Digital Laboratory Power Supply : Design Aspects and Testing

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Abstract— Digital control power supply ranging from 0V-24V with maximum current of 2A is designed and developed for use in the laboratory set-up. The developed system is for precise control of applied voltage to the equipment thereby increasing the reliability of the laboratory equipment's. Unit.

Keywords-digital power supply, microcontroller, laboratory equipment

I. INTRODUCTION

Power supply is the most important aspect of electrical and electronics system as it provides the power to operate appliances or devices. This research focus on the development of a digital controlled bench power supply for laboratory utilization [1-3]. Basically there are few types of power supply and the most common are linear power supply and switching power supply. In addition to that, control and monitoring via real time software application is very rare in power supply development particularly for laboratory setup as it is oversees as a very useful tool to provide a very informative data for the user. Furthermore, by implementing the graphical user interface, it can provide control via specific communication protocol such as RS232. The control can be either voltage or, current value settings which is very important in laboratory equipment evaluations.

II. METHODOLOGY

A. Digital Power Supply

Typically regulated DC power supply is produce in such a way that the output comes directly from the regulators. But nowadays, digital control of regulated DC power supply is essential to provide a precise and stable supply for critical mission control systems. As mentioned in [13], in any battery powered and portable devices power dissipation efficiency is very important in order to have optimum output utilization. It also said that by reducing the frequency of the clock in synchronous digital clock it also reduces the power but the energy utilize remain the same. This is very crucial findings in the design of the digital power supply as it help to reduce the amount of the power usage but at the same time the amount of the energy is at its best. In any electrical and electronics devices the energy loss is really taken into picture because it Reflect how much efficient in any such system. Although to gain unity efficiency is almost impossible, engineers are still improvising in such a way any electrical and electronics appliances almost hit unity efficiency.

B. Hardware Development

(i)Step-down Transformer

The specification of the digital control power supply is to be designed for the range of 0 V DC to 24 V DC with maximum current of 1.5 A. Therefore the specification of the transformer chosen is a mid-point configuration of $18V_{RMS}$-0-$18V_{RMS}$ 100VA. Since it is centered tap transformer, the output is drawn peak to peak. The range of maximum current the transformer is shown in the Table 1 below. The rating of the transformer is purposely chosen with higher voltage and current value in order to overcome the system power supplement when full load applied. The stepping down of the mains voltage which is $240V_{RMS}$ 50 Hz to certain specified range is essential in order to provide a safe working environment as well as to provide isolation when any faulty occurred during the testing and analyzing stages.

V_{RMS} (V)	Volt-Ampere (VA)	Maximum Current (A)
18	100	5.55
36	100	2.77

TABLE 1. Transformer Specifications

(ii) Bridge rectifier and voltage regulator

Since the research only provide a DC output, the voltage input from the stepped down transformer need to be rectified to produce a DC value that can feed the electronics system which include the voltage regulator. A full bridge rectifier had been used to produce a signal that oscillates in positive voltage. This rectified signal has ripple voltage which is equivalent to the peak voltage of the signal. With a fixed resistance value of 1000 ohm, ripple voltage of 36 V_{RMS}, current rating of $100VA/36V_{RMS} = 2.7A$, mains frequency (f) of 50 Hz, the value of the designed capacitor is using Equation (1)

$$C = I/\ 2fV_{RIPPLE} \qquad (1)$$

Based on the calculation the product of the capacitor value and the resistance which is the time constant must exceed the time period of the system which is 1/50 Hz = 0.02 seconds. Therefore the value of the resistor and capacitor above must satisfy the Equation (2).

$$RC >> 1/f \qquad (2)$$

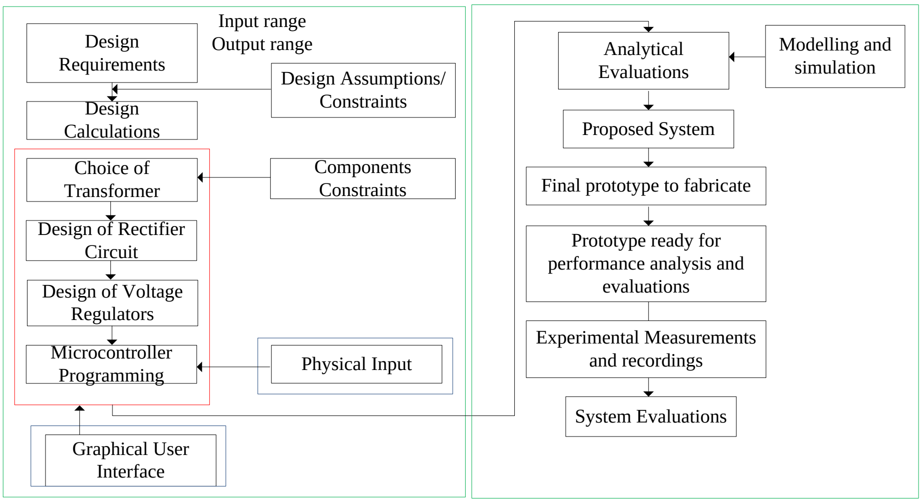


Figure 1 Block representations of the investigations

Figure 2 shows the bridge circuit used in the design. Figure 3 shows the simulation results. The value of the capacitor is being varied to monitor the ripple voltage of the output. In Figure 3 (a) shows the signal of the stepped down signal of 36 V_{RMS}. The peak value is 50.9 V_P. The figure simulates a perfect sine wave with no ripple. Figure 3 (b) is the signal of the full wave bridge rectifier. The voltage ripple is equivalent to the peak voltage which is 50.9 V_{RMS} when there is no load. In Figure 3 (c) shows the same signal with a smoothing capacitor with the value of 100 µF giving 3.981 V_{RMS} of ripple voltage whereas in Figure 3 (d), with a smoothing capacitor of 530.45 µF giving 801.526 mV_{RMS}ripple voltage. Upon completing the simulation, another circuit had been built and tested in order to obtain more understanding and to perform a further investigation on how the system works.

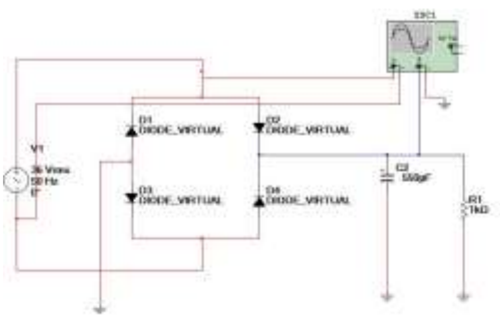
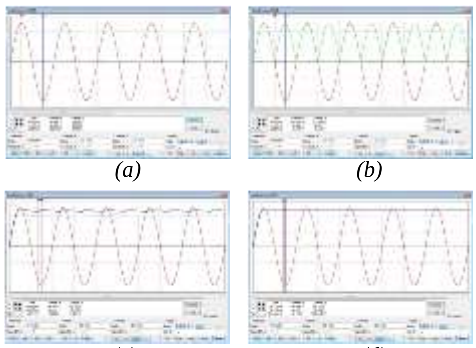


Figure 2 Rectifier Circuit

C. Software Development

Basically there are two parts that required software approach in order to develop the system. The first part is the embedded system that carries the functions of the microcontroller and the second part is the graphical user interface that control the system output and monitor both the system input and output.



(a) *(b)* *(c)* *(d)*

Figure 3 Simulation Results

Figure 4 shows the complete circuit diagram for the design proposed in this paper. The microcontroller is programmed based on the algorithm in Figure 5 - Figure 8. The process starts with the port initialization where in PIC16F877A it has four ports and each port can be either utilize as input or output. Subsequent to that, the communications speed between the graphical user interface and the microcontroller also need to be initialize. The ADC functions also need to be specified. The input for the power circuit can be obtained both from the user interface and physical input. Most of the time, the input be obtain from the interface. Figure 5 and Figure 6 explains the process of code compilation written based on the algorithm while Figure 7 shows how to import the HEX file and burn it into the microcontroller. Figure 8 describes the flow of how the graphical user interface works. The graphical user interface for the system is developed using Visual Basic 6.0 as it provides flexible working environment and the BASIC language is very easy to understand as it almost similar to complete English sentence. The graphical user interface as shown in Figure 9 provides a real time control and monitoring for the power circuit. This real time approach is essential in order to provide an accurate condition regarding the DC output produce by the power circuit. Figure 10 describes the experimental setup of the research.

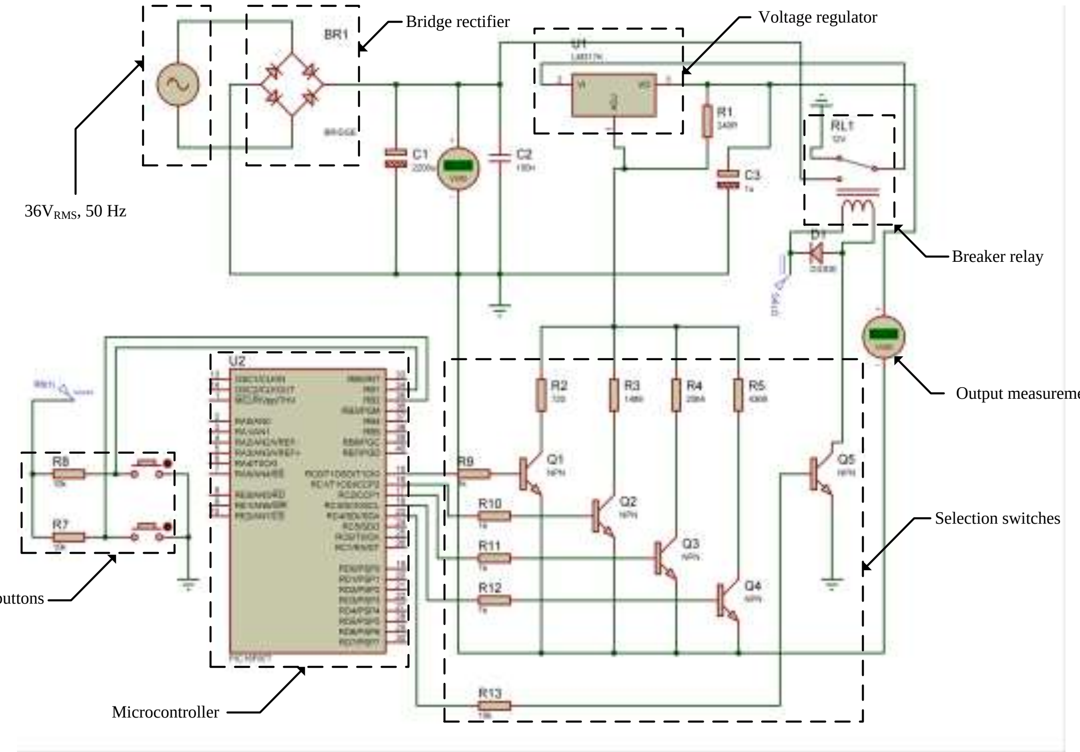


Figure 4 Complete Circuit

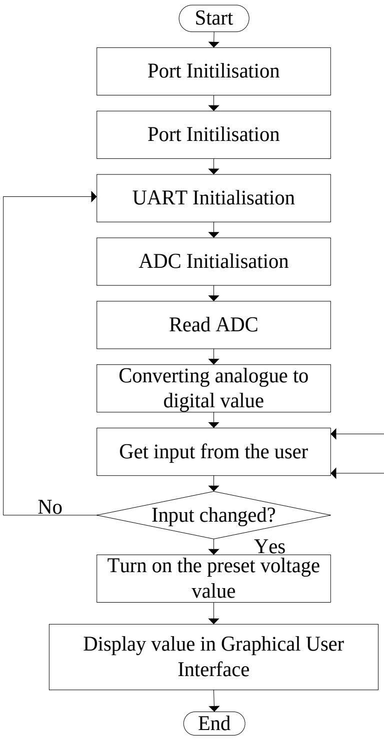


Figure 5 Embedded Logic

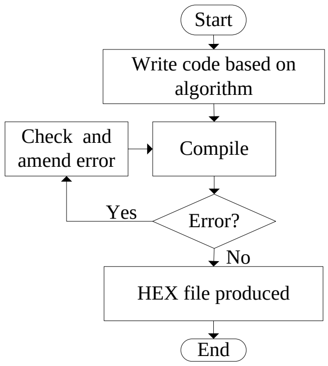


Figure 6 Logic Operations

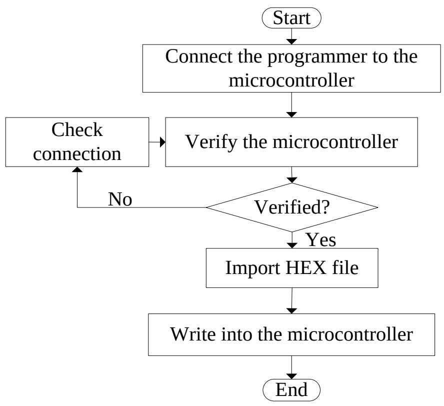


Figure 7 Programming Logic

The flow for programming the microcontroller.

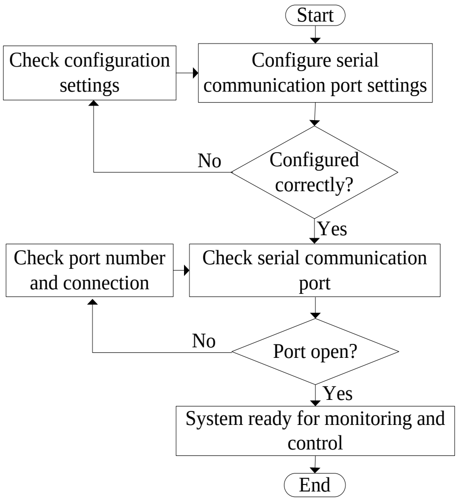


Figure 8 Programming Control Logic

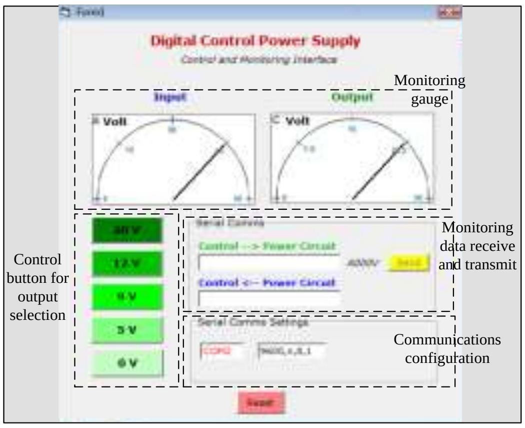


Figure 9 Graphical user interface Design

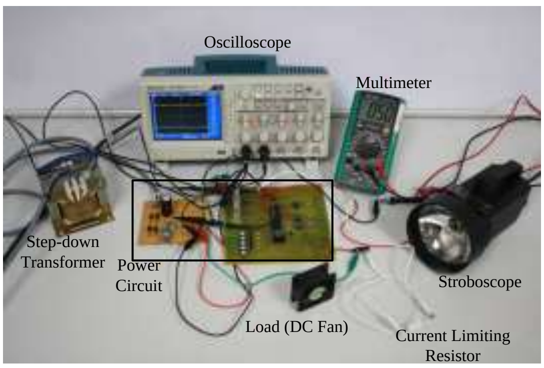


Figure 10. Experimental setup

III. Results and Discussions

The experiment is performed in order to analyze the output performance of the system. The load that being used is a DC fan with specification of 12V, 0.20A connected in series with been put on the blade of the fan. The 'freezing' moment can be obtained by tuning the stroboscope's frequency. The test is being performed by increasing the voltage source of the DC fan in the sequence of 0V, 5V, 9V, 12V and 20V. a current limiting resistor. In order to measure the speed of the fan, a stroboscope had been used to 'freeze' the mark that had Figure 11 shows the graphic user interface stages at various voltage levels at the input and the controlled voltage at the output.

The user can choose on the level of the voltage level and using the communication interface and the microcontroller the output is seen. Table 2 shows the various voltage level conditions both using the physical measurement and the measurement through the graphical user interface.

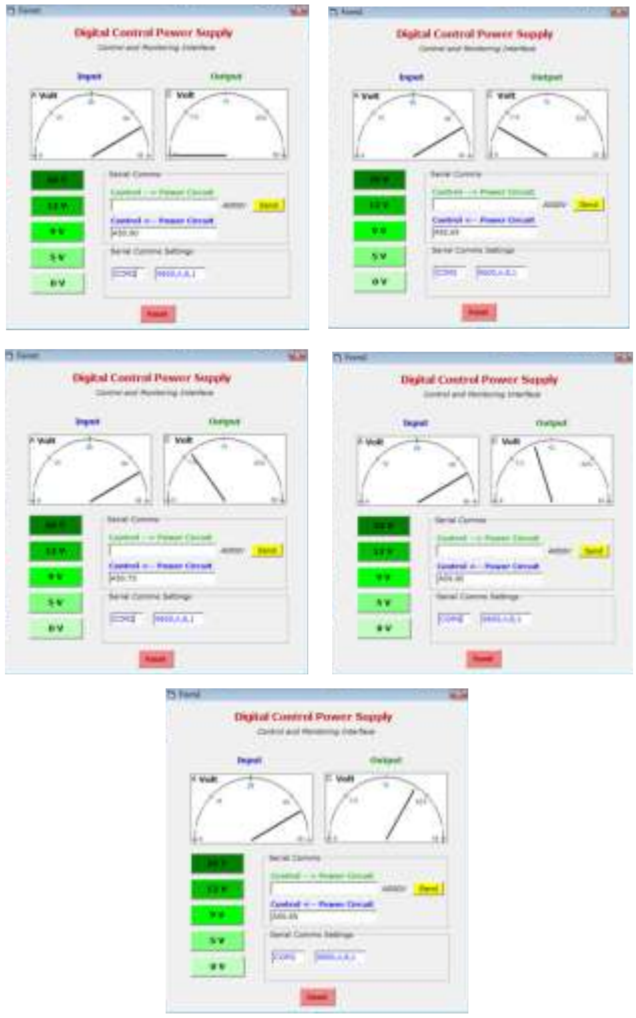


Figure 12 Graphical user interface Design

I. Conclusions

This thesis established the design and development of digital control power supply and the software application for monitoring and controls particularly the voltage input and output. There are two stages of regulated voltage where the first stage provides maximum voltage of 30VDC to utilize as input for the second stage regulator. The second stage regulator has two regulators which produced fix 5VDC for the electronics in the circuit and the other is variable output voltage for utilization ranging from 0VDC to 20VDC with the capability maximum current of 1.5A. The control and monitoring application at this point of writing can only manage the data obtained from the microcontroller whereas the data send to the microcontroller does not show any response which is the limitation of the work.

Voltage Selection (V)	Input Voltage (V)		Output Voltage (V)		Tolerance (±V)	
	Measured	Monitored	Measured	Monitored	Input	Output
0	51.4	50.90	0.00	0.20	0.50	0.20
5	50.9	50.65	4.9	5.44	0.25	0.54
9	50.8	50.75	9.1	9.80	0.05	0.7
12	50.9	50.80	12.2	12.92	0.10	0.72
20	50.9	50.65	19.8	20.46	0.25	0.66

TABLE 2. Results of non-mixed and two mixed signal

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