EDUCATIONAL PERSPECTIVE ON THE DESIGN AND IMPLEMENTATION OF 100 WATTS FLEXIBLE AC-DC POWER CONVERTER

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Abstract

A 100 watts AC – DC digital switch mode power converter using combined feedback and feed forward control techniques simultaneously is designed and implemented using microcontroller to achieve wide input voltage ranges. This produces a highly regulated and stable direct current output power which remains stable with wide range variations in the input voltage and load conditions. The converter is an electronic device that accepts alternating current (AC) and power and produces direct current (DC) outputs. This design actualized a peculiar and unique flexibility on chip; with precise stable output voltage. The overall functionality of the system is design in digital domain and is programmable.

Keyword: Design and simulation of flexible power converter

Introduction

The AC-DC flexible digital switch mode power converter is an electronic device that accepts alternating current (AC) power and produces direct current (DC) outputs using a combination of semiconductor devices. The operations of the system are controlled by the stored program codes uploaded to the microcontroller. Several methods/techniques can be employed to achieve tightly regulated output voltages in power converters. These include the utilization of a microcontroller (Atmel Corporation, 2000), feedback and feed forward control (Micheal, 1987; Raoji, 2001), adaptive control (Angel & Seth, 2005). Each control method has its own advantages and draw back due to the fact that each particular control method appears to be the most suitable control method under specific conditions compared to other control methods. The microcontroller is used to generate the signal through the program codes. The signal from the controller turns the power semiconductor on and off between cut off and saturation which forms the oscillator circuit in order to generate the alternating current (AC) at the transformer input terminals for the step-down transformation action to take place as well as other peripheral functions.

The alternating current at the output of the transformer is rectified and filtered using low pass filter. Switch mode power converters are the most typical power converters found in many consumers and industrial electronics, such as television sets, computer systems, radio tape recorders, audio amplifiers, and video compact disk among others. Most significantly any switching power converter must depict the block diagram shown in figure 1 [Erickson, 1997], which include; the input from the rectified DC supply, the power transistors used as the conversion devices. The feed forward and the feedback information utilized by the controller to regulate the rate of the switching of the power transistors between cut off and saturation in order to stabilize the output voltage. Through rectification and filtration pure DC voltage is realized which is used to power the device connected to the converter.

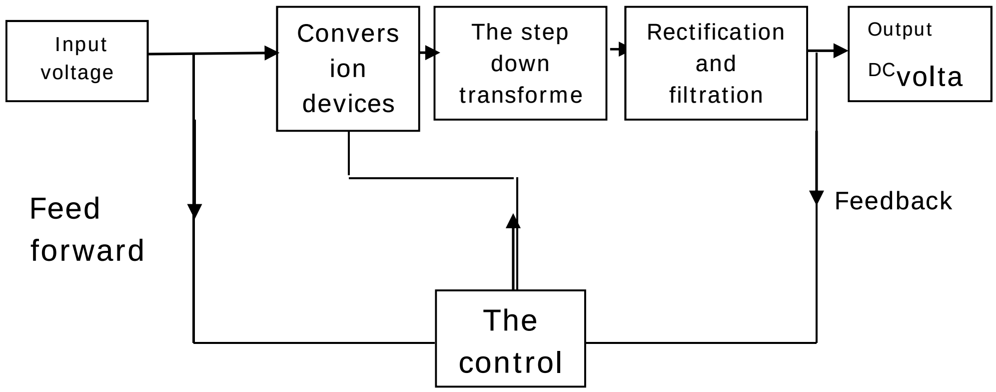


Figure 1: Block diagram of switching power converter

The development and integration of hardware and software design utilizing microcontroller, the keypad and the program codes to actualize the required flexibility, stable output voltage and overall functionality of the system are design in digital domain and are programmable. The device utilize an input system that enable the user to select the desired output voltage on chip within the range of 5V (DC) to 12V (DC) through the keypad other than the default voltage value of 12V (DC). This design has a tremendous performance advantage over the existing AC-DC switch mode power converters. The designed converter can be used to supply multiple output voltages to power sophisticated/sensitive equipment which may not be possible with linear or analog power converters. The designed converter can be easily be modified or transformed from one operation to another by changing the program code without changing the physical components which may not be possible with other design.

Statement of the Problem

The major source of the problem in AC-DC digital switch mode power converters is lack of flexibility to enable one to select the desired output voltage on chip. Another major source of the problem in AC-DC power converters is the limited regulation range of the input voltage. Therefore, there is the need for reliable solution of the above problems, taking cognizance of the increasing proportion by which the systems using power converters are manufactured all over the world.

Objectives

The objective of this research is to actualize a flexible AC-DC digital switch mode power converter with wide input voltage range using the stored software program in the microcontroller. This is achieved in line with the following set-objectives.

(i) To determine the appropriate regulation range of the input voltage under which the converter functions efficiently.

(ii) To determine the maximum output power rating of the converter under variable load conditions.

(iii) To develop the algorithm and the source codes in an embedded C programming language that will be uploaded to the microcontroller in order to control the operation of the flexible digital switch mode power converter.

(iv) To develop an input system that will enable the user to select the desired output voltage on chip within the range of the output voltage of the system.

The Operation of the System Circuit Diagram

Figure 2 is the system circuit diagram, the input inductors L1-L4 and the capacitors C7-C10 are used to remove the input AC ripple voltage and harmonics from the utility power supply. The filtered AC line voltage is applied to the bridge rectifier BR1, which rectifies the input AC voltage to DC voltage, the output DC voltage is filtered by capacitor C1 and the peak value DC voltage is obtained. The filtered DC voltage is applied through a low value resistor R1 to the center tap of the high frequency transformer isolation, the other input terminals of the transformer TR1 are connected to the drain of the power transistor Q1 and Q2 (MOSFET) which forms the oscillator circuit. The bridge rectifier containing D3 to D6 is used to power the devices that use low voltage values. The low voltage is obtained through the voltage divider network R12 and R13; the variable resistor RV2 preset the voltages to 5 volts value. Two ADC 0808 are used, ADC U4 for the feed forward and ADC U1 for the feedback, it converts the analog voltage to digital stream. The preset voltage from the input and the output voltage after the first stage filter C2 is applied to the ADC U4 through its input for the feed forward data, this is feed to the microcontroller AT89C52 port 1 through the bus line. Also the fraction of the output voltage is feed to the ADC U1 through its input with reference voltage connected, this is the feedback data and it is feed to the microcontroller AT89C52 port 2 through the bus line. The microcontroller AT89C52 controls the operation of the circuit through the software program uploaded to it, written in embedded C language format, and runs on proteus environment, using the data from feedback and feed forward network. The second stage filter is the low pass filter using the RC filter R35 and C6; the R_{load} is the output resistor.

The overall output is connected through the output transistor Q3, The 100 watts output load RP2 is subdivided to 10, 20, 40, 60, 80 and 100 watts respectively, and this is passed through selector 1 to the microcontroller input port 3. The 100 watts load is used to test the circuit under load conditions. The LCD displays the overall output voltage and current for visualization. The oscilloscope attached is used to display the waveforms at line input, the waveform at the center tap of the high frequency transformer and the waveform at the output of the transformer respectively. The feed forward voltage monitors the input set points voltage to ensure that it does not deviate from the set points voltage of 3% at the upper limit and the lower limit of -2%. At these set points the microcontroller is instructed to either decrease or increase the switching frequency of the oscillator, in order to maintain a stable output voltage as desired. The switching frequency is varied between 40 kHz to 100 kHz using counter program that runs between 100V (AC) to 261V (AC) of the input voltage; it is also used to control the output. The feed forward monitors the input and it is not error based, it takes care of the input voltage fluctuation before it gets to the output. The feedback is error based and it only acts when there is error from the output. Usually the error occurs at the output at the initial loading of the system, when the power stabilizes there may not be error because the load is stable and does not vary since it is dedicated to a particular system as the power supply of that system. When there is decrease or increase in the output the feedback takes priority over the feed forward control and the output is adjusted as a function of the error voltage value to obtain the desired output voltage. The system utilized an input keypad system that enable the user to select the desired output voltage between 5V (DC) to 12V (DC).

The circuit is interfaced to the microcontroller, it consist of the micro switch button labeled 0 to 9 and the set. The microcontroller controls the operation of the system and compares the feed forward data and the feedback data with reference to the set points and knows which to use to increases or decrease the switching frequency of the oscillator circuit.

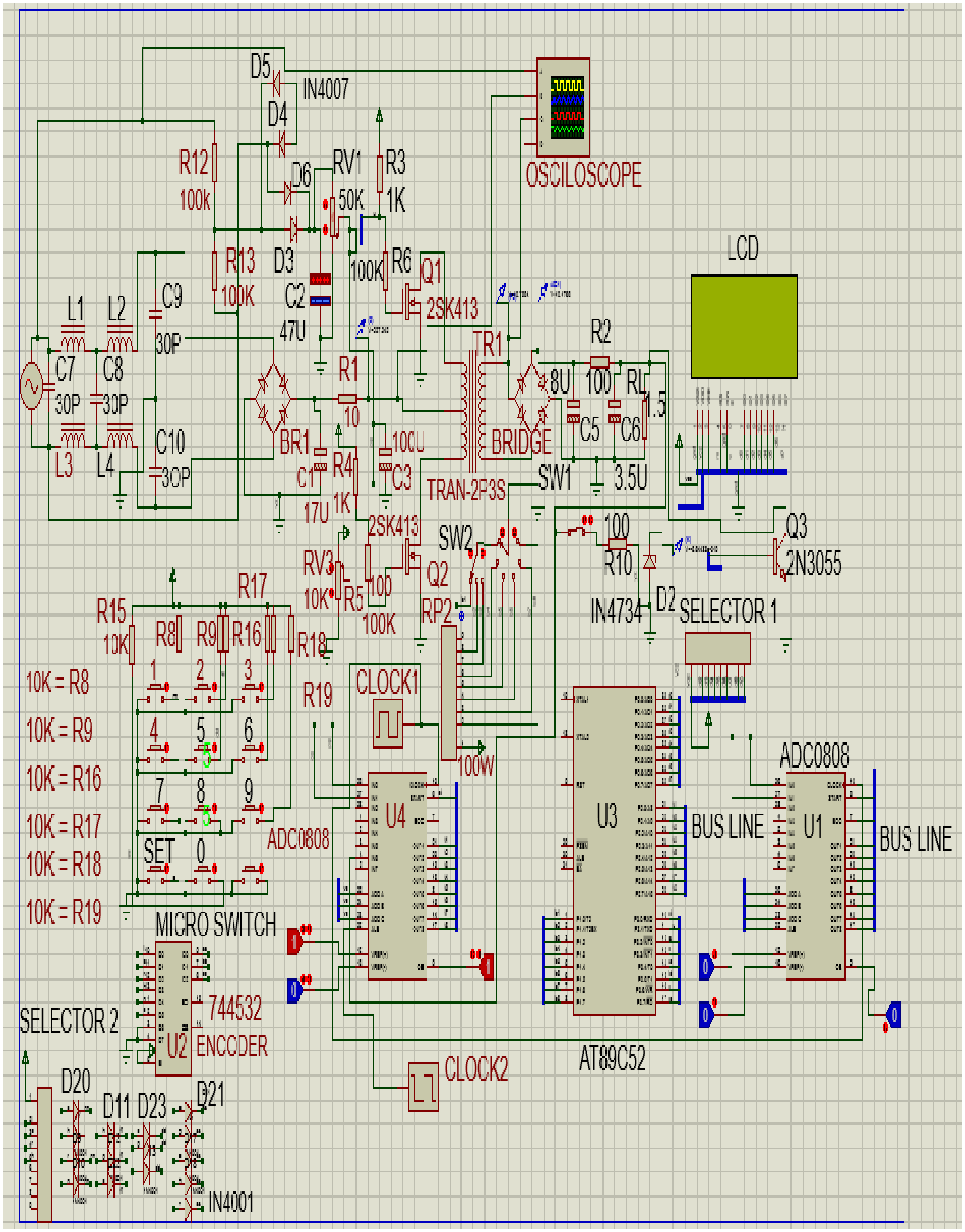


Figure 2: System circuit diagram

Results

Simulation Results At Infinite Load Conditions atDefault Output Voltage Of 12v (DC)

The test at infinite load condition was carried out at default value when there was no load connected to the converter. The input voltage was varied between 100V (AC) to 261V (AC). The output voltage and current captured are displayed at the LCD. Wide input voltage range was achieved. The captures are shown in figure 3a-3d.

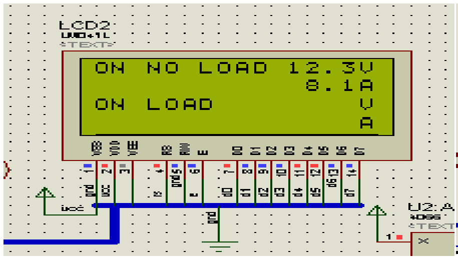


Figure 3a: Input voltage = 120VAC
Output voltage =12.3VDC
Output current = 8.1A

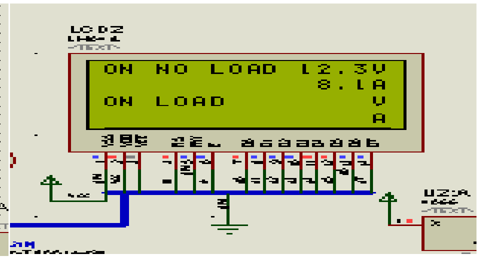


Figure 3b: Input voltage = 180 VAC
Output voltage =12.3VDC
output current = 8.1A

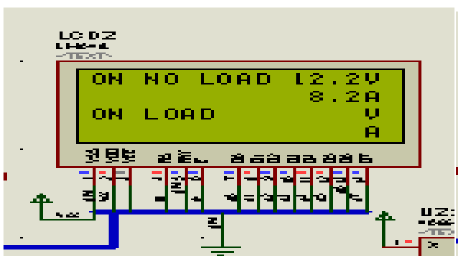


Figure 3c: Input voltage = 220 VAC
Output voltage =12.2VDC
Output current =8.2 A

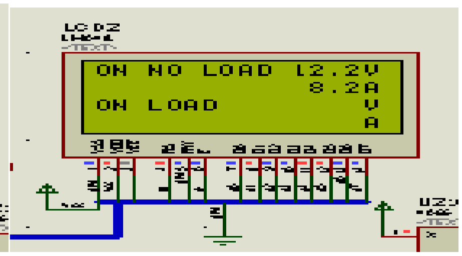


Figure 3d: Input voltage = 260VAC
Output voltage =12.2VDC
Output current = 8.2 A

Simulation Results Under Load Conditions at Default Output Voltage of 12v (DC)

The simulation of the power converter was carried out under load conditions using a 100 watts load RP2 in the main circuit diagram of figure 2, subdivided into 10, 20, 30, 40, 60, 80, and 100 watts respectively. The selection of the load was through the switch connection (SW1) and (SW2) configured in such a way that when a particular load is selected only that load will be connected to the output. When these loads were varied the corresponding output voltage and current captured at LCD are shown in figure 4a-4d

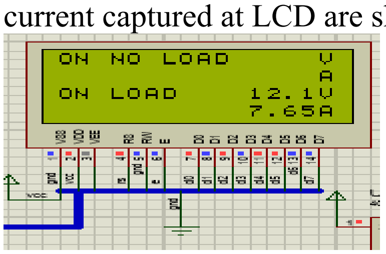


Figure 4a: Output voltage = 12.2 VDC
Output current= 8.01 A
when the load of 20 watts was connected

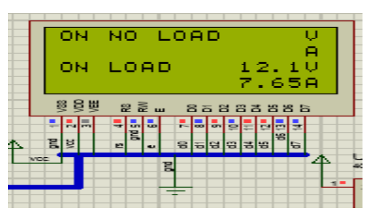
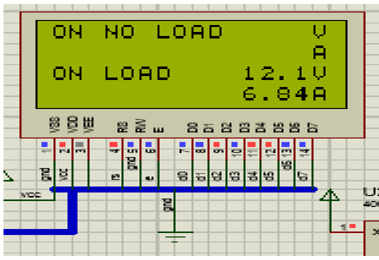


Figure 4b: Output voltage = 12.1 VDC
Output current = 7.65
when the load 40 watts was connected



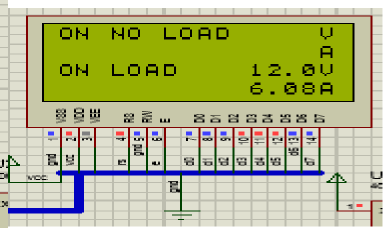
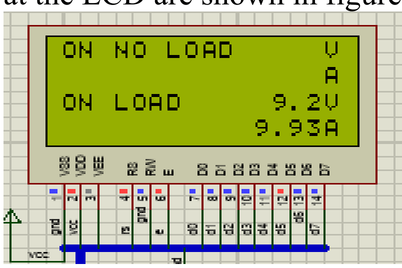


Figure 4c: Output voltage = 12.1 VDC
Output current = 6.84 A
when the load of 60 watts was connected

Figure 4d: Output voltage = 12.0 VDC
Output current = 6.08 A
when the load of 100 watts was connected

Simulation Results Under Load Conditions at Output of 9V (DC) Selected By User

The keypad is used to enable the user of the device to select the output voltage on chip as desired. Example, to get the desired output voltage of 9V (DC); press the set button at the keypad until a message is displayed at the LCD asking the user to select the desired output voltage, then press zero (0) and then press nine (9), the numbers pressed will appear at the LCD. The system automatically resets to the desired output voltage value selected after two seconds. The captures at the LCD are shown in figure 5a-5d.



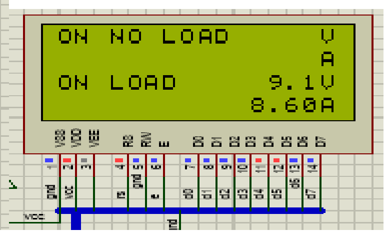
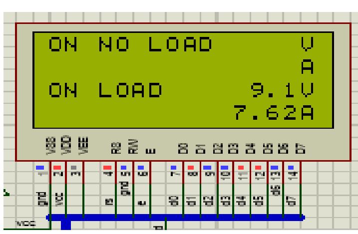


Figure 5a: Output voltage = 9.2 VDC
Output current = 9.93 A
when the load of 20 watts was connected

Figure 5b: Output voltage = 9.1 VDC
Output current = 8.60 A
when the load 40 watts was connected



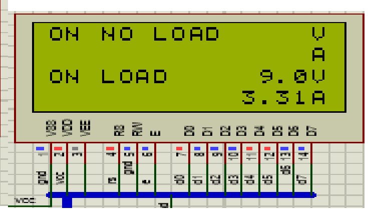


Figure 5c: Output voltage = 9.1 VDC
Output current = 7.62 A
when the load of 60 watts was connected

Figure 5d: Output voltage = 9.0 VDC
Output current = 3.31 A
when the load of 100 watts was connected

Plot Of Output Current Variation Against Load

The plot of the output current variation against load is given in figure 6

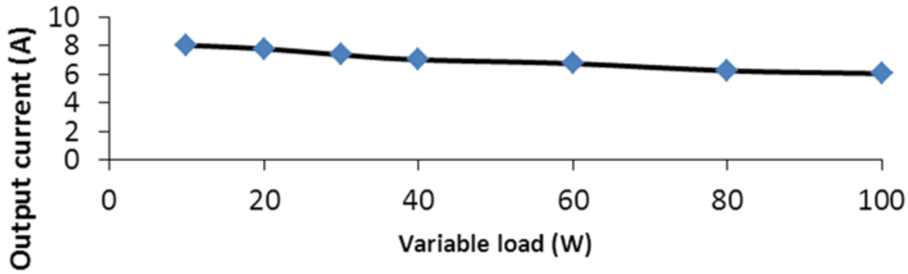


Figure 6: Plot of the output current against load

The plot shows that the output current slightly decreases as the load increases.

Findings

For the course of this research it was found that switching power converters generate electrical noise in the form of radiated and conducted energy resulting in radio frequency interference (RFI) and electromagnetic interference (EMI) causing malfunction of sensitive equipment connected to the utility power supply. Adequate input and output filters are necessary to attenuate the electrical noise in order to improve the system performance.

Conclusion

The work features a new control method which combines both feedback and feed forward networks simultaneously to actualize a very stable output voltage of 12V (DC) at default, within a very wide range of input voltage and load condition. It also enables the user to select the desired output voltage on chip within the range of 5V (DC) to 12V (DC), hence achieving the desired flexibility. The regulation of the output voltage is achieved using the feedback and feed forward data through the program code executed by the controller with variable duty cycle and variable switching frequency which is a more accurate and reliable technique than the utilization of discrete integrated circuit (IC) voltage regulators which has limited voltage regulation range and low current capacity.

The limitation of the design is that the switching frequency is consistently adjusted with respect to the changes in load and the input voltage and in the absence of this adjustment it results to poor regulation which engenders unacceptable switching losses. The problem is avoided with an internal clamp down programme, whose function is to maintain the range of the switching frequency within the required limits. The comparison of the results shows that the digital switch mode power converter has superior performance over other converters. The methods adopted in this research can be utilized to improve the performance and the functionality of the existing power converters.

Recommendation for Further Research

The efficiency of the digital switch mode power converters can be improved by utilization of very large scale integration (VLSI) and for components and cost reduction.

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