

TRANSFORMER-LESS BASED VARIABLE DC SUPPLY

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Abstract- Electronics circuitry needs DC power source of a specific value to work effectively. This paper considers the design and evaluation of transformer-based and transformer less-based variable regulated DC power supply with the aim of presenting a comparative analysis between them; and their respective areas of applications. The quality, cost, size, weight, performance and efficient production of DC power supply thus pose a great deal of concern and attention in the DC power production of any electronic device. The design methodology used in this work involves Software design for component selection, improved hardware design, computer simulation and evaluation of transformation, rectification, filtration and regulation stages for both transformer-based and transformer less -based adjustable DC power supply with graphical outputs. The results obtained after following the design specification was very satisfactory. The transformer-based has a robust output current and well isolated from the supply voltage, which makes it more suitable for high current application, highly reliable for powering electronics devices while the transformer less based DC source has smaller size, weight and cheaper so as to miniaturize electronics devices but limited to low current devices . It also generates far less noise, heat, input harmonic distortion levels, and higher transient response but lack of proper isolation unlike its counterpart thus result in lower Mean Time To Failure (MTTF).Transformer less variable DC power supply should be considered a viable option for lower power, small and low current applications where achieving the highest availability is not the top concern and cost, size and weight restrictions inhibit the use of traditional transformer-based DC power supply.

Index Terms- MTTF , X-RATED CAPACITOR.

I. INTRODUCTION

In electrical engineering field, systems and equipments like amplifiers, satellites, microwave link systems to name but a few depend upon the availability of a stable and quality well regulated Direct Current (DC) power supplies for their correct operations. No electronics laboratory or technology is complete without a well regulated (or variable) DC power supply. It is the first essential element required

in any electronics device. The construction, design and evaluation of this piece of electronic equipment- will find use both now and in future. The main and basic requirements of a well regulated DC power supply unit are Isolation between source and load, Low ripple, Low output impedance, Power factor, High transient response, Low levels of input harmonic distortion , Reduced power losses ,Good regulations, Strict output short-circuits protection, Workable size and weight. Transformer-less power supplies provide a low-cost alternative to transformer-based and switcher-based power supplies. The two basic types of transformer-less power supplies are resistive and capacitive. This application note will discuss both with a focus on the following:

1. A circuit analysis of the supply.
2. The advantages and disadvantages of each power supply.
3. Additional considerations including safety requirements and trade-offs associated with half-bridge versus full-bridge rectification.

II. DESIGN METHODOLOGY

The design methodology of both the transformer and transformer less based system involves five stages as shown in Figures.

Figure 1:- Flow diagram of transformer-based dc supply

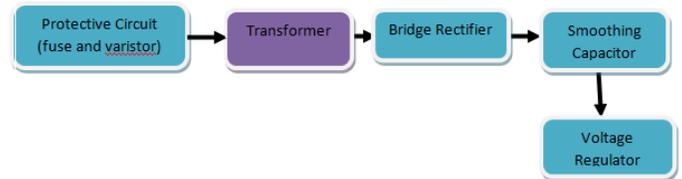


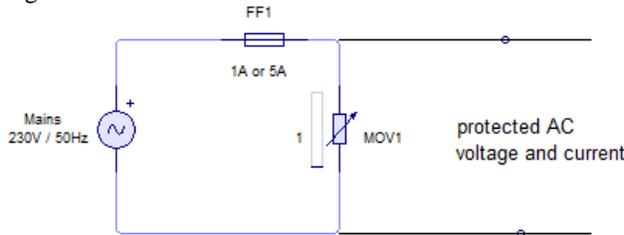
Figure 2:- Flow diagram of transformer-less dc power supply



The protection stage provides reliable and economical protection against high voltage transients, surges and over-current which may be produced. It comprises of fuse and varistor.

In this work, the maximum current is 4A for the transformer-based and 1A for the transformer less type thus stating the rating of the fuse to be used in each of them. Since the main supply voltage is approximately 230, the voltage rating of the varistor used 250Vac; the protection circuit is as shown below:

Figure 3: Protection circuit from the mains



A. Transformation stage is used to transform the incoming line voltage of 230 down to a required voltage value for the power supply unit. For the two types of power supply that is the transformer less and the transformer based power supply, **x-rated capacitor** and step-down transformer are used respectively. Step-down transformer: The simulation waveform circuit analysis shown below involves both the protection and the transformation stage using transformer as the transformation device.

Figure 4: waveform analysis of both protection and transformation stage for transformer based DC power supply

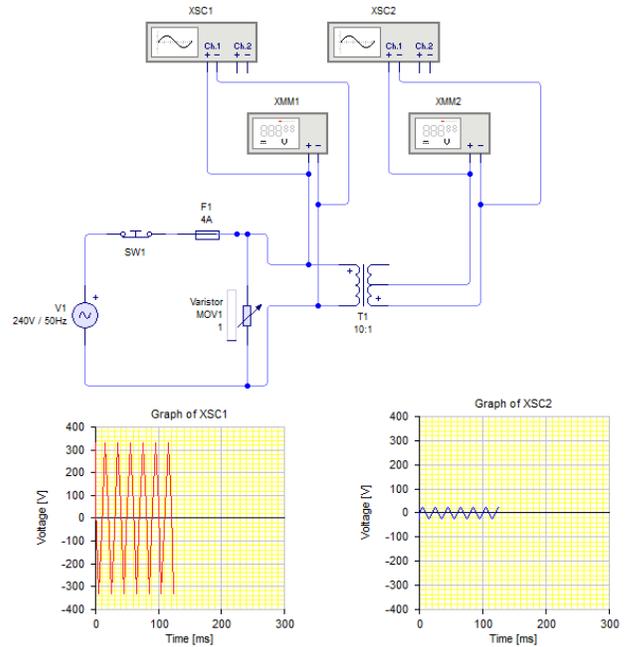
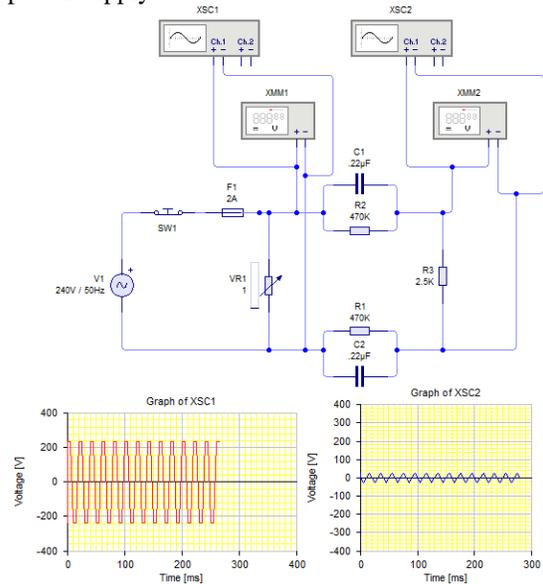


Figure 5 : waveform analysis of both protection and transformation stage for transformer less based DC power supply



B. Rectification stage is the stage after transformation stage that aids in the conversion of AC to DC signal. In this work a full wave rectification is used, because of its fundamental advantages over the half wave rectifier counterpart. Bridge rectifier is used rather its counterpart because it does not require a special centre tapped transformer, thereby reducing its size and cost. The bridge rectifier consists of 4 IN4001 silicon diodes. Livewire simulation

of both the transformation and rectification stage for the transformer based and transformer less based Dc power supply are as shown below.

Figure 6: waveform analysis of transformation and rectification stage for the transformer based circuit

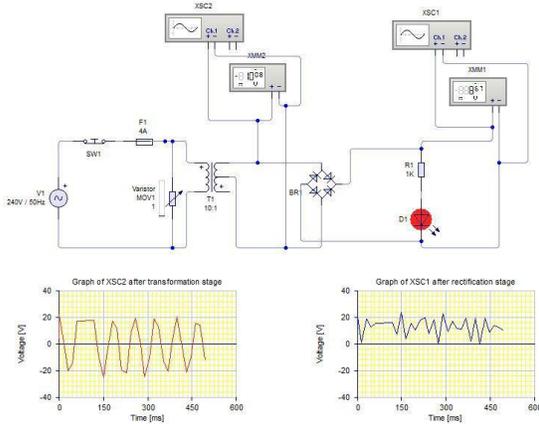
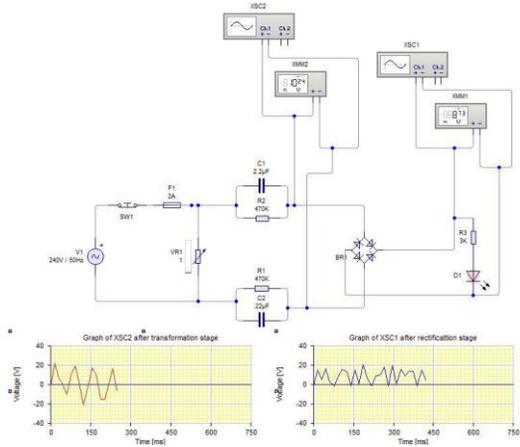


Figure 7 : waveform analysis of transformation and rectification stage for the transformer less based circuit



- C. Filtration stage: Smoothing Capacitor is used to generate ripple free DC. Its function is to convert half wave / full wave output signal of the rectifier into smooth DC signal. Livewire simulation of both the rectification and filtration stage for the transformer based and transformer less based Dc power supply are as shown below.

Figure 8: waveform circuit analysis of rectification and filtration stage for the transformer based circuit

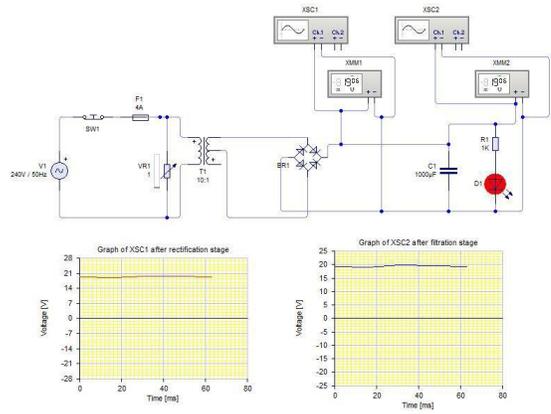
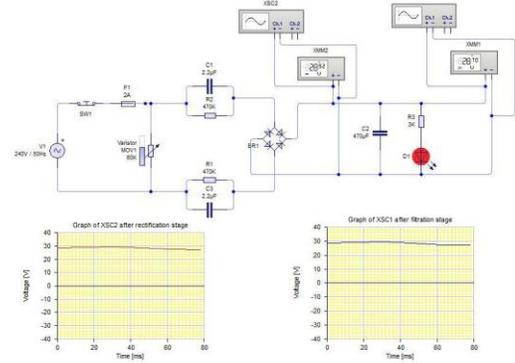
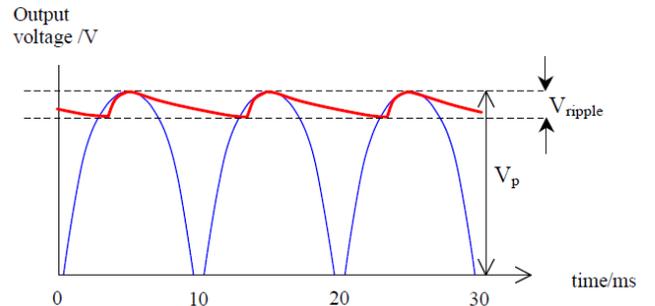


Figure 9: waveform circuit analysis of rectification and filtration stage for the transformer based circuit



The power rating and the capacitance of the capacitor are two most important aspects to be considered while selecting the smoothing capacitor. The power rating must be greater than the off load output voltage of the power supply. The capacitance value determines the amount of ripples that appear in the DC output when the load takes current (The larger the capacitor -for a given load, the smaller the ripple voltage).

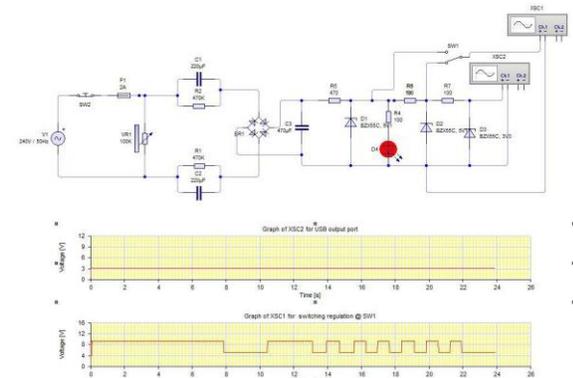
Figure 10: Output waveform of bridge rectifier with RC filter



III. WORKING PRINCIPLE OF CAPACITIVE VARIABLE DC POWER SUPPLY:-

The figure shown above is a transformer less or capacitive power supply. This capacitor power supply can deliver 12 volt DC and 100mA current to power low current devices. It is provided with surge protection and is totally isolated from mains supply using two X-rated capacitors in the phase and neutral lines. So the connected device is safe even if the phase and neutral lines changes. The main supply is also connected to the protection circuit comprising of safety fuse in the phase line and an MOV across the phase and neutral lines as safety measure if there is voltage spike or short circuit in the mains. The safety circuit is in turn connected across the two 225k J , 400 volts X rated capacitor that is in parallel with R1 and R2 known as the bleeder resistor. These resistors help remove the stored current from the capacitor when the circuit is unplugged. A full wave rectifier is used to rectify the low voltage AC from the X-rated capacitors and C3 removes ripples from the DC. With this design, around 24 volts at 100mA current will be available in the output. This 24 volt DC can be regulated o required output voltage using a suitable 1 watt Zener. Three zener diodes: ZD1=12V and ZD=5V are alternated by switch SW2 while ZD3 is outputted through the USB ports.

Figure 11: Detailed Circuit diagram of a Switching Regulation Method using Zener Diode for Transformer less Variable DC Power Supply



IV. CAPACITIVE TRANSFORMERLESS POWER SUPPLY

A capacitive transformer-less power supply is shown in Figure . The voltage at the load will remain constant so long as current out (IOUT) is less than or equal to current in (IIN). IIN is limited by R1 and the reactance of C1.

Figure 12:- Capacitive power supply

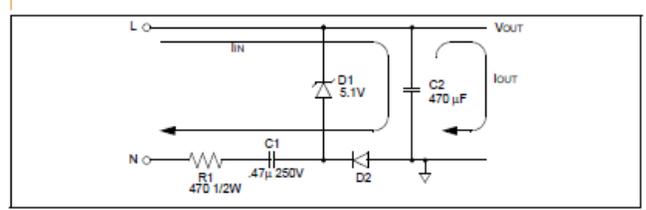
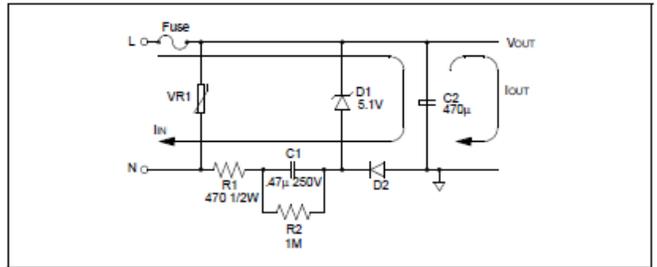


Figure 13:-Capacitive power supply with safety considerations



V. RESISTIVE TRANSFORMERLESS POWER SUPPLY

A basic resistive transformer-less power supply is shown in Figure . Instead of using reactance to limit current, this power supply simply uses resistance. As with the capacitive power supply, VOUT will remain stable as long as current out (IOUT) is less than or equal to current in (IIN.)

Figure 14:- Resistive power supply

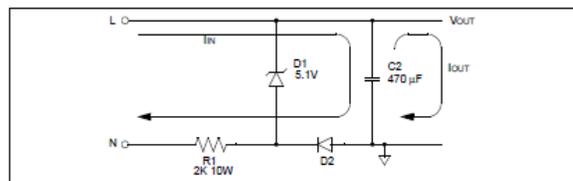
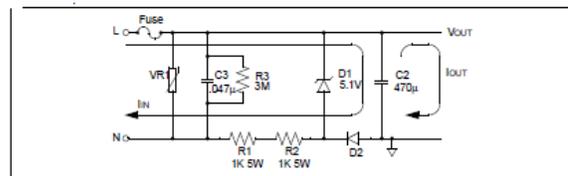


Figure 15:- Resistive power supply with safety considerations



VI. CONCLUSIONS

Transformer-less power supplies are instrumental in keeping costs low in microcontroller-based

applications powered from a wall receptacle. Both resistive and capacitive power supplies offer substantial cost and space savings over transformer-based and switch based supplies. Capacitive power supplies offer an energy efficient solution, while resistive power supplies offer increased cost savings. In this paper, a comparative analysis Transformer less-based variable DC Power supply systems have been achieved with their design analysis successfully presented too. The software design and design simulation of the both transformer less and transformer based variable DC power supply with their performance analysis using livewire simulation software was satisfactory. Hardware production of transformer less of variable voltage between 3-10 Volts, 100mA and transformer based of variable voltage between 1.25 -25 Volts, 1.5A DC power supply was tested and results were satisfactory. The transformer-based has a robust output current and well isolated from the supply voltage, which makes it more suitable for high current application, highly reliable for powering electronics devices while the transformer less based DC source has smaller size, weight and cheaper so as to miniaturize electronics devices but limited to low current devices . It also generates far less noise, heat, input harmonic distortion levels, and higher transient response but lack of proper isolation unlike its counterpart thus result in lower Mean Time To Failure (MTTF). Transformer less variable DC power supply should be considered a viable option for lower power, small and low current applications where achieving the highest availability is not the top concern and cost, size and weight restrictions inhibit the use of traditional transformer-based DC power supply.

TABLE 1: COST ANALYSIS OF A +5V POWER SUPPLY WITH/WITHOUT A TRANSFORMER:

Components	Unit Price(₹)	Qty	Transformer P.S.	Qty.	Transformerless P.S
1.1 VA transformer	5.65	1	5.65	0	-
1N4005 diode	0.05	2	0.10	2	0.10
1 μ F/250V cap	0.57	0	-	1	0.57
5.1V Zener	0.11	1	0.11	1	0.11
330 μ F/25V filter cap	0.17	1	0.17	1	0.17
Total			6.03		0.95

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