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Title	Recording Delta Tau motor positions and variables using PMAC Plot Pro
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Revision	B
Applicable to	All systems

1 Introduction

This document describes how to record motor positions and PMAC variables as a function of time using PMAC Plot Pro, which is part of the PMAC Executive Suite provided by Delta Tau. The program is installed on many Xradia systems.

2 Starting the program

The program can be started either from the Windows start menu, or from the Tools menu in PEWIN32PRO.

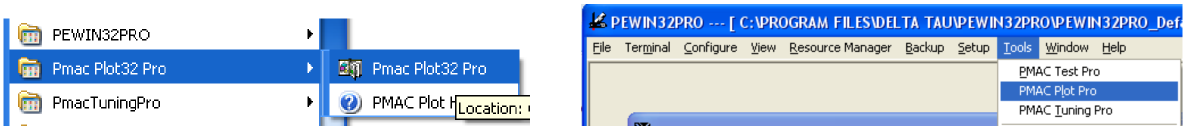


Figure 1: Starting PMAC Plot Pro.

3 Program overview

The data collection typically involves the following steps:

1. Defining which data to gather (record), and at what rate
2. Setting up a gather buffer on the Delta Tau controller
3. Gathering the data
4. Uploading the data from the Delta Tau controller to the PC
5. Plotting the data
6. (Optional) Saving the data

Each of those steps will be explained in detail below.

Figure 2 shows the PMAC Plot Pro program window (in Quick Plot mode). There are two different program modes, selectable through the tabs at the top:

- Quick Plot is easier to set up, but allows collecting only motor positions in counts and servo command output (no scaling, no collection of variables).
- Detail Plot is more difficult to set up, but allows applying scale factors and collecting any Delta Tau M-, P- and Q-variable.

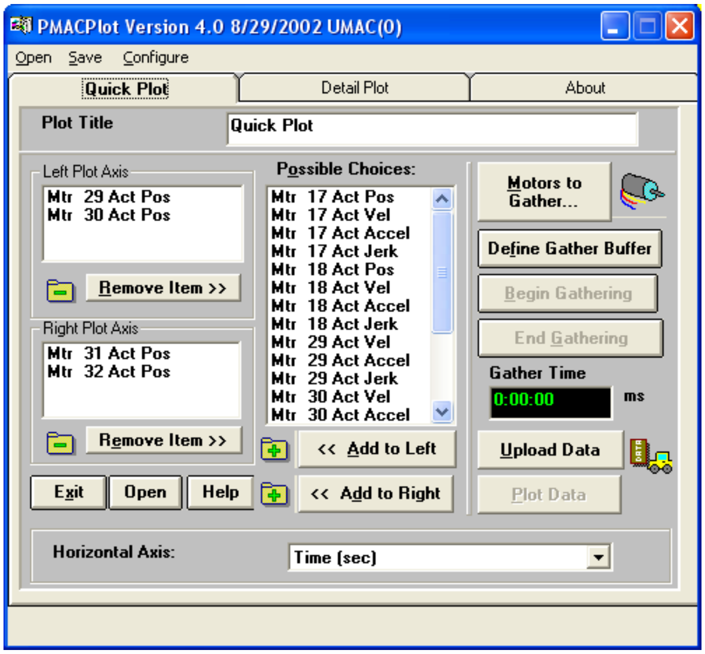
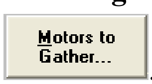


Figure 2: PMAC Plot Pro program window in Quick Plot mode.

4 Quick Plot

4.1 Defining which data to gather

Click 

. The following window opens:

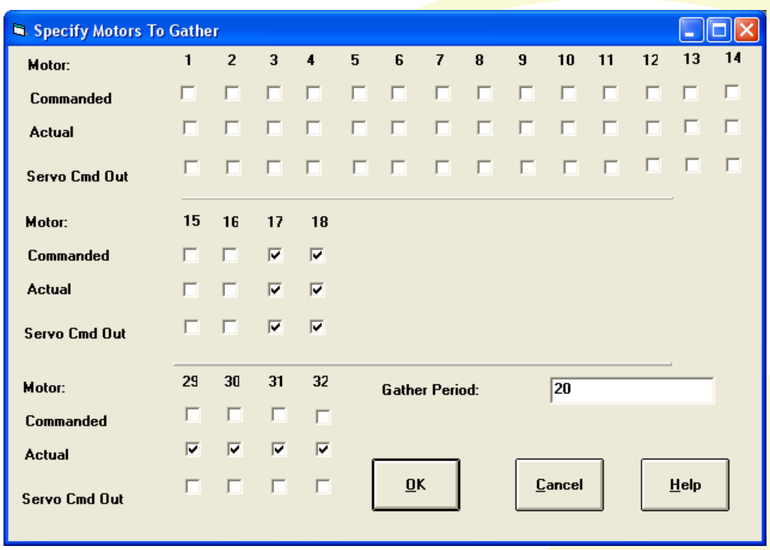


Figure 3: Motor gathering setup.

4.1.1 Motors to gather

The window lists all motors set up on the Delta Tau controller. In the example of Figure 3, motors 1 through 18 and 29 through 32 are set up. For each motor, you can collect the commanded (desired) position, the actual position and the Servo Command Output, which is the driving signal sent to the motor amplifier. Select which data you want to gather by checking the appropriate box.

4.1.2 Gather period

The Gather Period tells the controller how often to collect data, in units of servo cycles. A value of 1 means to collect every servo cycle, 2 means every other servo cycle, and so on.

The servo cycle is given by variable I10, in units of 1 / 8,388,608 msec. For example, if I10 = 419 413, the servo cycle is 50.0 microseconds.

Note that if you want to do a Fourier analysis on the data and want the spectrum to go up to a frequency of *f*, you need to collect data up at a frequency of 2*f*. For example, with the above servo cycle of 50 microseconds, you need to set a gather period of 20 (1 msec or 1 kHz) if you want the Fourier spectrum to go up to 500 Hz.

When you are done with the settings, click OK to exit the dialog.

4.2 Setting up the gather buffer

The next step is to set up a gather buffer on the Delta Tau controller. This can be done simply by clicking [Define Gather Buffer]. However, in this way you have no control over the size of the gather buffer (it will use all available memory; the currently available size in 48-bit long-words can be obtained in the PEWIN terminal using the *size* command).

4.2.1 Defining the gather buffer size to collect for a specified time

If you want to set up a gather buffer of a specified size (to collect for a specified time), you can use the *defgat n* command in the PEWIN terminal (not in Plot Pro!), where *n* is the desired size of the gather buffer in 48-bit long words. Each checked *position* (commanded or actual) selected in Sec. 4.1.1 above fills one long word every collection cycle (defined in Sec. 4.1.2), whereas each checked *servo command output* value fills half a long word (a 24-bit short word) every collection cycle.

Following the example of Figure 3, if you have eight position boxes and two servo command output boxes checked with a gather period of 20, and you want to collect for two seconds (with a servo cycle of 50 microseconds), you need a gather buffer of 18,000 (8 long words plus 2 short words = 9 long words total per gather cycle, and collecting for 2000 gather cycles total). In this case, you would type *defgat 18000* in the terminal window.

Typically there is a small discrepancy in the number of actually collected data points compared to the calculation presented above, the reason for which is currently not understood.

4.3 Gathering data

To start gathering, simply click [Begin Gathering]. The elapsed gather time will be shown in the field below. Click [End Gathering] to stop gathering. Gathering will also stop automatically when the buffer is full.

If you want to synchronize gathering with specific commands, you can use the *gat* command in the PEWIN terminal. For example, if you want to jog motor 17 by 2000 counts and record that move, type *#17 j:2000 gat* (after defining the gather buffer).

4.4 Uploading data to the PC

When gathering is complete, upload the data from the motion controller (where it is collected) to the PC (where the program runs) by clicking Upload Data. For large gather buffers (size of tens of thousands), this can take a few seconds.

4.5 Plotting the data

When the upload is complete, you can plot the desired quantities. The available quantities are shown in the list in the center; they correspond to the selections from 4.1.1 and their time derivatives (i.e. if you collected position, you can also plot velocity, acceleration etc.). The following error (calculated from commanded minus actual position) is also available.

You can plot up to four quantities on the left plot axis, and another four on the right. Select the desired one and click << Add to Left or << Add to Right. You can also remove any quantity from the left or right axes. Finally, click Plot Data.

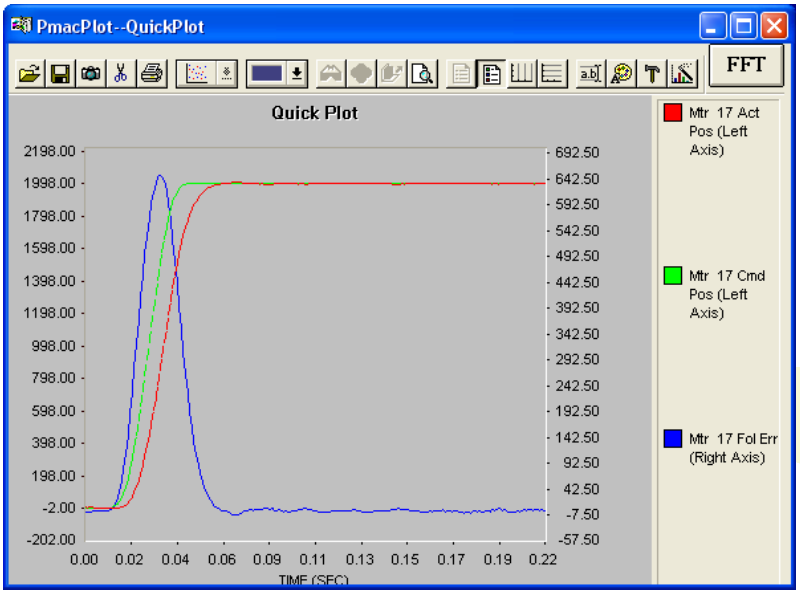


Figure 4: Example plot.

Figure 4 shows an example plot of actual and commanded position on the left and following error on the right axis.

Typically the axes are scaled in odd intervals by default. To change that, click the “Change PmacPlot options” button in the toolbar and switch to the “Scale” tab to adjust it to your liking. Make sure to select the radio button for the appropriate axis. There are many more options available that should be self-explanatory.

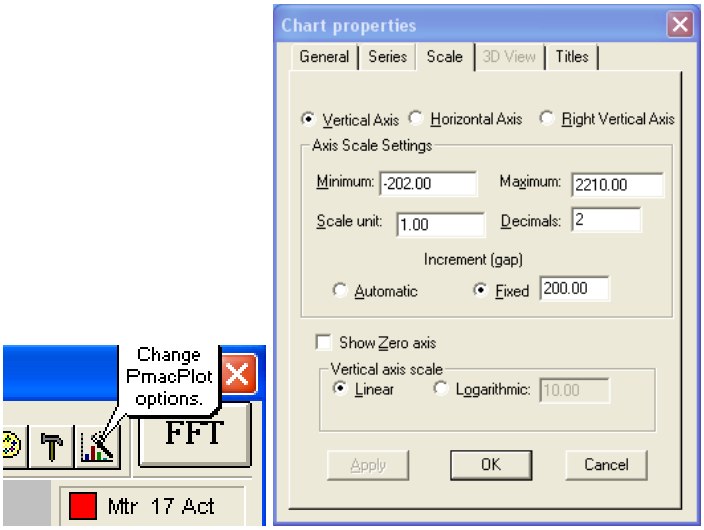


Figure 5: Changing plot options and axis scaling.

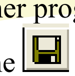
4.5.1 Plotting the Fourier transform

To plot the Fourier transform of the data, click the 

button in the upper right of the plot window. For each curve in the time series plot, the program will ask you if you want to plot the FFT on a log scale. Again, you might want to change the axis scaling to more meaningful tick intervals.

4.6 Saving the data

4.6.1 Storing for analysis with external programs

To import the data into Excel, MatLab or other programs for further analysis, it is most convenient to export to a tab-delimited ASCII file. Click the  button in the plot window and pick “tab-delimited text (*.txt)” from the dropdown list. This will store all the curves that are plotted in this window (as time series or Fourier spectrum, depending on what is plotted).

4.6.2 Storing for future review

If you want to keep the data for future review, you can also pick the tab-delimited format described above. However, it can be useful to store the original data in the PMAC-proprietary *.Qgd format (Quick plot Gathered Data). This will store the whole gather buffer and not only the curves that are plotted in the plot window. To choose this option, go to Save → Gathered Data (see Figure 6) in the main PMAC Plot Pro window (not in the graph window where the curves are plotted). This file can later be opened (Open → Gathered Data from File) and plotted / exported as if it had just been collected.

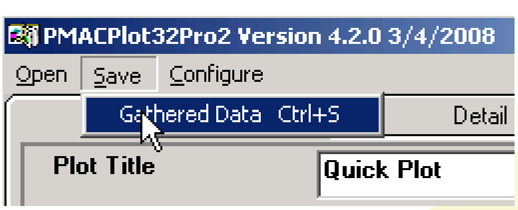


Figure 6: Saving gathered data in PMAC-proprietary format for future review.

5 Detail Plot

Detail Plot allows collecting the value of any Delta Tau memory register, which includes all M-, P- and Q-variables. It can be started by clicking the Detail Plot tab below the menu bar. See Figure 7 for a screenshot.

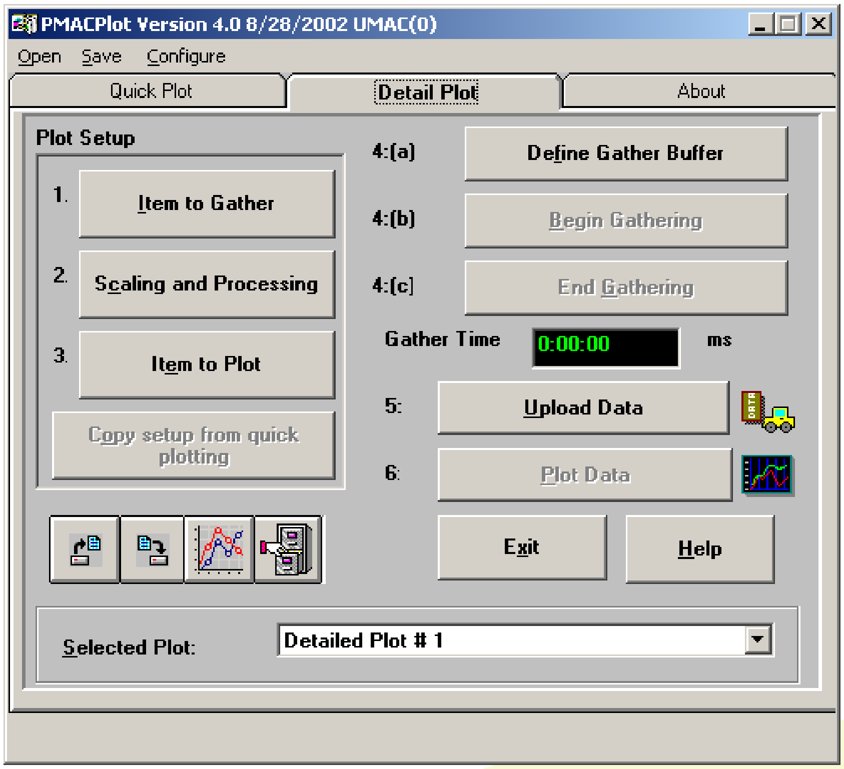
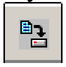


Figure 7: Detail Plot screen.

The basic procedure to use the program is the same as in Sec. 3 above, but the setup of the gather sources is more elaborate. Moreover, several different plots can be predefined. We will concentrate on those settings below.

5.1 Storing and recalling Detail Plot settings

Before setting up Detail Plot, read the following warning: The settings (gather sources, scaling / processing etc.) are lost if you close the program or even if you change to the Quick Plot tab. Therefore it is important to save your settings to a file by clicking the  button. Then you can recall them using the  button if necessary. The settings are stored in a proprietary format with a .dpc (Detail Plot Configuration) extension.

5.2 Items to Gather

Click 

to open the corresponding dialog (Figure 8). The Gather Period is the same as in Quick Plot (see Sec. 4.1.2). You can specify up to 24 gather sources. The ones that have a checkmark in the last column are actually gathered.

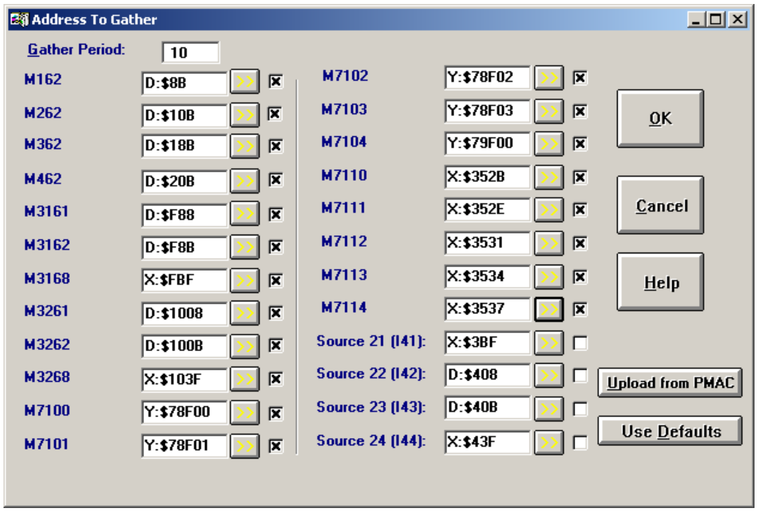


Figure 8: Detail Plot gather source setup.

If you know the address of the memory register you want to gather, you can simply type the address in the corresponding field. However, usually you just know the variable, in which case you can click the yellow arrow button to open the dialog shown in Figure 9.

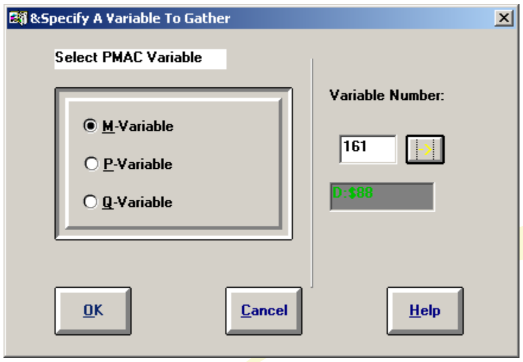


Figure 9: Detail Plot setup of variables to gather.

Select the variable type and fill the variable number into the corresponding field, then click the yellow arrow. The program will then automatically fill in the memory address.

5.2.1 Relevant M-variables

Some variables of interest are listed here. The default M-variables are listed in the *Turbo PMAC/PMAC2 Software Reference Manual* in the section *Suggested M-variable Definitions* (the *UMAC Turbo* is the relevant one for most Xradia systems, but verify if necessary). The units are also listed there.

- Motor *xx* commanded position: M*xx*61
- Motor *xx* actual position: M*xx*62
- Motor *xx* servo command output: M*xx*68

Moreover, for the scaling / processing (see below) it is important to know how much memory is occupied, and how it is occupied. This can be read from the M-variable definition, which can be obtained by typing *Mxxxx->* in the terminal (for M-variable *xxxx*). See the *M{constant}->…* commands in the *Turbo PMAC on-line command specification* section in the Software Reference Manual for details. For example, all M-variables assigned as *D:* are long (48-bit) fixed-point words, whereas *X:* or *Y:* variables are short (24-bit) fixed-point words. A 16-bit variable typically occupies a 24-bit X: or Y: register, so that possibly a bit mask and shift have to be applied in Scaling and Processing (see below).

5.3 Scaling and Processing

Most variables (memory registers) will require some processing to give you the number you actually want. Click the Scaling and Processing button on the Detail Plot main screen to open the dialog shown in Figure 10.

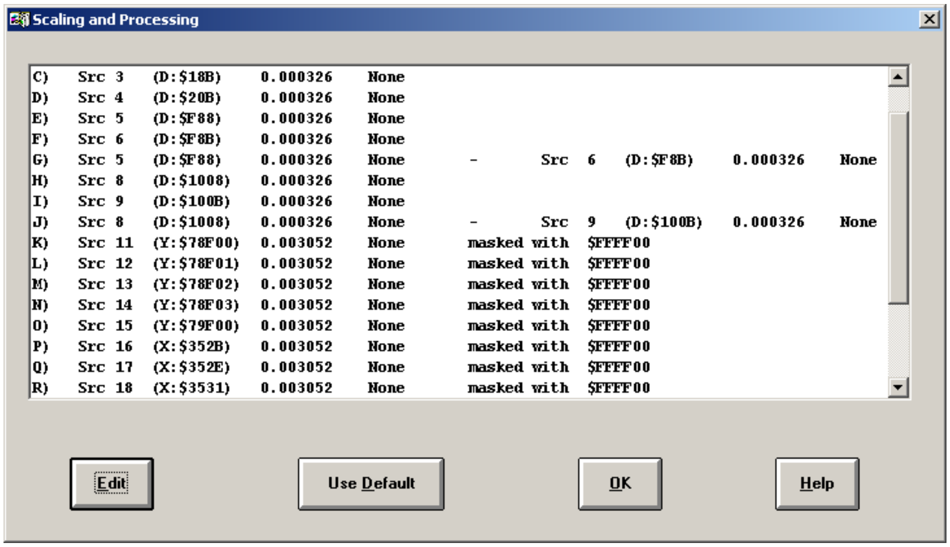


Figure 10: Scaling and Processing main screen.

You can configure up to 24 “Plot items” A through X, which are scaled / processed outputs from the gather sources. The 24 plot items can, but don’t have to, correspond to the 24 gather sources. For example, a plot item can represent the combination of two gather sources (e.g., the following error, which is commanded minus actual position), or two plot items could represent the same gather source with different scaling. Highlight the plot item that you want to set up and click Edit. Depending on whether the plot item is currently configured for one gather source or the combination of two gather sources, the corresponding dialog will open. The Combine Above With a 2nd Source >> or Do Not Combine with Primary Item button will swap between the two modes

5.3.1 Setup for one gather source

The Scaling and Processing dialog for one gather source is shown in Figure 11.

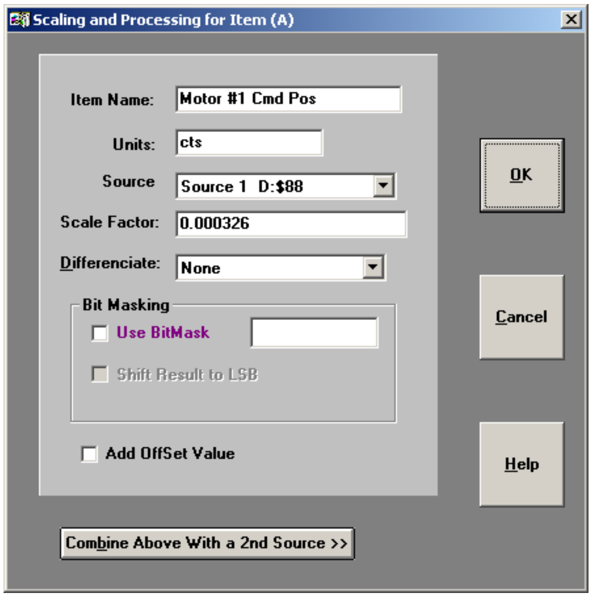


Figure 11: Scaling and Processing for one gather source.

You can specify the *Item Name* and *Units* to your liking; they will appear on the legend when you plot data. Pick the desired gather source from the dropdown list. The *Scale Factor* and *Add Offset Value* fields will allow a linear transformation of the data, see below for specific examples. *Differentiate* allows you, for example, to calculate velocity or acceleration from position data. The *Bit Masking* group of fields is required, for example, to properly output 16-bit numbers that are stored in 24-bit memory registers. Again, see below for specific examples.

5.3.1.1 Setup for position data

The proper setup for position data is shown in Figure 11. Position data are held in D:-registers, i.e. they are 48-bit long words. The units are in 1/[I*xx*08*32] counts for motor *xx*, and since I*xx*08 = 96 by default, the scale factor is typically 1/3072 = 0.000326. If you want to plot in microns, you can apply the additional resolution scale factor.

5.3.1.2 Setup for 16-bit ADC data

The data from 16-bit ADC (Acc-28E) boards, like the metrology capacitive sensors, are typically written to M-variables in the form *Mxxxx->Y:$yyyyy,8,16*, where *xxxx* is the M-variable number used and *yyyyy* is the memory address in hex format. That means, they are unsigned 16-bit numbers occupying a 24-bit register, with an offset of 8 bits. Therefore we need to apply a bitmask of $FFFF00 (to mask out the eight unused bits) and then shift the result to the Least Significant Bit (LSB). The settings are shown in Figure 12.

Then the result will be the expected number from 0 to 65535 ADC counts. If the ADC is configured for a range of -10 to +10 V, you can apply a scale factor of 20 V / 65536 counts = 3.052e-4 V/count and an offset of -10 V so that the numbers will be plotted in Volts. If you want to convert Volts further into some other quantity, you can modify the scale factor and offset accordingly.

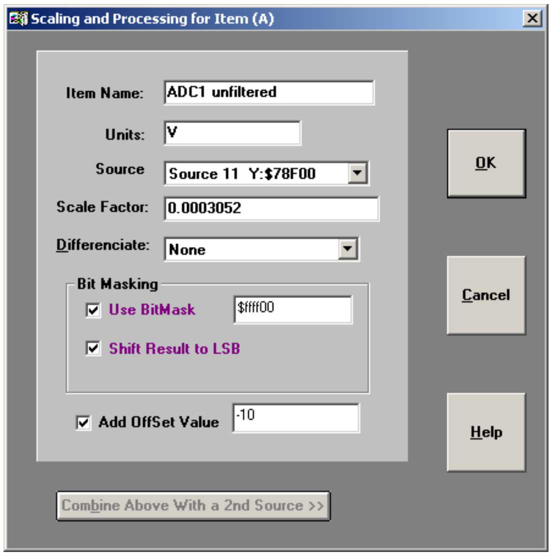


Figure 12: Scaling and Processing for 16-bit ADC data.

5.3.1.3 Setup for servo command output

Since the servo command output (M*xx*68) is a 16-bit number occupying a 24-bit register, the setup is presumably similar to Sec. 5.3.1.2 above (with the same bit mask and bit shift, but no scale factor / offset; the result should then go from -32768 to +32767 since the variable is defined as signed 16-bit). However, this has not been tested yet.

5.3.2 Setup for a combination of gathering sources

The dialog for combining two gather sources in a plot item is shown in Figure 13. Typically this is used to calculate the following error (commanded minus actual position). You can select source, scale factor and differentiation for the two sources to be combined, as well as the mathematical operation to be applied. There is no offset or bit masking.

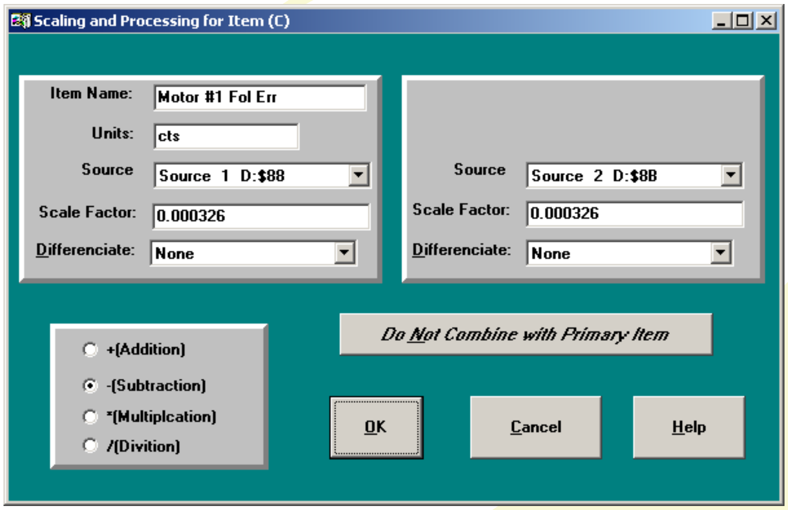


Figure 13: Scaling and Processing for a combination of gather sources.

5.4 Item to Plot

Click 

in the main Detail Plot window to set up the actual plots (Figure 14). Up to 24 different plots can be set up concurrently (which are then available in the dropdown list at the bottom of the main Detail Plot screen).

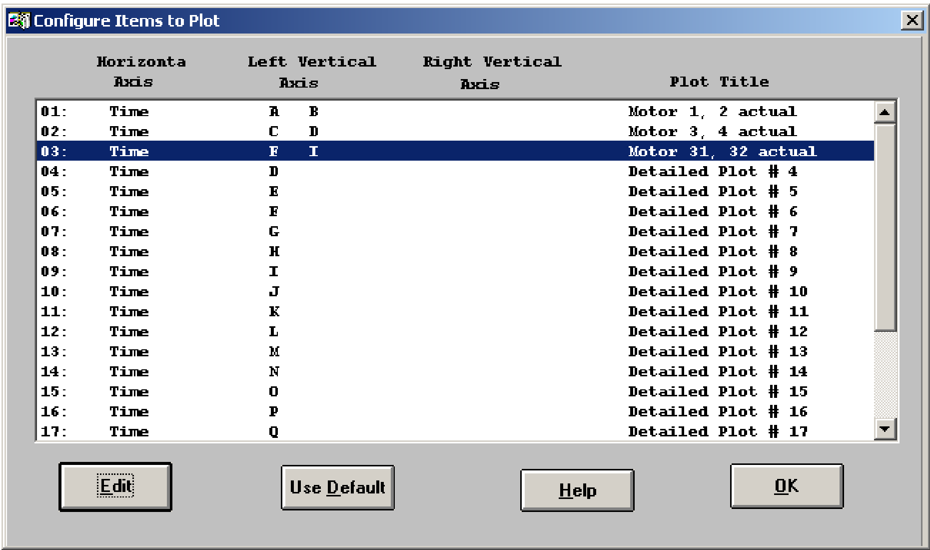


Figure 14: Dialog to set up items to plot.

Highlight any plot setup and click 

. The dialog shown in Figure 15 opens.

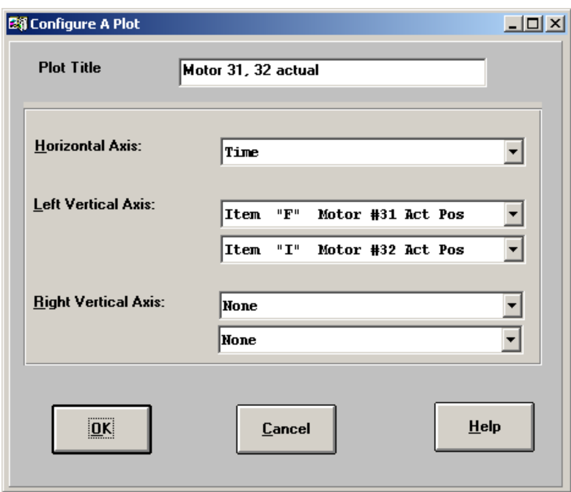


Figure 15: Configure plot items dialog.

You can specify a plot title which then shows up in the dropdown list in the main Detail Plot window, and also on the plot itself. Then you can select what to plot on the horizontal axis (which will typically be *Time* most), and up to two items on the left and right vertical axis each.

5.5 Further steps

After setting up the gather sources and plot items as described above, the further steps are the same as in Quick Plot mode (Sec. 4). You define the gather buffer, start and stop gathering, upload the data and plot.

You can select among the plots configured in Sec. 5.4 by using the dropdown list at the bottom. The plot window itself is equivalent to the Quick Plot version.

If you want to save the original data in the proprietary PMAC format (similar to Sec. 4.6.2), they will be stored with the extension .Dgd (Detail plot Gathered Data). Presumably this format is slightly different from the Quick Plot version.

Don't forget to save the detail plot settings (see Sec. 5.1) if you don't want to go through the setup again!