Design and development of an automatic testing equipment for a switch mode power supply (SMPS) and its analysis and data acquisition using LabVIEW

B.E Project

Submitted in partial fulfillment of
the requirements for the degree of

Bachelor of Engineering
In
Instrumentation & Control Engineering

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(2018-2019)

Acknowledgement

Inspiration and guidance are invaluable in every aspect of the life, especially in the field of the academics, which we have received from our respected project guide Prof. H. P. Chaudhari and sponsors Jambhekar Automation Solutions. We would like to thank them for their endless contributions of time, effort, valuable guidance and encouragement they have given to us. We would like to extend our gratitude to thank Head of the Department Dr. D.R . Shende and all staff members for genuine support and encouragement. We would also like to thank principal Dr. P B Mane without whom we would not have opportunity to reach up to this level. We would also like to thank our families and friends for their inspiration and motivation which helped us directly or in directly for our project work.

Abstract

An automated testing equipment plays a key role in increasing the speed, accuracy and efficiency for testing any electronic equipment. This report presents detailed review of the designing of an automatic testing equipment for SMPS. A SMPS (Switch Mode Power Supply) is a device that provides a constant and uninterrupted voltage current supply and is used as a power source in many electronic devices. Manual testing of SMPS is a very time consuming and may not also be error free. In order to save time and get results with desired accuracy we have designed an automatic testing equipment to test the SMPS. Here we measure, evaluate and analyse different performance characteristics of SMPS, and this charateristics of SMPS is used to determine whether the SMPS is working properly under the different conditions.

The LabVIEW software is used for data acquisition and analysis of the test data acquired from the testing equipment. The data acquired by the software from the hardware, is processed based upon the algorithm developed, and then it is displayed in numerical and graphical formats representing the proper working of the SMPS

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Chapter 1

Literature Survey

The power supply is an essential element for electronic product, so analyzing its performance and design margins is necessary to ensure its high quality and reliability Not verifying a power supply leaves a designer vulnerable to a potentially unpleasant situation, if problems arise after products are in the field. Power supplies may operate fine under typical conditions, but may be at the edge of normal operation. When a power supply is heated or cooled, or when components age, its characteristics change to a point where a marginal design might fail.

Power supply testing is not complex. One only needs a good understanding of which tests are needed, and how to properly perform them. A designer should establish a test specification and a test plan for the power supply. The test specification should include all acceptable operating limits and the various operating conditions (temperature, line conditions, and so forth), under which the system must operate. A test plan describes the process on how to ensure the design meets the test specification.System conditions (line, loads, etc.) and the environment vary greatly from application to application. Therefore, specific test specifications and plans vary from one system to another.

Small component size, greater efficiency and lower cost have resulted in widespread use of the SMPS in nearly all electronic equipment. Recent innovations have permitted its use in high-power applications. But SMPS implementation has not been totally free of problems. One of these is the generation of electronic noise, which if not mitigated can appear at both the input and output of the SMPS. In addition, electronic noise generated by the switching process can propagate as radiation from the device. This is because the square wave, with its near instantaneous rise and fall times, resembles a high-frequency energy source rich in damaging harmonics.

When powered on, the SMPS exhibits inrush current, which can affect nearby sensitive equipment through the power distribution system. Another potential problem caused by harmonics is the heating of the neutral conductor in the power supply. The solution is to oversize this wire. Generally speaking, even where refinements are required, the overall benefits in SMPS are significant regardless of scaling.Voltage regulation is an integral part of the SMPS. It works by varying the ratio between on time and off time. This technique is a decisive advance over the linear power supply, where output voltage has to be dissipated in the semiconductor.

Chapter 2

Introduction

Application-specific integrated circuits or ASICs are now being widely used in circuit design technologies and in telecommunication system design as well. Higher current and current steps with higher slew rates are a need in ASIC and system designs nowadays. Designers try to consider these requirements in all parts of their design process, but due to the process steps and non-ideal conditions in design and manufacturing, the final product always shows some deviation from primary design specifications. It is a challenging process to have a final product with specification as close as possible to the required details. As an important part of every design, testing and verification of performance aspects are needed in order to produce high efficiency systems and must be done as accurately as possible.

When verifying the performance of a designed circuit, it is necessary to create a similar environment to the real situation. Many studies are done in order to increase the precision in the verification step. If testing is done in an accurate way, then the results can be used to improve the system specifications in a way to get results as close as possible to the system requirements. Switched mode converters are tested using load steps. When testing on-board power supplies, different kinds of external electronic loads are used. These external loads are often placed at a significant distance from the converter which means that long cables must be used to connect the equipment together. This leads to high inductance in the load current path, which limits the maximum slew rate. To make the test environment as good as possible, the wire inductance must be minimized so that the tests can be performed with high slew rates.

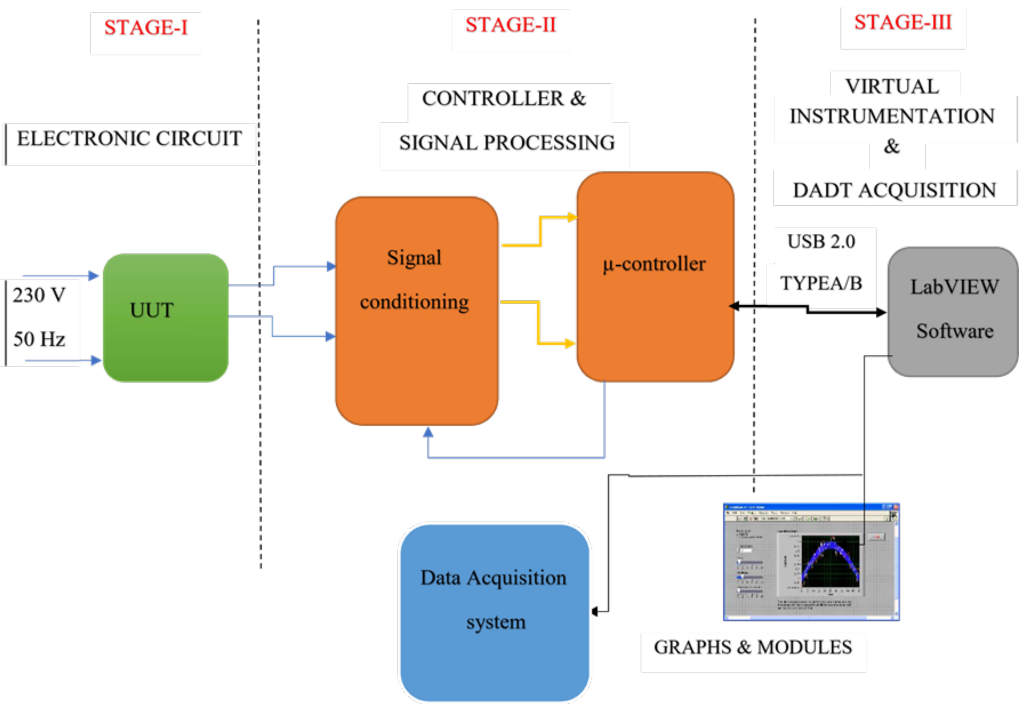

Figure 2.1: Block diagram of automatic testing equipment

Chapter 3

Switched Mode Power Supply

Switched Mode Power Supplies (SMPS) are replacing the linear power supplies due to their higher efficiency, better voltage regulation and capability to achieve an excellent input power quality. Multiple output SMPS are commonly used in various consumer electronic appliances where all the outputs need to be isolated and regulated. In an 'n' output SMPS, normally (n+1) DC-DC converters are used for obtaining independent control of individual outputs. This makes the multiple output SMPS very expensive and unreliable because of the increase in the number of hardware components. Regulation of all the outputs using a single converter, especially when each of the power supplies faces a variable load, becomes difficult. Switched-mode power supplies are classified according to the type of input and output voltages. The four major categories are:

1. AC to DC
2. DC to DC
3. DC to AC
4. AC to AC

3.1 Components of isolated AC to DC SMPS:-

- Input rectifier and filter
- Inverter consisting of switching devices such as MOSFET
- Transformer
- Output rectifier and filter
- Feedback and control circuit

The input DC supply from a rectifier or battery is fed to the inverter where it is turned on and off at high frequencies of between 20 kHz and 200 kHz by the

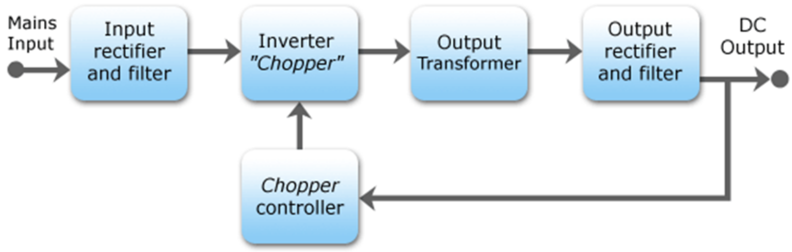

Figure 3.1: Block diagram of SMPS

switching MOSFET or power transistors. The high-frequency voltage pulses from the inverter are fed to the transformer primary winding, and the secondary AC output is rectified and smoothed to produce the required DC voltages. A feedback circuit monitors the output voltage and instructs the control circuit to adjust the duty cycle to maintain the output at the desired level. Most of the commonly used topologies such as push-pull, half bridge and full bridge, consist of a transformer to provide isolation, voltage scaling, and multiple output voltages. The non-isolated configurations do not have a transformer and the power conversion is provided by the inductive energy transfer.

3.2 Characteristics Of SMPS

The various performance characteristics of SMPS are as follows:-

- **Soft start** : It is a gradual tuning of the power supply to avoid the stressing of the electronic components by sudden current and voltage surge associated with the initial charging of the capacitors and transformers.
- **Over shoot**: It is the occurrence of high peak voltage as result of addition of incoming voltage wave and reflected voltage wave, due to the mismatch of impedance in a power supply.
- **Dynamic load response**: Measurement of the variations in the output voltage of the power supply due to changes in the load.
- **Output voltage ripple**: Measurement of the residual periodic variation of the DC voltage in power supply derived from an AC (Alternating Current) source.
- **Settling time**: Time required by the system to restrain its output value to specified band.

3.3 Advantages of switched mode power supply:-

- Higher efficiency

- Regulated and reliable outputs regardless of variations in input supply voltage
- Small size and lighter
- Flexible technology
- High power density

3.4 Disadvantages of switched mode power supply:-

- Generates electromagnetic interference
- Complex circuit design
- Expensive compared to linear supplies

Switched-mode power supplies are used to power a wide variety of equipment such as computers, sensitive electronics, battery-operated devices and other equipment requiring high efficiency.

Chapter 4

DC Programmable Load

A programmable load is a type of test equipment or instrument which emulates DC or AC resistance loads normally required to perform functional tests of batteries, power supplies or solar cells. By virtue of being programmable, tests like load regulation, battery discharge curve measurement and transient tests can be fully automated and load changes for these tests can be made without introducing switching transient that might change the measurement or operation of the power source under test.

A fully programmable load is simply a programmable power supply that applies a voltage and sinks current (absorbing power) or sources current (transferring power). This is necessary to simulate real loads where there are moments when current and voltage have polarity which makes the load appear to act as a source of power; for example, circuits with capacitive or inductive elements when an AC or varying DC is applied. By being able to change the current direction, the programmable load schematically will still "look like" a programmable resistor while still being a programmable voltage source.

However, most commercially available "electronic DC loads" or "programmable DC loads" on the market cannot source power, since by being DC loads, by strict definition, they do not need to. (They are not power supplies), being only able to absorb power (sinking current from a positive voltage, or sourcing to a negative voltage). These most commonly use one transistor/FET, or an array of parallel connected transistors/FETs for more current handling, to act as a variable resistor. Internal circuitry in the equipment monitors the actual current through the transistor/FET, compares it to a user-programmed desired current, and through an error amplifier changes the drive voltage to the transistor/FET to dynamically change its resistance. This 'negative feedback' results in the actual current always matching the programmed desired current, regardless of other changes in the supplied voltage or other variables. Of course, if the power source is not able to supply the desired amount of current, the DC load equipment cannot furnish the difference; it can restrict current to a level, but it cannot boost current to a higher level. Most commercial DC loads are equipped with microprocessor front end circuits that allow the user to not only program a desired current through the load ('constant current' or CC), but the user can alternatively program the load to have a constant resistance (CR) or constant power dissipation (CP).

4.1 Elements in DC programmable load

- Operational Amplifier
- Operational Amplifiers as an impedance converter
- Operational Amplifiers as an error amplifier
- MOSFET Transistors

4.1.1 Operational Amplifier

The operational amplifier is a fundamental building block in analog circuits. Its name originates from its usage within analog computers where it can achieve scaling, summation and integration. It is mostly built up by transistors, one operational amplifier consists of about 20 - 50 transistors. The non-ideal operational amplifier has limitations in form of finite gain, bandwidth and input and output resistances, common-mode rejection, offset voltage and bias current.

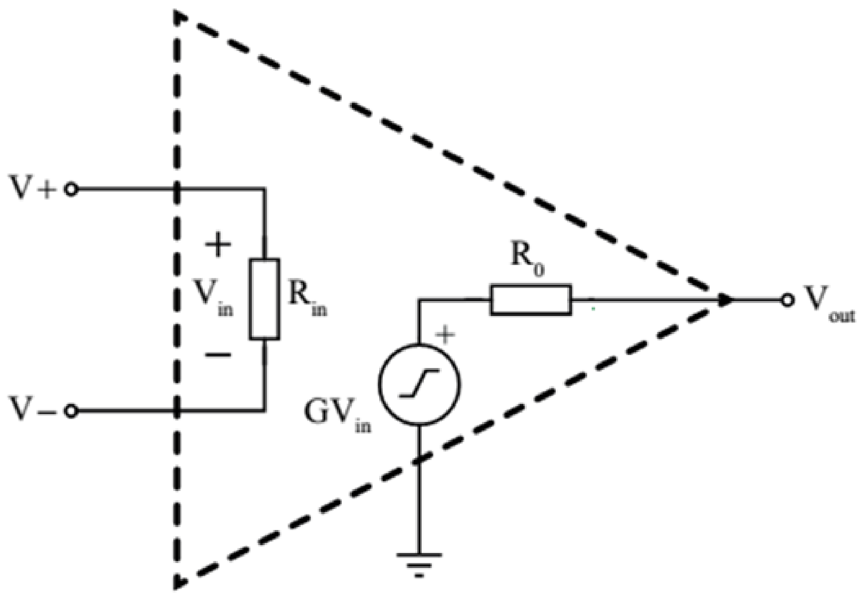

Figure 4.1: Internal Model of basic operational amplifier

Figure 4.1 shows an internal model for the basic operational amplifier. It has two inputs and one output. The inputs consist of one non-inverting input marked with a plus sign and one inverting input marked with a minus sign. For simplicity the schematic symbol is often drawn without the power and ground.

The operational amplifiers output is a high amplification of the voltage difference between the inputs. When using an ideal model of the operational amplifier, the input impedance Rin is considered to be infinitely large and the output impedance R0 to be zero. This results in zero current flowing at the inputs and the ability to supply unlimited current at the output without voltage drop. In reality, Rin can be a few megaohms and R0 some of ohms. Several different standard circuits can be designed by using the operational amplifier, this project uses two of them. First it is used as an impedance converter and also as an error amplifier.

4.1.2 Operational Amplifier as an Impedance Converter

The high input impedance and the low output impedance of the operational amplifier makes it useful as an impedance converter. By feeding the output signal back to the inverting input, the output voltage will follow the non-inverting input but will be able to drive loads without affecting the input signal.

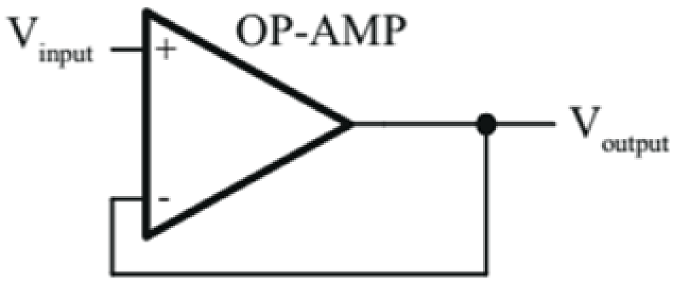

Figure 4.2: Operational amplifier as an impedance converter

The high impedance inputs results in input currents which can be considered to be close to zero. The output is low impedance which makes it able to output currents without significant voltage drop at the output. The impedance converter is found in many sensor and data acquisition applications where it is needed to drive loads with a signal without loss of signal voltage.

4.1.3 Operational Amplifier as an Error Amplifier in a Control Circuit

Within electronics, one of the strong usage areas for the operational amplifier is to use it in controller circuits as an error amplifier.

The error signal is the difference between the input reference value and the actual value. The process or variable that needs to be controlled by the output of the operational amplifier is fed back into the inverting input. The result is that the operational amplifier constantly will change its output so that the difference between the inputs gets as low as possible. In a good controller circuit, the operational amplifier will force the feedback signal equal to the signal fed into the non-inverting input. For example voltage regulators works this way and uses a feedback loop to control the output voltage and keep it constant.

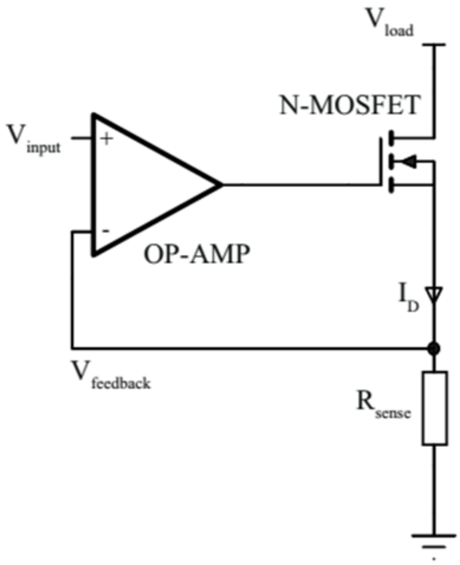

Figure 4.3: Operational amplifier as an error amplifier

Figure shows the basic control loop used in this thesis. The error signal which is the difference between the input reference signal (Vinput) and feedback signal (Vfeedback) is amplified to control the MOSFET. The gate voltage controls the current flowing through the MOSFET and the current sensing resistor (Rsense) and therefore the feedback voltage. There is no distinct transition between the different regions and it can change from linear to saturation mode and vice verse very fast. The electrical properties can also vary depending on manufacturing variations, mounting and body temperature. By using feedback that is proportional to the actual current, many of these influencing factors can be eliminated.

4.1.4 MOSFET Transistors

In principle, basic circuit of an electronic dc load contains an op-amp that drives a power MOSFET with a current sense resistor also called as load resistor. When the external voltage to be loaded is connected to the power MOSFET, and a control voltage is set by the multi-turn potentiometer in the circuit, the op-amp buffers this

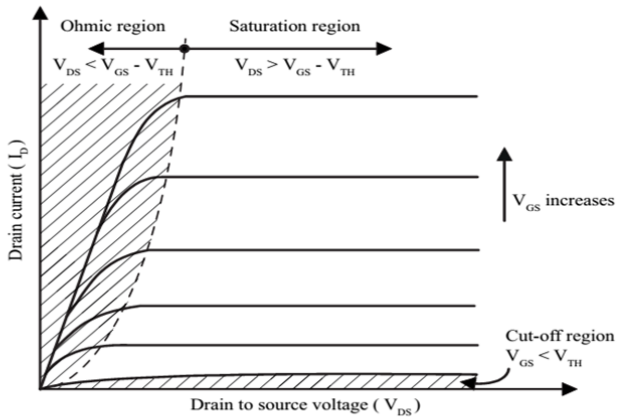

Figure 4.4: Characteristics of MOSFET

and sets a voltage on the gate of the MOSFET. This causes the MOSFET to allow some current through the drain to the source. The current sense resistor helps share the power with the MOSFET and also provides a feedback to the op-amp to hold the current level to detain constant.

Need of MOSFET

Among the available power transistor technologies, the one with the highest switching speed is the MOSFET. The fastest units can handle switching frequencies higher than 1 MHz. This makes them an excellent choice when it comes to designing small power supplies since the energy storage inductor can be made smaller as the frequency increases. The MOSFET can operate in three different regions; cutoff, ohmic and saturation. Figure shows the characteristics of an arbitrary n-channel MOSFET transistor. It can be seen that the current flowing between drain and source (ID), does not only depend on the voltage applied to the gate (VGS) but also the voltage between drain and source (VDS). When the voltage at the gate is lower than the device threshold voltage (VTH), the MOSFET is operating in its cut-off region. No channel is created between drain and source and the MOSFET will not carry drain current. In its ohmic region, the MOSFET can be treated as a voltage controlled resistor. The gate voltage will control the resistance between drain and source. When operating in its saturation region the drain current is independent of the voltage between drain and source.

In the ohmic region, the channel of the device acts as a constant resistance, RDS(on) .its relation to VDS band ID follows ohms law as

The value of the on-state resistance RDS(on) varies significantly between devices, from tens of milliohms to a few ohms. It is an important parameter which determines the device forward voltage drop and its power losses. The MOSFET has slightly higher conduction losses compared to the BJT but it's electrical properties are less sensitive to temperature changes. Between the different regions inside

$$R_{DS(on)} = \frac{V_{DS}}{I_D}|_{V_{GS}=Constant}$$

Figure 4.5: Ohm's Law

the MOSFET there exist parasitic elements as resistance's and capacitance's due to charge accumulation. The values of these capacitance's are non-linear and a function of device structure, geometry and applied external voltages.

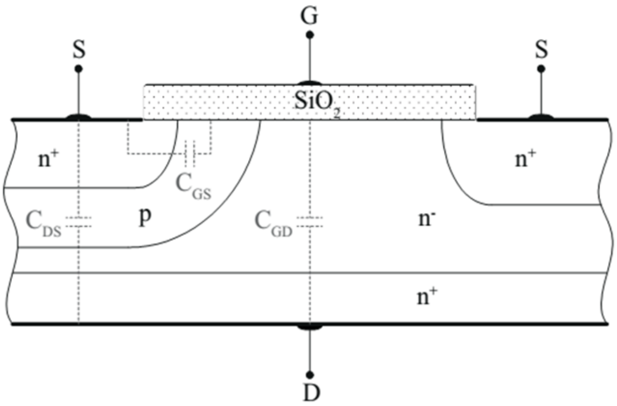

Figure 4.6: Cross section of a vertically diffused n-channel power MOSFET

4.2 Load Regulation using DC programmable load

Load Regulation is a static characteristic, that ascertains the ability of the power supply to remain within specified output range for a preordained load change. In order to carry out the load regulation testing of SMPS we use DC programmable load. A DC programmable load is a testing equipment which emulates the DC /AC resistance loads which is used for testing of batteries, power supply, solar cell etc. Figure (1) shows the circuit diagram of DC programmable load. The operational amplifier (A1) is a buffer/voltage follower circuit whose main function is to provide a voltage isolation between input stage and op-amp (A2) of the DC programmable load and also to reduce loading effect on op-amp (A2), so that the input signal reaches the op-amp (A2) without any distortion and noise. The operational amplifier (A2) is used in non-inverting amplifier with negative feedback configuration, which forms the basis for the working of DC programmable load, in here the amplifier tries to maintain the same voltage across the two input terminals which leads to change in the output of the op-amp.

MOSFET plays a very important role in the working of the DC programmable load circuit by generating variable load resistance when used in the ohmic (active)

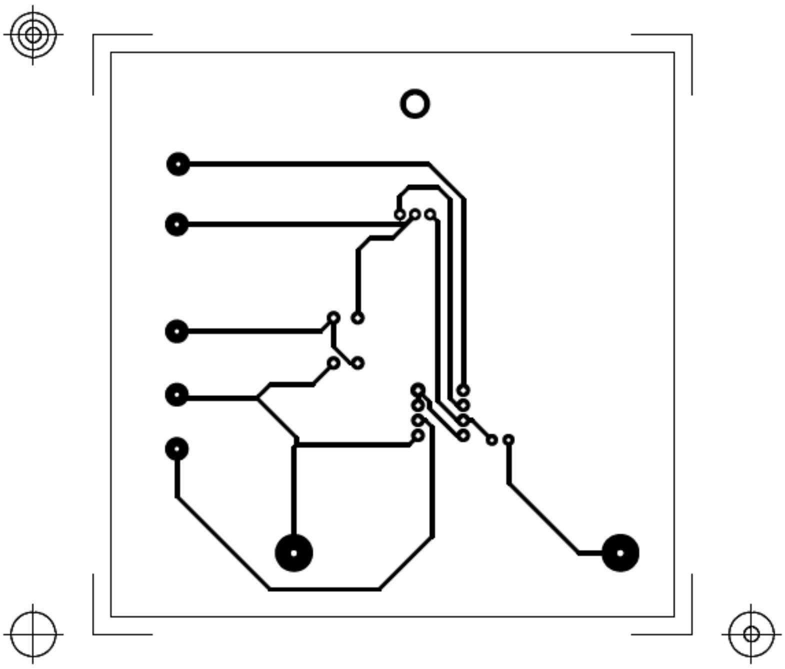

Figure 4.7: PCB Layout of DC Programmable Load

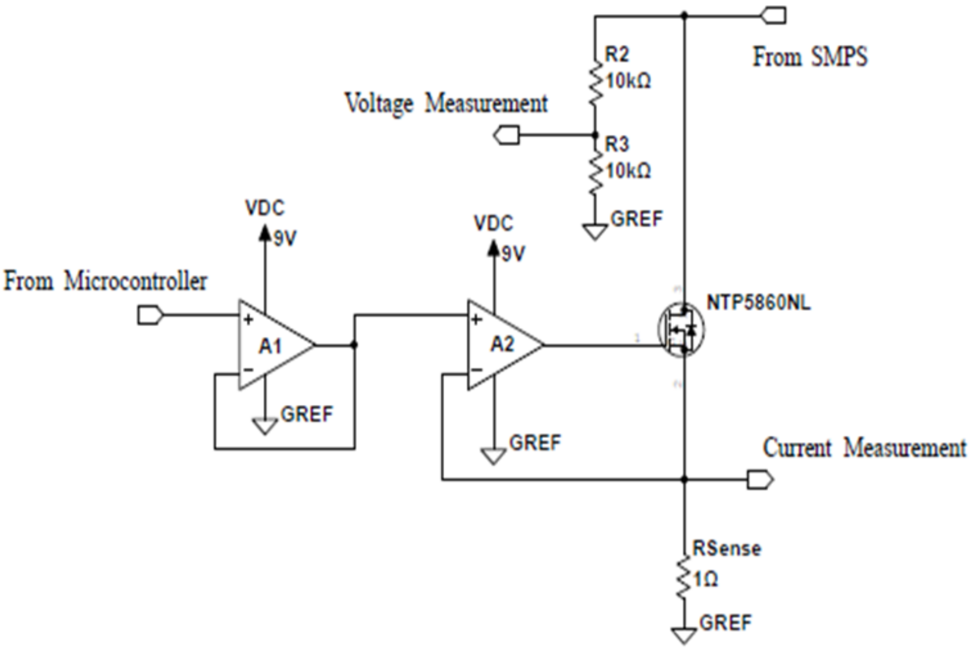

Figure 4.8: DC programmable load

region. MOSFET is voltage-controlled device and has an advantage over a simple transistor as it has the capability to handle large amount of current, very high switching speed, low switching losses, requires very small current to operate and also MOSFET can operate in three different regions; cut off, ohmic and saturation. It can be seen that as the current flowing between drain and source ID, not only depends on the voltage applied to the gate VGS but also on the voltage between drain and source VDS. When the voltage at the gate terminal is lower than the device threshold voltage VTH, the MOSFET is operating in its cut-off region. No channel is created between drain and source and the MOSFET will not carry drain current. In its ohmic region, the MOSFET can be treated as a voltage-controlled resistor. The gate voltage will control the resistance between drain and source. When operating in its saturation region the drain current is independent of the voltage between drain and source. In order for DC programmable load to work we use the MOSFET in ohmic region where Vgs >Vth and Vds <Vgs-Vth As shown in figure the basic control loop of the op-amp (A2) tries to maintain the same voltage across the input terminals, Thus the error signal generated which is the difference between the input reference signal Vinput and feedback signal Vfeedback is amplified to control the MOSFET.

$$I_D = \mu_n C_{ox} \frac{W}{L} \left((V_{GS} - V_{th}) V_{DS} - \frac{V_{DS}^2}{2} \right) \qquad (1)$$

The gate voltage controls the current flowing through the MOSFET and the current sensing resistor Rsense and therefore the feedback voltage and the equation (1) models the flow of current from drain to source in an ohmic region, where VGS is gate to source bias, Vth is device threshold voltage, VDS is drain to source bias, is charge carrier effective mobility, W is gate width, L Gate length, is the gate oxide capacitance per unit area .Thus, by giving a controlled structured input to the DC programmable load from the Arduino Uno we control the output voltage of op-amp (A2), which drives the gate terminal of the MOSFET and in turn we control the resistance between the drain and source terminals, and as a result the MOSFET acts a voltage-controlled resistor.

4.3 Pulse Waveform Generation

In order to emulate different loading conditions using the DC programmable load we need to provide an anolog signal to it, so that as per the different voltage level supplied the different loads are emulated. This is done by providing the signal from the microcontroller to the (A1) op-amp. We use pulse wave form generation to get a analog voltage output from the digital circuit (microcontroller).

In digital circuits a signal can only have two distinct states, either on or off. Digital outputs works in the same way, if the system voltage is 3.3 V then it is either 3.3 V or 0 V. When there is a need to produce an output voltage that is in between these levels a form of Digital-to-Analog Converter (DAC) is needed. Shape of the test pattern or pulse decides, a voltage pulse which will be transformed to a current pulse in the active load circuit. So, in oreder to construct the analog voltage we use PWM method which involves high frequency switching between two output states, on or off. Example if the user demands a voltage that is half of the system voltage the duty cycle must be set to 50 %, which means that the output is high for half the switching period and low for the other half. This gives an average value that corresponds to 50 % of the on-state output voltage. hi

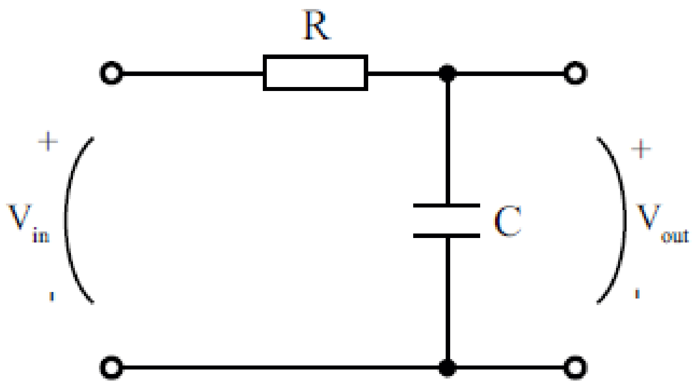

Figure 4.9: RC low pass filter circuit

In order to achieve a smooth output waveform and not a high frequency pulse train with varying duty cycle a low pass RC filter is used as shown in figure 4.8. In order to achieve a smooth waveform, the switching frequency needs to be much higher than the frequency of the signal that should be generated. The figure 4.9 depicts the output of the RC low pass filter when the PWM signal is given as a input to achieve the smooth waveform.

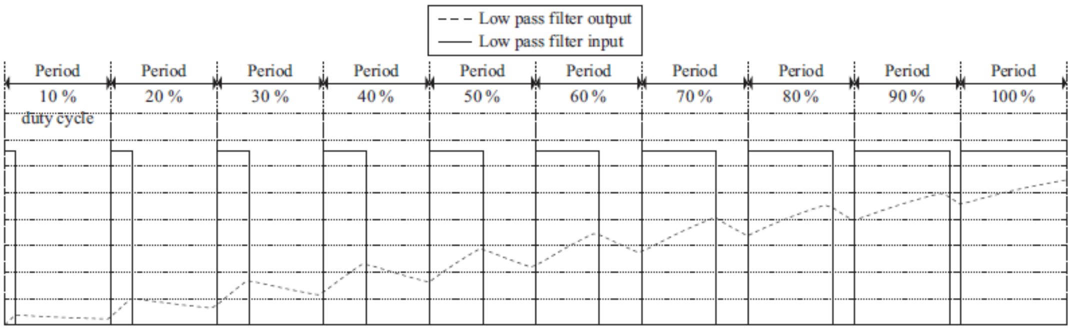

Figure 4.10: Digital to Analog Converter (DAC) using Pulse Width Modulation (PWM)

Chapter 5

Labview

Laboratory Virtual Instrument Engineering Workbench (LabVIEW) is a system-design platform and development environment for a visual programming language from National Instruments.

LabVIEW integrates the creation of user interfaces (termed front panels) into the development cycle. LabVIEW programs-subroutines are termed virtual instruments (VIs). Each VI has three components: a block diagram, a front panel, and a connector pane. The last is used to represent the VI in the block diagrams of other, calling VI's. The front panel is built using controls and indicators. Controls are inputs: they allow a user to supply information to the VI. Indicators are outputs: they indicate, or display, the results based on the inputs given to the VI. The back panel, which is a block diagram, contains the graphical source code. All of the objects placed on the front panel will appear on the back panel as terminals. The back panel also contains structures and functions which perform operations on controls and supply data to indicators. The structures and functions are found on the Functions palette and can be placed on the back panel. Collectively controls, indicators, structures, and functions are referred to as nodes. Nodes are connected to one another using wires, e.g., two controls and an indicator can be wired to the addition function so that the indicator displays the sum of the two controls. Thus, a virtual instrument can be run as either a program, with the front panel serving as a user interface, or, when dropped as a node onto the block diagram, the front panel defines the inputs and outputs for the node through the connector pane. This implies each VI can be easily tested before being embedded as a subroutine into a larger program.

The graphical approach also allows non-programmers to build programs by dragging and dropping virtual representations of lab equipment with which they are already familiar. For complex algorithms or it is important that a programmer possess an extensive knowledge of the special LabVIEW syntax and the topology of its memory management.

Steps to interface Arduino with LabVIEW are as follows:

- Step 1: Install LABVIEW Software and activate the software using LABVIEW activator.
- Step 2: Install VISA Driver to Enable serial port of system to communicate with LABVIEW environment.
- Step 3: After every installation please restarts your system to avoid NI server location is not running error.
- Step 4: Search LIFA 2.2.0.79 version VI package and install the package.
- Step 5: After installation connect your Arduino board to your laptop and from device manager find COM port where Arduino is connected.
- Step 6: After connection of Arduino open LABVIEW software.
- Step 7: Select device type Arduino UNO
- Step 8: Specify the COM port.
- Step 9: Develop the 'function block diagram' as per the application.

Labview program

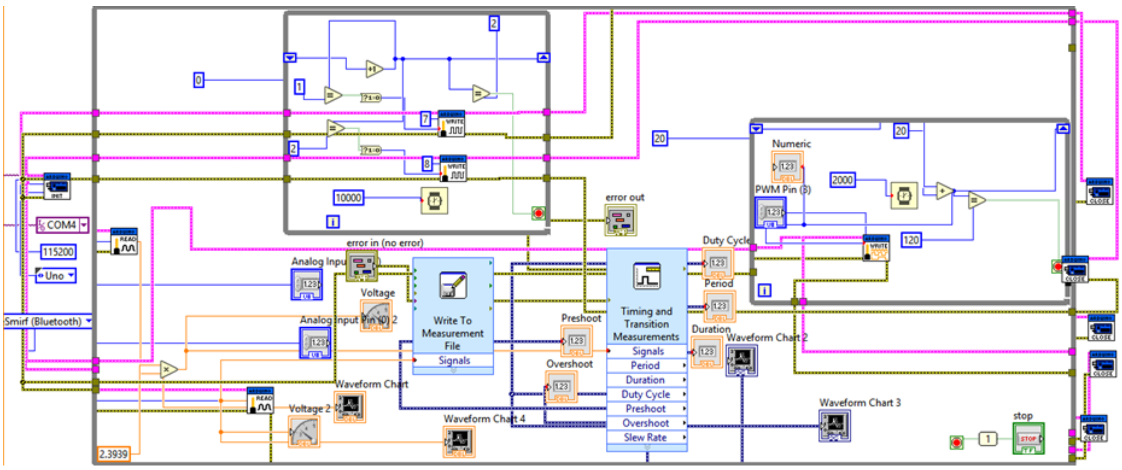

Figure 5.1: Functional Block Diagram of the working model

Chapter 6

Observation Table

Table 6.1: Voltage across R_{sense} resistor, as a function of changes in input voltage to DC programmable load, for the SMPS operated on 230V AC.

Sr No.	Input Voltage	Voltage across R_{sense} resistor
1	1.16	1.19
2	2	2.02
3	2.21	2.39
4	2.5	2.52
5	2.8	2.78
6	3	3.04
7	3.3	3.36
8	3.6	3.59

Table 6.2: Output voltage of the SMPS operated on 230V AC input supply, as the function of load change.

Sr No.	Input Voltage	Output Voltage
1	1.16	13
2	2	12.6
3	2.21	12.4
4	2.5	12.7
5	2.8	12.8
6	3	12.54
7	3.3	12.6
8	3.6	12.6

Table 6.3: Voltage across R_{sense} resistor, as a function of changes in input voltage to DC programmable load, for the SMPS operated on 110V AC.

Sr No.	Input Voltage	Voltage across R_{sense} resistor
1	1.16	1.18
2	2	2.04
3	2.21	2.42
4	2.5	2.58
5	2.8	2.78
6	3	2.95
7	3.3	3.28
8	3.6	3.62

Table 6.4: Output voltage of the SMPS operated on 110V AC input supply, as the function of load change.

Sr No.	Input Voltage	Output Voltage
1	1.16	13.02
2	2	12.6
3	2.21	12.4
4	2.5	12.58
5	2.8	12.54
6	3	12.6
7	3.3	12.58
8	3.6	12.6

Chapter 7

Graphs

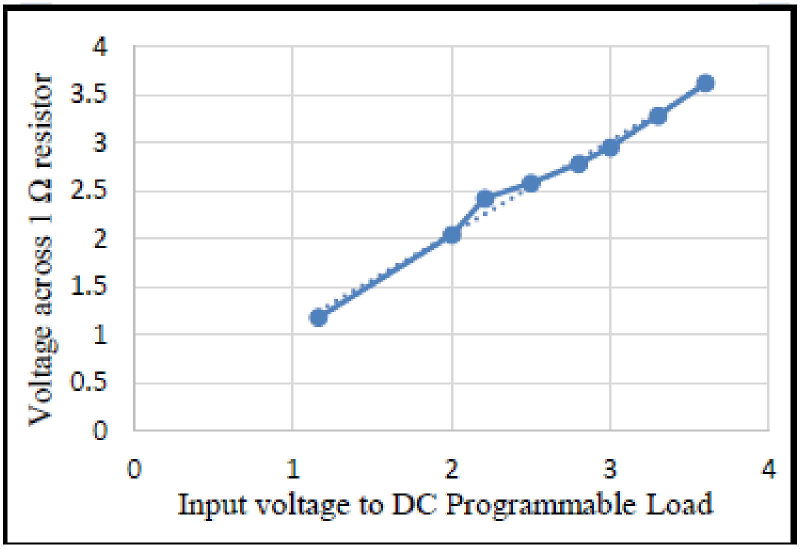

Figure 7.1: The above graph describes the relationship of variation in voltage across R_{sense} resistor, as a function of changes in input voltage to DC programmable load, for the SMPS operated on 230V AC.

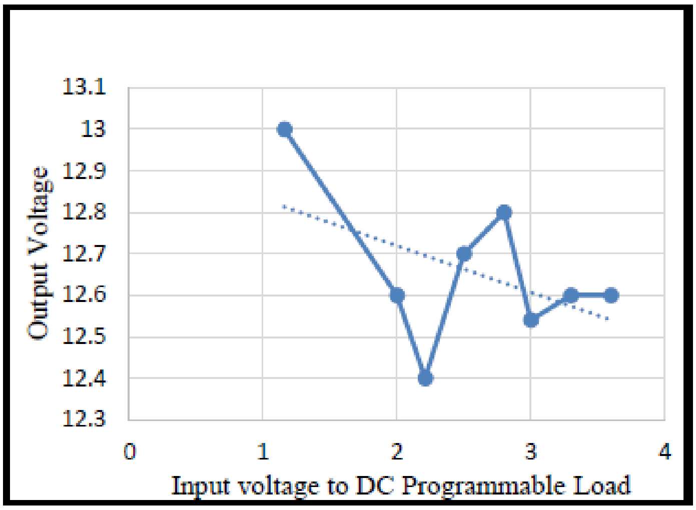

Figure 7.2: The above graph shows that how the output voltage of the SMPS operated on 230V AC input, varies as the function of load change.

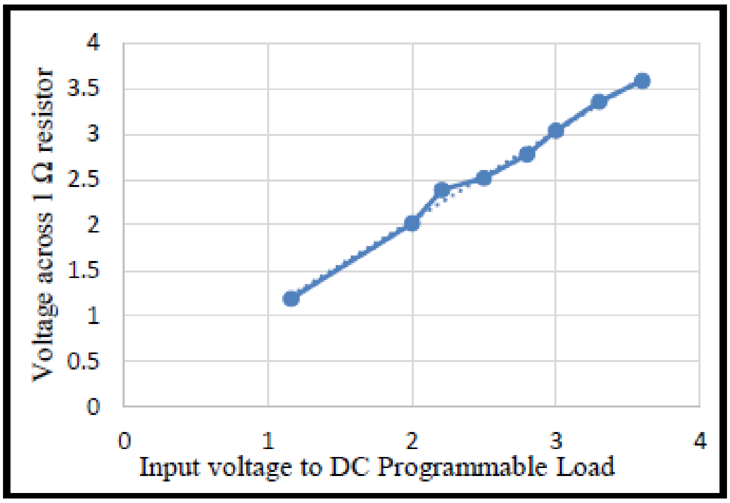

Figure 7.3: The above graph describes the relationship of variation in voltage across R_{sense} resistor, as a function of changes in input voltage to DC programmable load, for the SMPS operated on 110V AC.

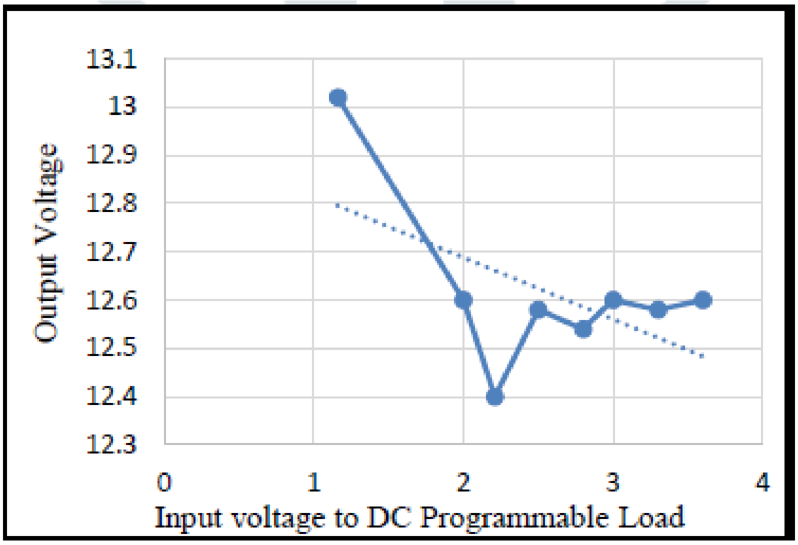

Figure 7.4: The above graph shows that how the output voltage of the SMPS operated on 110V AC input, varies as the function of load change.

Chapter 8

Result

The DC programmable load is used for testing of the SMPS, it can be inferred that as the SMPS is powered using 230 V & 110 V AC supply separately, then we observe that there is a sudden overshoot in the output to 13 V & 13.02 V respectively and later the output voltage settles to 12.6 V, further as the input is given to the DC programmable to emulate different loading conditions, the SMPS tries to maintain the output voltage to 12 V.

As different loads are emulated by the DC Programmable Load, we observe that the current supplied by the SMPS, powered by 230 V & 110 V AC supply separeately, remains constant within band of 1.90 A to 2.08 A. As different loads are emulated we observe the proportional voltage change across R_{sense} resistor indicating the decrease in the current as load is varied.

Chapter 9

Conclusion

The DC Programmable Load along with the LabVIEW software evaluates and analyses the performance characteristics of SMPS based on the variation in the input voltages and the different loading conditions specified for the SMPS. It is seen that as we supply the input voltage to the SMPS and measure its performance charateristics we observe that the output voltage rises suddenly of the SMPS and then settles to the constant DC voltage level.

It is also observed that as the different loading conditions are emulated to test the load regulation of SMPS we see that as the resistance is increased we observe the proportinal rise in the voltage which in turn indicates that the current owing through the DC programmable load is decrasing, this proportinal changes in the voltage due to current is as per the emulated loading conditions by the DC programmable load.

Chapter 10

References

[1] **Agilent AN 372-1 Power Supply Testing.**

[2] **Design and analysis of a small electronic load for testing on-board DC/DC converters, by Lukas Ros´En and Sahar Samimi, Department of Energy and Environment Division of Electric Power Engineering CHALMERS UNIVERSITY OF TECHNOLOGY G¨oteborg, Sweden 2012.**

[3] **SMPS AC/DC Reference Design User's Guide.**

[4] **An Automated Test Method for Robot Platform and Its Components Jae-Hee Lim1,Suk-Hoon Song1, Jung-Rye Son1, Tae-Yong Kuc2, Hong-Seong Park3, Hong-Seok Kim4 1,2School of Information and Communication, Sung Kyun Kwan University, Suwon 440-746 Korea; 3 Department of Electronic and TelecommunicationEngineering, Kangwon National University, 4Korea Institute of Industrial Technology, Ansan 1271-18 Korea 1homze007@skku.edu, 2tykuc@yurim.skku.ac.kr**

[5] **Cost effective test methodology using PMU for automated test equipment systems In-Seok Jung1, Yong-Bin Kim1 and Kyung Ki Kim2**; Department of Electrical and Computer Engineering, Northeastern University, Boston, MA, USA; 2Department of Electronic Engineering, Daegu University, Gyeongsan, South Korea.**

[6] **"Programmable DC electronic load, model 6310A series." Chroma ATE INC, 2000.**

[7] **I. Batarseh, "The power MOSFET," in Power Electronics Handbook (Second Edition) (M. H.Rashid, ed.), pp. 41–69, Elsevier Inc, 2007.**

[8] **"LM358- ON Semiconductor" datasheet.**

[9] **NTP5860NL N-Channel MOSFET by ON – Semiconductor.**