EXPERIMENT 1
LINEAR POWER SUPPLIES

Aim of Experiment
To introduce basic building blocks of Linear Power Supplies. Experimentally verify theoretical considerations.

Pre-experiment study

(1)Read Lab document thoroughly
(2)Read cited reference book chapters in the following text
(3) Work out exercises in the cited references

Pre-experiment study should provide the clear understanding of the following topics
- Transformer, Diode, Zener Diode and BJT
- Half-wave rectifier
- Full-wave rectifier
- Zener regulator
- Equivalent output resistance of a source
- Effective and Average values of half sine waves
- Effective and Average values of full sine waves

Note: Before running the experiment, you will take a **quiz** for the pre-experiment study

Introduction

Almost all electronic circuits require a decent power supply. Without a power supply, a circuit with any complexity (computers, cell phones,... etc) cannot function. To realise any electronic function, one first needs a power supply.

The power for electronic equipments and gadgets is provided either by batteries or by utility AC lines. Hand held equipments such as mobile phones, remote controllers, ... etc are generally powered by batteries. Large power required equipments, such as TV set, desktop Computers,... etc are powered by utility AC lines.

The power provided from utility lines is much cheaper than the batteries. Some batteries need AC lines to recharge as well. To sum up, getting power from utility AC lines and delivering it to circuits is a primary job for circuit design engineers.

As circuit get much more complex, they consume much more power. Today, particularly in IC design, some research is directed to the more power efficient circuit design.

Because the utility AC line provides power for all kind of appliances such as AC machines, heater,... etc, in addition to illumination. The utility AC lines output voltage cannot be used directly to power electronic circuits. It is first **reduced** to a smaller voltage via transformers. Then it is **rectified**, **filtered** and finally **regulated** to provide DC voltage. The following block diagram is description of this process.

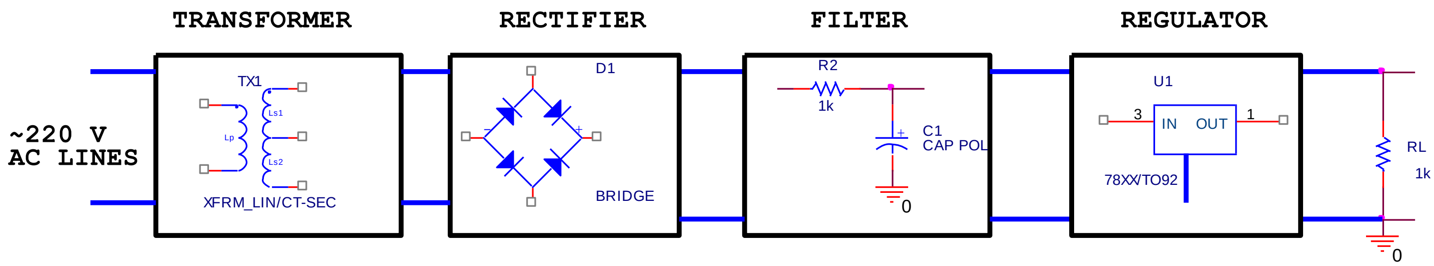

Fig. 1.1 Block diagram of a typical Linear Power Supply

The power supplies for electronic circuit come up with two main categories: Namely, Linear Power Supply and Switching Mode Power Supply.

Linear Power Supplies (LPS)

The LPS`s are easy to design. Components are widespread and cheap. Rectifiers are in standard packages. Filters are easy to develop. Regulators are in standalone single packages.

For more information about LPS's refer to Ref.1 Chap 5, Ref.2 Chap. 3 and Datasheets.

Switch Mode Power Supplies (SMPS)

Today SMPS's are widespread in use. Most of professional equipments such as Computers, TV sets ... etc are using SMPS instead of LPS's. They are much more power efficient (up to 95%)[5]. And they can provide much more output power. In SMPS's, heavy and large transformer is eliminated. So they are much lighter to carry and small in size. Their components are standardised and are available in widespread.

Some SMPS Control ICs: MC 1723 (Motorola); uA 78S40 (Fairchild) etc.

SMPS's are much harder to design. In addition to semiconductor and capacitors parts, inductors are also used. Because of switching circuit, they may cause some trouble to following circuits. SMPS design requires professional skills.

For further information refer to Ref.2, Chap.3 and Ref.3

Description of LPS Sub-Circuits

Rectifier

A rectifier turns a **bipolar** AC lines voltage to a **single polarity positive** or **negative** voltage. If the circuit rectifies the only one half of the wave then it is called **half-wave** rectifier. If the circuit rectifies the both half's of the wave then it is called **full-wave rectifier**.

Filter

To smooth out rectifier output, a **Low Pass Filter** (LPF) is used. The filter components are one resistor and one capacitor. The equivalent output resistance from rectifier output forms **resistor** of the filter. The externally connected large capacitor is **capacitor** of the filter. The pole frequency should be small as much as possible (~10 Hz). For large currents the regulator input resistance should be considered as well.

Regulator

The regulator fixes voltage at filter output. It produces final DC voltage. Its function is to keep output voltage fixed while delivering a variable current to the load. In some extent, it also tolerates variation in AC lines voltage. Regulator circuitry ranges from a simple resistor plus Zener diode to much more advanced complex circuits.

Some industry standard regulators for LPS are as follows:

Positive fixed voltage regulators:
    78xx series (Motorola): 7805 for +5V; 7810 for +10 V
Negative fixed voltage regulators:
    79xx series (Motorola): 7905 for -5 V; 7910 for -10 V
Positive variable voltage regulator:
    LM317 (National): +1.2 V to +37 V
Negative variable voltage regulator:
    LM337 (National): -1.2 V to -37 V

Generally these regulators are available for small power applications (up to 30 W). For large power application, one should design additional circuits. LPS regulators consume considerable power as it delivers the output power. LPS's efficiency depends on input and output voltage difference. As difference gets larger, the efficiency gets down. LPS efficiency is about 50%, at most [2]. LPS's are not power efficient as SMPS's.

Description of LPS Components

The short description of components is given here in the context of LPS (Fig.1.6). For more detailed information, one should refer to the cited references.

Transformer

Transformers reduce AC lines voltage to much smaller AC voltage. For example, they can reduce 220V to 20V (RMS). They have primary and secondary windings. The transformers that are used in LPS's are as follows:

(1) Single secondary transformer: The secondary has a single winding
(2) Centre- tapped transformer: The secondary has symmetrical two windings

In this experiment, the centre-tapped secondary transformer will be utilised.

The transformers also provide electrical isolation of LPS from AC lines. If not used, any short-circuit in LPS may cause some disruption in AC lines.
For more information refer to the Ref.1, Chap.5.

Diodes

Diodes are **one way** current conducting devices. When **anode** node has higher voltage then the **cathode** node (up to a threshold voltage), it **conducts** the current. Vice versa, it **blockades** the current.

In the experiment, diodes will be connected to transformer secondary. They function as **half-wave** or **full-wave** rectifiers according to the position of the switch.

For more information refer to the Ref.1, Chap.5 and Ref.4, Chap.3.

Zener Diode

Even it may function as a normal diode with a low reverse voltage, but normally it is used in **reverse bias** operation mode. It fixes a particular node voltage to Zener voltage where it is connected to. Let's assume a constant input current. When the load takes less current, Zener sucks excessive current with almost all a fixed voltage. When the load takes more current, Zener decreases its current to compensate the increase with again almost all a fixed voltage. As result, an increase or decrease in load current does not change output voltage considerably (the change may be in range of mV). This is what we want from a power supply. When input voltage is well below the Zener voltage, the Zener diode behaves as an **open circuit** switch.

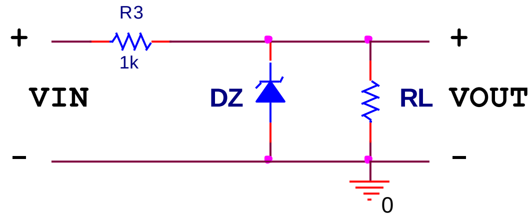

Fig. 1.2 Simple Zener Regulator circuit

In the experiment, Zener diode will be used in regulator circuit to fix the base voltage of BJT. As a result, it **fixes** the output voltage.

For more information about Zener diode refer to Ref.4, Chap.3 and other cited references.

BJT

BJT in regulator circuit behaves as a **current amplifier**. And it takes out excessive voltage between input and fixed output. Say, if Zener diode can provide 10mA current to load, then using a BJT of β of 10, increases that current capacity 10 times to 100 mA.

In the experiment, BJT, Zener diode and biasing resistors form a simple regulator circuit. In industry much advanced regulators (78xx, 79xx,... etc) are in use.

For more information on BJTs refer to the cited references.

Capacitor

The capacitor saves electronic charges when input is high enough (in one phase). Then, it releases electronic charges when not enough input voltage is available (in the following phase). It helps smoothing out the load voltage.

In the LPS literature, capacitor is described as a component of **Low Pass Filter.** The simplest LP filter elements are equivalent output resistance of rectifier circuit plus the capacitor. It filters out the output of rectifier circuits. For different filter configurations refer to the cited references. The larger the capacitor, the smoother the output voltage is. But very large capacitor increases volume and cost of LPS. One should find a trade off in between.

Generally in LPS, large electrolyte capacitors are used. They have (+and -) polarity leads which means to always (+) lead should have higher voltage then the (-) lead. Reversing capacitor polarities **damages** the component!

Load

A load can be simply a pure resistor to an electronic circuit of any complexity. In the experiment to investigate LPS performance, a simple pure resistor (rheostat) will be used to mimic the load.

Power Supply Specifications

Maximum output current

Each Power Supply delivers a maximum current. If it is not protected, drawing more current results a decrease in output voltage. Further increase in current may **damage** Power Supply as well!

Output Voltage

Some Power Supplies have fixed output voltage such as ±5V, ±10, ... etc. Some Power Supplies have a variable voltage range such as 0 to ±15. For a Power Supply, It is essential to keep its output voltage constant while delivering the variable current to the load. Every Power Supply has a maximum output voltage. No more voltage will be available than designated maximum voltage.

Ripple Voltage

The ripple voltage at output is a remnant of AC lines voltage. It runs on top of output DC voltage. It has harmonic of line voltage frequency such as 2f, 3f,...etc. It can increase as the load draws larger current. It can be decreased by a larger capacitor. In a quality PS, the ripple voltage can be small enough (~mV) that it can be usually neglected.

A typical figure for ripple voltage can be given as follow [1]:
The ripple factor(RF):

$$RF = \left[\frac{\Delta V(pp)}{2}\right] / [V(DC)]$$

$$RF = 1/[f_r \cdot R_L \cdot C_F] \tag{1.1}$$

$\Delta V(pp)$: ripple voltage peak-to-peak; V(DC): DC output voltage
f_r =2* f , for half-wave rectifier,
f_r = 4*f, for full-wave rectifier. f =50 Hz, AC lines voltage frequency.
$\mathbf{R_L}$ is load resistor, and $\mathbf{C_F}$ is filter capacitor.

Load Regulation Factor

This is a figure for how any **change in output current** can affect output voltage.

Line Regulation Factor

This is a figure for haw any **change in AC lines voltage** can affect output voltage.

Short-circuit Protection

A good Power Supply should provide short-circuit protection. When accidently, a short-circuit happens at output, the PS limits load current. This way, it protects itself. And a lesser extent, it may protect load too.

Output Resistance

A Power Supply output voltage decreases as load draws more current in practice. This drop is modelled with an equivalent output resistance (even if the drop is small). For a good PS, the output resistance should be small as much as possible.

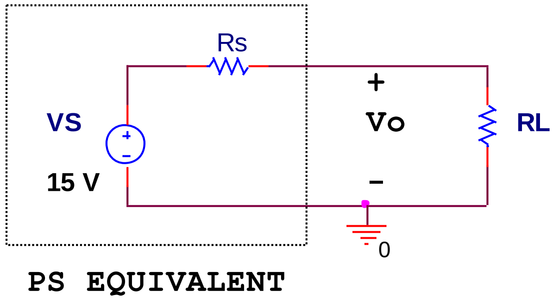

Fig. 1.3 Power Supply equivalent circuit. V_S is voltage of PS. And R_S is equivalent output resistance of PS

Running The Experiment

To be ready to run the experiment, study the following Measurement Circuits
How do they work? Draw output voltage and current waveforms.

Notes

- Tthe ampermeter is assumed to have zero input resistance (short-circuit).
- The sum , RL=Ry+Rk+Ra is consider as the **total load**.
- The transformer is 220V to 2x17 V (RMS)

Positive LPS

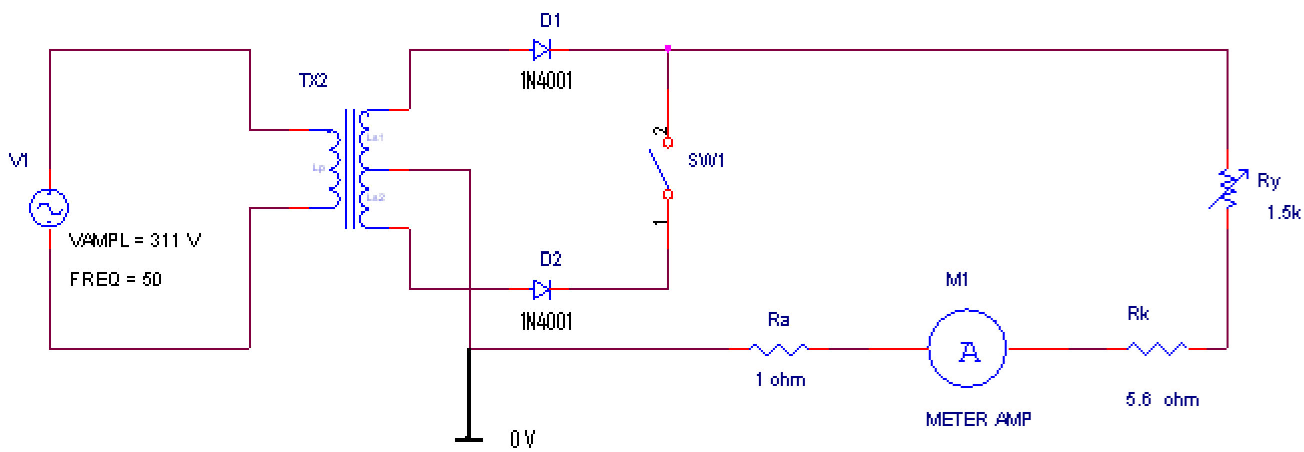

Fig.1.4 Positive rectifier circuit

Negative LPS

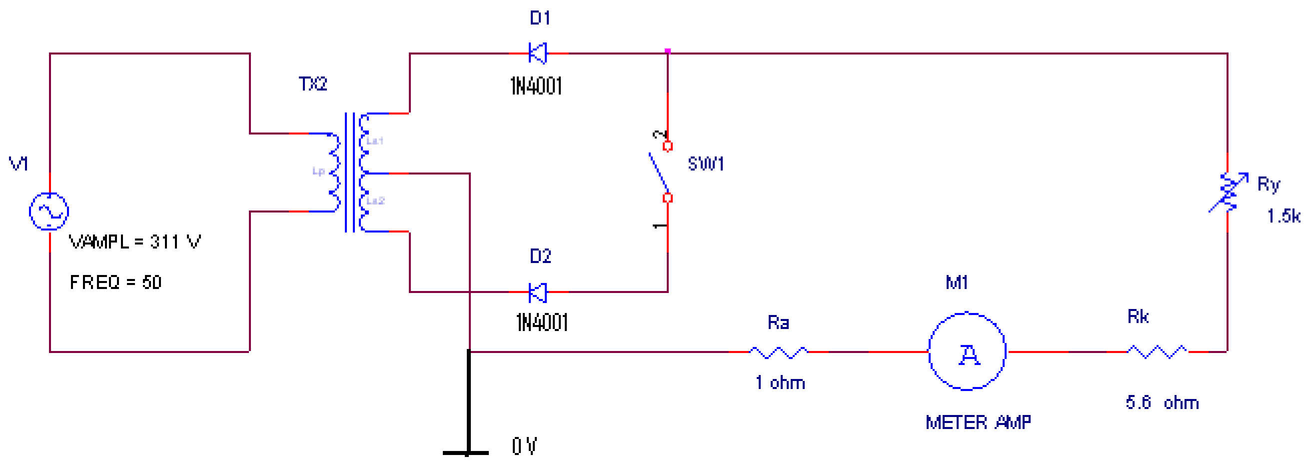

Fig. 1.5 Negative rectifier circuit

Regulated Positive LPS

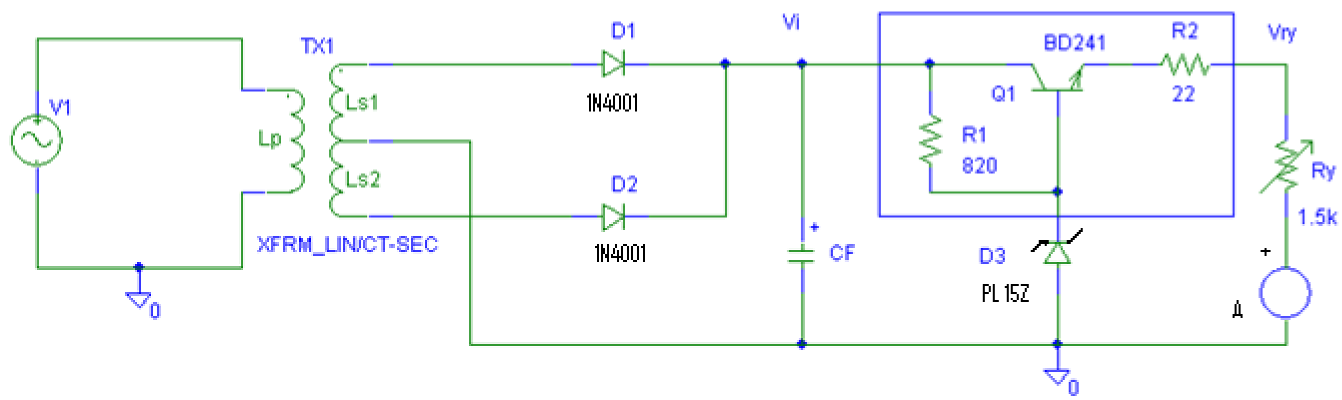

Fig.1.6 Regulated positive linear power supply.

Note: Detailed measurement procedure of the experiment will be provided in separate sheets

References

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