DESIGN OF TRANSFORMER LESS POWER SUPPLY FOR LOW POWER APPLICATION

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Abstract

Appropriate power supply is the most required parameter for any electronics gadget. We need it for all kind of works related to electronic world (example: you need it if you are working on any project or to power up your designed device). Most of the electronic components work with DC power supply. To power up these components we can use various D.C. sources i.e. battery, AC to DC converter, Rectifier Circuit etc. We can use any of them depending upon our need. But sometimes we may fall in situation that we need only few mA of current at very low voltage and we may not have the option to use costly and bulky AC to DC converter circuit, any battery source or any other power source like DC adapter available in the market (example: you have designed a device and you want to build a separate power supply source for it so that it can operate directly from AC mains) but on the other hand you don't want to use step down transform in the converter circuit to reduce the size and cost. To solve the issue we have designed a circuit which can be used anywhere to provide power supply for current requirement up to few mA at low voltage. Circuit has very good response to the high voltage surge and spikes even which lasting for few milliseconds. Further circuit is modified from the conventional techniques available across the internet [1] to get the step type voltage response across capacitor at output side to avoid any malfunctioning of connected device.

Keywords: *Regulated Power Supply, Transformer less Power Supply, Bridge Rectifier, Low Power Application, A.C. to D.C. converter etc…*

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1. INTRODUCTION

To get DC supply from AC mains, bridge rectifier circuit is well known circuit for the people working in the field of electronics. Its simplest block diagram is shown below:

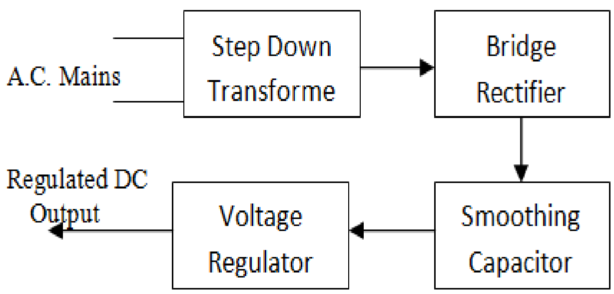


Fig.1: Block Diagram of Regulated Power Supply

The main disadvantage of above circuit is that it uses a step down transformer and because the low frequency transformers are heavy and large, it increases the system size [2]. Also sometimes it's tough to get a low power small size transformer from market and if you want to use one that available in the market then it may possible that the size of the circuit designed on the final PCB comes out less than that of transformer size (as happened with us). To come out from this situation we can use simple resistor network or capacitor network instead of using a step down transformer to reduce the voltage [3].

As we know from ohm's law voltage and current are related to each other (V=IR). So by choosing the appropriate value of resistor we can easily design the circuit which will give us required voltage at output. We can select the resistor by our power rating requirement and availability in the market but try to avoid high power rating resistors as it may cause problem to the rest of the circuit by generating heat which dissipated in the resistor. You can use few resistors in parallel instead to increase the total current.

Here in our paper we have designed a circuit which can provide 10mA of current at 5 V for a range of input voltage from 260Vp-p to 370Vp-p (180V_{RMS} to 261V_{RMS}). The whole circuit is simulated in PSIM software.

2. CIRCUIT DIAGRAM

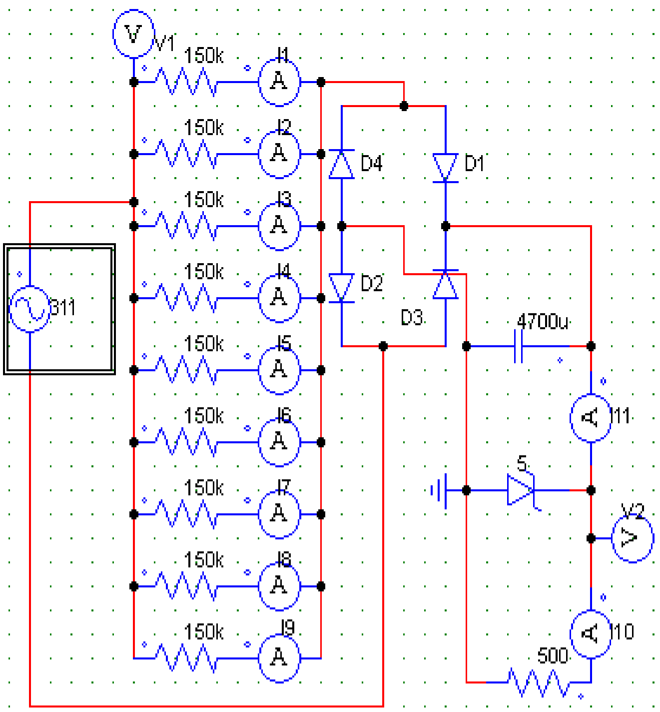
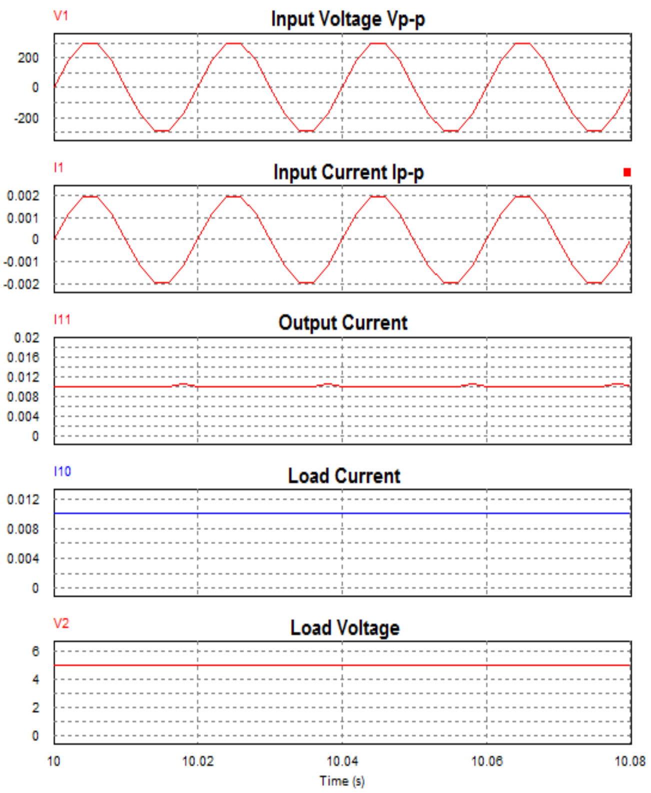


Fig.2: Circuit Diagram

3. WORKING AND SIMULATION RESULTS

This circuit is simulated for the various input voltages and works fine with the voltage range from 260Vp-p to 370Vp-p (180V_{RMS} to 261V_{RMS}). Below is the simulation result of the above circuit at 311Vp-p (220 V_{RMS}):



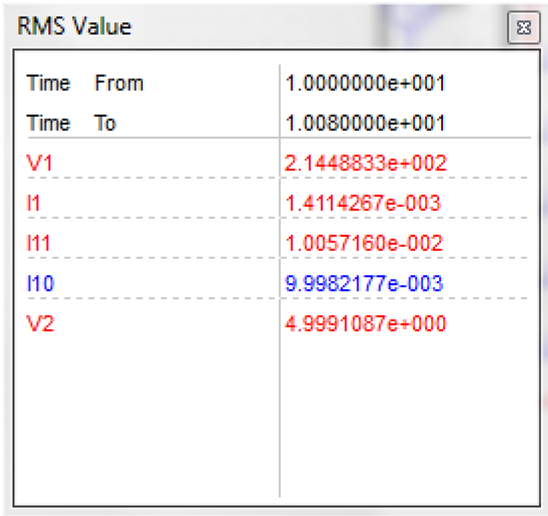
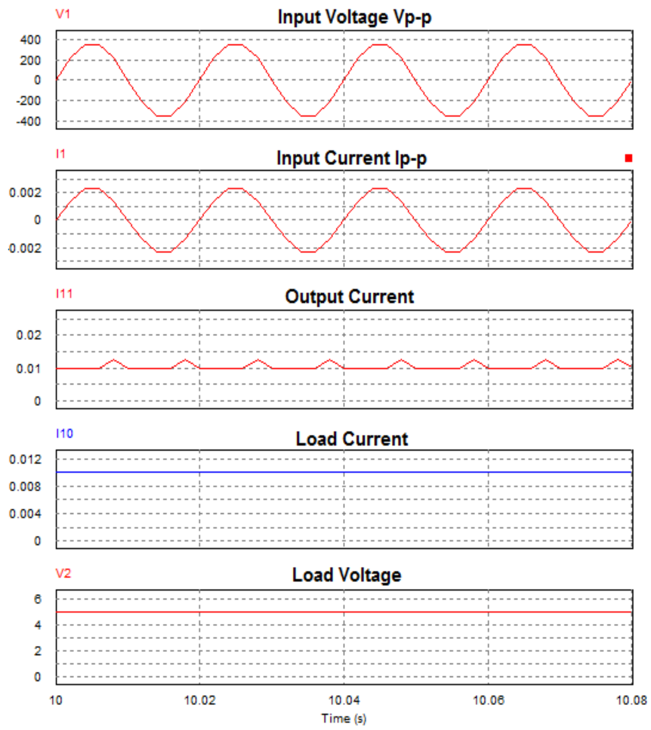
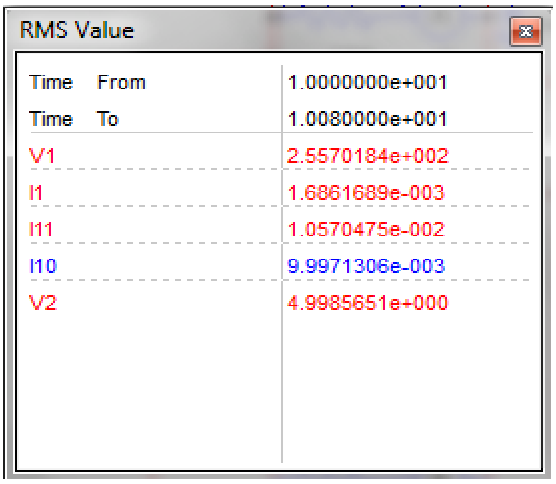


Fig.3: Simulation Result at 311Vp-p (220 V_{RMS})

From the above data almost 1.41mA of current flows through the series resistors which is equivalent to the power rating of 0.298 W so if we use resistors having power rating of 0.5 W then we can use it efficiently for the mentioned range of input voltage. It can be observed from the simulation result obtained at 370Vp-p (261V_{RMS}).





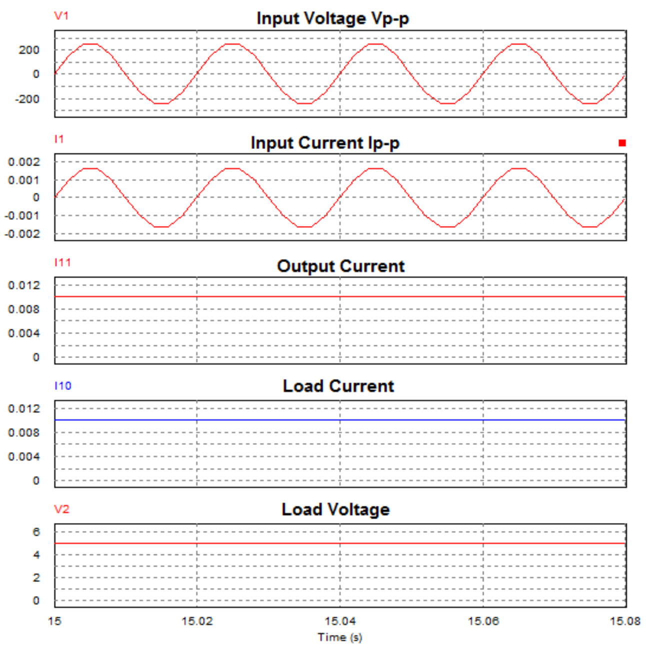
RMS Value

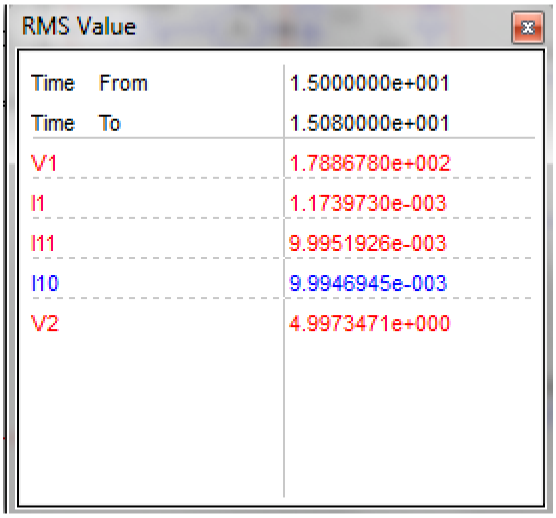
Time From	1.0000000e+001
Time To	1.0080000e+001
V1	2.5570184e+002
I1	1.6861689e-003
I11	1.0570475e-002
I10	9.9971306e-003
V2	4.9985651e+000

Fig.4: Simulation Result at 370Vp-p (261V_{RMS})

Here we can see that current which flows through series resistors is 1.68mA which is equivalent to the power rating 0.42 W. So resistor having power rating equivalent to 0.5 W will work fine for the selected voltage range.

Selection of Zenor Diode: From the result it is clear that current flowing through Zenor Diode is (Output Current – Load Current) i.e. I_{11}- I_{10} which is very small in magnitude when load is connected to the power supply module but if the load connected draw less current than the desired current i.e. 10mA then the Zenor current will increase in the same amount to keep the output at 5 V. maximum amount of current will flow through the Zenor when there will be an open circuit condition occur in that situation Zenor current will be equal to the Output current. So by assuming the maximum output current at 2mA @5V we can choose the Zenor diode rating which comes out to be 0.01 W. so we choose any Zenor diode for this application having power rating more than above mentioned value. Now below is the simulation result obtained at 260Vp-p (180V_{RMS}) i.e. at minimum input voltage:





RMS Value

Time From	1.5000000e+001
Time To	1.5080000e+001
V1	1.7886780e+002
I1	1.1739730e-003
I11	9.9951926e-003
I10	9.9946945e-003
V2	4.9973471e+000

Fig.5: Simulation Result at 260Vp-p (180V_{RMS})

From the simulation result data it is observed that almost no current flows through the Zenor Diode and output current is equal to the load current. It means that if input voltage will drop below 260Vp-p (180V_{RMS}) then Output voltage will drop below 5 V.

4. RESPONSE TO HIGH VOLTAGE SURGE

To get the high voltage surge response of the circuit we applied a high voltage having a peak of 1000 V and pulse duration of 2ms as shown in adjacent simulation result:

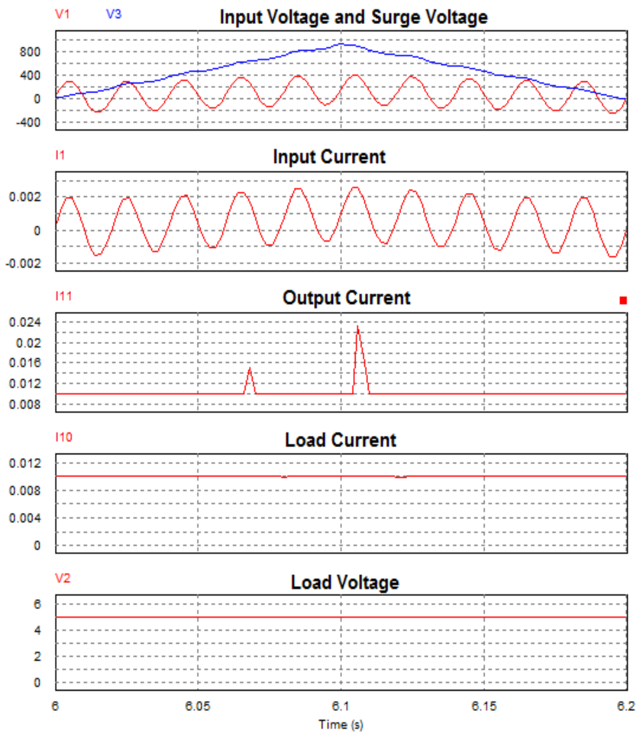


Fig.6: Simulation Result for Voltage Surge Response

If we observe the simulation result then we will find that in response to the high voltage surge, we will get a spike in the output current having peak value of 24mA only and for very small duration, concentrated near the peak of input surge voltage. Further it is also clear that the excess current will flow through Zenor diode and our load will not be affected from it. Reason why system can handle this amount of voltage surge is that the smoothing capacitor (4700 µF) is charged through a series resistor of 150K and its time constant (RC value) comes out 750 seconds which is almost 12.5 minutes. Now if we increase the capacitor value than our system response will be more efficient towards the high voltage surge or spikes but generally voltage or spikes not last that longer [4] so it will be better not to increase the capacitor value because in the beginning capacitor will take more time to charge up to desired voltage level. It can be observed from the simulation result shown below:

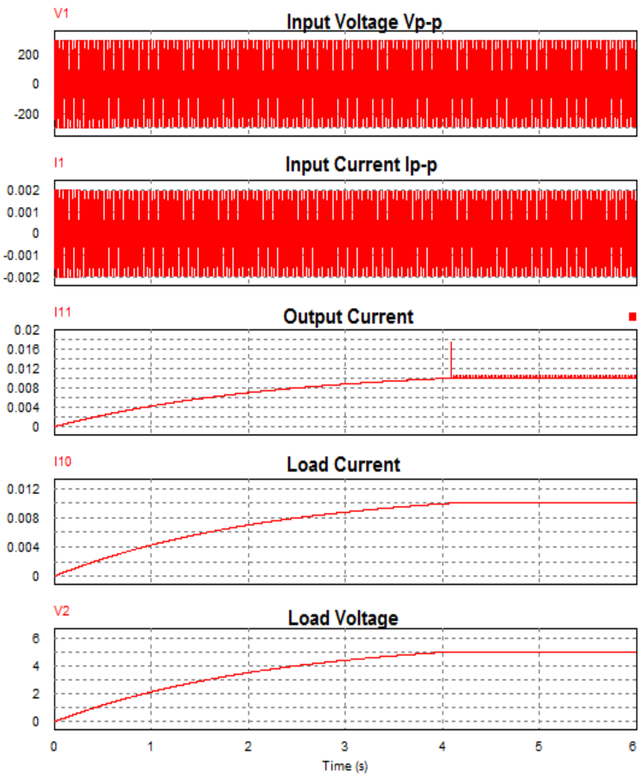


Fig.7: Voltage Change across the Smoothing Capacitor

It is clear from result that after almost 4 seconds voltage across the capacitor reaches to the desired voltage level. We can reduce the smoothing capacitor value to reduce this time but on the other hand we will get high voltage ripples in the output voltage. This may not be the problem for some components but may cause serious problem for some components (it may stop functioning or start malfunctioning).

To solve that issue we have modified our circuit and it will switch on power supply for the rest of the circuit only when the voltage reaches the desired voltage level. For that we have used a Zenor diode (having break down voltage equal to the desired output voltage) and connected it with a series resistor across the capacitor. Junction point of Zenor and resistor is connected to the base of a NPN transistor switch through an ON-OFF controller (to make sure that transistor only works as switch). Now as soon as the voltage across capacitor reaches the desired value Zenor diode will start conducting current and a voltage drop will occur across the resistor which will switch on the transistor and power up the whole circuit connected. Modified circuit and its output response are shown below:

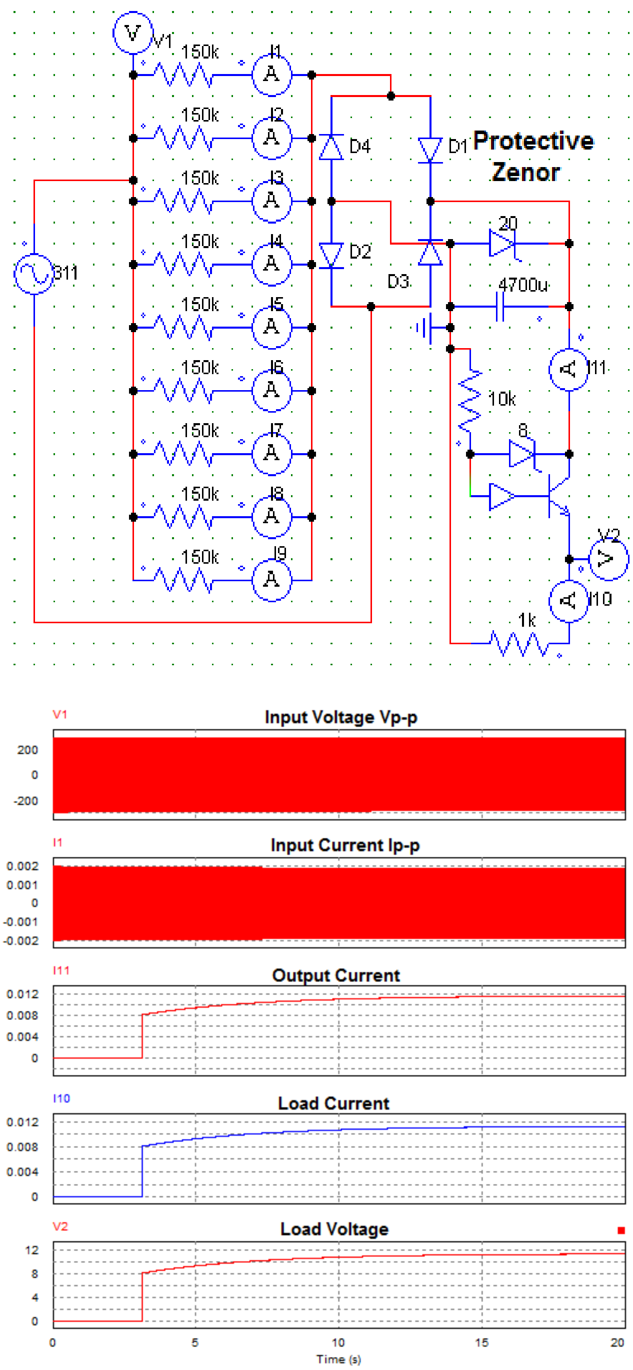


Fig.8: Modified Circuit and Its Output Response

Here the response is shown considering ideal conditions; in practice we will get the output voltage when the voltage across Zenor will reach voltage more than that of its break down voltage.

Here it is clear that the Zenor diode is not used for the voltage regulation but for switching load at desired voltage. To get regulated voltage use voltage regulators instead of

Zenor diode as series resistor with Zenor diode will limit the load current. If one want to use the Zenor diode then make sure that the switching Zenor diode break down voltage is more than that of regulating Zenor diode break down voltage otherwise you will get and switching output voltage instead of regulated DC voltage output. Protective Zenor diode is connected to make sure that in case of open circuit condition voltage won't go beyond its break down voltage.

5. ADVANTAGES

- Cheap, uses only few resistors instead of a transformer.
- Compact, can be designed within a small space.
- Good response to high voltage spikes and surge, can handle surge lasting even for few milliseconds.
- You can increase load current by adding more resistors in parallel.

6. DISADVANTAGES

- Isolation problem, circuit is in the direct contact with the high voltage.
- Accidental shock, in case of open circuit if the protective Zenor diode will not conduct then we will get a very high voltage across the output terminal which may cause shock.
- Can be designed only for fixed load current.
- Low efficiency, part of power will be wasted in the series resistors.

7. PRECAUTIONS

- Try not to use with open circuit condition.
- Connect earth ground with the circuit to avoid any kind of accidental shock.
- Use load current within the designed capacity to avoid overheating of the series resistors.

8. CONCLUSION

Here we have explained that how we can design a transformer less power supply for low power application within a small space and within almost negligible price. We can use the circuit confidently anywhere if we keep few things in mind i.e. precautions. It is also shown that it has a very good response to the high voltage surge and spikes even which lasting for few milliseconds. Circuit is also modified to get the step type voltage response across the capacitor at output side to avoid any malfunctioning of connected device.

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