DIODE TEMPERATURE SENSING

Diodes make excellent temperature sensors. At low values of forward current (usually refereed to as measurement current [I_M] or sense current [I_S]), the junction temperature [T_J]– junction forward voltage [V_F] correlation is very nearly linear to the second order. Thus a change in junction temperature produces a corresponding change in junction forward voltage with a constant correlation factor of the form –

$$\Delta T_J = K \times \Delta V_F$$

where the correlation factor is referred to as the K Factor. The units of K are in °C/mV and the value is typically in the range of 0.4 to 0.8 °C/mV.

No one value of I_M is suitable for all diodes. The selection of I_M is based on the diode size and type. Industry practice is to use a value of I_M that corresponds to the break in the diode's forward voltage curve as shown in Figure I. Choosing a too low a I_M value will cause problems in measurement repeatability for a specific diode and potentially large variations between devices of the same part number. Too large a values of IM will cause significant self-heating within the diode junction area and give rise to potentially large temperature measurement errors. When ever possible, IM is selected to some nominal value, such as 0.1, 1.0, 5.0 or 10.0 mA, the exact value depending on the current-handling capabilities of the diode to be calibrated.

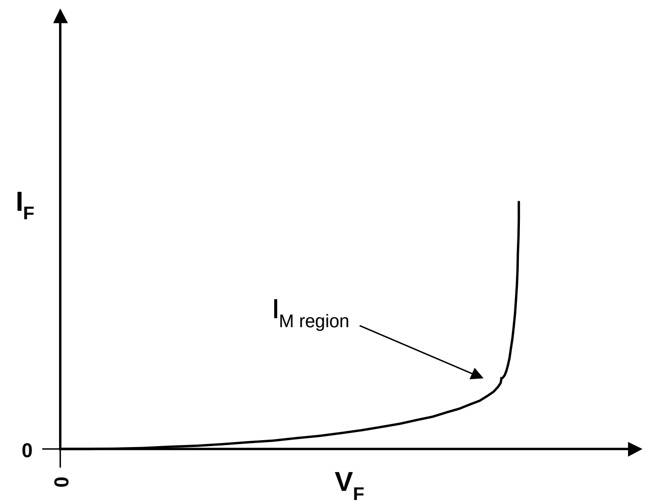

Figure 1

Typical practice is to calibrate five or more devices at a single time. Batch calibration serves two purposes. First, it reduces the time necessary to calibrate all the devices individually. The initial temperature and the final temperature stabilization periods, which can take 30 minutes or more depending on the temperature environment used for the calibration, only has to be done once instead of for each diode. Second, making measurements in batch form helps to reduce potential errors if the data is averaged.

The equipment setup for performing K Factor calibration measurements is shown in Figure 2. The temperature-controlled environment can be a small oven that maintains uniform temperature in an area large enough to contain the test fixture. The test fixture only has to provide electrical connection to the individual diodes to be calibrated. The temperature calibration system provides the measurement current and measures the environment temperature and the diode forward voltage. The diode forward voltage is read and recorded for each device once the environment temperature has stabilized at a fixed value. Temperature stability has occurred when neither the diode voltage(s) nor environmental temperature measurements shows any significant fluctuations.

DIODE TEMPERATURE SENSING (cont'd)

Once the diodes are mounted in the test fixture, the fixture inserted into the temperature–controlled environment, and the fixture is connected to the measurement system, the next step is to wait for initial temperature stabilization at the low temperature [T_{low}]. This temperature is usually near room temperature, something in the 25 °C range. After readings are obtained at this temperature, the temperature is increased to a higher value [T_{high}], typically in the 100 °C range, stabilization allowed to occur, and new set of voltage readings taken.

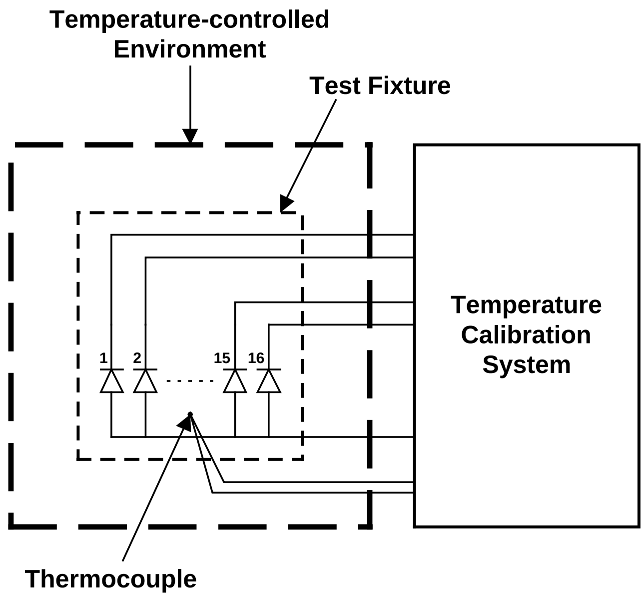

Figure 2

Figure 3 shows graphically the results of the two different temperature conditions. K Factor [K] is defined as the reciprocal of the slope of the V_F – T_J line, and is usually in the range of 0.4 to 0.6 °C/mV for a single diode junction. The equation is –

$$K = \left| \frac{T_{high} - T_{low}}{V_{low} - V_{high}} \right|$$

To save thermal testing time, the results of calibration batch are usually averaged (K_{avg}) and the standard deviation (σ_K) determined. If the ratio of σ_K/ K_{avg+} is less than 1.03, then thermal testing on the batch units can proceed using the K_{avg} for all units without causing a significant error in the thermal test results. A ratio of greater than 1.03 requires using the individual values of K for thermal testing. The higher ratio also indicates potential process control problems in the fabrication of the diodes.

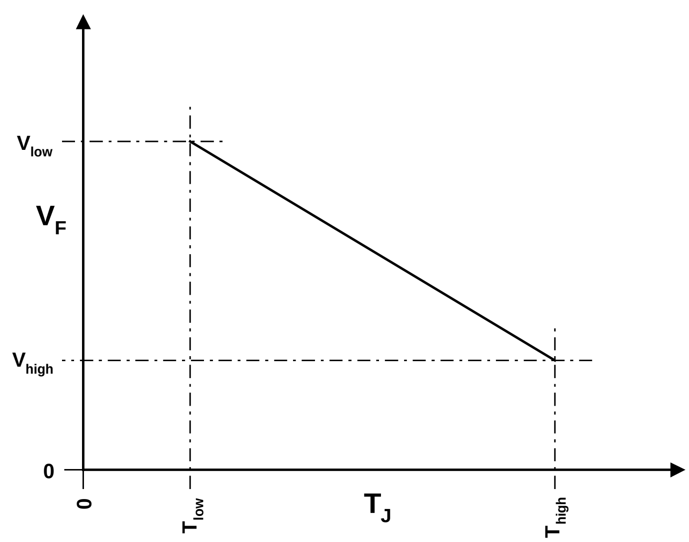

Figure 3

The K Factor is highly dependent on the value chosen for I_M. It is imperative that the same value of I_M be used during the thermal testing.

The discussion above is generic in that it applies to any diode – PN Junction, Schottky Junction, Substrate Isolation diode in an integrated circuit, Source-Body diode in a MOSFET, etc. Also, the V_F-T_J relationship is usually assumed to be linear (hence, the two point measurement of K) but may actually be slightly non-linear (second or third order effect) but usually not enough to significantly affect thermal data.

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