WHEN YOU NEED TO BE SURE

Three-Dimensional Tables Reference

Version 4

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Developed by SGS North America, Inc.

Version History

Version	Date	Revision Description
1	1/25/2016	Initial publication
2	8/23/2018	Format with SGS brand
3	4/6/2020	Retrofit to new template
4	4/19/2021	Widen page size in *Section 3* example on page 5 to correct column data alignment.

Document Conventions

This document uses the following typographic and syntax conventions.

- Commands, command options, file names or any user-entered input appear in Courier type. Variables appear in Courier italic type.

  Example: Select the `cmdapp-`*`relVersion-buildVersion`*`.zip` file….

- User interface elements, such as field names, button names, menus, menu commands, and items in clickable dropdown lists, appear in Arial bold type.

  Example: **Type**: Click **Select Type** to display drop-down menu options.

- Cross-references are designated in Arial italics.

  Example: Refer to *Figure 1*…

- Click intra-document cross-references and page references to display the stated destination.

  Example: Refer to *Section 1 Overview* on page 1.

  The clickable cross-references in the preceding example are *1*, *Overview*, and on page 1.

CyFlex Documentation

CyFlex documentation is available at https://cyflex.com/. View **Help & Docs** topics or use the **Search** facility to find topics of interest.

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1 Overview

CyFlex three-dimensional calibration tables provide the capability to define a variable value as a look-up result from a table of two other variables. This document provides background on how CyFlex's three-dimensional tables are configured and may be used, as well as the theory of operation behind their use.

Calibration tables are used in CyFlex to relate one value to another through a mapping process. These tables are typically used to map a raw input channel in the transfer layer to the corresponding analog input real variable value. There is also the capability to use calibration tables as part of computed variable expressions. In this case the relationship in the table may be used to map any real-variable value to another real-variable.

Three-dimensional calibration tables are tables in which an input-output relationship is established for the case in which there are two input variables and a single output variable.

Three dimensional tables are useful in the following applications:

- Analog input channel calibration
- Parameter modeling for performance monitoring and safeties
- Parameter modeling for establishing target test conditions

2 Theory of Operation

The two-dimensional interpolation function operates on a table that contains sets of three-space points. Each point is a set of three coordinates (XYZ) defining one point on a surface in three-space. The purpose of the two-dimensional interpolation is to determine the value of a dependent coordinate for points between the sets of three-space points, given the values of the other two coordinates at that point.

The two-dimensional interpolation process works by determining triangular planar surfaces for sets of three three-space points. These planar surfaces have planar equations associated with them that allow the dependent coordinate to be determined from the two independent coordinates. The edges of the projection of the triangular planar surface onto the XY plane define the bounds over which the interpolation will be made for that surface.

None of the triangular planar surfaces overlap, and every point within the entire XY space should map into exactly one triangular planar surface.

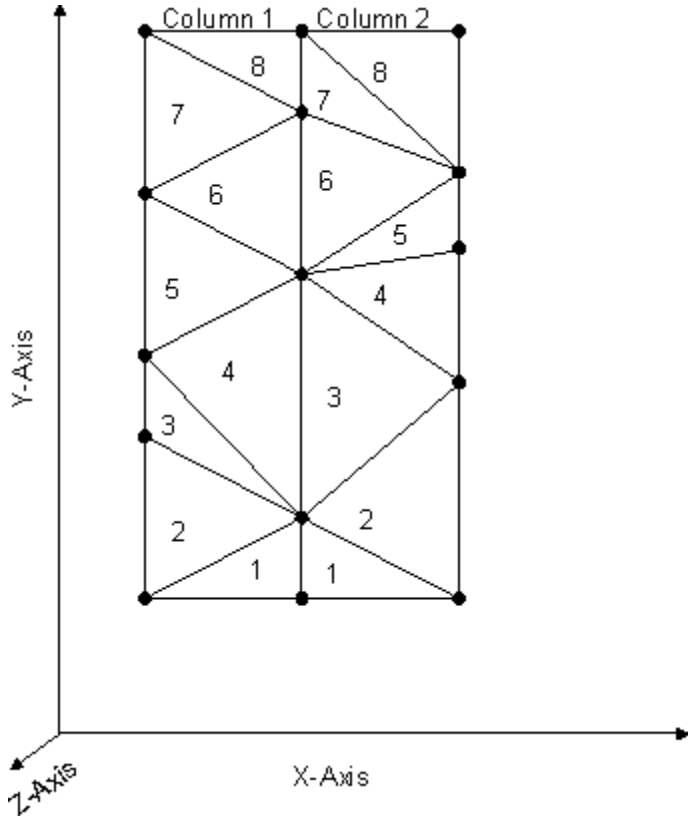
2.1 Algorithm

The method of breaking the sets of three-space points into triangular planar surfaces is:

1. Break the X-axis into columns (rectangles). This is easily accomplished since there are multiple YZ pairs for each X coordinate value in the three-space data set.
2. Determine the number of triangles in each column. This is the total number of points in the two columns minus two.
3. For each triangle in the column:
    - Determine the corners.
    - The two lower corners are the most recently selected points that determine the top line of the previous triangle. For the first triangle the two lower corners are the lowest Y points in each column.
    - The one upper corner is the lower of the next point in each column.
    - Determine the surface equation given the three corners.
    - Pre-calculate and store the surface coefficients required to determine a dependent value from two independent values to minimize the amount of real-time computing.

Figure 1 on page 3 illustrates an example result of the preceding steps.

Figure 1: Triangular Planar Surfaces Illustration



2.2 Table Types and Uses

There are two types of three-dimensional tables. The first are three-dimensional tables located in the long calibration table area. The second are "local" three-dimensional tables. The "local" three-dimensional tables are so-called because the space for these tables is allocated locally in the using application. Local three-dimensional tables are permitted to be larger than long-calibration table are three-dimensional tables.

The long-calibration table type is required in order to use a three-dimensional table for analog input calibration purposes. For this table type the table name is placed in `inpt_specs.`*nnn* as would be the case for any other calibration table. The raw analog input value is treated as the x-axis variable for this table type. The y and z-axes variables are identified within the table file itself.

The following example is a specification from the `inpt_specs` file for a case in which a `NOx` sensor can provide a `NOX` reading, but requires temperature compensation. In this case, the `NOx` sensor's output is the X variable, the temperature is the Y variable, and the output (ppm of `NOx`) is the Z variable.

```
#type chan interval f_const compen table label units format range_x
#
AI    0    FAS          .9      -    nox   nox   ppm    1       1
```

Three-dimensional table types are used when it is desirable to model a parameter as a function of two other variables. In this case the table is used in conjunction with a function call in a computed variable expression in `gen_labels.`*nnn*.

The following examples are of specifications from the `gen_labels` specification file for the short (from long calibration table area) and long (a locally allocated three-dimensional table) table types. In these examples the X variable is the variable whose label is identified as the first calling argument of the function. The identity of the Y and Z variables are located in the three-dimensional table file. The table file to use is specified by the second argument in the function call. For the `shrt_3d_comp` function call the table file to be used is `two_d_2.tbl`. For the `long_3d_comp` function call the table file to be used is `loc_two_d_1.tbl`.

```
#label          units       format    initial_value      interval
oil_press3D     psi          2        -                  1000
@shrt_3d_comp( RPM, 2[none] )
int_man_t3d     deg_f        2        -                  1000
@long_3d_comp( TORQUE, 1[none] )
```

3 Example Three-Dimensional Table File

```
# Description/Serial Number
Intake Manifold Temp Mapping
# Table Type Table Name
5 loc_two_d_0
# x units y units z units
RPM LB_FT deg_F
# x label
RPM
# x coordinate values
800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100
# y/z coordinate pairs
# x values:
#800      900       1000     1100     1200     1300     1400     1500     1600     1700     1800     1900     2000     2100
# spd tmp| spd tmp| spd tmp| spd tmp| spd tmp| spd tmp| spd tmp| spd tmp| spd tmp| spd tmp| spd tmp| spd tmp| spd tmp| spd tmp
    0  77    0  77    0  77    0  77    0  77    0  77    0  77    0  77    0  77    0  77    0  77    0  77    0  77    0  77
  100  78  100  78  100  78  100  79  100  79  100  79  100  79  100  80  100  80  100  80  100  80  100  80  100  80  100  80
  200  79  200  80  200  80  200  81  200  81  200  81  200  82  200  82  200  84  200  83  200  83  200  82  200  82  200  82
  300  79  300  80  300  81  300  82  300  83  300  83  300  83  300  85  300  86  300  86  300  86  300  85  300  85  300  84
  400  81  400  82  400  83  400  84  400  85  400  85  400  86  400  87  400  89  400  89  400  89  400  88  400  87  400  86
  500  82  500  83  500  84  500  86  500  88  500  88  500  90  500  91  500  92  500  92  500  92  500  91  500  91  500  90
  600  83  600  84  600  85  600  87  600  88  600  89  600  90  600  92  600  94  600  95  600  94  600  94  600  93  600  92
  700  84  700  85  700  87  700  88  700  89  700  91  700  92  700  95  700  97  700  98  700  97  700  97  700  97  700  96
  800  85  800  86  800  88  800  90  800  91  800  93  800  94  800  97  800 100  800 101  800 101  800 100  800 100  800  99
  900  85  900  87  900  89  900  91  900  93  900  94  900  96  900  99  900 102  900 104  900 104  900 103  900 103  900 102
 1000  86 1000  88 1000  90 1000  93 1000  94 1000  97 1000  99 1000 103 1000 106 1000 107 1000 107 1000 108 1000 107 1000 106
 1100  86 1100  88 1100  91 1100  94 1100  96 1100  99 1100 101 1100 105 1100 110 1100 110 1100 110 1100 110 1100 110 1100 108
 1200  86 1200  89 1200  92 1200  95 1200  98 1200 101 1200 103 1200 107 1200 115 1200 112 1200 112 1200 112 1200 111 1200 111
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 1500  87 1500  91 1500  95 1500  98 1500 102 1500 105 1500 108 1500 112 1500 120 1500 125 1500 118 1500 114 1500 112 1500 111
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 1800  88 1800  93 1800  97 1800 101 1800 106 1800 110 1800 113 1800 116 1800 120 1800 125 1800 118 1800 114 1800 112 1800 111
```