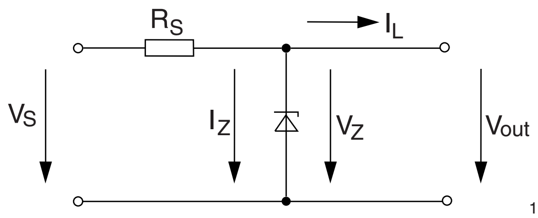
# Temperature-Compensated Stabilizing Circuits

Two Zener diode parameters in particular affect the stabilizer performance – the voltage temperature coefficient $\alpha_{vz}$ and the differential resistance $r_{zj}$. These parameters are determined by the physical properties of the conventional Zener diodes and their effect on stabilization performance will be better appreciated if the simple stabilizer circuit shown in the figure below, consisting of a resistor in series with a Zener diode, is considered.

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In this circuit the output voltage $V_{out}$ (which in this case is the same as the Zener voltage $V_Z$) is related to the supply voltage $V_S$, the load current $I_L$ and the ambient temperature $T_{amb}$ by the expression

$$\Delta V_{out} = \frac{r_z}{R_S} \cdot \Delta V_S + r_z \cdot \Delta I_L + \alpha_{vz} \cdot V_Z \cdot \Delta T_{amb} \quad (1)$$

As far as the differential resistance $r_z$ is concerned a distinction should be made between the inherent differential resistance $r_{zj}$ and the static differential resistance $r_{zu}$. The following equation applies:

$$r_{zu} = r_{zj} + \alpha_{vz} \cdot V_z^2 \cdot R_{th} = r_{zj} + r_{zth} \quad (2)$$

where $R_{th}$ is the thermal resistance and $r_{zth}$ the thermal differential resistance of the diode.

The second term in this expression takes into account the change in dissipation $V_Z \cdot \Delta I_L$ due to the current variation $\Delta I_L$, which, for a thermal resistance $R_{th}$, produces a crystal temperature change of

$$\Delta T_j = V_Z \cdot R_{th} \cdot \Delta I_L \quad (3)$$

and consequently an output change of

$$\Delta V_Z = \alpha_{vz} \cdot V_Z \cdot \Delta T_j = \alpha_{vz} \cdot V_Z^2 \cdot R_{th} \cdot \Delta I_L \quad (4)$$

Let us, by way of an example, calculate the performance of a stabilizer circuit which incorporates a Zener diode type ZPD22 from Vishay General Semiconductor and operates from a high supply voltage and with low load current. For this type the following data are published for $I_Z = 5$ mA:

$$V_Z = 22\,V$$

$$r_{zu} = r_{zj} + r_{zth} = 25\Omega + 100\Omega = 125\Omega$$

$$\alpha_{vz} = 9 \cdot 10^{-4} / K$$

For a supply voltage of $V_S = 220$ V, a load current of $I_L = 5$ mA and a diode Zener current of $I_Z = 5$ mA the value of the series resistor works out to

$$R_S = \frac{220\,V - 22\,V}{5\,mA + 5\,mA} = 19.8 \approx 20\,k\Omega$$

Let us also assume that the supply voltage varies by ± 10 %, i. e. $\Delta V_S \approx 40$ V, the load current by $\Delta I_L = 2$ mA and the ambient temperature by $\Delta T_{amb} = 20$ K, then, according to equation (1), the output varies by

$$\Delta V_{out} = \frac{125\Omega \cdot 40\,W}{20\,k\Omega} + 125\Omega \cdot 2\,mA + 9 \cdot 10^{-4} / K \cdot 22\,V \cdot 20\,K$$
$$= 250\,mW + 250\,mV + 396\,mW$$

This example shows that ambient temperature variations exercise a larger effect on the output than supply voltage or load current variations.

Let us consider once more the example of the simple stabilizer circuit operating under low load current and high supply voltage conditions, discussed at the beginning of this section, but this time under the assumption that a temperature-compensated diode ZTK22 is used in place of the conventional ZPD22 device. Using equation (1) and inserting the same values for supply voltage, load current and ambient temperature variations into the expression, one obtains

$$\Delta V_{out} = + \frac{-8.4\Omega - 40\,W}{20\,k\Omega} + 8.4\Omega \cdot 2\,mA + (-10 \cdot 10^{-5} / K \cdot 22\,V \cdot 20\,K)$$
$$= -16.8\text{mW} - 16.8\text{mV} - 44\text{mV}$$

The output voltage variation due to the specified change in temperature is only one tenth of that obtained in the previous mentioned example using the conventional Zener diode ZPD22. Moreover it should be noted that the temperature coefficient used in the calculation ($- 10 \cdot 10^{-5}$/K) is the one guaranteed in the data, whereas the typical temperature coefficient of a ZTK device is normally $- 2 \cdot 10^{-5}$/K.

Use of this value would reduce the temperature effect, as expressed in the third term of the equation, even further, namely to – 8.8 mV.

The conclusion is that in all applications where a simple stabilizer circuit is considered the use of ZTK temperature-compensated stabilizing circuits can bring a considerable improvement.