V H Raybagkar
Department of Physics
N. Wadia College
Pune 411001, India.

A Perspective on Line Regulation of DC Power Supplies

A simple and economical experiment to study line regulation, which is suitable for schools and colleges, is described.

The Need

Electricity is undoubtedly the most convenient form of energy. One can experience the benefits of using electrical energy in real life through numerous appliances working on AC or DC power supplies. There are several occasions when the use of DC power sources becomes essential. The use of batteries allows designers to make their instruments portable. Such instruments serve different purposes in many fields including automobiles, agriculture and medicine.

While the use of batteries provides a *clean* DC considered very healthy for all DC instruments, there are some practical limitations in using batteries everywhere. Electrical energy available from AC mains supply (domestic or industrial) works out to be much cheaper than the use of batteries. This is particularly true for high power requirements. Therefore, the use of either rechargeable batteries or DC power supplies with instruments that can be placed temporarily at a location where mains AC supply is available is preferred. Batteries are used only during the fieldwork.

A DC power supply consists of a mains power transformer, a rectifier, a filter to minimize *ripple* in the rectified output and often also a regulator. A regulator circuit improves the quality of DC so obtained, to make it act as good as DC available from batteries. Non-critical applications, such as a pocket transistor radio receiver, can do without a regulator circuit although a regulator circuit certainly improves their performance. However, there are many types of industrial and medical equipment that demand the use of a highly regulated DC for their operation to produce reliable measurements. It is for this reason that well-defined parameters have been identified to specify the quality of regulation of DC power supplies. DC power supplies is a major topic of study in science as well as engineering

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faculties. One finds experiments such as half wave, full wave rectifier circuits with and without filters, zener diode regulators, transistorized series/shunt regulators and IC regulators like IC 723/ 7805 or equivalents as laboratory curriculum of higher secondary or undergraduate classes in almost all premier educational institutions.

For reasons of economy and ease of maintenance, educational institutions derive the DC power from AC *mains line* like many other users do. This seems to have created some confusion about the term line regulation defined with reference to a DC power supply.

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The Common Method

Students generally are directed to use a dimmerstat (auto-transformer) to vary the primary voltage fed to a step-down transformer. As a result, the secondary voltage of the transformer that is subsequently rectified also varies proportionally. If this is followed by a filter (usually a capacitor of a few hundred microfarads) and an electronic regulator circuit, there is often a plot of line regulation. In this graph, students are instructed to plot the mains line voltage on the X-axis and the output voltage of the regulator on the Y-axis. Given in *Figure* 1 is a typical zener diode regulator set-up used in some colleges. *Table* 1 reproduces a typical set of observations taken with such a set up. *Figure* 2 shows the nature of the conventional graph obtained using the observations. Based on this plot, a student is instructed to calculate the *line regulation* as the change in voltage at

Figure 1. Conventional set up for study of line regulation.

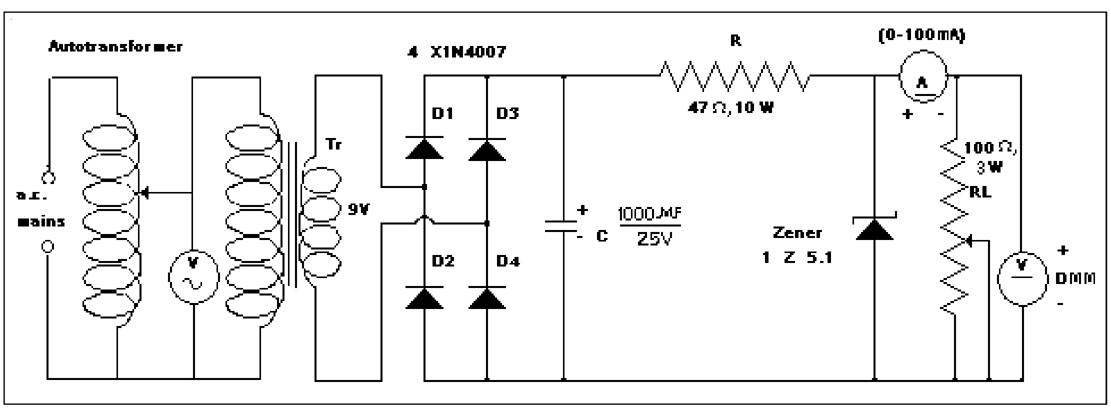

Table 1. A typical set of observations with a zener diode regulator circuit.

Mains (AC RMS) Voltage, V	'Line' Voltage	Output Voltage	Load Current (Load resistance kept constant), mA
0	0	0	0
50	1.38	0.72	10
60	1.98	1.15	18
70	2.40	1.34	22
80	3.01	1.67	28
90	3.60	2.05	36
100	4.08	2.4	42
110	4.52	2.63	48
120	5.18	2.95	54
130	5.67	3.27	60
140	6.27	3.57	66
150	6.33	3.85	72
160	7.14	4.1	78
170	7.61	4.43	84
180	8.19	4.73	90
190	8.71	5.06	96
200	9.05	5.12	98
210	9.61	5.19	100
220	10.33	5.22	100
230	11.50	5.23	100

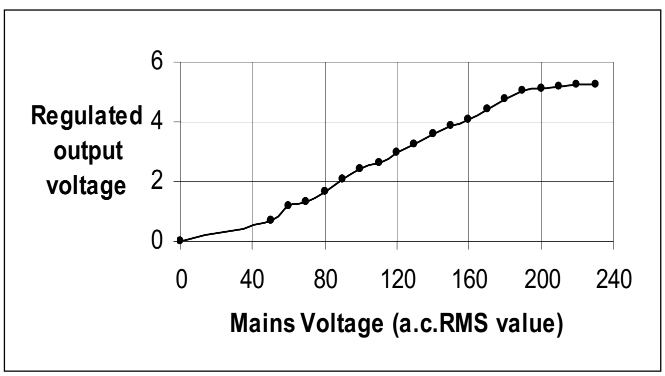

Figure 2. Conventional regulation curve.

the output of the regulator (across load resistor in the circuit of *Figure* 1) corresponding to a selected change in the mains voltage. The resulting magnitude of the fraction (or percentage) is usually small whereby the student believes in the 'good quality' of the regulator circuit.

Common Misconception

The procedure described in the previous paragraph is erroneous. It seems that the term 'line' is invariably interpreted as mains AC supply line. This is a misconception. The term 'line' in line regulation of a linear regulated power supply refers to the unregulated DC voltage that is fed as the input to any regulator circuit. This is evident from IC data manuals[1] as well as good books[2] on electronics. By definition, line regulation is the change that occurs at the output of the regulator under study for a specified change in the unregulated input voltage *due to whatever reasons,* except variation in the load resistance connected to the regulator output. Due to the fact that the mains line drives majority of the supplies, students and even some teachers seem to have developed a notion that it must be only the AC mains voltage that qualifies for the title *line*.

[1] For example, see Test Conditions Under Electric Characteristics for LM723, High Precision Voltage Regulator, page 3/16 www.ST.com

[2] T*he Art of Electronics by Paul Horowitz and Winfield Hill*, Cambridge University Press, II Edition, pp.341–342.

An Illustration Using Real Laboratory Measurements

Let us look at the observations in *Table* 1 to calculate the line regulation using the following values:

Mains voltage = 230 V, Line voltage = 11.50 V, zener regulator output voltage = 5.23 V

Mains voltage = 180 V, Line voltage = 8.19 V, zener regulator output voltage = 4.73 V

Therefore, line regulation (as per the conventional calculation) = (5.23 – 4.73)/ (230 – 180) = 0.01 or 1%. This quantitative inference is likely to create a wrong impression in the mind of a user that the zener regulator has a very high degree of regulation. (An ideal power supply has zero percent line and load regulation.) However, this would not be so if one looks at *Figure* 3 and realizes that the denominator in line regulation parameter has been inadvertently

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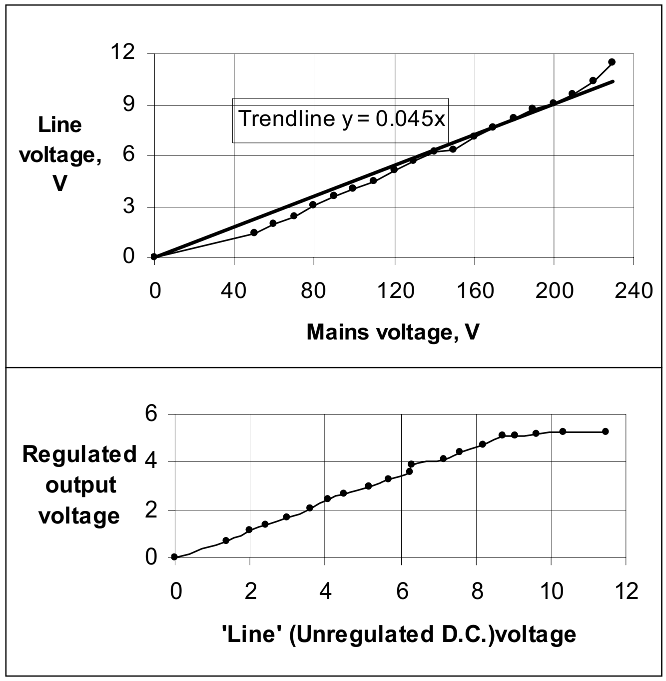

Figure 3 (top). Proportionality of mains and line voltages.
Figure 4 (bottom). True line regulation curve.

magnified by a factor dependent on the transformation ratio. For example, if the circuit of *Figure* 1 were used, the magnification factor would be 230/11.5 = 20. The real *line* voltage change was only from 8.19 Volts to 11.50 volts corresponding to mains line voltages of 180 and 230 V respectively. Therefore, the real line regulation value must be reported as $[(5.23 - 4.73)/(11.50 - 8.19)] \times 100 = 15.10\%$. *Figure* 4 shows the graph of real line regulation.

A Practical Difficulty in conducting the Experiment at Higher Secondary Level

It would also be worthwhile discussing a practical aspect of the common misconception about line regulation. Almost everywhere, teachers strongly believe that it is essential to use a dimmerstat to study line regulation of any regulator circuit. In the Indian market, a good quality dimmerstat costs not less than Rs.3,000 depending on its power handling capacity. Thus it is an expensive electrical item. The cost is a major hurdle in performing the complete experiment on zener regulator at the higher secondary level since a large number of dimmerstats may be required in city colleges where the strength of

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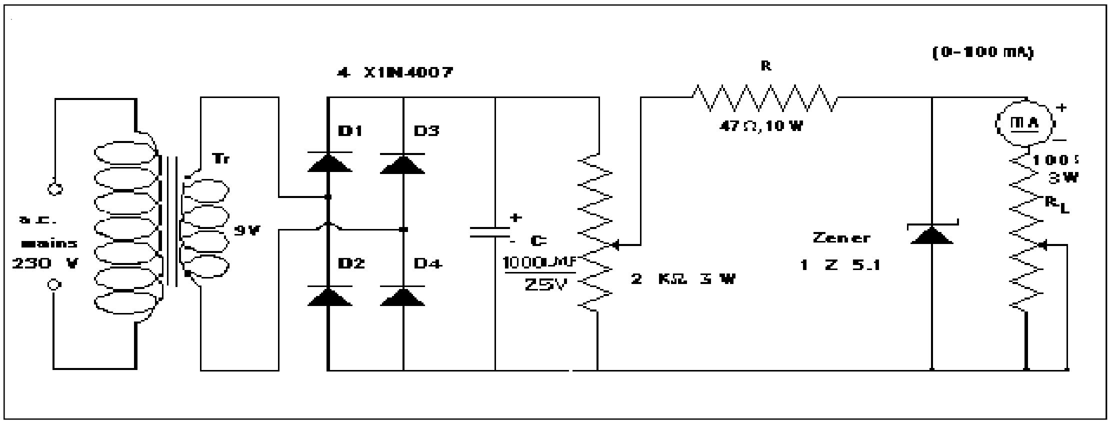

Figure 5. Modified economical set-up to study line regulation.

higher secondary students runs into several hundreds, and the number of students per batch may be as large as sixty. The risk of exposing young students to electrical shock while using an autotransformer is also not ill founded either.

A Cost-effective Solution to the Difficulty

The difficulty mentioned in the previous paragraph can be overcome most satisfactorily by simply introducing a potentiometer of suitable specifications on the input side of the regulator circuit. (This remedy applies to other regulators like IC 723 or 7805 as well.) It does not need a dimmerstat yet permits the measurement of line regulation without any difficulty. The circuit employing a potentiometer is shown in *Figure* 5.

Conclusions

On the basis of the discussion above and our practical testing of the modified circuit in our laboratory, we feel that an experiment on zener regulation can be satisfactorily conducted without the fear of electrical shock or budget constraints even at the higher secondary level.