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Department of Physics and Electronics

Name of the course— B.Sc. (H) Physics

Semester- IV

Name of the paper—Electrical circuits and Network Skills

Paper code-32223903

Lecture timings: 10:40 to 12:40 AM

Topics to be covered:

- *Zener diode as a voltage regulator*
- *Fuses and surges*
- *Relay and its functioning*
- *Conduits*
- *Grounding, fault protection, isolated grounds*

Zener diode as a voltage regulator

The Zener diode is like a general-purpose signal diode. When biased in the forward direction it behaves just like a normal signal diode, but when a reverse voltage is applied to it, the voltage remains constant for a wide range of currents.

***Avalanche Breakdown*:** There is a limit for the reverse voltage. Reverse voltage can increase until the diode breakdown voltage reaches. This point is called *Avalanche Breakdown* region. At this stage maximum current will flow through the zener diode. This breakdown point is referred as "Zener voltage".

Fig 1: Zener diode

The Zener Diode is used in its "reverse bias". From the I-V Characteristics curve we can study that the zener diode has a region in its reverse bias characteristics of almost a constant negative voltage regardless of the value of the current flowing through the diode and remains nearly constant even with large changes in current as long as the zener diodes current remains between the breakdown current $I_{Z(min)}$ and the maximum current rating $I_{Z(max)}$.

This ability to control itself can be used to great effect to regulate or stabilise a voltage source against supply or load variations. The fact that the voltage across the diode in the breakdown region is almost constant turns out to be an important application of the zener diode as a voltage regulator

Characteristics

Figure 2 shows the current versus voltage curve for a Zener diode. Observe the nearly constant voltage in the breakdown region.

The forward bias region of a Zener diode is identical to that of a regular diode. The typical forward voltage at room temperature with a current of around 1 mA is around 0.6 volts. In the reverse bias condition the Zener diode is an open circuit and only a small leakage current is flowing as shown on the exaggerated plot. As the breakdown voltage is approached the current will begin to avalanche. The initial transition from leakage to breakdown is soft but then the current rapidly increases as shown on the plot. The voltage across the Zener diode in the breakdown region is very nearly constant with only a small increase in voltage with increasing current. At some high current level the power dissipation of the diode becomes excessive and the part is destroyed. There is a minimum Zener current, $I_{z(min)}$, that places the operating point in the desired breakdown. There is a maximum Zener current, $I_{z(max)}$, at which the power dissipation drives the junction temperature to the maximum allowed. Beyond that current the diode can be damaged.

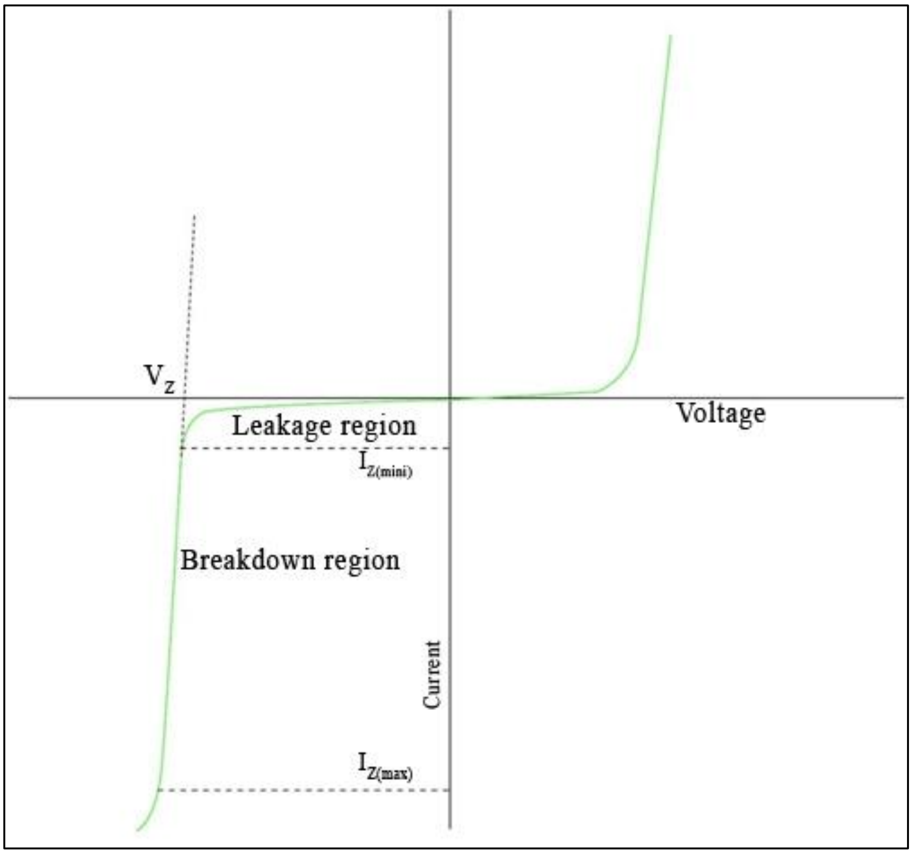


Fig 2: Zener diode characteristic curve

Zener diodes are available from about 2.4 to 200 volts typically using the same sequence of values as used for the 5% resistor series –2.4, 2.7, 3.0 3.3, 3.6, 3.9, 4.3, 4.7, 5.1, 5.6, 6.2, 6.8, 7.5, 8.2, 9.1, 10, 11, 12, 13, 15, 16, 18, 20, 22, 24, etc. All Zener diodes have a power rating, Pz. From Watt's law the maximum current is $I_{Z(MAX)}=P_Z / V_Z$. Zener diodes are typically available with power ratings of 0.25, 0.4, 0.5, 1, 2, 3, and 5 watts although other values are available.

Zener Diode as Voltage Regulators

The function of a regulator is to provide a constant output voltage to a load connected in parallel with it in spite of the ripples in the supply voltage or the variation in the load current and the zener diode will continue to regulate the voltage until the diodes current falls below the minimum $I_{Z(min)}$ value in the reverse breakdown region. It permits current to flow in the forward direction as normal, but will also allow it to flow in the reverse direction when the voltage is above a certain value - the breakdown voltage known as the Zener voltage. The Zener diode specially made to have a reverse voltage breakdown at a specific voltage. Its characteristics are otherwise very similar to common diodes. In breakdown the voltage across the Zener diode is close to constant over a wide range of currents thus making it useful as a shunt voltage regulator.

The purpose of a voltage regulator is to maintain a constant voltage across a load regardless of variations in the applied input voltage and variations in the load current. A typical Zener diode shunt regulator is shown in Figure 3. The resistor is selected so that when the input voltage is at $V_{IN(min)}$ and the load current is at $I_{L(max)}$ that the current through the Zener diode is at least $I_{z(min)}$. Then for all other combinations of input voltage and load current the Zener diode conducts the excess current thus maintaining a constant voltage across the load. The Zener conducts the least current when the load current is the highest and it conducts the most current when the load current is the lowest.

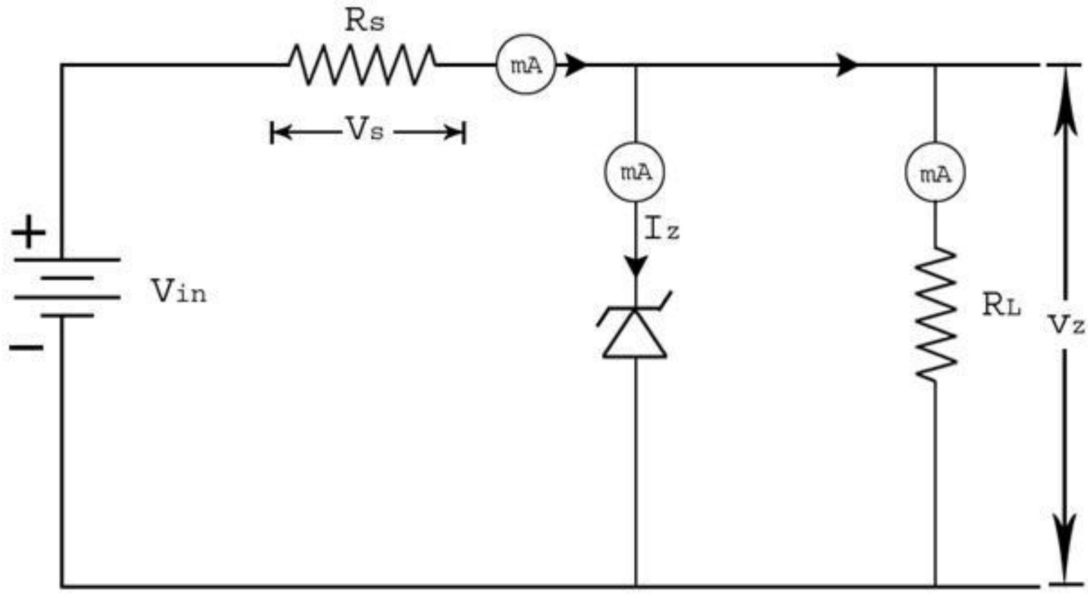


Fig 3: Zener diode shunt regulator

If there is no load resistance, shunt regulators can be used to dissipate total power through the series resistance and the Zener diode. Shunt regulators have an inherent current limiting advantage under load fault conditions because the series resistor limits excess current.

A zener diode of break down voltage V_z is reverse connected to an input voltage source V_i across a load resistance R_L and a series resistor R_S. The voltage across the zener will remain steady at its break down voltage V_Z for all the values of zener current I_Z as long as the current remains in the break down region. Hence a regulated DC output voltage $V_0 = V_Z$ is obtained across RL, whenever the input voltage remains within a minimum and maximum voltage.

Basically there are two type of regulations such as:

a) Line Regulation

In this type of regulation, series resistance and load resistance are fixed, only input voltage is changing. Output voltage remains the same as long as the input voltage is maintained above a minimum value.

Percentage of line regulation can be calculated by = $\frac{\Delta V_0}{\Delta V_{IN}} * 100$

where V_0 is the output voltage and V_{IN} is the input voltage and ΔV_0 is the change in output voltage for a particular change in input voltage ΔV_{IN}.

b) Load Regulation

In this type of regulation, input voltage is fixed and the load resistance is varying. Output volt remains same, as long as the load resistance is maintained above a minimum value.

Percentage of load regulation = $\left[\frac{V_{NL} - V_{FL}}{V_{NL}}\right] * 100$

where V_{NL} is the null load resistor voltage (ie. remove the load resistance and measure the voltage across the Zener Diode) and V_{FL} is the full load resistor voltage

Design a Voltage Regulator

When selecting the zener diode, be sure that its maximum power rating is not exceeded.

I_{max} Maximum current for Zener diode

$$I_{max} = \frac{Power}{Zener\ voltage}$$

V_Z Zener Diode standard voltage

V_{in} Input voltage(it is known)
V_s Voltage across series resistance
V_L Voltage across the load resistance
I_S Current passing through the series resistance
I_Z Current passing through the Zener diode
I_L Current passing through the load resistance

Calculating voltage and current

The total current drawn from the source is the same as that through the series resistor

$$I_S = \frac{V_S}{R_S}$$

The current through the load resistor is

$$I_L = \frac{V_L}{R_L}$$

and the zener diode current is

$$I_Z = I_S - I_L$$

If the voltage source is greater than Vz

$V_s = V_{in} - V_L$ and $V_L = V_Z$

If the voltage source is less than Vz

$V_s = \frac{R_S * V_{in}}{(R_S + R_L)}$ and $V_L = \frac{R_L * V_{in}}{(R_S + R_L)}$

Fuses and Surges

Please follow the link for details.

https://www.explainthatstuff.com/surgeprotectors.html

Relays

Please check lec 19 and 20 for relay details.

Conduits

The main advantage of conduit systems is their ability of grounding and bonding. Both of these qualities are crucial in minimizing electromagnetic interference. Safety is the key aspect of the conduits. Raw or cracked wires are covered with conduits to make the connections safer. It is important to determine which electrical wires and conduits should be used at home, office or garage.

Let us look at the different kinds of conduits you can choose from:

- **PVC Conduit:**

  They are often used in wet locations and underground applications. They have their own PVC fittings, couplings, connectors and elbows. They are quite easy to attach to one another with PVC glue and a cleaner. Do ensure that you always run a green ground wire in the conduit for correct grounding at connecting points, as PVC conduit is not conductive.

- **EMT Conduit:**
  They are lightweight and easy to bend. They are mainly used within the walls, but are prone to damage unlike rigid conduit or IMC.

- **Flexible Metal Conduit:**

This conduit is great for areas that require close quarters and tight bends, which would otherwise be difficult to achieve with a regular conduit as you can't easily bend it. Some examples of flexible conduit installations include attic vents, water heaters, etc.

- **IMC Conduit:**

  This is a thicker conduit which is galvanized. This makes it a great choice for outdoor installations. You can also use it in exposed walls in garages, basements and areas where the conduit can be hit or damaged.

- **Rigid Metal Conduit:**

  This is the thickest and heaviest of all the conduits, making it suitable for usage in extreme condition areas. It can also be used to run wires under driveways and service feeder installations. They are more expensive than the other conduits listed above. Most companies recommend the installation of these conduits in the piping of service entrance area as it can withstand the powerful winds, falling branches, and storm damage.

Grounding

Grounding is done for the safety of the power system or equipment by connecting the live parts of it to the earth. This will provide the return path for the current in case of abnormal conditions. These conditions may include transients and lighting etc.

Return path is the path that current traces to reach back to the source in order to make the complete looping. The whole process is made with the low impedance value path.

Types of grounding

There are two types of grounding:

- Multi point grounding
  - The multi-point system does not trace a singular path back to building.
  - Many existing buildings use multi-point grounding by bonding the same pieces of electrical equipment to ground bars, building steels, cold water pipes or other electrodes.
- Single point grounding
  - Single-point grounding means that only one physical point in the entire circuit system is defined as a ground reference point, and other points that need to be grounded are directly connected to this point. In low frequency circuits, there is not much influence between the wiring and the components.

Generally, circuits with a frequency less than 1MHz are grounded at one point.

Isolated Ground

The **Isolated Ground** (IG) is a type of equipment ground that, *in theory*, reduces interference experienced by electronics and instrumentation from radio frequency (RF) noise, by connecting that equipment directly to the grounding terminal of the service equipment, without ever making contact with another metal component or grounded surface, that could potentially be serving as an antenna for airborne RF noise.

Isolated Ground System

The **Isolated Ground** system (IG), relies on bringing an Equipment Grounding Conductor (EGC), all the way from the point of ground-*origin*, (such as a load center / electrical panel / etc.) to the point where it terminates onto the load that it is serving – without *ever* contacting another equipment ground, metal outlet box, metallic conduit system, etc. This method of specialized grounding has been a widely-accepted practice, for the minimizing of Radio-Frequency (RF) feedback(s) on computer and electronic branch-circuit equipment grounds, for decades.

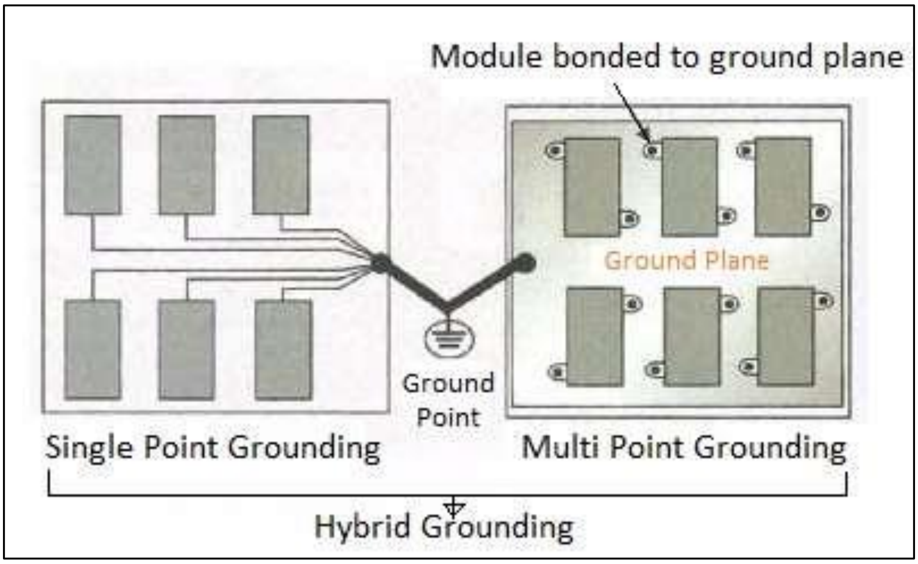
When the required Equipment Grounding Conductor (EGC) within a branch-circuit is connected to delicate instrumentation or sensitive electronics, reducing or eliminating the "antenna effect" of that conductor, and its ability to pick up various airborne radio frequency, is tops on everyone's "to-do" list when it comes to protecting that sensitive equipment from damage, as well as establishing a dependable baseline for dialing-in the equipment for consistent readings and results. RF interference is the enemy of "consistency" when you are dealing with low output/input equipment.

The Isolated Ground system, generally serves its intended *load or device* in the form of an Isolated Grounding *Receptacle*, connected to the aforementioned "Isolated" Equipment Grounding Conductor (EGC). This conductor is shielded from excessive RF noise by donning a mandatory insulation along its entire length. Again, this Isolated Grounding Conductor is required to stay remote (disconnected) from all other grounding splices within the grounding system, until it reaches its target: *the EGC terminal bar inside of the panel*. **The purpose:** To keep unwanted RF noise from entering our delicate electronics via the EGC.

By insulating the Isolated Grounding conductor for its entire length, and then prohibiting additional splicing on this conductor to boot, we are providing the equipment grounding conductor a path back to the electrical panel, without allowing it to ever touch another piece of *conductive metal* on its way there; a "**conductive metal"** that *may* be serving as an antenna for RF noise, through its deliberate contact with structural, plumbing, and electrical system metal throughout the building.

Utilizing an *Isolated Grounding system* is a well-known and widely accepted method for reducing this interfering (if not damaging) "noise" on electronics, when RF is abundantly present. *However,* there are some that speculate as to whether the practice of installing an Isolated Ground works- *at all!* And stand in firm opposition to those who would recommend it as a solution, citing that it can actually *INCREASE RF interference, instead of reducing it.*

Regardless of which camp you fall in, "for" or "against"….the Isolated Ground can also serve ***one other purpose***. It can function as the equipment grounding conductor (EGC) for a device or load, while providing protection for that load, from any "objectionable current" that may be occurring on the grounding system of that electrical system**.**



Best of Two Systems

Single-point grounding should be utilized as the backbone of the building grounding system. Provide a main ground bar to act as a common distribution point for ground risers and connections. Tie the *main electrical ground bar* (MEGB) to the ground bus of the main switchgear and then go to the building from there. Ground bars for power and telecommunications should be utilized in each closet, while providing a single path back to the source (transformers). Also, one should tie telecommunication and IT grounding systems to the power grounding system and final connection at the MEGB.

Multi-point grounding should be used almost as a grounding subsystem for data centers and computer rooms filled with high-frequency electronic equipment, where the benefits of multi-point grounding can be efficiently achieved.

It is crucial, however, that this multi-point subsystem be tied to the single-point building grounding system. It should not be thought of as a separate grounding system. This type of hybrid system will work in most applications.

What is grounding fault?

A ground fault is an unwanted connection **between the system conductors and ground**. Ground faults often go unnoticed and cause havoc on plant production processes. Shutting down power and damaging equipment, ground faults disrupt the flow of products, leading to hours or even days of lost productivity.

Ground fault protection system

A designed, coordinated, functional, and properly installed system that provides protection from electrical faults or short circuit conditions that result from any unintentional, electrically conducting connection between an ungrounded conductor of an electrical circuit and the normally non–current-carrying conductors, metallic enclosures, metallic raceways, metallic equipment, or earth.

Further, a system intended to provide protection of equipment from damaging line-to-ground fault currents by operating to cause a disconnecting means to open all ungrounded conductors of the faulted circuit. This protection is provided at current levels less than those required to protect conductors from damage through the operation of a supply circuit overcurrent device.

"An intentionally constructed, [permanent,] low-impedance electrically conductive path designed and intended to carry current under ground-fault conditions from the point of a ground fault on a wiring system to the electrical supply source and that facilitates the operation of the overcurrent protective device or ground fault detectors on high-impedance grounded systems."

There are two (2) types of ground-fault protection.

1. Personnel Protection

- GFCI = Ground Fault Circuit Interruption
- GFCI devices operation is much less than GFP for Equipment
    - ❖ Residences / Hotels – in kitchen / bathroom areas, or on outdoor outlets
    - ❖ On the jobsite – for power tools
    - ❖ For protection of high-value inventory
- Current requires for operation range between 5mA and 15mA
- For branch-circuit applications

2. Equipment Protection •

- Normal Capacitive Charging Current Exceeds 100mA.
- Primarily Employed at Services and on Feeder Circuits
- Employed in some Applications on Sub-Feeder or Branch Circuits
- Is Intended to Protect Equipment (Not Intended to Protect People)

Note: All the topics are discussed in detail in the last few lectures including previous year question paper. This is to explain you the topics in details. When it comes to the question paper, you can chose according to the marks. Few of them are not even mentioned in the syllabus but you can read it here.

Good Luck ....