

## Introduction to the FTA2000

This document will help you get started with your new FTA2000.

The FTA2000 is a highly automated instrument, which may seem complex at first, but each of its individual functions is straightforward. The instrument can be run with various levels of automation, from fully manual to fully automated with the script-based Sequencer. The FTA2000 can also be easily interfaced to other automation or robotics to build even more complex systems. The best way to learn its operation is to start with the manual modes and then build up to sequencer operation.

### Overview of Capabilities

An Autosampler provides liquid handling for all types of measurements. The Autosampler has six independent dispense tips that can aspirate liquid from any of 17 standard 12mm diameter, 2ml vials arranged in a circle under the Autosampler. The dispense tips have Z axis drives to bring them into the field of view of the video camera where surface tension and contact angles are measured. The dispense tips have Luer hubs to accept a wide variety needle types. The pump aspirates only the required volume for the experiment into the needle. Sample liquid does not reach into the system tubing or the pump, as an airgap separates the sample liquid from the distilled water used as a system liquid. Needles are changed manually on the standard instrument, but an optional carousel holds up to 96 tips or needles that can be attached and detached automatically.

The sample stage is a large 12 inch, 300mm diameter platter. It can also easily be replaced by the user's custom stage. It is primarily intended for contact angle work but can be configured to hold large numbers of liquid samples instead. The stage is driven by three axes in a radial-theta - Z configuration (referred to as RQZ). This arrangement is used because it minimizes the footprint of the instrument when a large stage is desired. The stage can be programmed in an X-Y-Z mode when it is more convenient to think in these terms. Software then converts the rectangular coordinates to cylindrical coordinates.

The entire stage and camera assembly can be tilted through 90° for advancing and receding contact angle measurements.

The microscope has auto zoom, auto focus as an option. The microscope has a 6:1 zoom and can be tilted down slightly to achieve reflection images on large contact angle samples.

The instrument has a full enclosure with temperature and relative humidity measurement, plus temperature stabilization from ambient to 40C.

## **Power and Computer Connections**

The FTA2000 can be powered from either 100/120VAC or 220-240VAC. The current draw is 15A at 120VAC or 7.5A at 240VAC. The majority of the power consumption is for the enclosure heaters. Because the heaters are connected directly to the AC line through a semiconductor switch, the desired line voltage must be specified at the time of the order so the heaters can be wired in series or in parallel to match the line voltage. If these are not installed or used, the current draw is less than 2A at 120VAC. Fuses are installed on both sides of the AC line in the power entry module on the rear of the cabinet.

The power entry module contains an on/off switch. The on state is indicated by a green LED visible from the front of the instrument, below the camera.

The instrument is controlled from a host computer through an RS-232 line. The 9 pin D cable must be connected to an available serial port on the host computer. If the external robotic interface is used, a second serial port is required on the host computer for it.

Finally, video is carried to the host computer either through a BNC or a USB cable, depending on which kind of camera is fitted, from a rear panel connector. When a traditional frame grabber board is fitted, the BNC coax cable is used. When a USB camera is used, the USB cable is connected to any available USB port on the host computer.

## **Configuration File**

All settings in the software are preserved in a single file called the configuration, or config, file. The file is an Access database file and so its extension must be mdb. The default name for this file is simply default.mdb, but it can be renamed on the LogOn screen. You can have more than one config file and select which one to use on the LogOn screen. A copy of the config file used at the factory to test your instrument is included with your documentation. It is strongly recommended that you copy the factory file to your application directory after you have installed the software but before you run Fta32 Video for the first time. Then the software will start with all settings correct.

## **Software Installation**

Complete instructions for installing the software on your computer are found in How to Install, which is included in the instruction manual and available on the FTA website under Software. To summarize the process,

1. Install the frame grabber driver for your system.
2. Install the Fta32 Help files.
3. Install the main program, Fta32 Video. Do this after the frame grabber.
4. Copy the custom config file to the same directory as you installed Fta32 Video.
5. Copy the license file to the hard disk.
6. Install the frame grabber hardware, restart the computer, and let the Found New Hardware wizard make the necessary Registry setup.

## Manual and Automatic Operation

The instrument can be run three different ways:

- manually, where every movement and every operation is commanded by the user clicking a button,
- semi-automatically, where common operations are strung together by checkbox selection, and
- automatically from the Sequencer.

You always want to start with manual operation so that you understand the response of the instrument. Once you are comfortable, you can move to automatic modes. The common semi-automatic mode is the Run command which will take a Movie with a Trigger defining the exact timing. The Sequencer, discussed below, allows fully automatic handling and measurement of many samples. The nice thing about the Sequencer is that everything it does is really pushing some button or filling some value in a text box. This means Sequencer is really emulating something you could do (and understand), but the Sequencer of course remembers every detail and can do it many times.

## External Robotic Interface

The Fta32 Video software can communicate with external robots through a second serial line on the host computer. All robotic communications take place through the Sequencer, which is a Basic-like script-based interpreter. The robotic interface can be customized to meet the needs of individual customers, since there are many protocols in use. The interface does three kinds of transactions:

- the Sequencer can execute an instruction to transmit user-defined messages to the robot,

- the Sequencer can Wait until it receives an OK from the robot, and
- the robot can send file names to the Sequencer for Movies that it will take.

## Sample Stage

The specimen platter is held on the motorized stage by a single M6 flat head screw in the center. The standard platter is 12 inches in diameter, but an optional platter, slightly larger, will hold 12 inch semiconductor wafers and has Teflon wafer clips to prevent the wafer from actually touching the platter surface.

All three axes on the stage have home sensors so they can return to an absolute position. Each has an “offset” which is a user-entered distance away from the home sensor position. After finding the sensor home position, the stage will move this offset (which may be set to zero) and then declare this new position to be the origin. This allows any position to be called the origin.

The positive direction for the radial axis, the one that moves the stage nearer or farther from the camera, is towards the camera. The positive direction for the rotation, or theta, axis is clockwise when looking down on the platter. The positive direction for the Z stage is up. The user may remove the standard platter and fit their own chuck on the stage. A dowel pin hole is provided so the user chuck can have a pin to absolutely locate it on the stage.

In addition to optionally controlling the stage by X-Y-Z coordinates, the software provides a user determined “load location” to which it will move the stage to facilitate changing chucks or placing new samples on the stage.

Upper and lower motion limits can be set in the software for the radial and Z motions. There is no limit on theta rotation. It is always possible that, because you do not have the motion limits correctly set, an axis will mechanically crash at the end of its travel. Almost always you can back it off by requesting a movement in the opposite direction, but occasionally it will “stick.” If this happens, reduce the speed to about 1/4 its previous value and try again. The stepper motor develops more torque at lower speeds and this will normally be sufficient.

Motion rate can be set for each axis, but must not be more than the maximum rate set in the Driver Setup frame. Normally you will run axes at their maximum rate.

The Stage | R-Q-Z-Tilt tab contains all stage setup information and provides for manual operation of the stage. The Position text box shows the current axis position. You may *redefine* the current position by editing this value, but this will not cause any movement. To move an axis, enter an Increment value and then click Move. Most motions have an emergency Stop button available, and the find home operation is initiated by the Home button. Short-hand versions of axis motions are also available from a drop-down list box on the Video tab. This allows you to control basic movements while watching the Live video.

## Tilt Stage

The tilt stage is controlled from the same R-Q-Z-Tilt tab as the sample stage. The tilt stage is used to perform tilting plate contact angle measurements. The camera is mounted to the stage so the image always perceives the sample as horizontal. This simplifies image analysis. The downhill side of the sessile drop will be the advancing angle and the uphill side the receding angle. The measurement is made just as the drop is ready to roll or slide downhill.

The tilt stage is always run slowly, something like 1 degree per second, to minimize the vibration induced into the drop being measured. Vibration is the enemy of good receding angle measurements.

Finally, note that very slight movements of the tilt stage about its nominal level position have the effect of shifting the dispense needle left or right in the video image. Often a tenth of a degree or so will shift the needle noticeably in the image, so you can use this as a means of centering the needle if need be.

## Autosampler

The autosampler is the single most complicated part of the instrument. It contains robotics to position one of six dispense tip arms for pickup from source vials or in the video field of view for measurements. It also contains a single precision pump that is shared between the six tips by a 6-way distribution valve. There is not contamination problem because the sample fluid never reaches the distribution valve or the pump. Instead, distilled water system fluid fills the plumbing except for the dispense tip itself, into which the sample fluid is contained. An airgap separates the system fluid from the sample fluid.

Sample liquids are placed in standard 12mm diameter glass vials arranged in a circle around the autosampler. These are numbered 1 through 17 in a clockwise fashion from the front.

Each dispense tip holder has a separate Z axis for positioning. The Z axis has a 100mm range. The origin is the uppermost position and down is negative. Each tip is connected to the distribution valve by flexible Hamilton Teflon tubing and 1/4-28 flat-bottom fittings. The tip holder has a 1/4-28 union to join the tubing to a Luer hub needle holder. The user may fix any standard Luer needle. When using stainless steel needles with plastic hubs, choose a 1/2 inch or 1 inch needle. Choose all plastic dispense tips with an overall length of about 1 inch.

System fluid is held in a 20ml bottle next to the distribution valve. The tubing from it leads to a Lee normally closed inert valve. This is the inlet valve to the Lee pump. The pump is a stepper motor driven diaphragm pump, which functions much like a piston. The capacity of the pump is 50µl and its resolution is 25nl. The pump feeds an outlet valve that is similar to the inlet valve. Next, the outlet valve feeds the Hamilton 6-way distribution valve and the outlet ports of this feed the individual tips.

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Be careful not to operate the pump too quickly, else cavitation will cause bubble formation within the system fluid and this will make the pumping system “loose.” 10µl/s is a conservative limit, but you may be able to use 20µl/s. Cavitation is far more of a problem with aspiration than it is with dispense.

Before the Autosampler can be used, you must Home All on the Pump | Autosampler tab. This takes about a minute and homes all six Tip Z drives, the carousel itself (leaving Tip 1 at Vial 1), and the distribution valve.

To move large liquid volumes through the system, you use the Prime function. To Prime In is to move liquid towards the dispense tips; Prime Out is the opposite, moving liquid towards the system fluid bottle. You set the total volume to move in the text box before starting the prime. The first motion of the pump is always to home itself and it will make some noise doing this as it drives all the way to one end. The prime volume required at the very beginning for a dry system is roughly 500-750µl.

You can arrange to leave the pump in a mid-position by choosing a prime volume that is not an integer multiple of 50µl, the pump capacity, but is a multiple of 25µl. You can leave it at other positions also by appropriately choosing the prime volume. The purpose of leaving the pump at a mid-position is so you can either dispense or aspirate as you start your method. If the pump is all the way at one end, then you can only go in the other direction.

## Camera and Microscope

The camera and microscope normally require no user setup. The microscope is aimed by two sets of four M3 setscrews, one at the each end of the microscope. The standard microscope consists of the following optical components:

- a 0.5x minification auxiliary lens to provide a working distance of 175mm,
- a 6:1 zoom cell with magnification from 0.7x to 4.2x,
- a 2x adaptor tube, and
- a C-mount adaptor for the camera.

The microscope has three controls:

- an aperture, or iris, which is the ring closest to the camera on the zoom cell and adjusts from open to closed through a 90° twist,
- zoom magnification in the middle of the cell (may be motor driven), and
- focus at the end of the cell (may be motor driven).

The camera may have either a 1/2 inch format, in which case the CCD is 6.4mm x 4.8mm, or a 1/3 inch format, in which case the CCD is 4.8mm x 3.6mm. The field of view of the micro-scope, i.e., the area imaged, is the size of the CCD divided by the total magnification of the microscope.

The camera should always be operated with automatic gain control (AGC) on and back light compensation (BLC) off.

## **Auto Zoom and Auto Focus**

The microscope's zoom and focus controls are optionally stepper motor driven. This provides three features:

- magnification calibration can be determined in advance for each zoom step position and stored in a lookup table, this we call AutoZoom,
- a software algorithm can provide AutoFocus by searching various focus positions and selecting the one with the highest contrast, and
- the Sequencer can command different zoom and focus settings during an automated run.

For a complete description of Auto Zoom/Focus, see the FTA website FAQ | How to Use Auto Zoom/Focus. The key setting is the "Autozoom sets mag in Calibration" checkbox on the Auto Zoom/Focus tab. There are effectively three possibilities:

- AutoZoom sets mag checkbox is checked but you make no magnification correction on the Calibration tab: the Zoom Sweep lookup table will be used directly. Every time you change Zoom, the internal magnification calibration is updated.
- AutoZoom sets mag checkbox is checked and you do make a magnification correction on the Calibration tab: the internal magnification calibration is linearly scaled by the ratio of your user-set magnification to the lookup table magnification, at this Zoom setting. This forms an "Auto Zoom/Focus Magnification Ratio" that is reported on the Calibration tab. This ratio will be used on all subsequent Zoom settings. This protocol has the following advantage: the Zoom Sweep lookup table characterizes the opto-mechanical response of the microscope's zoom cell. The overall magnification, however, can vary slightly with temperature, contrast, and focus. Thus the ratio will be a slight tweak on the basically-correct lookup table.
- AutoZoom sets mag checkbox is not checked: the lookup table is not used, nor is mag ratio, and calibration is done the ordinary, simple way by user entries on the Calibration tab. Internal calibration is not changed when the Zoom motor is moved.

There is an addition capability on the Auto Zoom/Focus tab. This is the Focus/Zoom slope value found in the Driver Setup frame. This allows you to have the focus control track each time zoom is changed. The algorithm multiplies the number of zoom steps by this slope and moves the focus stepper motor if the resulting product is equal or greater than one step. To use this function, find the best focus at the extremes of the zoom range you plan to use, divide the focus steps (focus position) by the zoom steps and enter this value in the text box. Note the value will be a real number, typically small and not an integer.

## Temperature and Relative Humidity Control

Temperature and relative humidity within the enclosure can be measured and their values stored in Movies. These measurements are enabled by checkboxes on the Stage | Chambers tab. Temperature can be controlled within the ambient to 40C range by heaters mounted in the enclosure base. The user must specify a setpoint and enable heater drive with a checkbox. It takes some time to stabilize the temperature within the relatively large enclosure. The temperature controller uses a PID algorithm and the PID constants can be changed in the Driver Setup frame to provide faster response at the expense of some overshoot.

## Sequencer Operation

The Sequencer is found on the Video |Analysis | Sequencer tab. The Sequencer is an interpreter that will take a user written automation script and execute it. Scripts are stored in individual Access databases and you can have as many as you wish. Scripts are loaded and saved like any other file. The default name for the Sequencer script is Sequencer.mdb.

The Sequencer has a set of control buttons that govern execution:

- Start. Start continuous execution at the beginning of the program.
- Single Step. Execute only the instruction highlighted, the current instruction.
- Pause. Stop continuous execution after the current instruction.
- Resume. Resume continuous operation.
- Quit. Abandon this execution. You must start at the beginning next time.

These functions are also available in the drop-down list on the Live Video image form, so you can control the Sequencer while watching the video.

You write, or edit, a Sequencer script by selecting instructions from the pair of drop-down lists on the Sequencer tab. Instructions are grouped in the following categories:



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- Stage Moves. Sample stage and tilt control.
  - Liquid Dispense. All Autosampler control.
  - Movie Capture. Frame timing and trigger options to capture a Movie.
  - Movie Analysis. Image analysis functions you can use after you have a Movie.
  - Chambers. Temperature and relative humidity measurement and control.
  - Program Control. Script flow control such as subroutines and loops.

Once you select a group, the lower list is populated with the instructions available to you.

Instructions are identified by line numbers and the script is executed in line number order. This is just like early Basic. It is advisable to leave gaps between line numbers so other instructions can be inserted between existing ones.

The process for writing a new instruction and for editing an existing instruction are similar but not identical. To edit an existing instruction:

- click on the instruction in the listing to highlight it,
- click Edit Row to copy the instruction into the editing region where are details about the instruction are listed, including a short help description to the left,
- change the value of any parameters by typing in the text boxes, or
- click the drop-down lists to change the fundamental instruction type, then
- when you are finished, click Update Row to restore the edited instruction to the listing and the database file on disk, or...
- click Cancel Edit to make no changes.

To write a new instruction, click New Row and then edit the text boxes just as you would have with an existing instruction, but notice that a line number will have been assigned and this may or may not be the line number you wish. You can edit the line number just like any other parameter, with the following proviso: if you assign the current instruction the same line number as an existing instruction, you will create a conflict. The only way out is to close the program and re-open it, at which time one of the two instructions with the same line number will appear and the other will be discarded.

Finally, there are log and data listings that are filled in as the Sequencer runs. These let the user know what is happening and what the data looks like. These can be printed or opened as simple text files by other programs.

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