Power supply project

Student: Pop Razvan Valentin

Contents

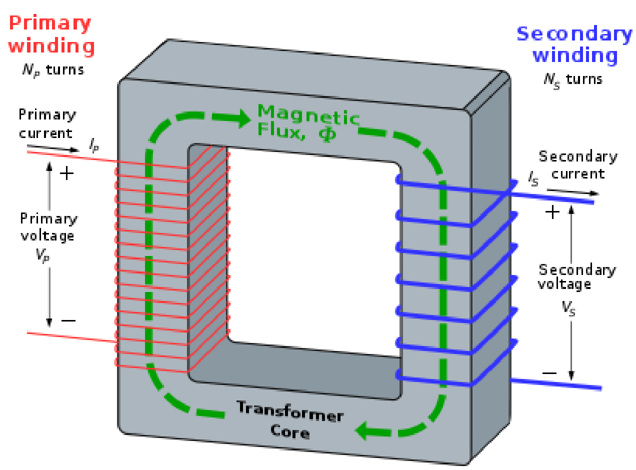
Transformer

1.Description

A power supply is an electrical device that supplies electric power to an electrical load. The primary function of a power supply is to convert electric current from a source to the correct voltage, current, and frequency to power the load.

2.Components of power supply

3.The transformer



A transformer is a passive component that transfers electrical energy from one electrical circuit to another circuit, or multiple circuits. A varying current in any one coil of the transformer produces a varying magnetic flux in the transformer's core, which induces a varying electromotive force across any other coils wound around the same core.

4.Selecting a transformer for our need

Our transformer needs to be able to power the following: a transistor regulator with the specs: 12V 0.5A efficiency 30%, I.C Regulator with the specs: 5V 1A efficiency 30% and a Buck Converter with the specs: 3.3V 4A and efficiency 90%.

It has to work with the following input : 230 VAC and rated frequency of 50-60Hz

We compute the power needed for each input component as follows:

$$n = \frac{Pout}{Pin}$$

$$Pin = \frac{I\ x\ V}{n}$$

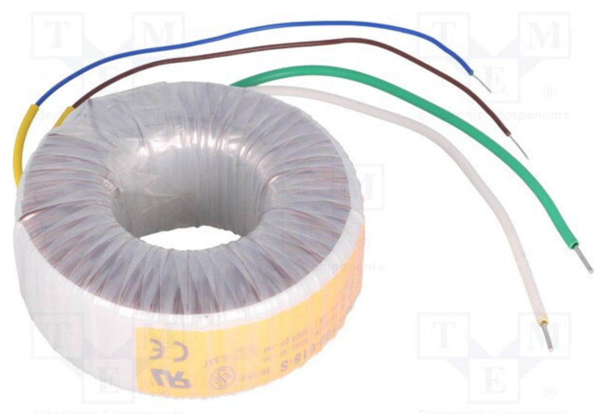
1. Input power for the transistor regulator is 20W
2. Input power for the I.C regulator 16.6 W
3. Input power for the buck : 14.66w
4. Total of power needed : 51.32 W

U1 = 230V

U2 = 18 V

Imax = 4A

Chosen transformer **58-0100-018-S:**



Rectifier

1.Type and circuit of rectifier used

Full-wave rectifier with capacitive filter and simulation of the circuit before any values for this project.

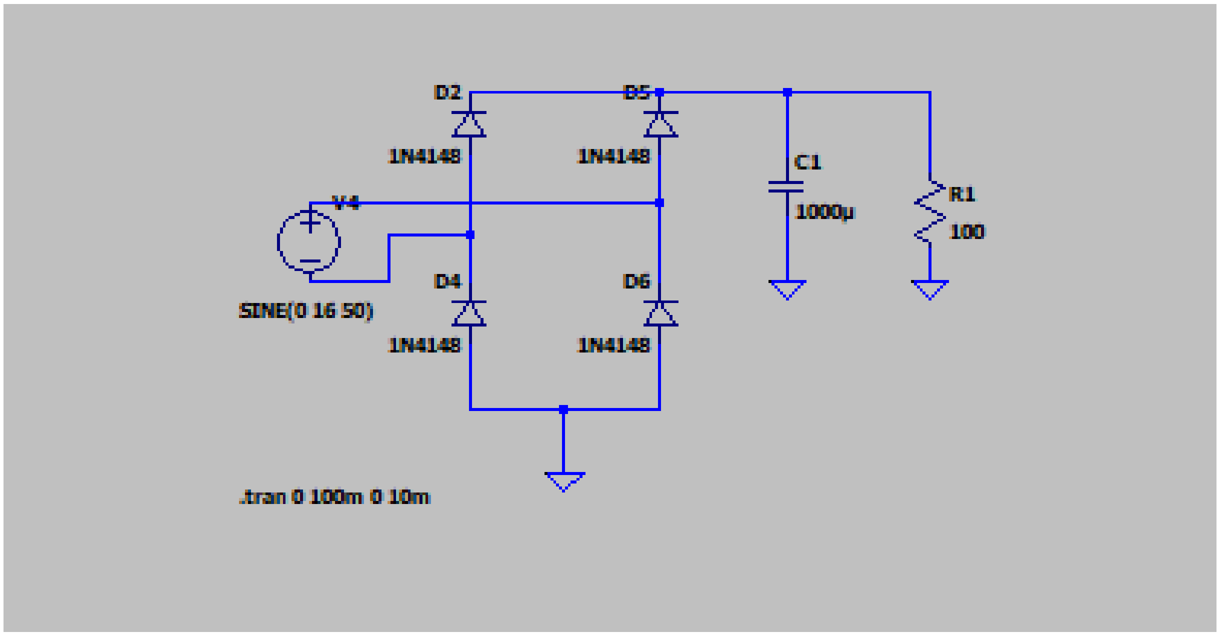


Figure 1 Circuit of full-wave rectifier with capacitive filter

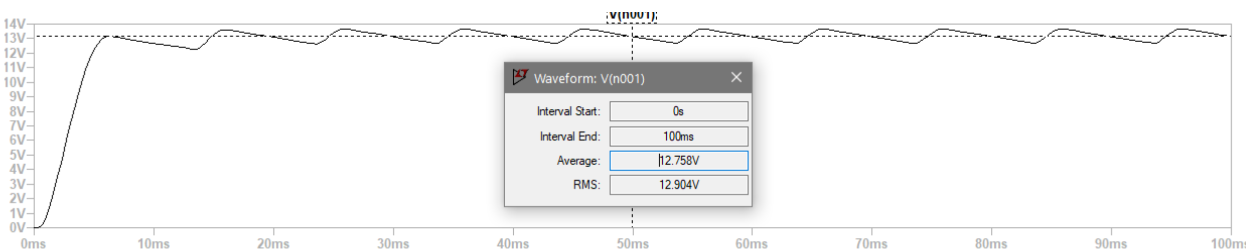


Figure 2 Output of the circuit with 16v input and 1N4148

2.Configuration

$$V_{out_{rectifier}} = 16V$$

$$P_{out_{rectifier}} = 51.32W$$

$$\eta \geq 70\%$$

$$\Delta V_{out} = 0.5\ V$$

$$f_{in} = 50Hz$$

3.Computations

$$I_{Out} = \frac{P_{out_{rect}}}{V_{out_{rect}}} = 3.2\ A$$

$$\gamma = \frac{\frac{\Delta V_{out}}{2}}{V_{out_{rectifier}}} = 0.016 - ripple\ factor$$

$$f_{out} = 2 * f_{in} = 100\ Hz$$

$$\omega = 2 * \pi * f_{out} = 628.31\ \frac{rad}{s}$$

$$R_s = \frac{V_{out_{rectifier}}}{I_{out_{rectifier}}} = 4.98 \cong 5\ Ohm$$

$$C = \frac{\pi}{2 * \omega * R_s * \gamma} = 0.032\ F = 32mF$$

$$V_{in_{rect}} = Vout + 2 * V_F \cong 18 = V_D max$$

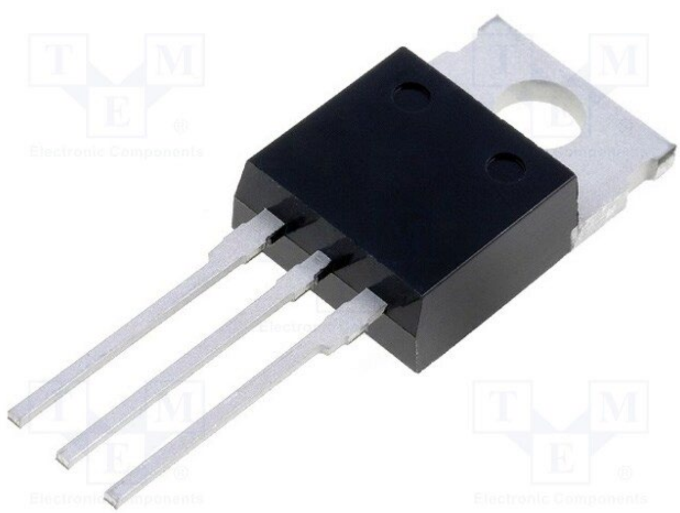
VF considered 0.8

$$I_D \max = \sqrt{(\pi * \omega * R_s)} * I_{out_{rectifier}} = 57\ A$$

4.Result from calculation

We need a diode that can support at least 57 A and 18 V.

The diode chosen :



Manufacturer	ONSEMI
Type of diode	Schottky rectifying
Mounting	THT
Max. off-state voltage	100V
Load current	2x 30A
Max. load current	60A
Semiconductor structure	common cathode, double
Case	TO220-3
Kind of package	tube
Heatsink thickness	1.15...1.39mm
Max. forward impulse current	350A
Max. forward voltage	0.81V

5.Simulations with the results and a similar Schottky diode

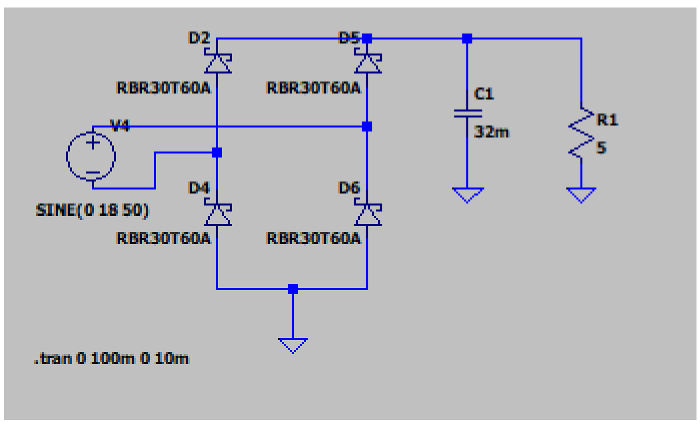


Figure 3 New circuit with changed values accordingly

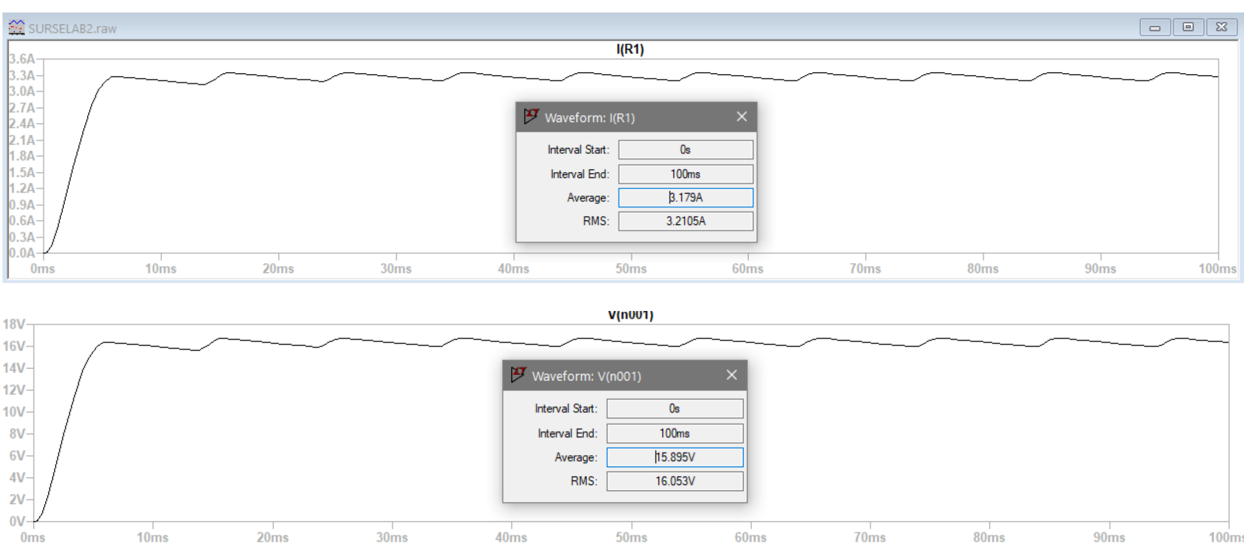
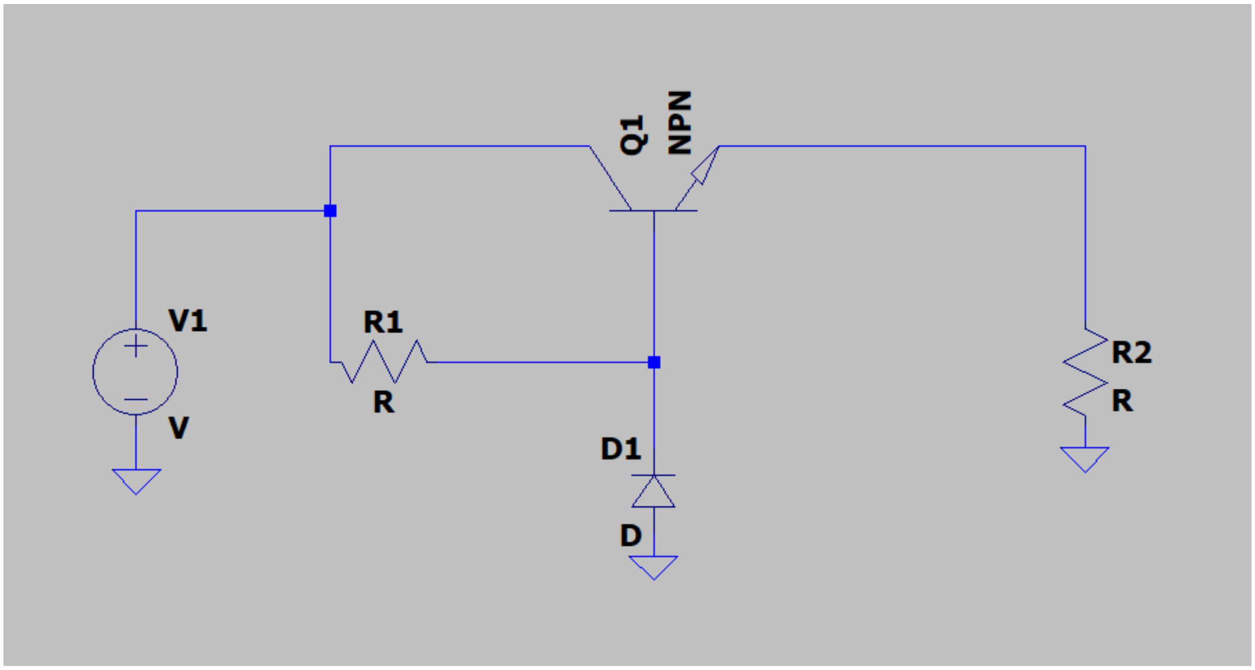


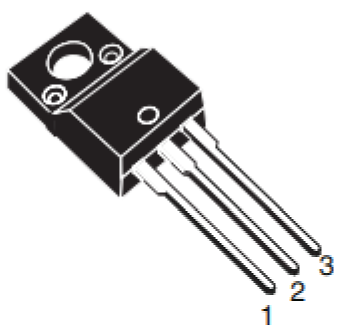
Figure 4 Results of simulation

Linear regulator with transistor

Circuit:



Choosing a transistor **2STP535FP** with high hFE :



TO-220FP

hFE	4000
VBE	5V
Total dissipation	37W
VCE	180V

Calculus :

$\eta := 30\%$ $V_{in} := 16\ V$ $V_{in\_min} := 15.8\ V$ $Iz := 10\ mA$

$\beta := 4000$ $V_{out} := 12\ V$ $V_{in\_max} := 16.2\ V$ $I_{out} := 0.5\ A$ $Ta := 35\ °C$

$V_{BE} := 5\ V$

$$P_{out} := V_{out} \cdot I_{out} = 6\ W \qquad P_{in} := \frac{P_{out}}{\eta} = 20\ W$$

$$LOAD := \frac{V_{out}}{I_{out}} = 24\ \Omega \qquad I_{in} := \frac{P_{in}}{V_{in}} = 1.25\ A$$

$$I_E := I_{out} = 0.5\ A \qquad I_C := I_E \qquad I_B := \frac{I_{out}}{\beta + 1} = 124.969\ \mu A$$

$$Ir := Iz + I_B = 0.01\ A$$

$$V_Z := V_{out} + V_{BE} = 7\ V$$

$$P_D := P_{in} - P_{out} = 14\ W$$

$$P_Z := V_Z \cdot Iz = 0.07\ W$$

$$P_T := 13.83\ W$$

$$V_R := V_{in} - V_Z = 9\ V$$

$$R := \frac{V_R}{Ir} = 888.892\ \Omega$$

$$P_R := V_R \cdot Ir = 0.091\ W$$

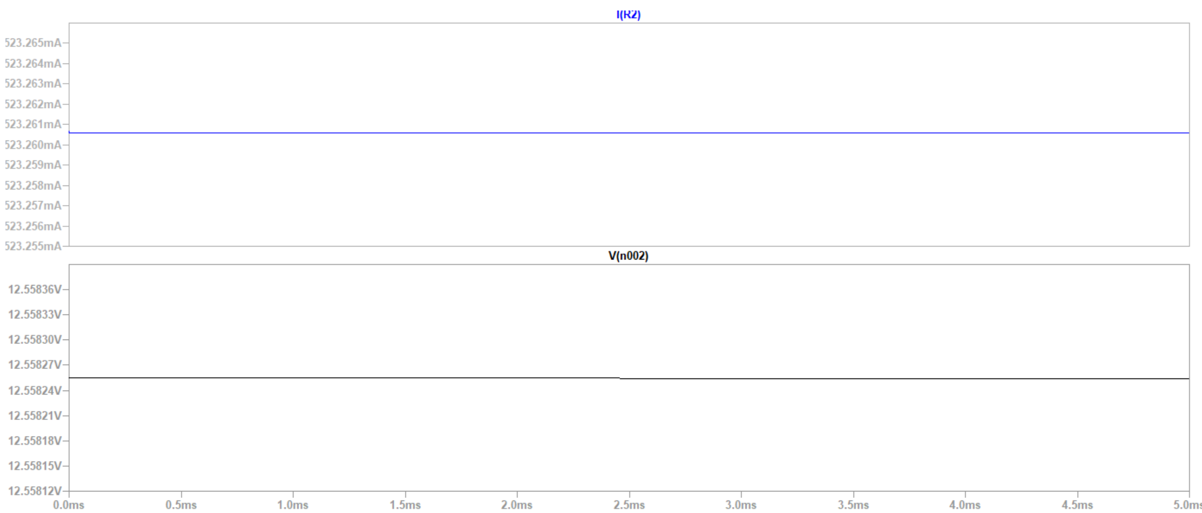
Diode **BZX84C7V5**:

Vz	7.45
Pz	0.35W
Iz	5mA

Resistance after modifying the Zener current

$$R := \frac{V_R}{Ir} = 1.756\ k\Omega$$

Output results running a transient analysis for 5ms

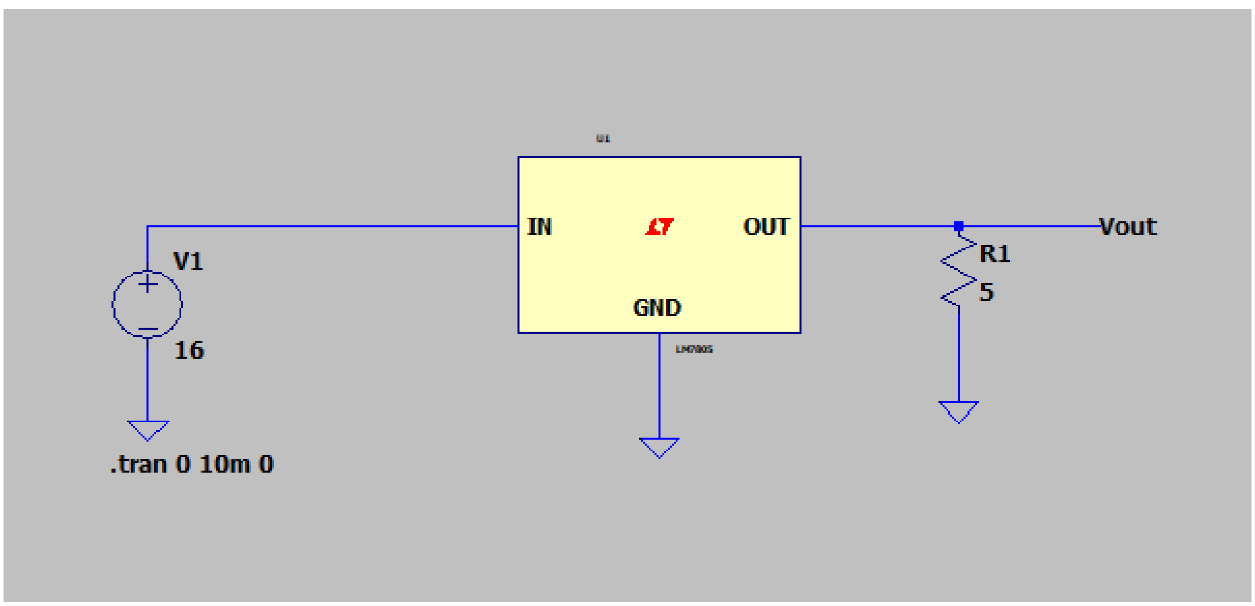


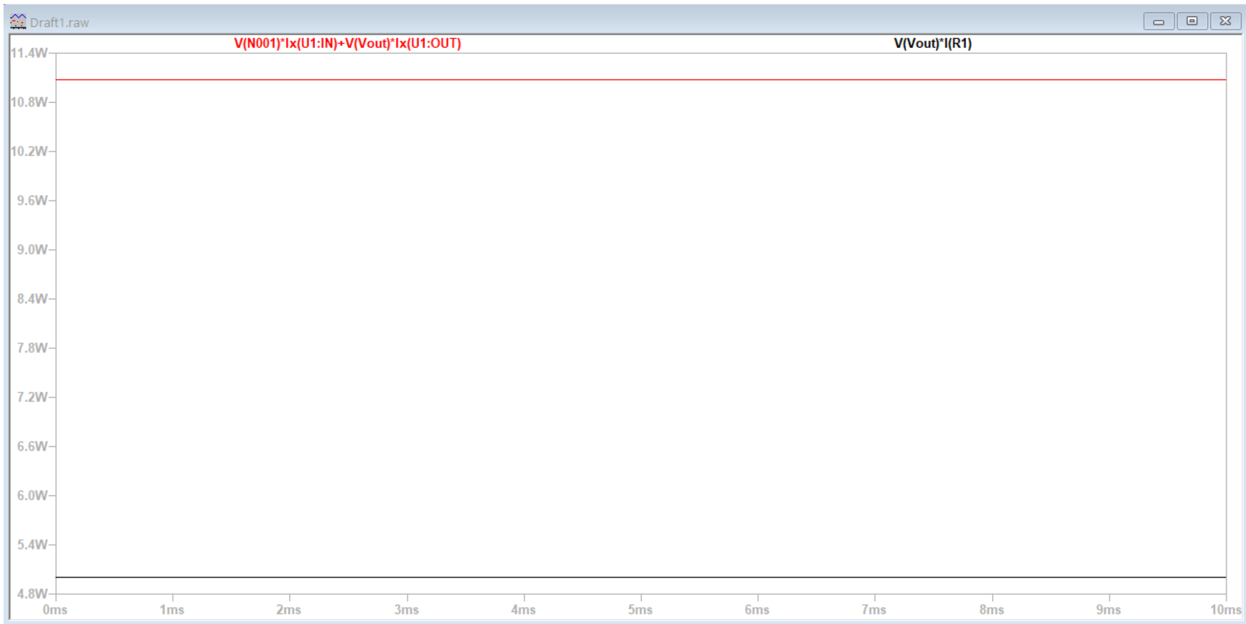
Power supply project – Voltage regulator with integrated circuit

1.Voltage regulator chosen - **LM7805**

Manufacturer	TEXAS INSTRUMENTS
Voltage drop	2V
Output voltage	1.5A

2.Circuit used and simulation





3.Load resistance calculation and choosing - **90J5R0E**

$V_{in} := 16\ V$

$V_{out} := 5\ V$

$I_{out} := 1\ A$

$P_{out} := V_{out} \cdot I_{out} = 5\ W$

$n := 30$

$P_{in} := \frac{(100 \cdot P_{out})}{n}$

$P_{in} = 16.667\ W$

$I_{in} := \frac{P_{in}}{V_{in}} = 1.042\ A$

$R_{Load} := \frac{V_{out}}{I_{out}} = 5\ \Omega$

$T_{JMAX} := 125$

$T_A := 25$

$\theta_{JA} := 19\ \frac{C}{W}$

$\theta_{JC} := 3 \cdot \frac{1}{W} \quad \frac{C}{W}$

$forLM7805 \quad P_D := (V_{in} - V_{out}) \cdot I_{out} = 11\ W$

$5\ W\ \ resistor$

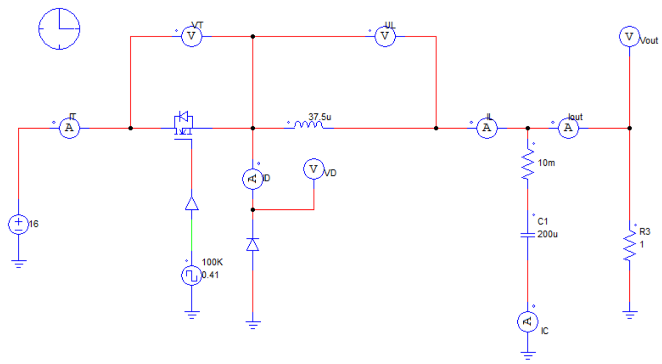
$\theta_{JATOTAL} := \frac{(T_{JMAX} - T_A)}{P_D} = 9.091\ \frac{1}{W} \quad \frac{C}{W}$

Since θJA(TOTAL) < θJA, a heat sink will definitely be required.

$\theta_{SA} := \theta_{JATOTAL} - \theta_{JC} = 6.091\ \frac{1}{W}$

Buck Converter Step Down

Circuit:



Calculations:

Specifications

$U_{in\_max} := 16\ V$ $\quad fc := 100\ kHz$ $\quad I_{out\_min} := 400\ mA$

$ripl := 20\ mV$ $\quad I_{out\_max} := 4\ A$ $\quad T := \frac{1}{fc} = 10\ \mu s$

$U_{in\_min} := U_{in\_max}$

$U_{forward} := 0.5\ V$ $\quad U_{ripple} := 0.2\ V$ $\quad U_S := 3.3\ V + 0.5\ V + 0.2\ V = 4\ V$

Output voltage due to non-ideal conditions

$$T_C := T \cdot \left(\frac{U_S}{U_{in\_max}}\right) = 2.5\ \mu s \qquad \delta := \frac{U_S}{U_{in\_max}} = 0.25 \quad 25\% \qquad T_B := T \cdot \left(1 - \frac{U_S}{U_{in\_max}}\right) = 7.5\ \mu s$$

$$I_{Dmax} := I_{out\_max} = 4\ A \qquad I_{Dmed} := I_{out\_max} \cdot (1 - \delta) = 3\ A$$

$$L_{min} := \frac{(U_S \cdot T)}{2 \cdot I_{out\_min}} \cdot \left(1 - \frac{U_S}{U_{in\_max}}\right) = 37.5\ \mu H \qquad U_{TMAX} := U_{in\_max} = 16\ V$$

$$I_{Tmax} := I_{out\_max} + \frac{(U_S \cdot T)}{2 \cdot L_{min}} \cdot \left(1 - \frac{U_S}{U_{in\_max}}\right) = 4.4\ A$$

$$I_{Lmin} := I_{out\_max} - \frac{(U_S \cdot T)}{2 \cdot L_{min}} \cdot \left(1 - \frac{U_S}{U_{in\_max}}\right) = 3.6\ A$$

$$I_{Lmax} := 2 \cdot I_{out\_max} - I_{Lmin} = 4.4\ A \qquad I_{Lmax\_DISC} := \frac{(U_{in\_max} - U_S)\ T_C}{L_{min}} = 0.8\ A$$

$$U_L := L_{min} \cdot \left(\frac{(I_{Lmax} - I_{Lmin})}{T_C}\right) = 12\ V \qquad Maximum \quad current \quad discontinous$$

$$Q := \frac{T^2}{8} \cdot \frac{\left(1 - \frac{U_S}{U_{in\_max}}\right) \cdot U_S}{L_{min}} = 1\ \mu C \qquad I_{cef} := \frac{I_{out\_min}}{\sqrt{3}} = 0.231\ A$$

$$C := \frac{1}{8} \cdot \frac{\left(1 - \frac{U_S}{U_{in\_max}}\right) \cdot U_{in\_max} \cdot T^2}{L_{min} \cdot 20\ mV} = 200\ \mu F \qquad R_{load} := \frac{U_S}{I_{out\_max}} = 1\ \Omega$$

Choosing the components:

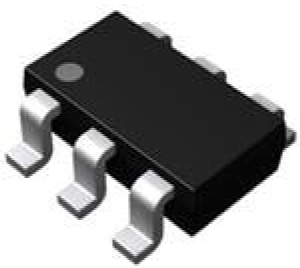
Diode - Schottky SD1040CS_S2_00001

Maximum current 5A   Vrrm - Repetitive Reverse Voltage:40 V   Vf - Forward Voltage:550 mV

Maximum average forward rectified current – 10A

Price 5 Ron

Transistor - RQ6E050AJTCR N-CHANNEL



ID 5A   Vgs th - Gate-Source Threshold Voltage: 500 mV

Vds - Drain-Source Breakdown Voltage: 30 V

Price 3 Ron

Capacitor MCAX25V207K8X16

Voltage Rating: 25V

Price 4 Ron

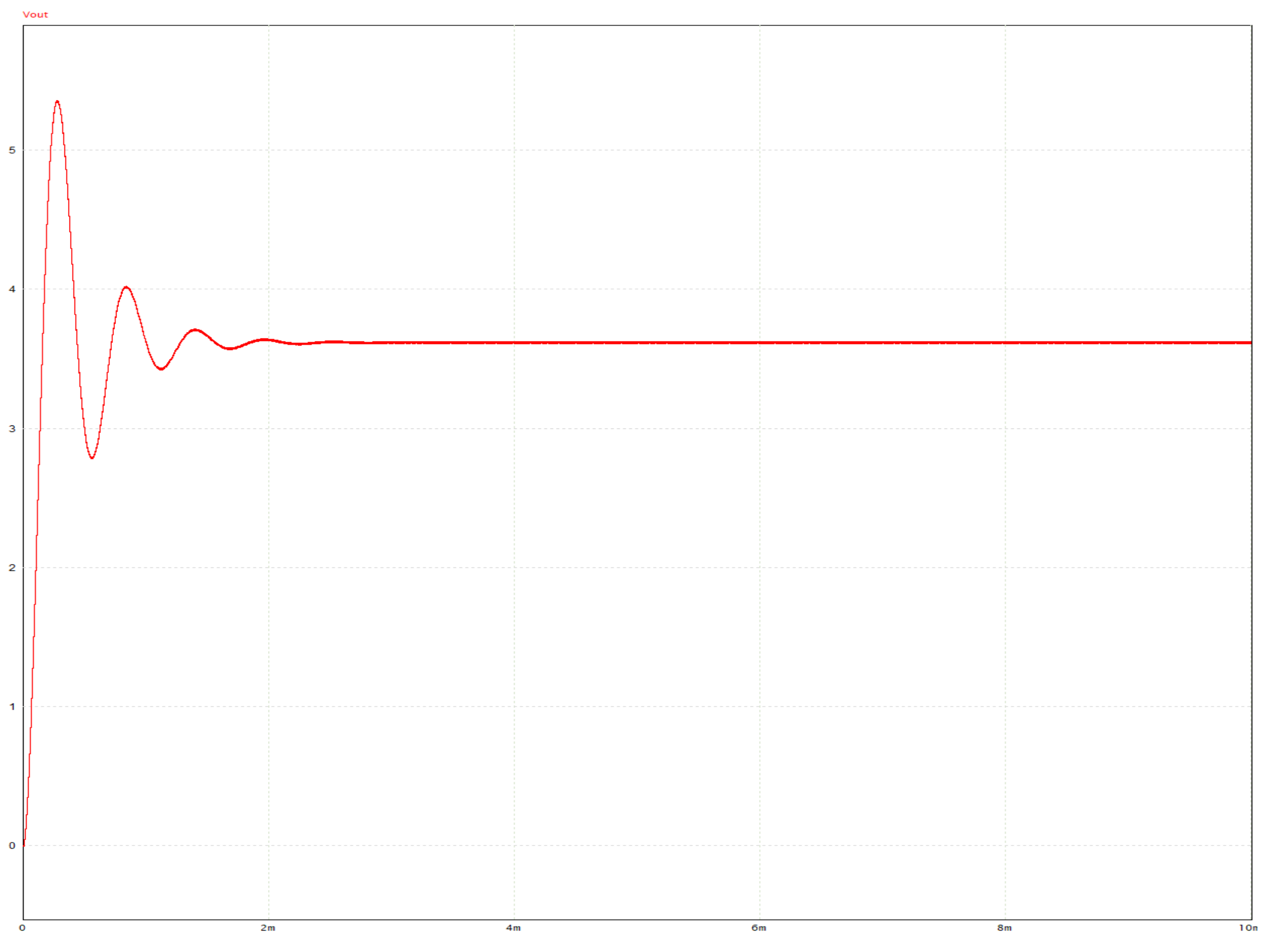
Capacitance Tolerance: ± 10%

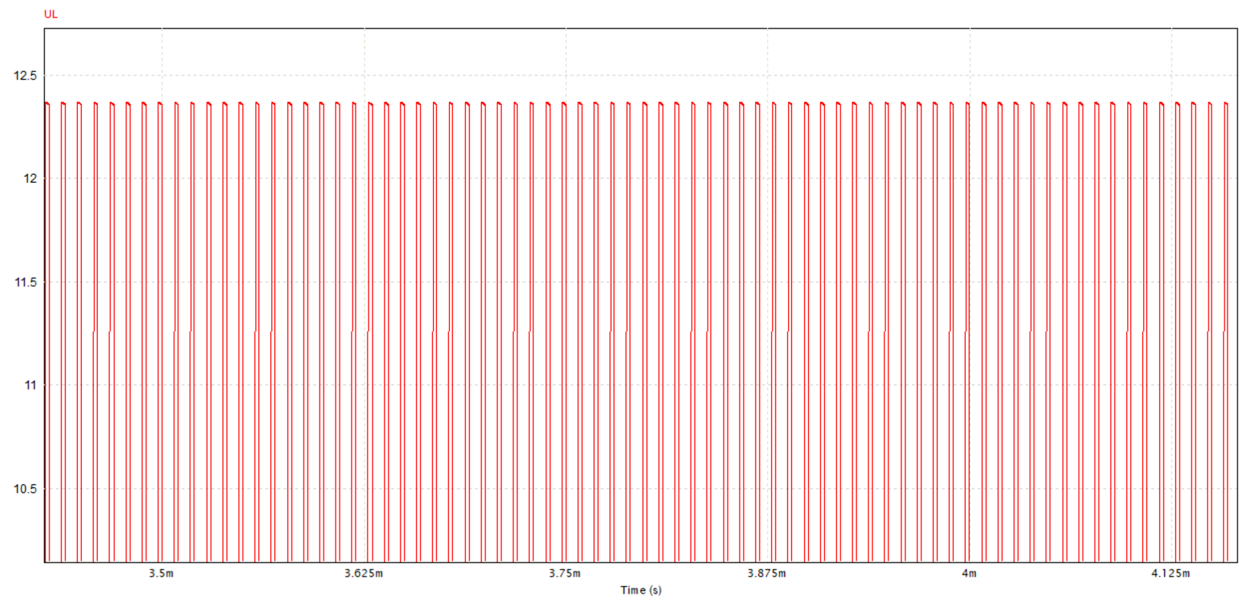
Inductor - PL8916NL

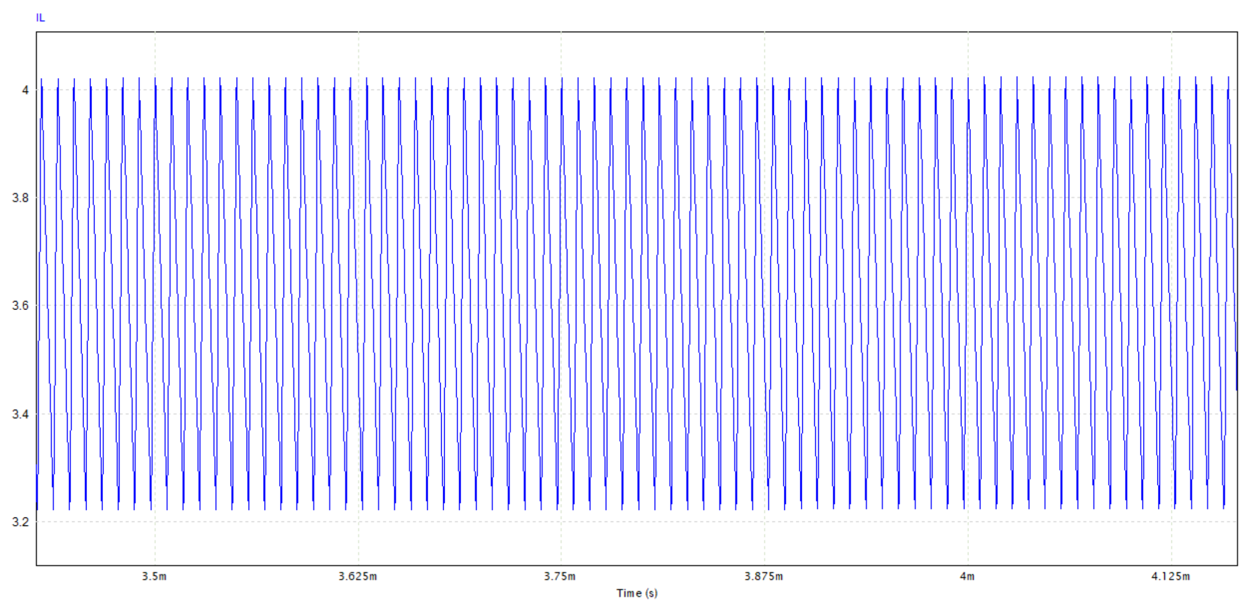
Inductance: 37.6 uH

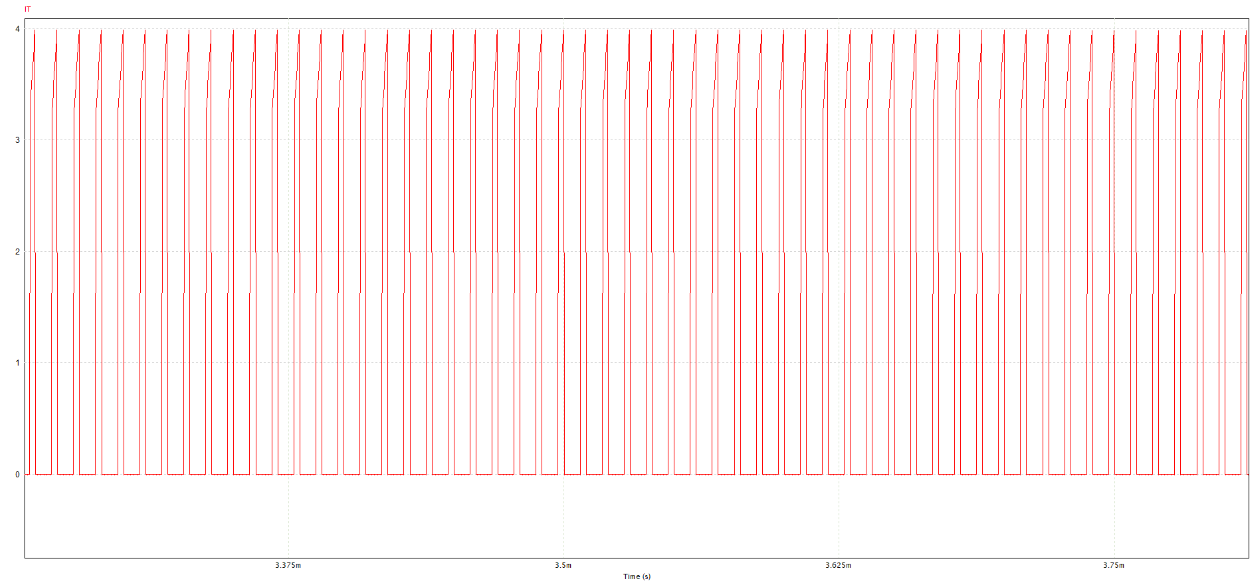
Maximum DC Current: 11 A

Simulations:




UL
12.5
12
11.5
11
10.5
3.5m
3.625m
3.75m
3.875m
4m
4.125m
Time (s)


IL
4
3.8
3.6
3.4
3.2
3.5m
3.625m
3.75m
3.875m
4m
4.125m
Time (s)



The PID controller

A PID controller is an instrument used in industrial control applications to regulate temperature, flow, pressure, speed and other process variables. PID (proportional integral derivative) controllers use a control loop feedback mechanism to control process variables and are the most accurate and stable controller.

Calculus(specifications taken from buck):

$$w0 := \frac{1}{\left(\sqrt[2]{37.5\ \mu H \cdot 200\ \mu F}\right)} = 11.547\ kHz$$

$$wfz := w0 \qquad whf := 314\ kHz$$

$$wzea := wfz$$

$$Rfbt := 25\ k\Omega \qquad wfp := \frac{1}{(0.01\ \Omega \cdot 200\ \mu F)} = 500\ kHz$$

$$Rcomp := 8.742 \cdot Rfbt = 218.55\ k\Omega$$

$$Cff := \frac{1}{wfz \cdot Rfbt} = 3.464\ nF$$

$$Ccomp := \frac{1}{(wzea \cdot Rcomp)} = 0.396\ nF$$

$$Chf := \frac{1}{(whf \cdot Rcomp)} = 0.015\ nF$$

$$Rff := \frac{1}{(wfp \cdot Cff)} = 577.35\ \Omega$$

$$Rfbb := \frac{(Rfbt \cdot 4)}{4 - 2.5} = 66.667\ k\Omega$$

Simulations: