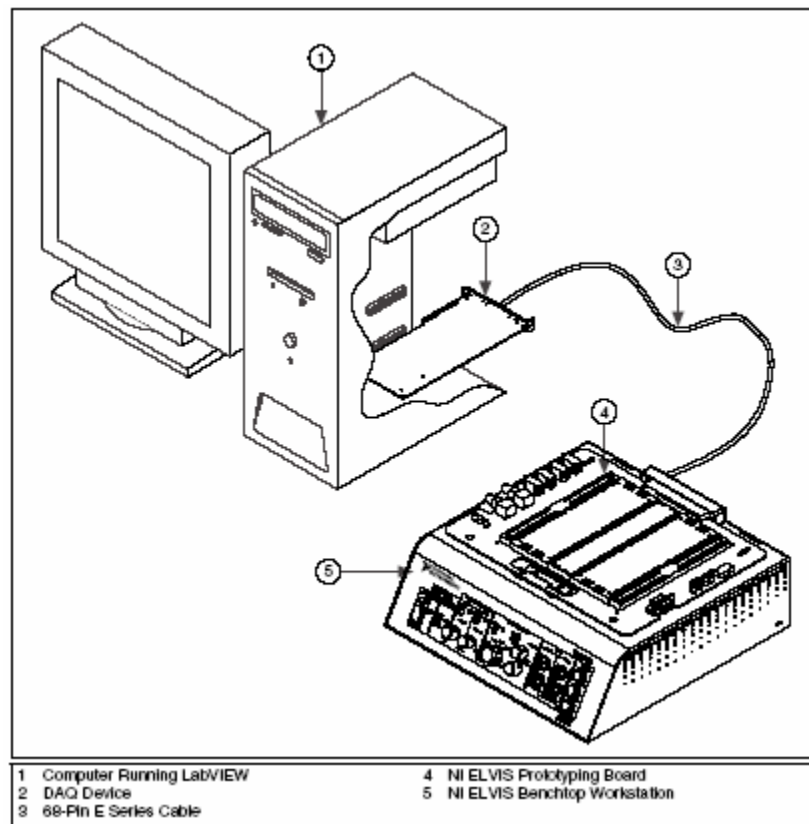# MASSACHUSETTS INSTITUTE OF TECHNOLOGY
## 6.071 Introduction to Electronics, Signals and Measurement
Spring 2006


## Becoming Familiar with the hardware and software.

The laboratory equipment for our class are comprised of a set of hardware and software technologies which are tightly integrated, yet very flexible in their use, and will give us the opportunity to investigate in a practical way all concepts introduced in the class.

The hardware part of our instrument is shown below.



| 1 | Computer Running LabVIEW | 4 | NI ELVIS Prototyping Board |
| 2 | DAQ Device | 5 | NI ELVIS Benchtop Workstation |
| 3 | 68-Pin E Series Cable | | |

Courtesy of National Instruments. Used with permission.

The software is based on the National Instruments LabVIEW program. In a simple phrase the LabVIEW software gives us the opportunity to 1) control the hardware, 2) generate and manipulate the various electrical signals of the system and 3) create effective presentation of the analyzed data.
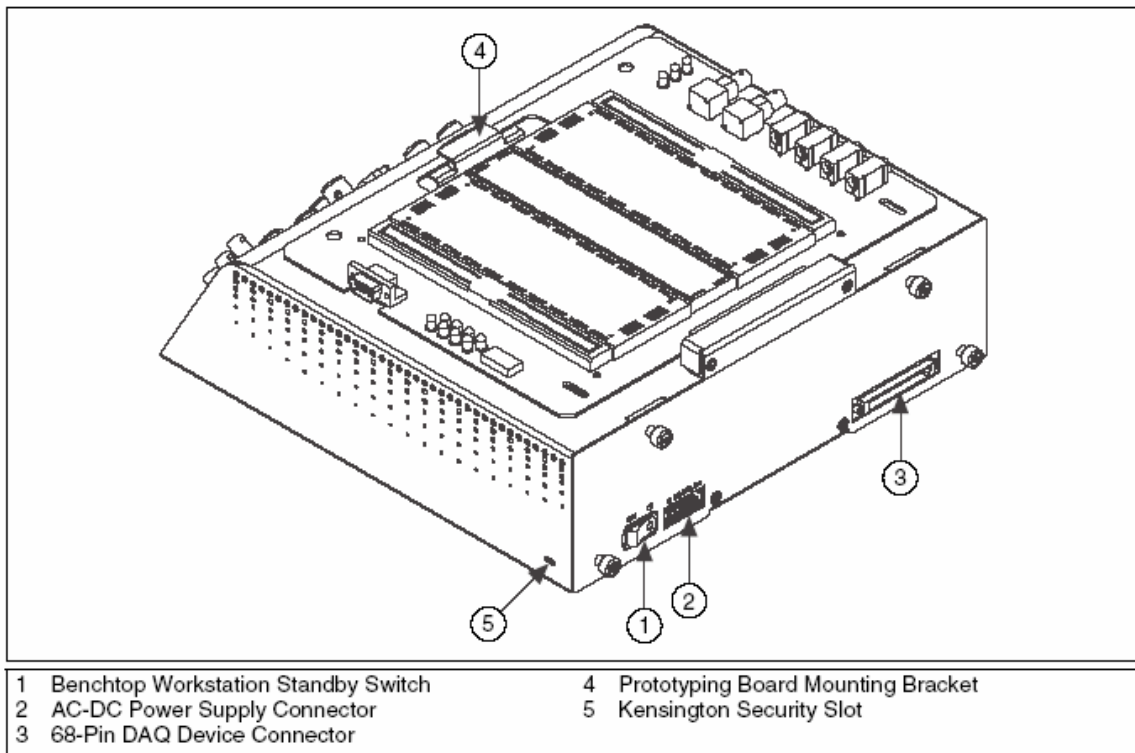
The document with the manual of our system is located at the MIT server.
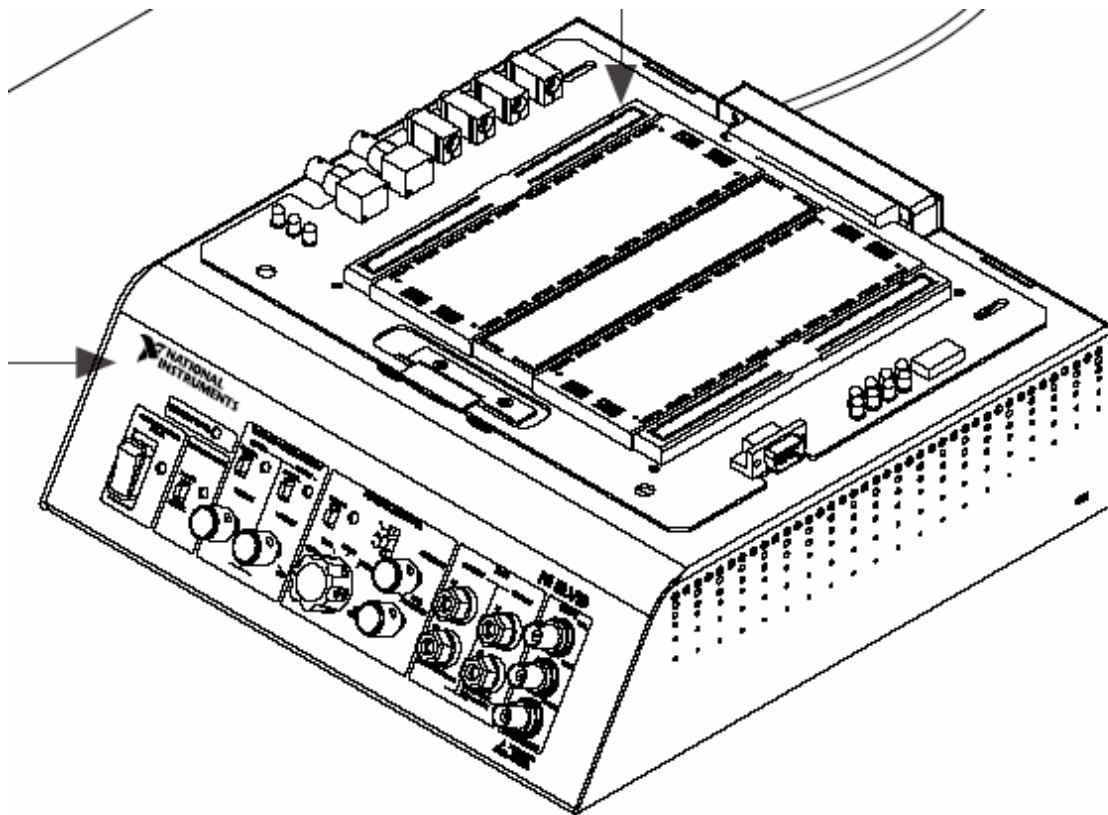
# Let's Play Around

During this first encounter with our system we will go through a number of exercises designed to help us understand the operation and the overall characteristics of the system.

Exercise 1. Turning on the System, launching the program.

The power switch for the system is located on the rear of the device. The prototyping board is powered by the switch on the left of the front panel. The first thing to check is the status of the system indicated by the three green leds on the lower left hand corner of the prototyping board. If any of these lights is off the appropriate fuse must be replaced.



| 1 | Benchtop Workstation Standby Switch | 4 | Prototyping Board Mounting Bracket |
|---|---|---|---|
| 2 | AC-DC Power Supply Connector | 5 | Kensington Security Slot |
| 3 | 68-Pin DAQ Device Connector | | |

Courtesy of National Instruments. Used with permission.

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Once the system is powered we can turn our attention to launching the software that drives and controls the device.
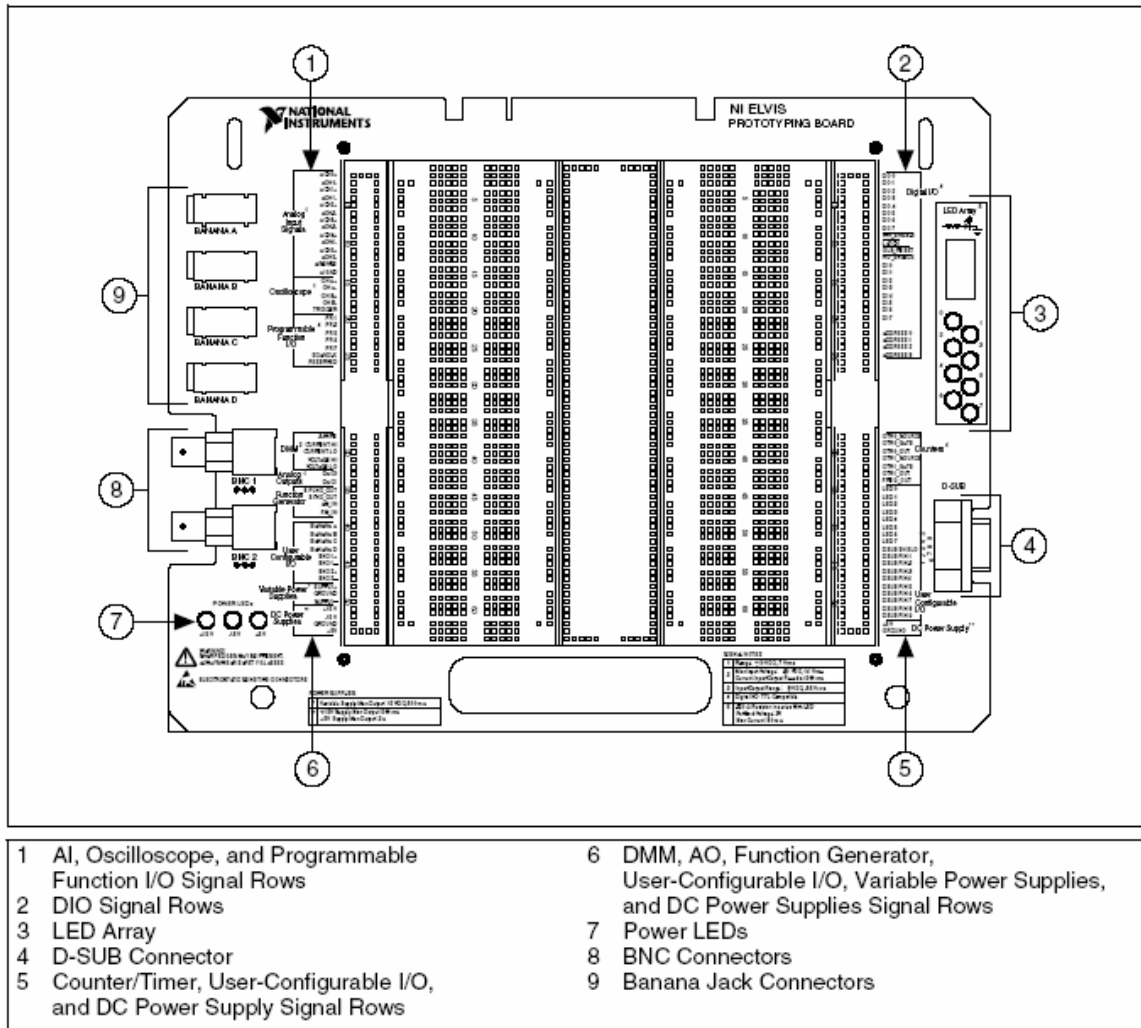
The ELVIS software can be launched from the icon named Elvis on your desktop. The following information will appear.
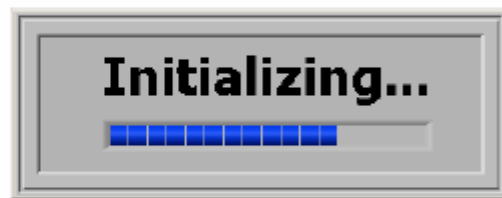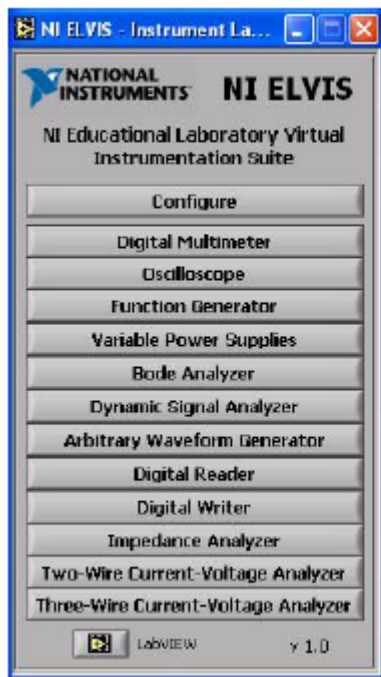


Courtesy of National Instruments. Used with permission.

The initializing progress bar indicates that communication is established among the various hardware components (PC to PCI card, PCI card to ELVIS).

Now we are ready to start. First let us take a close look at the prototyping board. A schematic of it is shown below.



| 1 | AI, Oscilloscope, and Programmable Function I/O Signal Rows | 6 | DMM, AO, Function Generator, User-Configurable I/O, Variable Power Supplies, and DC Power Supplies Signal Rows |
| 2 | DIO Signal Rows | 7 | Power LEDs |
| 3 | LED Array | 8 | BNC Connectors |
| 4 | D-SUB Connector | 9 | Banana Jack Connectors |
| 5 | Counter/Timer, User-Configurable I/O, and DC Power Supply Signal Rows | | |

Courtesy of National Instruments. Used with permission.

The main section of the prototyping board is made up of the power traces labeled with the red and blue lines and the space for component placement sandwiched between the power traces. For effective circuit building on the prototyping board we should adhere to the following guidelines.

1. Make sure the system power is off while you are building your circuits.
2. Establish power traces and test them. For example if you will be building a circuit that needs +5V and ground then first establish the +5V as one of the red traces and the ground as the adjacent blue by connecting them to the power supply (region 6). Test the actual value of the voltage at the power traces with the multimeter or the oscilloscope (more on this later).

3. Turn the system back off and start building your circuit.
4. Keep your wires short and do not run wires over components
5. Build your circuit is sections and test each section before proceeding.

Exercise 2.

For this exercise we will use the Digital Multimeter (DMM) feature to measure the value of some electronic signals and electronic components.

We may also use the DMM to measure the potential (voltage) at some point of a circuit. Well, here is a question that you may very well ask. Does the measurement itself affect the result? The answer to this question is YES if you are not careful or if the measuring device is not appropriately designed. The two electronic engineering phrases to these questions are "proper grounding" and "impedance matching". We will explore these issues as well in a few days. For now let's just keep asking the questions.

Our device has some power supply capabilities and we will use these to create and measure the voltage generated by the supply. Notice that in section 6of the prototyping board there are two regions labeled DC Power Supplies and Variable Power Supplies.

First lets measure the +5 Volts. To do this connect the +5V to the VOLTAGE HI and the Ground to VOLTAGE LO. By selecting the appropriate Function on your DMM instrument you should be able to perform this voltage measurement. Do the same for the +15V and the -15V.

Next let's connect to the Variable Power Supply and measure the Voltage. We will change the actual voltage of the Variable Power Supply manually. We can do this by switching the Variable power supply to the manual mode with the switch located on the front of the unit. Measure the voltage for both the Supply+ and Supply- .

Next let us measure the value of a resistor.

Just a brief note on how the actual measurement of resistance is accomplished: In order to determine the resistance value the device measures an electrical signal, a voltage in this case, and it then relates the value of the voltage to the resistance. (A big lesson here: NEVER MEASURE COMPONENT VALUES WHILE THE COMPONENT IS CONNECTED TO THE CIRCUIT, OR EVEN WORSE WHEN THE CIRCUIT IS POWERED.)

Select a resistor and connect it to the pins labeled CURRENT HI and CURRENT LO located in the DMM section of your protoboard. Set your DMM to the resistnace measuring mode denoted by **Ω.** Play with the range have fun.

Now lets measure the value of a capacitor. (Yes I know we haven't learned about these components yet but so what?). Again connect the capacitor to the pins labeled CURRENT HI and CURRENT LO and experiment by changing the range.

Next we will do an experiment to measure the temperature in the room. For this you will use a thermistor, which as we just learned is a temperature dependent resistor.

Connect the thermistor to the pins labeled CURRENT HI and CURRENT LO.

What is the resistance you are measuring?

Does it fluctuate or does it change monotonically?

Once the value stabilizes read and record the resistance.

In order to determine the corresponding temperature look up the resistance versus temperature curve included in today's notes.

What is the room temperature?

As the last experiment for today touch the thermistor and see the effect in the resistance reading.

Does the resistance increase or decrease with temperature?

How close to your body temperature ($37^0$C) can you reach by holding the thermistor in your fingers?
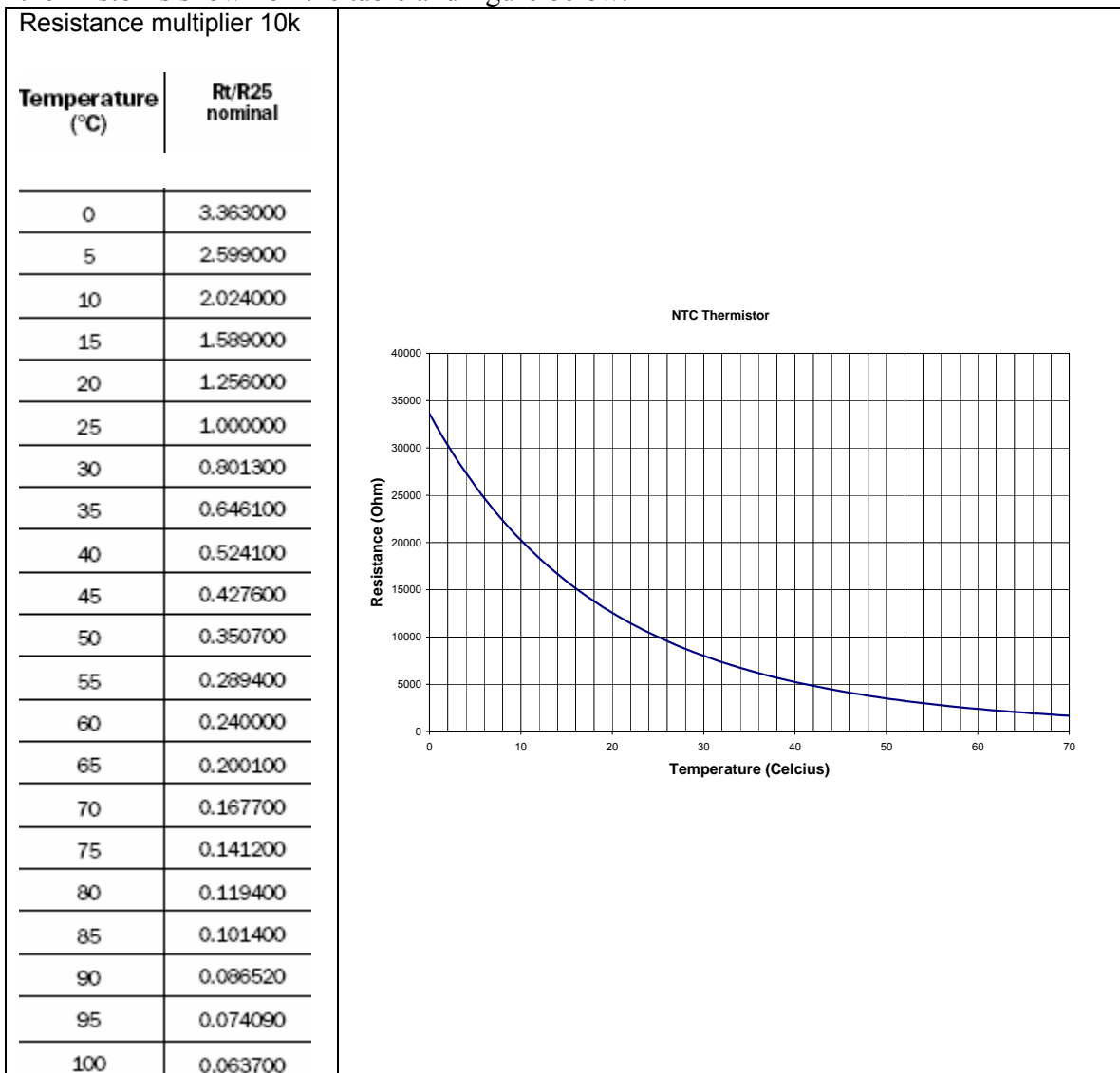
Close the Digital Multimeter instrument window.

## Thermistor. A Thermoelectric transducer

Thermistors are non-linear temperature dependent resistors with a high resistance temperature coefficient. They are advanced ceramics where the repeatable electrical characteristics of the molecular structure allow them to be used as solid-state, resistive temperature sensors. This molecular structure is obtained by mixing metal oxides together in varying proportions to create a material with the proper resistivity.

Two types of Thermistors are available: Negative Temperature Coefficient (NTC), resistance decreases with increasing temperature and Positive Temperature Coefficient (PTC), resistance increases with increasing temperature. In practice only NTC Thermistors are used for temperature measurement. PTC Thermistors are primarily used for relative temperature detection.

In this class we will use an NTC thermistor. The temperature versus resistance data of our thermistor is shown on the table and figure below.

| Resistance multiplier 10k | |
|---|---|
| Temperature (°C) | Rt/R25 nominal |
| 0 | 3.363000 |
| 5 | 2.599000 |
| 10 | 2.024000 |
| 15 | 1.589000 |
| 20 | 1.256000 |
| 25 | 1.000000 |
| 30 | 0.801300 |
| 35 | 0.646100 |
| 40 | 0.524100 |
| 45 | 0.427600 |
| 50 | 0.350700 |
| 55 | 0.289400 |
| 60 | 0.240000 |
| 65 | 0.200100 |
| 70 | 0.167700 |
| 75 | 0.141200 |
| 80 | 0.119400 |
| 85 | 0.101400 |
| 90 | 0.086520 |
| 95 | 0.074090 |
| 100 | 0.063700 |



NTC Thermistor

For convenience we would like derive a mathematical expression which describes the behavior of the device. The Steinhart and Hart equation is an empirical expression that has been determined to be the best mathematical expression for resistance temperature relationship of NTC thermistors. The most common form of this equation is:

$$\frac{1}{T} = a + b(\ln R) + c(\ln R)^3$$

Eq. 1

Where $T$ is in Kelvin and $R$ in $\Omega$. The coefficients $a, b, c$ are constants which in principle are determined by measuring the thermistor resistance at three different temperatures $T_1, T_2, T_3$ and then solving the resulting three equations for $a, b, c$.

$$\frac{1}{T_1} = a + b(\ln R_1) + c(\ln R_1)^3$$

$$\frac{1}{T_2} = a + b(\ln R_2) + c(\ln R_2)^3$$

$$\frac{1}{T_3} = a + b(\ln R_3) + c(\ln R_3)^3$$

The parameters $a, b, c$ for the thermistors provided with the lab kit in the temperature range between 0-50 degrees Celcius are:

$a = 1.1869 \times 10^{-3}$
$b = 2.2790 \times 10^{-4}$
$c = 8.7000 \times 10^{-8}$

The Steinhart and Hart equation may be used in two ways.

1) If resistance is known, the temperature may be determined from Eq. 1
2) If temperature is known the resistance is determined from the following equation:

$$R = \exp\left[\left(\beta - \frac{\alpha}{2}\right)^{1/3} - \left(\beta + \frac{\alpha}{2}\right)^{1/3}\right],$$

Where, $\alpha = \dfrac{a - \dfrac{1}{T}}{c}$ and $\beta = \sqrt{\left(\dfrac{b}{3c}\right) + \left(\dfrac{\alpha^2}{4}\right)}$

The non-linear resistance versus temperature behavior of the thermistor is the main disadvantage of these devices. However, with the availability of low cost microcontroller systems the non linear behavior can be handled in software by simply evaluating the Steinhart and Hart equation at the desired point.

The sensitivity of the thermistor, $\dfrac{dR}{dT}$, varies with temperature. For our thermistor the sensitivity as a function of temperature is shown on the following figure.



NTC Thermistor Sensitivity
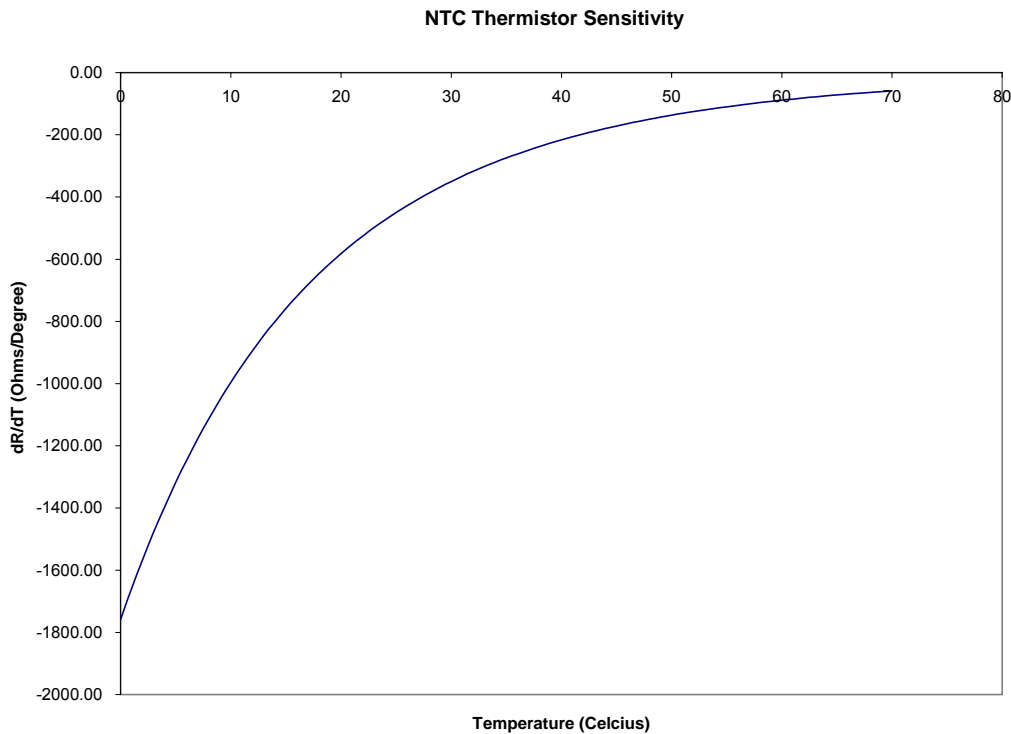
Note that the thermistor sensitivity decreases with increasing temperature. This is the primary reason for the small temperature measuring range of thermistors. Notice however that in temperature range of interest to biological and most environmental applications the sensitivity is greater than $100\Omega$/degree Celsius which results in the design of sensitive and robust systems.