Half Bridge Buck Converter

EE - 136 Semiconductor Power Electronics

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PROJECT DESIGN REPORT

INTRODUCTION

The project aims to build a Half-Bridge Buck Converter with following specifications:

Converter Type	Input Voltage	Output Voltage	Power Level
Half-Bridge CCM	24-36 V	5 V	300 W

The designed Half-Bridge converter accepts 24 V to 36 V Input Voltage. Output voltage results at 5 V.

Using the design simulation tool developed by Plexim, Plexis, we design the entire Half-Bridge converter system to meet the required specifications. Functional Block diagram and Schematic including PWM Mode, RC feedback circuit are enclosed in the below figures. Simulation waveforms and BOM are enclosed as well.

A half-bridge converter[1] is a type of DC-DC converter that, like flyback and forward converters, can supply an output voltage either higher or lower than the input voltage and provide electrical isolation via a transformer. The load current can flow in both directions. Unlike the buck converter, the input current is continuous. This topology is used extensively in Uninterruptible Power Supplies (UPSs) to generate an output sine wave. The project aims to lower the input voltage and provide isolation to the system. The half-bridge circuit provides isolation, and the inductor, capacitors, and other components are responsible for lowering the voltage.

To guarantee stability and for the fastest, most accurate control of output voltage, error-amplifier frequency response compensation is used. There are three schemes, called Type I, Type II, and Type III wherein the type number corresponds to the number of poles in the error-amplifier response. In the case of Half-Bridge, Type III compensator is used, which has three poles (one at the origin) and two zeros. In practice, it is usually arranged to have two coincident zeros and two coincident poles, and the loop crossover frequency is placed somewhere between the zeros and poles. In systems where fx is less than fESR, the Type 2 compensator may not be able to provide the desired closed-loop system response and stability. A Type 3[2] compensator can then be used.

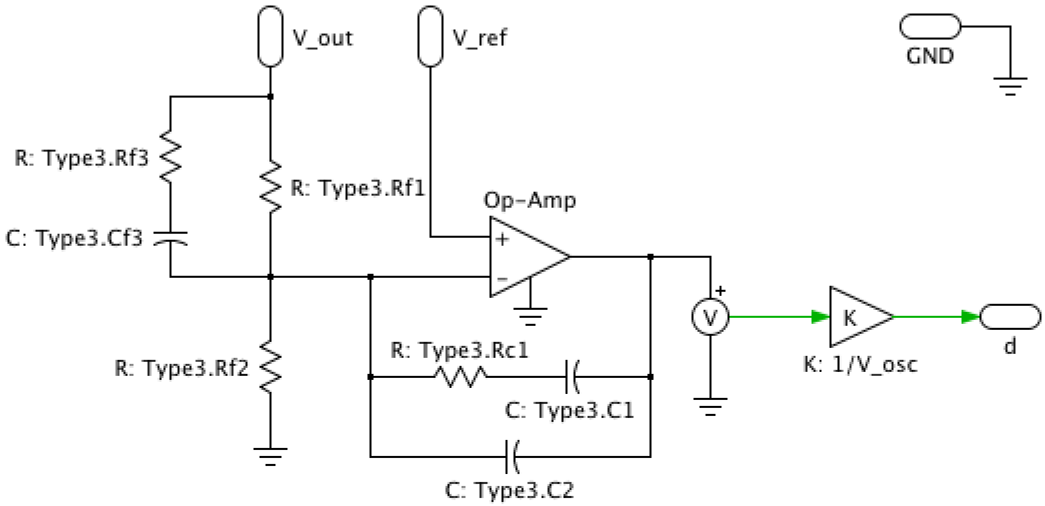

Fig.1: Type 3 Compensator

As with the Type 2 compensator, the Type 3 compensator is implemented with an ideal, finite-gain op-amp. The simplified transfer function of the Type 3 compensator is given by:

$$H_{type3}(s) = \frac{(1 + C_1 \cdot R_{C1} \cdot s)[1 + C_{f3} \cdot (R_{f1} + R_{f3})]}{C_1 \cdot R_{f1} \cdot s(1 + C_2 \cdot R_{C1} \cdot s) \cdot s(1 + C_{f3} \cdot R_{f3} \cdot s)}$$

This causes the open-loop transfer function of the closed-loop system to demonstrate the desired characteristics. It boosts the phase up to 180 degrees. The inductor peak current is monitored on a cycle-by-cycle basis and compared to the voltage at the output of the voltage error amplifier. The regulator's duty cycle is modulated based on the inductor's peak current value. The inductor current emulates a controlled current source. As a result, the inductor's pole frequency is shifted beyond the gain bandwidth of the regulator. The entire system aims to not only isolate and lower the input voltage but also stabilizes the output.

Design

Design Requirements

The inductor was initially designed based on the results from a simple buck converter; we found that it only needed to be larger than 2.4uH for continuous conduction mode. With that inductor value, the output capacitor value should be at least 723.4uF. However, when increased the inductor drastically so, we could reduce the size of the capacitor by orders of magnitude. The agreed value for the inductance is 100uH, and output capacitance is 100uF both standard easy-to-find values. All the components are designed with standard values in mind.

The type III compensator is designed around a 2 V Zener diode reference voltage. Its component values are selected for very slightly underdamped system response. The voltage output of the compensator is bounded between 0 and 0.5 times the oscillator voltage to limit the duty cycle between 0.0 and 0.5. The oscillator chosen operates at 100 kHz. Additionally, linear power regulators are needed to supply the Zener diode, the compensator’s op-amp, the comparator, the oscillator, and the isolated gate driver; however, we’ve omitted the linear regulators to simplify this report.

SCHEMATIC

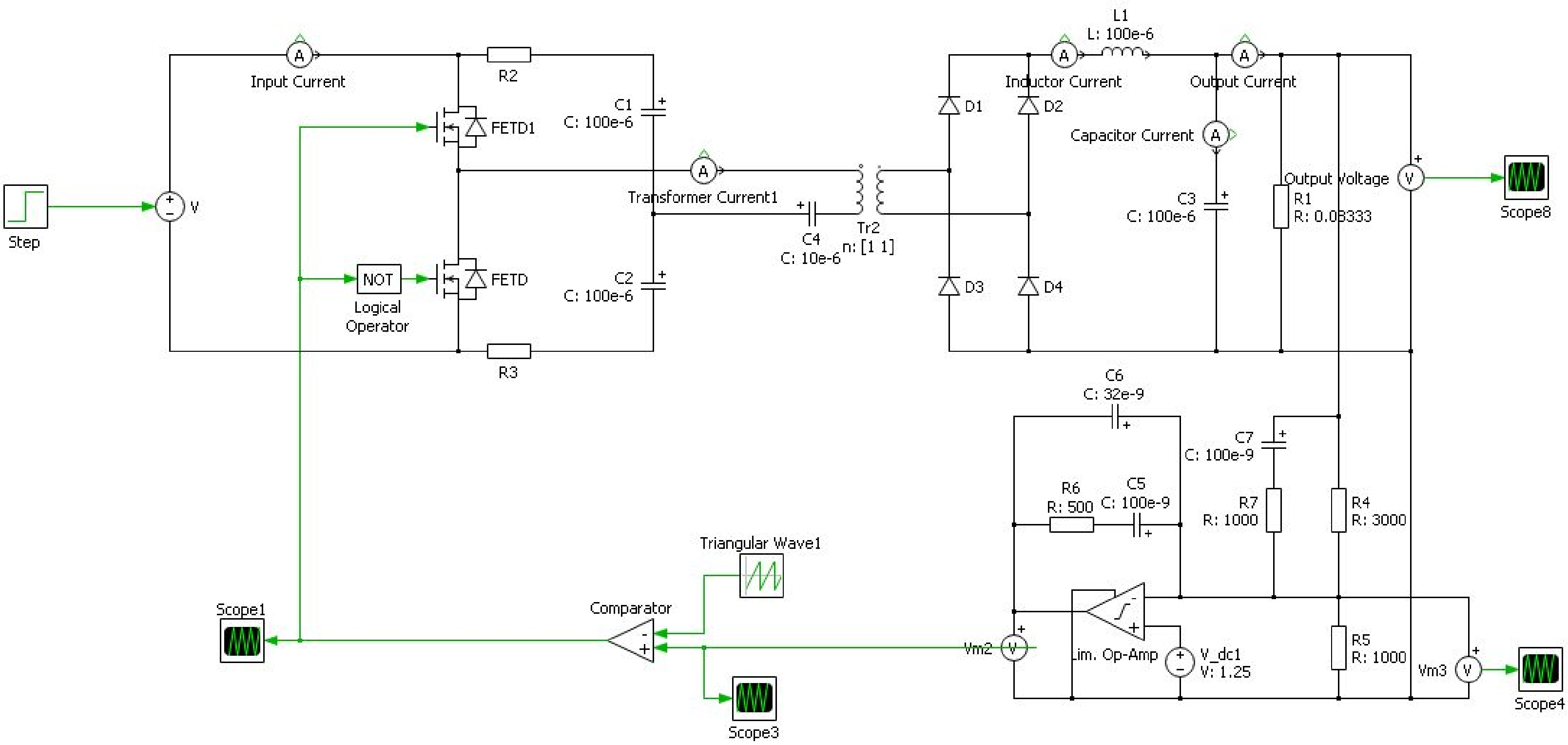

Fig 2: Half-bridge isolated buck converter PLECS schematic

SIMULATION

PLOTS

a) The following plots are in case of input voltage being 30 volt:

i) Output voltage (volts) versus Time (seconds).

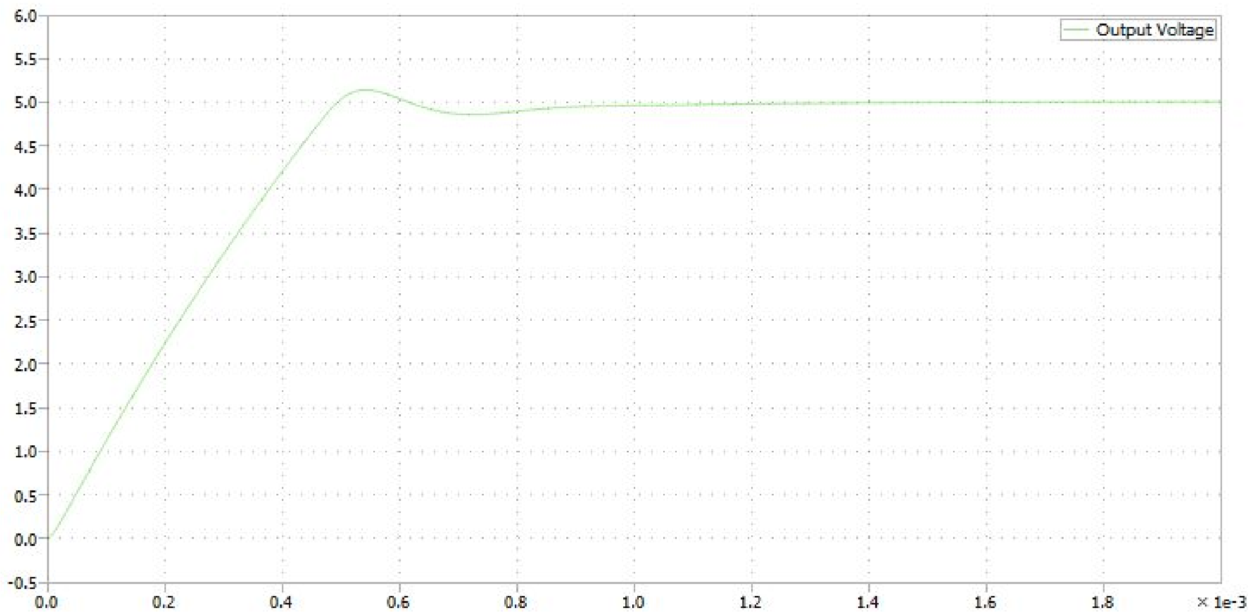

Fig 3: Output voltage transient startup with 30 volt input

ii) Output current (amps) versus time (seconds).

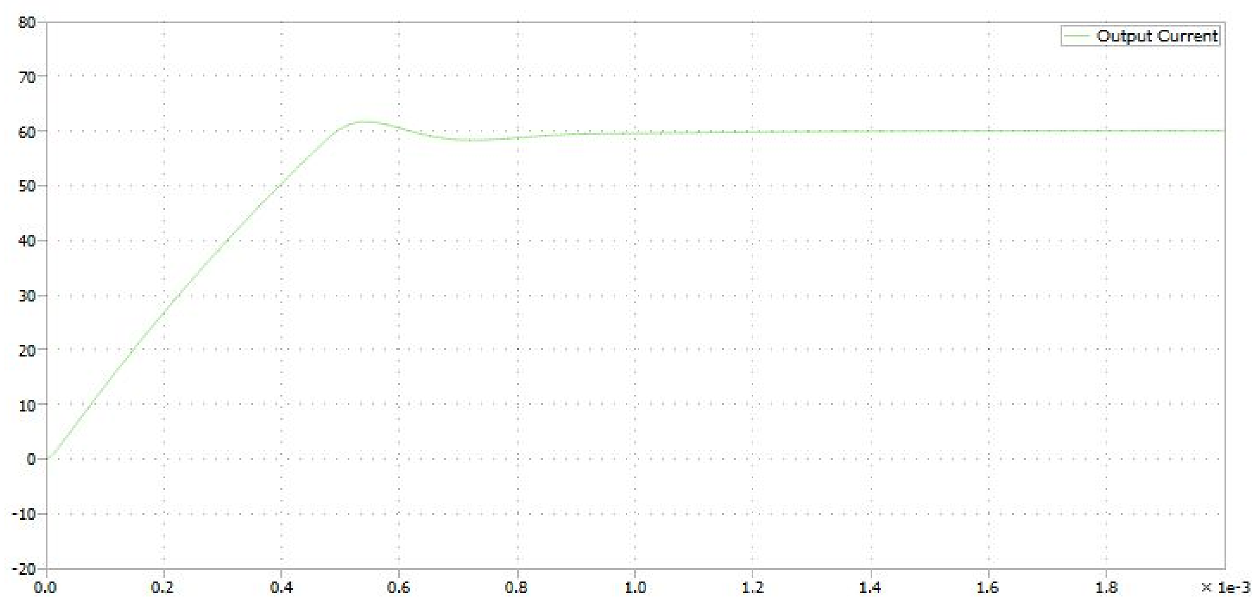

Fig 4: Output current transient startup with 30 volt input

iii) Input current (amps) versus time (seconds).

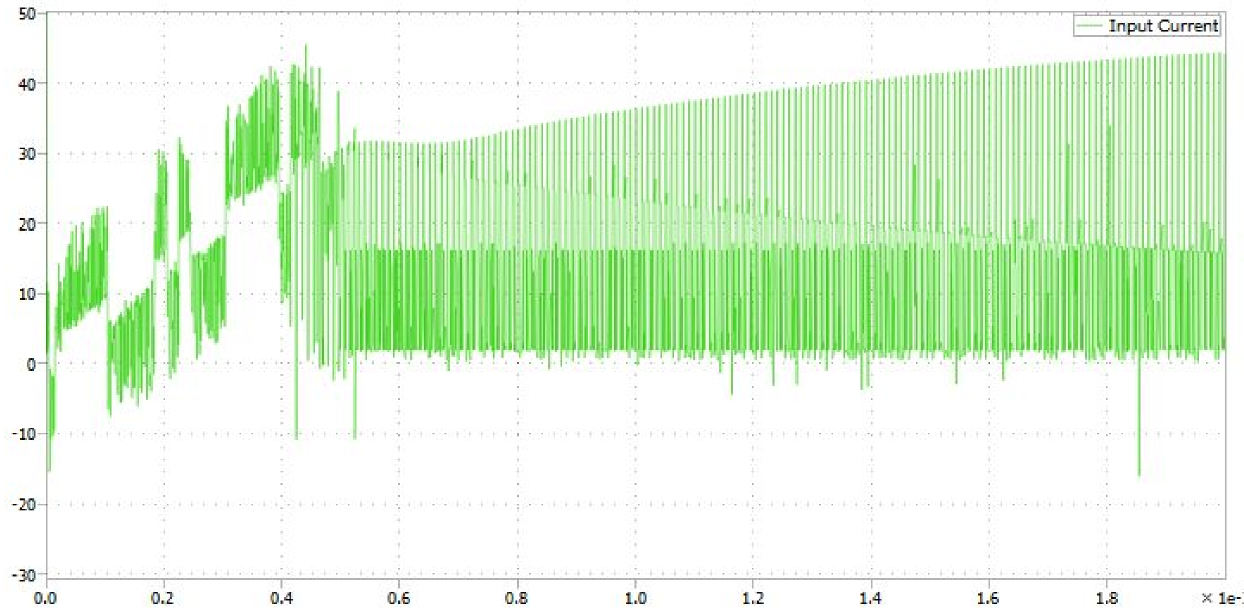

Fig 5: Input current transient startup with 30 volt input

iv) Inductor voltage (volts) versus time (seconds) during startup.

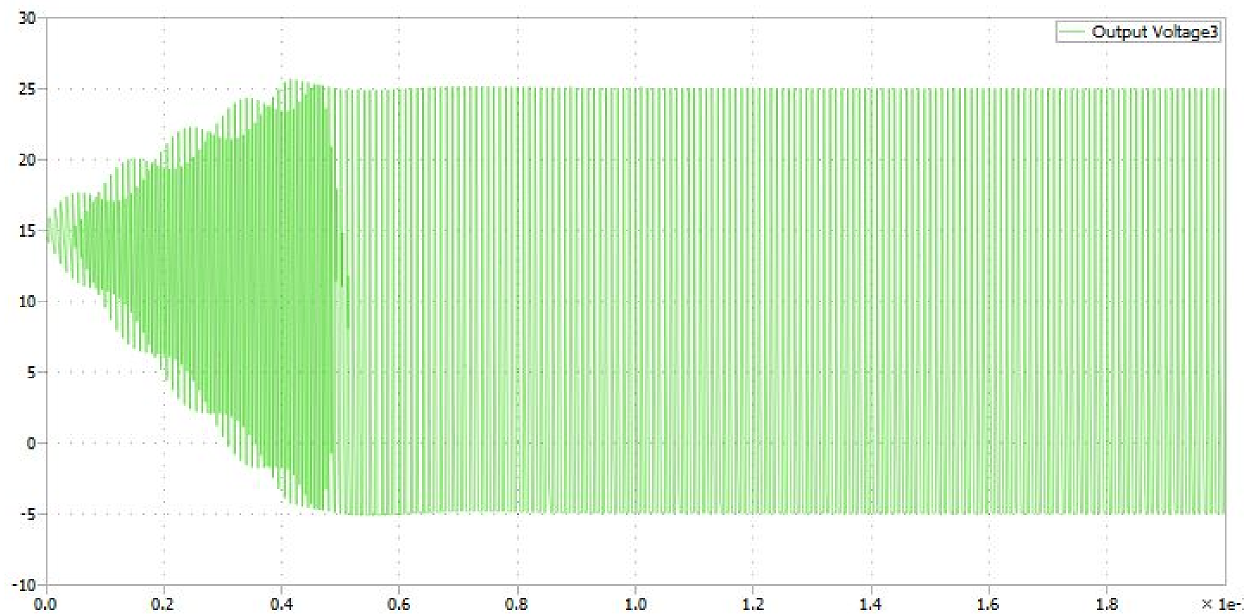

Fig 6: Inductor voltage transient startup with 30 volt input

v) Inductor current (amps) versus time (seconds).

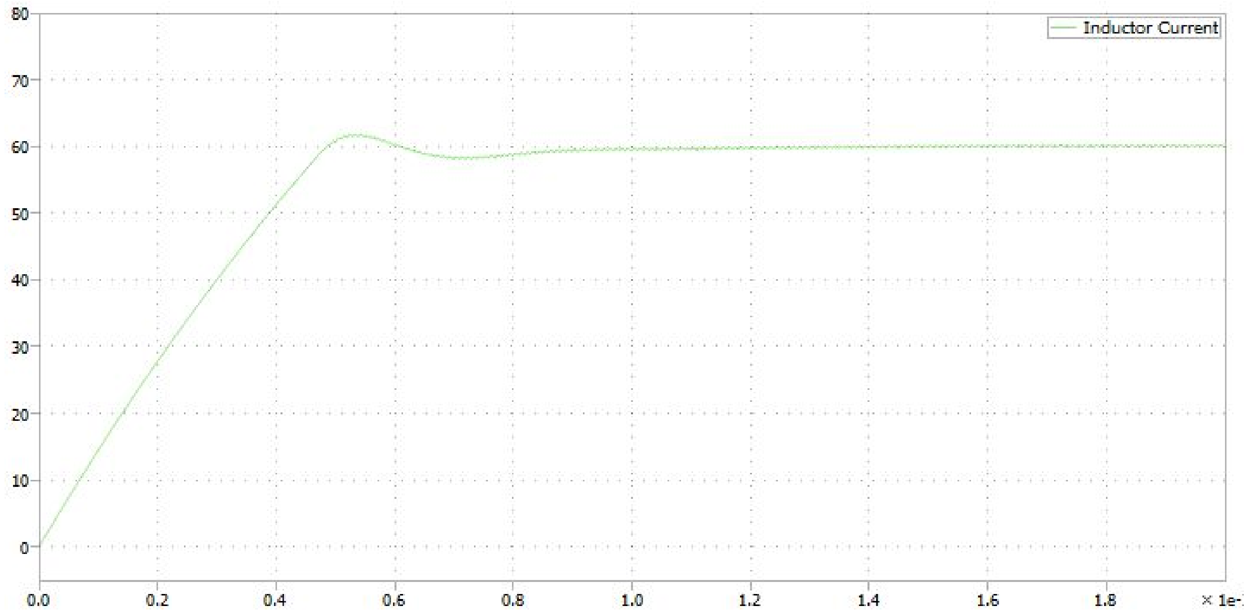

Fig 7: Inductor current transient startup with 30 volt input

vi) Output capacitor current (amps) versus time (seconds).

Fig 8: Output capacitor current transient startup with 30 volt input

b) The following plots are in case of input voltage varying from 24 volts to 36 volts:

i) Output voltage (volts) versus time (seconds).

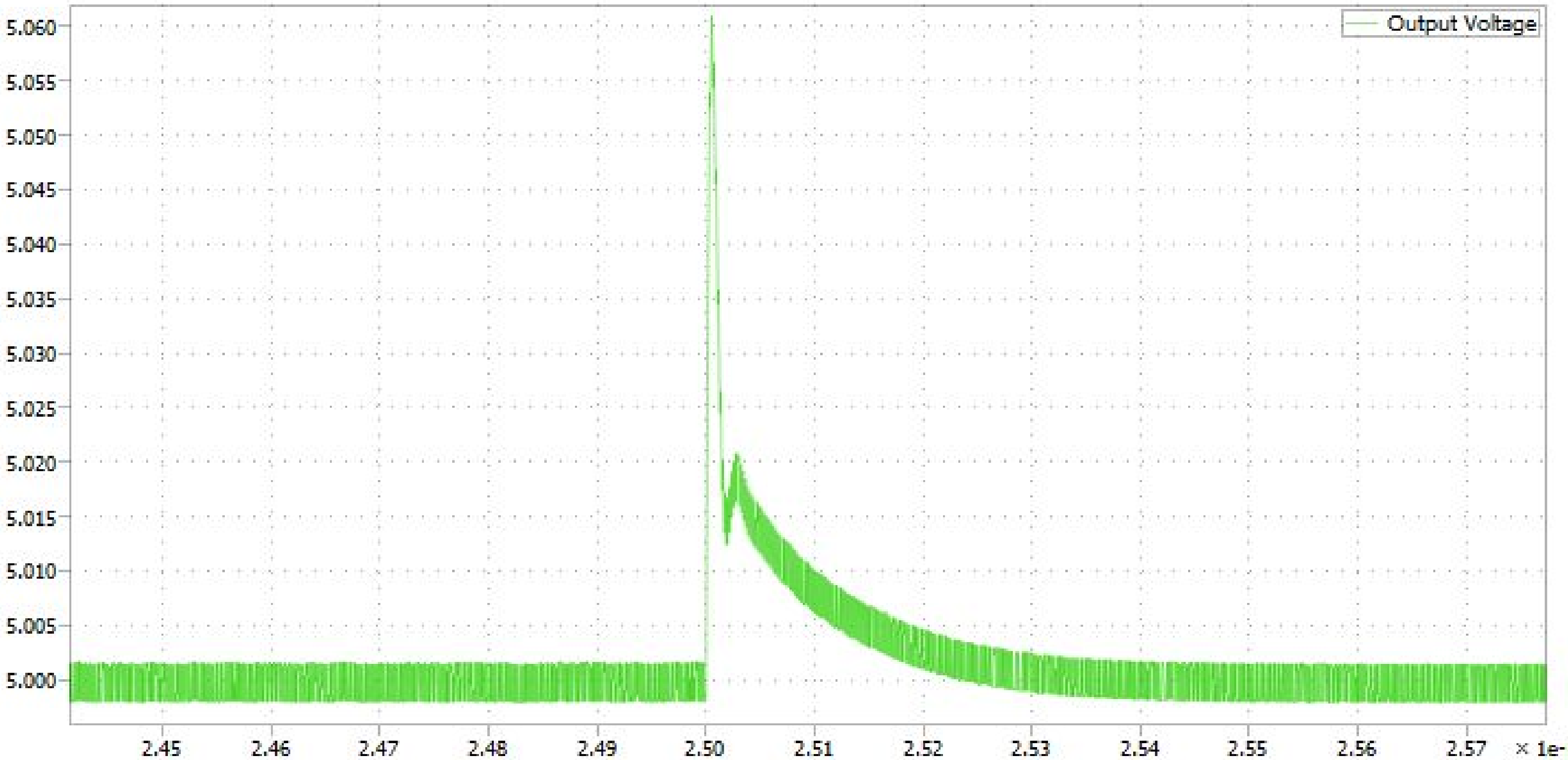

Fig 9: Output voltage transient response.

BILL OF MATERIALS

Actual construction of this half-bridge isolated DC-DC converter circuit would require the items in the following list:

Number	Label	Quantity	Value	Details	Description
1	Cin1	2x	100 uF	50 volt, ceramic general purpose	capacitor
2	Cin3	1x	10 uF	50 volt, ceramic general purpose	capacitor
3	Cout	1x	100 uF	10 volt, ceramic general purpose	capacitor
4	C1	1x	100 pF	10 volt, ceramic general purpose	capacitor
5	C2	1x	32 pF	10 volt, ceramic general purpose	capacitor
6	C3	1x	100 pF	10 volt, ceramic general purpose	capacitor
7	L1	1x	100 uH		inductor
8	T1	1x	1:1 turns ratio		transformer
9	RL	1x	0.0833 ohm		Load resistance to test 300 Watts
10	R1	1x	3 kohm		

Number	Label	Quantity	Part number	Manufacturer	Description
11	R2	1x	2 kohm		
12	R3	1x	500 ohm		
13	R4	1x	1 kohm		
14	D1	4x		Reverse voltage > 50 volt, forward current > 60 amp, Scottky	General purpose diode
15	Z1	1x		Zener voltage = 2 volt	Zener diode reference voltage
16	U1	2x			NMOS Power-FET
17	U2	1x			Opamp
18	U3	1x			Comparator
19	U4	1x	UCC23511	Texas Instruments	Isolated half-bridge gate driver
20	Q1	1x			100 kHz Oscillator

CONCLUSION

This half bridge DC-DC converter we have designed suits a 300 watt application nicely. However, it struggles with controlling lower power loads, around 30 watts, as it becomes underdamped near undamped. When asked to supply much more than 300 watts it is unable to maintain a 5 volt output. However, in simulation, this converter can accept a much wider range of voltages as inputs than intended. Perhaps the input range with acceptable startup overshoot and voltage ripple is approximately between 18 and 120 volts when it was originally designed to accommodate between 24 and 36 volts.

REFERENCE

1. Electronics, M. (n.d.). Half-Bridge DC/DC Converter. Retrieved December 17, 2019, from https://www.mouser.com/applications/power-supply-topology-half/.
2. Electronics, P. (2019, February 26). Type 2 and Type 3 Compensator Analysis for Power Supplies. Retrieved December 17, 2019, from https://www.plexim.com/support/application-examples/1026.
3. Electronics, P. (2019). Retrieved 18 December 2019, from https://www.plexim.com/files/plecsmanual.pdf