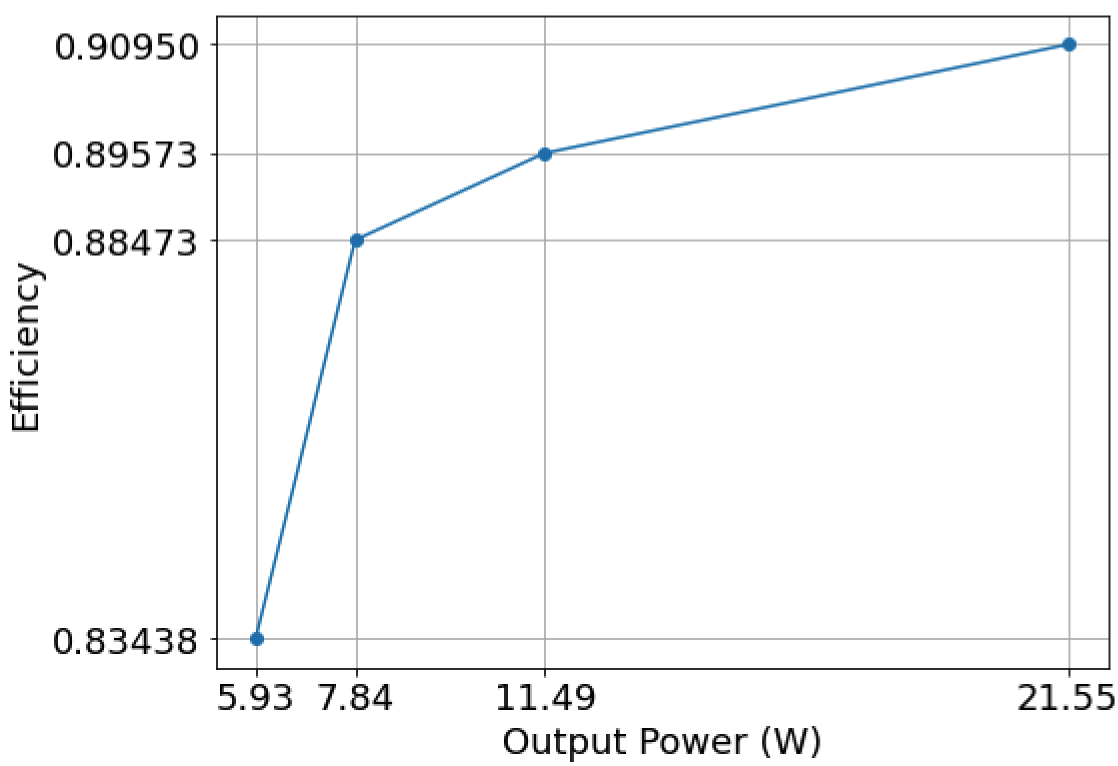
R_{LOAD} = 200 Ω							
Duty Cycle D	**Input**			**Output**			**Efficiency η**
	V_{in} (Volts)	**I_{in} (Amps)**	**P_{in} (Watts)**	**V_{out} (Volts)**	**I_{out} (Amps)**	**P_{out} (Watts)**	
60	24	0.8068	19.364	59.7703	0.2965	17.721	0.91516
50	24	0.5435	13.044	48.7036	0.2436	11.867	0.90981
40	24	0.4170	10.008	41.2655	0.2067	8.531	0.85248
30	24	0.3274	7.859	35.3934	0.1790	6.336	0.80617
20	24	0.2701	6.4836	32.5843	0.1632	5.320	0.82063



Efficiency sweep: Compute the efficiency at four load stages and draw up a graph of the measured efficiencies with power level. (25 pts)

$$\eta = \frac{P_{out}}{P_{in}} = \frac{V_{out} I_{out}}{V_{in} I_{in}}$$

Load R_{LOAD}	Input			Output			Efficiency η
	V_{in} *(Volts)*	I_{in} *(Amps)*	P_{in} *(Watts)*	V_{out} *(Volts)*	I_{out} *(Amps)*	P_{out} *(Watts)*	
100 Ω	24	0.98729	23.6949	46.3015	0.46544	21.5505	0.9095
200 Ω	24	0.5343	12.8232	47.775	0.2402	11.4860	0.8957
300 Ω	24	0.36925	8.862	48.4848	0.16171	7.8404	0.8847
400 Ω	24	0.29594	7.1025	48.1769	0.12301	5.9262	0.8344



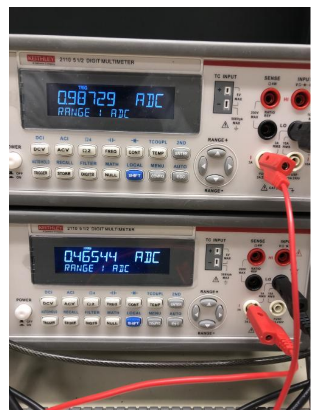
Bonus: Connecting with wheel

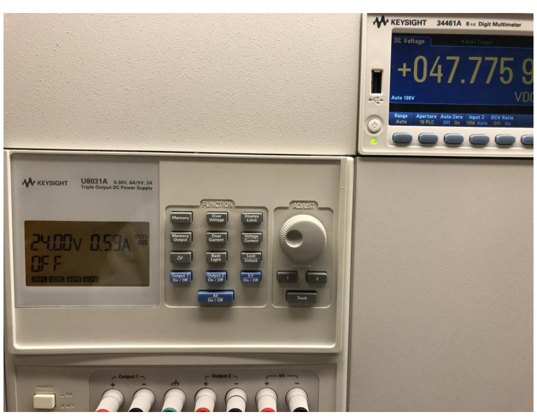
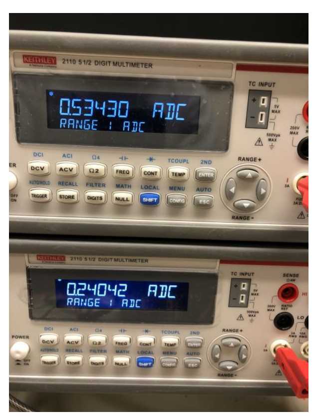
Figure: Wheel Motor Operating at 5.1A Input Current

Appendix

This appendix shows captures for Efficiency sweep measurements (note duty sweep data was collected with the same setup). Note that input voltage was not measured with a DMM; considering the quality of power supply used, it was assumed the input voltage was a steady 24 Volts.

Keysight Power Supply: Input Voltage
Keysight 6 ½ digit DMM: Output Voltage
Keithley 5 ½ digit DMM (top): Input Current
Keithley 5 ½ digit DMM (bottom): Output Current

R_{LOAD} = 100 Ω	
Voltage	**Current**
	

R_{LOAD} = 200 Ω	
Voltage	**Current**
	

<table>
<tr><th colspan="2">R_{LOAD} = 300 Ω</th></tr>
<tr><th>Voltage</th><th>Current</th></tr>
<tr><td>
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<table>
<tr><th colspan="2">R_{LOAD} = 400 Ω</th></tr>
<tr><th>Voltage</th><th>Current</th></tr>
<tr><td>
</td><td>
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