UNIVERSITATEA TEHNICĂ
DIN CLUJ-NAPOCA

Power Supplies

Prof: drd. Ing. Mirela Olteanu

Student: Cristescu Vlad-Andrei

Group: 2041

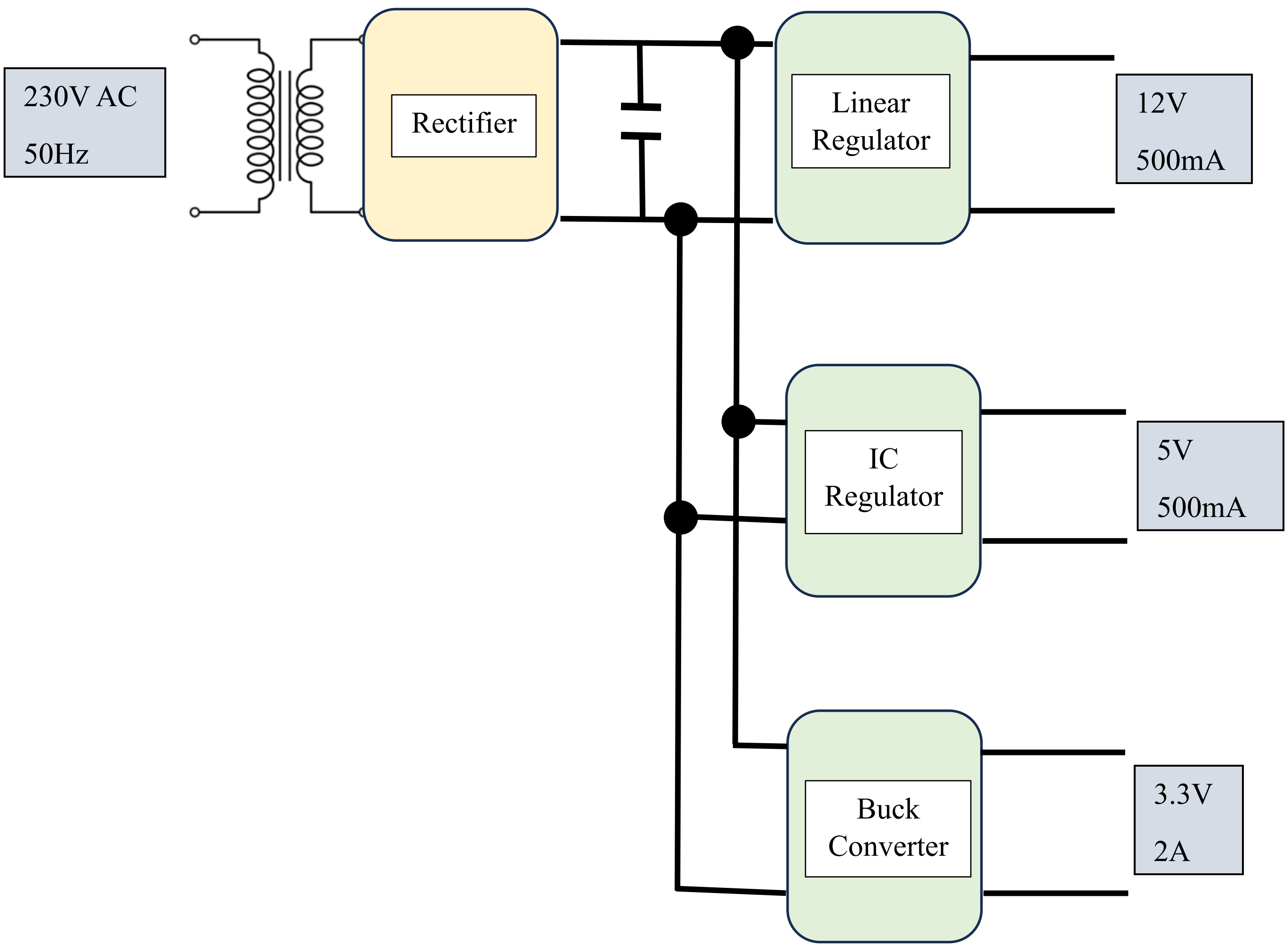
Table of Contents

1. Introduction

1.1. Project Theme

The goal of this project is to take the power from the electrical grid of the city and convert it to something that we can use to supply different electrical and electronic devices. We will have 3 outputs so that it can be used for devices that need 12V, 5V and 3.3V respectively.

1.2. Block Diagram



1.3. Design Requirements

Because the linear regulator needs to output 12V and this circuit requires 1.2V in order to function we need a minimum of 13.2V at the output of the rectifier. At the input of the rectifier we will require additional voltage, more specifically the forward voltage of 2 diodes of 1.1V each and half the value of the ripple ($\frac{1V}{2}$ = 0.5V), so the minimum voltage after the transformer is 15.9V, rounded up to 18V.

Transformer ratio:

$$\frac{N_1}{N_2} = \frac{U_1}{U_2} = \frac{230\sqrt{2}V}{18V} = \frac{325.26V}{18V} = 18.07$$

Linear Regulator

$$\left.\begin{array}{l} U_1 = 12\text{V} \\ I_1 = 500\text{mA} \end{array}\right\} \Rightarrow P_{1out} = U_1 * I_1 = 12\text{V}*0.5\text{A} = 6\text{W}$$

$$\eta_1 = 60\% \quad \Rightarrow \quad \frac{P_{1out}}{P_{1in}} = 60\% \quad \Rightarrow \quad P_{1in} = \frac{6W}{0.6} = 10\text{W}$$

IC Regulator

$$\left.\begin{array}{l} U_2 = 5\text{V} \\ I_2 = 500\text{mA} \end{array}\right\} \Rightarrow P_{2out} = U_2 * I_2 = 5\text{V}*0.5\text{A} = 2.5\text{W}$$

$$\eta_2 = 40\% \quad \Rightarrow \quad \frac{P_{2out}}{P_{2in}} = 40\% \quad \Rightarrow \quad P_{2in} = \frac{2.5W}{0.4} = 6.25\text{W}$$

Buck Converter

$$\left.\begin{array}{l} U_3 = 3.3\text{V} \\ I_3 = 2\text{A} \end{array}\right\} \Rightarrow P_{3out} = U_3 * I_3 = 3.3\text{V}*2\text{A} = 6.6\text{W}$$

$$\eta_3 = 90\% \quad \Rightarrow \quad \frac{P_{3out}}{P_{3in}} = 90\% \quad \Rightarrow \quad P_{3in} = \frac{6.6W}{0.9} = 7.33\text{W}$$

The rectifier has to provide enough power for all 3 of these devices so the minimum amount is:

$$P_{outRect} = P_{1in} + P_{2in} + P_{3in} = 23.58\text{W} \approx 24\text{W}$$

We can also compute the input current of the Buck converter and the total output current of the rectifier:

$$I_{inBuck} = \frac{U_3 * I_3}{\eta_3 * U_{inBuck}} = \frac{3.3V * 2A}{90\% * 14V} = 0.523\text{A}$$

$$I_{outRect} = I_1 + I_2 + I_{inBuck} = 0.5 + 0.5 + 0.523 = 1.523\text{A}$$

2. The Transformer

In order to be able to choose the right transformer for our application, we need to first understand what a transformer is and how it works.

2.1. Physical Layout

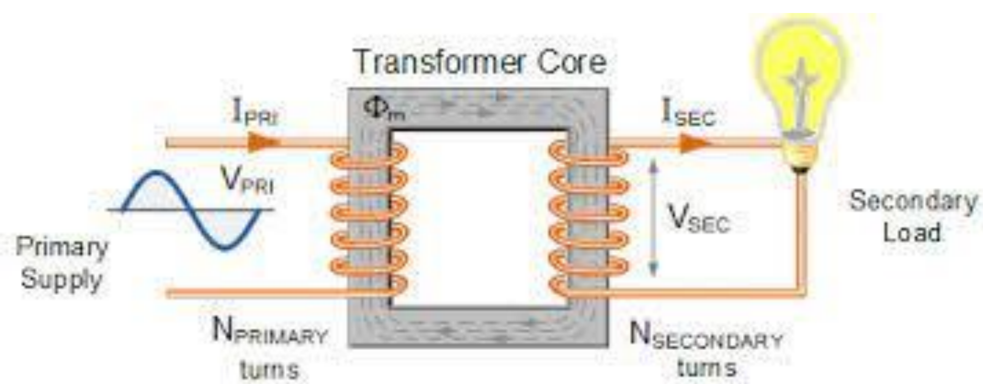


Figure 1: Schematic of a Transformer

An electrical transformer is a device that transfers electrical energy between circuits through mutual induction. It consists of a core, a primary winding connected to the input voltage source, and a secondary winding connected to the load. Transformers are used to change voltage levels while keeping power constant, making them essential in power transmission, distribution, and various electrical devices. They can either step up or step down voltage and inversely affect current. Transformers are designed for specific frequencies and are highly efficient, minimizing energy losses.

2.2. Working Principle

When AC flows through the primary winding, it generates a changing magnetic field, inducing voltage in the secondary winding. The main parameter of interest is the transformation ratio, defined by the following formula:

$$\frac{N_1}{N_2} = \frac{U_1}{U_2} = \frac{I_1}{I_2}$$

Ideally, the output power is equal to the input power. However, in reality we need to factor in the loss resistance:

$$R_T = r_1 * \left(\frac{N_1}{N_2}\right)^2 + r_2$$

2.3. Picking the Transformer

When choosing the transformer we need to consider the following aspects:

- Primary voltage must be at least 230V
- Secondary voltage must be 18V
- Power rating must be above 24W
- Secondary current must be at least $\frac{24W}{15V}$ = 1.6A

Simbol	Clasă etanșeitate	Putere [VA]	U_{prim} [V AC]	$U_{sec. 1}$ [V]	$U_{sec. 2}$ [V]
PSS63/230/12V	IP30	63	230	12	-
PSS63/230/18V	IP30	63	230	18	-
PSS63/230/24V	IP30	63	230	24	-

Figure 2: Transformer Family

PSS63/230/18V seems to fulfill the above conditions.

Figure 3: Price on TME.eu

3. The Rectifier

3.1. General Aspects

The purpose of the rectifier is to convert the AC voltage from the secondary winding of the transformer to a DC voltage that can be used by the regulators and the Buck Converter. There are 2 types of rectifiers: half-wave and full-wave. For our application we will require a full-wave rectifier as it is double as efficient. For this we are faced with another choice: with center-taped transformer or with a diode bridge. We will design our rectifier using the full-wave diode bridge circuit, mainly because it requires a single transformer, as opposed to the center-taped rectifier where we use 2. However, the disadvantage is that we will have a voltage drop on 2 diodes instead of a single one.

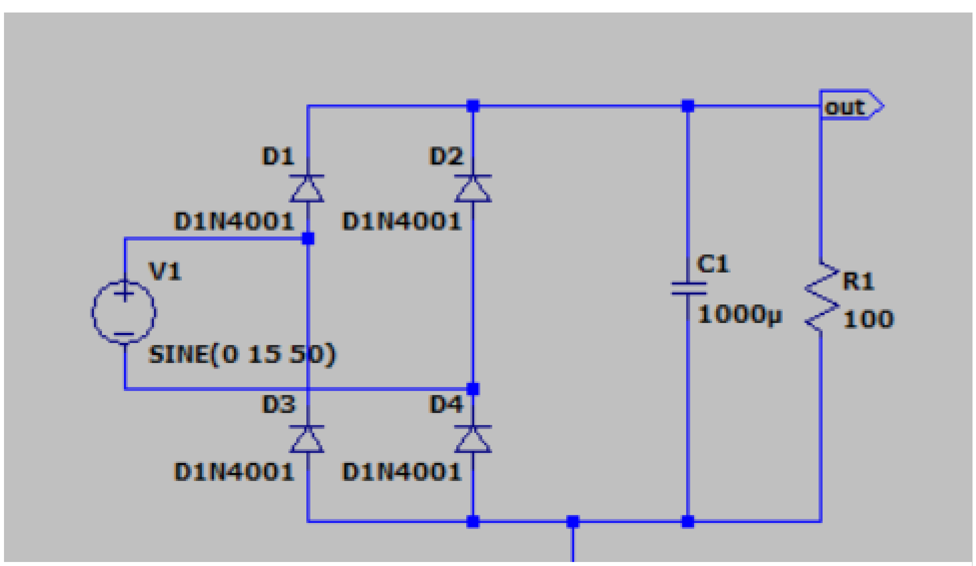


Figure 4: Full-wave diode bridge rectifier with capacitive filter

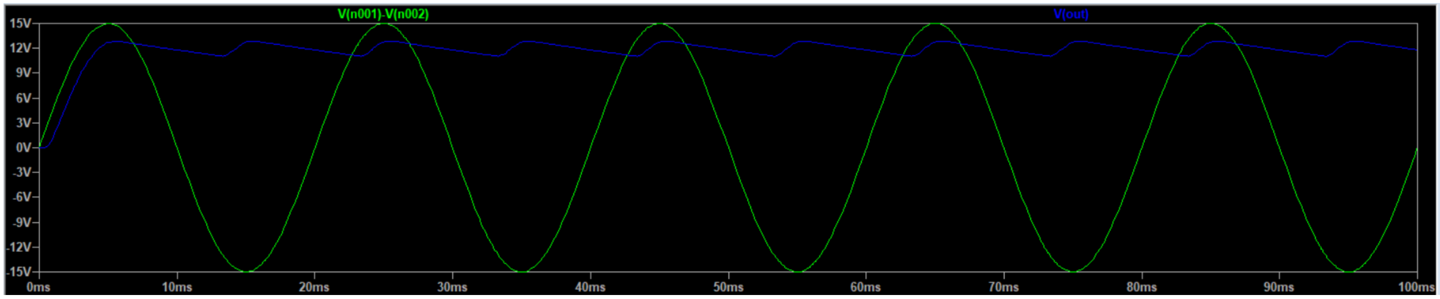


Figure 5: Input vs Output Voltage

3.2. Sizing the components

We know that the voltage in the secondary winding of the transformer U_2 = 15V, the maximum ripple ΔU_S = 1V, $I_{outRect}$ = 1.523A = I_S and $P_{outRect}$ = 24W.

The output voltage can be computed using the formula:

$$U_S = U_2 - 2 \cdot U_D - \frac{\Delta U_S}{2} = 18\text{V} - 2 \cdot U_D - \frac{1V}{2} > 13.2\text{V}$$

$$\Rightarrow U_D < 2.15\text{V}$$

If we choose U_D = 1.1V => U_S = 17.5V – 2•1.1V = 15.3V

The capacitance of the filter:

$$\Delta U_S = I_S \cdot \frac{\pi}{\omega \cdot C} \Rightarrow C = \frac{I_S}{2 \cdot f \cdot \Delta U_S} = \frac{1.523A}{2 \cdot 50Hz \cdot 1V} = 0.015\text{F} = 15\text{mF}$$

The output resistance:

$$R_{out} = \frac{U_{outRect}}{I_{outRect}} = \frac{15.3V}{1.523A} = 10.04 \approx 10\ \Omega$$

The ripple factor:

$$\gamma = \frac{\pi}{2 \cdot C \cdot \omega \cdot R_{out}} = \frac{1}{4 \cdot C \cdot f \cdot R_{out}} = \frac{1}{4 \cdot 0.015 \cdot 50 \cdot 10} = 0.033$$

The maximum diode current:

$$I_{Dmax} = \frac{I_S}{2} \cdot \sqrt{\pi \cdot \omega \cdot C \cdot R_{out}} = 12.24\text{A} \approx 12.3\text{A}$$

The medium diode current:

$$I_{Dmed} = \frac{I_S}{2} = 0.76\text{A}$$

3.3. Picking the components

All components will be chosen based on the constraints mentioned and computed above.

3.3.1. The diodes

When choosing the diodes we will follow these guidelines:

- Forward voltage drop = 1.1V
- Maximum current > 12.3A
- Medium current > 0.76A
- Maximum reverse voltage > U_2 = 18V

PRIMARY CHARACTERISTICS	
$I_{F(AV)}$	1.0 A
V_{RRM}	50 V, 100 V, 200 V, 400 V, 600 V, 800 V, 1000 V
I_{FSM} (8.3 ms sine-wave)	30 A
I_{FSM} (square wave t_p = 1 ms)	45 A
V_F	1.1 V
I_R	5.0 μA
T_J max.	150 °C
Package	DO-41 (DO-204AL)
Circuit configuration	Single

Figure 6: 1N400x diode family

The 1N4001 diode seems to fulfill all the above requirements.

	*Mfr. Part No.* 1N4001 *Mouser Part No* 637-1N4001	Diotec Semiconductor	Rectifiers Diode, DO-41, 50V, 1A	Datasheet	47.020 On Order View Dates	**1:** 1,06 RON **10:** 0,609 RON **100:** 0,436 RON **500:** 0,317 RON **Reel** **5.000:** 0,163 RON **10.000:** View

Figure 7: Price on Mouser.com

3.3.2. The capacitor

When choosing the capacitor for our application we only need to keep in mind the capacitance: 15mF, and the voltage rating: >15.3V.

	***Mfr. Part No.*** B41231B4159M000 ***Mouser Part No*** 871-B41231B4159M000	EPCOS / TDK	Aluminium Electrolytic Capacitors - Snap In 16VDC 15000uF 20% PVC 6mm Terminals	Datasheet	302 In Stock	**1:** 10,74 RON **10:** 8,51 RON **100:** 6,63 RON **520:** 4,88 RON **1.040:** 4,77 RON

Figure 8: Price on Mouser.com

The value of the capacitance has to be so large because we want to diminish the effects of the ripple to the greatest extent possible, enabling the rectified signal to be as smooth as possible, ideally DC.

3.4. LTSpice Simulations

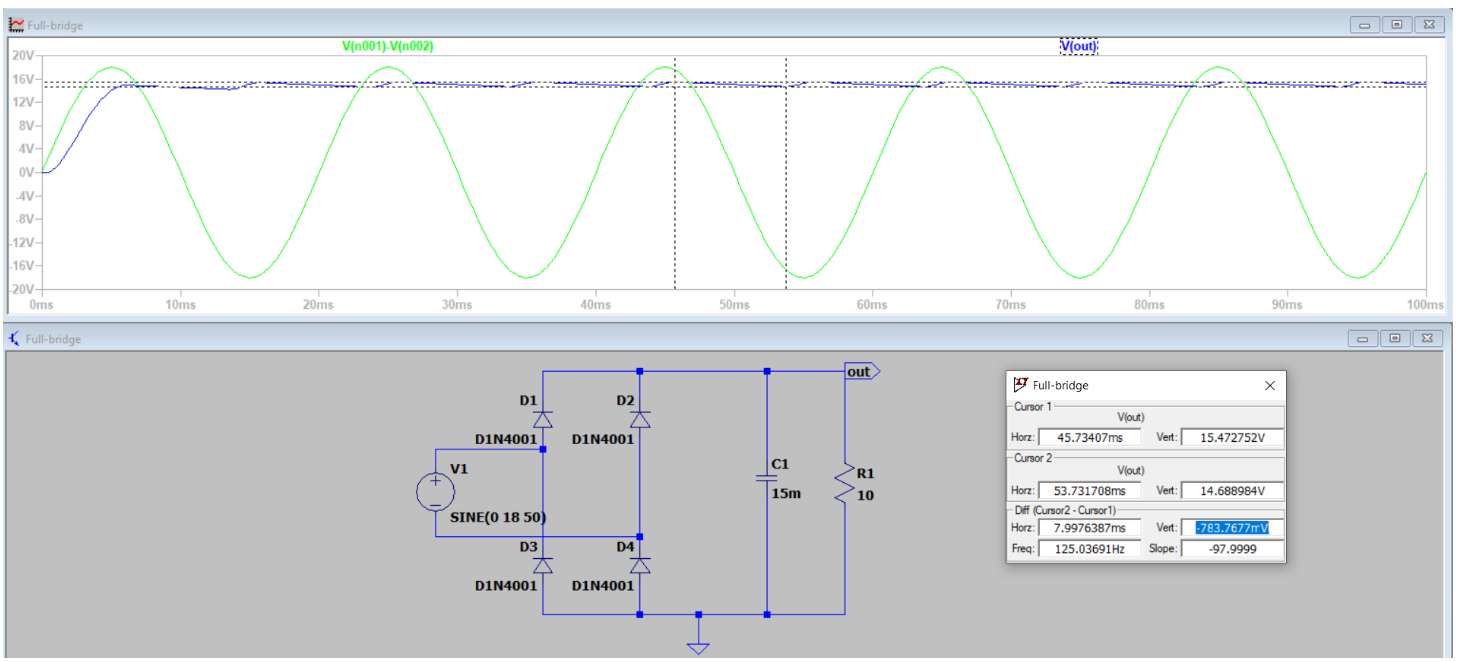


Figure 9: Schematic with updated values; Input vs. Output Voltage; Ripple Voltage Value

The ripple voltage:

$$\Delta U_S = 784\text{mV} \approx 0.8\text{V}$$

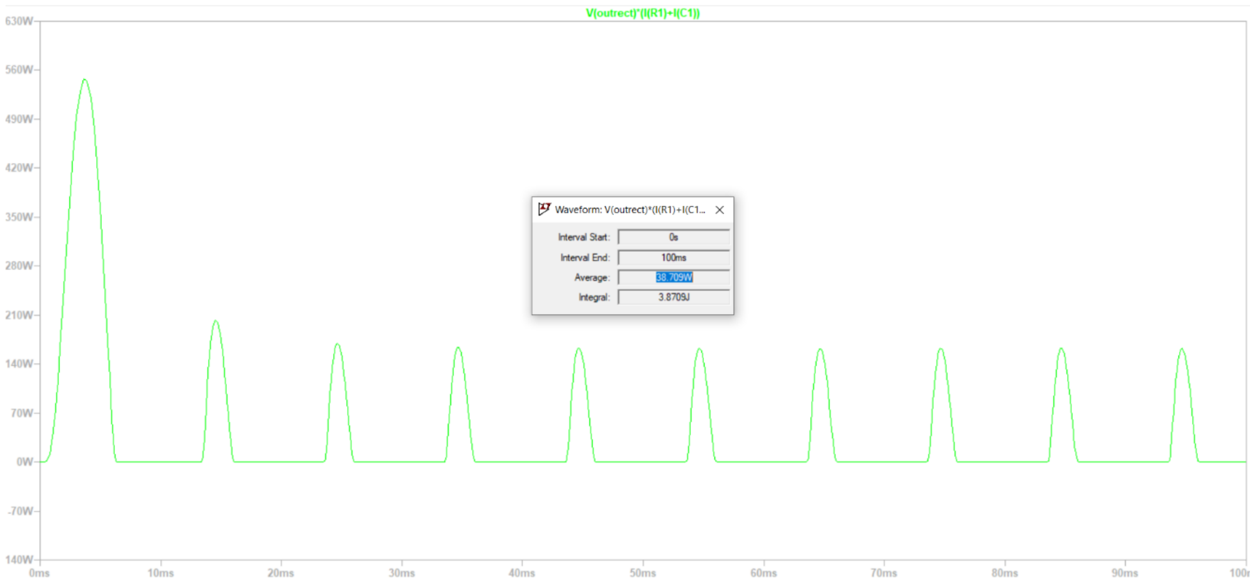


Figure 10: Output Power

4. The Linear Regulator

4.1. General Aspects

The purpose of the linear regulator is to provide a steady output voltage regardless of the variations of the input voltage, temperature and load current. This circuit will also greatly reduce the effects of the ripple created in the previous stage, during rectifying.

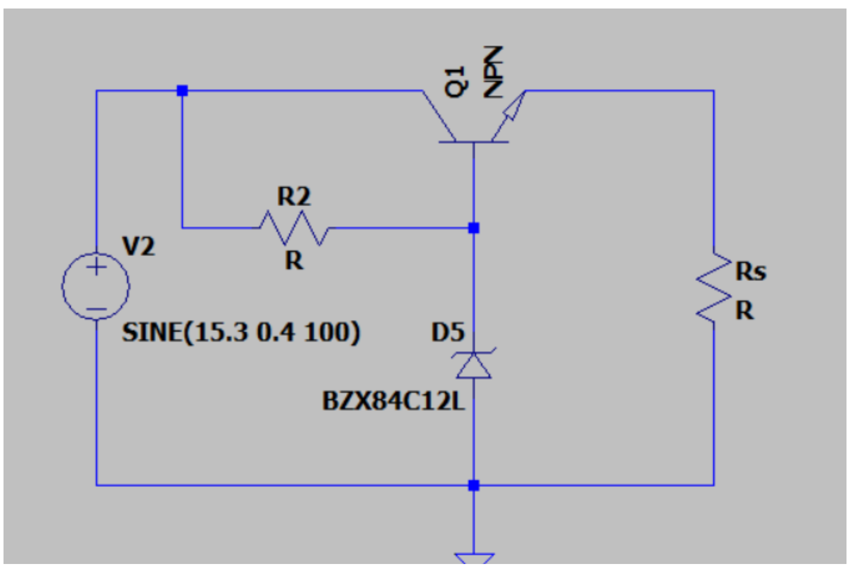


Figure 11: Schematic of series linear regulator

4.2. Sizing the components

Values we obtained from previous calculations and from the design specifications:

- $U_{outRect} \in$ [14.7V, 15.5V]
- U_{out} = 12V
- I_{out} = 0.5A
- S_{UI} = 100
- R_{out} = 0.2Ω

The load resistance:

$$R_S = \frac{U_{out}}{I_{out}} = \frac{12V}{0.5A} = 24\ \Omega$$

The Zener diode voltage:

$$U_Z = U_{out} + U_{BE} = 12\text{V} + 0.6\text{V} \approx 13\text{V}$$

The transistor base current:

$$I_B = \frac{I_C}{\beta+1} = \frac{I_{out}}{\beta+1} = \frac{0.5A}{101} = 0.00495\text{A} = 4.95\text{mA}$$

The voltage on the ballast resistor:

$$U_R = U_{outRect} - U_Z \in [1.7\text{V}, 2.5\text{V}]$$

The current through the ballast resistor:

$$I_R = I_B + I_Z = 4.95\text{mA} + 5\text{mA} \approx 10\text{mA}$$

Where I_Z is taken from the datasheet of a Zener diode that will be presented in the following.

The ballast resistance:

$$R_{Bal} = \frac{U_R}{I_R} = \frac{[1.7V, 2.5V]}{0.01A} \in [170\Omega, 250\Omega]$$

A standard value in this range is 180Ω.

The Zener diode internal resistance:

$$R_Z = \frac{\Delta U_Z}{\Delta I_Z} = \frac{5.63mV}{4.41mA} \approx 1.3\Omega$$

The datasheet of the chosen diode mentions only the maximum value of this parameter, 30Ω, so I decided to measure it by sweeping a DC source at the input of the diode and measuring the variation of both the Zener voltage and current on the interval that we are interested in, 14.7V to 15.5V. I then used the measured values in Ohm's Law to determine the resistance.

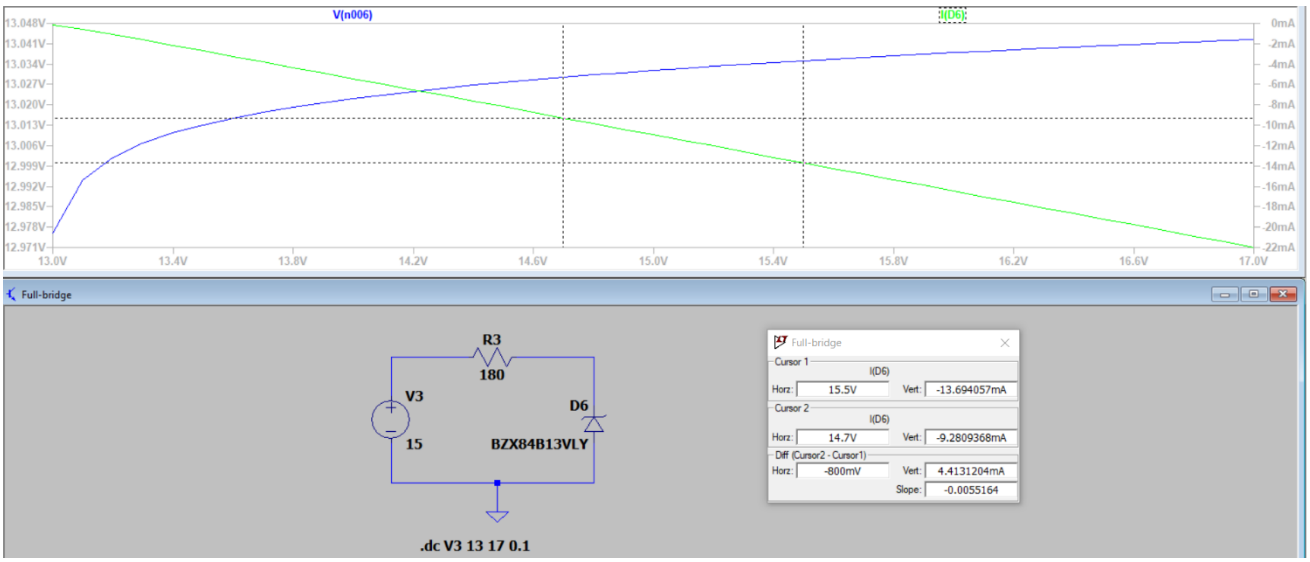


Figure 12: Zener resistance measurement

The line regulation:

$$S_{UI} = \frac{R_{Bal}}{R_Z} = \frac{180\Omega}{1.3\Omega} = 138.5 > 100$$

The output resistance:

$$R_{out} = \frac{\Delta U_{test}}{\Delta I_{test}} = \frac{10.41mV}{25.97mA} = 0.4\Omega$$

This value was obtained by extracting a test current at the output of the regulator and measuring the output voltage. The slope is the output resistance.

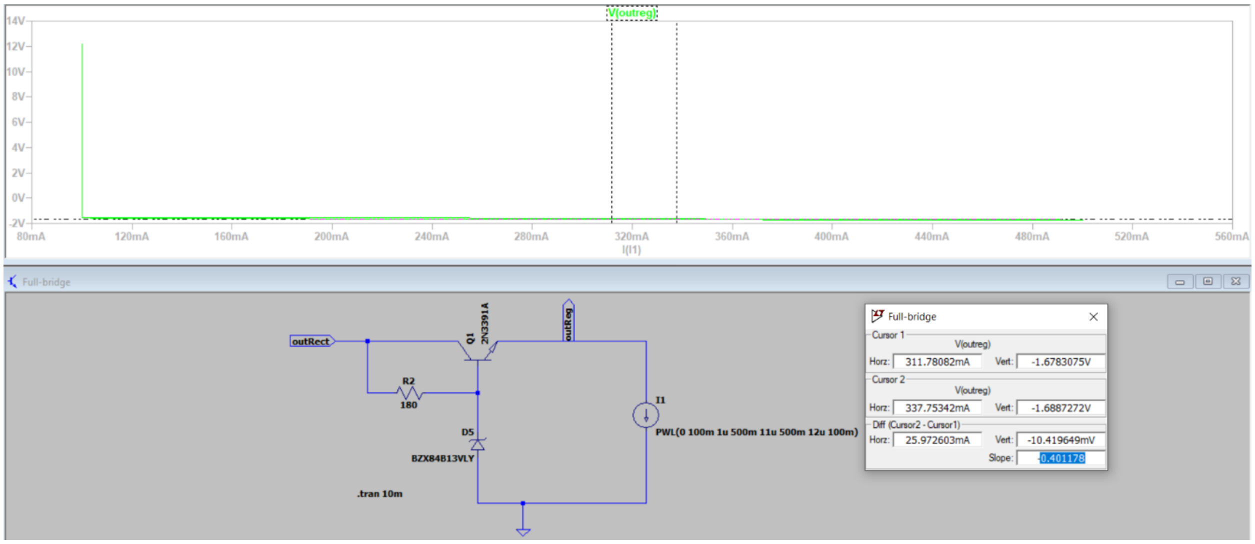


Figure 13: Output resistance measurement

4.3. Picking the components

All components will be chosen based on the constraints mentioned and computed above.

4.3.1. The Zener diode

From the previous computations we have obtained:

- $U_Z = 13\text{V}$
- $R_Z = 1.3\Omega$
- $I_Z = 5\text{mA}$

Luckily, we already found a diode that can fulfill all the necessary conditions, the BZX84B13VLY.

●Characteristic ($T_a = 25°C$)

Parameter	Symbol	Conditions	Min.	Typ.	Max.	Unit
Zener Voltage	V_Z	$I_Z = 5\text{mA}$	12.70	-	13.30	V
Reverse Current	I_R	$V_R = 8.0\text{V}$	-	-	0.1	μA
Dynamic Impedance	Z_Z	$I_Z = 5\text{mA}$	-	-	30	Ω
Temperature Coefficient	γ_Z	$I_Z = 5\text{mA}$	7.9	-	11.0	mV/°C

Figure 14:Zener diode datasheet

	***Mfr. Part No.*** BZX84B13VLYT116 ***Mouser Part No*** 755-BZX84B13VLYT116	ROHM Semiconductor	Zener Diodes 250mW, 13V, SOT-23, Zener Diode (BZX84B series) Learn More	Datasheet	8.173 In Stock	**Cut Tape** **1:** 2,07 RON **10:** 1,44 RON **100:** 0,594 RON **1.000:** 0,441 RON

Figure 15: Price on mouser.com

4.3.2. The transistor

This components acts as the pass element, it needs to be able to handle the load current and to absorb the voltage difference between the input and output. This element is essentially an error amplifier. What we need to look for:

- I_E = 500mA
- β = 100
- U_{CE} = 15.5V – 12V = 3.5V

●**Absolute maximum ratings** (T_a = 25°C)

Parameter	Symbol	Values	Unit
Collector-base voltage	V_{CBO}	60	V
Collector-emitter voltage	V_{CEO}	60	V
Emitter-base voltage	V_{EBO}	6	V
Collector current	I_C	2	A
	I_{CP} *1	4	A
Power dissipation	P_D *2	0.5	W
Junction temperature	T_j	150	℃
Range of storage temperature	T_{stg}	-55 to +150	℃

Figure 16: 2SC5866 transistor datasheet

	***Mfr. Part No.*** 2SC5866TLQ ***Mouser Part No*** 755-2SC5866TLQ	ROHM Semiconductor	Bipolar Transistors - BJT NPN 60V 2A Learn More	Datasheet	11.549 In Stock	**Cut Tape** **1:** 2,12 RON **10:** 1,81 RON **100:** 1,36 RON **500:** 1,07 RON **1.000:** 0,822 RON

Figure 18: Price on mouser.com

4.4. LTSpice Simulations

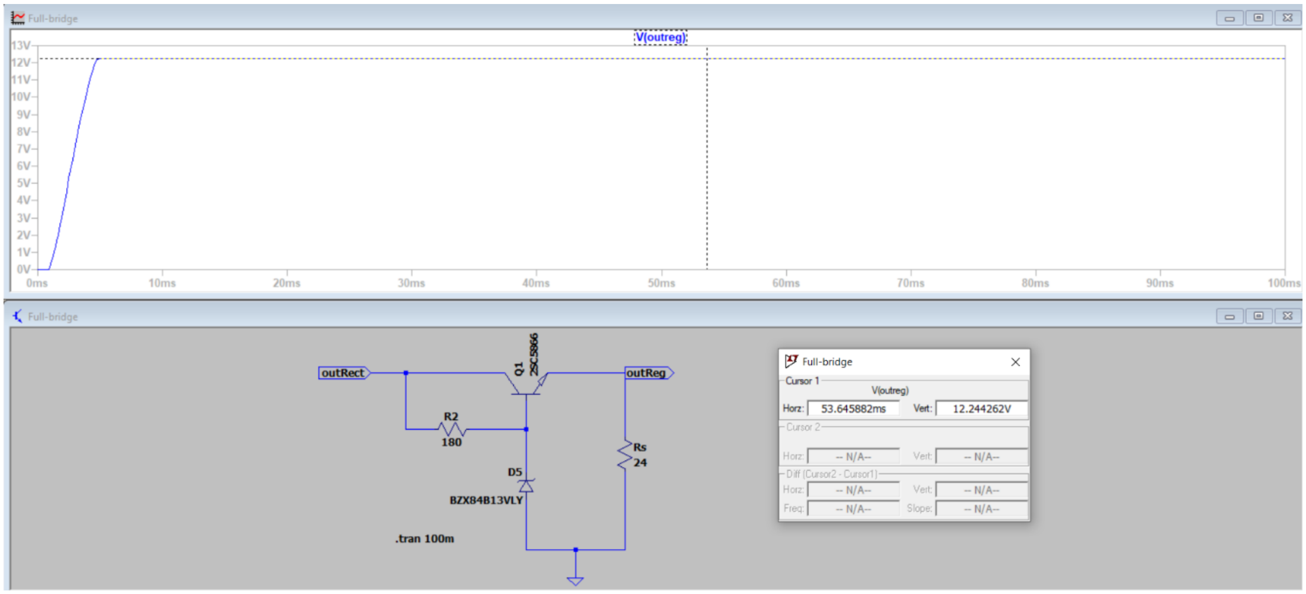


Figure 19: Output Voltage

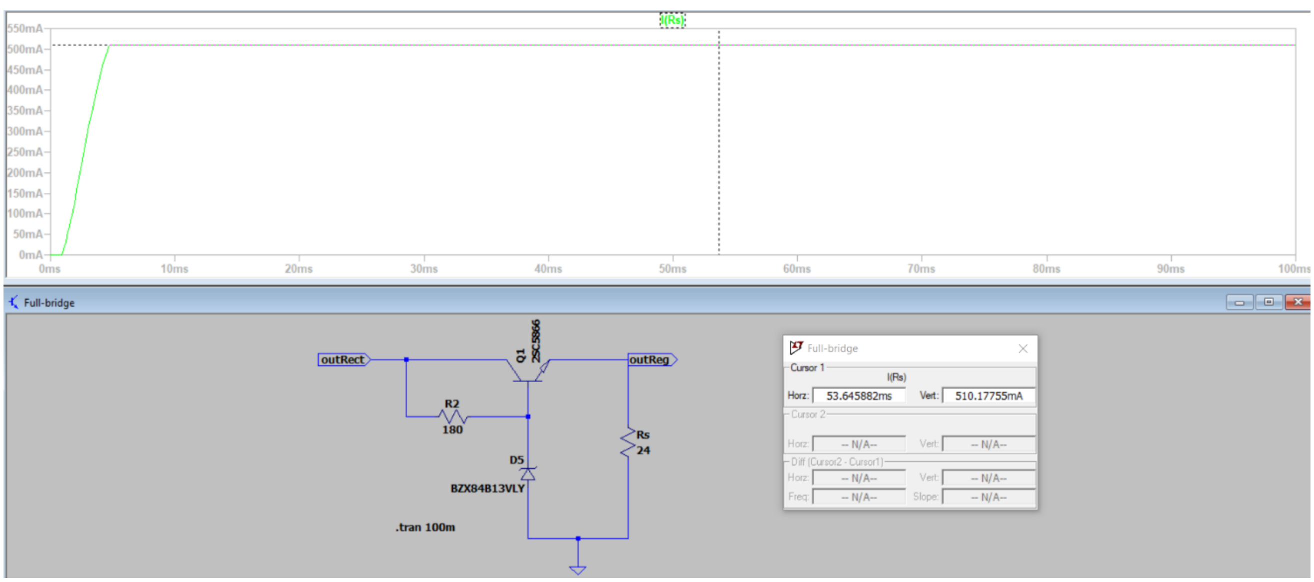


Figure 20: Output Current

4.5. Designing the Heatsink

In order to maintain the circuit within nominal parameters we will need to implement a heatsink to facilitate the dissipation of power on the transistor and keep the temperature from getting high enough to damage the components.

The 2SC5866 transistor comes in a TSMT3 package and we have the following facts:

- $T_j = 150°C$
- $T_a = 25°C$
- $R_{Tj-a} = 250°C/W$
- $R_{Tj-c} = 75.5°C/W$
- $P_d = U_{CE} \cdot I_C = 3.5V \cdot 0.5A = 1.75W$

Without a heatsink, the junction temperature would be:

$$T = T_a + P_d \cdot R_{Tj-a} = 462.5°C >> T_j$$

The thermal resistance of the heatsink:

$$R_{T\_hs} = \frac{T_j - T_a}{P_d} = \frac{150°C - 25°C}{1.75W} = 71.42°C/W$$

For the material the 2 most popular are copper and aluminium. We will choose aluminium due to its cost-efficiency. Since the maximum value is 71.42°C/W, we ended up choosing a heatsink with a thermal resistance of 12.5°C/W :

	*Mfr. Part No.* M-C421 Heat Sink Kit *Mouser Part No* 418-MC421HEATSINKKIT	Cincon	Heat Sinks Heat Sink Kit, Transverse Fins, Quarter Brick (Includes: 1 Heatsink / 4 Screws / 4 Washers / 1 Thermal Pad)	Datasheet	139 In Stock	**1:** 22,87 RON

Figure 21: Price on mouser.com

5. The IC Regulator

5.1. General Aspects

The purpose of the integrated circuit-based regulator is to provide a steady 5V at the output regardless of the variation of the input voltage, the temperature and the load current. With this in mind I have decided to go with the LT317A chip.

5.2. Sizing the components

LT317A is a 3-terminal adjustable, positive voltage reference.

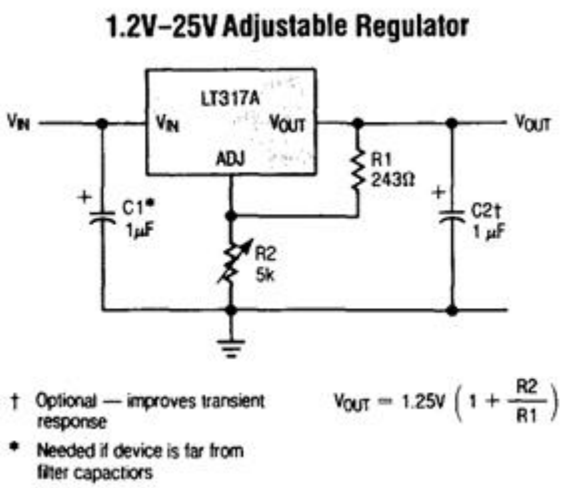


Figure 22: Typical application for LT317A

We know that U_{out} = 5V => $\frac{R_2}{R_1} = 3$

The adjustement resistances:

If we choose $R_1 = 120\Omega$ => $R_2 = 360\Omega$

The internal output resistance:

$$R_{out} = \frac{U_{out}}{I_{out}} = \frac{5V}{500mA} = 10\Omega$$

5.3. LTSpice Simulations

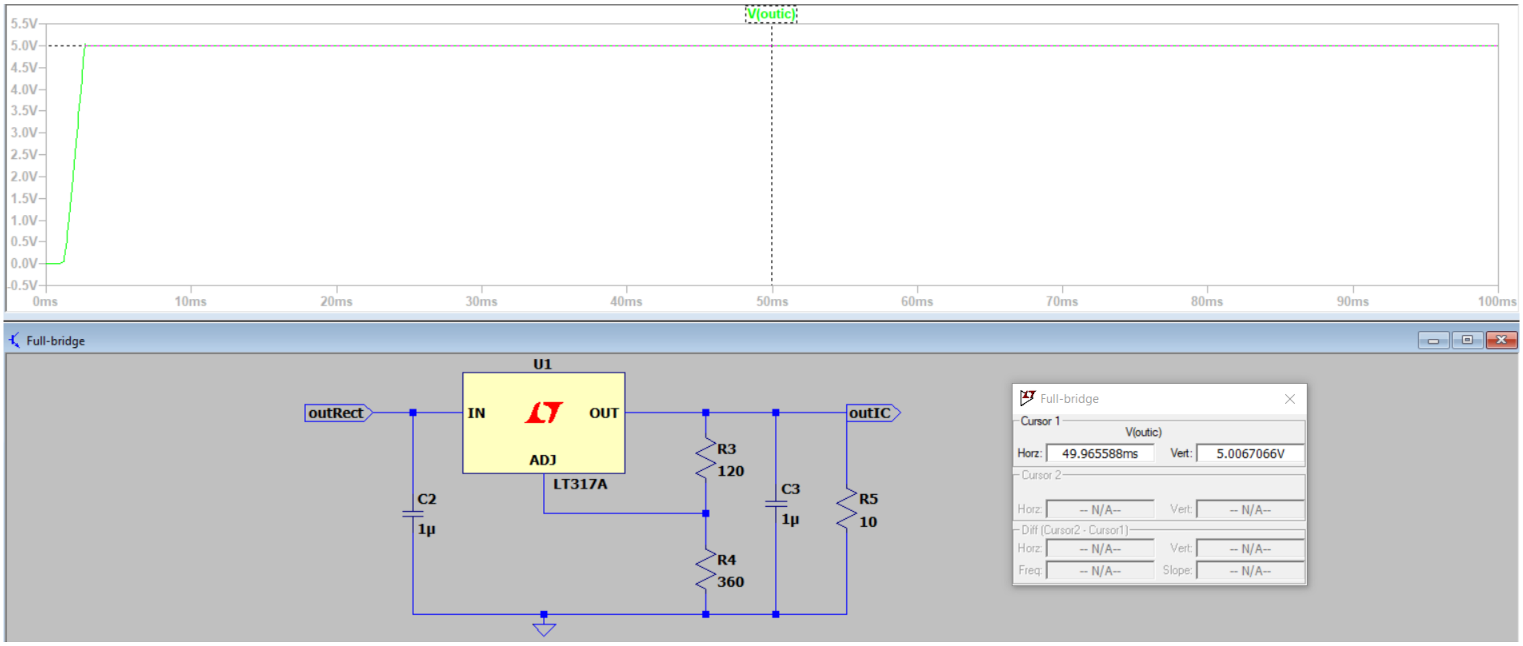


Figure 23: Output Voltage

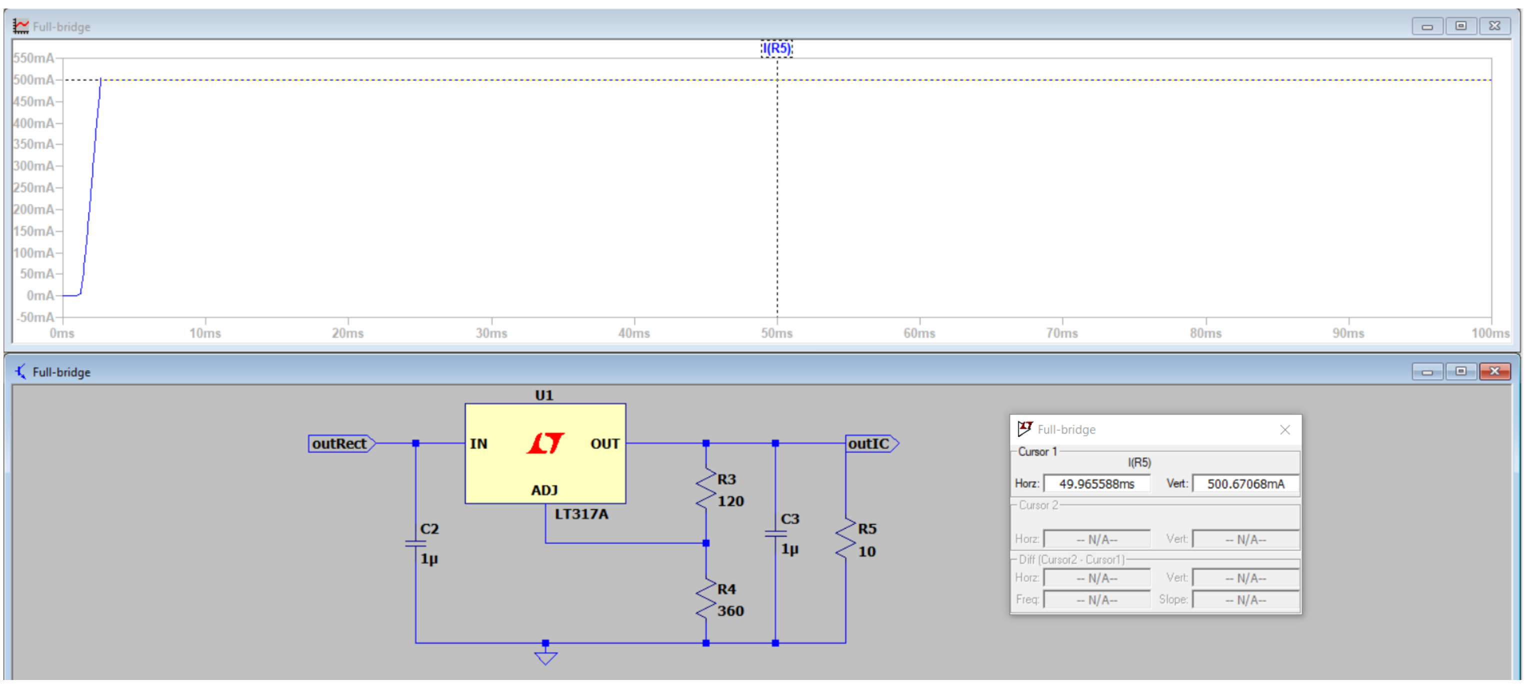


Figure 24: Output Current

5.4. Designing the Heatsink

	*Mfr. Part No.* LT317AT#PBF *Mouser Part No* 584-LT317AT#PBF	Analog Devices	Linear Voltage Regulators Pos Adj Reg	Datasheet	577 In Stock	1: 30,44 RON 10: 26,93 RON 50: 26,19 RON

Figure 25: IC regulator price on mouser.com

We can read in the datasheet of this IC that it comes in a TO-220 plastic package, with a metal backplate that already has a screwhole, making it easy to mount a heatsink on it. Additionally, we find even more useful information inside:

- T_j = 150°C
- T_a = 25°C
- R_{Tj-a} = 12°C/W
- R_{Tj-c} = 2.3°C/W
- P_d = P_{2in} - P_{2out} = 6.25W – 2.5W = 3.75W

Without a heatsink, the junction temperature would be:

$$T = T_a + P_d \cdot R_{Tj-a} = 70°C < T_j$$

Since the junction temperature at working conditions does not exceed T_j, we actually do not need a heatsink for this IC.

6. The Buck Converter

6.1. General Aspects

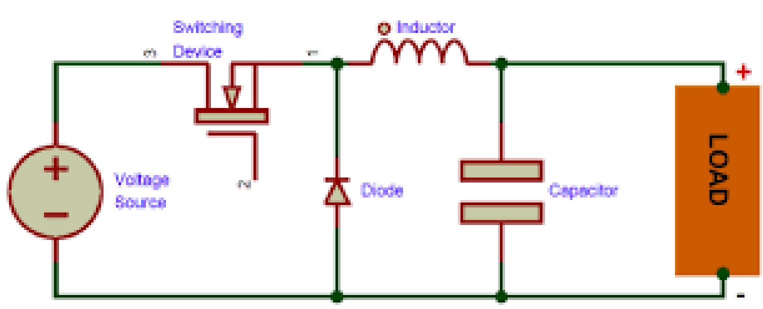


Figure 26: Schematic

A buck converter is a DC-DC power converter that steps down a higher DC voltage to a lower one. It operates using pulse-width modulation (PWM) and includes components like a high-side switch (transistor), a diode, an inductor, and an output capacitor.

In operation, the high-side switch is rapidly switched on and off. During the on-state, current flows through the inductor, storing energy. When off, the inductor releases this stored energy. The average voltage across the inductor, and consequently the output voltage, is regulated by the rapid switching of the transistor, controlled by the duty cycle.

The switching action transfers energy from the input source to the inductor. When the switch is off, the inductor releases energy to the load through a diode, bypassing the switch. An output capacitor further smoothens the output voltage by filtering any residual ripples. Buck converters are valued for their high efficiency.

6.2. Sizing the components

Values we obtained from previous calculations and from the design specifications:

- $U_{in} = U_{outRect} \in [14.7\text{V}, 15.5\text{V}]$
- $U_{out} = 3.3\text{V}$
- $I_{out\_max} = 2\text{A}$
- $I_{out\_min} = 40\% \cdot I_{out\_max} = 0.8\text{A}$
- $\Delta U_S = 50\text{mV}$
- $f_{sw} = 50\text{kHz} \Rightarrow T_{sw} = 20\mu\text{s}$

The load resistance:

$$R_{s\_min} = \frac{U_{out}}{I_{out\_max}} = \frac{3.3V}{2A} = 1.65\Omega$$

$$R_{s\_max} = \frac{U_{out}}{I_{out\_min}} = \frac{3.3V}{0.8A} = 4.125\Omega$$

The duty cycle:

$$\delta_{min} = \frac{U_S}{U_{I\_max}} = \frac{U_S}{U_{outRect\_max}} = \frac{3.3V}{15.5A} = 0.213$$

$$\delta_{max} = \frac{U_S}{U_{I\_min}} = \frac{U_S}{U_{outRect\_min}} = \frac{3.3V}{14.7A} = 0.224$$

The limit current between CCM and DCM:

$$I_{SL} = I_{out\_min} = 0.8\text{A}$$

The inductance:

$$\text{L} = \frac{\text{U}_S \cdot T}{2 \cdot \text{I}_{SL}} (1 - \frac{\text{U}_S}{U_{I\_max}}) = \frac{3.3V \cdot 20\mu\text{s}}{2 \cdot 0.8A} (1 - \frac{3.3V}{15.5V}) = 32.5\mu\text{H}$$

This represents the minimum value, so we will round this up to 50µH.

The current through the inductance:

$$\text{I}_{L\_min} = I_{SL} - \frac{\text{U}_S \cdot T}{2 \cdot L} (1 - \frac{\text{U}_S}{U_I}) = 0.8\text{A} - \frac{3.3V \cdot 20\mu\text{s}}{2 \cdot 50\mu\text{H}} (1 - \frac{3.3V}{15.1V}) = 0.28\text{A}$$

$$\text{I}_{L\_max} = I_{SL} + \frac{\text{U}_S \cdot T}{2 \cdot L} (1 - \frac{\text{U}_S}{U_I}) = 0.8\text{A} + \frac{3.3V \cdot 20\mu\text{s}}{2 \cdot 50\mu\text{H}} (1 - \frac{3.3V}{15.1V}) = 1.31\text{A}$$

The current through the transistor:

$$\text{I}_{T\_max} = I_{S\_max} + \frac{\text{U}_S \cdot T}{2 \cdot L} (1 - \frac{\text{U}_S}{U_{I\_max}}) = 2\text{A} + \frac{3.3V \cdot 20\mu\text{s}}{2 \cdot 50\mu\text{H}} (1 - \frac{3.3V}{15.5V}) = 2.51\text{A}$$

The voltage on the transistor:

$$\text{U}_{T\_max} = \text{U}_{I\_max} = 15.5\text{V}$$

The current through the diode:

$$\text{I}_{D\_max} = \text{I}_{L\_max} = 1.31\text{A}$$

$$\text{I}_{D\_avg} = \text{I}_S \cdot (1 - \delta) \quad \in [0.4\text{A}, 1\text{A}]$$

The voltage on the diode:

$$\text{U}_{D\_max} = \text{U}_{T\_max} = \text{U}_{I\_max} = 15.5\text{V}$$

The dissipated power on the diode:

$$\text{P}_D = \text{I}_{D\_max} \cdot \text{U}_{D\_max} = 1.31\text{A} \cdot 15.5\text{V} = 20.3\text{W}$$

The capacitance:

$$\text{C}_{min} = \frac{1}{8} \frac{(1 - \frac{\text{U}_S}{U_{I\_max}}) \cdot \text{U}_I \cdot T^2}{L \cdot \Delta\text{U}_S} = \frac{1}{8} \frac{(1 - \frac{3.3V}{14.7V}) \cdot 14.7V \cdot (20\mu\text{s})^2}{50\mu\text{H} \cdot 50\text{mV}} = 228\mu\text{F}$$

This represents the minimum value, so we will round this up to 300µF.

The current through the capacitor:

$$\text{I}_{C\_ef} = \frac{\text{I}_{S\_min}}{\sqrt{3}} = \frac{0.8}{\sqrt{3}} = 0.46\text{A}$$

6.3. Picking the components

6.3.1. The inductor

- L = 50µH
- $I_{L\_min} = 0.28A$
- $I_{L\_max} = 1.31A$

	*Mfr. Part No.* B82442T1106J50 *Mouser Part No* 871-B82442T1106J50	EPCOS / TDK	Power Inductors - SMD AEC-Q200 Learn More	Datasheet	369 In Stock	Cut Tape **1:** 6,53 RON **10:** 6,04 RON **100:** 4,25 RON **500:** 3,44 RON

Figure 27: Price on mouser.com

6.3.2. The transistor

- $I_{T\_max} = 2.51A$
- $U_{T\_max} = 15.5A$

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
V_{DS}	drain-source voltage	-55 °C ≤ T_j ≤ 150 °C		-	-	650	V
V_{TDS}	transient drain to source voltage	pulsed; t_p = 1 µs; δ_{factor} = 0.01		-	-	800	V
I_D	drain current	V_{GS} = 6 V; T_{mb} = 25 °C	[1]	-	-	11.5	A
P_{tot}	total power dissipation	T_{mb} = 25 °C; Fig. 1		-	-	125	W

Figure 28: GAN190 datasheet

	*Mfr. Part No.* GAN190-650FBEZ *Mouser Part No* 771-GAN190-650FBEZ	Nexperia	MOSFET MOS DISCRETES Learn More	Datasheet	2.340 In Stock 250 On Order	Cut Tape **1:** 13,51 RON **100:** 13,32 RON **250:** 13,02 RON

Figure 29: Price on mouser.com

6.3.3. The diode

- $I_{D\_max} = 1.31A$
- $U_{D\_max} = 15.5A$
- $I_{D_{avg\_max}} = 1A$

Product summary	
$I_{F(AV)}$	2 A
V_{RRM}	100 V
T_j (max.)	175 °C
V_F (typ.)	0.620 V

Figure 30: STPST2H100 datasheet

	*Mfr. Part No.* STPST2H100ZF *Mouser Part No* 511-STPST2H100ZF New Product	STMicroelectronics	Schottky Diodes & Rectifiers 100 V, 2 A Power Schottky Trench Rectifier Learn More	Datasheet	8.935 In Stock	Cut Tape **1:** 2,12 RON **10:** 1,62 RON **100:** 1,01 RON **1.000:** 0,549 RON Reel

Figure 31: Price on mouser.com

6.3.4. The capacitor

- C= 300µF
- $I_{C\_ef} = 0.46A$

	*Mfr. Part No.* TVA1208.5 *Mouser Part No* 75-TVA1208.5	Vishay / Sprague	Aluminium Electrolytic Capacitors - Axial Leaded 25V 300uF CASE DD	Datasheet	983 In Stock	**1:** 22,72 RON **10:** 19,55 RON **50:** 17,77 RON **100:** 14,70 RON

Figure 32: Price on mouser.com

6.4. LTSpice Simulations

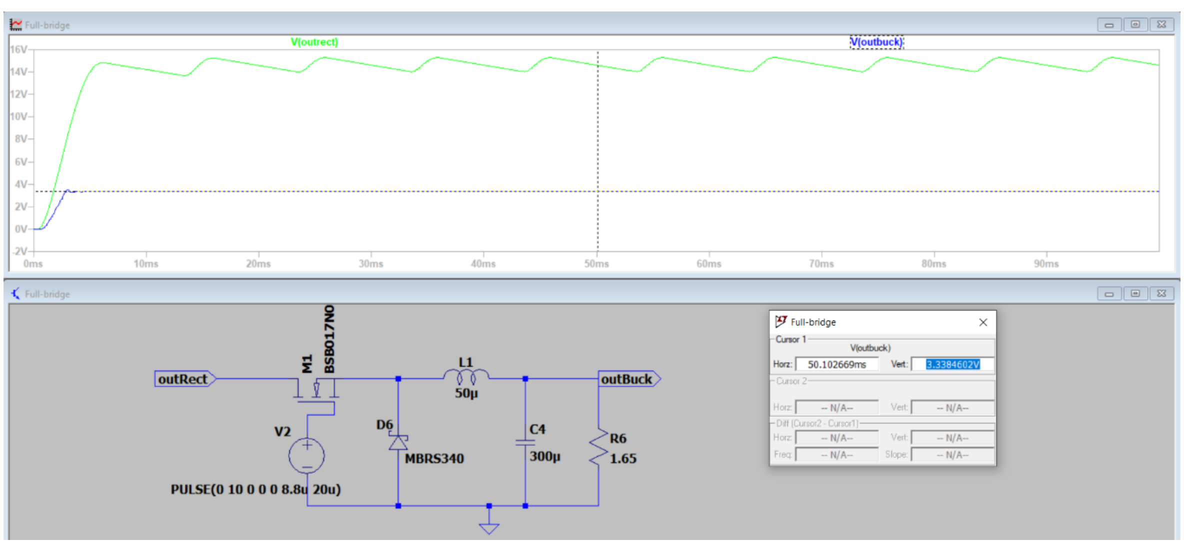


Figure 33: Output Voltage

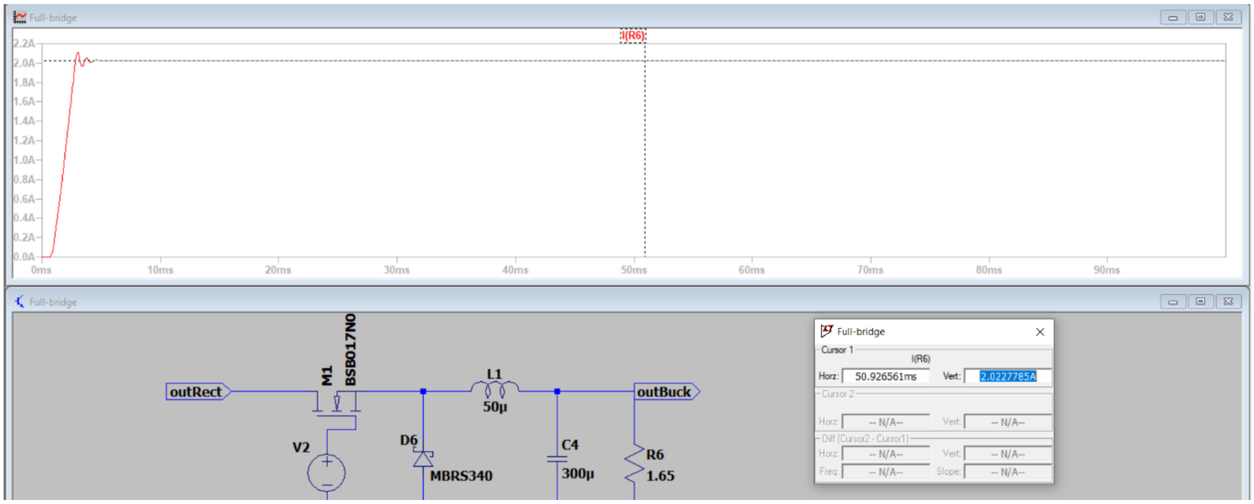


Figure 34: Output Current

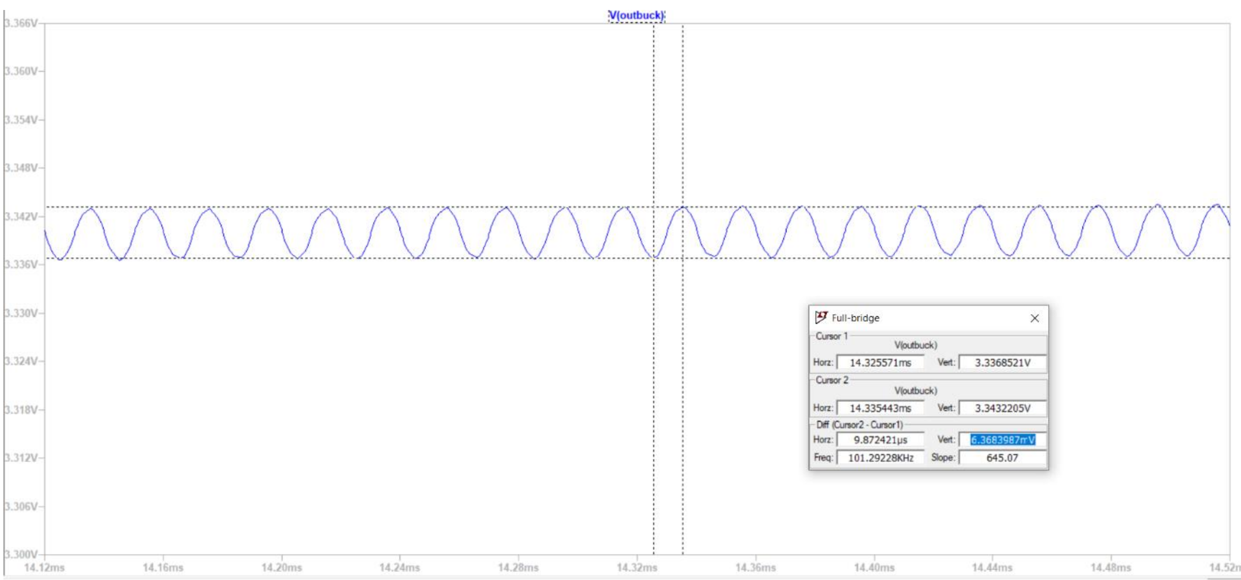


Figure 35: Output Voltage Ripple

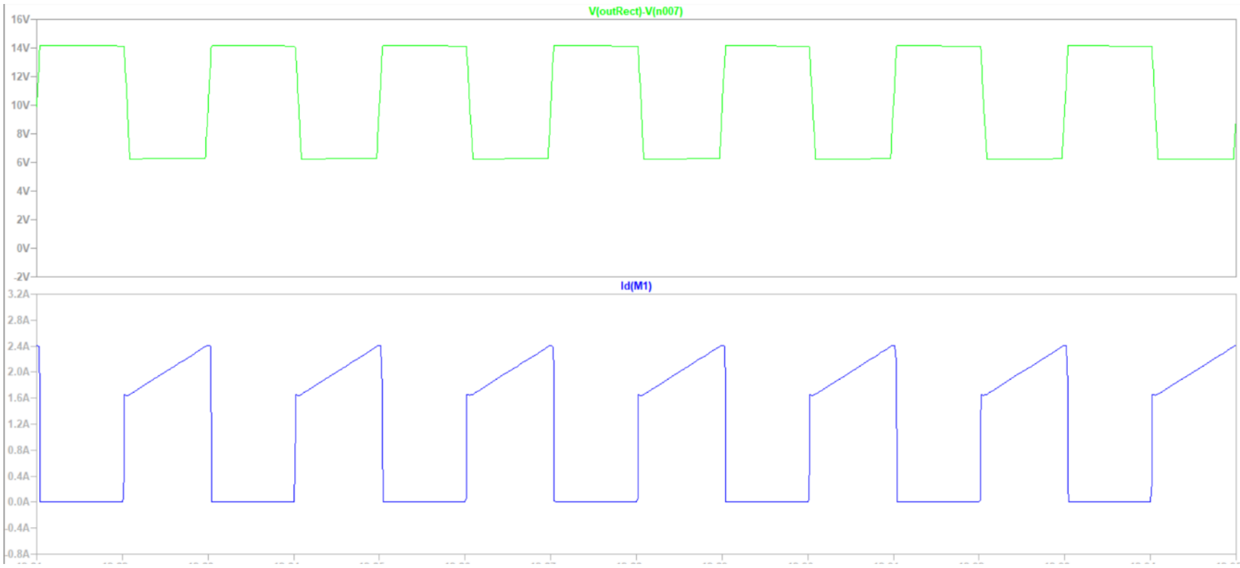


Figure 36: Transistor Voltage and Current

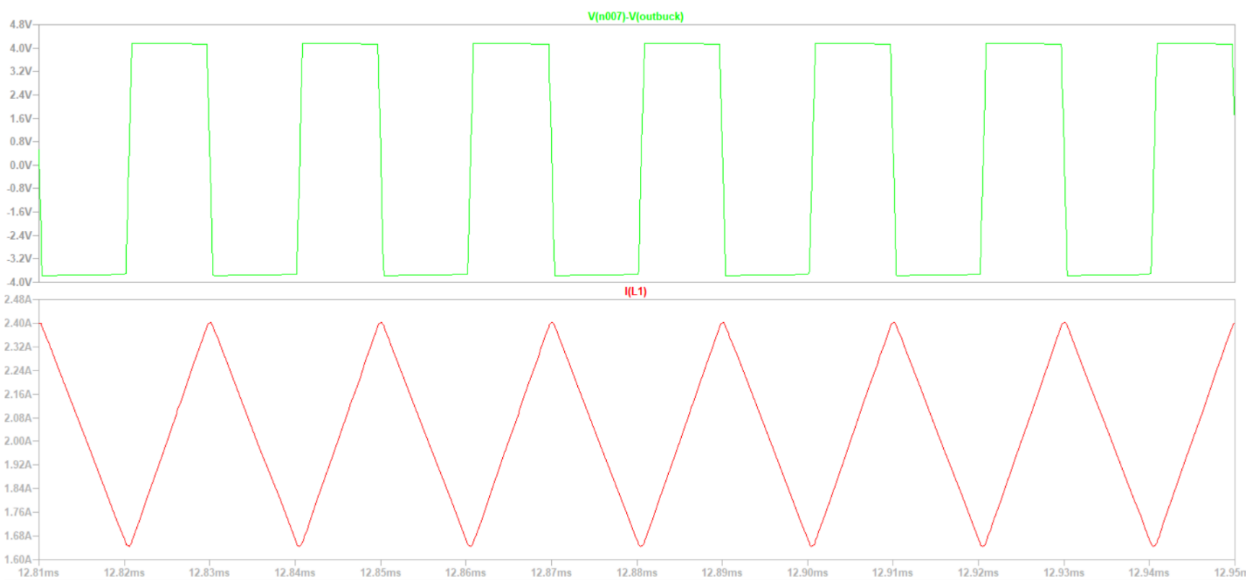


Figure 37: Inductor Voltage and Current

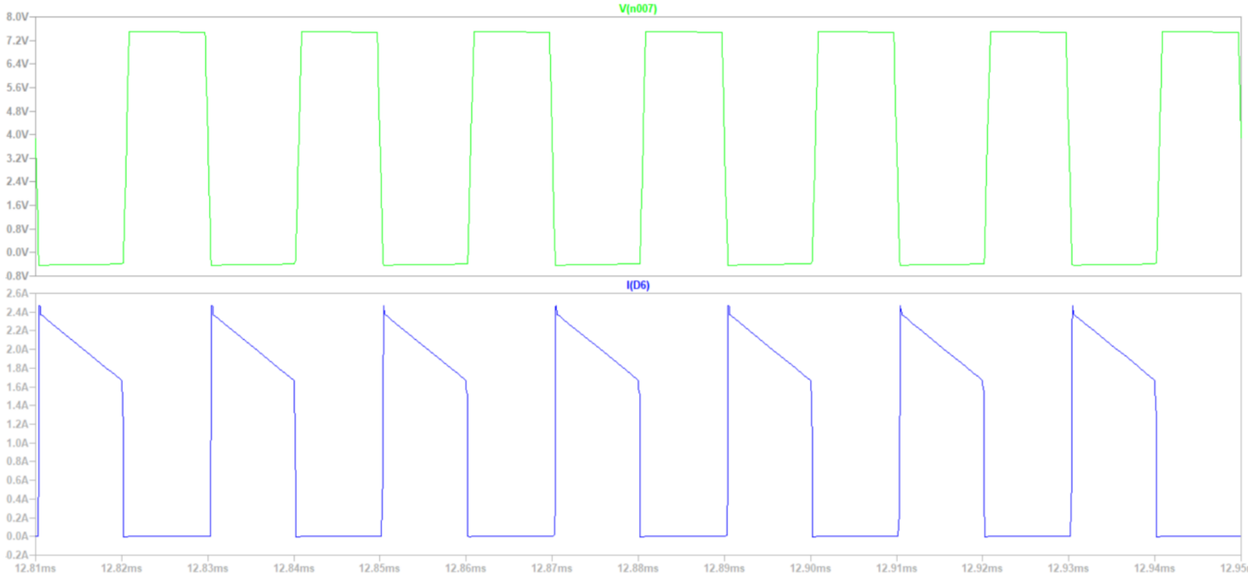


Figure 38: Diode Voltage and Current

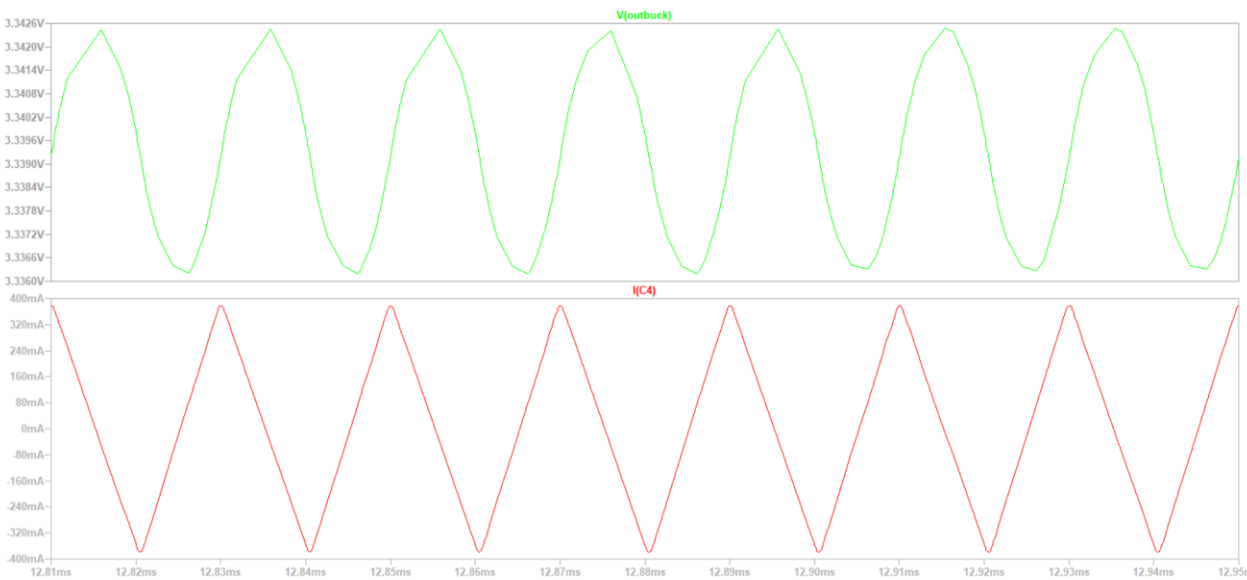


Figure 39: Capacitor Voltage and Current

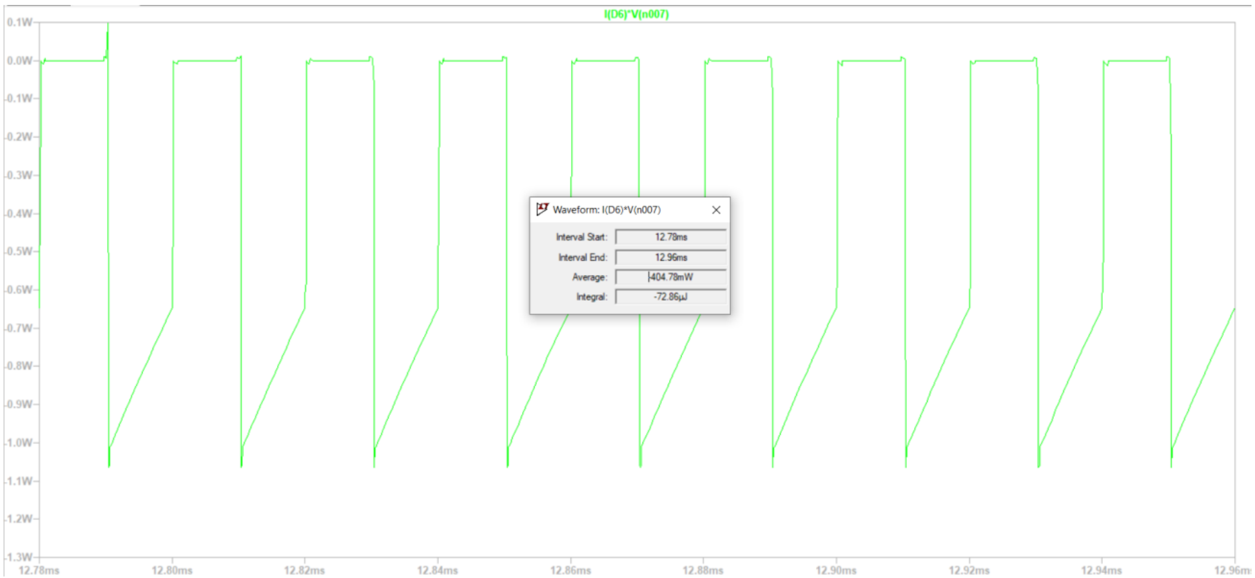


Figure 40: Diode Power

T_j	Maximum operating junction temperature(2)	+175	°C

1. *Please refer to Figure 1 and Figure 2 for the unclamped inductive switching test circuit, and waveform.*
2. *(dP_{tot}/dT_j) < ($1/R_{th(j-a)}$) condition to avoid thermal runaway for a diode on its own heatsink.*

Table 2. Thermal resistance parameter

Symbol	Parameter		Typ. value	Unit
$R_{th(j-l)}$	Junction to lead	SOD123Flat	15	°C/W
		SOD128Flat	14	
		SMB Flat	11	

Figure 41: Diode thermal resistance

As we can see in figures 40 and 41, the average power on the diode is 400mW and the maximum power is 1W. Even if we choose the package with the highest thermal resistance, our diode can reach only 15°C in the worst case scenario, which is way below the maximum operating temperature of 175°C. Therefore, this diode requires no additional heatsink.

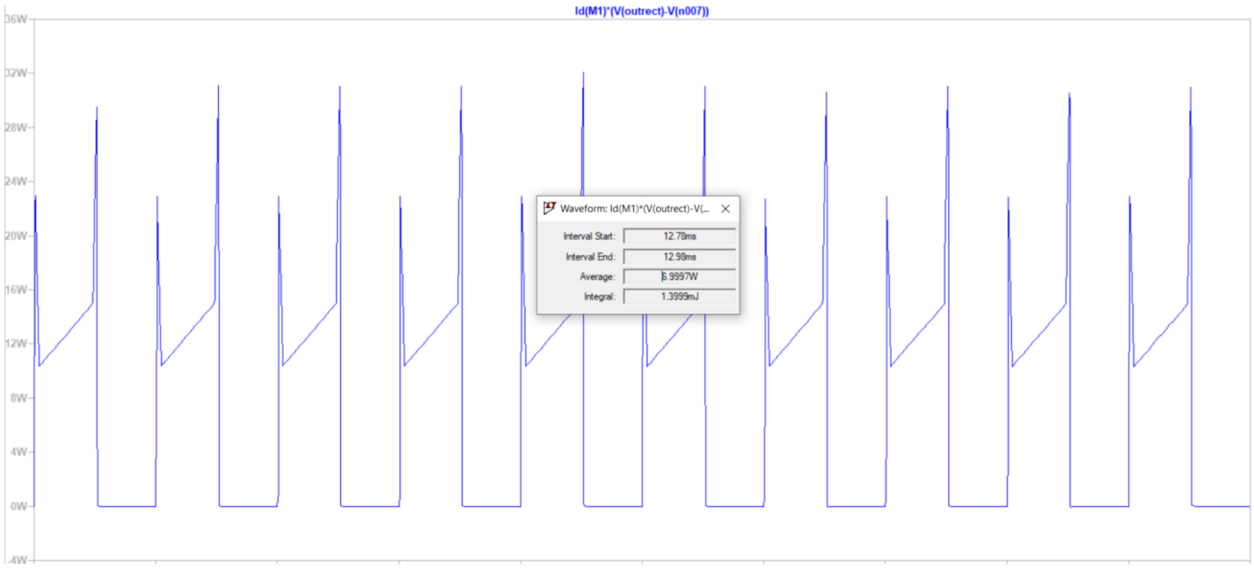


Figure 42: Transistor Power

Table 6. Thermal characteristics

Symbol	Parameter	Conditions		Min	Typ	Max	Unit
$R_{th(j-c)}$	thermal resistance from junction to case	Fig. 3		-	-	1	K/W
$R_{th(j-a)}$	thermal resistance from junction to ambient			-	-	35.9	K/W

Figure 43: Transistor thermal resistance

Since the maximum operating temperature of the transistor is 150°C, 7W with 1°C/W does not raise the need of an additional heatsink.

References

https://www.tme.eu/ro/details/pss63_230_18v/transformatoare-cu-prindere/breve-tufvassons/

https://www.vishay.com/docs/88503/1n4001.pdf

https://ro.mouser.com/ProductDetail/Diotec-Semiconductor/1N4001?qs=OlC7AqGiEDlll8NA510wmA%3D%3D

https://ro.mouser.com/c/passive-components/capacitors/aluminum-electrolytic-capacitors/?capacitance=15000%20uF&voltage%20rating%20dc=16%20VDC

https://www.tdk-electronics.tdk.com/inf/20/30/db/aec/B41231.pdf

https://fscdn.rohm.com/en/products/databook/datasheet/discrete/diode/zener/bzx84b13vlyt116-e.pdf

https://ro.mouser.com/c/?q=BZX84B13VLY

https://my.centralsemi.com/datasheets/2N3391A-3393.PDF

https://ro.mouser.com/c/?q=2N3391A

https://ro.mouser.com/datasheet/2/609/lt0117-3123447.pdf

https://ro.mouser.com/c/?q=lt317a

https://docs.rs-online.com/19e9/0900766b8101a040.pdf

https://fscdn.rohm.com/en/techdata_basic/transistor/thermal_resistance/2SC5866_Thermal_Resistance-e.pdf

https://ro.mouser.com/datasheet/2/609/lt0117-3123447.pdf

https://ro.mouser.com/datasheet/2/916/GAN190_650FBE-3159422.pdf

https://www.st.com/resource/en/datasheet/stpst2h100.pdf