ID Field Integral Measurement System User's Guide

Date: May 25, 2004
Author: **Joseph Z. Xu**
Version: 2.1

Reviewed and Approved By: Date
Isaac Vasserman
Tel: 2-9612, Email: Isaac@aps.anl.gov

Reviewed and Approved By: Date
Shigemi Sasaki
Tel: 2-9702, Email: sasaki@aps.anl.gov

Functional Owner Date
Ned D. Arnold
Tel: 2-6332, Email: nda@aps.anl.gov

Functional Owner Date
Elizabeth R. Moog
Tel: 2-2787, Email: moog@aps.anl.gov

Version Control

Release	Publish Date	Comments
1.0	3/8/2004	Draft for Review
1.1	4/6/2004	Revised for Signature
2.1	5/25/04	Revision with New Features

TABLE OF CONTENTS

1. EXECUTIVE SUMMARY

Stretched coil system can be used to measure the vertical and horizontal components of the ID magnetic field integrals along the ID longitudinal direction. The APS ID Field Integral Measurement System consists of a set of stretched coil supported by two automated 4-dimentional stages W, X, Y, and Z. The control and data acquisition system is a PXI based computer system. With the latest state of the art Field Programmable Gate Array (FPGA) technology, the system is capable of synchronized measurements of position (0.005 degree/0.5 micron in resolution), time (25 ns), and voltage (16 bit), with the following options:

1. Rotation Coil
   a. First Field Integrals (horizontal and vertical) measurements at X=0. Averaging over undulator half period could be applied to improve accuracy;
   b. Second Field Integrals (horizontal and vertical) measurements at X=0. Averaging over undulator half period could be applied to improve accuracy;
   c. Multipole components of First Field integrals measurements ($J1_{x,y}$ vs. X).

   Second field integrals measurements are done with one end of the coil rotated by 180° (8-shape coil)

2. Translation Coil
   a. Multipole components of First Field integrals measurements. This option is preferable with translation coil rather than with rotation coil, because it allows saving time.
3. Translation Wire
   a. First Field Integrals (horizontal and vertical) measurements;
   b. Second Field Integrals (horizontal and vertical) measurements.

   Second field integral measurements are done with ends of the wire moving in opposite direction. This option is preferable with translation wire rather than with rotation coil, because it allows saving time and provides better accuracy: coil width errors do not contribute to accuracy of measurements and averaging over undulator half period is not required. Usually this option is used to measure only vertical field integrals due to lack of the undulator space, needed for translation in Y.

A computer control software has been developed to coordinate and automate the control, data acquisition, and real-time data analysis effort. This document provides the User's Guide information for the Field Integral Measurement System. The current issue of the document provides system descriptions, software installation, and detailed step-by-step guide to the applications of the system. The document is structured to provide descriptions/scenarios and application guiding information, in meeting the current and possible future needs of the scientists who use the system in the lab.

2. INTRODUCTION

The APS Magnetic Measurement Lab ID Field Integral Measurement System consists of two rotary stages, W1 and W2. The rotary stages are supported by six orthogonal linear stages, three each, Y1 and Y2, Z1 and Z2, and X1 and X2, respectively. The rotary stages are Parker Automation 205 RT series worm gear drive with 1:90 ratio. The linear stages are home made aluminum stages with one pitch lead screws. All the stages are automated, driven by 8 SmartMotors, controlled via RS-232 interface. The angular position of the W1 axis is defined by a Heidenhain rotary encoder with 0.005 degree of resolution. The encoder has a 20mm diameter hollow shaft that allows the coil to go through the center. The X1 linear axis position is defined by an ACU-RITE linear encoder with 0.5 micron resolution. The signal collected from the coil goes through a differential DC signal conditioner that pre-amplifies the signal ~3,000 times. The signal then feeds into a 16 bit analog input of a FPGA reconfigurable data acquisition card.

The software system has four main modules, the Motion Control Module, the Integral Average Module, the Integral Multi-measurement Module, and the Translation Scanning Module. Each module provides user with friendly GUI interfaces. The Motion Control Module allows user to monitor both the W1 and X1 encoder positions, all 8 axis positions via the SmartMotors, and fine tune the position of each axis. It also monitors the Voltage measurement. Within the module, there is a velocity and acceleration sub-module, where displays the velocities and accelerations of each motors and one can change the settings to new values as needed.

The Integral Average Module does multiple rotary scans the voltage and the time duration versus the angular position at a specific X, Y, and Z positions, calibrate the voltage signal with the time duration, numerically integrates the signal, and plots each scan (Integral vs. Angle), fits the data with sinusoidal function, and extrapolates the x and y integral components. It then plots the x and y integral components and calculates the mean values for both x and y components. It also has the option of first order (0 coil) or second order (8 coil), as well as average off (Z=0) or average on (average upon Z=0 and Z=1/2 λ of the ID period). It then writes all the data information into an integral average file. Within the Integral Average Module, there is a Plot sub-module that plots the saved integral average files. The sub-module displays the file path and the file header information. It plots each individual scan, along with the fitting data, the x, y components, and the fitting mean square error. It also plots the x and y components vs. the number of scan, as well as their mean values and standard deviation values.

The Integral Multi-measurement Module measures the x and y integral components along the X direction. It plots each measurement (Integral vs. Angle) at X positions, fits the integral data with a sinusoidal function, and extrapolates the x and y integral components. It then plots the x and y components along the X axis, fit the components with a polynomial function to plot out the field integral distribution along the X axis. It has the measurement option of first order or second order. After measurements done, it writes all the data information into an integral multi-measurement file. Within the Integral Average Module, there is a Plot sub-module that plots the saved integral average files. The sub-module displays the file path and the file header information. It plots each individual scan, along with the fitting data, the x, y components, and the fitting mean square error. It also plots the x and y components mean value vs. the X position, as well as their polynomial fitting coefficient values. By shifting the X position, it displays polynomial fitting coefficients at the new X origin.

The Integral Translation Measurement Module measures the first field integrals variation along the X axis. It plots each measurement (Field integral vs. X position), fits the integral data with a polynomial function. It also plots the averaged data up to the current scan and fits the averaged data with a polynomial function. It has the option of choosing 1-wire or 2-wire. It will save all the data information into a data file. It has a plot function that plots out the saved data, along with the fitting coefficients. Again, by shifting the X position, it displays polynomial fitting coefficients at the new X origin.

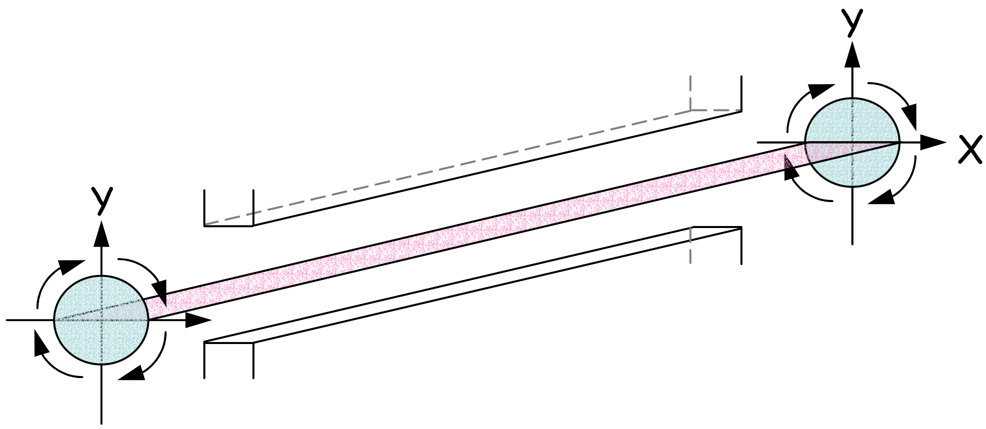
This document provides the detailed User's Guide information for the APS Magnetic Measurement Lab ID Field Integral Measurement System. It includes a general overview of the calibration system, descriptions of all the sub-systems, and the step-by-step guide to the software system that integrates the sub-systems and automates the control and measurements. This document shall be revised to reflect the modification of the system. This is a living document.

3. SYSTEM OVERVIEW

Insertion Devices (IDs) at the APS are characterized and fine tuned against their design specifications at the Magnetic Measurement Lab before they get installed into the storage ring. One of the specifications is to make sure that the IDs have their field integral along the longitudinal (Z) direction below certain value.

3.1 Theory of Operation

Stretch coil magnetic field integral measurement is a very powerful way to characterize ID field integrals. The APS Field Integral Measurement System is designed to verify that the field integrals meat or exceed their specifications before their deployment or re-deployment. The system is based upon the following theory of operation.



3.1.1 First Field Integrals of the Coil Rotation Mode

Magnetic flux time dependence over the area of rotating coil is defined by expression:

$$\Phi_y(t) = d * \cos\varphi \int_{-L/2}^{L/2} B_Y(z)dz = \overline{B_y} * L * d * \cos\varphi = J1_y * d * \cos\varphi$$

$$\Phi_x(t) = d * \sin\varphi \int_{-L/2}^{L/2} B_x(z)dz = \overline{B_x} * L * d * \cos\varphi = J1_x * d * \cos\varphi$$

$$\varphi = \left(\frac{2\pi}{T}\right) * t$$

where $\overline{B_x}$ and $\overline{B_y}$ are averaged over *Z* components of magnetic field, L is coil length, d is the coil width and T is rotation period, $J1_x$ and $J1_y$ are first field integrals.

This expression is valid, when field integral change over the width of the coil (5 mm in our case) is small enough to allow the fitting to sinusoidal function.

Signal from coil:

$$U(t) = -N * \frac{\partial \Phi}{\partial t} = J1_y * d * N * \frac{2\pi}{T} * \sin\varphi - J1_x * d * N * \frac{2\pi}{T} * \cos\varphi \qquad (1)$$

N is the number of coil turns. First field integrals could be found from above expression by integrating the signal and fitting the flux dependence on the time.

3.1.2 Second Field Integrals of the Coil Rotation Mode

One end of the coil is rotated by 180° to perform these measurements (8-shape coil).

$$\Phi_y(t) = \Theta * \cos\varphi \int_{-L/2}^{L/2} B_y(z) * z dz$$

$$\Phi_x(t) = \Theta * \sin\varphi \int_{-L/2}^{L/2} B_x(z) * z dz$$

$$J2_{x,y} = \pm \frac{\Phi_{x,y}}{\Theta} + \frac{L}{2} J1_{x,y} \qquad (2)$$

where $+$ in expression (2) corresponds to rotation of the 2nd stage by 180°, – for rotation of the 1st stage, $\Theta = \frac{2d}{L}$

Flux is defined by the same way as for the first field integrals, and second field integrals are defined from equation (2).

3.1.3 Coil Translation Mode

In translation mode, coil moves in X direction and measure flux difference from initial value. Orientation of coil is vertical to measure the horizontal component of field integral, and horizontal to measure the vertical component of it. This option is preferable for multipole component measurements.
Magnetic flux time dependence:

$$\Phi_{x,y}(x) - \Phi_{x,y}(0) = \Delta J1_{x,y} * d = -\frac{1}{N} \int_0^x U_{x,y}(x) dx(t)$$

3.1.4 Single Wire Translation Mode

Only one side of the coil is moving at this option, so area of the coil is changing with time. Usually this mode is used for measurements of only vertical component of first field integral due to limitation in space for Y-direction

$$\Phi_y(x_i) = J1_y(x_i) * (x_i - x_{i-1}) = -\frac{1}{N} \int_{x_{i-1}}^{x_i} U_{x,y}(x) dx(t)$$

This option is preferable for first field integral measurements, and does not require averaging over half undulator period.

Measurements of second field integrals have to be performed with cross motion of the ends: i.e. while one end of the coil moves from – maximum position to + maximum X position, other end moves in opposite direction from + maximum X position to – maximum X position. Flux $\Phi_y(x_i)$ is defined by the same way as for first field integral, where position x_i corresponds to the end of the wire, and it should be divided by $2*(x_i - x_{i-1})/L$, instead of $2*d/L$, as in (2).

An option of moving only one end of the wire is possible. Change of the angle Θ has to be taken into account in this case.

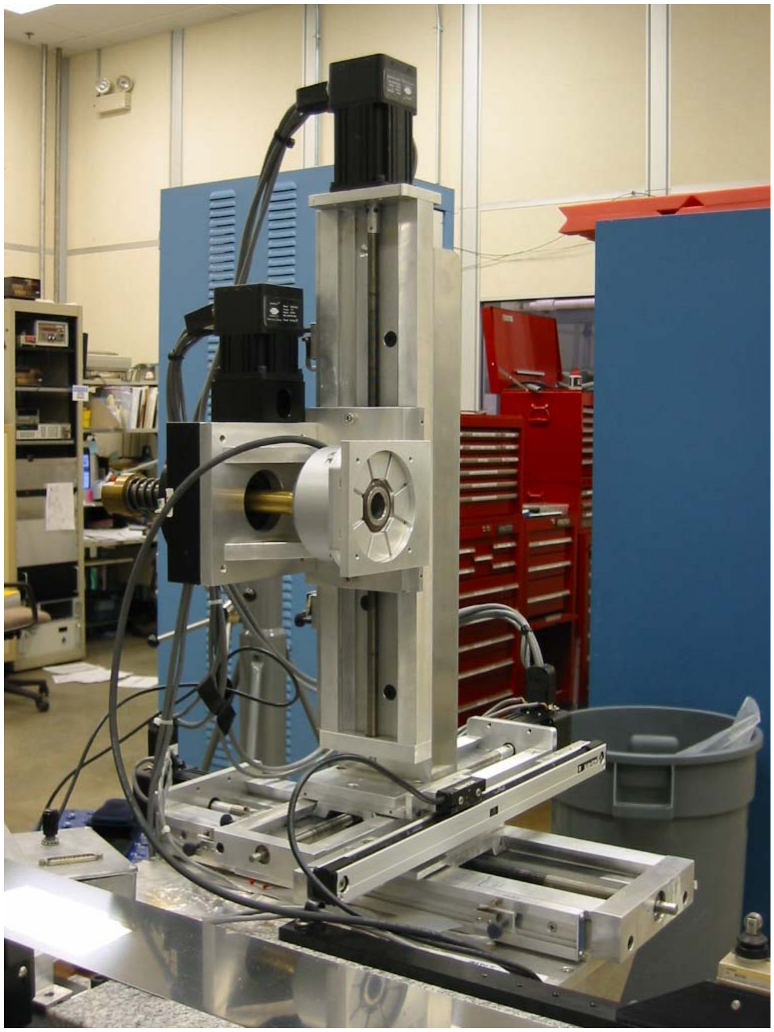
4. SYSTEM HARDWARE

The Field Integral Measurement System hardware consists of the following sub-systems:

1. 2 sets of 3-axis precision linear positioning stages, remotely controlled by SmartMotros.
2. 2 sets of precision rotary positioning stages, each with a spring loaded coil holder, remotely controlled by SmartMotros.
3. 1 linear encoder.
4. 1 rotary encoder.
5. 1 pre-amplifier with low-pass signal filter.
6. 1 set of coil.
7. 1 FPGA reconfigurable data acquisition card.
8. 1 PXI control card.
9. 1 PXI shielf.

4.1 3-Axis Precision Linear Positioning Stages

The system has two 3-axis precision linear positioning stages, stage assembly A and stage assembly B. The stage bases are made of non magnetic aluminum. The stage travel distance is 180 mm. The stage lead screw has 1.00 mm pitch. The linear stages are assembled in such way that the Y motion is stacked on top of the Z motion that in turn is stacked on top of the X motion.



Motorized Precision Stages

Each axis is remotely controlled by a SmartMotor. The SmartMotor is a brushless DC servo-motor that uses a built in controller and amplifier to perform programmed motion. The servo controller uses closed loop PID control. The SmartMotors run from commands received from RS232 communication cable.

Animatics SmartMotor

4.2 Precision Rotary Positioning Stages

On each of the Y linear stage table, there is a precision rotary positioning stage. The rotary stages are 205 RT series worm gear drive tables from Parker Automation. The base of the stage again is made of non-magnetic aluminum. They have 1:90 gear ratio. Each rotary stage is remotely driven by a SmartMotor.

Parker Rotary Stage

4.3 Linear Encoder

There is a linear encoder mounted on the X linear stage of the stage assembly A. The linear encoder is ENC 150 series encoder from ACU-RITE. It has 12" measuring length with 0.5 micron resolution. The linear encoder is used to accurately define the position of the stretched measure coil on the X axis.

ACU-RITE Linear Encoder

4.4 Rotary Encoder

A rotary encoder is mounted on the rotary stage of the stage assembly A. The rotary encoder is RON 225 precision rotary encoder from HEIDENHAIN. It has a 20 mm hole on the shaft that allows the stretched coil to go through. The encoder has 360 degree freedom with 0.005 degree resolution. The rotary encoder is used to accurately define the angular position of the stretched measure coil.

Heidenhain Rotary Encoder

4.5 Pre-Amplifier with Low-Pass Signal Filter

A differential DC signal conditioner is used as pre-amplifier. It is Ectron 428-O with auto zero suppression.

Ectron 428-O DC Signal Conditioner

4.6 Stretch Coil

The coil is made with a 10-strand Litz wire. The coil is spring loaded on to a set of coil holders mounted on the rotary tables. The spring constant is about 10 N/cm.

4.7 FPGA Reconfigurable Data Acquisition Card

While the stretched coil is rotating along the direction perpendicular to its stretched direction, any field integral along that axis will generate a voltage signal in the coil. The signal strength is defined by the strength of the field integral, the width of the coil, and the rotating speed. The width of the coil can be measured independently. In order to define the field integral strength, the signal measurement and the rotation speed (angular position and time) measurement has to be synchronized. The PXI-7831R FPGA Reconfigurable Data Acquisition card from National Instruments provides a flexible hardware platform for the tasks. The 96 channels of on-board digital I/O can be reconfigured at the hardware level into encoder readouts. The 8 channels of on-board 16 bit analog input can be reconfigured into voltage measurement. The 200 MHz clock can be used to synchronize the positions and voltage measurement and provide the time stamp for the measurement to yield the speed information.

PXI-7831R FPGA Reconfigurable Data Acquisition Card

4.8 PXI Control Card

The PXI Control Card is a PXI-8174 embedded controller for PXI and CompactPCI from National Instruments. It has a 566 MHz CPU and 256 MB on-board memory.

PXI-8174 Embedded PXI Controller

4.9 PXI Shelf

The shelf is a PXI-1002 PXI shelf from National Instruments. The shelf has 4 slots. Slot 1 hosts the embedded controller. Slot 2 is occupied with the PXI-7831R FPGA reconfigurable data acquisition card.

PXI-1002 PXI Shelf

5. SYSTEM SOFTWARE

The Field Integral Measurement system software has a Main Interface and the following main modules and sub-modules:

1. Advanced Motion Control Module.
    a. Motor Velocity and Acceleration Control and Monitoring Sub-module.
2. Integral Average Measurement Module.
    a. Advanced Motion Control Module.
    b. Integral Average Measurement Analysis and Plot Sub-module.
3. Integral Muli-measurement Module.
    a. Advanced Motion Control Module.
    b. Integral Muli-measurement Analysis and Plot Sub-module.
4. Integral Translation Measurement Module
    a. Advanced Motion Control Module.
    b. Integral Translation Measurement Analysis and Plot Sub-module.
5. Integral Measurement FPGA Firmware Module.

Each module and sub-module has its own GUI interface. The Main Interface provides an access interface to all the main modules and hence the sub-modules. It checks the status of the FPGA reconfiguration data acquisition. If the FPGA card is not running or is running on different firmware, the module will download and initialize the card with the appropriate firmware. It also checks the status of all 8 SmartMotors. If the motors are not initialized, it will try to re-initialize the motors.

For advanced motion control, the system checks the status of all 8 SmartMotors. If they are not initialized, it will try to re-initialize the motors. The module monitors all 8 motor positions and the encoder positions, as well as voltage measurements. It provides motor absolute motion and relative motion control interfaces. From the advanced motion control, one can access the velocity and acceleration control interface.

The velocity and acceleration control interface sets and gets the motor velocity and acceleration values.

Integral measurement modules set the measurement parameters, pass the parameters to the FPGA card, set the motor positions, retrieve the measurement data from the FPGA on-board memory, carry out real time data analysis, plot out the data and fitting parameters, and write the data, fitting parameters, as well as the ID information to a file.

Each measurement module has its own post-analysis and plot module. The plot modules retrieves the data and parameters from files, fits the data with user defined parameters, and plots them out on the screen.

From each measurement module, one can access the advanced motion control module.

6. PREPARATIONS

The system involves 110 AC Voltage, Mechanical Motion, and possibly High Magnetic Field. Extra safety precaution has to be taken. Users shall take proper safety training classes before operation of the system.

7. HARDWARE CONNECTIONS

All the hardware sub-system shall be wired appropriately according to their user's manual.

7.1 SmartMotor Connections

Make sure the DB9 connector of RS-232 cable from the back of the Animatics SmartMotors mounted on the motorized stages is connected to the COM1 port of the computer. The connectors to the SmartMotors are labeled and shall be connected in the following sequence:

Motor Axis	W1	X1	Y1	Z1	W2	X2	Y1	Z2
Motor Connector	1	2	3	4	5	6	7	8

SmartMotor 1 through 4 powered by power supply A. SmartMotor 5 through 8 powered by power supply B. Please reference to the SmartMotor User's Manual for multi-motor cabling.

7.2 Rotary Encoder Connections

The HEIDENHAIN RON 225 rotary encoder to the FPGA data acquisition card connections:

RON 225	A	B	Z	+5V	0V
PIN #	5	8	3	12	10
FPGA	DIO0	DIO1	DIO2	+5V	DGND
MIO PIN#	36	37	38	1	2

7.3 Linear Encoder Connections

The ACU-RITE ENC 150 linear encoder to the FPGA data acquisition card connections:

ENC 150	A	B	Z	+5V	0V
PIN #	2	4	8	7	6
FPGA	DIO3	DIO4	DIO5	+5V	DGND
MIO PIN#	39	40	41	35	5

7.4 Pre-AMP Connections

The stretched coil shall be terminated by a differential pre-amp, that in turn, connected to the FPGA MIO Analog Input 0+ and 0- (MIO ping number 68 and 34).

7.5 Other Connections

For external triggered measurements such as those electric magnetic devices, the external TTL triggering signal shall be wired to MIO DIO7 (MIO ping number 43).

8. COMPUTER REQUIREMENTS

The PXI controller is loaded with Windows XP Professional that is registered to the APS network. Therefore, any computer that is registered to the APS network can access the PXI controller. Currently, the controller can be accessed from a PC based computer through Remote Desktop provided by Microsoft. The application can also be accessed through other machines such as Apple computers or Unix based computers via http interface in the future. In that cases, the client machine has to load the LabVIEW Run Time Machine from National Instruments.

9. SOFTWARE INSTALLATION

The Field Integral Measurement System Control Software Package includes the following files:

1. setup.exe
2. setup.ini
3. install.msi
4. InstMsi.exe
5. InstMsiW.exe
6. data.cab
7. system.db

If the package is on a CD, insert the CD into the CD ROM of the PC, double click the setup.exe file and follow the instruction to install the software package.

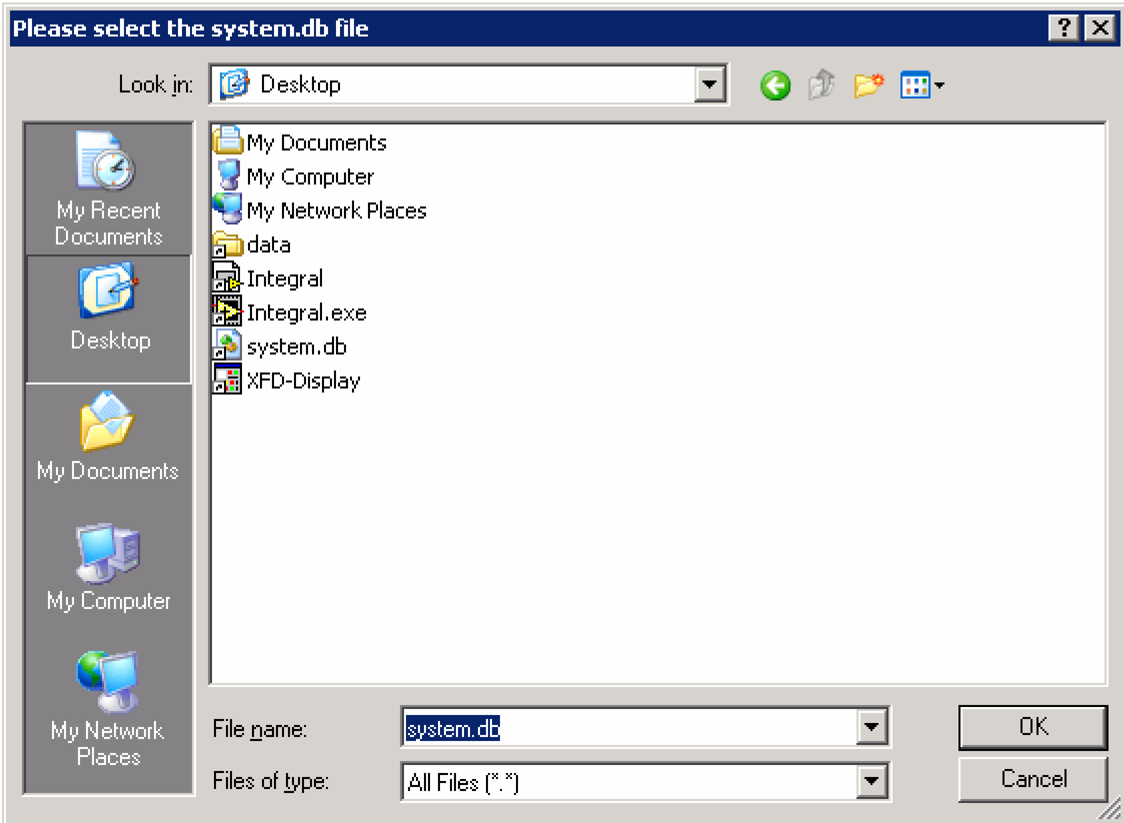
10. SYSTEM CONTROL SOFTWARE INTRODUCTION

The control software consists of the main user control interface, and four user interface modules. The user interface modules include:

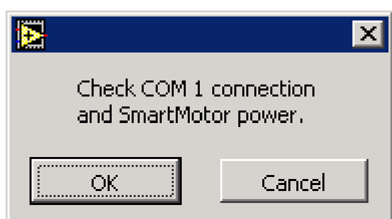
1. Advanced Motion Control Module.
2. Integral Average Measurement Module.
3. Integral Multi-measurement Module.
4. Integral Translation Measurement Module

10.1 Main Interface Window

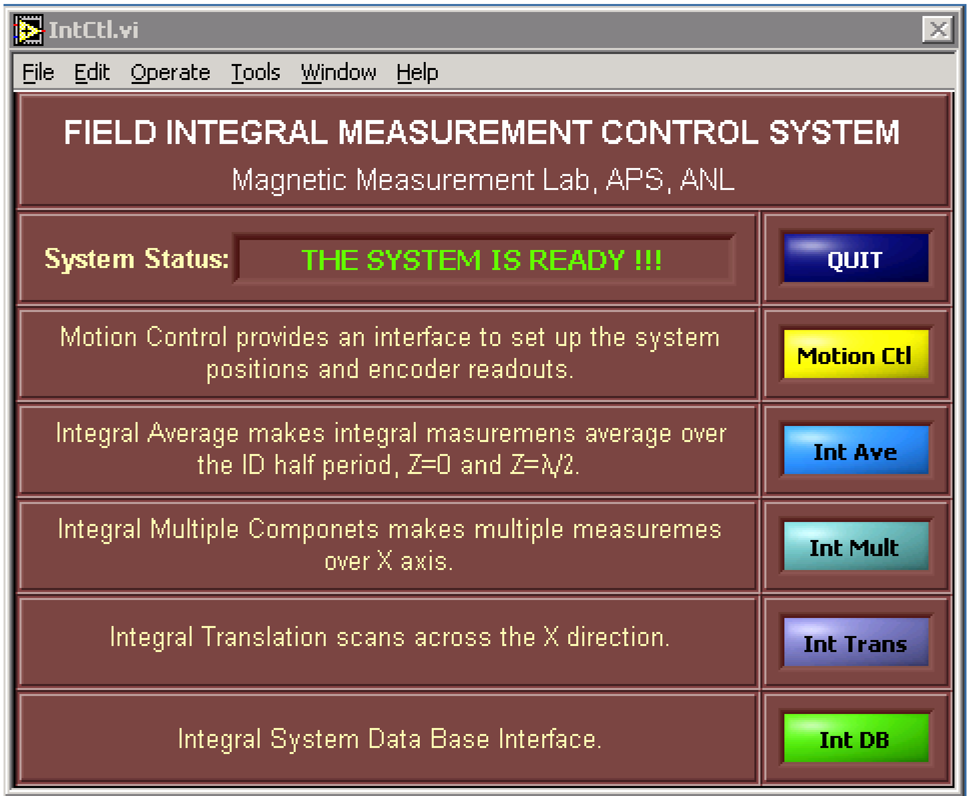
At launch, the main interface asks for the system.db file to be loaded.



After the system.db file gets loaded, the system checks the status of the FPGA reconfiguration data acquisition. If the FPGA card is not running or is running on different firmware, the module will download and initialize the card with the appropriate firmware. It also checks the status of all 8 SmartMotors. If the motors are not initialized, it will try to re-initialize the motors. If the motors are not powered up or the communication cable is not connected, the system will popup a window to ask you to check.



If every thing is ok, the system will then provide the Main Interface Window that shows the System Status information and an access interface to all the main modules as shown in the diagram.



The Main Interface Window

10.1.1 Display and Control Fields

- **QUIT** button quits the program. It does not exit the program. To completely exit the program, you have to go to the File menu and chose Exit.
- **Motion Ctl** button launches the Advanced Motion Control Interface Window that allows you to set up the system position and encoder readout parameters.
- **Int Ave** button launches the Period Average Field Integral Measurement Control Interface Window. Integral average makes integral measurement average over the ID half period, Z=0 and Z=λ/2.
- **Int Mult** button launches the Multiple Components Integral Measurement Control Interface Window. Multiple component integral makes multiple integral measurement over X axis.
- **Int Trans** button launches the Integral Translation Scan Measurement Control Interface Window. The integral translation scan makes scans across the X axis.
- **Int DB** button launches the System Database Management Control Interface Window. The System Database Management manages the system parameter database.

10.2 Advanced Motion Control Interface

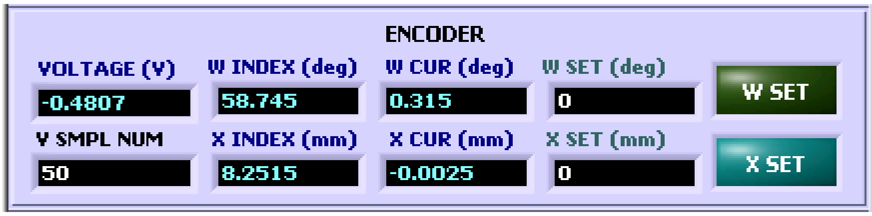
By clicking the **Motion Ctl** button in the main interface windows above, the system launches the Advanced Motion Control Interface Window as shown bellow.

The Advanced Motion Control Window has over 50 display and control fields. The detailed description of each field is listed in the following paragraphs.

10.2.1 GENERAL

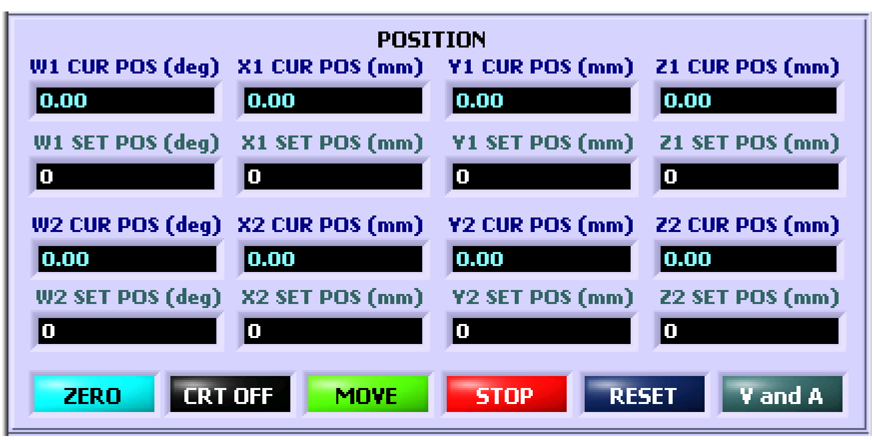
- **SYSTEM STATUS** field at the up left side of the window displays the system current status.
- **COM PORT** field sets the RS-232 motor control interface. The default value is COM1
- **INIT** button, forces the system to re-initialize the SmartMotors
- **Back to Main** button, closes the window.

10.2.2 ENCODER



- **VOLTAGE (V)** field displays the voltage measurement average upon the number of measurements set in the **V SMPL NUM** field in volts.
- **W INDEX (deg)** field displays the rotary encoder index position in degree.
- **W CUR (deg)** field displays the current position of the rotary encoder position in degrees.
- **W SET (deg)** field let one enter the current rotary encoder position to be set.
- **W SET** button, sets the rotary encoder current position to the value entered in the **W SET (deg)** field.
- **V SMPL NUM** field sets the number of voltage samples averaged for each measurement to the entered value.
- **X INDEX (mm)** field displays the linear encoder index position in millimeter.
- **X CUR (mm)** field displays the current position of the linear encoder in millimeter.
- **X SET (mm)** field let one enter the current linear encoder position to be set.
- **X SET** button, sets the linear encoder current position to the value entered in the **X SET (mm)** field.

10.2.3 POSITION

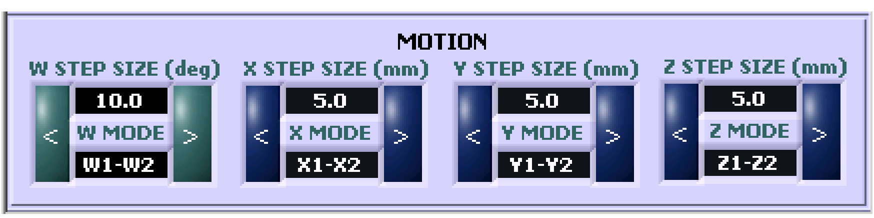


- **W1 CUR POS (deg)** field displays the current W1 motor position converted to the rotary table of the stage assembly A angle position unit in degrees.
- **X1 CUR POS (mm)** field displays the current X1 motor position converted to the X axis table of the stage assembly A position in millimeter.
- **Y1 CUR POS (mm)** field displays the current Y1 motor position converted to the Y axis table of the stage assembly A position in millimeter.
- **Z1 CUR POS (mm)** field displays the current Z1 motor position converted to the Z axis table of the stage assembly A position in millimeter.

- **W2 CUR POS (deg)** field displays the current W2 motor position converted to the rotary table of the stage assembly B angle position unit in degrees.
- **X2 CUR POS (mm)** field displays the current X2 motor position converted to the X axis table of the stage assembly B position in millimeter.
- **Y2 CUR POS (mm)** field displays the current Y2 motor position converted to the Y axis table of the stage assembly B position in millimeter.
- **Z2 CUR POS (mm)** field displays the current Z2 motor position converted to the Z axis table of the stage assembly B position in millimeter.
- **W1 SET POS (deg)** field let one enter the current W1 position to be set.
- **X1 SET POS (deg)** field let one enter the current X1 position to be set.
- **Y1 SET POS (deg)** field let one enter the current Y1 position to be set.
- **Z1 SET POS (deg)** field let one enter the current Z1 position to be set.
- **W2 SET POS (deg)** field let one enter the current W2 position to be set.
- **X2 SET POS (deg)** field let one enter the current X2 position to be set.
- **Y2 SET POS (deg)** field let one enter the current Y2 position to be set.
- **Z2 SET POS (deg)** field let one enter the current Z2 position to be set.
- **ZERO** button sets all the motor current positions (all the **CUR POS** fields) to zero.
- **CRT OFF** button sets all the motor servo current to zero. In the CRT OFF mode, the **SYSTEM STATUS** field will show **Current Off** and all the LEDs on the SmartMotor shall turn from green to red.
- **MOVE** button moves the motors to the values shown in the **SET POS** fields.
- **STOP** button stops all motors during motion.
- **RESET** button resets the **SET POS** field values to their **CUR POS** field values respectively.
- **V and A** button launches the motion velocity and acceleration setting windows described in the **Motion Velocity and Acceleration Control** section.

10.2.4 MOTION

The MOTION panel provides relative motion control to the motors.



- **W STEP SIZE (deg)** pull down menu provides a selection of the rotary motion step sizes among 0.1, 1.0, 5.0, and 10.0 degrees.
- **W MODE** pull down menu provides a selection of the rotary motion between two rotary axes: W1, W2, W1+W2, and W1-W2.
- **<** button in the left moves backwards.
- **>** button in the right moves forwards.
- **X STEP SIZE (mm)** pull down menu provides a selection of the X linear motion step sizes among 0.1, 0.5, 1.0, and 5.0 millimeters.
- **X MODE** pull down menu provides a selection of the rotary motion between two X linear axes: X1, X2, X1+X2, and X1-X2.

- **<** button in the left moves backwards.
- **>** button in the right moves forwards.
- **Y STEP SIZE (mm)** pull down menu provides a selection of the X linear motion step sizes among 0.1, 0.5, 1.0, and 5.0 millimeters.
- **Y MODE** pull down menu provides a selection of the rotary motion between two Y linear axes: Y1, Y2, Y1+Y2, and Y1-Y2.
- **<** button in the left moves backwards.
- **>** button in the right moves forwards.
- **Z STEP SIZE (mm)** pull down menu provides a selection of the X linear motion step sizes among 0.1, 0.5, 1.0, and 5.0 millimeters.
- **Z MODE** pull down menu provides a selection of the rotary motion between two Y linear axes: Z1, Z2, Z1+Z2, and Z1-Z2.
- **<** button in the left moves backwards.
- **>** button in the right moves forwards.

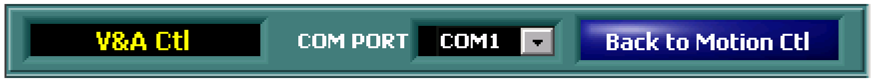
10.3 Motion Velocity and Acceleration Control

By clicking the A & V button in the Advanced Motion Control Window, the system launches the Motor Velocity and Acceleration Control interface window as shown bellow.

Motion Velocity and Acceleration Control Window

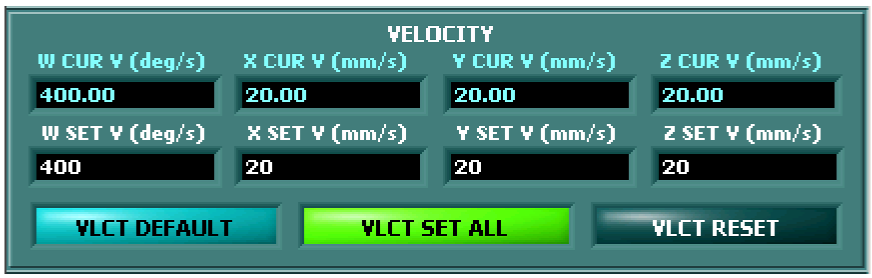
The Motor Velocity and Acceleration Control Window has over 25 display and control fields. The detailed description of each field is listed in the following paragraphs.

10.3.1 GENERAL



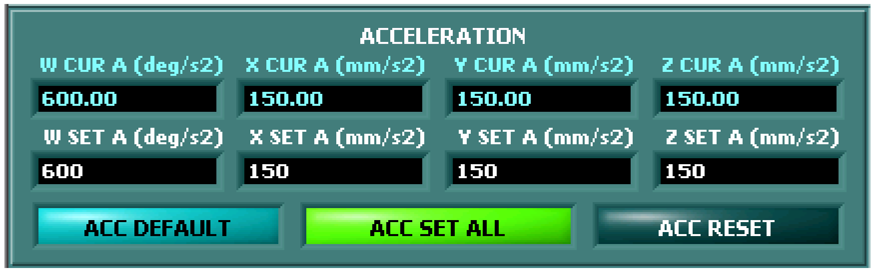
- **SYSTEM STATUS** field at the up left side of the window displays the system current status.
- **COM PORT** field sets the RS-232 motor control interface. The default value is COM1
- **Back to Main** button, closes the window.

10.3.2 VELOCITY



- **W CUR V (deg/s)** field displays the current rotation speed for both rotary stages in degrees per second.
- **W SET V (deg/s)** let one enter the current rotation speed to be set.
- **X CUR V (mm/s)** field displays the current motion speed for both X linear stages in millimeters per second.
- **X SET V (mm/s)** let one enter the current X linear motion speed to be set.
- **Y CUR V (mm/s)** field displays the current motion speed for both Y linear stages in millimeters per second.
- **Y SET V (mm/s)** let one enter the current X linear motion speed to be set.
- **Z CUR V (mm/s)** field displays the current motion speed for both Z linear stages in millimeters per second.
- **Z SET V (mm/s)** let one enter the current Z linear motion speed to be set.
- **VLCT DEFAULT** button sets the current velocity values to the system default values as shown in the diagram.
- **VLCT SET ALL** button sets all the system velocity to the values in the **SET V** fields entered by the user.
- **VLCT RESET** button resets all the **SET V** fields to the **CUR V** field values.

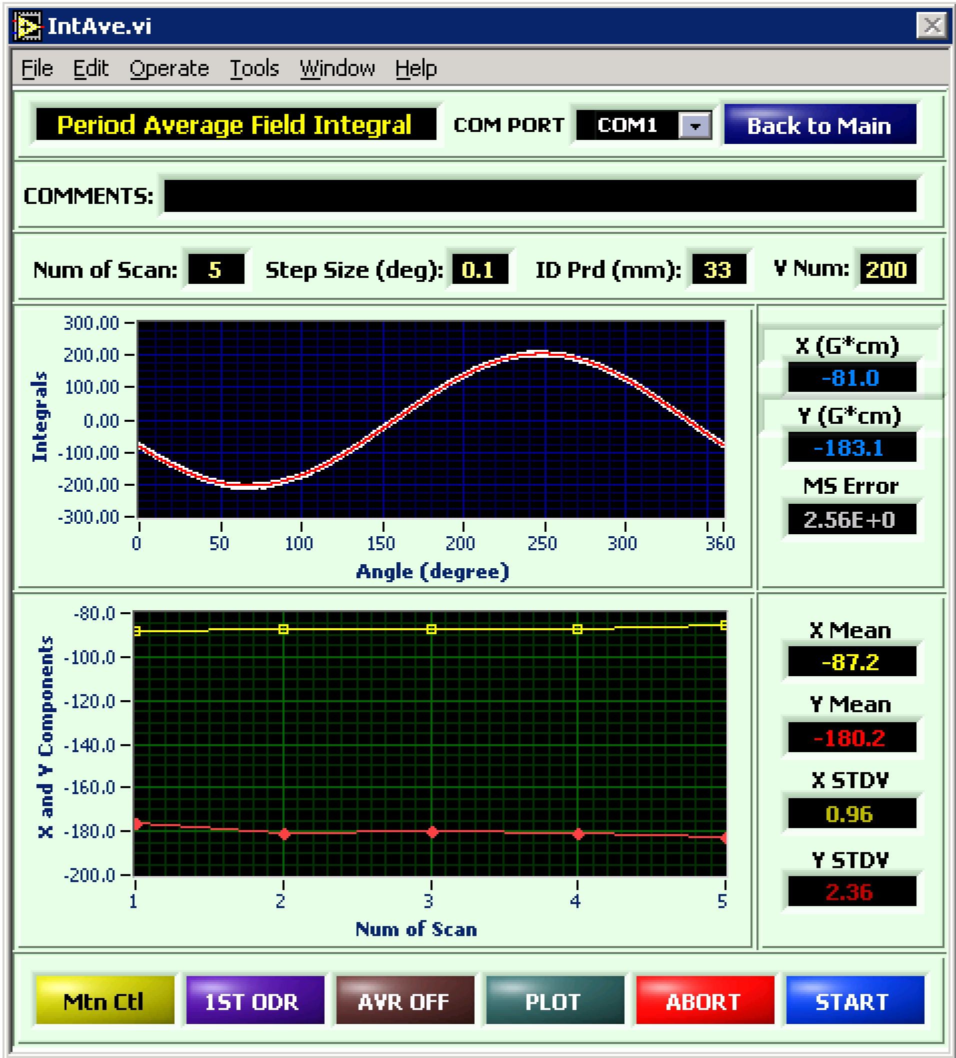
10.3.3 ACCELERATION



- **W CUR A (deg/s2)** field displays the current rotation acceleration for both rotary stages in degrees per second square.
- **W SET A (deg/s2)** let one enter the current rotation acceleration to be set.
- **X CUR A (mm/s2)** field displays the current motion acceleration for both X linear stages in millimeters per second square.
- **X SET A (mm/s2)** let one enter the current X linear motion acceleration to be set.
- **Y CUR A (mm/s2)** field displays the current motion acceleration for both Y linear stages in millimeters per second square.
- **Y SET A (mm/s2)** let one enter the current X linear motion acceleration to be set.
- **Z CUR A (mm/s2)** field displays the current motion acceleration for both Z linear stages in millimeters per second square.
- **Z SET A (mm/s2)** let one enter the current Z linear motion acceleration to be set.
- **VLCT DEFAULT** button sets the current acceleration values to the system default values as shown in the diagram.
- **VLCT SET ALL** button sets all the system acceleration to the values in the **SET A** fields entered by the user.
- **VLCT RESET** button resets all the **SET A** fields to the **CUR A** field values.

10.4 Period Average Field Integral Control Interface

Integral average makes integral measurement average over the ID half period, Z=0 and Z=λ/2. By clicking the **Int Ave** button in the main interface windows above, the system launches the Period Average Field Integral Control Interface Window as shown bellow.



The Period Average Field Integral Control Window has over 20 display and control fields and two real time plot fields. The detailed description of each field is listed in the following paragraphs.

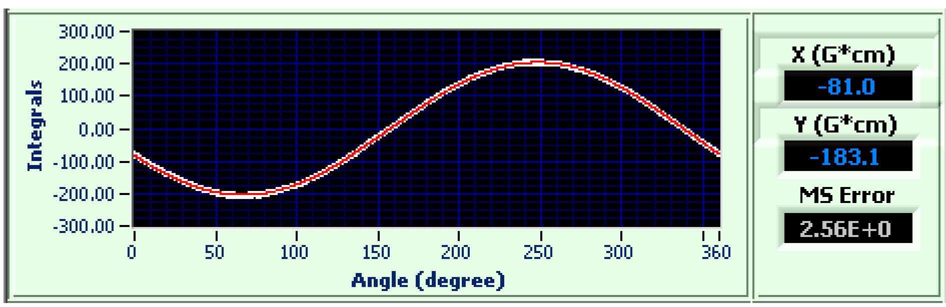
10.4.1 GENERAL

- **SYSTEM STATUS** field at the up left side of the window displays the system current status.
- **COM PORT** field sets the RS-232 motor control interface. The default value is COM1
- **Back to Main** button, closes the window.

10.4.2 CONTROL INPUT FIELDS

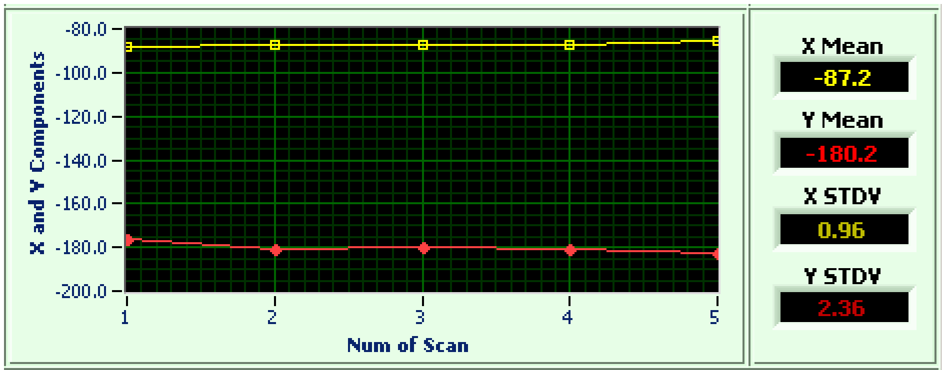
- **COMMENTS** field allows user to enter the ID device information including the serial number of the device to be tested.
- **Num of Scan** field sets the number of scans for each measurement.
- **Step Size (deg)** pull down menu provides angular scan step size in degrees. The selections are 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.8, 0.9, and 1.0 degrees.
- **ID Prd (mm)** field allows user to enter the ID device period in millimeter. The information is need for measurements average over the ID periods.
- **V Num** field allows user to enter the number of voltage samples taken for each data point for display only. The number of voltage samples taken during real-time data acquisition is optimized by the hardware to the maximum number the system can reach based on the dynamic time duration between two data points.

10.4.3 SCAN REAL TIME FIT AND PLOT



- **Integral(G*cm) vs. Angle (degree)** plots each individual scan raw data along with their sinusoidal fitting data in real time.
- **X Comp.** field displays the X fitting Component.
- **Y Comp.** field displays the Y fitting Component.
- **MS Error** field displays the fitting Mean Square Error.

10.4.4 SCAN COMPONENTS ANALYSIS AND PLOT

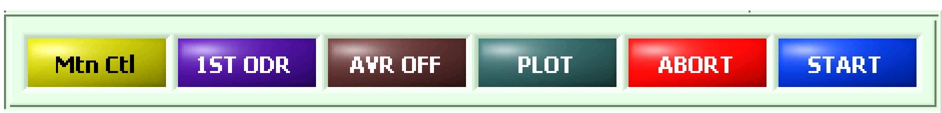


- **X and Y Components vs. Num of Scan** plots the X and Y components against the Number of Scans.
- **X Mean** field shows the mean value of the X component up to the current scan.
- **Y Mean** field shows the mean value of the Y component up to the current scan.
- **X SDTV** field shows the Standard Deviation Value of the X component up to the current scan.
- **Y SDTV** field shows the Standard Deviation Value of the Y component up to the current scan.

The colors in the plots match the colors to the numbers shown in the fields in the widow.

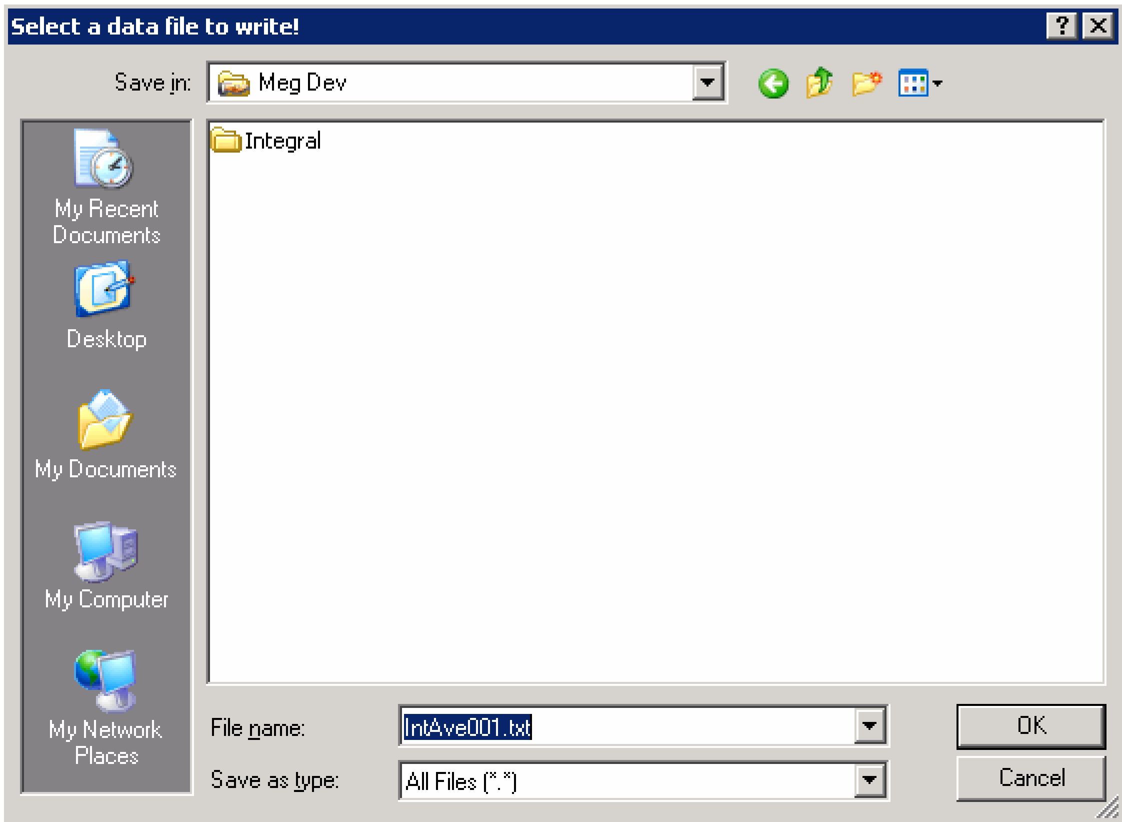
10.4.5 INTEGRAL AVERAGE CONTROLS

There are 6 control buttons at the bottom of the window as shown in the diagram bellow.



- **Motion Ctl** button launches the Advance Motion Control interface windows describe in the Advanced Motion Control section above.
- **1ST ORDER/2nd ORDER** button selects the order of the scan. The 1st order option does the flat coil scan and the 2nd order option does the cross over coil scan.
- **AVR OFF/AVR ON** button turns the scan average over ID period off/on. When AVR OFF, the system will scan at the current Z =0 poison while if it is AVR ON, the system scans at Z=0, move to Z=λ/2 and does another set of scans.
- **PLOT** button launches the Integral Average Data Plot Windows as described in its section bellow.
- **ABORT** button aborts the measurements and saves the data up to the current measurement.
- **START** button starts the measurements with the parameters defined in the above fields.

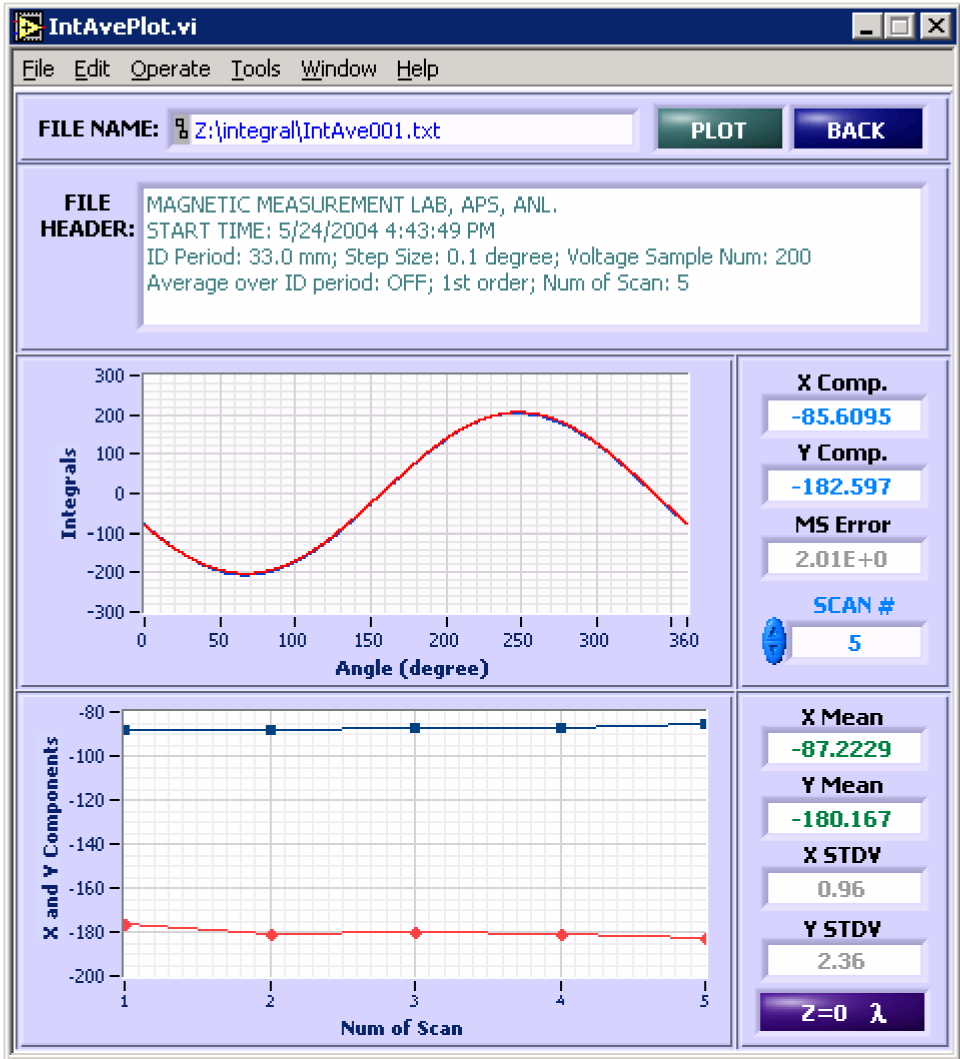
After clicking the START button, the system will launch a window shown bellow ask you to enter a file path and name to save the data and information to.



If you enter a file name that exists in the directory, it will ask you if you want to replace the existing file. You may click Replace to replace the existing file or Cancel to enter a new file name.

10.4.6 Integral Average Data Plotting

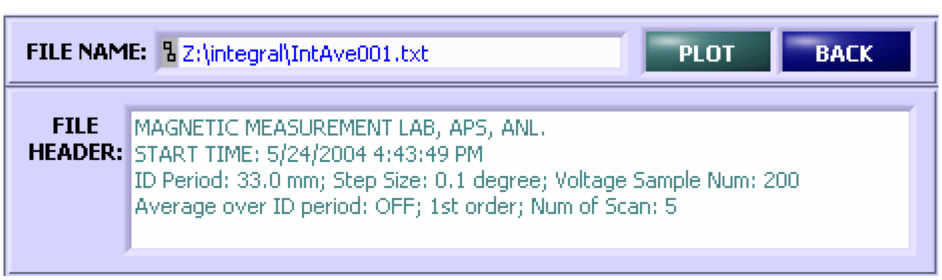
Click the **PLOT** control button in the Period Average Field Integral Control Interface Window, a PLOT Sub-Control Panel will display as shown below.



Integral Average Plot Window

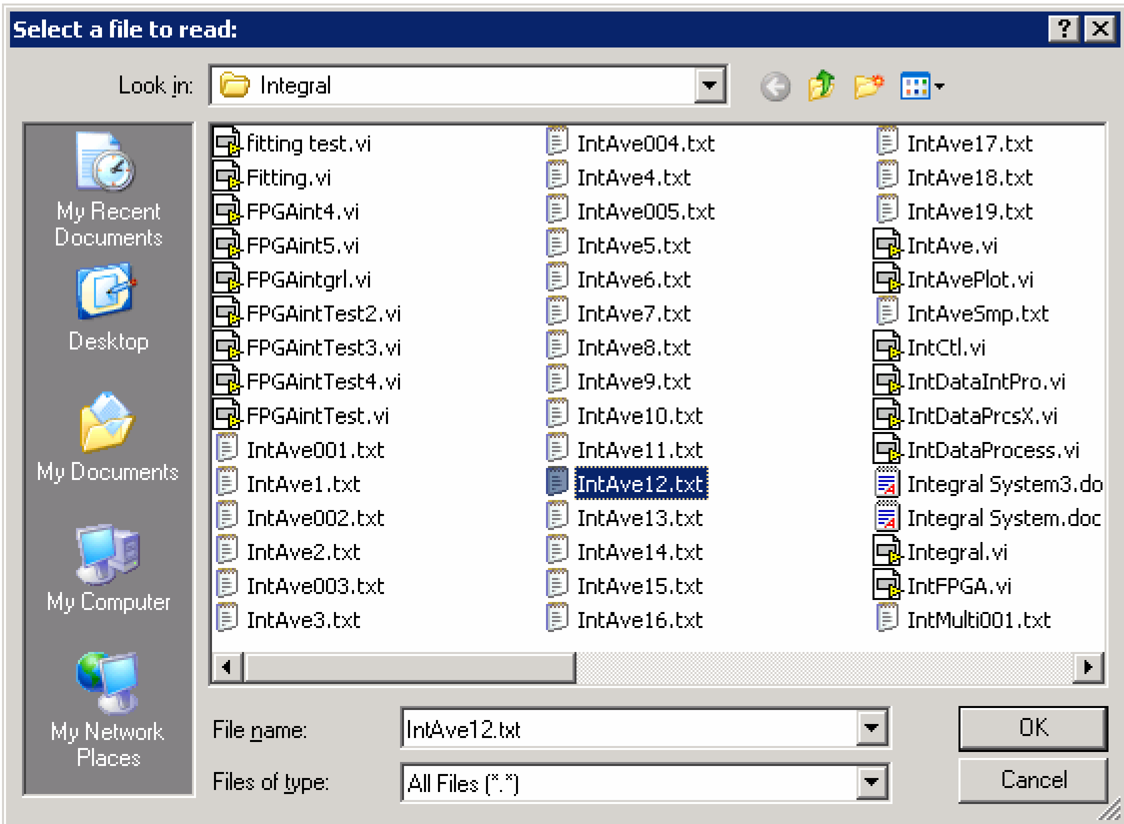
The Integral Average Plot Window has over a dozen display and control fields and two data plot fields. The detailed description of each field is listed in the following paragraphs.

10.4.6.1 GENERAL



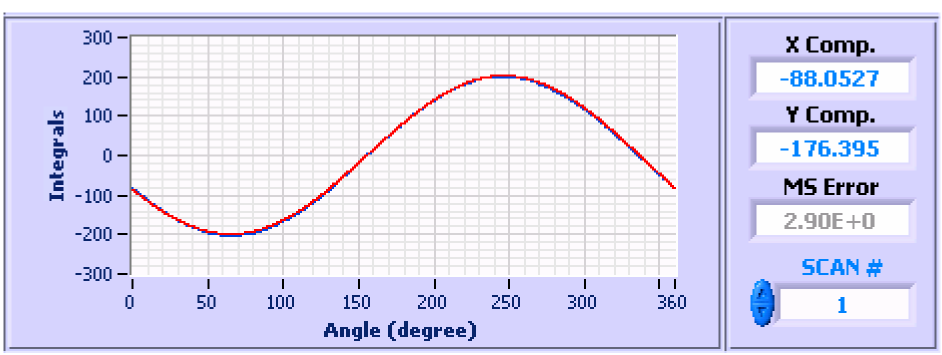
- **FILE NAME** displays the data file path and the data file name to be analyzed and plotted.

- **PLOT** control button launches a file selection window to let user to select a file to be analyzed and plotted.



- **BACK TO MAIN** control button will close the window and go back to the Period Average Field Integral Control Interface Window.
- **FILE HEADER** displays the header information of the data file.

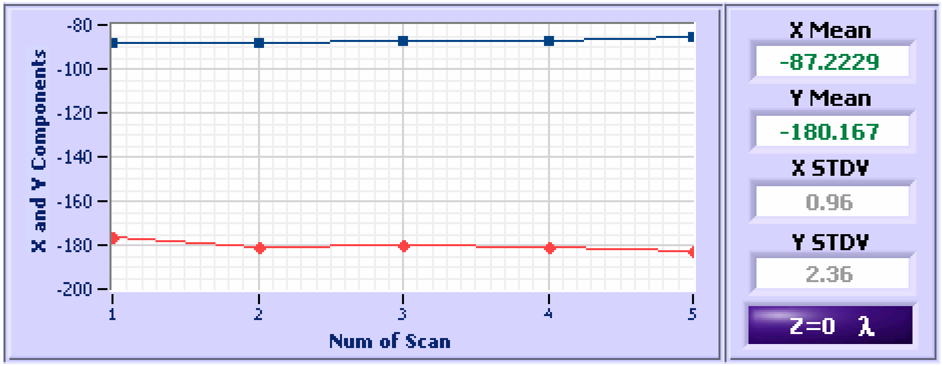
10.4.6.2 INTEGRAL AVERAGE DATA FIT AND PLOT



- **Integrals vs. Angle (degree)** plots each individual scan raw data along with their sinusoidal fitting data from the file.
- **X Comp.** field displays the X fitting Component.
- **Y Comp.** field displays the Y fitting Component.
- **MS Error** field displays the fitting Mean Square Error.

- **SCAN #** control field allows user to select which scan to be analyzed and plotted.

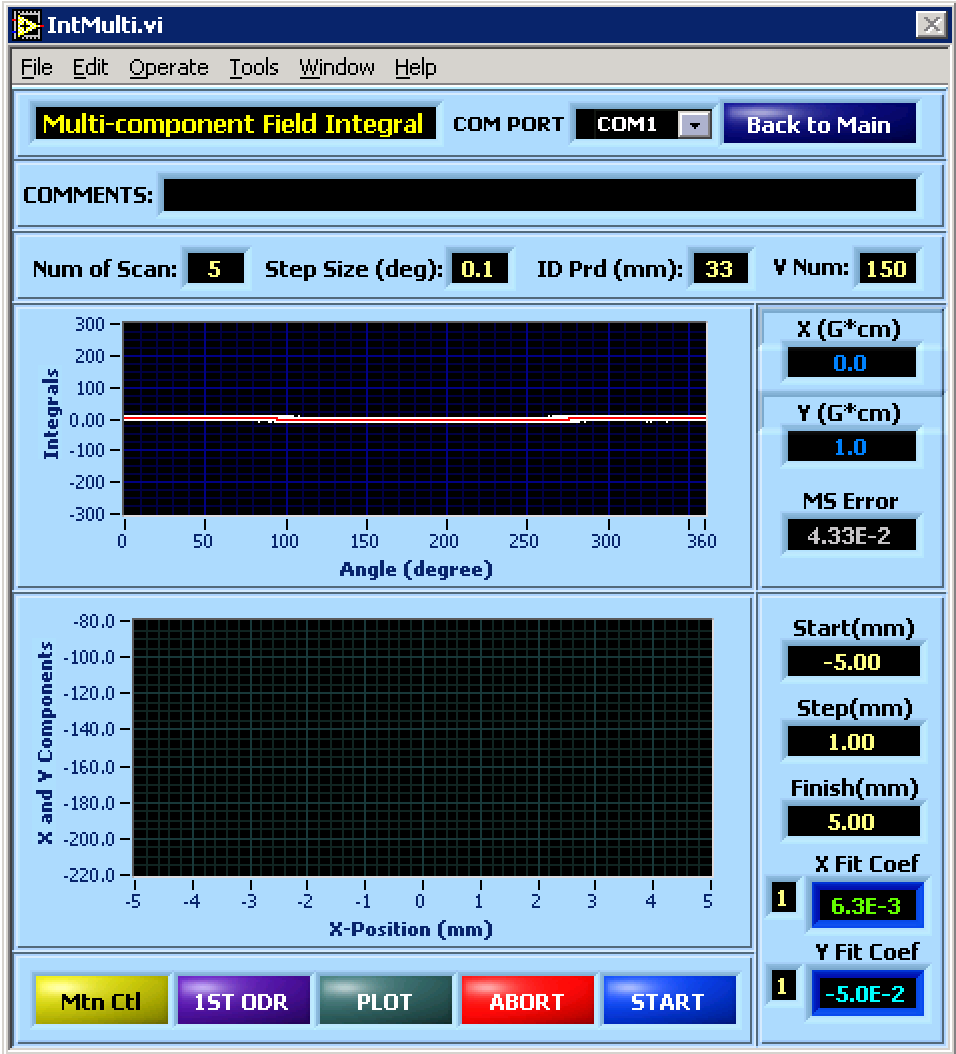
10.4.6.3 INTEGRAL AVERAGE COMPONENTS ANALYSIS AND PLOT



- **X and Y Components vs. Num of Scan** plots the X and Y components against the Number of Scans.
- **X Mean** field shows the mean value of the X component up to the current scan selected.
- **Y Mean** field shows the mean value of the Y component up to the current scan selected.
- **X SDTV** field shows the Standard Deviation Value of the X component up to the current scan selected.
- **Y SDTV** field shows the Standard Deviation Value of the Y component up to the current scan selected.
- **Z=0** λ**/Z=1/2** λ control button allow user to select the data set at Z=0 or Z=1/2 λ period.

10.5 Multi Scan Field Integral Control Interface

Multi component field integral makes multi integral measurements over the X axis. By clicking the **Int Mult** control button in the main interface windows above, the system launches the Multi Scan Field Integral Control Interface Window as shown bellow.



The Multi Scan Field Integral Control Interface Window has over 20 display and control fields and two real time plot fields. The detailed description of each field is listed in the following paragraphs.

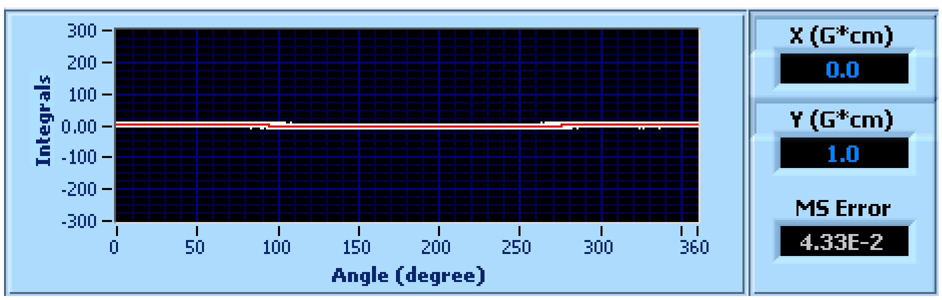
10.5.1 GENERAL

- **SYSTEM STATUS** field at the up left side of the window displays the system current status.
- **COM PORT** field sets the RS-232 motor control interface. The default value is COM1
- **Back to Main** button, closes the window.

10.5.2 CONTROL INPUT FIELDS

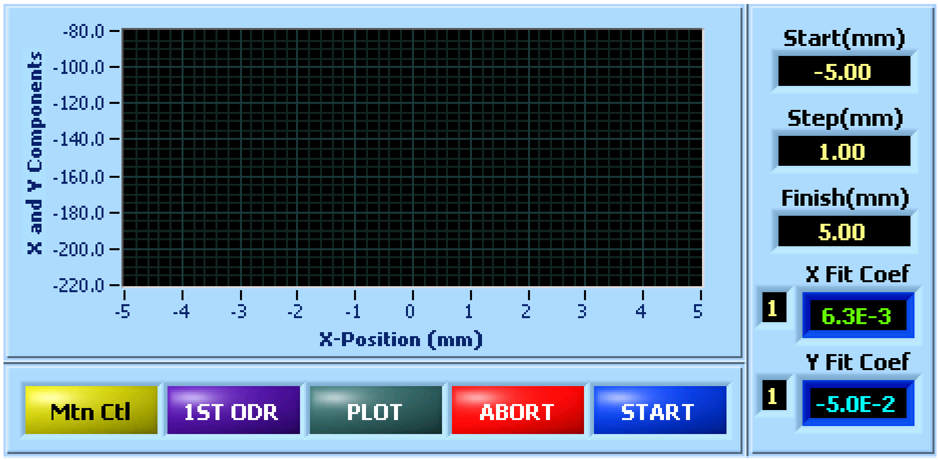
- **COMMENTS** field allows user to enter the ID device information including the serial number of the device to be tested.
- **Num of Scan** field sets the number of scans for each measurement.
- **Step Size (deg)** pull down menu provides angular scan step size in degrees. The selections are 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.8, 0.9, and 1.0 degrees.
- **ID Prd (mm)** field allows user to enter the ID device period in millimeter. The information is need for measurements average over the ID periods.
- **V Num** field allows user to enter the number of voltage samples taken for each data point for display only. The number of voltage samples taken during real-time data acquisition is optimized by the hardware to the maximum number the system can reach based on the dynamic time duration between two data points.

10.5.3 SCAN REAL TIME FIT AND PLOT



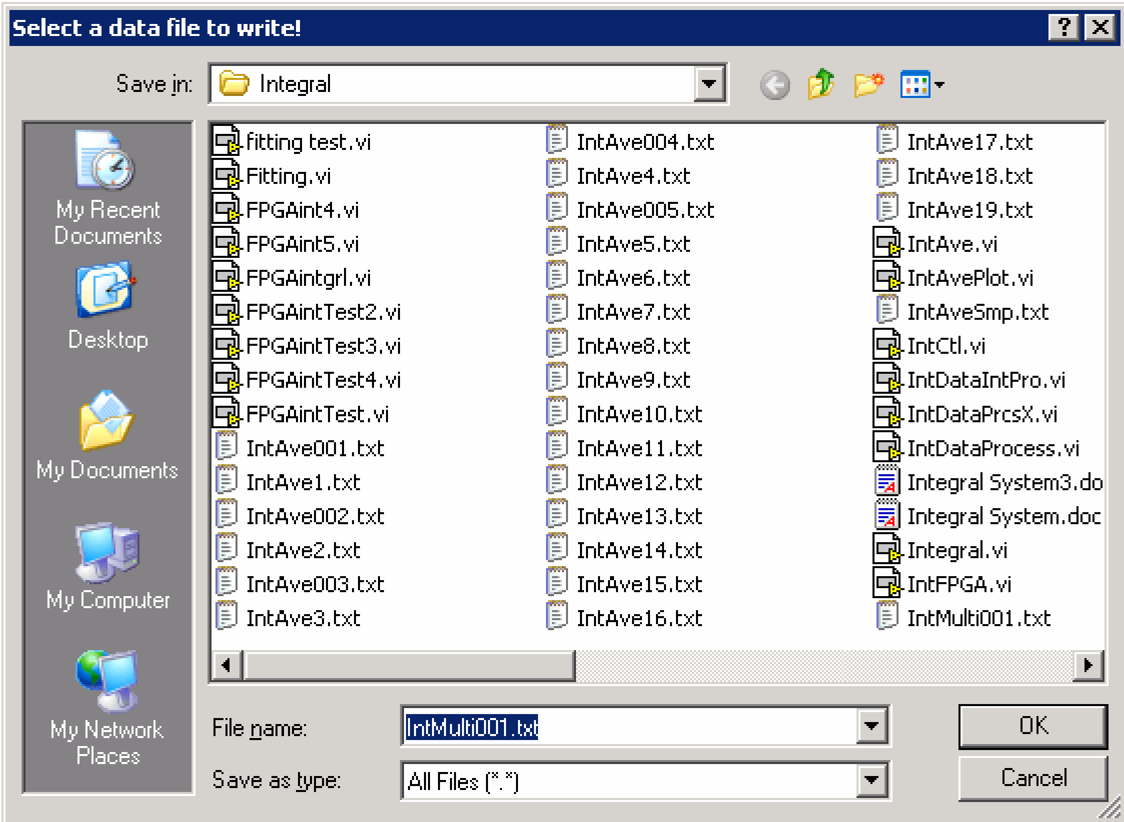
- **Integrals(G*cm) vs. Angle (degree)** plots each individual scan integral raw data along with their sinusoidal fitting data in real time.
- **X(G*cm)** field displays the X fitting Component.
- **Y(G*cm)** field displays the Y fitting Component.
- **MS Error** field displays the fitting Mean Square Error.

10.5.4 SCAN COMPONENTS ANALYSIS, PLOT, AND CONTROLS



- **X and Y Components vs. X-Position (mm)** plots the X and Y multi scan average components against the X axis position.
- **Start(mm)** field sets the X axis measurement start position.
- **Step(mm)** field sets the X axis measurement step.
- **Finish(mm)** field sets the X axis measurement finish position.
- **X Fit Coef** fields show Polynomial fitting coefficients of the X components along the X axis. User may enter different order numbers at the left field, the right filed will show the relative order coefficient parameter.
- **Y Fit Coef** fields show Polynomial fitting coefficient of the Y components along the X axis. User may enter different order numbers at the left field, the right filed will show the relative order coefficient parameter.
- **Motion Ctl** button launches the Advance Motion Control interface windows describe in the Advanced Motion Control section above.
- **1ST ORDER/2nd ORDER** button selects the order of the scan. The 1st order option does the flat coil scan and the 2nd order option does the cross over coil scan.
- **PLOT** button launches the Multi Scan Measurement Data Plot Windows as described in its section bellow.
- **ABORT** button aborts the measurements and saves the data up to the current measurement.
- **START** button starts the measurements with the parameters defined in the above fields.

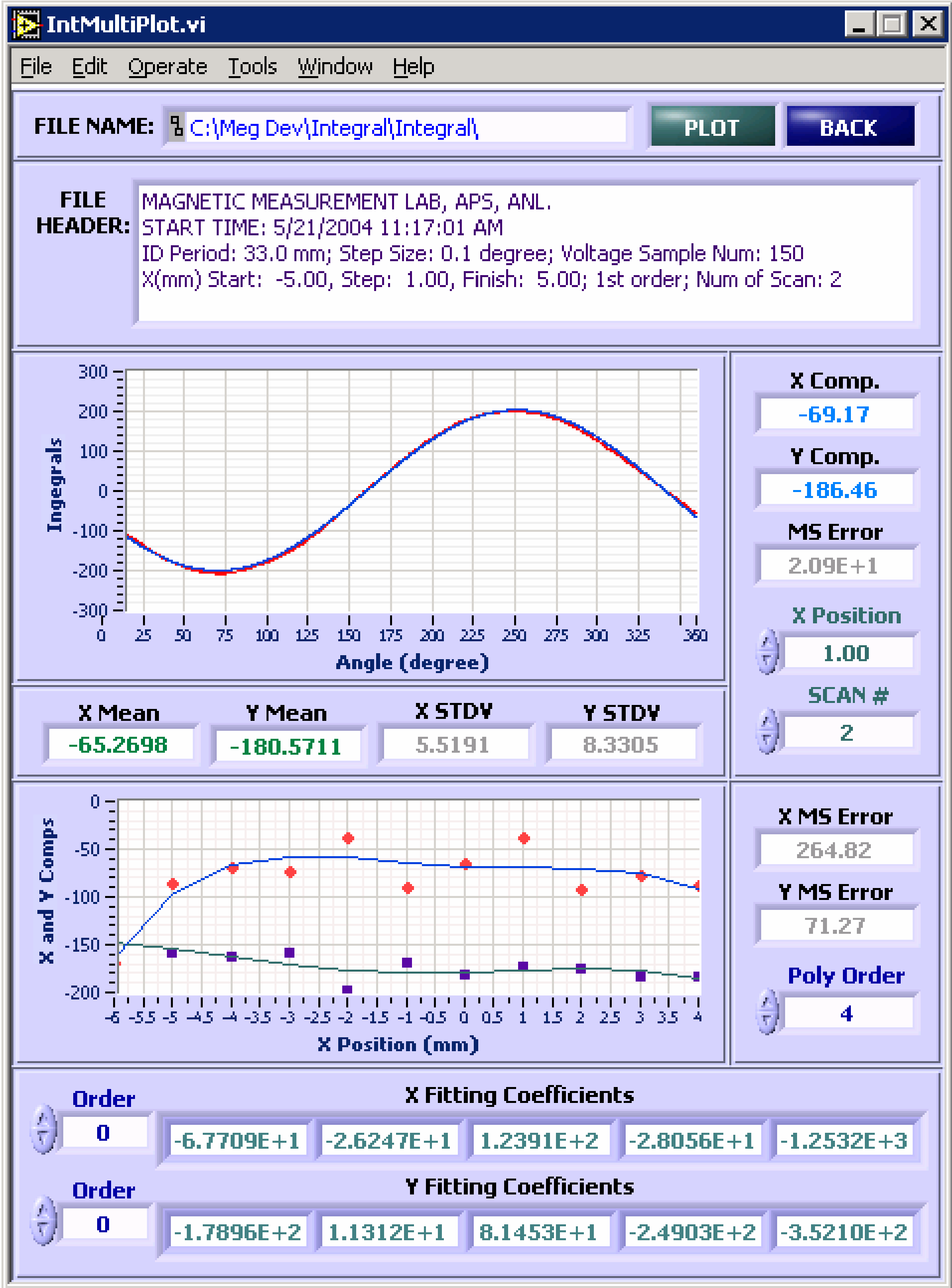
After clicking the START button, the system will launch a window shown bellow ask you to enter a file path and name to save the data and information to.



If you enter a file name that exists in the directory, it will ask you if you want to replace the existing file. You may click Replace to replace the existing file or Cancel to enter a new file name.

10.5.5 Multi Scan Field Measurement Data Plotting

Click the **PLOT** control button in the Multi Scan Field Integral Control Interface Window, a PLOT Sub-Control Panel will display as shown below.

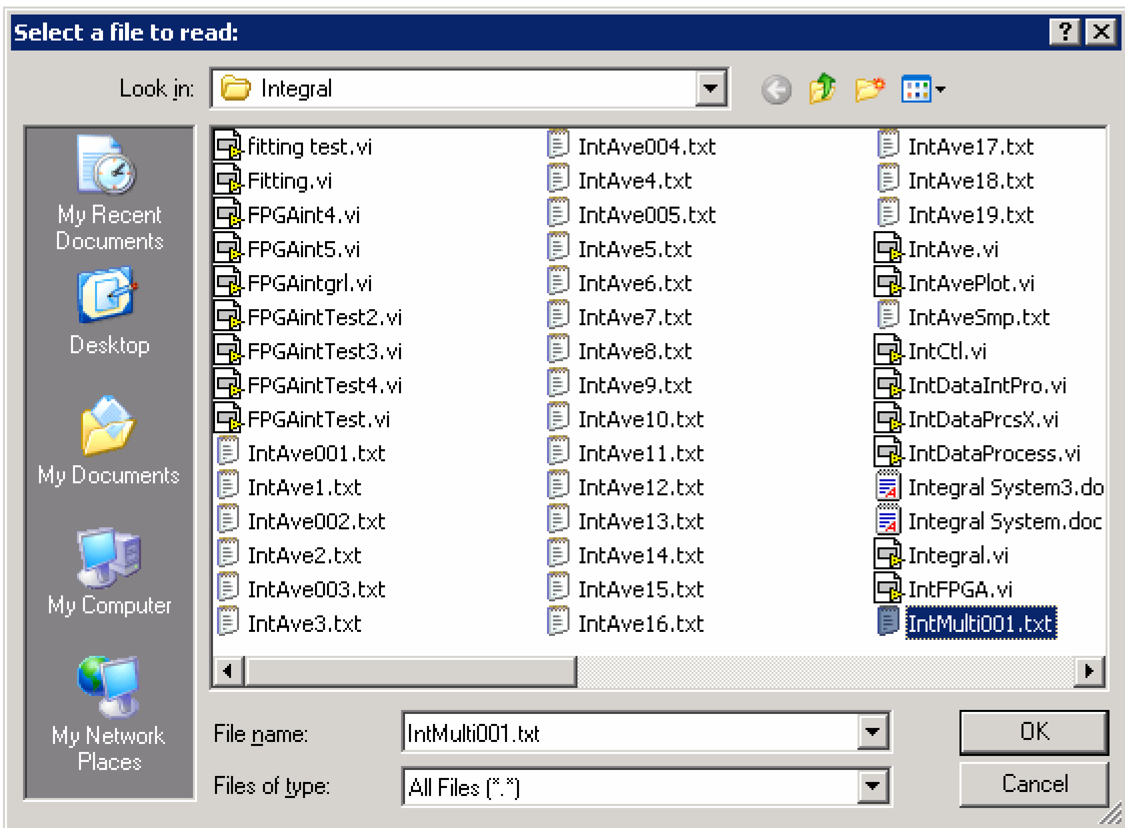


Multi Scan Field Measurement Data Plot Window

Multi Scan Field Measurement Data Plot Window has over two dozen display and control fields and two real data plot fields. The detailed description of each field is listed in the following paragraphs.

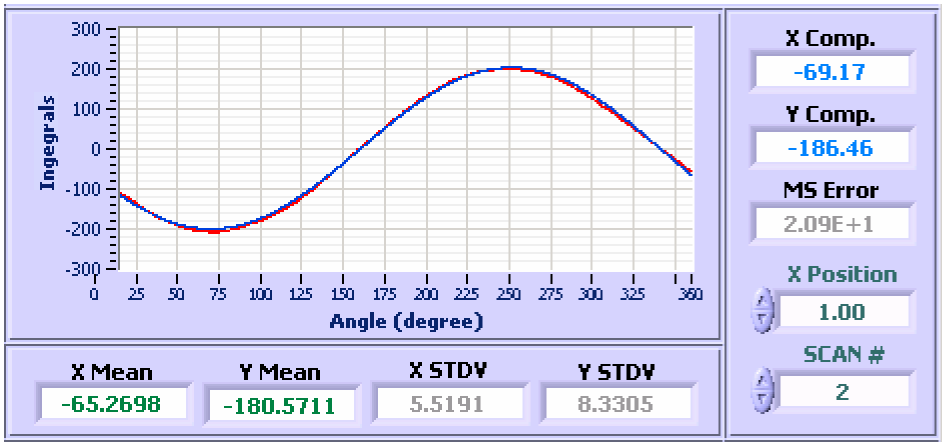
10.5.5.1 GENERAL

- **FILE NAME** displays the data file path and the data file name to be analyzed and plotted.
- **PLOT** control button launches a file selection window to let user to select a file to be analyzed and plotted.



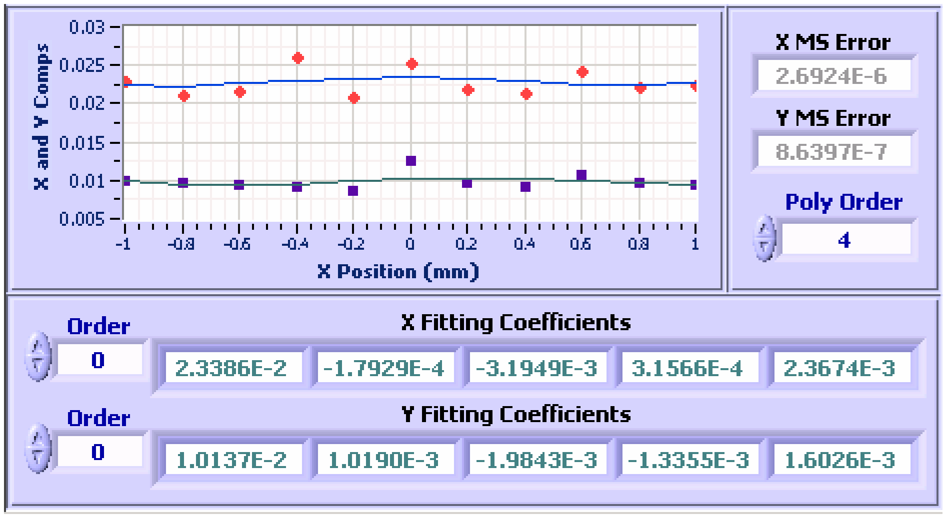
- **BACK TO MAIN** control button will close the window and go back to the Period Average Field Integral Control Interface Window.
- **FILE HEADER** displays the header information of the data file.

10.5.5.2 MULTI SCAN FIELD MEASUREMENT DATA FIT AND PLOT



- **Integrals vs. Angle (degree)** plots each individual scan raw data along with their sinusoidal fitting data from the file.
- **X Comp.** field displays the X fitting Component.
- **Y Comp.** field displays the Y fitting Component.
- **MS Error** field displays the fitting Mean Square Error.
- **X Position** control field allows user to select which X position data to be analyzed and plotted. This field is also used as reference to the fitting X axis origin and will change the fitting coefficients.
- **SCAN #** control field selects which scan to be analyzed and plotted.
- **X Mean** field shows the mean value of the X component up to the current scan selected.
- **Y Mean** field shows the mean value of the Y component up to the current scan selected.
- **X SDTV** field shows the Standard Deviation Value of the X component up to the current scan selected.
- **Y SDTV** field shows the Standard Deviation Value of the Y component up to the current scan selected.

10.5.5.3 DATA X-AXIS FITTING ANALYSIS AND PLOT

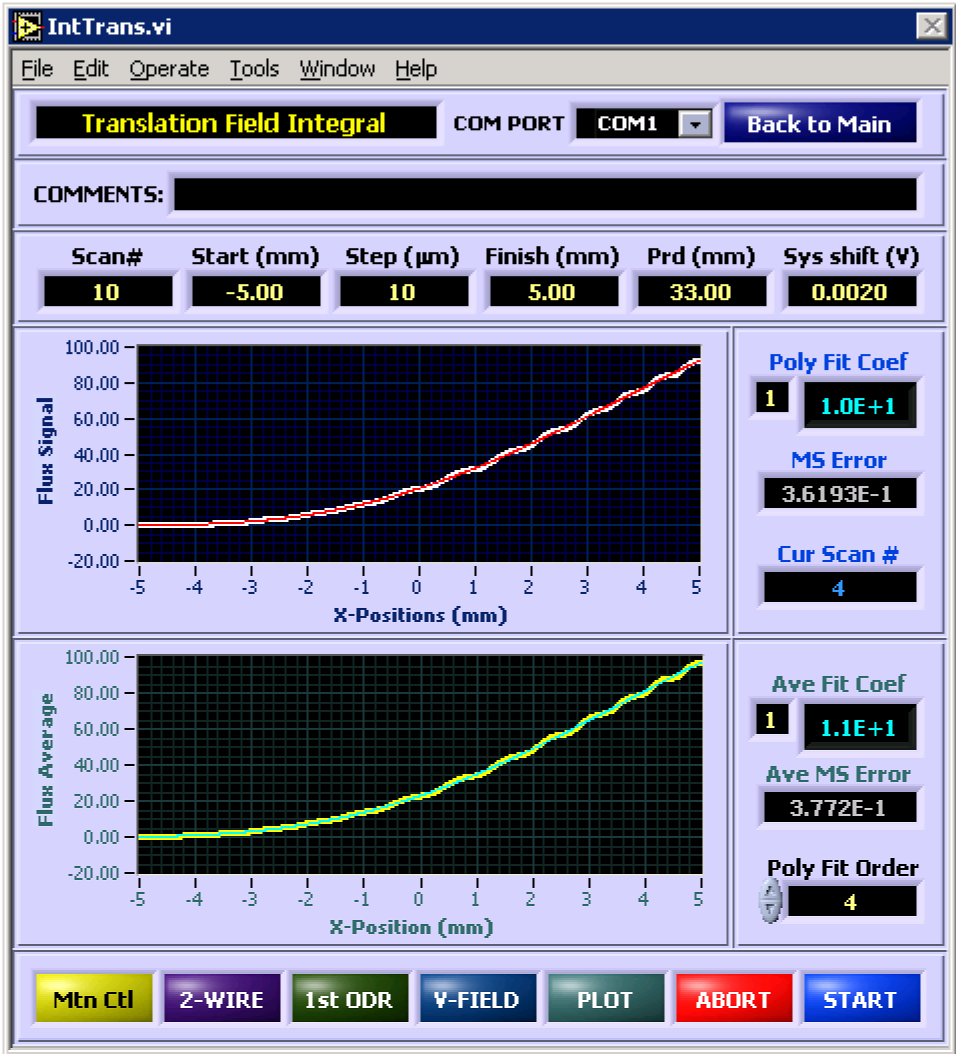


- **X and Y Components vs. X-Position (mm)** plots the X and Y multi scan average components against the X axis position.
- **X MS Error** field shows the Polynomial fitting Mean Square Error value of the X components along the X axis.
- **Y MS Error** field shows the Polynomial fitting Mean Square Error value of the Y components along the X axis.
- **Poly Order** control field sets the Polynomial fitting order parameter.
- **X Fitting Coefficients** fields shows the first 5 (0-4) Polynomial fitting order parameters for the X components. The **Order** control field sets the first fitting parameter to be displayed.
- **Y Fitting Coefficients** fields shows the first 5 (0-4) Polynomial fitting order parameters for the Y components. The **Order** control field sets the first fitting parameter to be displayed.

By changing the value in the **X Position** control field above, the **X Fitting Coefficients** fields and the **Y Fitting Coefficients** fields will show the fitting coefficients correspond to the new X position.

10.6 Translation Scan Field Integral Control Interface

Translation scan field integral makes translation integral measurements over the X axis. By clicking the **Int Trans** control button in the main interface windows above, the system launches the Translation Scan Field Integral Control Interface Window as shown bellow.



The Translation Scan Field Integral Control Interface Window has over 20 display and control fields and two real time plot fields. The detailed description of each field is listed in the following paragraphs.

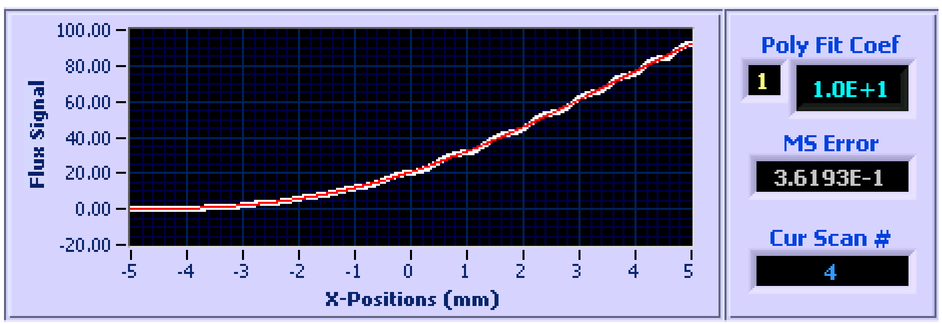
10.6.1 GENERAL

- **SYSTEM STATUS** field at the up left side of the window displays the system current status.
- **COM PORT** field sets the RS-232 motor control interface. The default value is COM1
- **Back to Main** button, closes the window.

10.6.2 CONTROL INPUT FIELDS

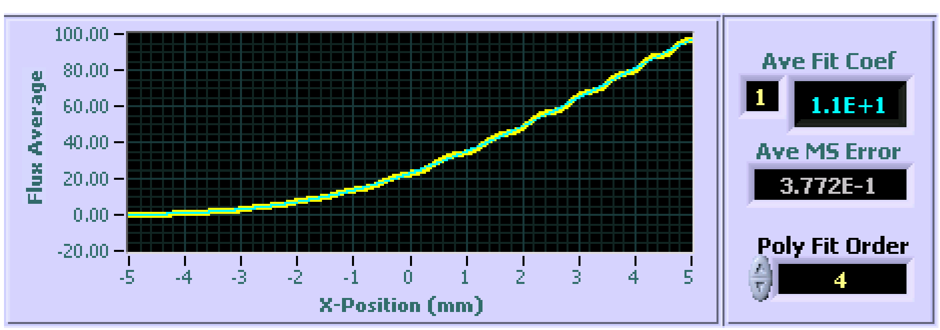
- **COMMENTS** field allows user to enter the ID device information including the serial number of the device to be tested.
- **Scan#** field sets the number of scans for each measurement.
- **Start (mm)** field sets the X axis measurement start position.
- **Step (mm)** field sets the X axis measurement step.
- **Finish (mm)** field sets the X axis measurement finish position.
- **Prd (mm)** field allows user to enter the ID device period in millimeter.
- **Sys shift (V)** field allows user to enter a system shift value to further correct the system shift.

10.6.3 SCAN REAL TIME FIT AND PLOT



- **Flux Signal vs. X-Positions (mm)** plots each individual scan flux raw data along with their Polynomial fitting data in real time.
- **Poly Fit Coef** fields show Polynomial fitting coefficients of the **Flux Signal** scan along the X axis. User may enter different order numbers at the left field, the right filed will show the relative order coefficient parameters.
- **MS Error** field displays the fitting Mean Square Error.
- **Cur Scan #** field displays the current scan number.

10.6.4 SCAN AVERAGE REAL TIME FIT AND PLOT



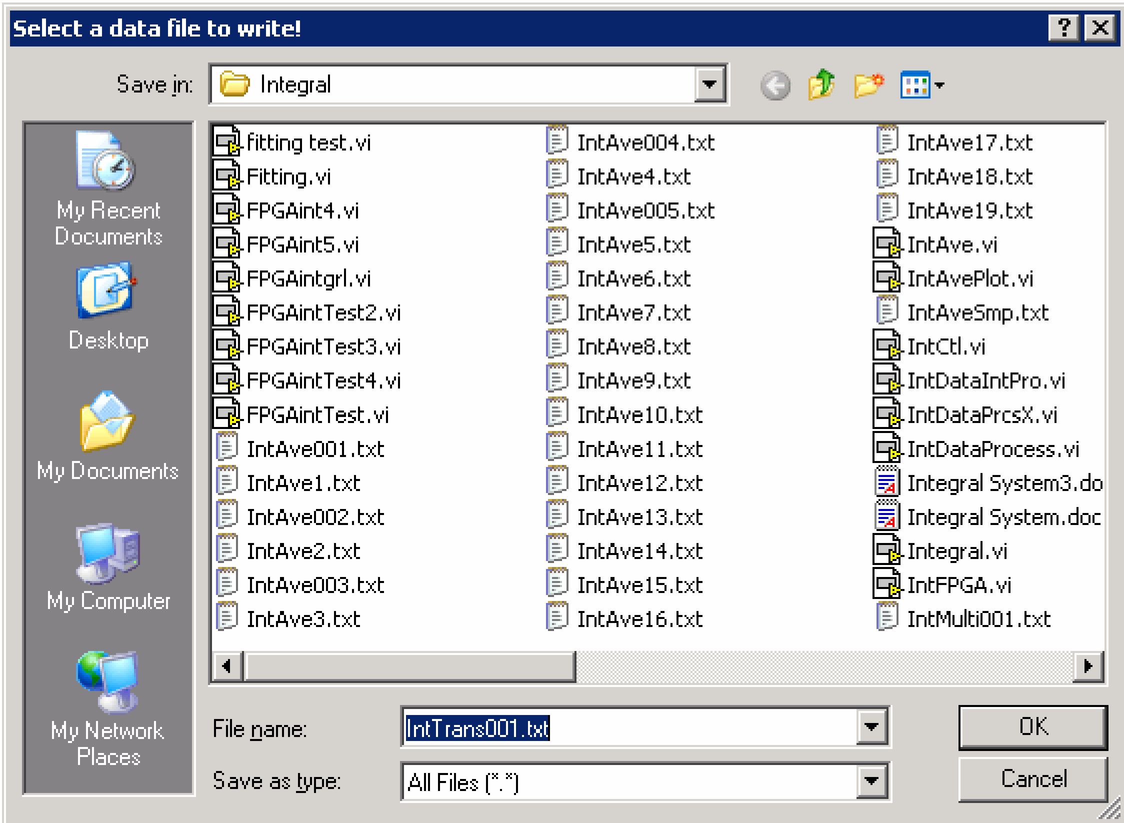
- **Flux Average vs. X-Positions (mm)** plots the averaged data up to the current scan along with their Polynomial fitting data in real time.

- **Ave Fit Coef** fields show Polynomial fitting coefficients of the **Flux Average** scan along the X axis. User may enter different order numbers at the left field, the right filed will show the relative order coefficient parameters.
- **MS Error** field displays the fitting Mean Square Error.
- **Poly Fit Order** control field sets the order for the next Polynomial fitting.

10.6.5 TRANSLATION SCAN CONTROLS

- **Motion Ctl** button launches the Advance Motion Control interface windows describe in the Advanced Motion Control section above.
- **1-WIRE/2-WIRE** control button selects the coil mode for the scan. The **1-WIRE** option scans with a single looped wire and the **2-WIRE** option scans with a looped coil.
- **1st ORDER/2nd ORDER** control button selects the mode to scan. The option is only activated in the case of **1-WIRE** and ignored if **2-WIRE** is selected. The **1ST ORDER** option scans at the X axis with bother X stages in the same direction. The **2nd ORDER** option scans with X stages in the opposite direction.
- **V-FIELD/H-FIELD** control button selects the coil mode for the scan. The option is only activated in the case of **2-WIRE** and ignored if **1-WIRE** is selected. The **V-FIELD** option scans with the coil normal in-line with the field. The **H-FIELD** option scans with the coil normal perpendicular to the field.
- **PLOT** button launches the Multi Scan Measurement Data Plot Windows as described in its section bellow.
- **ABORT** button aborts the measurements and saves the data up to the current measurement.
- **START** button starts the measurements with the parameters defined in the above fields.

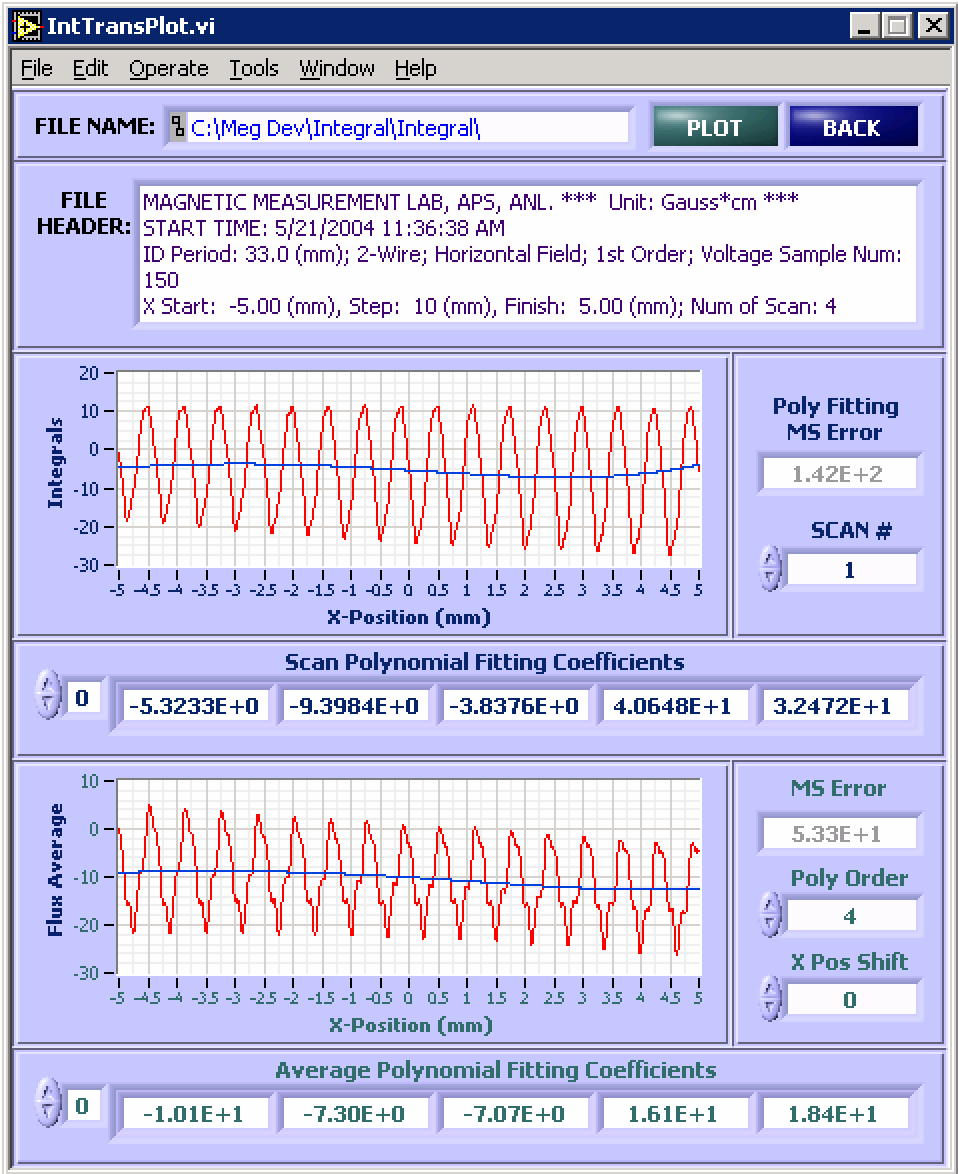
After clicking the **START** button, the system will launch a window shown bellow ask you to enter a file path and name to save the data and information to.



If you enter a file name that exists in the directory, it will ask you if you want to replace the existing file. You may click Replace to replace the existing file or Cancel to enter a new file name.

10.6.6 Translation Field Scan Measurement Data Plotting

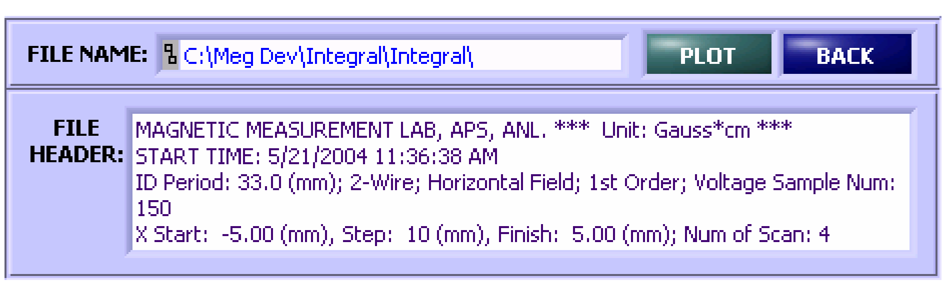
Click the **PLOT** control button in the Translation Field Scan Integral Control Interface Window, a PLOT Sub-Control Panel will display as shown below.



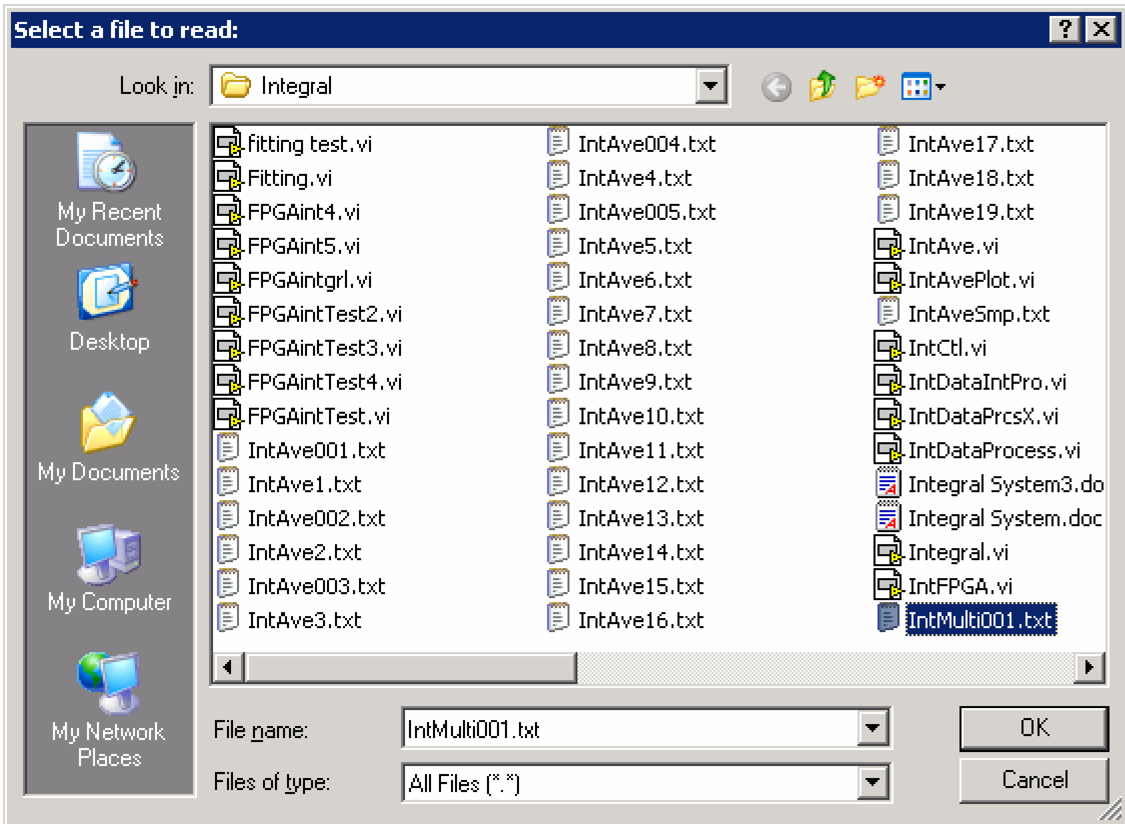
Translation Field Scan Integral Measurement Data Plot Window

The Translation Field Scan Integral Measurement Data Plot Window has over 10 display and control fields and two real time data plot fields. The detailed description of each field is listed in the following paragraphs.

10.6.6.1 GENERAL

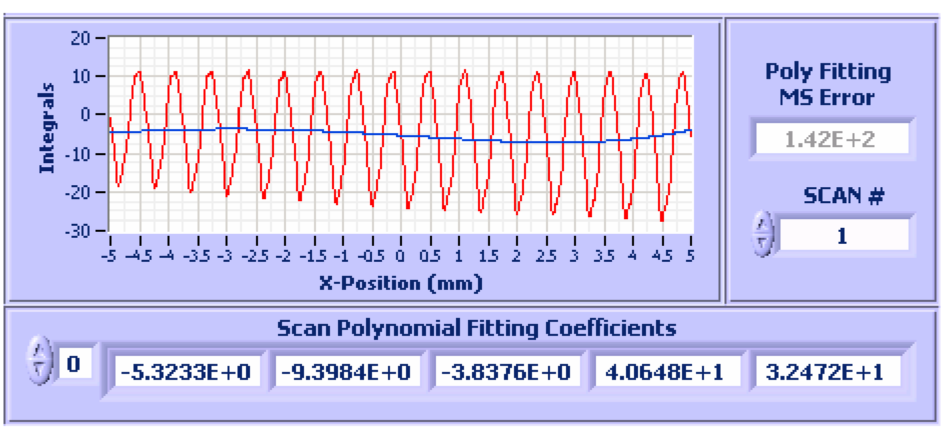


- **FILE NAME** displays the data file path and the data file name to be analyzed and plotted.
- **PLOT** control button launches a file selection window to let user to select a file to be analyzed and plotted.



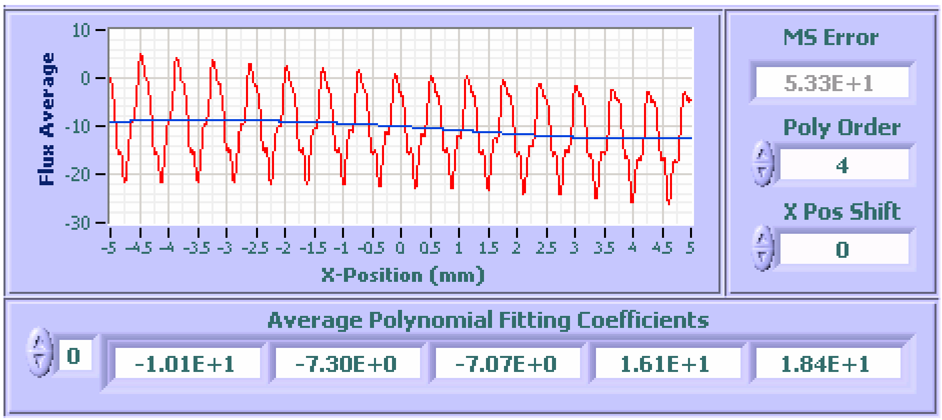
- **BACK TO MAIN** control button will close the window and go back to the Period Average Field Integral Control Interface Window.
- **FILE HEADER** displays the header information of the data file.

10.6.6.2 TRANSLATION SCAN FIELD DATA FIT AND PLOT



- **Integrals vs. X-Positions (mm)** plots each individual scan data in the file along with their Polynomial fitting data.
- **Poly Fitting MS Error** field displays the fitting Mean Square Error.
- **SCAN #** control field selects which scan to be displayed, fitted and plotted.
- **Scan Polynomial Fitting Coefficients** fields show Polynomial fitting coefficients of the **Integrals** scan data along the X axis. User may enter different order numbers at the left field, the right fields show the relative order coefficient parameters.

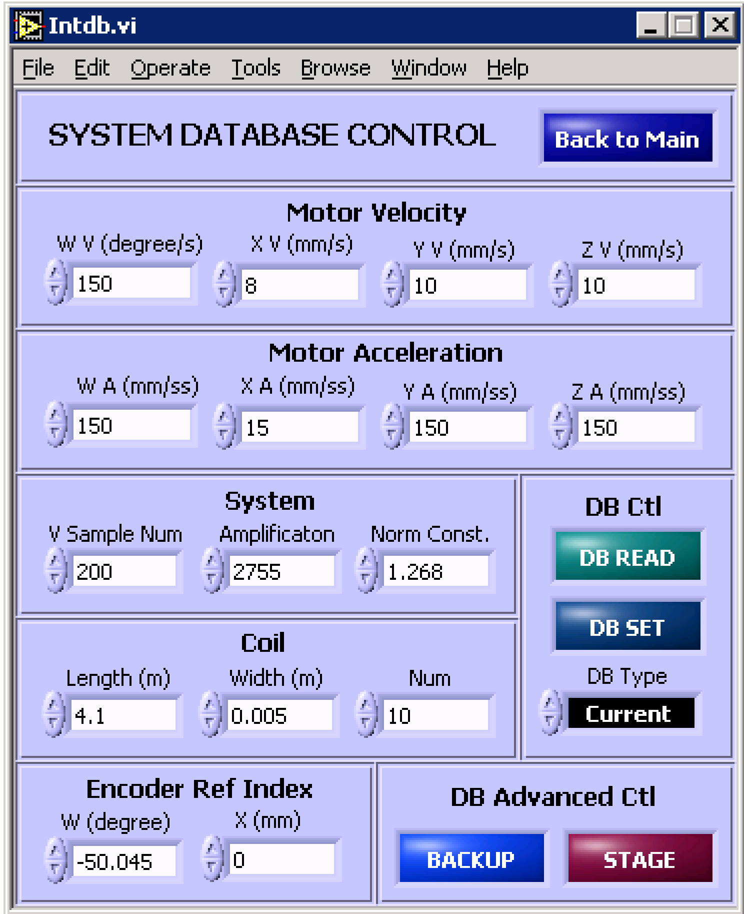
10.6.6.3 TRANSLATION SCAN DATA AVERAGE FIT AND PLOT



- **Integral Average vs. X-Positions (mm)** plots the averaged data up to the current scan read from the file along with their Polynomial fitting.
- **Ave Poly Fit MS Error** field displays the fitting Mean Square Error.
- **Poly Fit Order** control field sets the order for the next Polynomial fitting.
- **Average Polynomial Fitting Coefficients** fields show Polynomial fitting coefficients of the **Integral Average** scan along the X axis. User may enter different order numbers at the left field, the right fields show the relative order coefficient parameters.

10.7 SYSTEM PARAMETER DATABASE MANAGEMENT INTERFACE

System parameter database control interface manages all system parameters. By clicking the **Int DB** control button in the main interface windows above, the system launches the System Database Control Interface Window as shown bellow. The parameters are pre-loaded and saved in the system.db file.



The System Database Control Interface Window has over 20 display and control fields. The detailed description of each field is listed in the following paragraphs.

10.7.1 Motor Velocity

- **W V (degree/s)** field displays the W (rotary) table velocity in the unit of degree per second.
- **X V (mm/s)** field displays the X linear table velocity in the unit of mm per second.
- **Y V (mm/s)** field displays the Y linear table velocity in the unit of mm per second.
- **Z V (mm/s)** field displays the Z linear table velocity in the unit of mm per second.

You may enter a different numbers and save the parameters into the database. However, the new parameters will not be loaded into the motors till the motors get initialized. When the advanced motion control interface gets activated, the current section of database will be updated to the current motor settings.

10.7.2 Motor Acceleration

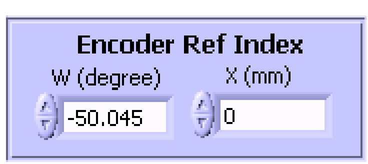
- **W A (degree/ss)** field displays the W (rotary) table acceleration in the unit of degree per second^2.
- **X A (mm/ss)** field displays the X linear table acceleration in the unit of mm per second^2.
- **Y A (mm/s)** field displays the Y linear table acceleration in the unit of mm per second^2.
- **Z A (mm/s)** field displays the Z linear table acceleration in the unit of mm per second^2.

Same as that of the Motor Velocity parameters, you may enter a different numbers and save the parameters into the database. However, the new parameters will not be loaded into the motors till the motors get initialized. When the advanced motion control interface gets activated, the current section of database will be updated to the current motor settings.

10.7.3 System Parameters

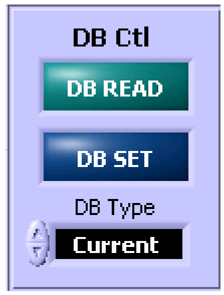
- **V Sample Num** field displays/sets the number of voltage samples taken for each data point for display. The number of voltage samples taken during real-time data acquisition is optimized by the hardware to the maximum number the system can reach based on the dynamic time duration between two data points.
- **Amplification** field displays/sets the amplification parameter based upon the DC pre-amplifier settings.
- **Norm Const.** field displays/sets the normalization constant, that needs to be calibrated during initial system setup.

10.7.4 Encoder Reference Index



- **W (degree)** field displays/sets the W (rotary) encoder index reading. This parameter is very useful for bring the coil rotary position back to the reference position in the case of power to both the motors and the FPGA control system fail.
- **X (mm)** field displays/sets the X linear encoder index reading.

10.7.5 Database Control



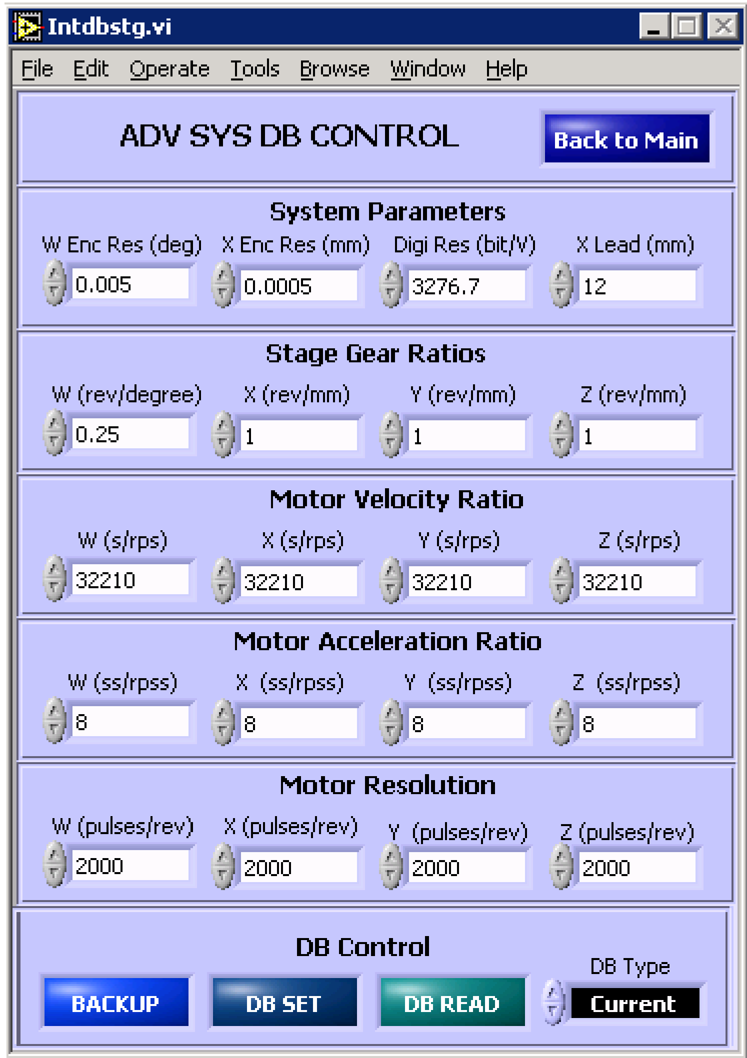
- **DB READ** control button reads the parameters in the selected DB Type section.
- **DB SET** control button sets (writes) the parameters in the selected DB Type section.
- **DB Type** selects the database type (section) to operate (read or set). There are three types: Current, Backup, and Default. The Default is read only.

10.7.6 Database Advanced Control

- **BACKUP** control button backups the current system.db file to a backup db file with the file name and place of your choice.
- **STAGE** control button launches the Stage related advanced system parameter database control interface window.

10.7.7 ADVANCED SYSTEM DATABASE CONTROL

Click the **STAGE** control button in the System parameter database control interface Window, an Advanced System Database Control Panel will display as shown below.



The Advanced System Database Control Interface Window has over two dozens of display and control fields. The detailed description of each field is listed in the following paragraphs.

10.7.7.1 SYSTEM PARAMETERS

- **W Enc Res (deg)** field displays/sets the W rotary encoder resolution.
- **X Enc Res (mm)** field displays/sets the X linear encoder resolution.
- **Digi Res (bit/V)** field displays/sets the digitizer resolution.
- **X Lead (mm)** field displays/sets the X lead distance between motion start position and measurement start position for the integral translational scans.

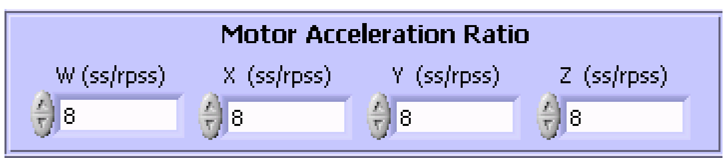
10.7.7.2 STAGE GEAR RATIOS

- **W (rev/degree)** field displays/sets the W rotary stage gear ratio.
- **X (rev/mm)** field displays/sets the X linear stage gear ratio.
- **Y (rev/mm)** field displays/sets the Y linear stage gear ratio.
- **Z (rev/mm)** field displays/sets the Z linear stage gear ratio.

10.7.7.3 MOTOR VELOCITY RATIOS

- **W (s/rps)** field displays/sets the W rotary stage servo motor velocity ratio.
- **X (s/rps)** field displays/sets the X rotary stage servo motor velocity ratio.
- **Y (s/rps)** field displays/sets the Y rotary stage servo motor velocity ratio.
- **Z (s/rps)** field displays/sets the Z rotary stage servo motor velocity ratio.

10.7.7.4 MOTOR ACCELERATION RATIOS



- **W (ss/rpss)** field displays/sets the W rotary stage servo motor acceleration ratio.
- **X (ss/rpss)** field displays/sets the X rotary stage servo motor acceleration ratio.
- **Y (ss/rpss)** field displays/sets the Y rotary stage servo motor acceleration ratio.
- **Z (ss/rpss)** field displays/sets the Z rotary stage servo motor acceleration ratio.

Please refer to the motor user's manual for motor velocity and acceleration ratio parameters.

10.7.7.5 MOTOR RESOLUTION

- **W (pulses/rev)** field displays/sets the W rotary stage servo motor resolution.
- **X (pulses/rev)** field displays/sets the X rotary stage servo motor resolution.
- **Y (pulses/rev)** field displays/sets the Y rotary stage servo motor resolution.
- **Z (pulses/rev)** field displays/sets the Z rotary stage servo motor resolution.

10.7.7.6 DATABASE CONTROL

- **BACKUP** control button backups the current system.db file to a backup db file with the file name and place of your choice.
- **DB READ** control button reads the parameters in the selected DB Type section.
- **DB SET** control button sets (writes) the parameters in the selected DB Type section.
- **DB Type** selects the database type (section) to operate (read or set). There are three types: Current, Backup, and Default. The Default is read only.

11. SYSTEM OPERATION PROCEDURES

A detailed system operation procedure includes the following steps:

1. System Setup.
2. System Preparation.
3. System Alignment.
4. System Measurement.

If you are sure that the system has been properly set up and aligned, you may skip Steps 9 and 12.

12. SYSTEM SETUP PROCEDURE

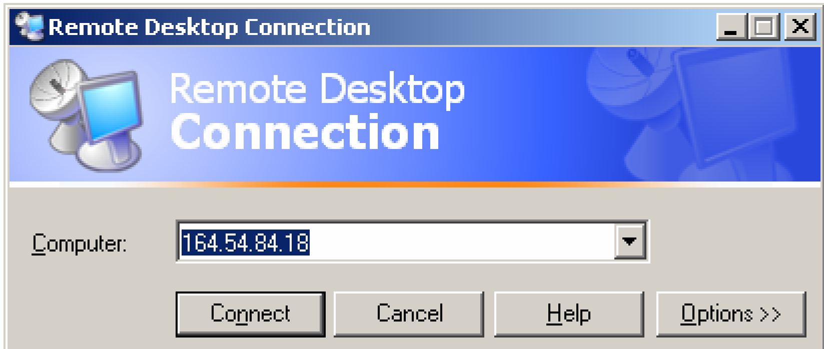
Before launching the software system, the hardware sub-system connections have to be checked and powered on. If any of the sub-system is not connected and powered on appropriately, the software system will inform you that the specific hardware system is not connected or power up or communication port address is not set correctly.

Step 1. Check all the cables, the network cables to the PXI shelf and the host computer, the smart motor RS-232 communication cables, the smart motor power supply cables, the rotary encoder cable, the linear encoder coble, and the coil signal cables are properly connected and secured.

Step 2. The two smart motor power supplies are powered on.

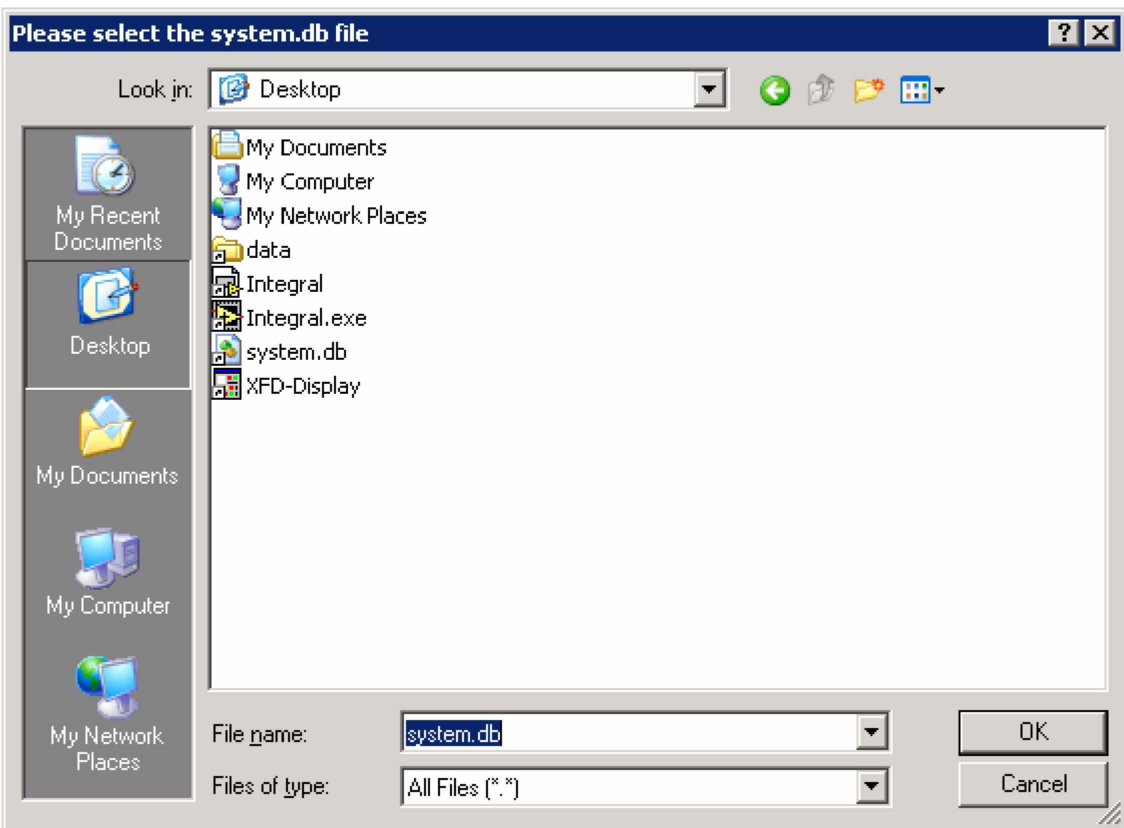
Step 3. The PXI shelf is powered up.

Step 4. Log on to any APS host computer. Start **Remote Desktop Connection** from **Start**, **Programs**, **Accessories**, and **Communications**. In the **Computer** field, type in **164.54.84.18**, click **Connect**.



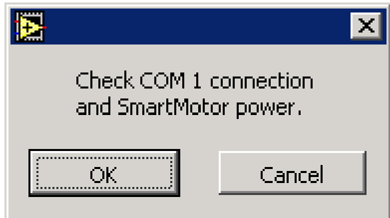
Step 5. Launch the Integral Measurement Control Software by double click the IntCtl icon on the Remote Desktop.

Step 6. The system will prompt you with a window ask for the right path to load the system.db file.

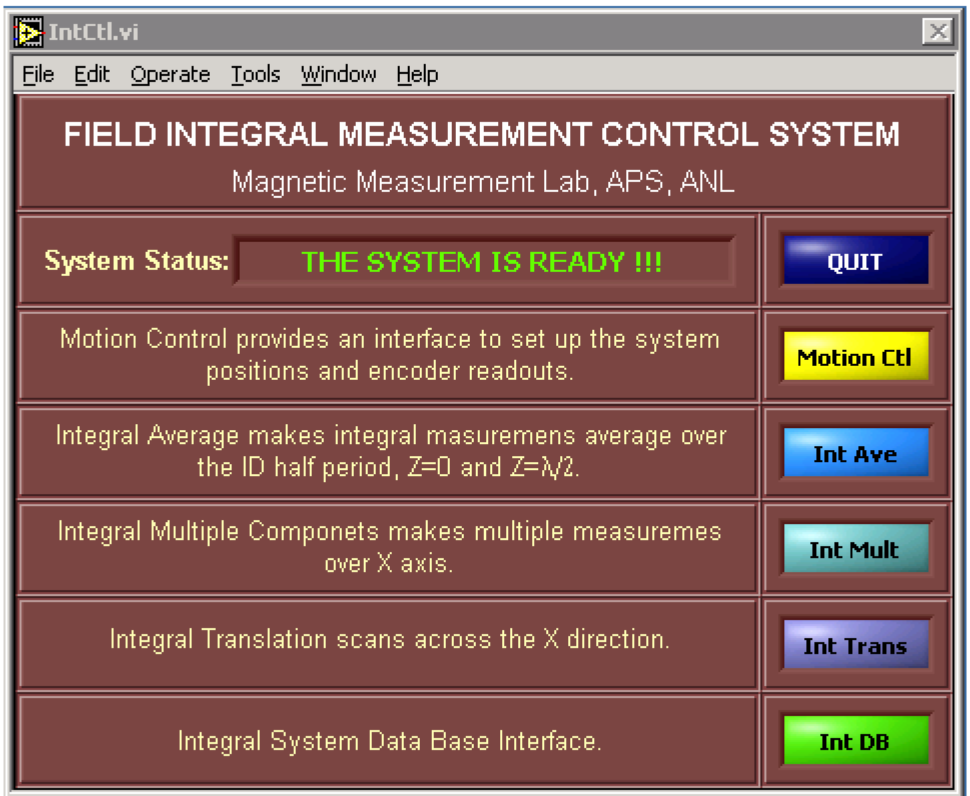


Select the right path where your system.db file is located.

Step 7. If the following window pops up, check the appropriate cable connections, power cables, and address settings, and click OK button to continue.



If the servo motors are not initialized, the system will try to initialize the motors automatically. If every thing is ok the following system main interface window will show with the status of "THE SYSTEM IS READY!!!"



13. SYSTEM PREPARATION PROCEDURE

Before each measurement, collect all the information about the ID to be measured. The preparation procedure includes the following steps:

Step 8. Collect the ID information including:

- The manufacture.
- The part number.
- The serial number.
- The period (in millimeters).

- The environment temperature.
- Other information as necessary.

Step 9. Check all the control cable connections from the ID control racks to the ID motors and encoders. Check all the power switches are on in the control racks. Launch the ID Control MEDM windows. Test the ID control system and make sure the ID gap moves accordingly.

14. SYSTEM ALIGNMENT PROCEDURE

After the preparation, the system needs to be properly aligned, before measurements scan can be executed.

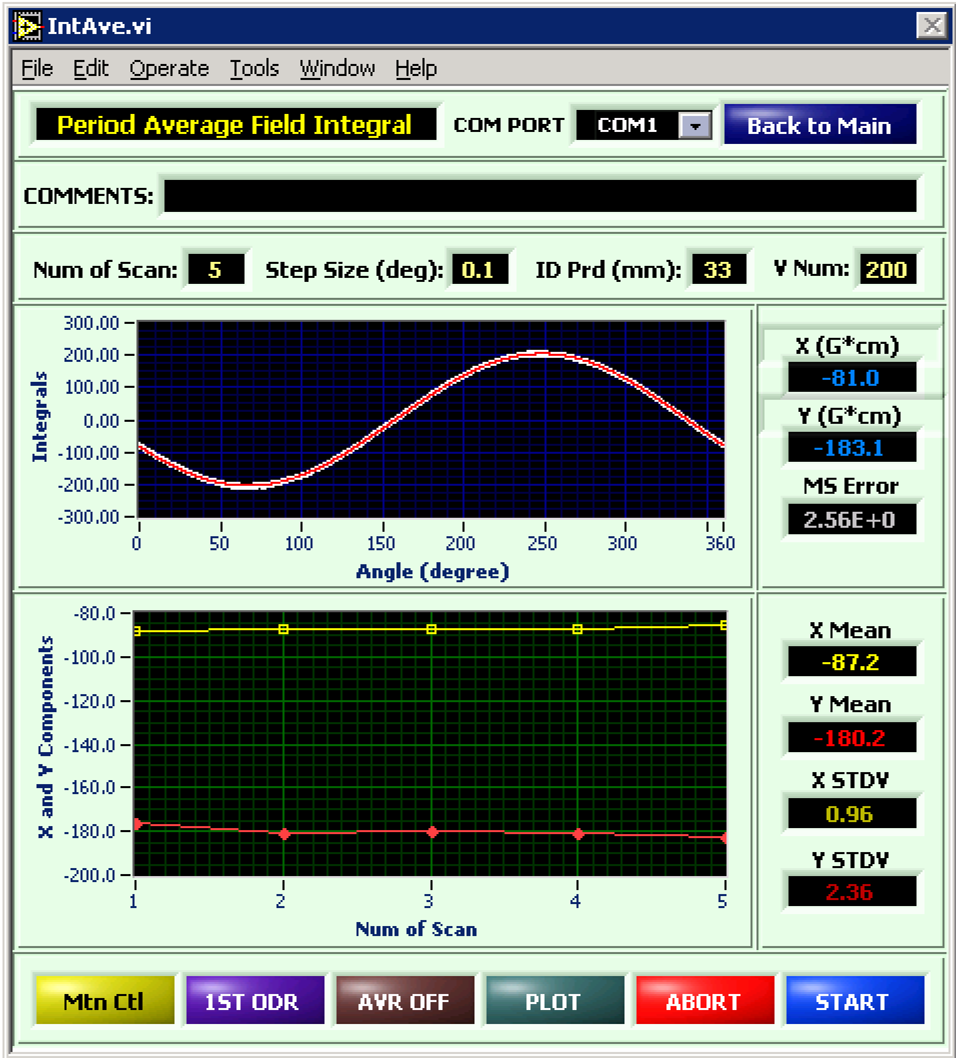
Step 10. Align ID gap leveled horizontally, in the reach of the coil system center within about one inch in distances.

Step 11. Click the **Motion Ctl** control button in the Field Integral Measurement control interface window to launch the Advanced Motion Control interface window. Use the motion control interface to carefully move the coil into the center of the ID gap by move the Y axis to level the coil axis to the gap level and then move the X axis to slide the coil to the center of the gap. *Reset the linear encoder readouts and motor readouts to zero*.

Step 12. If the rotary tables have been pre-surveyed into the position to level the coil vertically, move the rotary tables to the zero rotary encoder readout position. Otherwise, resurvey the coil level position by moving the rotary tables till the coil is leveled in line with the ID gap. *Reset the rotary encoder readout to zero. Reset all motor positions to zero.* Click the **RETURN TO MAIN** control button to close the motion control window and go back to the main window.

15. FIELD INTEGRAL AVERAGE MEASUREMENT PROCEDURE

Click the **Int Ave** control button in the Main Control Windows to launch the Integral Average Field Measurement Control Interface window.



Before you click the **START** control button, the following Steps have to be completed.

Step 13. Enter the ID information of the probe needs to be calibrated into the **COMMENTS** field.

Step 14. Enter the number of scans for the measurement in the **Num of Scan** field.

Step 15. Select the appropriate measurement step size in the **Step Size (deg)** field.

Step 16. Enter the ID period in the **ID Prd (mm)** field.

Step 17. Select the coil measurement order by clicking **1st ORDER/2nd ORDER** control button.

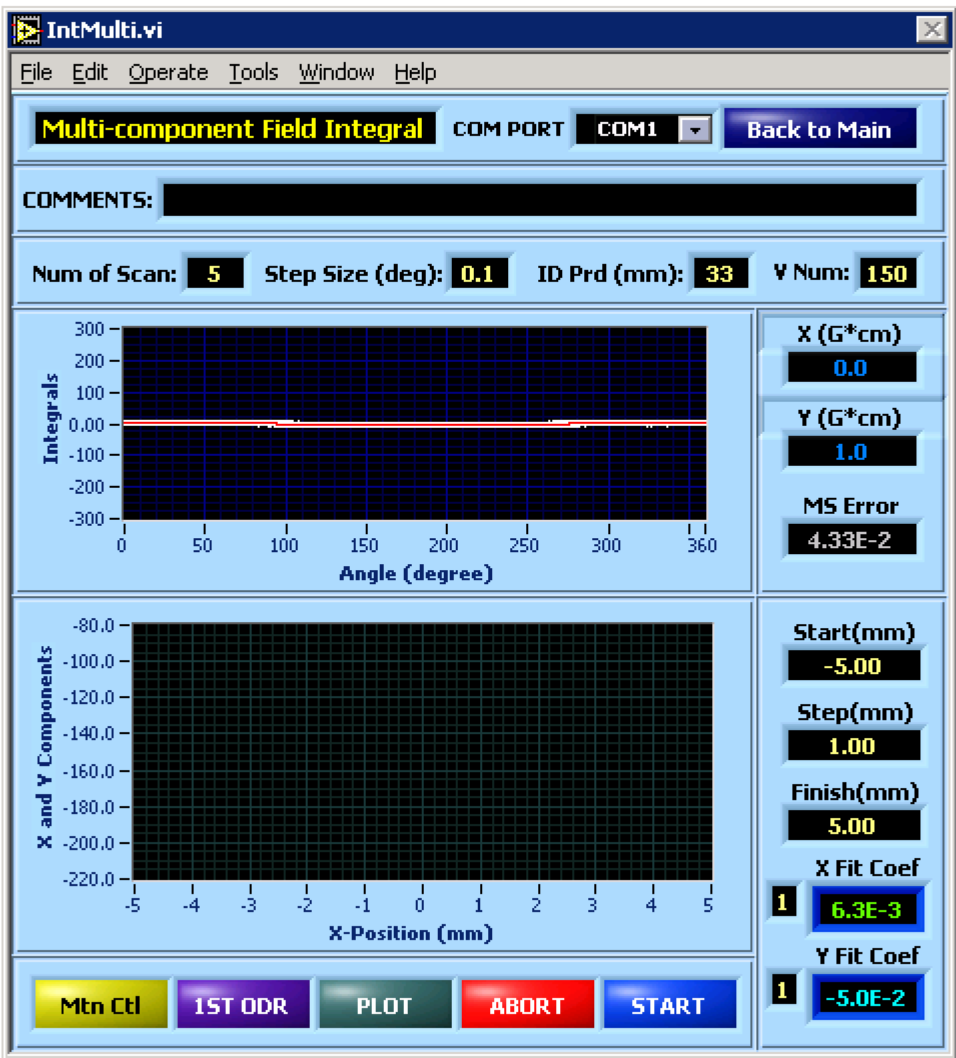
Step 18. Select the measure average over the ID period by clicking **AVR OFF/AVR ON** control button.

Step 19. Click the **START** control button, the system will prompt you with a window to select the path and name of the file to save the measurement data. Select the right path, enter the data name and click **OK**, the system will start the measurements.

Step 20. After the measurements are completed, the program will set all the stages to the original positions. You may go back to **Data Plotting** section to find out how to plot the calibration data, or enter new parameters, click **START** control button to start another measurement. Otherwise, click the **Back to Main** to close the window and go back to the Main Control Window.

16. MULTI SCAN MEASUREMENT PROCEDURE

Click the **Int Mult** control button in the Main Control Windows to launch the Multi Scan Field Measurement Control Interface window.



Before you click the **START** control button, the following Steps have to be completed.

Step 21. Enter the ID information of the probe needs to be calibrated into the **COMMENTS** field.

Step 22. Enter the number of scans for the measurement in the **Num of Scan** field.

Step 23. Select the appropriate measurement step size in the **Step Size (deg)** field.

Step 24. Enter the ID period in the **ID Prd (mm)** field.

Step 25. Enter the X axis start position relative to the center position of the ID gap where the coil is aligned in the **Start (mm)** field.

Step 26. Enter the scan step in the **Step (mm)** field.

Step 27. Enter the X axis finish position relative to the center position of the ID gap where the coil is aligned in the **Finish (mm)** field.

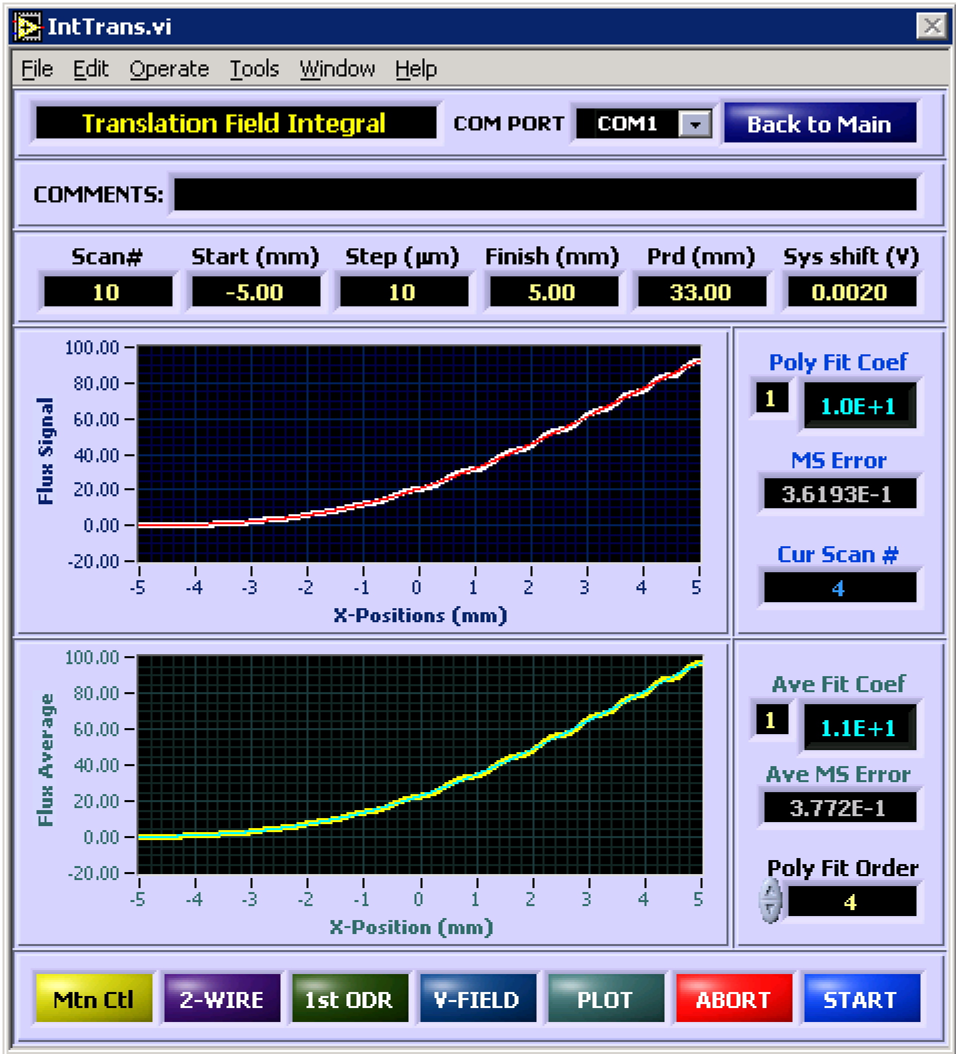
Step 28. Select the coil measurement order by clicking **1st ORDER/2nd ORDER** control button.

Step 29. Click the **START** control button, the system will prompt you with a window to select the path and name of the file to save the measurement data. Select the right path, enter the data name and click **OK**, the system will start the measurements.

Step 30. After the measurements are completed, the program will set all the stages to the original positions. You may go back to **Data Plotting** section to find out how to plot the calibration data, or enter new parameters, click **START** control button to start another measurement. Otherwise, click the **Back to Main** to close the window and go back to the Main Control Window.

17. TRANSLATION INTEGRAL MEASUREMENT PROCEDURE

Click the **Int Trans** control button in the Main Control Windows to launch the Translation Integral Measurement Control Interface window.



Before you click the **START** control button, the following Steps have to be completed.

Step 31. Enter the ID information of the probe needs to be calibrated into the **COMMENTS** field.

Step 32. Enter the number of scans for the measurement in the **Scan#** field.

Step 33. Enter the X axis start position relative to the center position of the ID gap where the coil is aligned in the **Start (mm)** field.

Step 34. Select the appropriate measurement step size in the **Step (µm)** field.

Step 35. Enter the X axis finish position relative to the center position of the ID gap where the coil is aligned in the **Finish (mm)** field.

Step 36. Enter the ID period in the **ID Prd (mm)** field.

Step 37. Select or enter the Polynomial fitting order in the **Poly Fit Order** field. You may change the value in this field as the system is in the state of measurement.

Step 38. Select the coil measurement mode by clicking **2-WIRE/1-WIRE** control button. *Make sure the coil physical setting reflects the mode selection*.

Step 39. Click the **START** control button, the system will prompt you with a window to select the path and name of the file to save the measurement data. Select the right path, enter the data name and click **OK**, the system will start the measurements.

Step 40. After the measurements are completed, the program will set all the stages to the original positions. You may go back to **Data Plotting** section to find out how to plot the calibration data, or enter new parameters, click **START** control button to start another measurement. Otherwise, click the **Back to Main** to close the window and go back to the Main Control Window.

18. TROUBLE SHOOTING

19. DATA ACQUISITION VELOCITIES

If the signal is week and noise is too big, you may go to the Motor Velocity and Acceleration Control window by click the **V & A** control button in the Advanced Motion Control window, increase the W and or X velocities.

20. SMART MOTOR INITIALIZATION

If the smart motors do not respond to the motion control commands properly, turn off both smart motor power supplies, wait for 10 seconds, and turn on the power back on. Go to the Advanced Motion Control window, click INIT control button to reinitialize the motors.

21. OPEN ISSUES

If one of the motor power supply gets a power recycle, the motor address will get lost. The system will pop up a window inform user that the power supply or COM port got disconnected. User has to power off both power supplies, power back one, and reinitialize the motor addresses by click the INIT control button in the Advanced Motion Control window.

22. ACRONYM LIST

APS Advanced Photon Source

GUI Graphic User Interface

ID Insertion Device