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Fig.1 (i) Solution : If you remove the zener diode in Fig. 1, the voltage V across the open-circuit is given by : Since voltage across zener diode is greater than $V_Z (= 50\text{ V})$, the zener is in the "on" state. It can, therefore, be represented by a battery of 50 V as shown in Fig. 1 (ii). Fig. 1(ii) (i) Referring to Fig. 1 (ii), (ii) (iii) Q2. For the circuit shown in Fig. 2 (i), find the maximum and minimum values of zener diode current. Fig.2 Solution : The first step is to determine the state of the zener diode. It is easy to see that for the given range of voltages ($80 - 120\text{ V}$), the voltage across the zener is greater than $V_Z (= 50\text{ V})$. Hence the zener diode will be in the "on" state for this range of applied voltages. Consequently, it can be replaced by a battery of 50 V as shown in Fig. 2(ii). Maximum zener current: The zener will conduct maximum current when the input voltage is maximum i.e. 120 V . Under such conditions : Minimum Zener current: The zener will conduct minimum current when the input voltage is minimum i.e. 80 V . Under such conditions, we have, Q3. A 7.2 V zener is used in the circuit shown in Fig. 3 and the load current is to vary from 12 to 100 mA. Find the value of series resistance R to maintain a voltage of 7.2 V across the load. The input voltage is constant at 12V and the minimum zener current is 10 mA. Fig. 3 Solution : The voltage across R is to remain constant at $12 - 7.2 = 4.8\text{ V}$ as the load current changes from 12 to 100 mA. The minimum zener current will occur when the load current is maximum. If $R = 43.5\text{ }\Omega$ is inserted in the circuit, the output voltage will remain constant over the regulating range. As the load current I_L decreases, the zener current I_Z will increase to such a value that $I_Z + I_L = 110\text{ mA}$. Note that if load resistance is open-circuited, then $I_L = 0$ and zener current becomes 110 mA. Q4. The zener diode shown in Fig. 4 has $V_Z = 18\text{ V}$. The voltage across the load stays at 18 V as long as I_Z is maintained between 200 mA and 2 A. Find the value of series resistance R so that E_O remains 18 V while input voltage E_i is free to vary between 22 V to 28V. Fig. 4 Solution : The zener current will be minimum (i.e. 200 mA) when the input voltage is minimum (i.e. 22 V). The load current stays at constant value $I_L = V_Z / R_L = 18\text{ V} / 18\text{ }\Omega = 1\text{ A} = 1000\text{ mA}$. Q5. A 10-V zener diode is used to regulate the voltage across a variable load resistor [See fig.5]. The input voltage varies between 13 V and 16 V and the load current varies between 10 mA and 85 mA. The minimum zener current is 15 mA. Calculate the value of series resistance R. Fig. 5 Solution : The zener will conduct minimum current (i.e. 15 mA) when input voltage is minimum (i.e. 13 V). Q6. The circuit of Fig. 6 uses two zener diodes, each rated at 15 V, 200 mA. If the circuit is connected to a 45-volt unregulated supply, determine : (i) The regulated output voltage (ii) The value of series resistance R. Fig. 6 Solution : When the desired regulated output voltage is higher than the rated voltage of the zener, two or more zeners are connected in series as shown in Fig. 6. However, in such circuits, care must be taken to select those zeners that have the same current rating. Q7. What value of series resistance is required when three 10-watt, 10-volt, 1000 mA zener diodes are connected in series to obtain a 30-volt regulated output from a 45 volt d.c. power source ? Solution : Fig. 7 shows the desired circuit. The worst case is at no load because then zeners carry the maximum current. Fig. 7 Q8. Over what range of input voltage will the zener circuit shown in Fig. 8 maintain 30 V across 2000 Ω load, assuming that series resistance R = 200 Ω and zener current rating is 25 mA ? Fig. 8 Solution : The minimum input voltage required will be when $I_Z = 0$. Under this condition, Q9. In the circuit shown in Fig.9 the voltage across the load is to be maintained at 12 V as load current varies from 0 to 200 mA. Design the regulator. Also find the maximum wattage rating of zener diode. Fig. 9 Solution : By designing the regulator here means to find the values of V_Z and R. Since the load voltage is to be maintained at 12 V, we will use a zener diode of zener voltage 12 V i.e., The voltage across R is to remain constant at $16 - 12 = 4\text{ V}$ as the load current changes from 0 to 200 mA. The minimum zener current will occur when the load current is maximum. Maximum power rating of zener is Q10. Fig. 10 shows the basic zener diode circuits. What will be the circuit behaviour if the zener is (i) working properly (ii) shorted (iii) open-circuited? Fig. 10 Solution : Zener diodes cannot be tested individually with a multimeter. It is because multimeters usually do not have enough input voltage to put the zener into breakdown region. (i) If the zener diode is working properly, the voltage V_O across the load ($= 5\text{ k}\Omega$) will be nearly 6V [See Fig. 10 (i)]. (ii) If the zener diode is short [See Fig. 10 (ii)], you will measure V_O as 0V. The same problem could also be caused by a shorted load resistor ($= 5\text{ k}\Omega$) or an opened source resistor ($= 1\text{ k}\Omega$). The only way to tell which device has failed is to remove the resistors and check them with an ohmmeter. If the resistors are good, then zener diode is bad. (iii) If the zener diode is open-circuited, the voltage V_O across the load ($= 5\text{ k}\Omega$) will be 10V. Q11. Fig. 11 shows regulated power supply using a zener diode. What will be the circuit behaviour if (i) filter capacitor shorts (ii) filter capacitor opens? Fig. 11 Solution : The common faults in a zener voltage regulator are shorted filter capacitor or opened filter capacitor. (i) When filter capacitor shorts : When the filter capacitor shorts, the primary fuse will blow. The reason for this is illustrated in Fig 11. When the filter capacitor shorts, it shorts out the load resistance R_L . This has the same effect as wiring the two sides of the bridge together (See Fig. 11). If you trace from the high side of the bridge to the low side, you will see that the only resistance across the secondary of the transformer is the forward resistance of the two ON diodes. This effectively shorts out the transformer secondary. The result is that excessive current flows in the secondary and hence in the primary. Consequently, the primary fuse will blow. (ii) When filter capacitor opens: When the filter capacitor opens, it will cause the ripple in the power supply output to increase drastically. At the same time, the d.c. output voltage will show a significant drop. Since an open filter capacitor is the only fault that will cause both of these symptoms, no further testing is necessary. If both symptoms appear, replace the filter capacitor. 1. What is a zener diode? Zener diode is a p-n junction diode specially designed for operation in the breakdown region in reverse bias condition. 2. Define what is zener voltage? The voltage at which the zener diode breaks down is called the zener voltage. 3. What is meant by the temperature coefficient? The effect of temperature on zener voltage is given in terms of temperature coefficient which is defined as the percentage change in nominal zener voltage for each degree centigrade of change in junction temperature. 4. Define what happens to the series current , load current and zener current when the dc input voltage of a zener regulator increases? Zener current and series current increases while the load current remains unchanged. 5. Why is zener diode used as a voltage regulator? Zener diode has the property of behaving like a dc battery in 'on' state (i.e. when the voltage across the zener diode exceeds its zener voltage rating V_Z) . In 'on' state , the voltage across zener diode remains constant until the voltage across it drops less than V_Z . This property of zener diode makes its use as a voltage regulator. 6. Explain how zener diode maintains constant voltage across the load? Zener diode has the property of behaving like a dc battery in 'on' state. If the zener diode is shunted across the load R_L and the voltage across zener diode is more than the zener voltage V_Z then zener diode is on 'on' state , and any variation in voltage across the zener diode due to variations either in supply voltage or in load resistance is not able to change the output voltage. Thus zener diode maintains voltage constant across the load. 7. What is the basic principle of zener diode? Zener breaks down 8. What is zener break down? When a diode is heavily doped, it's depletion region will be narrow. When a high reverse voltage is applied across the junction, there will be very strong electric field at the junction. And the electron hole pair generation takes place. Thus heavy current flows. This is known as Zener break down. 9. Mention any application of zener diodes in voltage regulators 10. Zener diodes are also known as a) Voltage regulatory b) Forward bias diode c) Breakdown diode d) None of the mentioned A Zener diode is connected in a voltage regulator circuit as shown in Figure P2.21. The Zener voltage is $V_Z = 10\text{ V}$ and the Zener resistance is assumed to be $r_Z = 0$. (a) Determine the value of R_i such that the Zener diode remains in breakdown if the load current varies from $I_L = 50$ to 500 mA and if the input voltage varies from $V_i = 15$ to 20 V . Assume $I_Z(\text{min}) = 0.1\text{ I}_Z(\text{max})$, (b) Determine the power rating required for the Zener diode and the load resistor. Zener diodes - named after its inventor Dr. Carl Zener are fundamentally used in electronic circuits for generating precise voltage references. These are devices that are able to create a practically constant voltage across them regardless of variations in circuit and voltage situations.Externally, you may find zener diodes a lot similar to standard diodes such as 1N4148. Zener diodes also work by rectifying AC into pulsating DC quite like their traditional alternatives. However contrary to standard rectifier diodes, zener diodes are configured with their cathode directly connected with the positive of the supply, and anode with the negative supply.CharacteristicsIn its standard configuration, Zener diodes exhibit a high resistance below a particular, critical, voltage (known as the Zierer voltage). When this specific critical voltage is surpassed, the active resistance of Zener diode falls to an extremely low level.And at this low resistance value, an effective constant voltage is held across the Zeners, and this constant voltage can be expected to retain regardless of any change in the source current.In simple words, whenever the supply across the zener diode exceeds the rated zener value, the zener diode conducts and grounds the excess voltage. Due to this the voltage drops below the zener voltage which switches OFF the zener, and the supply yet again tries to exceed the zener voltage, switching ON the zener yet again. This cycle repeats rapidly which ultimately results in stabilizing the output to exactly at a constant zener voltage value.This characteristic is graphically highlighted in the below figure which indicates that above the 'Zener voltage' the reverse voltage continues to be almost constant even with variations in reverse current. As a result Zener diodes are often used for getting a constant voltage drop, or reference voltage, with their internal resistance. Zener diodes are designed in many wattage ratings and with voltage ratings which range from 2.7 Volts to 200 Volts. (However mostly , Zener diodes with values far above 30 Volts are hardly ever used.) Basic Zener Diode Circuit WorkingA standard voltage regulator circuit, using a single resistor and a Zener diode, can be witnessed in the following image. Here, let's assume the value of the Zener diode is 4.7 V and the supply voltage V in is 8.0 V.The basic working of a zener diode can be explained with the following points:In an absence of a load across the output of the zener diode, a 4.7 Volts can be seen dropped across the Zener diode while a cut off 2.4 Volts is developed across resistor R.Now, in case the input voltage is altered, let's imagine, from 8.0 to 9.0 V, will cause the voltage drop across the Zener to still maintain the rated 4.7 V.However the voltage drop across the resistor R could be seen raised, from 2.4 V, to 3.4 V.The voltage drop across an ideal Zener can be expected to be pretty constant. Practically , you may find the voltage across the zener increasing slightly because of the dynamic resistance of the Zener.The procedure through which the change in Zener voltage is calculated is by multiplying the zener dynamic resistance with the change in Zener current.The resistor R1, in the above basic regulator design, symbolizes the preferred load that may be connected with the zener. R1 in this connection will draw certain amount of current which was moving through the Zener.Since the current in Rs will be higher than the current entering the load, an amount of current will continue to go through the Zener enabling a perfectly constant voltage across the Zener and the load.The indicated series resistor Rs should be determined in such a way that the lowest current entering the Zener is always higher than the minimum level specified for a stable regulation from the zener. This level starts just under the 'knee' of the reverse voltage/reverse current curve as learned from the previous graphical diagram above. You must additionally make sure that the selection of Rs ensures that current passing through the Zener diode never goes beyond its power rating; which may be equivalent to the Zener voltage x Zener current. It is the highest amount of current that may pass through the Zener diode in the absence of the load R1.READ MORE Comparing IGBTs with MOSFETsHow to Calculate Zener Diodes Designing a basic zener circuit is actually simple and can be implemented through the following instructions:Determine the maximum and minimum load current (Ii), for example 10 mA and 0 mA.Determine the maximum supply voltage that may develop, for example a 12 V level, also ensuring that the minimum supply voltage is always = 1.5 V + Vz (the zener voltage rating).As indicated in the basic regulator design the required output voltage which is the equivalent Zener voltage Vz = 4.7 Volts, and the selected lowest Zener current is 100 microamps. This implies that the maximum intended Zener current here is 100 microamps plus 10 milliamps, which is 10.1 milliamps. The series resistor Rs must allow the minimum amount of current 10.1 mA even when the input supply is at the lowest specified level, which is 1.5 V higher than the selected zener value Vz, and may be calculated using Ohms law as: Rs = 1.5 / 10.1 x 10-3 = 148.5 Ohms. The closest standard value seems to be 150 Ohm, so Rs may be 150 ohms.If the supply voltage rises to 12 V, the voltage drop across Rs will be Iz x Rs, where Iz = current through the zener. Therefore, applying Ohm's law we get Iz = 12 - 4.7 / 150 = 48.66 mAThe above is the maximum current that will be allowed to pass through the zener diode. In other words, the maximum current that may flow during maximum output load or maximum specified supply voltage input. Under these conditions, the zener diode will dissipate a power of Iz x Vz = 48.66 x 4.7 = 228 mW. The closest standard power rating value to fulfill this is 400 mW.Effect of Temperature on Zener DiodesAlong with voltage and load parameters, Zener diodes are also quite resistant to temperature variations around them. However, above an extent the temperature may have some effect on the device as indicated in the graph below-It shows the zener diode temperature coefficient curve. Although at higher voltages the coefficient curve responds at around 0.1% per degree Celsius, it moves through zero at 5 V and then turns negative for the lower voltage levels. Eventually it reaches -0.04% per degree Celsius at around 3.5 V.Using Zener Diode as Temperature Sensor One good use of the Zener diode's sensitivity to temperature change is to apply the device as a temperature sensor device as shown in the following diagram The diagram shows a bridge network built using a pair of resistors and a pair of Zener diodes having identical characteristics. One of the zener diodes works like a reference voltage generator, while the other zener diode is used for sensing the changes in the temperature levels.A standard 10 V Zener may have a temperature coefficient of +0.07% /°C which may correspond to 7 mV /°C variation in temperature. This will create an imbalance of around 7 mV between the two arms of the bridge for every single degree Celsius variation in the temperature. A 50 mV full FSD meter can be used in the indicated position for showing the corresponding temperature readings.Customizing Zener Diode ValueFor some circuit application it may be necessary to have a precise zener value which may be a non-standard value, or a value not readily available.For such cases an array of zener diodes can be created which may then be used for getting a desired customized zener diode value, as shown below:In this example, many customized, non standard zener values could be acquired across the various terminals, as described in the following list:You can use other values in the indicated positions to get many other customized sets of zener diode outputZener Diodes with AC SupplyZeners diodes are normally used with DC supplies, however these devices can be also designed to work with AC supplies. A few AC applications of zener diodes include audio, RF circuits, and other forms of AC control systems.As shown in the below example when an AC supply is used with a zener diode, the zener will instantly conduct as soon as the AC signal passes from zero towards the negative half of its cycle. Because, the signal is negative therefore the AC will be shorted via the anode to cathode of the zener, causing 0 V to appear the output.READ MORE LM567 Tone Decoder IC Features, Datasheet and ApplicationsWhen the AC supply moves across the positive half of the cycle, the zener doesn't conduct until the AC climbs up to the zener voltage level. When the AC signal crosses the zener voltage, the zener conducts and stabilizes the output to a 4.7 V level, until the AC cycle drops back to zero.Remember, while using zener with an AC input, makes sure that Rs is calculated as per the AC peak voltage.In the above example, the output is not symmetrical, rather a pulsating 4.7 V DC. In order to get a symmetrical 4.7 V AC at the output, two back to back zeners could be connected as depicted in the below diagramSuppressing Zener Diode NoiseAlthough zener diodes provide a quick and easy way to create stabilized fixed voltage outputs, it has one drawback which may affect sensitive audio circuits such as power amplifiers.Zener diodes generate noise while operating due to their junction avalanche effect while switching, ranging from 10 uV to 1 mV. This can be suppressed by adding a capacitor in parallel with the zener diode, as shown below:The value of the capacitor can be between 0.01uF and 0.1uF, which will allow noise suppression by a factor of 10, and will maintain the best possible voltage stabilization.The following graph shows the effect of the capacitor for reducing zener diode noise.Using Zener for Ripple Voltage FilteringZener diodes can be also applied as effective ripple voltage filters, just as it's used for AC voltage stabilization.Due to its extremely low dynamic impedance, zener diodes are able to work like ripple filter quite the same way as filter capacitor do. Very impressive ripple filtering can be obtained by connecting a Zener diode across the load, with any DC source. Here, the voltage must be same as the ripple trough level.In most circuit applications this may work as effectively as a typical smoothing capacitor having several thousand microfarads capacity, resulting in a significant reduction in the level of ripple voltage superimposed on the DC output. How to Increase Zener Diode Power Handling CapacityAn easy way to increase zener diode power handling capacity is probably to just connect them in parallel as shown below:However, practically this may not be as simple as it looks and may not work as intended. This is because just like any other semiconductor device, zeners also never come with exactly identical characteristics, therefore one of the zeners may conduct before the other drawing the entire current through itself, eventually getting destroyed.A quick way to counter this problem may be to add low values series resistors with each zener diodes as shown below, which will allow each zener diode to share the current uniformly through compensating voltage drops generated by the resistors R1 and R2. Although, the power handling capacity can be increased by connecting Zener diodes in parallel, a much improved approach may be to add a shunt BJT in conjunction with a zener diode configured as a reference source. Please see the following example schematic for the same.Adding a shunt transistor not only enhances the zener power handling capacity by a factor of 10, it further improves the voltage regulation level of the output, which may be as high as the specified current gain of the transistor.This type of shunt transistor zener regulator can be used for experimental purposes because the circuit features a 100% short circuit proof facility. That said, the design is rather inefficient because the transistor may dissipate a significant amount of current in the absence of a load.For even better results, a series pass transistor type of regulator as shown below looks a better option and preferable.In this circuit the Zener diode creates a reference voltage for the series pass transistor, which, essentially, works like an emitter follower. As a result the emitter voltage is maintained between a few tenths of a volt of the transistor base voltage as created by the Zener diode. Consequently the transistor works like a series component and enables effective control of the supply voltage variations.The entire load current now runs via this series transistor. The power handling capacity of this type of configuration is established totally by the value and the specification of the transistors, and also depends on the efficiency and quality of the heatsink used.READ MORE High Current MOSFET IRFP2907 DatasheetExcellent regulation could be achieved from the above design using a 1k series resistor. The regulation could be increased with a factor of 10 by replacing the normal zener with a special low dynamic zener diode such as a 1N1589).In case you want the above circuit to provide a variable voltage regulated output, it could be easily achieved by using a 1K potentiometer across the Zener diode. This allows a variable reference voltage to be adjusted at the base of the series transistor.However, this modification may result in a lower regulation efficiency due to some shunting effect created by the potentiometer.Constant Current Zener Diode Circuit A simple Zener-regulated constant current supply can be designed through a single transistor as a variable series resistor. The figure below demonstrates the basic circuit diagram.You can see a couples of circuit passages here, one via the zener diode connected in series with the biasing resistor, while the other path is through the resistors R1, R2, and the series transistor.In case the current deviates from its original range, it creates a proportionate change in the biasing level of R3, which in turn causes the series transistor resistance to increase or decrease proportionately.This adjustment in the resistance of the transistor results in an automatic correction of the output current to the desired level. The accuracy of the current control in this design will be around +/- 10% in response to an output conditions that may range between a short circuit and a loading of up to 400 Ohm.Sequential Relay Switching Circuit using Zener DiodeIf you have an application where a set of relays are required to be switched sequentially one after the other on power switch instead of all activating together, then the following design can prove quite handy.Here, sequentially incrementing zener diodes are installed in series with a group of relays along with individual low value series resistors. When power is switched ON, the zener diodes conduct one after the other in sequence in an increasing order of their zener values. This results in the relay switching ON in sequence as desired by the application. The values of the resistors can be 10 ohms or 20 ohms depending on the resistance value of the relay coil.Zener Diode Circuit for Over Voltage ProtectionDue to their voltage sensitive characteristic, it is possible to combine Zener diodes with the current sensitive characteristic of fuses for safeguarding crucial circuit components from high voltage surges, and additionally eliminating the hassle of fuse from blowing frequently, which may happen especially when a fuse rating is very near to the operating current spec of the circuit.By joining a correctly rated Zener diode across the load, a fuse which is suitably rated to handle the intended load current for extended periods can be employed. In this situation, suppose the input voltage increases to an extent that exceeds the Zener breakdown voltage - will force the Zener diode to conduct. This will cause a sudden increase in the current blowing the fuse almost instantaneously.The advantage of this circuit is that it prevents the fuse from blowing frequently and unpredictably due to its close fusing value to the load current. Instead, the fuse blows only when the voltage and current genuinely rises beyond a specified unsafe level.UnderVoltage Protection Circuit using Zener DiodeA relay and an appropriately selected zener diode are enough to create an accurate low voltage or under voltage cut off protection circuit for any desired application. The circuit diagram is presented below:The operation is actually very simple, the supply Vin which is acquired from a transformer bridge network varies proportionately depending on the input AC variations. That implies, if suppose the 220 V corresponds to 12 V from the transformer, then 180 V should correspond to 9.81 V and so on. Therefore, if 180 V is assumed to be the low voltage cut off threshold, then selecting the zener diode as a 10 V device will cut off the relay operation whenever the input AC drops below 180 V.

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