Voltage References:

The circuit that is primarily designed for providing a constant voltage independent of changes in temperature is called a voltage reference. The most important characteristic of a voltage reference is the temperature coefficient of the output= reference voltage Tc_R , and it is expressed as

$$T_{CR} = \frac{dV_R}{dT}$$

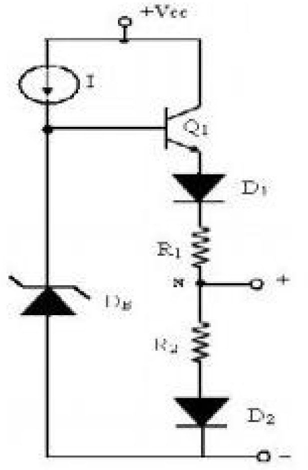
The desirable properties of a voltage reference are:

1. Reference voltage must be independent of any temperature change.
2. Reference voltage must have good power supply rejection which is as independent of the supply voltage as possible and
3. Output voltage must be as independent of the loading of output current as possible, or in other words, the circuit should have low output impedance.

The voltage reference circuit is used to bias the voltage source circuit, and the combination can be called as the voltage regulator. The basic design strategy is producing a zero TCR at a given temperature, and thereby achieving good thermal ability. Temperature stability of the order of $100ppm/^0$ C is typically expected.

Voltage Reference circuit using temperature compensation scheme:

The voltage reference circuit using basic temperature compensation scheme is shown below. This design utilizes the close thermal coupling achievable among the monolithic components and this technique compensates the known thermal drifts by introducing an opposing and compensating drift source of equal magnitude.



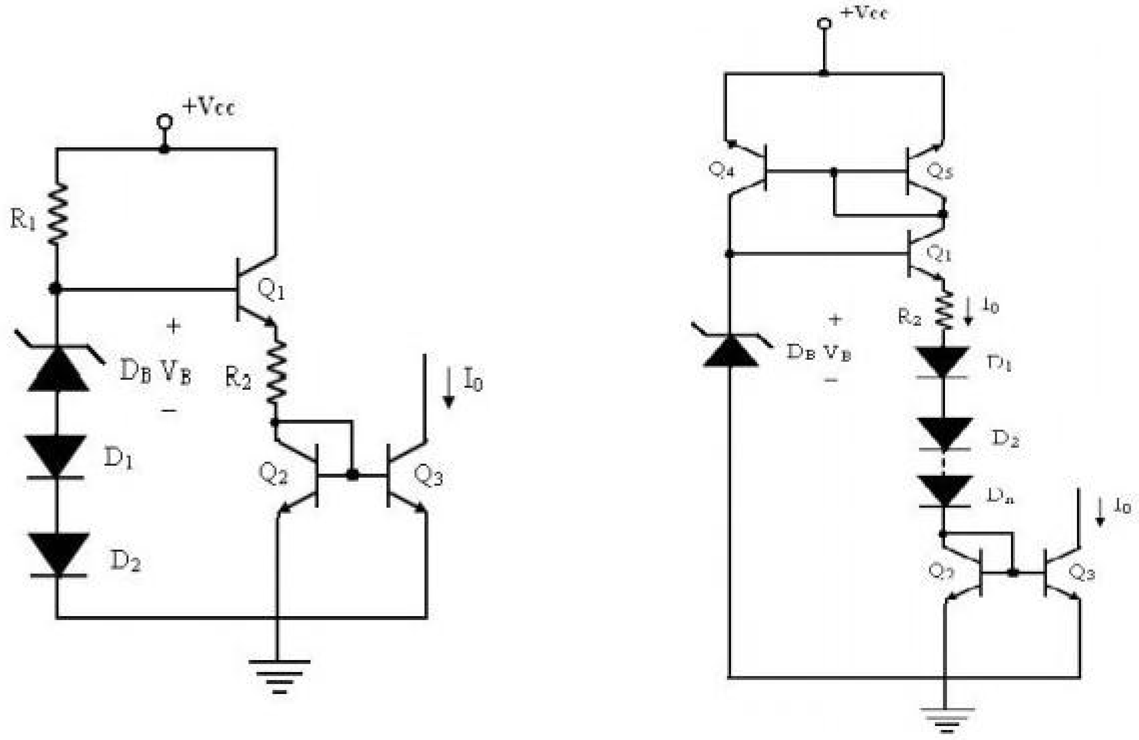
Voltage reference circuit using temperature compensation scheme

A constant current I is supplied to the avalanche diode D_B and it provides a bias voltage of V_B to the base of Q_1. The temperature dependence of the V_{BE} drop across Q_1 and those across D_1 and D_2 results in respective temperature coefficients. Hence, with the use of resistors R_1 and R_2 with tapping across them at point N compensates for the temperature drifts in the base-emitter loop of Q_1. This results in generating a voltage reference V_R with normally zero temperature coefficient.

Voltage Reference circuit using Avalanche Diode Reference:

A voltage reference can be implemented using the breakdown phenomenon condition of a heavily doped PN junction. The Zener breakdown is the main mechanism for junctions, which breakdown at a voltage of 5V or less. For integrated transistors, the base-emitter breakdown voltage falls in the range of 6 to 8V. Therefore, the breakdown in the junctions of the integrated transistor is primarily due to avalanche multiplication. The avalanche breakdown voltage VB of a transistor incurs a positive temperature coefficient, typically in the range of 2mV/0 C to 5mV/0 C.

Figure depicts a current reference circuit using avalanche diode reference. The base bias for transistor Q_1 is provided through register R_1 and it also provides the dc current needed to bias DB, D_1 and D_2 . The voltage at the base of Q_1 is equal to the Zener voltage V_B added with two diode drops due to D_1 and D_2. The voltage across R_2 is equal to the voltage at the base of Q_1 less the sum of the base – emitter voltages of Q_1 and Q_2.



Voltage reference using avalanche diodes and temperature compensated

Hence, the voltage across R_2 is approximately equal to that across $D_B = V_B$. Since $Q_2$and Q_3 act as a current mirror circuit, current I_0 equals the current through R_2.

$$I_0 = VB/R2$$

It shows that, the output current I_0 has low temperature coefficient, if the temperature coefficient of R_2 islow, such as that produced by a diffused resistor in IC fabrication.

The zero temperature coefficients for output current can be achieved, if diodes are added in series with R_2, so that they can compensate for the temperature variation of R_2 and V_B. The temperature compensated avalanche diode reference source circuit is shown in figure. The transistor Q_4 and Q_5 form an active load current mirror circuit. The base voltage of Q_1 is the voltage V_B across Zener D_B.

Then, $V_B = (V_{BE} * n) + V_{BE}$ across Q_1 + V_{BE} across Q_2 + drop across R_2. Here, n is the number of diodes.

It can be expressed as $V_B = (n+ 2)\ V_{BE} - I_0 * R_2$

Differentiating for V_B, I_0, R_2 and V_{BE} +partially,2 with respect to temperature T, we get

$$\frac{\partial V_B}{\partial T} = n + 2\frac{\partial V_{BE}}{\partial T} + R_2\frac{\partial I_0}{\partial T} + I_0\frac{\partial R_2}{\partial T}$$

Dividing throughout by $I_0 R_2$, we get

$$\frac{I}{I_O}\frac{\partial I_O}{\partial T} = 0 = \frac{1}{R_2 I_0}[\frac{\partial V_B}{\partial T} - (n+2)\frac{\partial V_{BE}}{\partial T} - \frac{1}{R_2}\frac{\partial R_2}{\partial T}$$

Therefore, zero temperature coefficient of I_0 can be obtained, if the above condition is satisfied.