A SIMPLE ZENER DIODE VOLTAGE REGULATOR¹

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It is not unusual for the power supply voltages used with relay circuitry to fluctuate over fairly wide ranges as the inductive loads change during normal operation. Unless the fluctuation is serious enough to cause marginal relay operation, it is usually not cause for much concern. However, if stimulus lights, or house lights, are powered from the same source as the control relays, serious problems can develop. Lamp intensity changes correlated with load changes, *e.g.*, when a reinforcement sets up, could, and most likely would, serve as an unwanted cue. The timing circuits used to control the closure and release times of relays are also sensitive to voltage fluctuations. Timing instabilities are a source of problems in the design of sequential circuits. In some instances, voltages other than the normal power supply voltage are needed to power satellite equipment.

Auxiliary supplies, or adequately regulated main supplies, are good but expensive solutions to these problems. An equally effective and much cheaper solution is afforded by the use of relatively inexpensive zener diodes. A single diode and resistor wired in at the trouble spot is all that is needed to provide auxiliary voltages and/or adequate regulation.

A zener diode looks much like a standard silicon diode but its internal composition has been altered to provide a special characteristic. When forward biased (positive to anode) it behaves like a regular diode, *i.e.*, low resistance, low voltage drop, and high current flow. When reverse biased (positive to cathode) the diode resistance remains high, and only microamperes of current flow, until a critical voltage, called the zener voltage, is reached. At this voltage, the resistance drops abruptly and current flow increases markedly. The effect is

similar to the breakdown of a standard diode when the peak inverse voltage rating is exceeded. In the case of the zener diode, however, the breakdown voltage is more sharply defined and non-destructive as long as the power handling capabilities of the diode are not exceeded.

The regulator circuit is shown in Fig. 1 below. The following design equations provide the values of the series resistor (in ohms) and the power rating of the diode (in watts).

$$R_s = \frac{V_{s(\min)} - V_z}{I_{L(\max)} + 0.1I_{L(\max)}}$$

$$P_{d(\max)} = \left(\frac{V_{s(\max)} - V_z}{R_s} - I_{L(\min)} \right) V_z$$

Where:

R_s = resistance of the series resistor

$V_{s(\)}$ = maximum or minimum value of the supply voltage

V_z = breakdown voltage of zener diode which is also the output voltage of the regulator (available at values from 3.9 to 200 v)

$I_{L(\)}$ = maximum or minimum value of the load current in amperes

$P_{d(\max)}$ = maximum power dissipation of the zener diode

Example. Two #313 lamps (28 v @ .17 amp each), wired in parallel, are to be used as house lights. The supply voltage fluctuates

Fig. 1. Schematic diagram of the simple zener diode voltage regulator.

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between 26 and 32 v. To ensure stability and lengthen lamp life, the lamps will be run at 20 v (the life of a lamp under normal conditions varies inversely to the twelfth power of applied voltage). At 20 v, each lamp draws .15 amp and the two wired in parallel would provide a load current of .30 amp. Substituting these parameters in the design equations it is found that $R = 18$ ohms and $P_d = 7.2$ w.

In practice, the next higher power rating for both the diode and the resistor would be chosen, in this case 10 w. The diode should be protected from developing excessive heat, the worst enemy of all semiconductors, by mount-

ing it on a heat-dissipating surface. The diodes can be used in parallel to achieve higher power ratings and in series to produce particular breakdown voltage values. The range of applicability of this circuit is limited only by the imagination of the user, the power dissipation capability of a particular diode, and the cost factor for high power ratings. A 1 w unit would cost about \$3.00, a 10 w unit about \$7.00 and a 50 w unit about \$15.00. Zener diodes are generally available in a wide range of voltage and power ratings from electronics supply houses.