Calibrating a Silicon Diode for Temperature Measurement

The main disadvantage of using common silicon diodes for temperature measurement is that they need to be individually calibrated as each one has slightly different properties. If the operating parameters are chosen such that the response is nearly linear calibration is required at only a few points.

To use the diode as a temperature sensor, you will need a stable constant current source (see the handout on "Building a Constant Current Source" or on Learning Suite ⇒ Content ⇒ Thermal Measurements Lab ⇒ Building a Constant Current Source). According to the handout on "Measuring Temperature with a Silicon Diode" or on Learning Suite ⇒ Content ⇒ Thermal Measurements Lab ⇒ Using a Diode as a Thermometer, you will want a source that provides about 100 μA (typically in the range of 90 to 110 μA is adequate). This current is chosen to minimize heating of the diode (it will deposit about 100 μW in the diode), to give an adequate range where the response is linear, and to give a reasonable output voltage. With this current, the voltage across the diode in boiling liquid nitrogen will be slightly above 1 V.

You can now perform the calibration through the following steps:

1. Connect the constant current source so that the entire output current flows through the diode. **NOTE**: Because the characteristics of electronic components vary with temperature you should allow the current to flow through the diode for several minutes to stabilize the temperature of both the diode and the power supply. Then measure the current to determine the output of your supply. Hint: *this is probably a value you will want to record in your notebook!*
2. Connect a voltmeter so that it measures the voltage across the diode. It is best to connect to the "Voltage Monitor" output on your constant current supply to avoid lots of clips on the diode leads.

   It should be around 0.5 V at room temperature. If the voltage is considerably higher than this, you probably have the diode reversed. Remember that the lead to ground on your supply, usually the black clip on the coax cable, should be connected to the cathode of the diode – the direction the current will flow *out* of the diode.
3. Replace the voltmeter with one of the computer analog inputs so the computer records the voltage across the diode. Because the tan power supplies connect the common output terminal to the chassis, you should have the input on the USB-6221-BNC set to the "GS" position.
4. Determine the temperature dependence of the voltage across the diode using LabVIEW when the diode is in boiling liquid nitrogen, ice water, and boiling

water. Simultaneously measure the temperature of the liquid in each case with the digital thermometer.

NOTE: When you place the diode in water you need to protect it from the water - the resistance of the water is low enough that you may lose several μA through the water which will result in an incorrect calibration.

Refer to the sections of the "Uncertainty, Errors, and Noise" handout ("Content ⇒ LabVIEW Basics Course ⇒ Measurements, Uncertainties, and Noise" on Learning Suite) on uncertainties and averaging before you set up your LabVIEW VI to make your measurements.

5. Note that any reference to temperature in the equations in the handout on "Measuring Temperature with a Silicon Diode" or on Learning Suite ⇒ Content ⇒ Thermal Measurements Lab ⇒ Using a Diode as a Thermometer, for the voltage across the diode are accompanied by a reference to k_B, Boltzmann's constant. This should be taken as a **very strong hint** that the temperature should be given in Kelvins.
6. From this data determine the calibration constants m and b by fitting a straight line to your data. You can use any software that provides fitting capabilities – but it is *strongly recommended that you do not use Excel* because it won't give you any possibility of recovering the uncertainties in the fitting parameters.

1.0 Diode calibration: analysis questions and requests

1. How much does the constant b differ from E_g/q? E_g is the band-gap energy of the silicon used in the diode. It is approximately 1.19 eV. q is the charge on the electron.

   The constant b is from the model equation $V = mT + b$ with T in Kelvins. (Refer to Section 1 of the handout `Measuring Temperature with a Silicon Diode` found on Learning Suite in `Content` ⇒ `Thermal Measurements Lab` ⇒ `Using a Diode as a Thermometer` for the derivation of this equation.) If your equation is in a different form or uses different units, you will have to rearrange your equation into this form to determine b from your fitting constants.
2. How far off is the calibrated diode temperature measurement at each of the three points? Give your response in degrees. This is found by looking at the temperature predicted by your calibration equation from the measured voltages and comparing them to the corresponding measured temperatures.
3. Is this error consistent with the estimated uncertainty of your calibration constants? (consult the temperature uncertainty section of the 'Measuring Temperature with a Silicon Diode" document ("Content ⇒ Thermal Measurements Lab ⇒ Using a Diode As a Thermometer" in Learning Suite). You may

also want to look at the *Mathematica* notebook SuperconductorParametersAndUncertainty.nb in `Content` ⇒ `Superconductivity Measurements Lab` on Learning Suite or at `https://www.physics.byu.edu/faculty/petersonb/Phys240/SuperconductorParametersAndUncertainty.nb` for help in finding the uncertainty in your temperature measurements (look at the second section "Calculate the uncertainty in a temperature determined from a diode"; you will need to enter the appropriate values of the parameters and data if you use this notebook).

4. How would you improve your calibration?
5. Include a plot of your calibration data and fit – *including the calibration constants* – in your notebook and in your report.

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