May 6, 2003 (original submitted Mar. 2003)

To: Tom Phillips
From: Melanie Leong

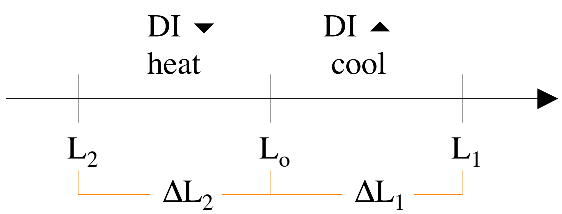
<u>Subject: Relation of Dish Surface Optimization System's Temperature to Length Change</u>

It was requested that this subject be explained. This document is an attempt to address this request.

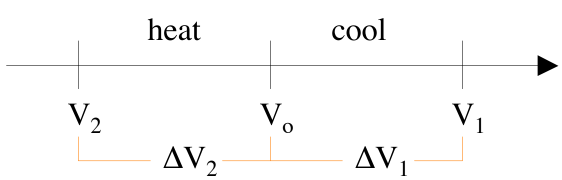
To form a starting place, ideal conditions were assumed – that there are no temperature gradients throughout the dish.

There are temperature gradients, but the temperature gradient will probably be addressed later in the future once the simpler model is understood and controlled.

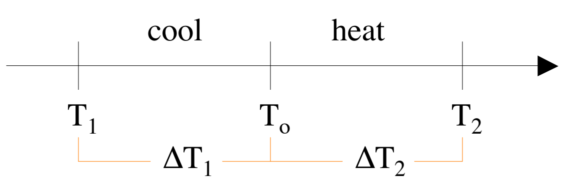
The following are the relations of length, L, voltage, V, temperature, T, and resistance, R (scales are NOT 1 to 1):



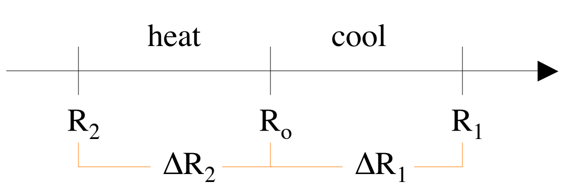

$\Delta L_1 = L_o - L_1$ $\quad$ $L_1 = L_o - \Delta L_1$




$\Delta V_1 = V_o - V_1$ $\quad$ $V_1 = V_o - \Delta V_1$




$\Delta T_1 = T_1 - T_o$ $\quad$ $T_1 = \Delta T_1 + T_o$




$\Delta R_1 = R_o - R_1$ $\quad$ $R_1 = R_o - \Delta R_1$

For calibration the starting temperature, length, and toothpick voltages are initialized and logged.

$T_o$ is the recorded temperature when everything is thermalized at the start. This is also the ambient temperature taken from the antenna computer and used as the reference for calibration. At $T_o$, which is $T_{amb}$, $\Delta L$ at $L_o = 0$.

$L_o$, $V_o$, $T_o$ ($T_{amb}$) , L, V, and T, are recorded and used to calculate the factors (a, b, c) needed to construct a Resistance vs. Temperature curve for each toothpick assembly.

The relations of ambient temperature, voltage, and length data, are the following:

By obtaining a thermistor's voltage, its resistance and thus its temperature can be determined. The manufacturer's thermistor data sheet is used to determine the temperature from its resistance value.

A thermistor's resistance, $R_1$, can be determined by:

$$R_1 = V_1 / 2.5\ \mu A$$

$V_1$ is obtained from the controller unit's A/D input.
The thermistor loop is provided with a constant current source of 2.5 $\mu$A.

From the manufacturer's thermistor R vs. T curve, temperature can be determined.

The change in length with temperature of the steel standoff is approximately:

$$\Delta L \approx \Delta\ 2.5\ \mu m / \Delta\ 1\ °C$$

From the above relation it is determined that the change in length for a given change in temperature is:

$$-\Delta L_1 = \Delta T_1 * 2.5$$
$$(L_o - L_1) = (T_1 - T_o) * 2.5$$
$$T_1 = T_o + \Delta T_1$$

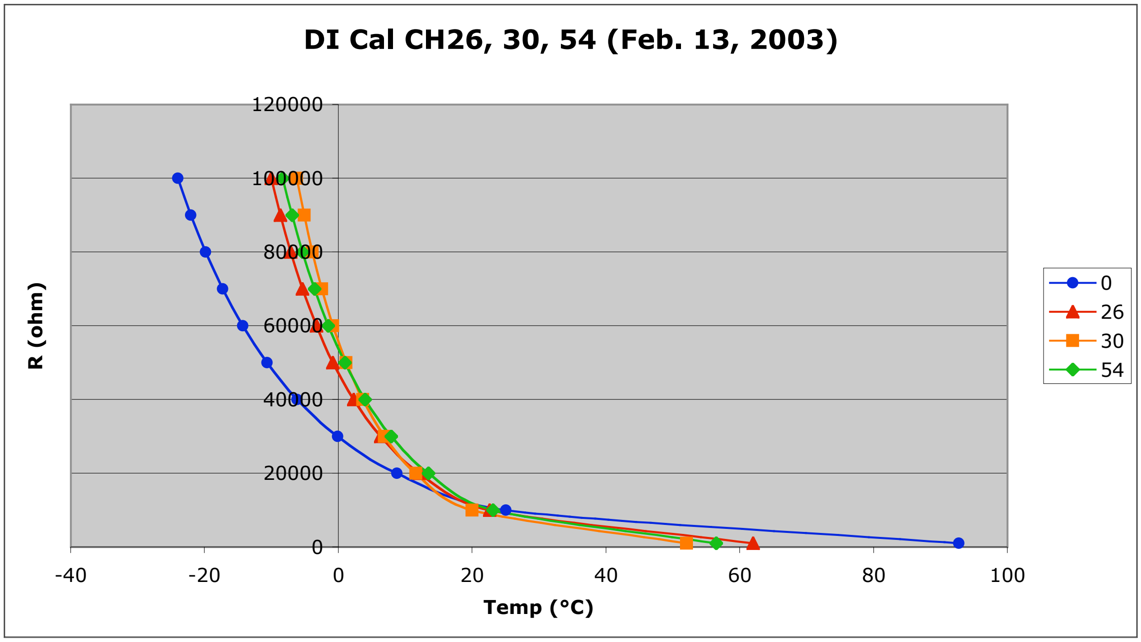
$\Delta L_1$ is a length change of the standoff in microns.
$T_o$ is the starting temperature (at ambient) where length change = 0.
$\Delta T_1$ is the change in standoff temperature from $T_o$. $T_1$ can be interpreted as the toothpick temperature, $T_{TP}$, for a length of $L_1$.

Recorded $T_o$, V (of four specific command values), and their respective length changes are used to determine the values of a, b, and c in the equation:

$$T = (1 / a + b * \ln (R) + c * \ln (R^3)) - 273$$

The curve derived from this equation is the calibrated fit to the toothpick.

An example of toothpick calibration curves is shown below. Included for comparison, the leftmost curve (labeled 0) is the data sheet ideal.




The a, b, and c values are stored and recalled during a dish correction call. The recalled values are used to calculate the command voltage for the desired micron change. The micron changes in relation to zenith angle are the cosine fits of measurements from past holography maps.

A quick summary flow is the following: present ZA → cosine fit lookup → T (R, a, b, c) → V (new command value)

The starting values of $T_o$ and $V_o$, are stored and used as the reference values for each new command determination.