Model 1025T
Small Animal Monitoring
and Gating System

Operation Manual

Document number 211021

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Introduction

This Operation Manual accompanies the release of Revision 12.00 of the PC software for SA Instruments' small animal monitoring and gating systems including the Models 1030, 1040, 1025T and 1025.

Every major medical school in the world has at least one of SA Instruments monitoring and gating systems and many have several. We are grateful to all those medical researchers who have used SAI equipment and offered constructive comments allowing us to improve the performance and capabilities of our systems.

The Model 1025T monitoring and gating system measures and records physiological parameters of small animals. It currently measures ECG, respiration (two ways) and temperature. In addition the following options are available for use with the 1025T: Pulse Oximetry, Capnography, Invasive Blood Pressure, Fiber Optic Temperature and minimal invasive Fiber Optic Pressure. There are four user auxiliary input channels which can be used as a data interface for equipment such as a stimulator, ventilator, the imager, etc. Options are also available for animal ventilation and an air or fluid based heater to regulate animal temperature

The 1025T can be factory configured with either fiber optic temperature or thermistor temperature sensors. Fiber optic sensors are very robust and CT-compatible.

The system generates an output trigger or gate based on a user defined algorithm composed of nearly any combination of the measurements.

Chapters 1 through 5 of the Operation Manual cover basic system operation for ECG, respiration and temperature. This information may be all that is needed for some users. Viewing and reformatting trend data for export to a spread sheet program is covered in Chapter 6. SnapShot data files are viewed using the program SnapView which is covered in Chapter 7. Options are available for use with the Model 1025T are covered in Chapters 10 through 16. Many advanced features such as the advanced gating menu and time stamping are discussed in Chapter 15.

Visit our web site www.i4sa.com for latest information on software and hardware upgrades and extended system capabilities. PC-sam software upgrades are free on the SAII website.

Please do not hesitate to contact us at service@i4sa.com or (631) 689-9408, if you have questions, comments or need additional information.

Ron Morris
President
SA Instruments, Inc.
Stony Brook, New York, USA
October 2025

Chapter 1
System Overview

Chapter 1
System Overview

Monitoring and gating:

The Model 1025T monitoring and gating system was designed to meet the physiological monitoring and gating needs for anesthetized mice, rats and larger animals in the PET, CT, SPECT. optical and laboratory environments. The system can also be used with some MR systems if the module is installed outside the magnet RF room using a special cable kit.

Both anesthesia and the local environment can adversely alter animal physiology. For that reason, research experiments often require measurement of physiologic parameters for heart rate, respiration rate, temperature, etc. It can also be necessary to control the temperature of the animal. For example, sedated mice can have heart and respiration rates depressed by more than a factor of two when exposed to a room temperature environment.

Motion artifacts in images can be eliminated or greatly reduced by employing gating techniques during the acquisition of the image data. By synchronizing data collection with the electrocardiogram, images can be obtained at specific times during the animal's cardiac cycle. These images, which are free of cardiac motion, can be viewed individually or in a cine time sequence to visualize heart movement.

Motion artifacts due to breathing can also be eliminated or reduced by synchronizing image data collection with the respiratory cycle. Typically, the largest movement of the diaphragm and abdomen is during inspiration. Thus, selective acquisition of image data during expiration can be effective in reducing breathing artifacts.

In some cases, it is advantageous to employ gating combinations to trigger image data acquisition. For example, both cardiac and respiratory gating can be employed to selectively acquire cardiac data only during expiration. These acquisition techniques can produce anatomic images free of breathing, heart and/or blood flow artifacts.

System Components:

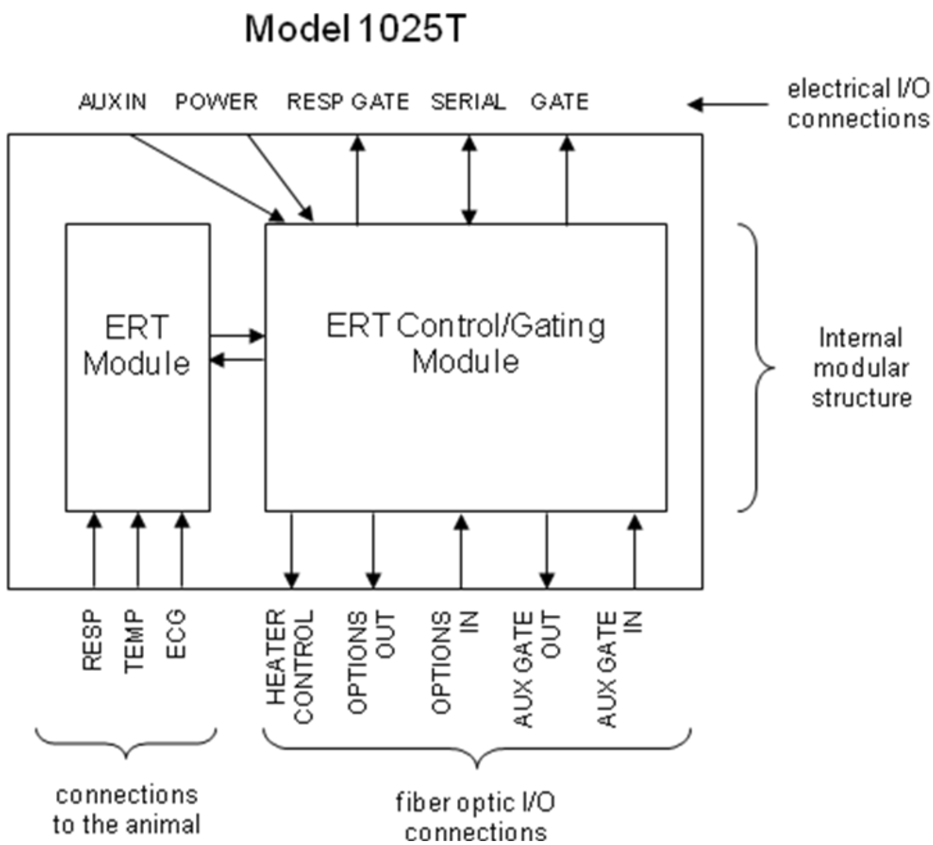
The Model 1025T monitoring and gating system measures ECG, respiration and temperature. The data acquisition module is typically positioned near the animal and it sends data to a PC located near the operator console.

The 1025T can be factory configured with the temperature measurement being made using a fiber optic sensor or a thermistor sensor. The fiber optic sensor offers several advantages over the thermistor sensor like being robust and CT-compatible. However, thermistor sensors are less expensive than fiber optic sensors.

System Overview

The Model 1025T is shown here with connections for 3-lead ECG, a pneumatic respiration pillow and a fiber optic temperature sensor. There are electrical and fiber optic input and output connections detailed on the next page. The 1025T also has LEDs that flash when ECG and/or respiration are detected. When the 1025T is configured for fiber optic temperature sensors it is labeled 1025T-FOT rather than 1025T.

The internal modular structure of the Model 1025T is shown below.



The ERT Module acquires data from sensors attached to the animal. The measured data is transmitted to the ERT Control/Gating Module. The ERT Control/Gating Module is covered in Chapter 3. The ERT Module is covered in Chapter 4.

The ERT Control/Gating Module sends data to the PC for display and receives instructions from the PC to control measurement and gating functions. Gates are generated by the module's microprocessor which can be sent to an imaging system. The delay from the R-wave peak to the scanner gate is user selectable as is the expiration gate delay and width. Two auxiliary gate input channels (AUX IN and FO AUX GATE IN) allow the user to synchronize gating to other external devices such as a ventilator and/or the scanner's imaging sequence.

The SAII Air Heater System (Chapter 9) or the Single Pump Fluid Heater System (Chapter 10) can be used with the monitoring system to regulate the temperature of small animals.

A fiber optic output provides control for the Air Heater Module. The ERT Control/Gating Module, using the measured value of rectal temperature and a user defined set point, controls current to the heating element in the Heater Module to regulate the animal's temperature.

The Single Pump Fluid Heater system (Chapters 10) can also be used with the Model 1025T to regulate the temperature of small animals.

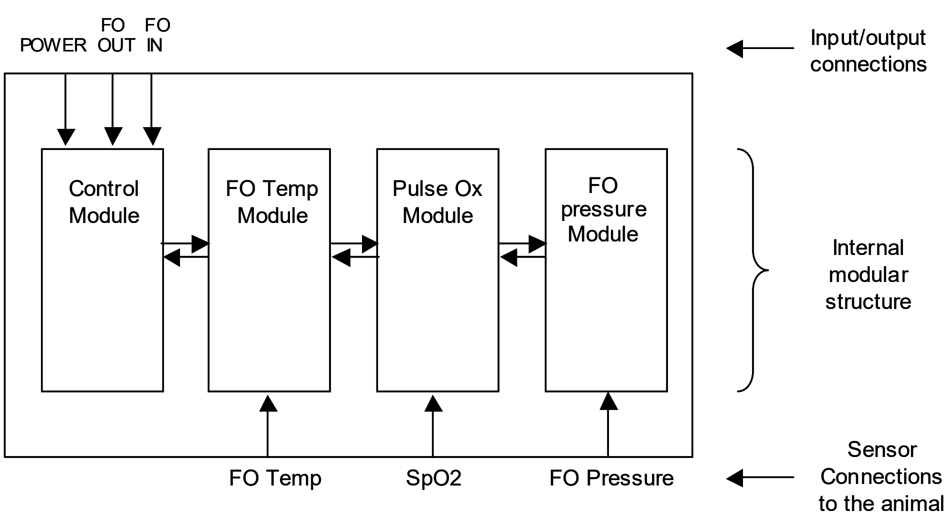
Several other modules can also be optionally used with the Model 1025T to acquire additional physiological measurements. The additional modules are located next to the Model1025T near the animal. Data and commands are transferred between the optional modules using short fiber optic cables. Connection is made using the Model 1025T ports labeled OPTIONS IN and OPTIONS OUT.

Three revisions of the Model 1025T have been released with different ways of implementing the use of optional modules. The early revision, RevA, required a fiber optic jumper cable be connected between the options ports if option were not in use. RevB replaced the jumper cable with a switch. Later revisions replaced the switch with electronics to automatically determine if options are in use or not.

An IBP Module can optionally measure invasive blood pressure using a blood pressure transducer connected with tubing to an invasive line in the animal. System design accommodates up to three IBP channels. The IBP measurement option is covered in Chapter 14.

Other optional parameters available are fiber optic temperature, fiber optic pulse oximetry and fiber optic pressure. These measurement functions can be either packaged each in a single module or all three packaged in the Multi-parameter Fiber Optic Module. The fiber optic sensors are both MR and CT-compatible. The internal modular structure of the Multi-parameter Fiber Optic Module is shown in the figure below. Pulse oximetry is covered in Chapter 11, fiber optic temperature is covered in Chapter 12 and fiber optic pressure is covered in Chapter 13.

Multi-parameter Fiber Optic Module



Chapter 2
System Setup

Chapter 2
System Setup

Installation of software:

If the system was supplied with a PC, the software will already be installed. To start the monitoring system double click the PC-sam icon on the desktop (refer to Chapter 3). To view and format trend data files click the TrendMap icon on the desktop (refer to Chapter 6). SnapShot data files are viewed with SnapView which is embedded in PC-sam version 7 and later. In this case, when PC-sam is opened an option is available to execute SnapView. For earlier versions of PC-sam, SnapView is executed by clicking on an icon on the desktop (refer to Chapter 7).

If a PC was not supplied, install the software following the instructions on the card that was supplied with the USB software drive. Specification requirements for the PC are listed in Appendix A. If a USB port is being used to communicate between the PC and the Model 1025T, use the appropriate driver from the USB Serial Converter CD supplied with the system.

Moving Windows

When a window is moved, the Windows operating system stops all other processes until the move is complete. That can cause loss of data, which can be a serious problem. As a work around this flaw, we have implemented an icon in the upper left on several windows that allow them to be moved without stopping other processes. To move the window, left click on the icon and drag it to a new location. When the icon is released, the window moves instantly to the new location.

Setting up the hardware:

The Model 1025T can be factory configured with the temperature measurement being made using a fiber optic sensor or a thermistor sensor. It also has several optional functions. This manual assumes all functions are present with the system. Ignore those sections for options not present with your system. Refer to Appendix B for a list of major system components and accessories.

1. Connect the 1025T (724101) to the PC using the Prolific USB to Serial Adapter (USB-21).

2. Power the Model 1025T using the external 12 VDC power supply (PS-2-12).

3. Position the AIR Heater Module (76n100) in a convenient location near the animal and connect it to AC power. Connect the fan air hose (FAH-10) (long tube) to the port on the Heater Module labeled “Fan”. Connect the warm air hose (WAH-5) (short tube) to the port on the Heater Module labeled “Warm Air”. Connect the simplex fiber optic cable (10SFOC-23) to the fiber optic receptacles on the Heater Module and Model 1025T labeled “Heater Control”. Follow the

color code on the fiber optic cables connecting gray plugs to gray receptacles and blue plugs to blue receptacles.

4. Locate the <u>Fan Module</u> (77n100) near the PC and connect it to AC power and to the fan air hose.

5. Position the <u>Multi-parameter Fiber Optic Module</u> (470100) next to or on top of the Model 1025T. Connect the <u>Duplex Fiber Optic Cable</u> (18INDFOC-23) to the two units making sure the color (blue or gray) of the cable connector matches the color of the fiber optic driver/receiver port. Connect the 12 VDC power using the <u>2 module Daisy Chain Power Cable</u> (DCPC-2). Note: early versions of the Model 1025T that do not have an options I/O switch need a short simplex fiber optic cable connected between the FO IN and FO OUT ports when optional modules are not in use. The latest versions of the Model 1025T automatically detects if options are in use.

6. For information on setting up invasive blood pressure refer to Chapter 10.

7. To provide a trigger to the imaging system, connect a BNC cable (not supplied) from the imaging system's gate inputs to the GATE connections on the 1025T.

Communication port assignment

Windows will automatically assign a communication port number for the serial or USB port which is being used for communication to and from the Control/Gating Module. The assignment is made when the PC is turned on. The most common port assignments are "com1" for a serial connection and "com4" for a USB connection. However, other assignments are possible.

Follow these instructions to determine the com assignment:

Windows XP: click Start>Settings>Control Panel>System>Hardware tab>Device Manager>expand Ports (COM & LPT) and read the serial or USB assignment.

Windows Vista and seven: click Start>Control Panel>System>Device Manager>select continue in the permission window>expand Ports (COM & LPT) and read the serial or USB assignment.

Windows 10 and later: Start>Device Manager> expand Ports (COM & LPT) and read the serial or USB assignment.

Setting the communication port in PC-sam

To set the com port double click the PC-sam icon on the desktop. Click the button labeled “Click Here to Show Full Setup Screen”. The com port assignment should be set in the upper right-hand portion of the Full Setup Screen. Note PC-sam can accept com port 1 through 8. Contact SAII if Windows assigned a port greater than 8.

Testing the monitoring and gating system:

The system can be tested using the Simulator (754100). Connect the Simulator to the Model 1025T using the simulator ECG leads (SEL-705). If the 1025T is configured to use a thermistor temperature sensor, also connect the simulator temperature cable (STC-105). The simulator generates an ECG waveform, a respiration waveform (E-Resp refer to Chapter 3) and a temperature reference for thermistor sensors.

Turning on the Simulator power should result in ECG and respiration waveforms and a temperature reading for a thermistor sensor on the PC display. If the 1025T is configured with the temperature measurement being made using a fiber optic sensor, connect the sensor to the 1025T to measure room temperature. In either case the temperature reading displays on the PC as T1.

It may be necessary to alter the monitor configuration to display the E-Resp waveform (refer to Chapter 3). The ECG waveform appears after the offset voltage reaches 2.5 V (refer to Chapter 3). Adjust the simulator amplitudes, if necessary, to obtain heart and respiration rate readings and indications of gate detection. The simulator is powered by an internal 9V battery, which is not rechargeable (refer to Chapter 8).

Open the SYSTEM INFO window and observe the 50/60 Hertz notch filter setting for the ERT Module. Make certain the filter is set properly for your location (50 Hz in Europe, 60 Hz in US, etc.) The filter setting for the Model 1025T can be changed by the user (refer to Chapter 4).

Connect an IBP Transducer (IBPX-A) to the IBP3 port. A yellow LED should flash indicating the need to zero the transducer. Press the zero button on the module. Apply pressure to the transducer by blowing on the input connection or by attaching a respiration pillow sensor to the input. Pressure on the transducer should produce waveform deflections on the PC’s IBP3 waveform display.

Connect a Fiber Optic Temperature Sensor (FOTS-6) to the Multi-parameter Module. A FOT1 temperature reading should appear on PC-sam’s display. It maybe necessary to select “all temperatures” in the Setup window (refer to Chapter 3).

Connect the Large Fiber Optic Clip Sensor (530100) to the Multi-parameter Module. You should observe a red light in the clip. Place the sensor on your little finger. You should observe a plethysmogram waveform and readings for heart rate and oxygen saturation. It may be necessary to set the detection threshold (refer to Chapter 11).

Attach a Fiber Optic Pressure Sensor (FOP-5-4) to the Multi-parameter Module according to the instructions in Chapter 13. Do not apply pressure to the tip of the sensor. Note that it is necessary to clean the connector surfaces before attaching the senor and/or extension cables. A yellow light should flash when the sensor is connected. Press the “zero” button to zero the pressure measurement. You can apply pressure to the tip of the fiber optic sensor either by lowering it in a container of water or by connecting a Tuohy Borst Adapter (FOP-TBA) to a Respiration Pillow Sensor using a stop cock. Refer to Chapter 13 for detailed instruction on handling the Fiber Optic Pressure Sensors.

Testing the air heater system:

Activation of the Fan Module power switch should produce air flow to the Air Heater Module. Turn on the Heater Module power switch and observe a green LED indication. Connect the Simulator or a Rectal Temperature Probe (RTB-101) to the Model 1025T and observe a temperature reading on the PC monitor display. Select a temperature control set point higher than the measured temperature by opening the heater window on the PC display (refer to Chapter 9). A yellow LED should pulse on the Heater Module indicating power is being delivered to the heating element. Within several seconds, warm air should be present.

Recommendations for daily operation

Model 1025T: 12 V power should be unplugged from the back of the module when not in use.

The power to the Air Heater and Fan Modules should be turned off when not in use.

FO Temperature, FO Pressure and Pulse Oximeter Modules - We recommend unplugging the 12 V power at the end of the day. Turning off power turns off the light source for the temperature, pressure and oximetry probes.

Fluid Heater System – turn off the power to the Heater Module and Circulation Module when not in use

Chapter 3
PC and ERT Control/Gating Module

Chapter 3
PC and ERT Control/Gating Module

Overview

The ERT Control/Gating Module, located in the Model 1025T, is connected to a PC to provide operator control as well as display and storage of waveforms, computed gates, measured values and trends.

The signal received at the ERT Control/Gating Module from the ERT Module is demodulated and separated into ECG, respiration from the pneumatic pillow sensor and temperature components before being processed to detect the R-wave (primary) peak of the ECG waveform. Operator control of the QRS (R-wave) detection algorithm is affected from the PC by selecting threshold values for the QR (leading) and RS (trailing of opposite polarity) slew rates as well as ECG gate blanking time. Slew rate control allows reliable determination of the ECG R-wave peak with minimal delay. Gate blanking time is set to eliminate unwanted gates from secondary peaks and/or interference.

The respiration waveform from the pneumatic pillow sensor is automatically processed to detect inspiration. When the animal takes air into the lungs, the pillow sensor is compressed and the respiration waveform changes. The change in the waveform is detected and an inspiration gate is generated. The inspiration gate is usually inverted to make an expiration gate. Both the beginning delay and maximum width of the gate are user controlled.

The E-Resp™ respiration waveform is extracted from digitized ECG measurements and processed to detect inspiration. Respiration gates (E-Resp™ gates) are determined either automatically or manually from the respiration waveform. Gate position in the respiratory cycle can be set by the user.

Monitor display

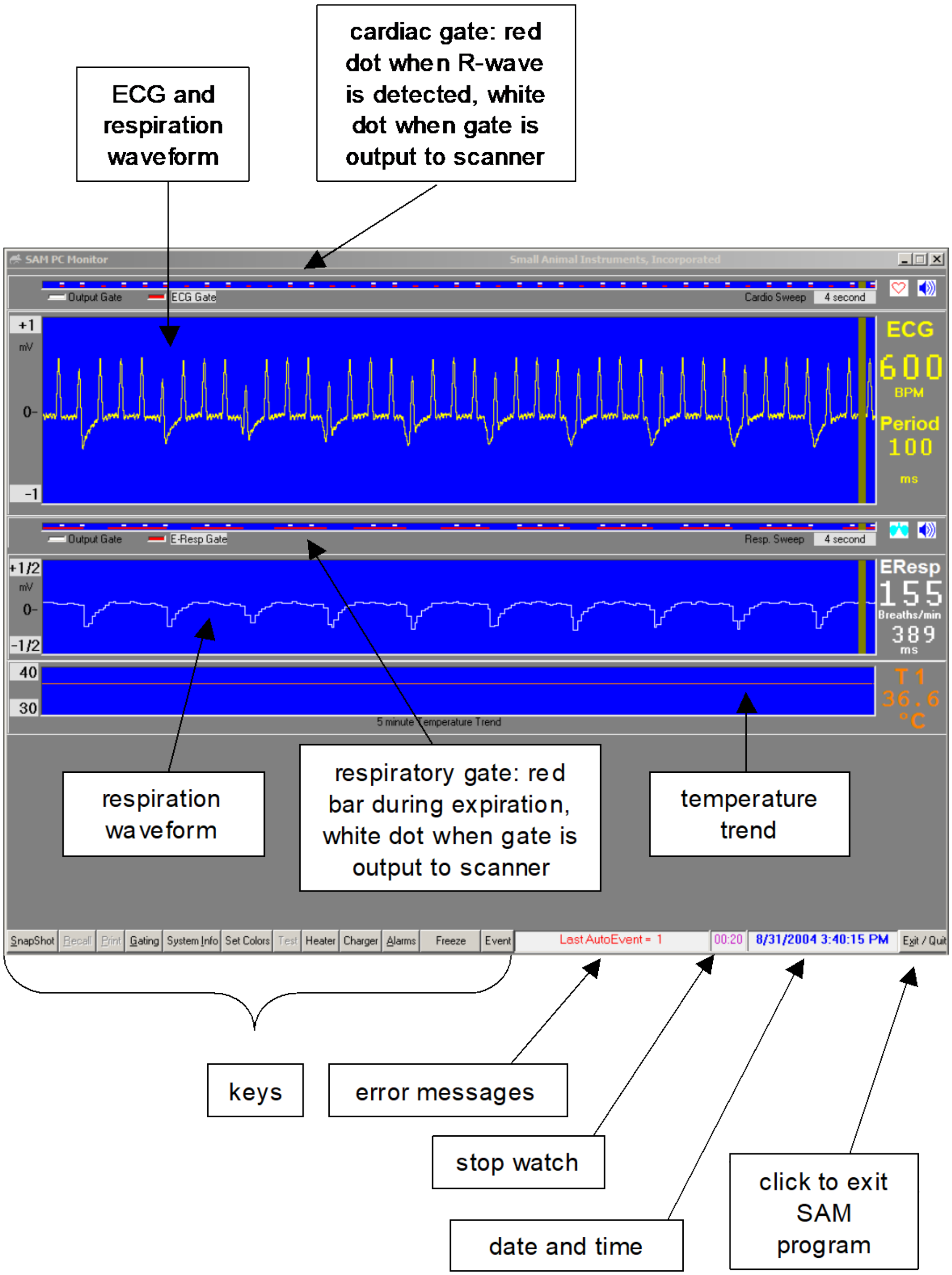
The monitor display is user configurable from the MONITOR SETUP window. Double clicking the PC-sam icon on the PC desktop generates an option to enter the MONITOR SETUP window before starting the monitor.

A typical monitor display configuration is shown on the next page. In this example, the parameters monitored are ECG, respiration and temperature. Detection of the R-wave (QRS complex) is indicated by the presence of a red dot on the cardio sweep display above the R-wave peak.

The respiration waveform goes positive or negative during animal inspiration, depending on the pressure transducer in the ERT Module. The waveform exhibits only small changes in amplitude during expiration. Expiration is indicated by the presence of a red bar above the appropriate portion of the waveform. Right click on the respiration waveform inverts the display, but has no effect on gating..

White dots in the cardio sweep display are also shown in the respiration sweep display. They indicate times when gates have been sent to the scanner to initiate image data acquisition. In this case, the gating algorithm included both ECG and respiration, so red dots (R-waves) only generate white dots (gates) when they occur during animal expiration.

Gates and waveforms sweep from left to right. The number of red dots (R-waves) determines the measured heart rate and the R to R period. Likewise the number of red bars (expirations) generates the measured respiration rate and period.

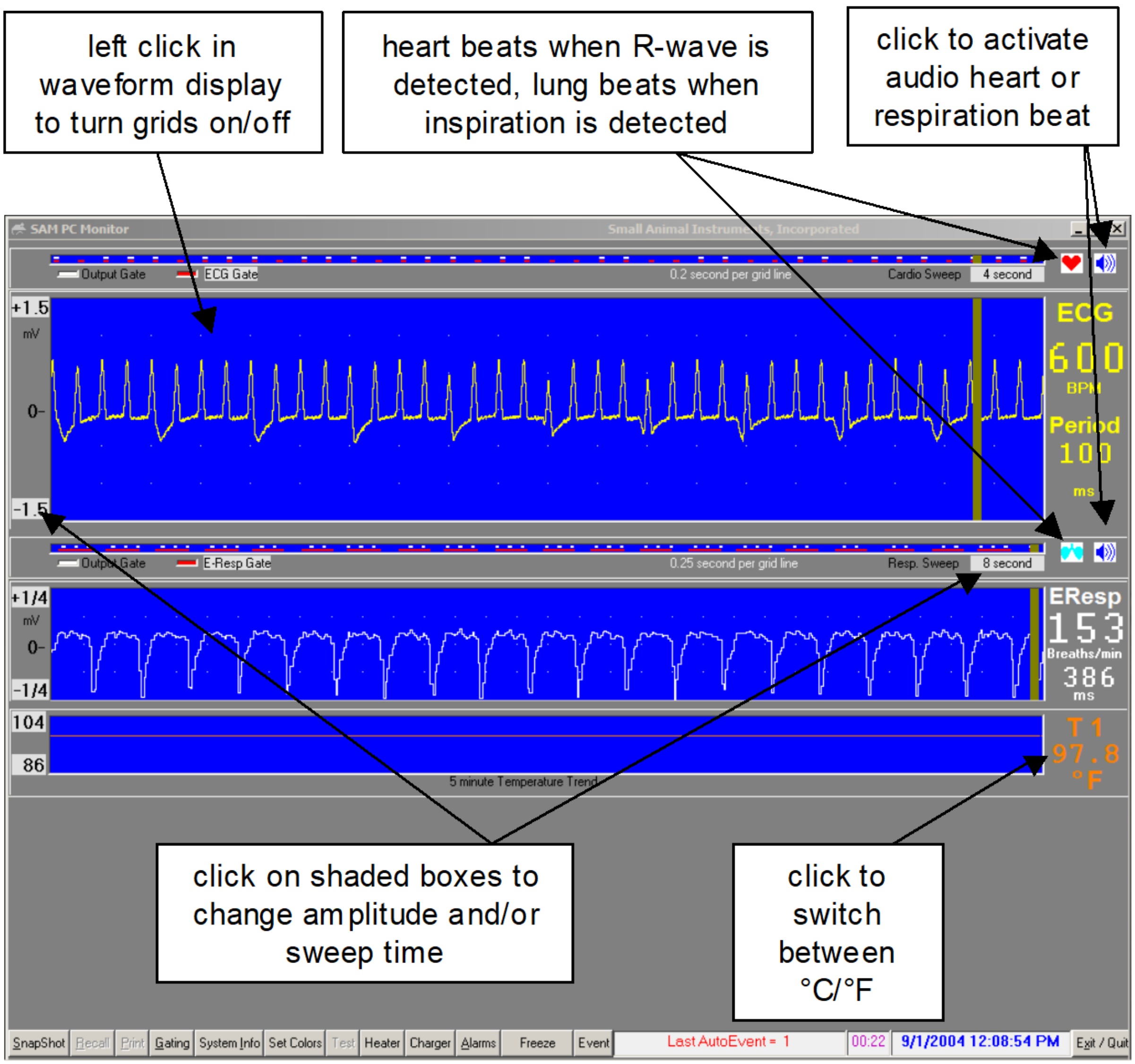


Temperature measurements are displayed in a 5 minute trend with the most recent measurement on the right of the display. Each new temperature measurement is displayed in digits as it is entered in the trend portion of the display.

Located along the bottom of the monitor display are several keys which perform special functions, display data or allow user entry of operating parameters. Each of the keys will be discussed in a later section of this chapter. In addition to the keys, there are regions for display of error messages, a stopwatch and the date and time.

The stopwatch displays in hours and minutes. A bar flashes to indicate the stopwatch is running. Click on the stopwatch display, to reset to zero.

Right click on the shaded waveform amplitude values to increase or left click to decrease the maximum and minimum values. Right click on the shaded sweep time



boxes to increase or left click to decrease the sweep time. Note the cardiac and respiratory sweep times are independent and can be set to different values.

Switch between °C and °F by clicking on the digits in the temperature display

Clicking on the speaker icon associated with the cardiac sweep activates an audible beep for each ECG R-wave. Likewise clicking on the speaker icon associated with the respiration sweep activates an audible beep for respiration. It is not intended for both the ECG and respiration audio indicators to be on at the same time.

Grids can be turned off and on by left clicking inside a waveform display. Note the time separation of the grid lines is displayed above the waveform.

Right or left clicking on the gray box next to the red indicator of the cardio or respiration sweep gate displays will sequentially change the gate displayed. For the cardiac sweep the most useful gates are ECG and R-detect + Blanking Time.

Labeling convention for respiration channels

Respiration waveforms, measured from ECG leads, and the associated gates are labeled as "E-Resp" or ''EResp". Respiration waveforms, measured from a pneumatic pillow, and the associated gates are labeled as "Resp" or "P-Resp". Waveforms and the associated gates for the User Spare Analog Channel are labeled "UserR" or "User Resp". Note that the "UserR" label can be changed in the User Spare Resp Setup menu. (refer to Chapter 15).

User Input channels

Up to three user auxiliary input channels are available, two digital (on/off) and one analog. The digital channels are useful to synchronize gating with external equipment such as a ventilator and/or to time stamp physiological measurements with an event marker from the scanner. The analog channel allow user defined waveform information to be input for recording, display and gating. (Refer to Chapter 15).

The digital auxiliary channels are input through the Model 1025T at "AUX IN" (0 – 5 V) and "AUX GATE IN" (fiber optic signal). They are digitized at 1800 samples/second.

The analog auxiliary channel is associated with the IBP Module. It is input at "IBP3". IBP3 is digitized at 900 samples/second. Refer to Chapter 10 for connector pin specifications and Chapter 15 for setup features.

Input/output connections

Electrical connections:

PC	Serial connection to PC
Gate	output gate to trigger scanner
RESP GATE	output respiration gate to trigger scanner
AUX IN	Aux gate input, a user digital input gate channel (on/off)
Power	12 VDC input power connection

Fiber optic connections:

AUX GATE IN	fiber optic aux in, a user digital gate input channel (on/off)
AUX GATE OUT	Gate or trigger pulse out
OPTION IN	Input from optional data acquisition modules
OPTION OUT	Output to optional data acquisition modules
HEATER CTL	control signal for the Air Heater Module

There have been several revisions of the Model 1025T. The early revision, RevA, required a fiber optic jumper cable be connected between the options ports if option were not in use. RevB replaced the jumper cable with a switch. Revisions later than B replaced the switch with electronics to automatically determine if options are in use or not.

Gate output pulse signal configuration

The Model 1025T is shipped from the factory with the gate output pulse configured appropriate for the user's imaging system either TTL (H) or active low (L). The gate output pulse can be changed by removing the cover of the Model 1025T. The switch is located inside a small access hole in the RF shield.

Most imaging systems require the gate output pulse to be TTL (H), but MR scanners manufactured by Bruker including the ICON require active low (L). The switch position as set by the factory is indicated on the bottom of the module.

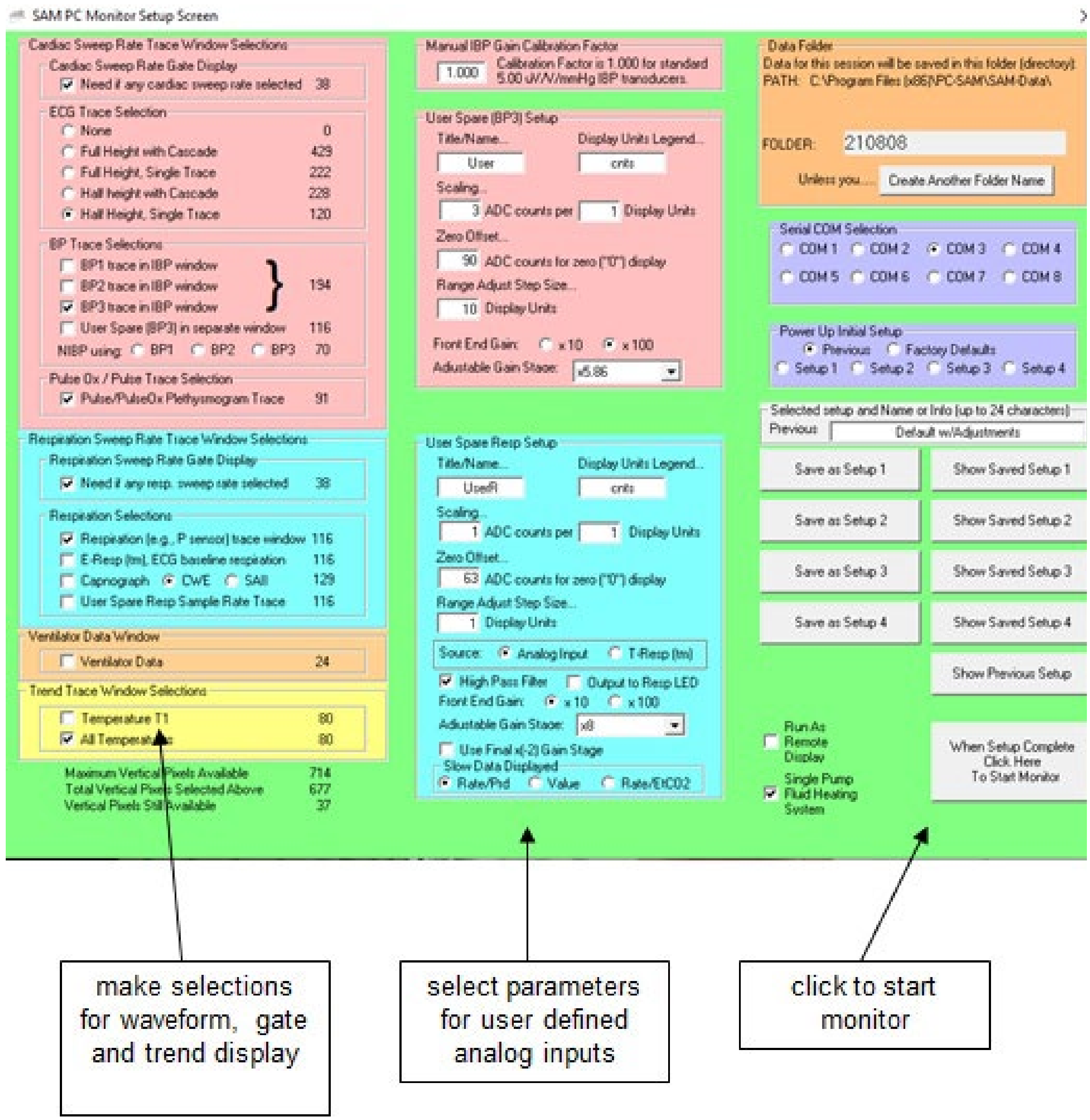
Altering monitor configuration

An option exists to open the MONITOR SETUP window after executing PC-sam. The SETUP windows is shown on the next page.

PC and ERT Control/Gating Module

The MONITOR SETUP window allows the user to do the following:

1. Define which waveforms, gates and trends to display
2. Setup user defined traces
3. Select the respiration channel signal source
4. Change the name for the data folder for the current session
5. Change the serial communication port
6. Select a default stored setup file at startup
7. Select an alternate stored setup for the current session.



The portion of the setup window for waveform, gate and trend selection includes sections for cardiac, respiration and temperature. The numbers to the right of the trace selections are the number of vertical pixels necessary for that portion of the display. The total number of pixels used can not exceed the number available for the PC's display. A calculation to determine the number of pixels still available is performed in the lower left corner of the display.

The portion of the setup window for user defined auxiliary waveforms allows selections for gain and labeling. These parameters can also be set in real time by right clicking the appropriate waveform from the main monitor display. (Refer to Chapter 15).

The data folder for storage of trend data defaults to a date encoded name of the form yymmdd(letter). The letter changes for each successive session during the day. The user can change the file name and storage location from the setup window.

Up to four user defined setup files allow different monitor configurations to be saved for easy retrieval. For example, setup files could be stored for different types of animals or different users or for different types of studies. In addition Factory Defaults can be selected or the previously configured setup. In the later case, any changes made during the last monitoring session will be remembered and restored for the next monitoring session.

SnapShot key

The SnapShot key in the lower left portion of the monitor's main display causes storage of the last 36 seconds of monitor data. All data transmitted to the PC during the last 36 seconds is stored not just displayed data. Parameter values set by the PC (e.g. slew rates for R-wave detection, blanking time, gating selections, etc.) are stored once, at the time the SnapShot key was clicked.

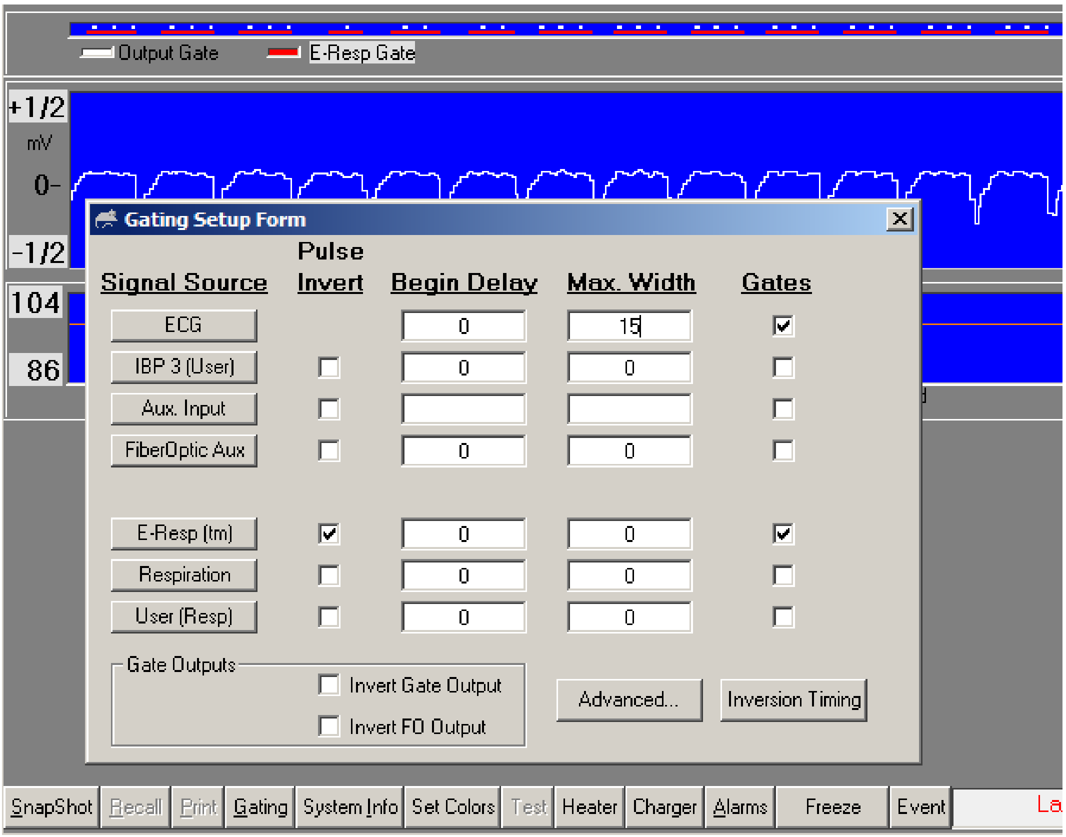
SnapShot data files can be viewed using SnapView.exe. Options exist to allow the entire file to be played back or to view the last few seconds of data. Most features available in PC-sam are also available in SnapView. For example sweep rates and amplitudes can be adjusted while viewing the files and the keys are active to display windows with associated parameter values. (Refer to Chapter 7).

Trend key

The Trend key in the lower left portion of the monitor allows the current Trend file to be restarted or saved. When the saved selection is made a new Trend file is automatically started.

GATING SETUP window

Click the Gating key to open the GATING SETUP window.



This window provides a means to include one or more signals in the gating algorithm. In the window above, both ECG and E-Resp gates must be satisfied for generation of an output gate (white dot).

Gate width and delay can be controlled for each signal source. Delay and width entries are in msec. A zero setting for Max Width is used to automatically determine the width from the gate detection software.

A check in the “Pulse Invert” column inverts the gate logic. For example, the E-Resp gate detection algorithm detects the dip in the waveform which occurs at inspiration. A check is placed in the Pulse Invert column to switch the gate to the expiration portion of the waveform. If desired, the expiration gate can be delayed in time or shortened in width.

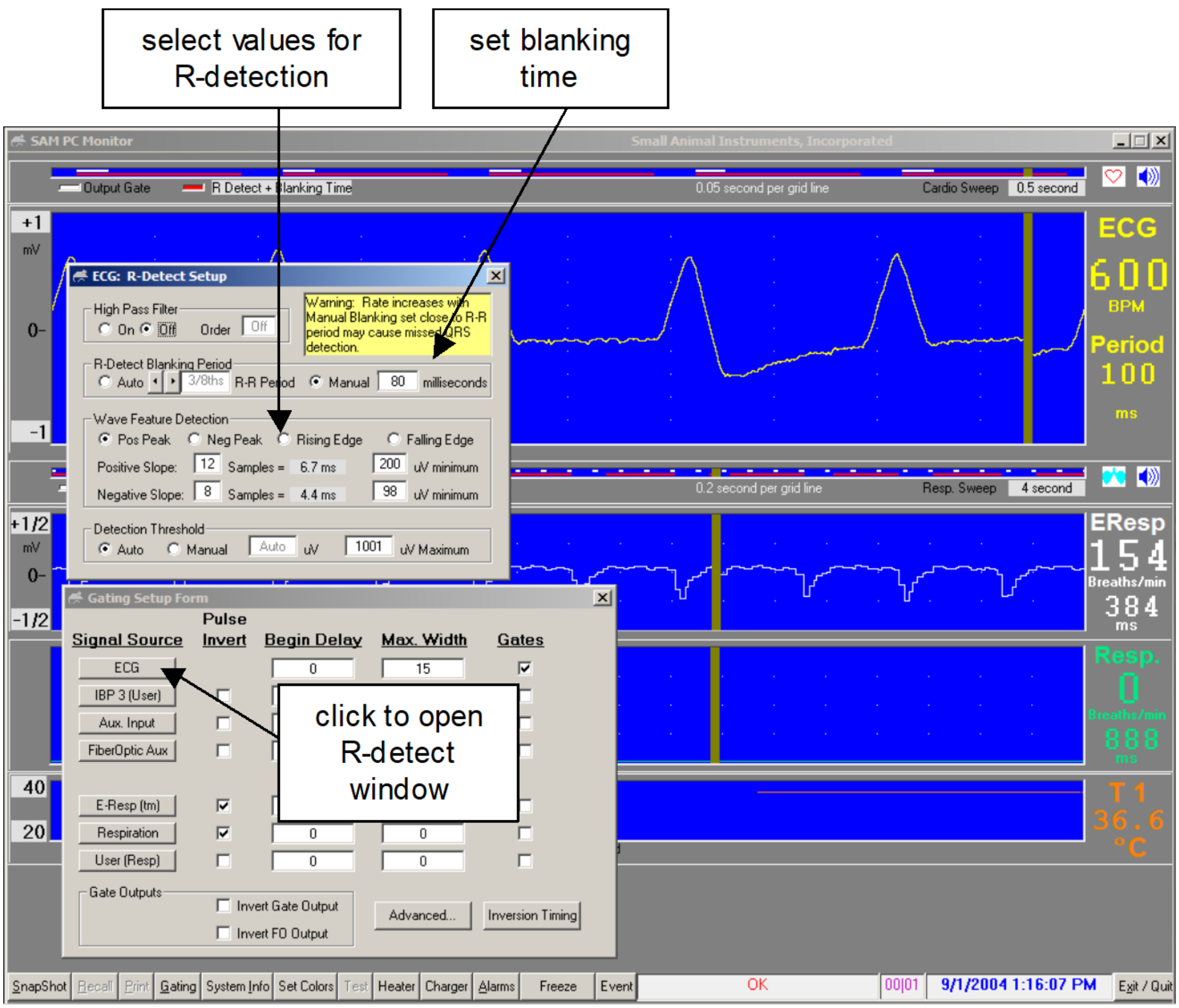
Clicking on either the Advanced or Inversion Timing keys expand the GATING SETUP window. (Refer to Chapter 15).

R-DETECT SETUP window

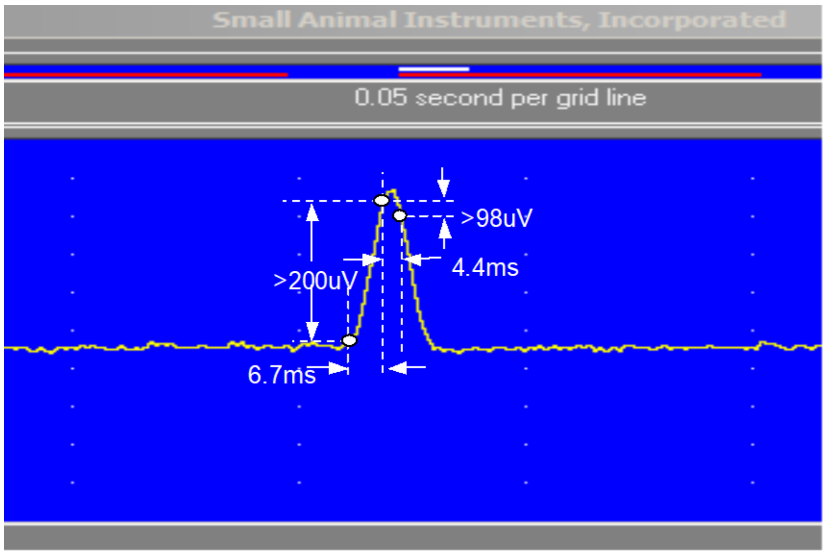
Click the ECG button in the GATING SETUP window or right click in the ECG waveform display to view the R-DETECT SETUP window.

The **high pass filter** removes low frequency components of the ECG waveform. It can be useful with large animals and low heart rates, but is of little benefit for mice. The order number can be selected between 16 and 6. Order number 6 produces the strongest filter function.

The **R-detect blanking period** or blanking time is a very useful feature. Once an R-wave has been detected, the software inhibits R-wave gate generation for the blanking time. This feature can be used to eliminate false triggers from interference.



The **R-detect algorithm** is based on 2 or 3 points and their positive and/or negative slew rates or slopes (amplitude/time). The waveform shown exhibits R-wave gate generation for factory defaults: positive peak with positive slope of 200µV/6.7ms and a negative slope of 98µV/4.4ms. The gate is generated at the end of the negative slope. In this example the R-wave is about 800µV in amplitude. The positive slope requirement is easily exceeded and the gate is generated as soon as the negative slope requirement is satisfied. Note that the mid point that satisfies the gate requirement is earlier in time than the R-wave peak. Thus the delay of the scanner gate is less than the negative slope time (i.e. less than 4.4 msec)



Proper selection of parameters for R-wave detection are important in obtaining reliable results. This is especially true when the ECG waveform contains large contributions from blood flow, vibration or respiration.

Perform the following steps to determine optimum settings for ECG detection (note we assume a positive R-wave for this discussion, but the software works in a similar manner for a negative R-wave):

Select a wave feature to detect: Usually this is a positive going R-wave. Selecting positive peak will give more reliable detection than selecting a rising edge. The only reason to select a rising edge would be to obtain a gate occurring before the R-wave peak in time.

Pick the times for the slopes: There are a maximum of 31 sample points or about 17 ms. Different animals have different rise times for the R-wave. Select the largest time appropriate for the animal's rise time. For mice the rise time is about 7.5 ms. Because the gate is generated at the end of the fall time, the fall time is usually set to be less than the rise time.

Select the amplitude(s): Determine the peak amplitude of the R-wave: usually 500 µV to 1000 µV. In the case of mice with a rise and fall time selected of 6.7 and 4.4 ms respectively, we select rise & fall amplitudes of less than 6.7/7.5 = 90% and 4.4/7.5 = 60% of the peak amplitude. The system can be used to determine the amplitudes: set the amplitudes smaller than you expect, but large enough not to get false gates, then slowly increase one of the amplitudes until gates begin to be missed. Final setting of 30 - 50% of max works well with auto detection threshold and 60 – 80% for manual detection threshold.

The **auto detection threshold** is a proprietary additional detection criterion. To turn it off, select manual and set the threshold to the positive slope amplitude.

CHARGER window

The CHARGER window reports the current status of the ERT Module Battery Pack and the IBP Module power. If the IBP Module has an internal battery it also reports the battery status..

Chapter 4
ERT Module

Chapter 4
ERT Module

Overview

The ERT Module located in the Model 1025T obtains the animal's electrocardiograph (ECG) from three leads connected to sub-dermal needle electrodes, gold disk surface electrodes or pads. The signal difference from two "active" leads generates the ECG waveform. The third "driven" lead provides a common mode signal from the ECG circuit.

A respiration waveform can be obtained from a small pneumatic pillow sensor taped to the animal's abdomen (P-resp) or from a signal induced on the ECG waveform due to the animal's motion (E-resp). In most situations, the pneumatic pillow sensor will provide the most reliable respiration waveform.

Temperature is measured using a temperature probe in the animal's rectum. The Model 1025T can be factory configured with the temperature measurement being made using a fiber optic sensor or a thermistor sensor.

ERT Module signals from the animal are passed through amplifier and filter electronics before being combined and digitized. The digitized signal is transmitted through optocouplers to the ERT Control/Gating Module to provide electrical isolation for the animal.

The QRS or R-wave is detected by the ERT Control/Gating electronics. Signals synchronous with the R-wave are subtracted from the ECG waveform to obtain the E-Resp^{TM} waveform. Gates are generated for both the R-wave and inspiration from P-Resp and E-Resp^{TM}. The gate position and width can be controlled by the user from the PC.

Attaching ECG electrodes

Electrode placement is typically in or on the right front leg and left rear leg for the active electrodes. The driven electrode can be connected at any convenient third location on the animal. The red and white ECG connections are for the active electrodes. The black ECG connector is for the driven lead. The red electrode should be above the heart on the patient's right. The white electrode should be below the heart and to the patient's left. The black electrode can be at any convenient location.

Attachment of sub-dermal ECG needle electrodes

Make certain the needle does not enter the muscle but rather is positioned between the muscle and skin. At least half the length of the needle should be inserted in the animal. Make certain the needle tip does not protrude. Use tape to secure the electrode. If the needle electrodes are inserted in the muscle, a large offset voltage can occur. The offset voltage should be 2.5 +/- 1 V. It is displayed in the SYSTEM INFO window on the PC (refer to Chapter 5).

Attachment of electrode pads

Pad electrodes may be used by shaving the attachment site or by application to the animal's paws. Tape can be helpful in securing the electrode.

Attachment of gold surface electrodes

Surface electrodes may be used by shaving the attached site or by application to the animal's paws. Apply electrode gel or paste to the electrode and to the animal before taping the electrode.

Positioning ECG lead wires

ECG extension leads can be used to extend lead length. ECG lead wires should be twisted with each other and as short as practical. Excess ECG lead wire length can cause 50/60 Hz interference on the ECG waveform.

Attachment of the respiration pneumatic pillow sensor

Position the pneumatic pillow sensor near the animal's abdomen and secure it with tape as shown in the photograph. Attach the sensor's tube to the Model 1025 at the Leur connection. It may be necessary to use one of the Respiration Extension Tubes to make the connection.

The respiration circuit incorporates an automatic gain stage that adjusts the amplitude of the respiration waveform within preset limits. After attaching the pillow, small respiratory signals may take a few seconds to gain up and produce respiration gates and a respiration rate.

The respiration waveform exhibits a positive or negative peak during inspiration, depending on the pressure transducer implemented in the circuitry. In either case, the gating algorithm detects inspiration and produces a respiration gate over the waveform. The P-resp waveform can be inverted by right clicking on the waveform display. To gate on expiration, check the “invert” box for respiration in the GATING SETUP window (refer to Chapter 3 and example waveforms in Appendix E).

Attaching the temperature probe

Use a lubricant or lubricated probe cover on the tip of the temperature probe before inserting it into the rectum. Secure the probe lead by taping it to the animal’s tail. Use extension cables to connect the probe to the Model 1025T. Clean the temperature probe with isopropyl alcohol.

The Model 1025T can be factory configured with the temperature measurement being made using a fiber optic sensor or a thermistor sensor. Fiber optic sensors are robust. Special care should be taken if your 1025T uses a thermistor temperature sensor.

Thermistor temperature probes are fragile and should be handled with care. The tip of the probe can be broken or cracked if the tip is bent. Problems with the thermistor temperature probe can occur if the probe develops a crack. Since the thermistor in the tip of the probe operates at 5 V and a break lets conductive fluid from the animal make contact with the thermistor wire, a small offset voltage can occur.

The offset voltage is displayed in the SYSTEM INFO window (refer to Chapter 5). It should be 2.5 V +/- 1.0 V for normal operation. If the offset goes close to 0 V or to 5 V the ECG will be flat lined by the software and a Lead Off error message will exist. An easy check to see if a large offset is due to the probe is to disconnect the probe from the monitor.(no need to remove it from the animal). If disconnecting the probe removes the offset, the probe is at fault. In an emergency a faulty thermistor probe will work if placed in a plastic or rubber sleeve (e.g. a thermometer cover or finger from a rubber glove). The sleeve provides electrical isolation.

Setting the 50/60 Hz notch filter

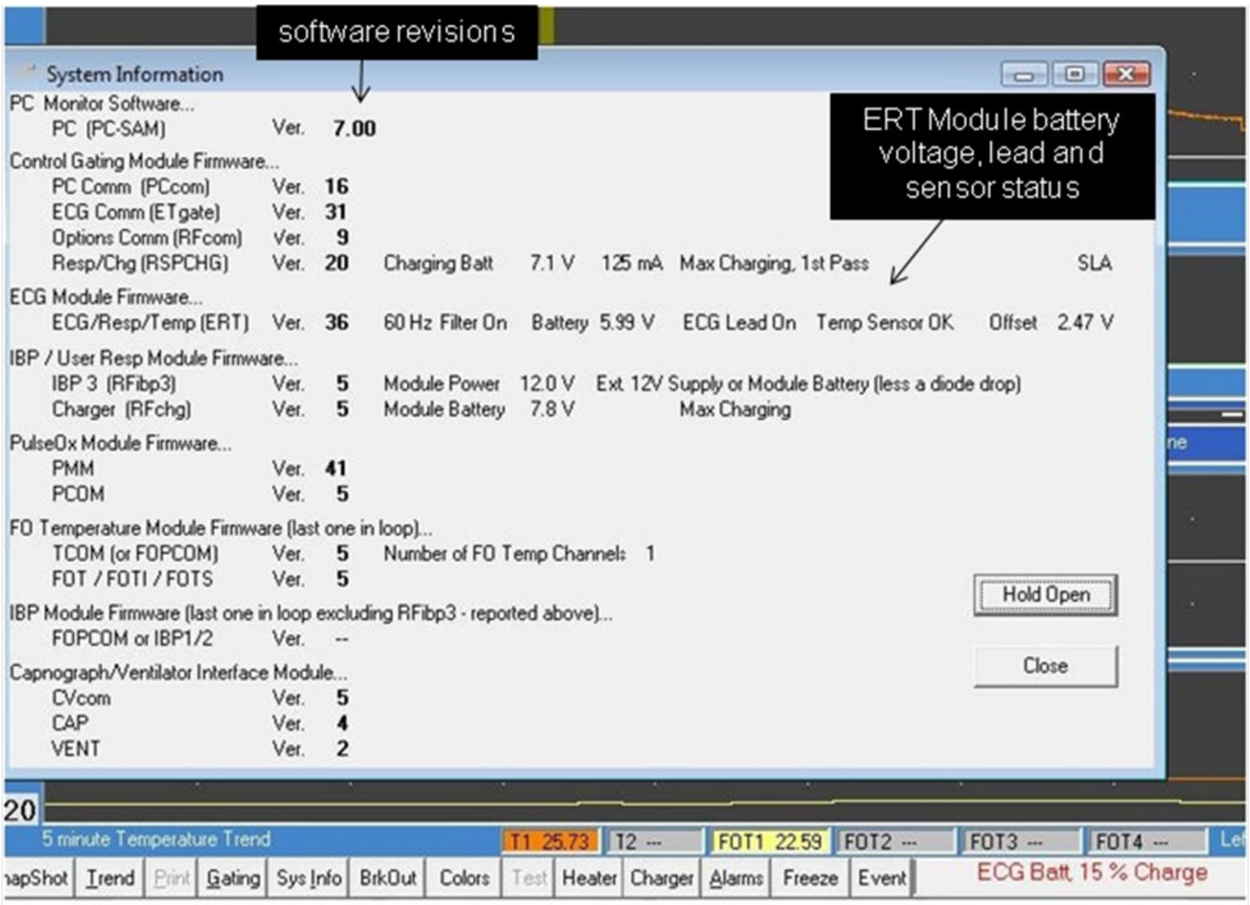
The notch filter is user selected for 50 or 60 Hz using a small switch located under the top cover of the Model 1025T. The switch should be set for your local power i.e. 60 Hz in the US and 50 Hz in Europe. The filter setting is reported in the SYSYEM INFO window on the PC (refer to Chapter 5).

Chapter 4
ERT Module

Chapter 5
Additional Features

SYSTEM INFORMATION window

The SYSTEM INFORMATION window lists software revisions, current status for the ERT Module and other useful information. The window will automatically close after several seconds. Click the “Hold Open” button to keep the window visible.



ERT Module status includes the 50Hz/60Hz notch filter setting, battery voltage which is the voltage from an isolated 6 VDC power supply, ECG and temperature lead status and offset voltage.

The ERT Module operates on 5VDC. But to display both positive and negative signals the zero point is offset to 2.5V. Any additional offset appears in this measurement and can affect the ECG. If the offset gets too close to zero or 5V, the software flat lines the ECG waveform and issues a lead off warning. The offset can deviate from 2.5V if needle electrodes are inserted in animal’s muscle or if the thermistor temperature probe is defective (refer to Chapter 4).

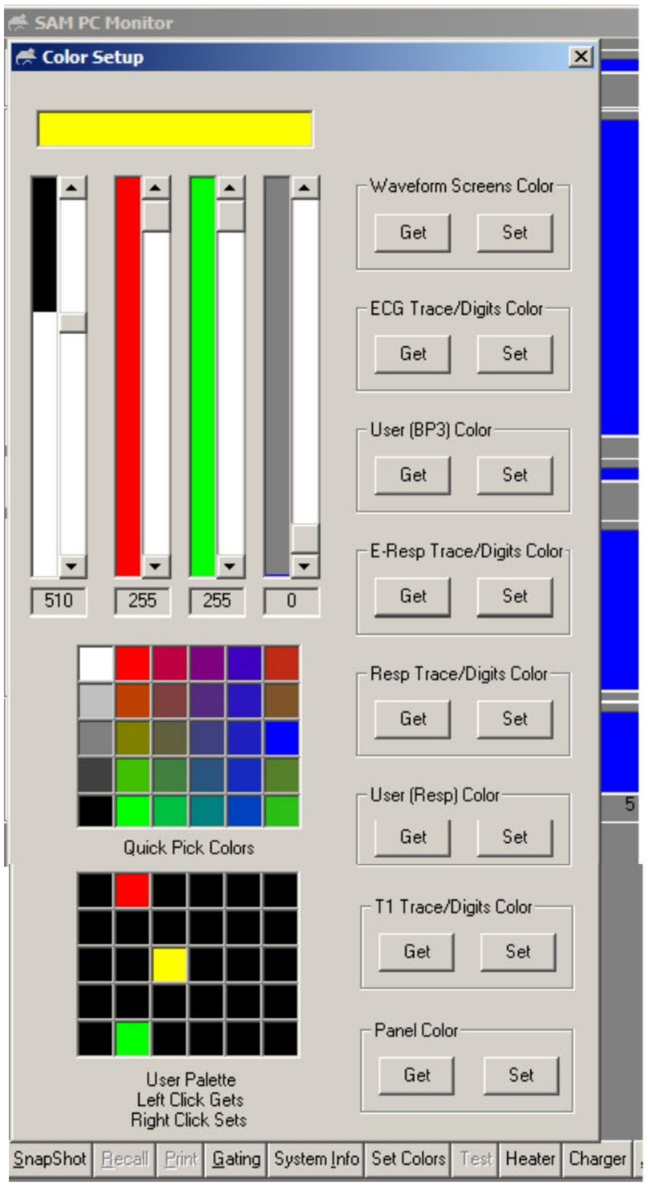
The IBP Module status includes the modules power source (12V or battery).

Additional Features

SET COLORS window

The SET COLORS window allows selection of colors for regions of the display and for waveforms and digits.

The set button sets the current color for the region or waveform selected. Colors can be

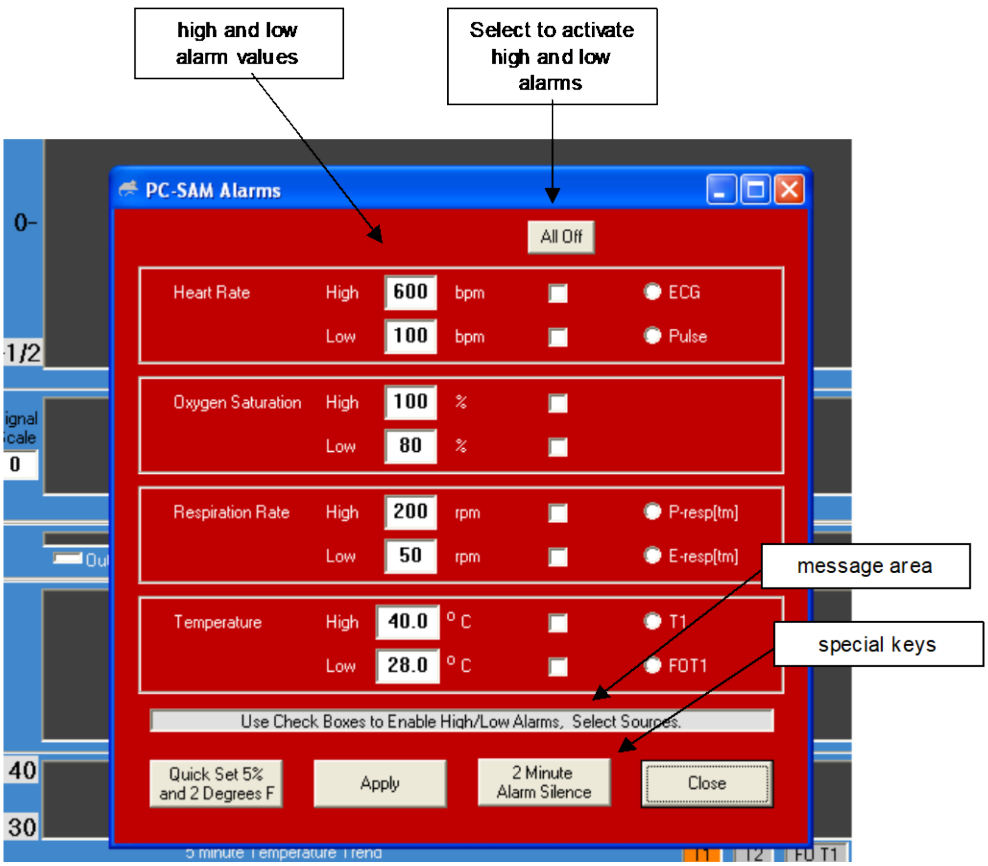


selected from Quick Pick or made from combinations of red, green and blue in the upper left of the window. Once colors have been constructed, they can be stored in the User Palette. Right click sets and left click gets.

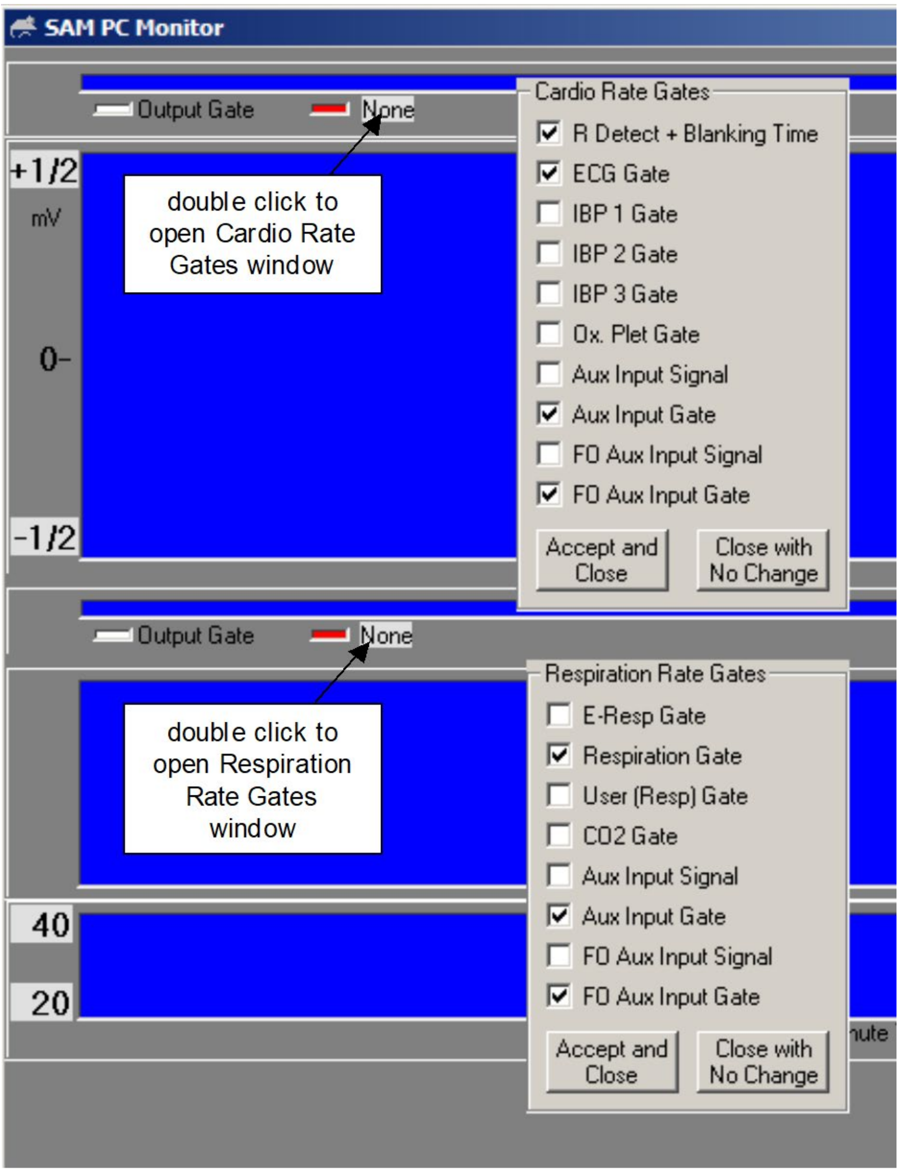
ALARMS window

The ALARMS window allows high and low alarm limits to be set for heart rate, oxygen saturation, respiration rate and/or temperature. A check mark next to an alarm limit followed by clicking the Apply key will activate the alarm. When the measured value meets or exceeds the limit, an audible alarm sounds.

The window has an area for messages and keys for Quick Set Alarms and Alarm Silence. The Quick Set key provides a convenient way to quickly set all alarm limits. Clicking the Quick Set key sets the high and low alarm limits 5% above and below the current measurement for heart rate, oxygen saturation and respiration rate and 2 ºF above and below the current temperature measurement.



Cardiac and respiratory sweep gates



Double clicking on the gray panel area of the cardio sweep display will open a window to allow other gates to be added to the selection list.

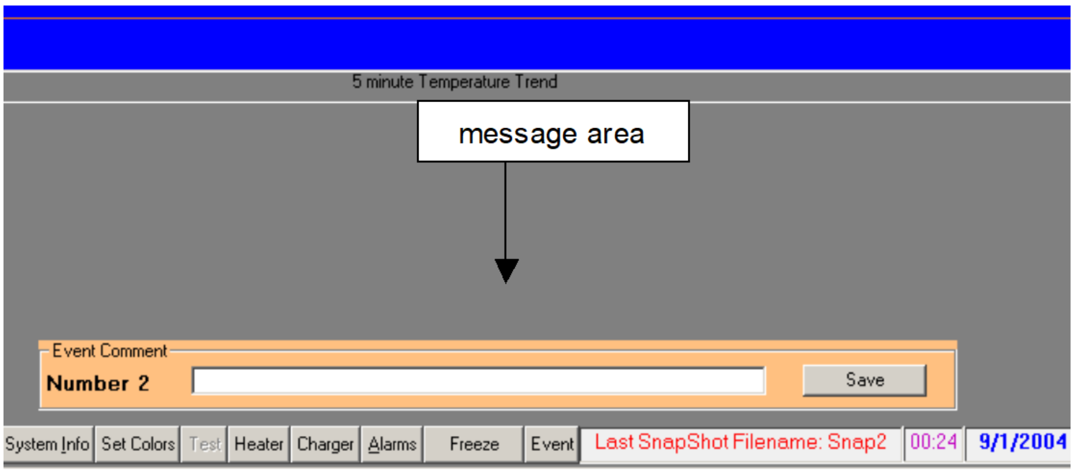
A indicator can be added to the ECG waveform to display timing of the selected cardio rate gate or the output gate by clicking on the colored box to the left of the cardio rate gate selection.

The respiration sweep display operates in a similar way to that on the cardio sweep display. Be certain the gate selected for display matches the waveform. For example if E-Resp™ is the waveform displayed for respiration, the selected gate should be E-Resp gate not Resp gate or User Resp gate.

FREEZE THAW key

The key freezes the waveform display. Pressing the key a second time restarts the waveform display.

EVENT key



Pressing (left clicking) the event key causes an event to be logged in the trend file at the time the event key is pressed.

Each event is given a number in sequence beginning with one for each monitoring session. Upon pressing the Event key, a window opens and a comment can be entered and saved. The event number, time and comment are logged in the trend data and can be viewed with TrendMap.

Chapter 6
Trends

Chapter 6
Trends

Overview

During operation, the Windows based PC-SAM software continuously logs data to a trend file located in a project folder. The data sample rate is once per second and more than 70 items are included in the recorded data point. The items include measured values of physiological functions (e.g. heart rate, temperature, etc) as well as status indicators of the hardware (e.g. battery voltage, offset voltage, etc.) The data file name and location is defined in the setup menu (refer to Chapter 3). The user has the option to save or discard the data when exiting the program.

To view data previously collected, execute the TrendMap program from the desktop. This program allows all or a subset of the data to be organized and output in a user defined format for import into a spread sheet program.

Provision exists to allow the user to configure the way the data is organized and viewed. Each new configuration can be saved as a setup file with the data set for recall at a later date.

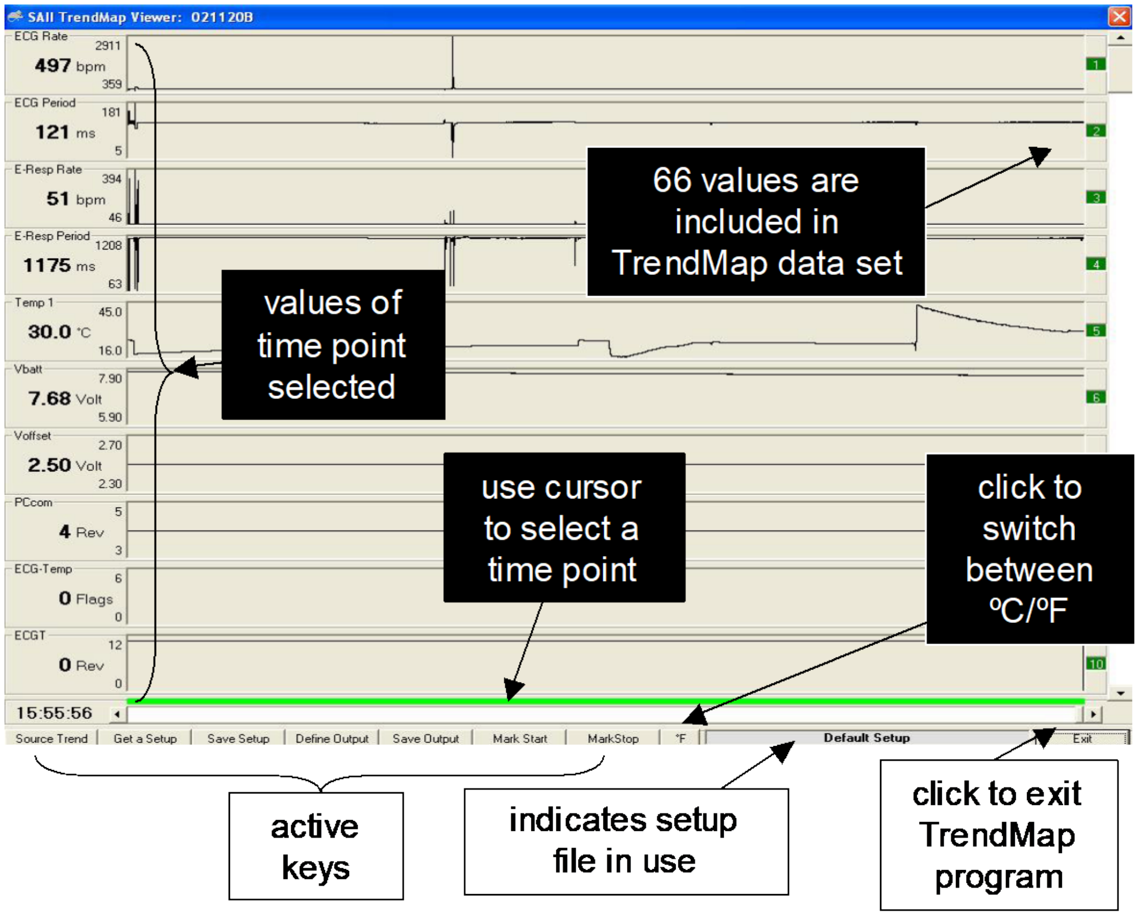
Events logged in PC-sam are recorded in the trend file as item 42 and can be viewed with TrendMap. Also AUX IN and Fiber Optic AUX IN are recorded in item 73.

TrendMap Viewer display

The TrendMap Viewer display is shown on the next page. More than 70 values are included in each TrendMap data set. A time cursor is displayed near the bottom and an item cursor is displayed on the right side of the display. Individual values are displayed on the left for the time point selected.

A subset of the trend data set is selected by the user for export. The exported data set is bound by a start and stop time and includes all trends up to one selected as the last to output. Commands exist to allow trend reordering before data is exported.

Trends



Several keys are located on the bottom of the display along with a message area. The following keys allow the data set to be retrieved, reconfigured and exported:

Source Trend – opens a trend data file
Get a Setup – opens a setup file for display of data
Save a Setup – saves a setup file
Define Output – specifies format for the exported data file
Save Output – saves the exported data file
Mark Start – selects the start time for data to be exported
Mark Stop – selects the stop time for data to be exported
°C/°F – toggle units for temperature measurements

In addition to the keys, a TREND ORDER ADJUSTMENT window is available to allow adjusting the order of trends in the data set. Click on any trend number on the right side of the TrendMap Viewer display to obtain the TREND ORDER ADJUSTMENT window.

A window for adjusting the displayed max/min of each trend data set is opened by clicking anywhere in the trend display

Source Trend key

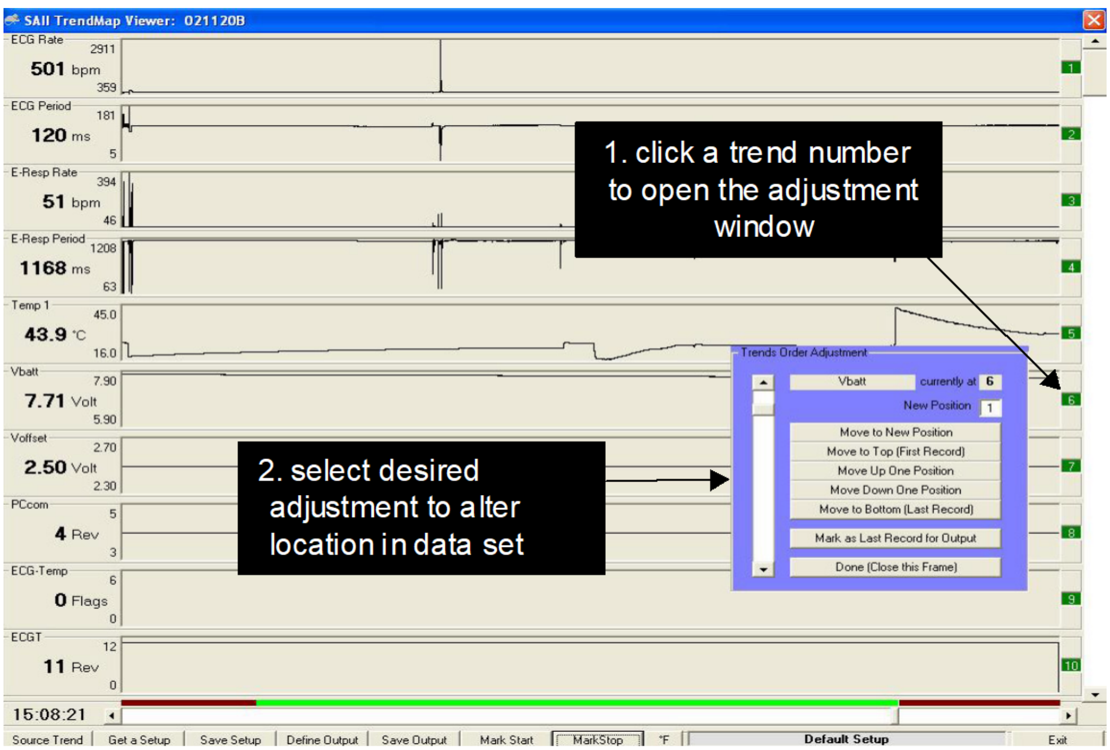
Clicking this key opens a window that allows selection of a trend data set. The window opens when TrendMap is executed or when the Source Trend key is clicked.

Get and Save Setup keys

These keys allow files which define the setup to be retrieved and saved. It can be useful after defining the order of trends in the data set (i.e. heart rate, temperature, respiration rate, time stamp events, etc.) and the output format to save the setup for future use.

TREND ORDER ADJUSTMENT window

Clicking any trend number opens the TREND ORDER ADJUSTMENT window. The scroll bar on the left of the window can select any trend location.



The trend selected is identified by name and current location number. Change the location of the selected trend by entering a new position number and clicking the Move to New Position key. Additional keys provide quick ways to move the trend up and down in the data set.

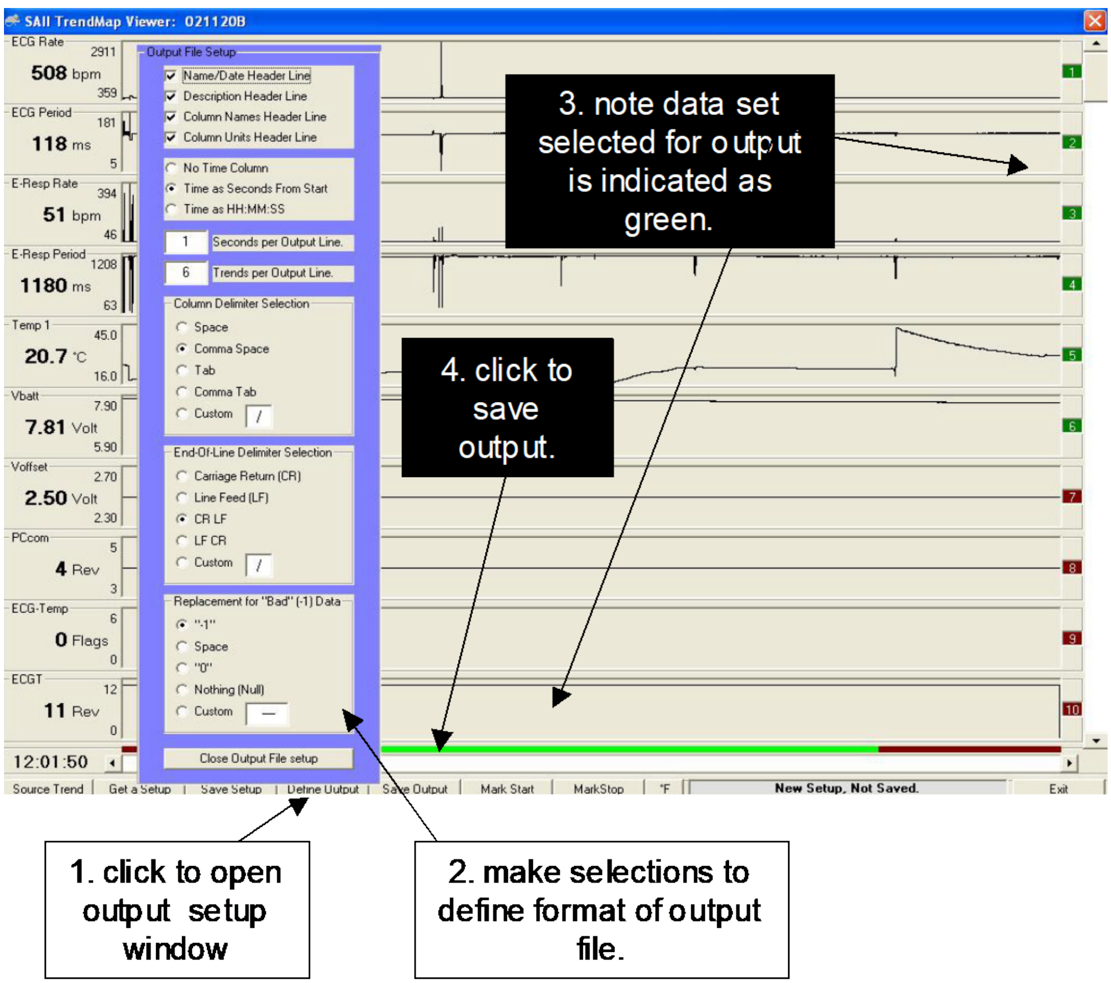
Trends

Clicking the “Mark as Last Record for Output” key defines the trends which will be included in the exported data set. The trends to be exported (number 1 through the last record) are indicated in green while all others are indicated in red.

Mark Start and Mark Stop keys

Mark Start and Mark Stop keys define the time portion of the exported data set. Select the beginning and end time points with the cursor as shown and click the keys.

Define Output key



The OUTPUT FILE SETUP window allows the following items to be defined for the exported data file:

Header information
Time column format
Seconds per output line
Trends per output line
Column and line delimiters
Number for bad data

The time exported can be as seconds from the start or actual time. Usually one second is output per line, but very large data sets may necessitate multiple seconds per output line. The number of trends per output line defaults automatically to the number selected for output. The most common choices for column and line delimiters are accommodated. Bad data which is set to “-1” in the trend file can be set to any other value.

Selecting events recorded in trend data

Events are recorded in the trend data file as item 42. An event selection key can be used to step through the events. A comment window displays comments entered for each event.

Trends

Trend data item list

The following table lists the items recorded in trend data.

Item #	Label	Unit	explanation
1	ECG rate	bpm	heart rate from ECG leads
2	Resp Rate	resp/m	respiration rate from the pneumatic pillow input
3	Temp 1	ºC or F	temperature from channel 1
4	SpO2	% Sat	oxygen saturation in % of hemoglobin
5	FOT1	ºC or F	temperature of fiber optic channel 1
6	BP3 Sys	mmHg	IBP channel 3 systolic pressure measurement
7	BP3 Dia	mmHg	IBP channel 3 diastolic pressure measurement
8	BP3 Mean	mmHg	IBP channel 3 mean pressure
9	EtCO2	mmHg	end tidal CO2 measurement
10	Insp CO2	mmHg	inspired CO2 measurement
11	FiO2	%	final inspired O2 measurement
12	E-resp rate	bpm	respiration rate from E-resp
13	ECG period	ms	R to R time interval from ECG leads
14	Resp Period	ms	respiration period from the pillow input
15	Ox Rate	bpm	heart rate from SpO2 waveform
16	Ox Period	ms	heart period from SpO2 waveform
17	BP3 rate	bpm	heart rate from IBP 3 measurement
18	BP3 period	ms	heart period from IBP3 measurement
19	CO2 rate	Resp/m	respiration rate from CO2 measurement
20	CO2 period	ms	respiration period from CO2 measurement
21	Vent period	ms	respiration period from the ventilator
22	Vent Insp time	ms	time of inspiration from the ventilator
23	Vent tidal vol	ml	tidal volume from the ventilator
24	E-resp period	ms	R to R time interval from E-resp
25	BP1 Sys	mmHg	IBP channel 1 systolic pressure measurement
26	BP1 Dia	mmHg	IBP channel 1 diastolic pressure measurement
27	BP1 Mean	mmHg	IBP channel 1 mean pressure
28	BP1 rate	bpm	heart rate from IBP 1 measurement
29	BP1 period	ms	heart period from IBP 1 measurement
30	BP2 Sys	mmHg	IBP channel 2 systolic pressure measurement
31	BP! Dia	mmHg	IBP channel 2 diastolic pressure measurement
32	BP2 Mean	mmHg	IBP channel 2 mean pressure
33	BP2 rate	bpm	heart rate from IBP 2 measurement
34	BP2 period	ms	heart period from IBP 2 measurement
35	FOT2	ºC or F	temperature of fiber optic channel 2
36	FOT3	ºC or F	temperature of fiber optic channel 3
37	FOT4	ºC or F	temperature of fiber optic channel 4
38	USER Rate	cpm	rate from USER Resp channel

Item #	Label	Unit	explanation
39	USER Period	ms	period from USER Resp channel
40	Pambient	mmHg	ambient barometric pressure
41	Temp; 2	ºC or F	n/a
42	Event	text	users text message input
43	Vbatt	volts	battery voltage of ERT Battery Pack
44	Voffset	volts	offset voltage of ECG leads measurement
45	Chg Vplus	volts	n/a
46	Chg Vbint	Volts	n/a
47	Chg Vbext	Volts	n/a
48	Chg Ipwm	mA	charging current for an external battery
49	Resp Gain	number	auto gain setting for the respiration channel
50	USER Gain	number	gain setting from USER Resp channel
51	Ox Monitor	level	auto gain level for oximeter measurement
52	ECG	Rev #	ECG software revision number
53	ETGate	Rev #	ETGate software revision number
54	PCcom	Rev #	PC com software revision number
55	RFcom	Rev #	RFcom software revision number
56	Resp	Rev #	respiration software revision number
57	Oximeter	Rev #	oximeter software revision number
58	FOT Rev	Rev #	Fiber Optic Temperature Module software rev
59	IBP	Rev #	IBP software revision number
60	Chg Rev	Rev #	battery charger software revision number
61	capnograph	Rev #	capnograph software revision number
62	Vent Rev	Rev #	ventilator software revision number
63	CVcom	Rev #	Capno/ventilator software revision number
64	POX Rev	Rev #	oximeter software revision number
65	FOT Rev	Rev #	fiber optic temp software revision number
66	ECG-Temp	flags	proprietary data for service
67	Resp	flags	proprietary data for service
68	Oximeter	flags	proprietary data for service
69	FOT Flags	flags	proprietary data for service
70	IBP	flags	proprietary data for service
71	Chg Flags	flags	proprietary data for service
72	Capno/vent	flags	proprietary data for service
73	Aux/FO in	flags	proprietary data for service
74	PCcom	flags	proprietary data for service
75	Number FOTs	number	number of fiber optic temperature channels
76	Plet signal	number	signal strength from the Oximeter Module

Chapter 7
SnapView

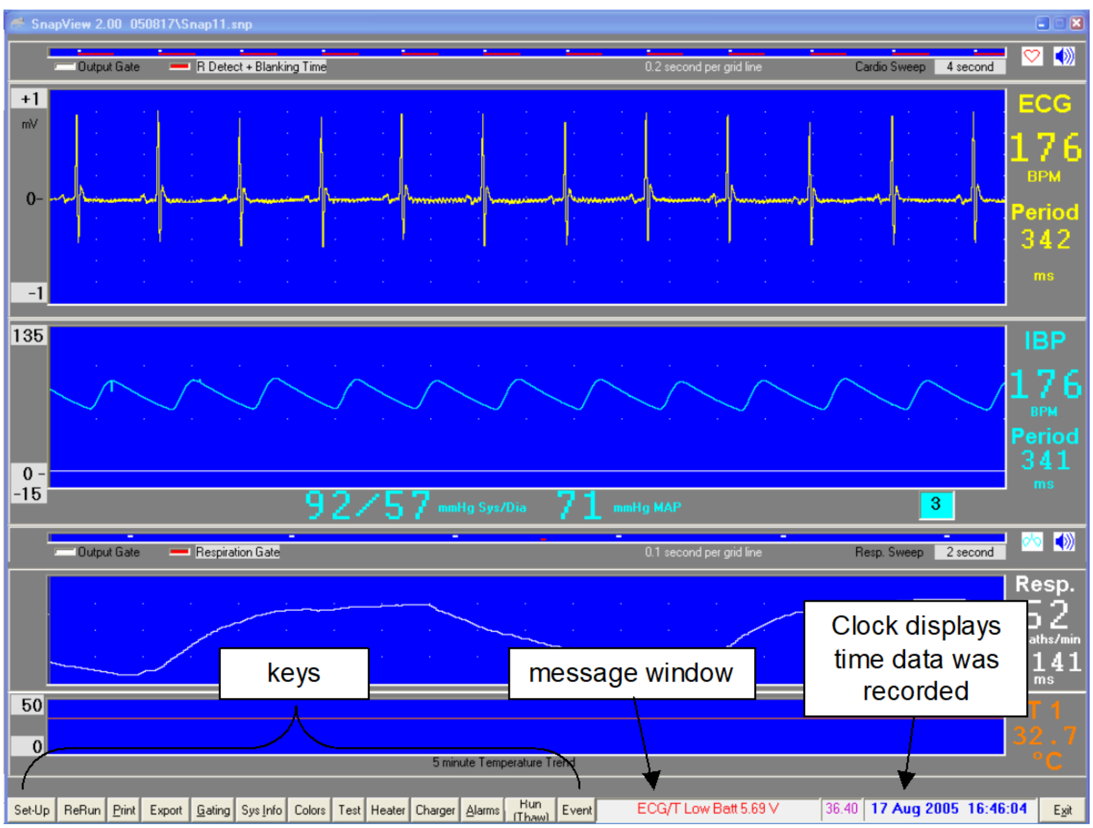
Overview

SnapShot data files record all measured data for a short time interval. The SnapShot key is located in the lower left portion of PC-sam's main display. Clicking the key causes storage of the last 36 seconds of all measured data.

SnapShot data files are viewed with SnapView. SnapView is embedded in PC-sam beginning with version 7. In this case, when PC-sam is opened an option is available to execute SnapView. For earlier versions of PC-sam, SnapView is executed by clicking on an icon on the desktop.

Most features available in PC-sam are also available in SnapView. For example sweep rates and amplitudes can be adjusted while viewing the files and the keys are active to display windows with associated parameter values.

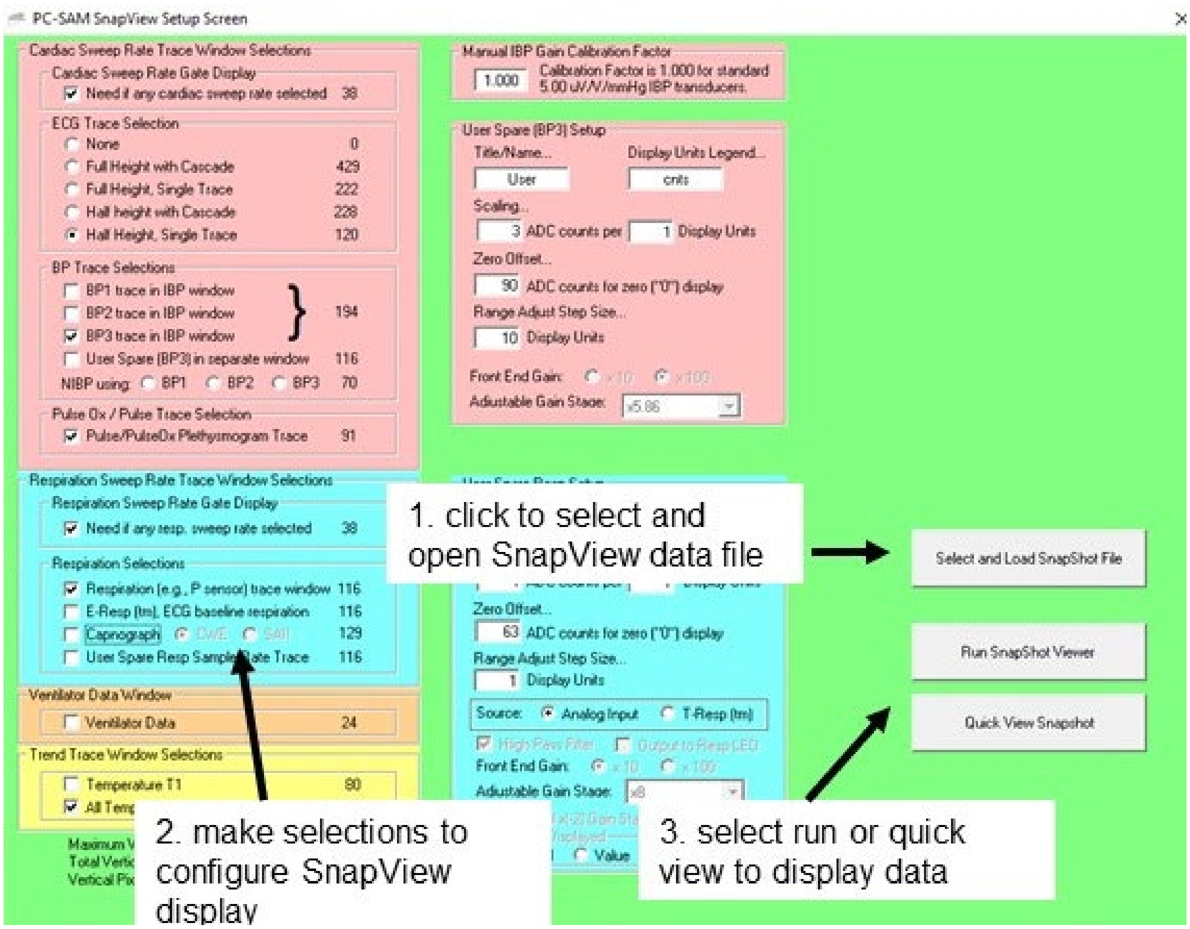
SnapView display



The SnapView main display is very similar to the monitor display of PC-sam. Most keys perform the same function as in PC-sam. The only differences are the Setup, ReRun, Print and Export keys.

SETUP window

The SETUP window is displayed when SnapView is executed or when the Set-Up key is clicked. First select and open a SnapView data file, then make any desired changes to the display configuration before displaying SnapView data.



Two keys for data display are available: Run SnapShot Viewer and Quick View SnapShot. The Run key plays back the entire 36 second data set before freezing the display waveforms with the most recent data. The Quick View key plays back 1 second of data before freezing the display waveforms with the most recent data.

ReRun key

Click the ReRun key on the SnapView display to play back the 36 second data set.

Print key

The print key will print a frozen display. The desired printer should be selected as the default printer and the paper orientation should be set to landscape before running SnapView.

Export key

The Export key allow SnapView's raw data to be exported. This feature can be useful in the event wave shapes or features need to be analyzed offline.

Keying the EXPORT key opens an export setup window with preset parameters. The user can modify the parameters and make measurement selections before exporting the data to a .txt file. Up to 32766 lines of 19 items comma delimited can be exported to a .txt file. Each text line starts with a time sample number (0-32766) followed by a raw data count for the measurements selected.

If SnapView is at the end of displaying the data set and EXPORT is keyed, then the export routine is setup to dump the entire data set. The resulting file when opened and saved by Excel will be about 4.6 Mbytes.

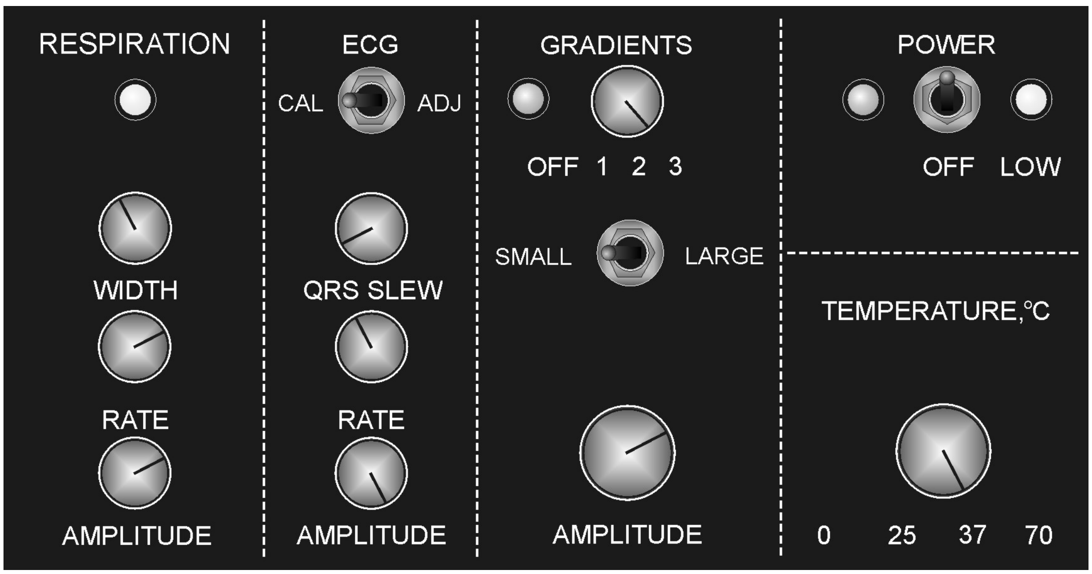
If SnapView is running (or FROZEN) and EXPORT is keyed the export parameters are setup to output data from the beginning of the data set up to the current (or frozen) time point. Note the time counter SS:HH (seconds: hundredths of seconds) displays the time of the data set from 0 to 36.4 seconds.

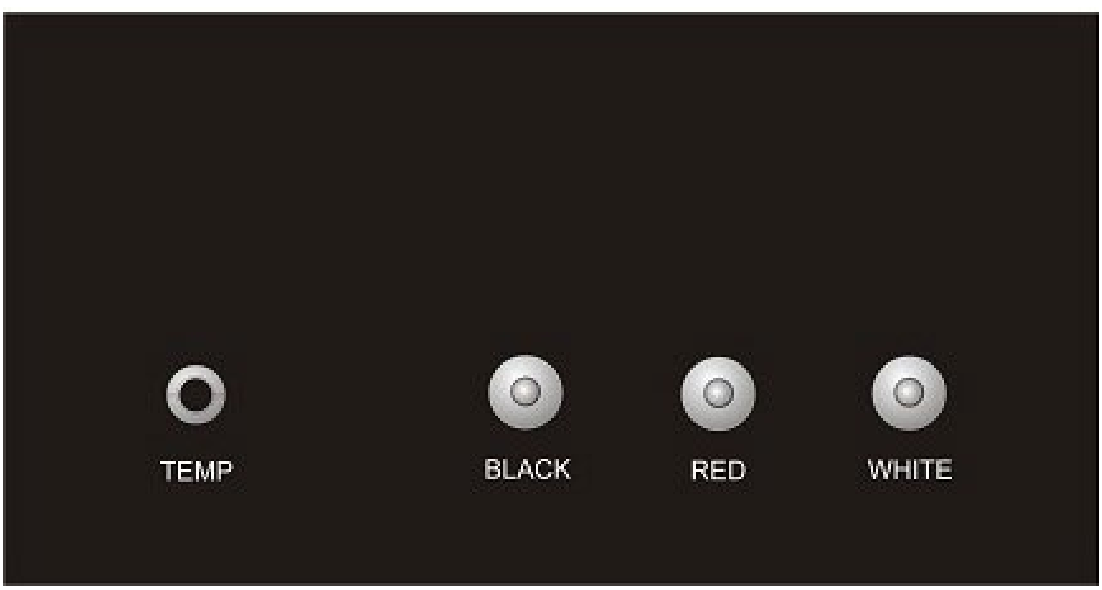
Chapter 8
Simulator

Chapter 8
Simulator

Overview

The simulator generates an ECG voltage waveform with respiration and gradient pulse interference superimposed. Connection to the Model 1025T is from the simulator rear panel connections with simulator ECG leads to black, red and white labeled studs. The simulator also provides a reference temperature impedance for use with 1025Ts configured to use thermistor sensors. Connection to the ERT Module is from the rear panel with a simulator temperature cable to the labeled phono jack. The simulator does not provide a reference for fiber optic temperature sensors.





Simulator

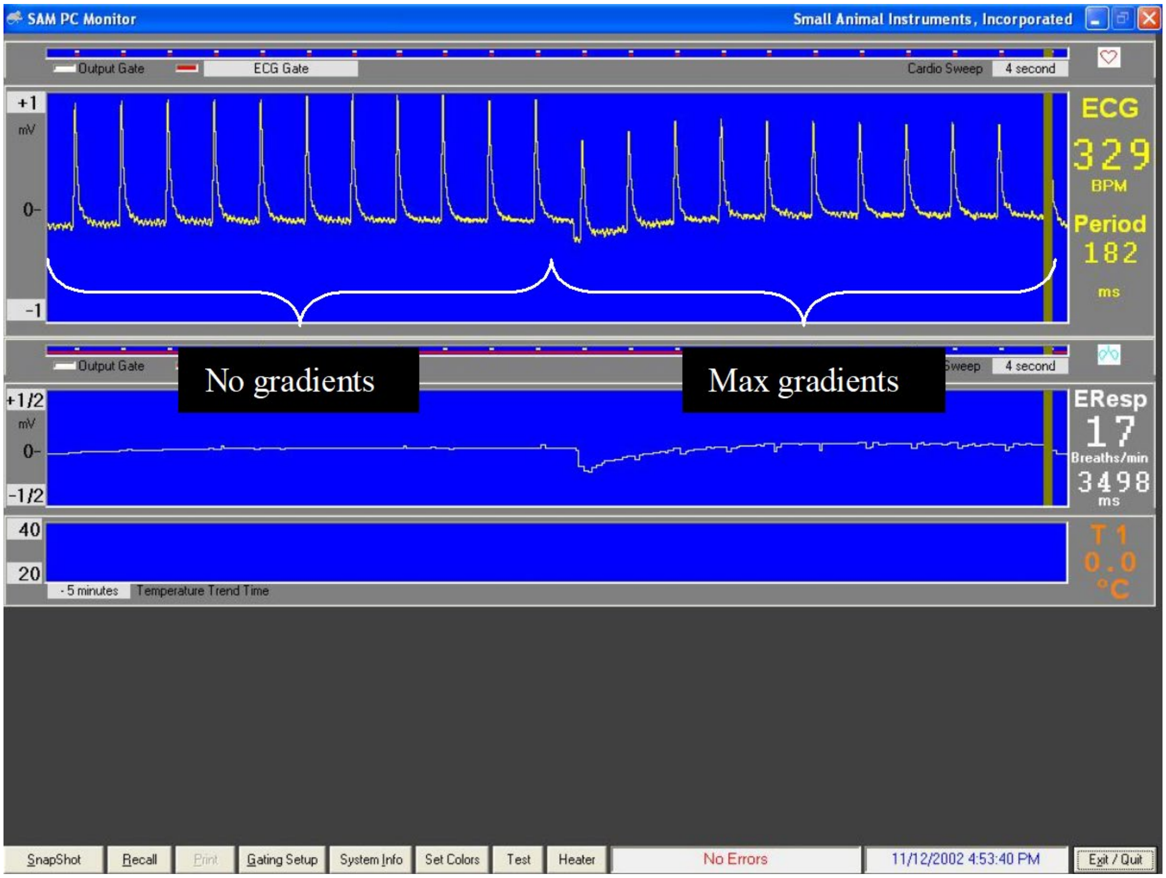
Operation

The Simulator is powered by a 9V internal battery. The power switch on the front panel activates the ECG and E-Resp waveforms. Green LEDs flash with the heart QRS and with respiration. A yellow LED flashes when the internal battery is low. Separate controls are provided for ECG rate and amplitude and respiration rate and amplitude. In addition the width of the respiration pulse can be controlled as can the slew rate for the rise and fall of the ECG waveform.

ECG rate:	30 - 700 beats per minute
ECG amplitude	0.25 - 2.5 mV
Respiration rate	60 - 300 breaths per minute
Respiration amplitude	0.0 - 0.50 mV

Turning on the power switch to the gradients, superimposes gradient spikes on the ECG/respiration waveform. The gradient spike width and duty factor are controlled by a rotary switch with 3 positions while the spike amplitude is controlled by the amplitude knob and a small/large gradient switch.
The waveform shown on the next page was obtained with the switch at position 1 and maximum gradient amplitude. Note the lack of gradient interference on the ECG baseline, however the R-wave amplitude decreases by about 15% during maximum gradient activity.

The ECG CAL switch generates an 0.8 mV QRS complex at 200 beats per minute.



Battery replacement

The simulator is powered by a 9 volt battery. Replace the battery when the battery low indication illuminates. To replace the battery, remove two screws from the simulator case and remove the simulator top. Replace the screws to reattach the cover after replacing the battery.

Chapter 9
Air Heater System

Chapter 9
Air Heater System

Overview

The Air Heater System controls the temperature of small animals undergoing imaging procedures. Animal temperature is measured using the rectal probe. The software continuously processes temperature measurements and sends a control signal to the Heater Module. The control signal depends upon the measured temperature, the user selected set point and the control method. Mouse temperature variations of less than ±0.1 ºC can typically be obtained.

The Air Heater System is MR-compatible. It can operate in the high RF and magnetic fields of a MR scanner. However, it can also be used in other imaging environments and in the laboratory.

Heater components

The SAII Air Heater System consists of a Fan Module located in the low fringe field of the magnet and a Heater Module with “smart circuitry” located near the bore of the magnet. The Heater Module is RF shielded and non-magnetic. It is powered from 100, 115 or 230 VAC 50 – 60 Hz. The Heater Module should be placed as close to the magnet bore as practical. It can be on the floor on a ladder or table or mounted in any convenient orientation. The optimum location will allow the 2 m air tube to supply warm air in the bore near the imaging volume. The Heater Module is controlled by the Control/Gating Module using a fiber optic cable connected to “Heater Control”. The fan and heater are connected to each other with a 7 m air hose.

If required, the Fan Module can be located inside the magnet room. In which case, the 7 m air hose can be shortened. To shorten the air hose, unscrew the cuff from one end and cut the hose with a knife.

Caution: The Fan Module contains small amounts of ferromagnetic components. It should be fix mounted if used in the RF shielded room or if it could inadvertently be moved into a region of large fringe magnetic field.

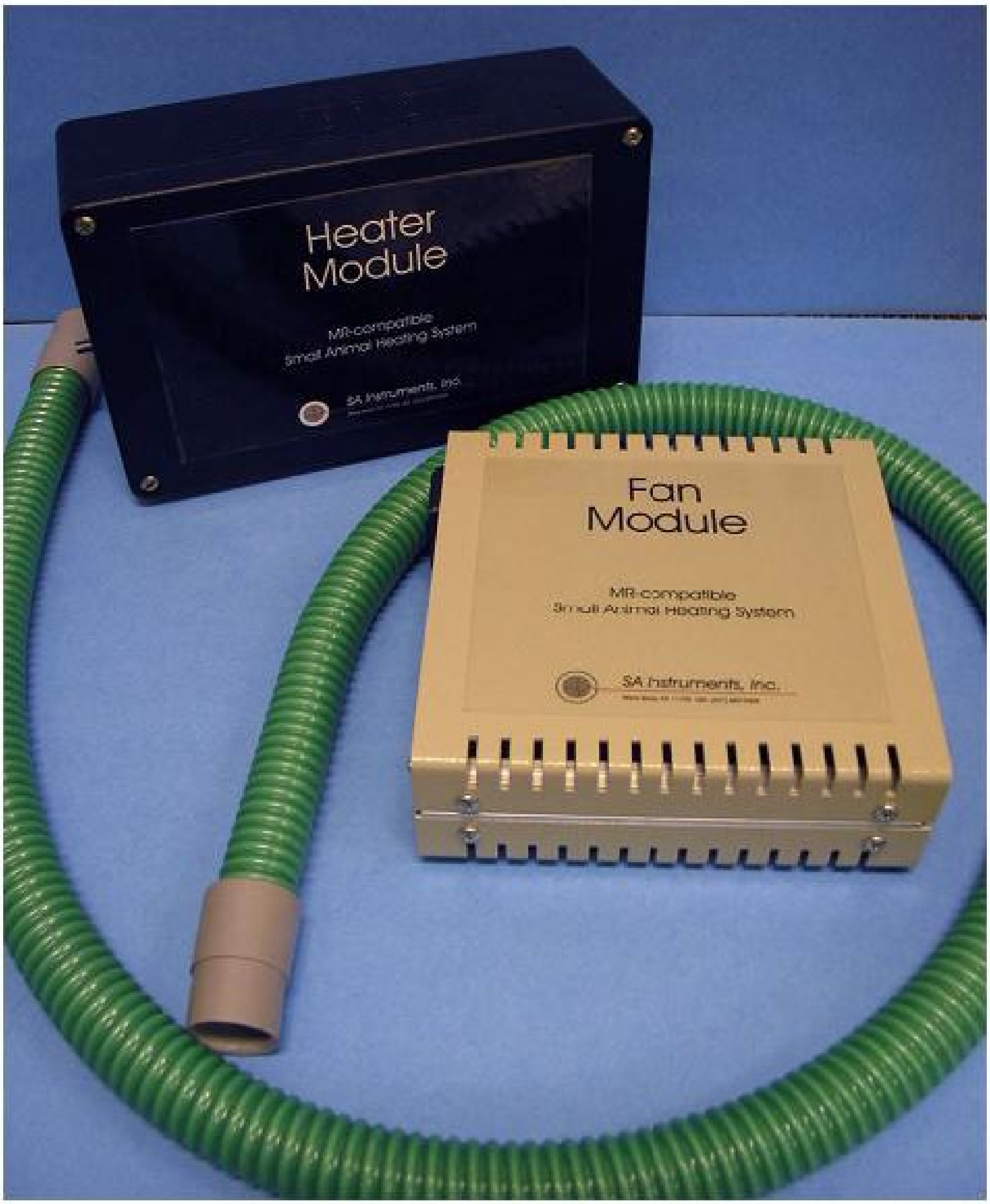
If power is not available in the magnet room, the Heater Module can be located outside the room with a longer air tube (up to 5 m) providing warm air to the bore. The longer tube will, however, somewhat degrade heater performance

It is important not to restrict the air flow coming from the Heater Module. Restricting the air flow by for example adapting smaller tubing can degrade system performance.

Caution: Do not restrict air flow from the Heater Module. Restricting air flow can reduce the amount of energy delivered into the bore and degrades performance.

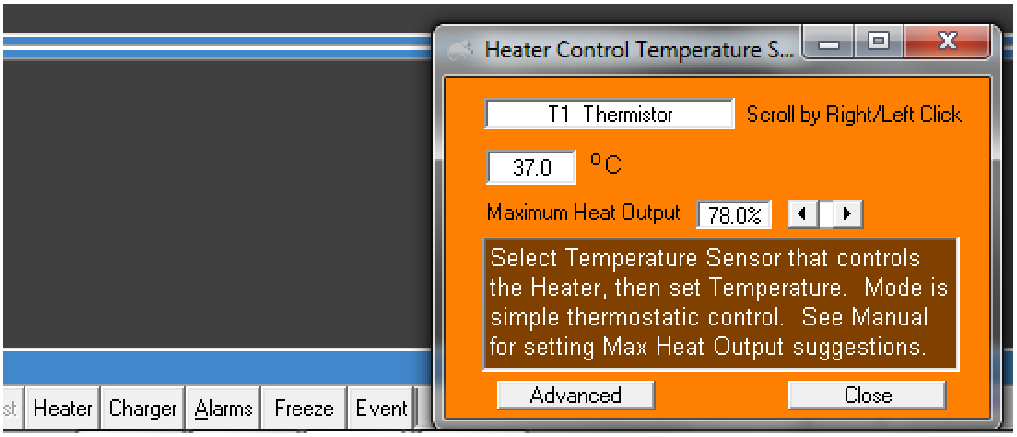
Air Heater System

A Higher Output Fan Module is available as an option to increase the delivery of energy in cases where the setup necessarily restricts air flow. In that case contact SAII's Customer Service.



Heater control

Clicking the Heater button at the bottom of the main waveform display in PC-sam opens the main HEATER window. The window can be used to select which temperature probe is to be used to control the heater, to enter the set point control value (usually around 37 ºC) and to set the maximum heat output (0 – 100%).

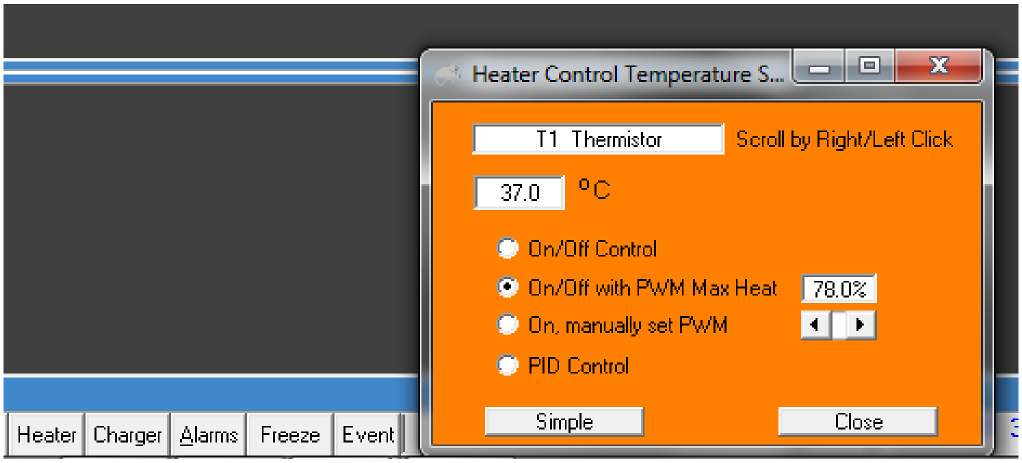


Select T1 control if the temperature probe is thermistor or fiber optic and the measurement comes directly from the 1025T and displays as T1. Select FOT1 if the temperature probe is being used with the Fiber Optic Temperature Module.

Clicking on the Advanced button opens the ADVANCED HEATER window shown on the next page.

PC-SAM software provides three methods for operating the heater: on/off control, on/off control with manual control of the duty factor and manual operation with manual control of the duty factor. The 4th option listed PID control is under development.

Selecting **on/off control** produces continuous light from the" Heater Control" port of either the ERT Control/Gating or Fiber Optic Temperature Module whenever the measured temperature is less than the user defined set point. Conversely the light from the "Heater Control" port is off whenever the measured temperature is greater than the set point. This method can be useful with external controllers and certain water bath heating systems. It will not provide control for the SAII Air Heater System.
On/off control with manual control of the heater duty factor should be selected when using the SAII Air Heater System. Here, heater duty factor, PWM max heat and Maximum Heat Output all refer to the same setting.



When the mouse temperature is several degrees below the desired set point, the duty factor should be set near 100%. As the mouse temperature gets closer to the set point, reduce the duty factor (to near 50%) to prevent temperature overshoot. Once the measured temperature has reached the set point the system will turn on and off as required to hold the temperature at the set point.

Light used to control the heater is pulse width modulated (PWM). Selecting a small duty factor results in narrow light pulses which turns the heating element on for short time durations. A large PWM value results in wide light pulses and increased heat from the Heater Module.

Manual operation with manual control of the duty factor allows the Air Heater System to operate without regard for the measured temperature or the value of the set point. This method can be used to heat the local environment in the magnet bore before positioning the animal.

Heating the mouse

In the main HEATER window, select the temperature probe and set the set point. Position the tube from the Heater Module a few inches from the mouse. It may be necessary to insulate the environment around the animal from the magnet bore. Chilled water for gradient coil cooling may dramatically reduce the temperature of the bore. A plastic tube section, a plastic sandwich bag or foam can be used to funnel air from the heater around the animal. When using a plastic sandwich or larger bag, open both ends of the bag to allow air flow both into and out of the bag.

Turn the Air Heater System on. Observe that the green power indicator is illuminated on the Heater Module. Also observe that the yellow heat indicator is intermittently flashing. If the heat indicator is not flashing check that the temperature measurement is lower than the set point (refer to Appendix C). Note that the control signal for the Heater Module will not be on if the temperature probe is not connected.

Set the duty factor based on the measured temperature of the mouse. If the mouse's temperature is more than 5 °C below the set point, use a duty factor of 100%. Observe the measured temperature of the mouse and decrease the duty factor to minimize overshoot. When the measured temperature reaches the set point, a duty factor of 50% or more should maintain the temperature within +/-0.1 °C.

Caution: The temperature at the end of the heater hose can be 55 °C or more. Do not position the hose closer than 4" to the mouse. Allow adequate air flow around the mouse.

The rectal probe can be used to check Air Heater System performance. Place the probe just inside the 2m warm air tube and set the set point high to 70 °C and the duty factor to 100%. The measured temperature on the monitor display should rapidly climb to 55 °C or more.

Chapter 10
Single Pump Fluid Heater System

Chapter 10
Single Pump Fluid Heater System

Overview

The MR-compatible Single Pump Fluid Heater System is used to control the temperature of animals undergoing imaging procedures. It is an option for the Model 1025T Monitoring and Gating System. The System has been designed to control the temperature of the fluid flowing to the heating pad or the heating pad temperature or the body temperature of animals.

The Single Pump Fluid Heater System, shown below, consists of a Circulation Module, a Heater Module and a Reservoir located near the patient. The system is MR-compatible but is also useful with other imaging systems. The Heater and Circulation Modules are RF shielded. The heater Module is non-magnetic. The Circulation Module contains a small amount of ferromagnetic material. The system is powered from 100, 115 or 230 VAC, 50 – 60 Hz.

Water is circulated through the closed loop system at constant flow (1.5 GPH) and low pressure (5 psi). The Heater Module's internal microprocessor controls the temperature of the water being circulated through a heating pad or blanket covering the animal in the magnet bore. Control is based on a user defined set point for the water output temperature, the heating pad temperature or the animal temperature.

Single Pump Fluid Heater System

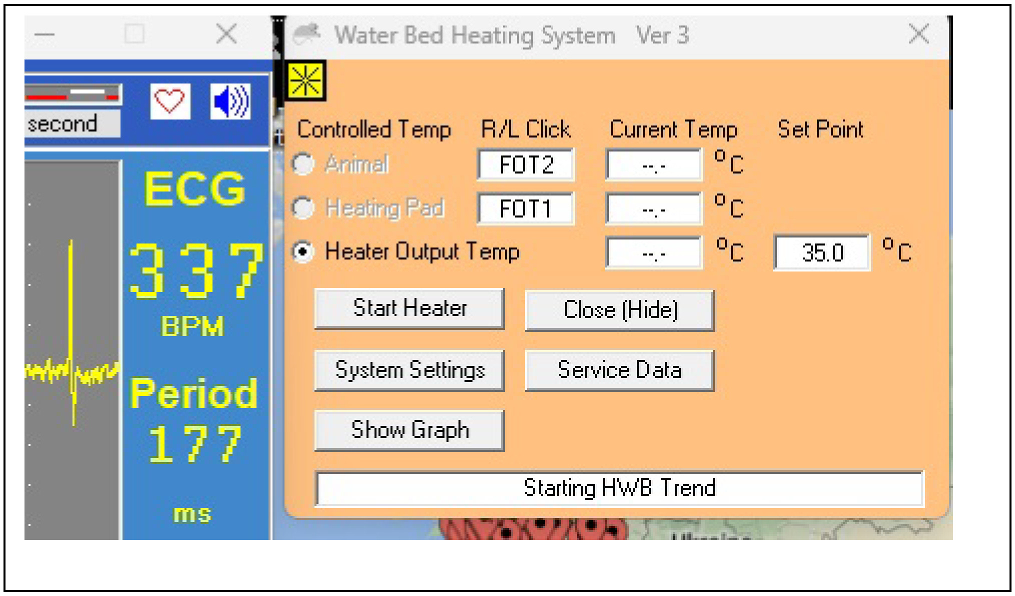
Operation

Make the selection in the “full setup” window to activate the Single Pump Fluid Heater System.

PC-SAM software provides user control of the heating system. The PC connects to the Heater Module through a FORT Module and to the Model 1025T Control/Gating Module using two separate USB ports.

Clicking on the Heater button at the bottom of PC-SAM’s main display opens the Air Heater window. Clicking on the Water Bed button opens the WBH USER INTERFACE window.

WBH USER INTERFACE window



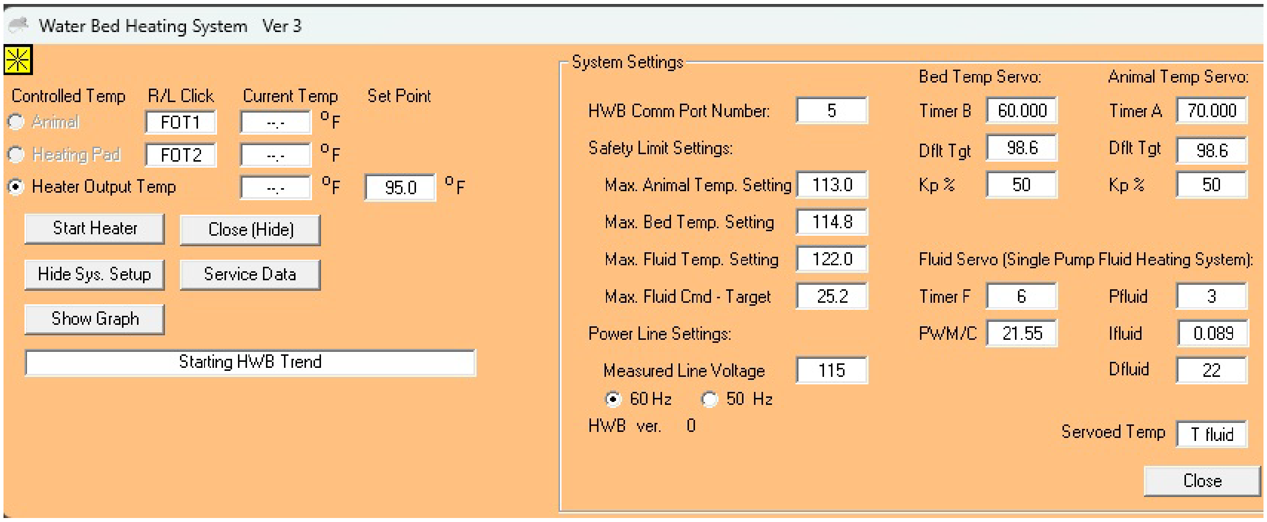
The message area at the bottom of the window gives system status and error messages. On the left of the window the user can select the method of control, the temperature probe in use for measuring the animal or heating pad and the temperature set point. Click in the box to change between available probes. Note the control selection is grayed out or made inactive if the probe selected does not have a valid temperature reading. Measured values for fluid output and temperature probes are displayed.

The window contains the following buttons:

Start or stop the heater
Display or hide Systems Settings window
Show or hide graph which displays temperature trends
Service data window

SYSTEM SETTINGS window

This window contains the communication port assignment, safety limit settings, power frequency setting, timer in seconds and controls for the heater output temperature and bed and animal control systems. These controls are discussed in a later section.



SERVICE DATA window

The Service Data window allows many parameters to be viewed which are not useful to the user. However, the window does allow the user to see the parameter that the control software is setting “PWM count” which determines the current delivered to the heating element. The window also displays Tin and Tout.   Tin is the fluid temperature entering the Heater Module which is also the Reservoir temperature. Tout is the fluid temperature exiting the Heater Module. This is the same temperature displayed in the WBH User Interface window.

PWM count is between 0 and 1024. PWM of 0 turns the heater off. PWM of 1024 delivers maximum current to the heating element.

GRAPH window

The graph window accumulates over time up to 8 WBH parameters including PWM, several temperatures and set points. The display is a useful tool to diagnose problems with the system.

Single Pump Fluid Heater System

Circulation Module input output connections

Electrical connections:

Power	12 VDC power connection

Fluid connections:

FROM RESERVOIR	cool fluid to Circulation Module
TO HEATER	cool fluid to Heater Module
FROM HEATER	warm fluid from Heater Module
TO RESERVOIR	cool fluid from Circulation Module

Heater Module input output connections

Cold fluid end:

FROM CIRCULATOR	cool fluid input
TO CIRCULATOR	warm output from the heating blanket
FROM FORT	optical input from FORT Module
TO FORT	optical output to FORT Module

Warm fluid end:

AC power	input power for 100 – 120 VAC or 230 VAC
WARM	output for fluid to the heating blanket
RETURN	input for fluid from the heating blanket

Heating pads

Flexible, curved and flat heating pads are available for small animals. Flexible pads have the shape of an inverted U and can cover the animal' back and sides or chest and sides. The beds are usually inserted in a thin disposable plastic cover before use.

Flexible heating pads	ODxLxT mm:
mouse	38x 76x3
large mouse	48x102x4
rat	57x152x5

Curved heating pads	WxLxT mm:
mouse	30x 76x3
large mouse	35x102x4
rat	40x152x5

Flat heating pads	WxLxT mm:
mouse	30x 76x3
large mouse	35x102x4
rat	40x152x5

Heating blanket

The heating blanket for large animals is a 12” x 24” thin flexible polycarbonate sheet with tubing attached. Two tubes 10’ long extend from the blanket and connect to the Heater Module without the need for fittings or connectors. This construction minimizes the risk of getting water in the bore of the magnet. A sheet is normally positioned between the animal and the heating blanket.

System setup

If using the roll stand position the shelf (321966) on the base of the roll stand and secure it with cable ties. Position the Single Pump Circulation Module (880200), the Heater Module (76x200) and the Reservoir (321322) on the shelf as shown in the photo on page 10-1. Fittings for the tubes are at the back of the stand while the power switches are at the front of the stand.

Connect the 3/8 OD tubing (SPFHSTS-10) as shown in the photo on page 21-1. Connect the heating blanket (FHS-BLANKET) or the heater to bed tube set (WBHHB-2) with one of the heating pads to the Heater Module at fittings labeled WARM and RETURN. Connect the Circulation Module to the 12 VDC power supply (SPCMPS-12)

Fill the Reservoir with water to the fill line. Water can be tap water or sterilized water. If using tap water, add 2 tablespoons of chlorine. Tap water can be sterilized by boiling it for a minute.

Prime the pump by disconnecting the hose at the “hot” connection of the Heater Module and hold it over a cup or pail lower than the Reservoir. Apply 12 VDC power.to the Circulator Module. The pump should prime in just a few seconds. Reconnect the hose to the hot connection of the Heater Module and run the Circulation Module to remove air from the system. Add water as needed.

Connect the duplex fiber optic cable to the Heater Module. Connect the other end of the duplex cable to the FORT Module (M92001) located near the PC and Control/Gating Module. Connect a USB to serial adapter cable (USB-21) to a USB port on the PC and to the FORT. The FORT gets power from the PC through the USB cable.

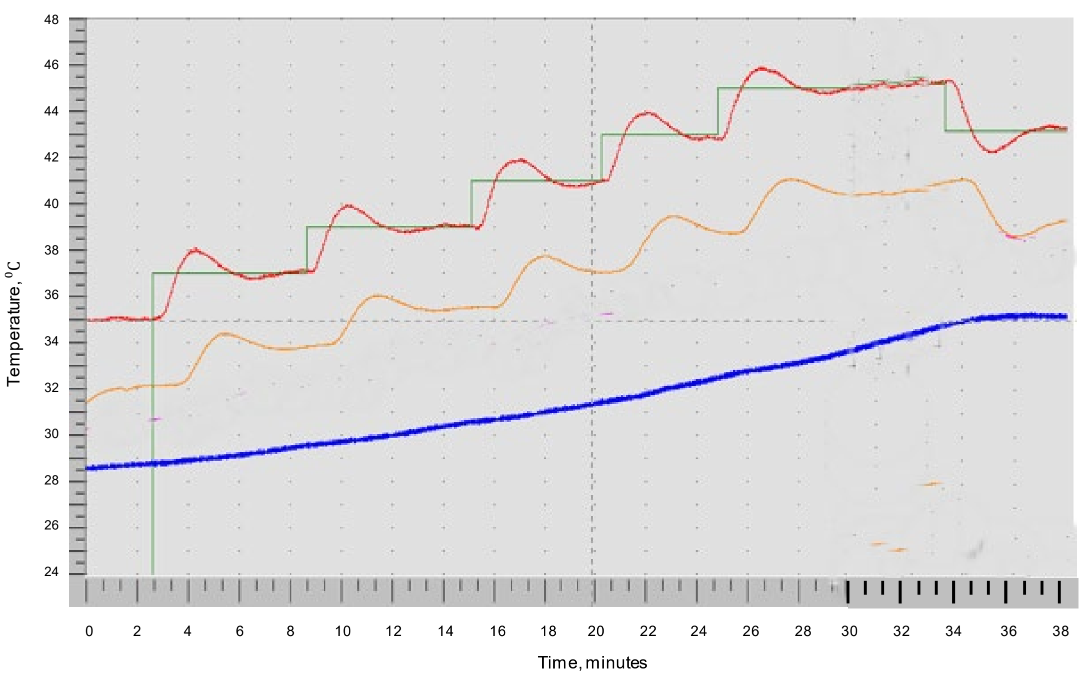
Control on Heater Module output fluid temperature

The simplest and a very effective way to regulate animal temperature is to control on the output fluid temperature. Power on the Heater and Circulation Modules. If the com port for the heater system has not been previously set, open the SYSTEM SETTINGS window and set the com. Select the option to control on output fluid temperature in the HWB USER INTERFACE window and enter a value for the set point. Click START HEATER. You should see the output temperature rapidly rise to the set point.

In the graph below, the output temperature is red, the blanket temperature is yellow and the reservoir temperature is blue. The set point was changed in 2 ^{0}C increments from 35 ^{0}C to 45 ^{0}C and then decreased to 43 ^{0}C. For each new setting the output temperature reaches the set point in just under a minute. Then there is an over shoot of about 1 ^{0}C for almost 2 minutes. Finally there is a very small decaying oscillation about the set point temperature.

Note that the blanket temperature is lower than the Heater Module output temperature by about 3 ^{0}C. But the difference will depend on the heat loss of each setup. The blanket temperature lags the Heater Module output temperature by about 40 seconds due to the flow rate and the length of tubing. The fiber optic temperature probe was positioned on the blanket at the middle of the tubing. That is the measurement was made at a position half of the total tubing length.

The PID control algorithm uses 4 parameters from the SYSTEM SETTINGS window PWM/c, Pfluid, Ifluid and Dfluid. Changing the flow or altering tubing length could make it necessary to calculate new parameters.



Controlling on heating pad temperature

The heating pad temperature control algorithm uses the values for Timer B and Kp listed in the Bed Temp Servo portion of the System Settings window. The algorithm is a simple PID control servo using just the proportional parameter. A new heating pad temperature (Tnew) is calculated every Timer B interval using the current heating pad temperature (T0), set point (Tsp) and Kp. As follows:

$$T_{new} = T0 + Kp*(Tsp - T0)$$

We get good results with a 60 second timer and Kp = 50 %.

Controlling on animal temperature

When controlling on animal temperature, first control on heater output temperature until the output temperature is within a few degrees of the animal setpoint temperature.

Controlling animal temperature uses the same control algorithm as used to control on the heating pad. In this case the timer is Timer A. We get good results with a 70 second timer and Kp = 50%.

Turning off the Fluid Heater System

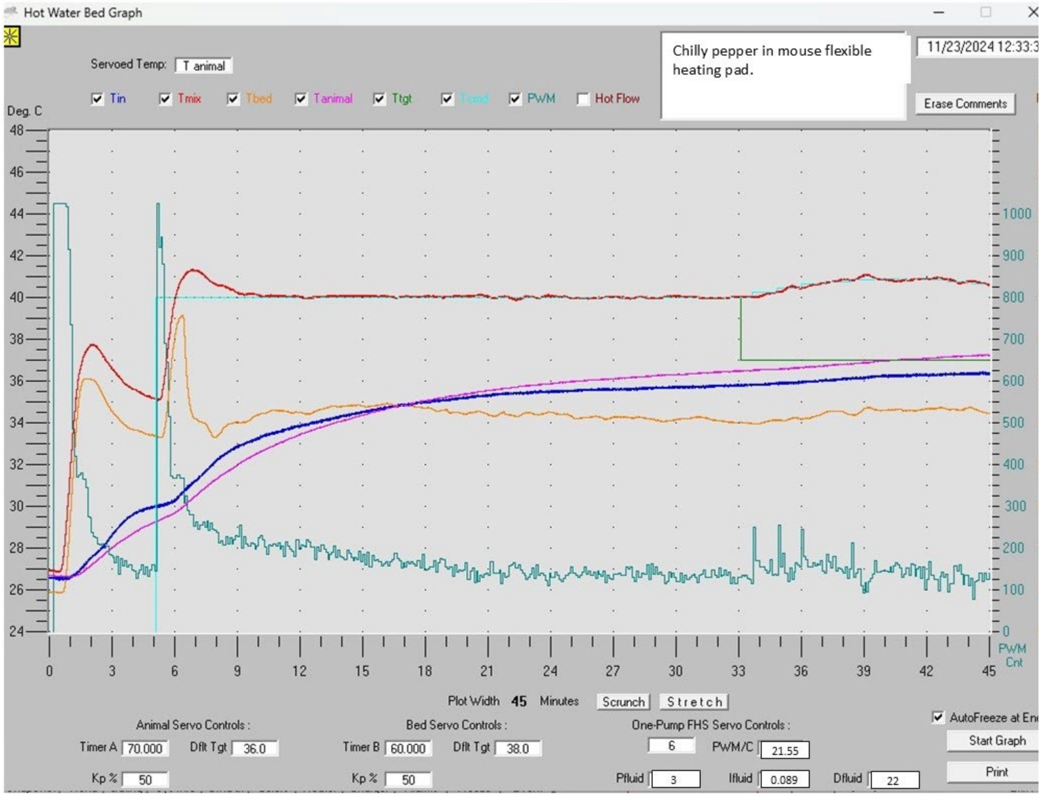
Let the Circulation Module run for a few minutes after turning off power to the Heater Module, to allow hot water in the system to cool.

Example of Controlling on Animal

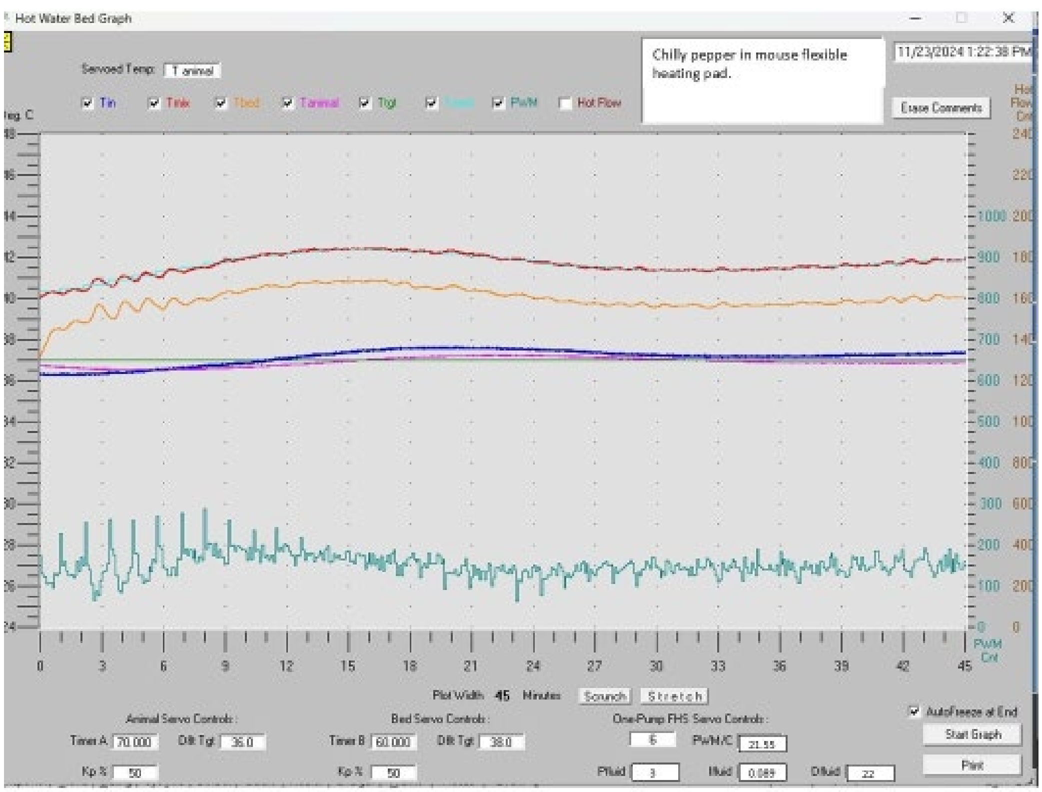
The graphs on the next page exhibit the Single Pump Fluid Heater System performance controlling first on output water at 35 ^{0}C, then at 40 ^{0}C and finally when the animal temperature gets near the 37 ^{0}C setpoint, control was switched to the animal temperature

In the graphs, the output water is in red, the heating pad temperature is in yellow, the animal temperature is pink, and the reservoir temperature is blue. The green trace is PWM which is proportional to the current in the heating element.

In the first graph at time 7 minutes, the temperature probe monitoring the heating pad came loose. It was attached to the heating pad for the 2nd graph.



Hot Water Bed Graph
Chilly pepper in mouse flexible heating pad.
11/23/2024 12:33:3
Servoed Temp: T animal
Tin
Tmix
Tbed
Tanimal
Ttgt
PWM
Hot Flow
Erase Comments
Deg. C
PWM Cnt
Plot Width 45 Minutes
Scrunch
Stretch
Animal Servo Controls :
Timer A 70.000
Dflt Tgt 36.0
Kp % 50
Bed Servo Controls :
Timer B 60.000
Dflt Tgt 38.0
Kp % 50
One-Pump FHS Servo Controls :
6
PWM/C 21.55
Pfluid 3
Ifluid 0.089
Dfluid 22
Start Graph
Print



Hot Water Bed Graph
Chilly pepper in mouse flexible heating pad.
11/23/2024 1:22:38 PM
Servoed Temp: T animal
Tin
Tmix
Tbed
Tanimal
Ttgt
PWM
Hot Flow
Erase Comments
PWM Cnt
Plot Width 45 Minutes
Scrunch
Stretch
Animal Servo Controls :
Timer A 70.000
Dflt Tgt 36.0
Kp % 50
Bed Servo Controls :
Timer B 60.000
Dflt Tgt 38.0
Kp % 50
One-Pump FHS Servo Controls :
6
PWM/C 21.55
Pfluid 3
Ifluid 0.089
Dfluid 22
AutoFreeze at End
Start Graph
Print

Chapter 11
Pulse Oximetry

Chapter 11
Pulse Oximetry

Overview

Pulse Oximetry allows noninvasive monitoring of arterial blood oxygen saturation. Fiber optic oximetry sensors are used to transmit pulses of red and infrared light through the animal's peripheral vascular region. Oxygen saturation is determined by measuring the differential absorption of the red and infrared light. In addition to oxygen saturation, the module measures the cardiac plethysmogram waveform, generates a plethysmogram gate, measures pulse distension and the animal's heart rate.

The Pulse Oximetry option is MR-compatible. It can operate in the high RF and magnetic fields of a MR scanner. However, it can also be used in other imaging environments and in the laboratory. The fiber optic sensors are MR and CT-compatible.

Oximeter components and connections

The Pulse Oximeter Module should be located within a few feet of the animal. When the Pulse Oximeter Module is the only optional module, it connects to the Model 1025T using a duplex fiber optic cable. The cable should be connected to the fiber optic ports labeled "option in" and "option out". When other optional modules are also present, the modules connect to form a data loop with one of the duplex fibers connecting to the 1st optional module and the other of the duplex fibers connecting to the last optional module. The modules are then connected to each other using short simplex fiber optic cables.

The fiber optic cables have blue and grey connectors. The driver and receiver ports are also blue and gray. The order of the modules in the data loop is not important. But, in all cases the color of the connector must match the color of the port. If the Model 1025T has an options switch, set it to “options in use”.
.
The Pulse Oximeter Module receives power from a dedicated 12V supply or from a daisy chain cable if other options are also in use.

The fiber optic oximeter sensor attaches to the Pulse Oximeter Module using a Lemo connector. To make the connection, align the red dots and push the connector straight into the receptacle. To disconnect the sensor grasp the connector with the thumb and index finger near the red dot and pull straight back. Do not turn or twist the connector housing.

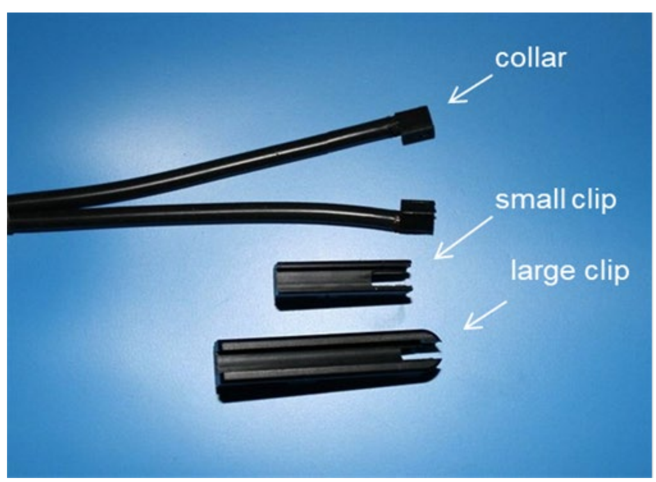
Display configuration

To add pulse oximetry to the monitor display configuration, execute PC-sam and select the option to “open the MONITOR SETUP window”. Select the Pulse Ox Plethysmogram Trace option on the left side of the window.

Changing sensor clips and forms

Fiber optic pulse oximetry sensors are constructed so the fibers can be detached from the clip or form that attaches to the animal. Small, large and extra large clips as well as mouse and rat tail/ankle forms are available.

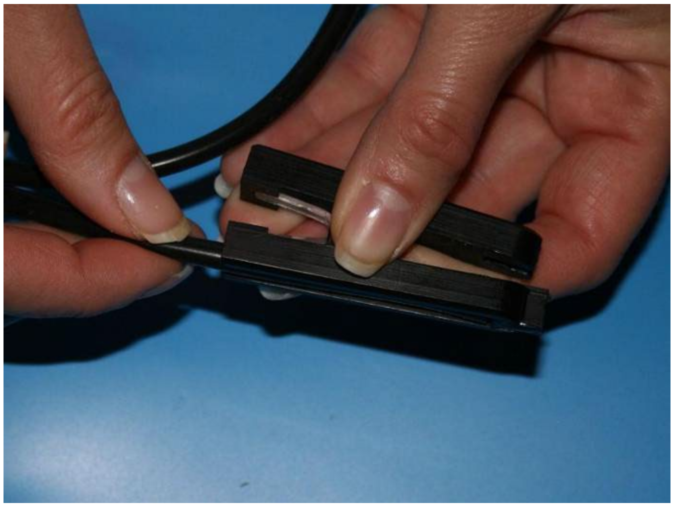
Each fiber has a collar. The collars have a grove on each side that lock into tracks on the clips and forms. Small and large clips are shown.



To attach a fiber to the clip, use the index finger to open the clip and position the fiber as shown. Push the fiber into the large grove along the length of the clip making sure the collar is in close proximity to the end of the clip.

Grasp the collar with the thumb and index finger and insert the collar groves into the tracks of the clip. Use the index finger to push the collar to the end of the clip opening.

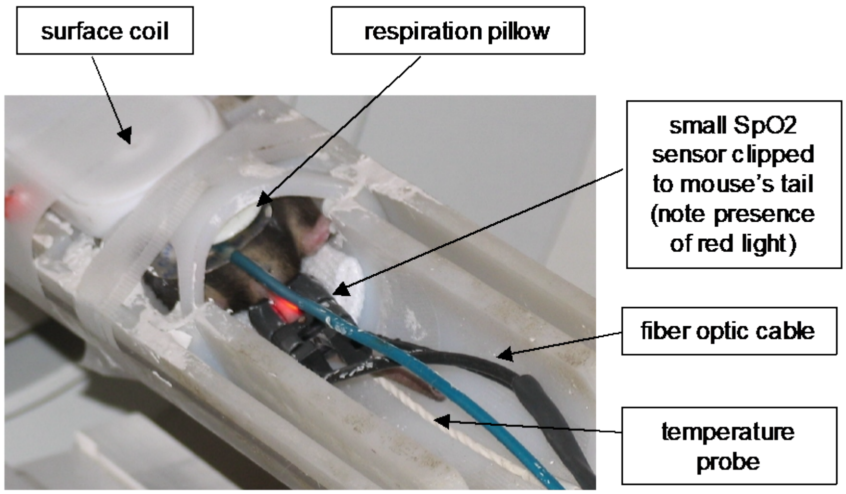
To remove the fiber, grasp the fiber with the thumb and index finger as shown. Push the fiber to move the collar away from the clip. Then grasp the collar with the thumb and index finger and remove the collar from the clip.



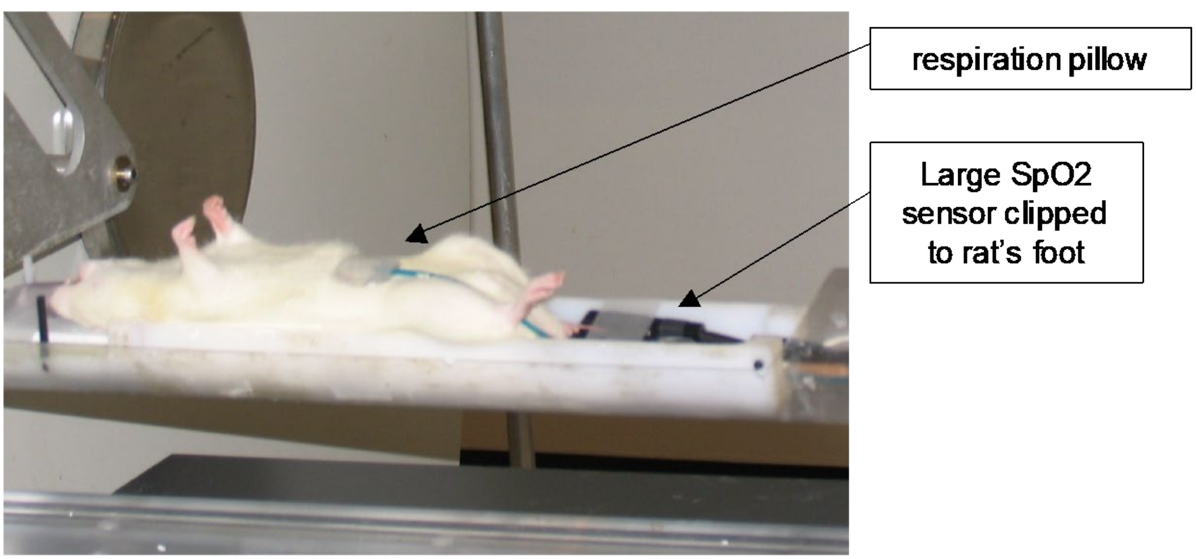
Pulse Oximetry

Attachment of fiber optic oximetry sensors

The clip on sensors are typically attached to the rat foot or the shaved mouse thigh. For rabbits, the ear is often the location of choice

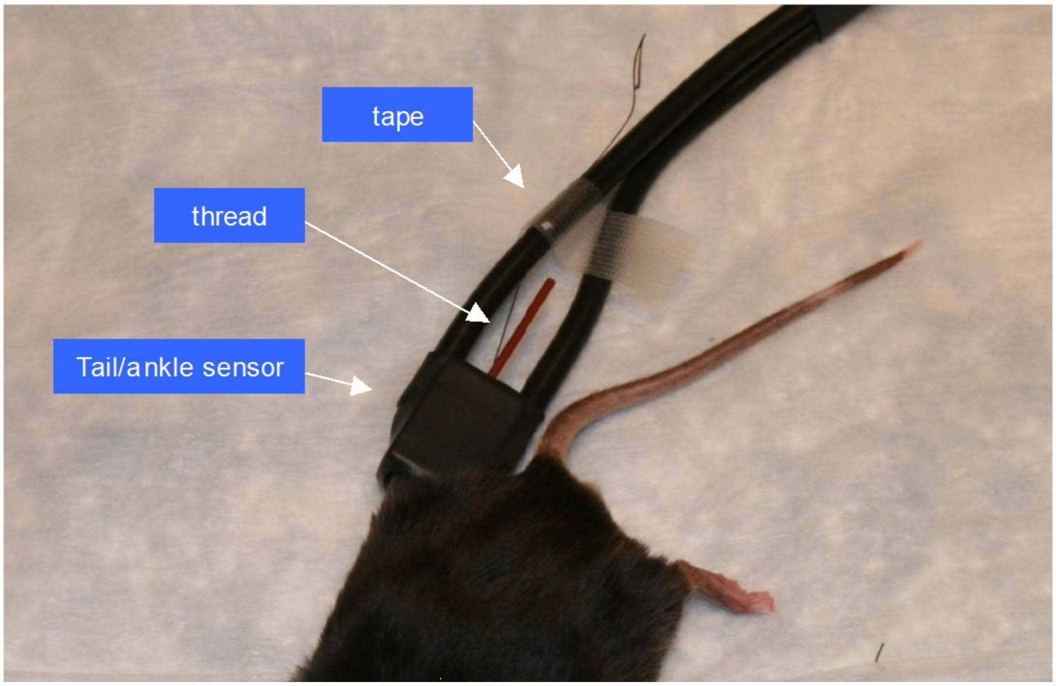


A black mouse is shown above prepared for MR with ECG, pulse ox, respiration and temperature sensors. The small pulse ox clip sensor is attached to the base of the tail.



A white rat is shown above prepared for MR with pulse ox, respiration and temperature sensors. The large pulse ox clip sensor is attached to the rat's foot.

The clip on sensors can exert pressure on the attachment site which in turn can restrict blood flow. Restricted blood flow results in a reduction of the oximetry signal. An O-ring fitted over the clip of the sensor can be used to reduce the pressure.

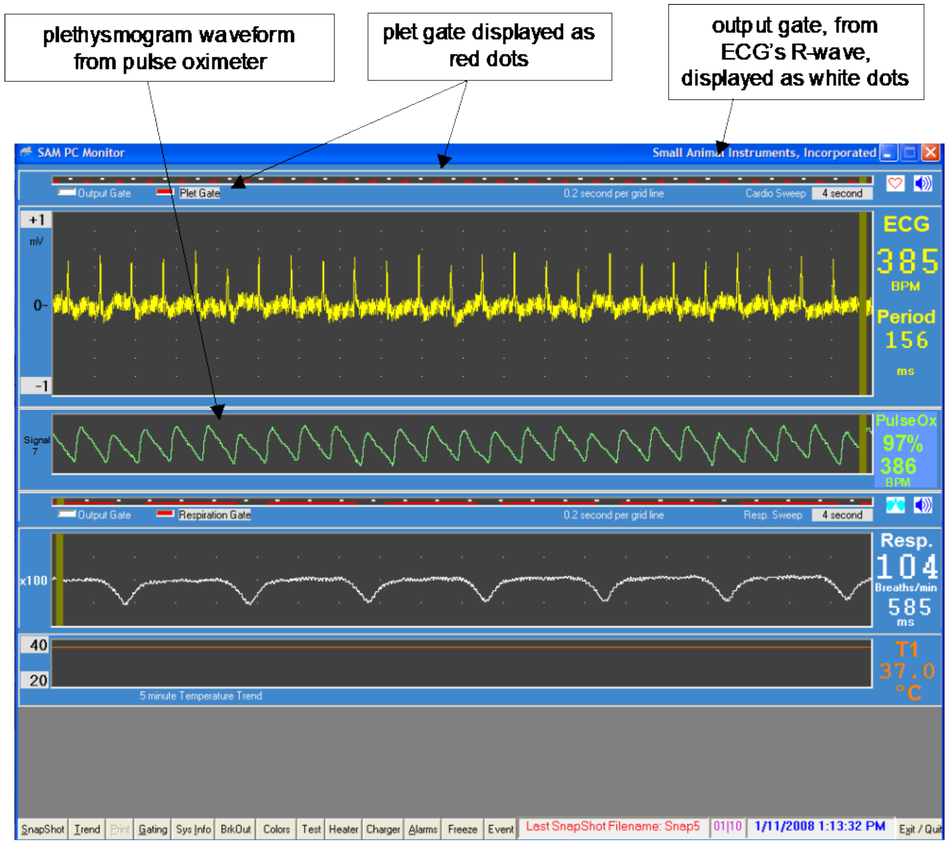


The mouse tail/ankle fiber optic sensor is shown above attached to the ankle of a black mouse. The sensor head holding the two fibers simply has a hole where the tail or ankle can be inserted. Note that the form does not apply pressure to the attachment site, so oximetry signals tend to be robust. In addition, the ankle and/or tail do not require shaving.

When attaching the sensor to the ankle, place a loop of thread around the mouse foot. Use the thread to pull the leg into the sensor form. Tape the thread to one of the fibers to keep the ankle in the sensor form.

PC-sam main display

The PC-sam main display is shown on the next page with ECG, pulse oximetry, respiration and temperature measurements. In this case, data was being collected for retrospective cardiac and respiratory gating of a black mouse in a 9.4T horizontal bore MR scanner. The animal's temperature was being regulated with a set point of 37 ºC. In the Gating window, ECG was selected so that a white dot in the Cardio Sweep display would indicate the detection of the R-wave. Plet Gate was selected to display as a red dot, by clicking on the label next to the red Cardio Sweep icon.



Note the following:

- There is a delay between the ECG and plet gates, because blood flows to a peripheral site after the heart beats.
- There is continuous presence of baseline interference in the ECG waveform, because the MR scanner is running continuously. i.e. not being triggered.
- The plethysmogram waveform has no interference from the MR scanner.
- There is a small modulation of the plethysmogram waveform from respiration.

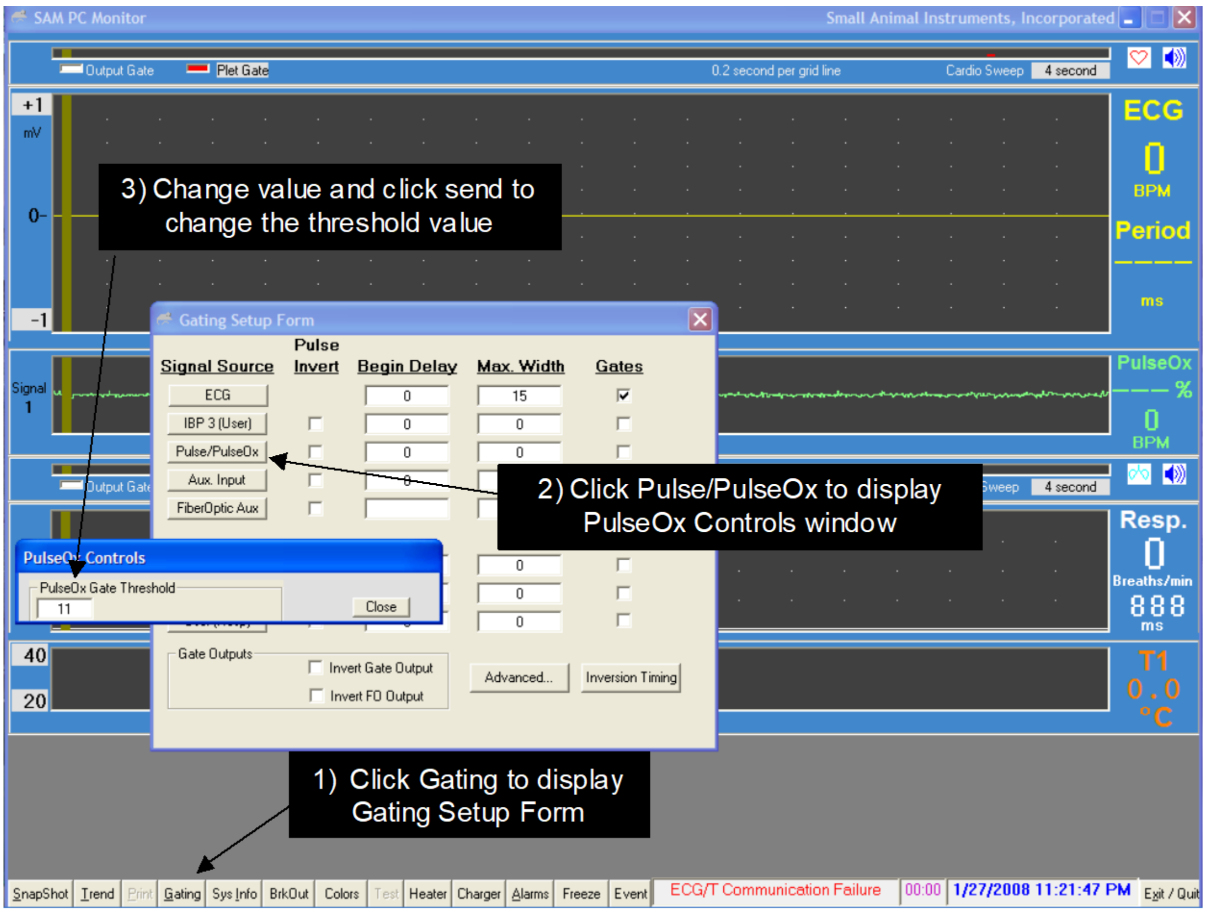
Plethysmogram gate threshold

A threshold parameter is used to detect the plethysmogram gates for oximetry. In the current version of the software, the threshold's default value can be changed in real time by the user.

The figure on the next page shows how to open the window that controls the pulse ox threshold. Factory default for the threshold is 11 counts. However, the best selection depends on the signal strength which is reported on the left side of the pleth waveform display. The higher the signal strength, the larger the optimum setting for the threshold.

The objective is to set the threshold so a gate is present above each peak in the pleth waveform with no extra gates.

For mice, the signal strength will be 4 or more and the best selection for the threshold is 11 to 20. For rats, the signal can be 6 or more and the threshold can increase to 20 to 40. For humans, the signal can be 10-15 with a threshold setting in excess of 75.

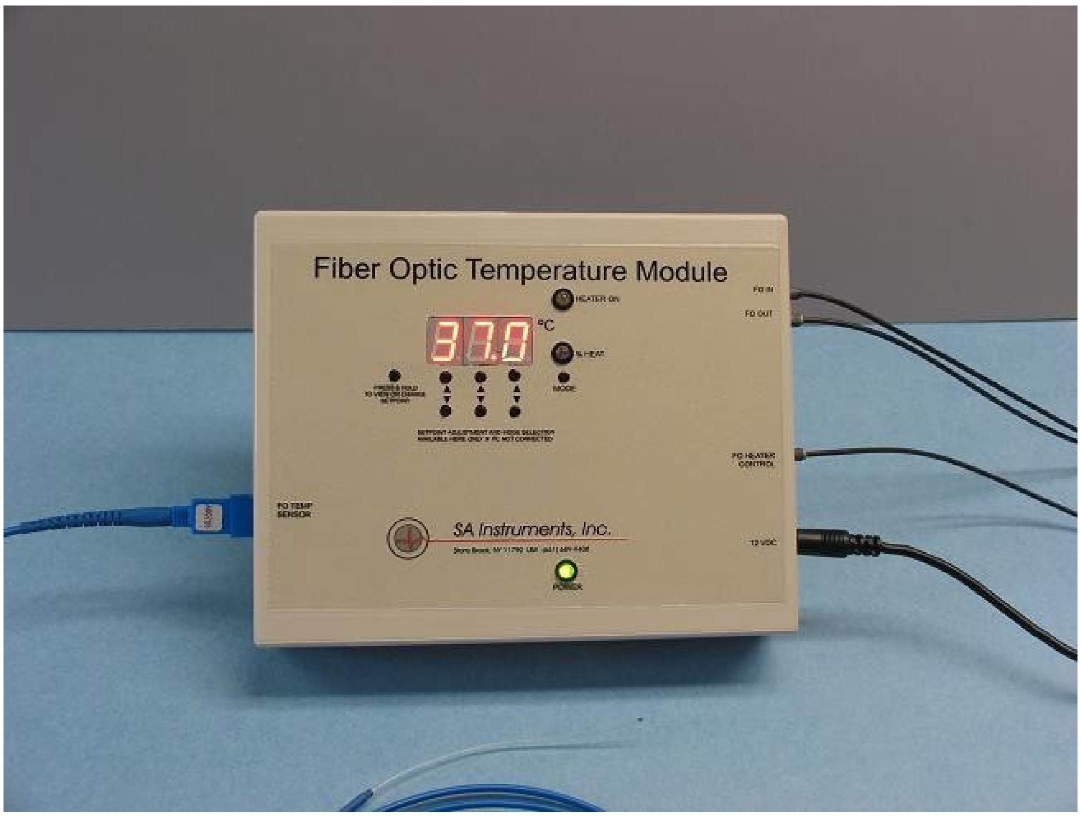


The standard plethysmogram detection algorithm is optimized for small signals and high heart rates. As a result, the standard algorithm does not give reliable results for humans and larger animals like pig and monkeys. There is an algorithm available that is optimized for large signal and low heart rates (contact SAII Customer Service).

Chapter 12
Fiber Optic Temperature

Overview

Fiber optic temperature probes provide an alternative method to thermistor temperature probes for measuring temperature. Fiber Optic Temperature is MR-compatible. It can operate in the high RF and magnetic fields of a MR scanner. However, it can also be used in other imaging environments. Fiber optic temperature probes are also CT-compatible.



Components and connections

There are 2 configurations for the Fiber Optic Temperature Module. One is shown above with large LEDs and buttons. This configuration can operate as a module with the Model 1025T or it can operate in standalone mode to control the Air Heater System. The other configuration has no LEDs or buttons and can only operate as a module with the Model 1025T. Both configurations use the same fiber optic temperature sensors and connect to the Model 1025T and other optional modules in the same way. Both configurations can have up to 4 channels of fiber optic temperature.

The Fiber Optic Temperature Module should be located within a few feet of the animal. When the Fiber Optic Temperature Module is the only optional module, it connects to the Model 1025T using a duplex fiber optic cable. The cable should be connected to the fiber optic ports labeled “option in” and “option out”. When other optional modules are also present, the modules connect to form a data loop with one of the duplex fibers connecting to the 1st optional module and the other of the duplex fibers connecting to the last optional module. The modules are then connected to each other using short simplex fiber optic cables.

The fiber optic cables have blue and grey connectors. The driver and receiver ports are also blue and gray. The order of the modules in the data loop is not important. But, in all cases the color of the connector must match the color of the port. If the Model 1025T has an options switch, set it to “options in use”.

The Fiber Optic Temperature Module receives power from a dedicated 12V supply or from a daisy chain cable if other options are also in use.

The temperature probe connects to the module by pushing the connector into the receptacle and turning to lock in place. To remove the probe, press and twist the connector.

When controlling a Heater System with the Fiber Optic Temperature Module, connect a simplex fiber between the port labeled “FO Heater Control” and the Heater Module.

Display configuration

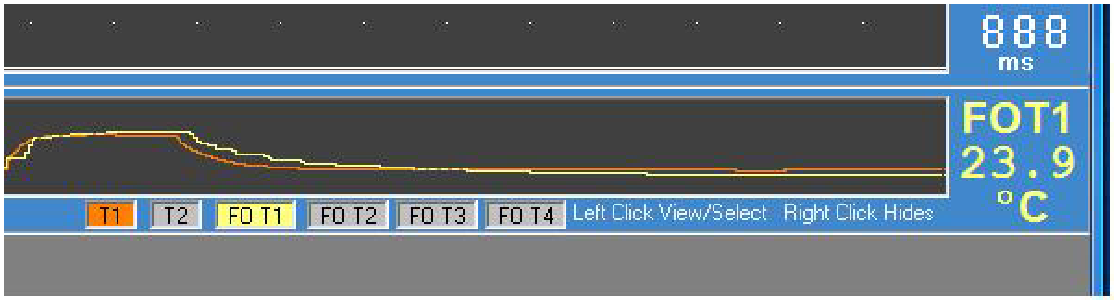
To add fiber optic temperature to the monitor display configuration, execute PC-sam and select the option to “open the MONITOR SETUP window”. Select the “all temperatures” box at the lower left hand portion of the display.

Attaching, handling and cleaning fiber optic temperature probes

Use a lubricant or lubricated probe cover on the tip of the temperature probe before inserting it into the rectum. Secure the probe lead by taping it to the animal’s tail. Clean the temperature probe with isopropyl alcohol.

Temperature probes should be handled with care. The tip of the probe can be broken or cracked if the tip is bent. We recommend the fiber optic probe be suspended from a hook when not in use to minimize the possibility of damage.

PC-sam's main display



When the "all temperatures" selection is made in the MONITOR SETUP window, a row of buttons appears below the temperature trend in PC-sam's main display. These buttons allow the user to select which temperatures are displayed in the trend and which current temperature is displayed in the digital display to the right of the trend.

In the example above, both T1 and FOT1 have been selected and are present in the trend display. FOT1 was selected last, so that probe's current measurement is also displayed. The current measurement can be switched to T1 by left clicking on the T1 button. To remove a measurement set from the trend display right click on the corresponding button.

Heater control

The SA Instruments warm Air Heater System can be controlled by the Fiber Optic Temperature module. The HEATER window can be used to select which temperature probe will be used to control the heater and to set the set point. Refer to Chapter 9 for a detailed explanation of the Air Heater System.

For the Fiber Optic Temperature Module with LEDs and buttons, the digital display on the module can display the current temperature, the set point or the PWM duty factor. Two buttons on the face of the module facilitate which value is displayed.

Chapter 13
Fiber Optic Pressure

Chapter 13
Fiber Optic Pressure

Overview

The Fiber Optic Pressure option provides the capability to continuously monitor physiological pressure using ultra-miniature, fiber optic pressure sensors. The ultra-miniature sensors are intended for use in small infusion needles, catheters and guide wires enabling minimally invasive physiology pressure measurements.

The pressure sensors can be used to measure pressure in several locations like the aorta, left ventricle of the heart, ventricles of the brain and in the spinal canal. However, for many users, the most exciting application is to provide minimally invasive, continuous monitoring of blood pressure and heart rate by simply inserting the sensor tip into an artery

The ultra-miniature pressure sensor consists of a tiny silicon cavity attached to a relatively long fiber optic cable. White light is sent via the fiber to and from the cavity. Polarization interferometer processing electronics precisely computes the Fabry-Perot cavity length and determines the corresponding pressure reading. An internal manometer automatically corrects the reading for changes in atmospheric pressure.

The fiber optic pressure option is MR-compatible. It can operate in the high RF and magnetic fields of a MR scanner. However, it can also be used in other imaging environments and in the laboratory. Fiber optic pressure sensors are also CT-compatible.

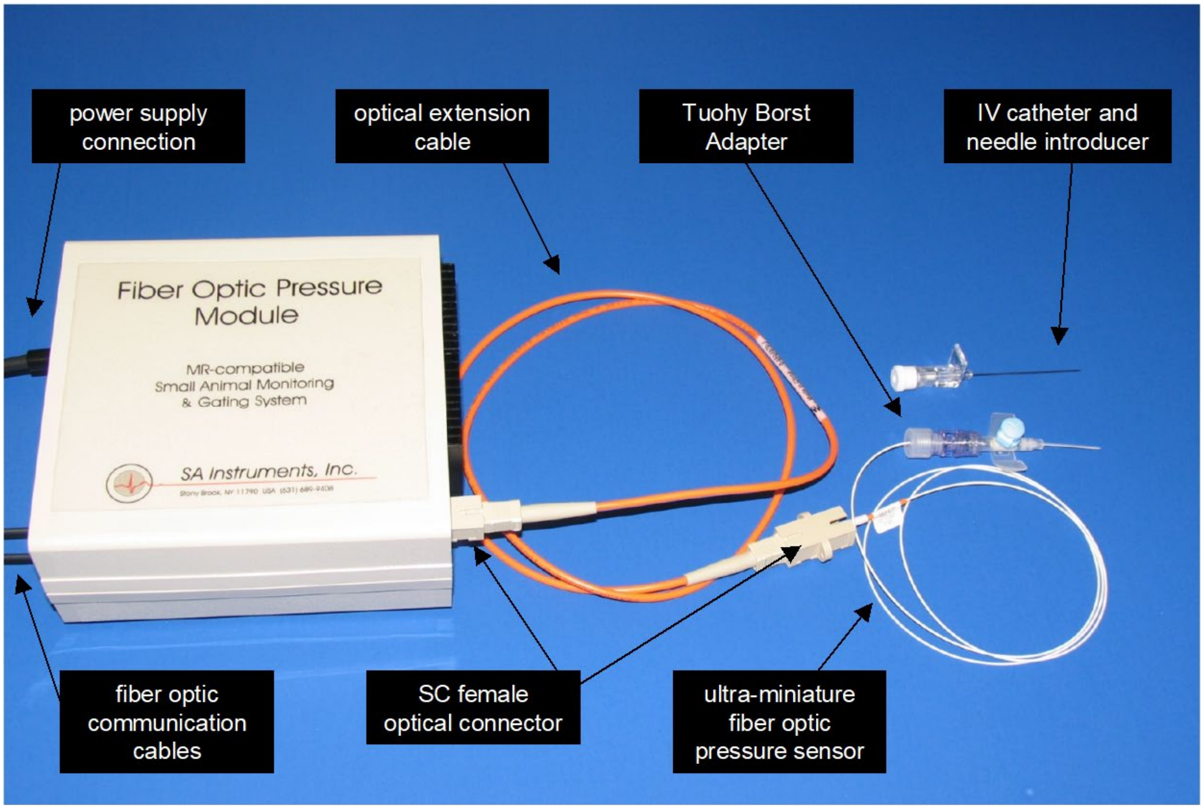
Sensor and extension connections

The pressure sensor connects to the module using an optical extension cable. A 1 m extension is standard but other lengths are available. Special cleaning procedures for sensors and extension cables, detailed later in this chapter, provide for reliable long term operation. We recommend leaving the extension cable connected to the module when disconnecting the pressure sensor.

The optical sensor extension cable (FOP-OEX-1M) has a male SC connector on one end and a female SC adapter on the other end. The male SC connector connects to the Fiber Optic Pressure Module at the port labeled “sensor”. Align the keyway and insert the male connector to make the connection. Use the thumb and forefinger to grasp the male connector housing on either side of the keyway and pull to disconnect.

Two fiber optic pressure sensors are available with tip OD of 0.3 mm and 0.4 mm. They have a male SC connector that connects to the extension cable’s female SC adapter.

Fiber Optic Pressure



Fiber optic communication cable connections

The Fiber Optic Pressure Module should be located within a few feet of the animal. When the Fiber Optic Pressure Module is the only optional module, it connects to the Model 1025T using a duplex fiber optic cable. The cable should be connected to the fiber optic ports labeled “option in” and “option out”, When other optional modules are also present, the modules connect to form a data loop with one of the duplex fibers connecting to the 1st optional module and the other of the duplex fibers connecting to the last optional module. The modules are then connected to each other using short simplex fiber optic cables.

The fiber optic cables have blue and grey connectors. The driver and receiver ports are also blue and gray. The order of the modules in the data loop is not important. But, in all cases the color of the connector must match the color of the port. If the Model 1025T has an options switch, set it to “options in use”.

The Fiber Optic Pressure Module receives power from a dedicated 12V supply or from a daisy chain cable if other options are also in use.

Handling and cleaning fiber optic pressure sensors

The sensors have a SC male connector on one end and a small pressure transducer on the other end. A white silicone jacket covers the fiber optic cable except for the last few inches near the transducer. For the larger sensor (FOP-5-4) the diameter of the transducer is 0.4 mm and the diameter of the fiber optic cable without the jacket is 0.2 mm, so the transducer diameter is considerably larger than the fiber diameter as shown in the photograph. The smaller sensor (FOP-3-3) has a polyimide protective sheath covering the pressure transducer.

Cleaning the transducer end of the pressure sensor

The transducer is glued to the fiber, but it can be broken off if not handled carefully. The sensor can not be mechanically cleaned by for instance rubbing with a tissue soaked in alcohol. Instead the tip is cleaned by soaking in a solution of enzyme-active detergent.

Clean the tip of the fiber optic pressure sensor as follows:

1. Make a fresh solution of 1 gm of Tergazyme powered detergent in 100cc of warm water (<130 °F or 55 °C).
2. Soak the sensor tip for at least 10 minutes.
3. Rinse in water.
4. Dip in rubbing alcohol.
5. Store in the sensor storage case.

Caution: The transducer tip of the fiber optic pressure sensor is delicate. Refrain from applying mechanical pressure to the transducer tip. Do not attempt to clean the sensor with mechanical pressure.

Cleaning the pressure sensor and extension cable SC male connectors

Clean the SC male connector ferrule end face before each use using the Fiber Optic Connector Cleaner included in the Cleaning Kit (FOP-CLNKIT). Clean the end face as follows:

1. Ensure a new cleaning surface by advancing cloth tape and tear off excess tape as required.
2. Softly press the connector end face on the clean cloth tape and drag it across the tape while rotating the connector.
3. Several connectors (<6) can be cleaned before advancing the tape.

Caution: The SC connector ferrule end face should be cleaned before each use. Failure to do so can result in permanent damage to the connector caused by hard particles trapped between the fiber optic end faces.

Fiber Optic Pressure

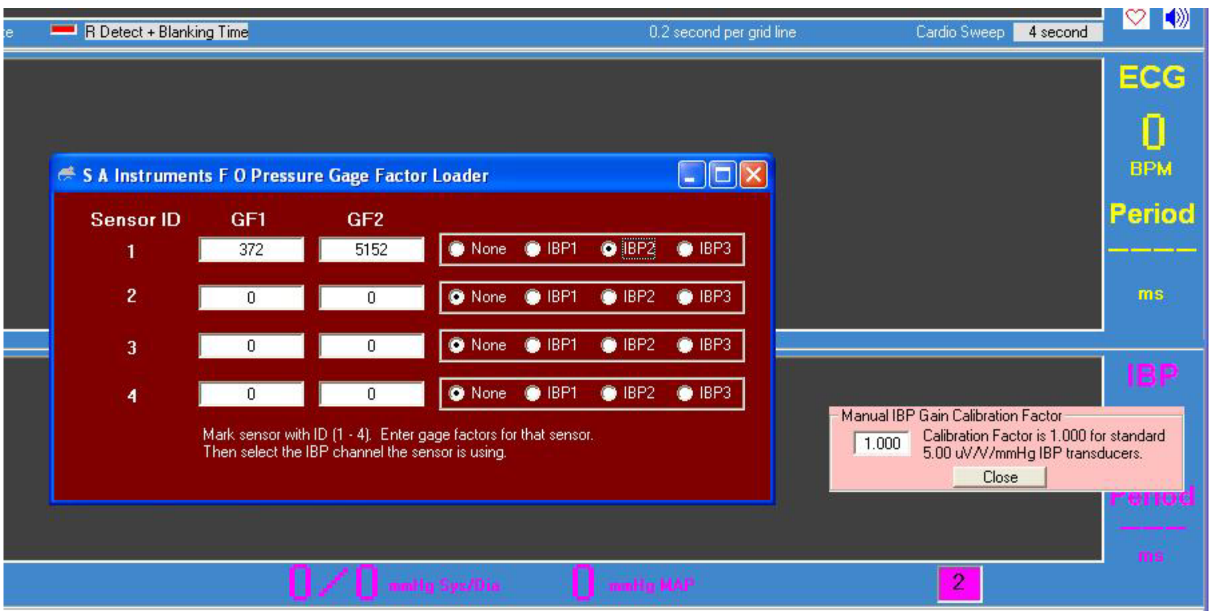
Cleaning the SC female connectors

Clean the SC female connectors as follows:

- Dip the tip of the cleaning stick included in the Cleaning Kit (FOP-CLNKIT) in alcohol.
- Insert the tip of the cleaning stick in the SC female connector and rotate the stick.
- Allow the SC connector to dry before inserting the SC male connector.

Display configuration

To add fiber optic pressure to the monitor configuration, execute PC-sam and select the option to "open the MONITOR SETUP window". Select the BP2 box on the left hand portion of the setup display.



Calibrating the fiber optic pressure sensor

Each fiber optic pressure sensor is factory calibrated. The calibration information unique to each sensor is contained in two gage factors. The gage factors are on a label next to the sensor's SC connector and on the sensor's storage case. The sensor gage factors need to be entered in PC-sam where they are automatically sent to the Fiber Optic Pressure Module.

Right click on the IBP2 waveform display to open the GAGE FACTOR LOADER window. The window has space for gage factors for up to 4 pressure sensors. Click the IBP2 selection for the sensor ID currently in use. Within 2 to 3 seconds, the gage factors will automatically be sent to the Fiber Optic Pressure Module.

Gage Factors sent to the Fiber Optic Pressure Module by the PC are first written into the module's volatile memory. i.e. memory that will be erased when power is removed. The Module also has EEPROM memory which is non-volatile. The EEPROM memory is used to store calibration parameters so they can be automatically used when the module is first turned on.

The Fiber Optic Pressure Module has two indicator lights and two push button switches as shown in the photograph below. A green light is present when power is on. A yellow light labeled "pulse" can have three conditions as follows:

1. On continuous to indicate either no sensor connected or the gage factors in EEPROM memory are different than those currently being sent from the PC.
2. Flashing to indicate a zero is or maybe needed.
3. Off to indicate pressure measurements are being sent to the PC.

If the yellow light is on continuous and a pressure sensor is connected, press the "send Cal" button to store the new gage factors in EEPROM memory. The yellow light should then begin flashing to indicate a zero is necessary.

Zeroing the fiber optic pressure sensor

Before inserting the sensor into an animal, the sensor must be zeroed in air to ensure that accurate absolute pressure values are displayed. The module can zero the sensor when the yellow light is flashing. In that case, perform the zero calibration by pressing the button labeled "zero". The yellow light should go out and the pressure reading on the PC should go to zero.

Small offsets may occur within the first 30 seconds of power up and/or when the Fiber Optic Pressure Module is in a very strong fringe field. Make certain the module has been powered on for at least 30 seconds before performing the zero. Then move the Fiber Optic Pressure Module into the location next to the bore where it will be located during the MR procedure. Observe if the zero value remained. If it did not, perform the zero again.

Fiber Optic Pressure

In the event that power is inadvertently interrupted to the Fiber Optic Pressure Module during a procedure, the yellow light will flash for 15 seconds after power is restored. The flashing yellow light is a reminder that a zero may be needed. However, in this case, with the sensor in the animal, a new zero should not be performed. Instead the previous calibration parameters written to the EEPROM memory are automatically used to make the pressure measurement.

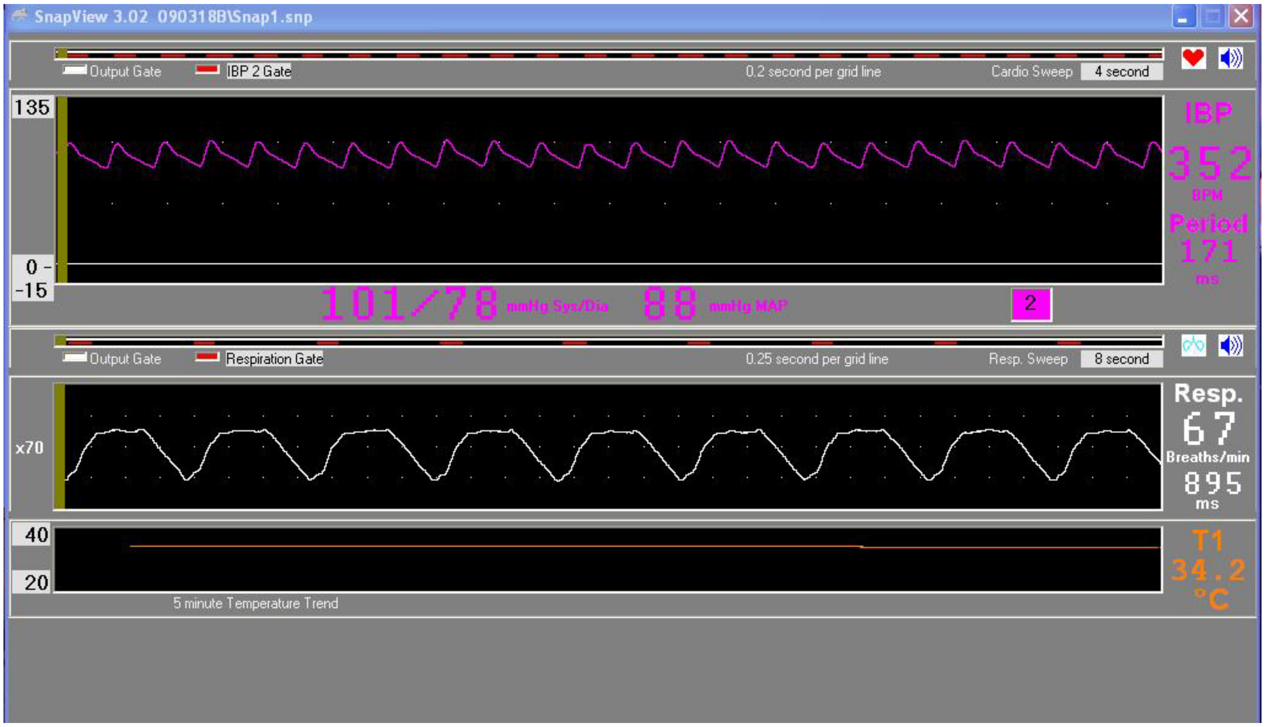
Inserting the fiber optic pressure sensor

The fiber optic sensor can be inserted at any location where a 22 gauge catheter can be inserted. One of the most common placements of the sensor is in the tail artery of a rat to make continuous real time blood pressure measurements.

In the case where the pressure sensor is inserted into a rats tail artery, the tail is first heated, usually in warm water, and a catheter is inserted in the tail artery. The fiber optic sensor is carefully inserted through a Tuohy Borst Adapter and then into the catheter. The Tuohy Borst Adapter is connected to the catheter and then the adapter gland is tightened around the jacket of the sensor to form a seal. A catheter with a 2nd port (IVC-22B) as shown on page 17-1 or a catheter without a 2nd port (IVC-22A) but with a 3 way stop cock allows heparinized saline to periodically flush the transducer to eliminate clotting.

PC-sam's main display

The IBP waveform obtained from the fiber optic pressure sensor in a rat's tail artery is shown on the next page. Note the IBP2 gates are displayed in the Cardio Sweep display. The heart rate and peak to peak period are displayed to the right of the waveform. The systolic, diastolic and mean arterial pressures are computed and displayed below the waveform.



Procedure for making IBP measurements from the rat tail artery

Heat the rat tail using warm water. A second set of hands is recommended to compress the tail artery and prevent bleeding. Insert the 22 gauge Terumo Surflo-W cannula with injection port in the tail artery outside the MR under a bright light. Flush the port with Heparin and seal the port.

Position the rat in the animal cradle. Insert the pressure transducer into the Tuohy Borst adapter. Zero the pressure transducer. Compress the tail artery to prevent bleeding, open the cannula port and insert the fiber optic transducer. Seal the Tuohy Borst adapter around the fiber. Flush with Heparin every 30 minutes or as needed.

Chapter 14
Invasive Blood Pressure

Chapter 14
Invasive Blood Pressure

Overview

The IBP Module measures invasive blood pressure using a blood pressure transducer connected with tubing to an invasive line in the animal. System design accommodates up to three IBP channels with one channel designated as IBP3 incorporated in the IBP Module. The other two IBP channels (IBP1 & IBP2) are either incorporated into the IBP Module or they are battery-powered modules which daisy chain with simplex fiber optic cables from IBP3. The IBP Module has two auxiliary inputs to allow the user to input event markers or acquire, record, display and gate from user generated analog waveforms.

The IBP option is MR-compatible. It can operate in the high RF and magnetic fields of a MR scanner. However, it can also be used in other imaging environments and in the laboratory.

Fiber optic communication cable connections

The IBP Module should be located within a few feet of the animal. When the IBP Module is the only optional module, it connects to the Model 1025T using a duplex fiber optic cable. The cable should be connected to the fiber optic ports labeled “option in” and “option out”. When other optional modules are also present, the modules connect to form a data loop with one of the duplex fibers connecting to the 1st optional module and the other of the duplex fibers connecting to the last optional module. The modules are then connected to each other using short simplex fiber optic cables.

The fiber optic cables have blue and grey connectors. The driver and receiver ports are also blue and gray. The order of the modules in the data loop is not important. But, in all cases the color of the connector must match the color of the port. If the Model 1025T has an options switch, set it to “options in use”.

The IBP Module receives power from a dedicated 12V supply or internal battery or from a daisy chain cable if other optional modules are also in use.

Invasive Blood Pressure

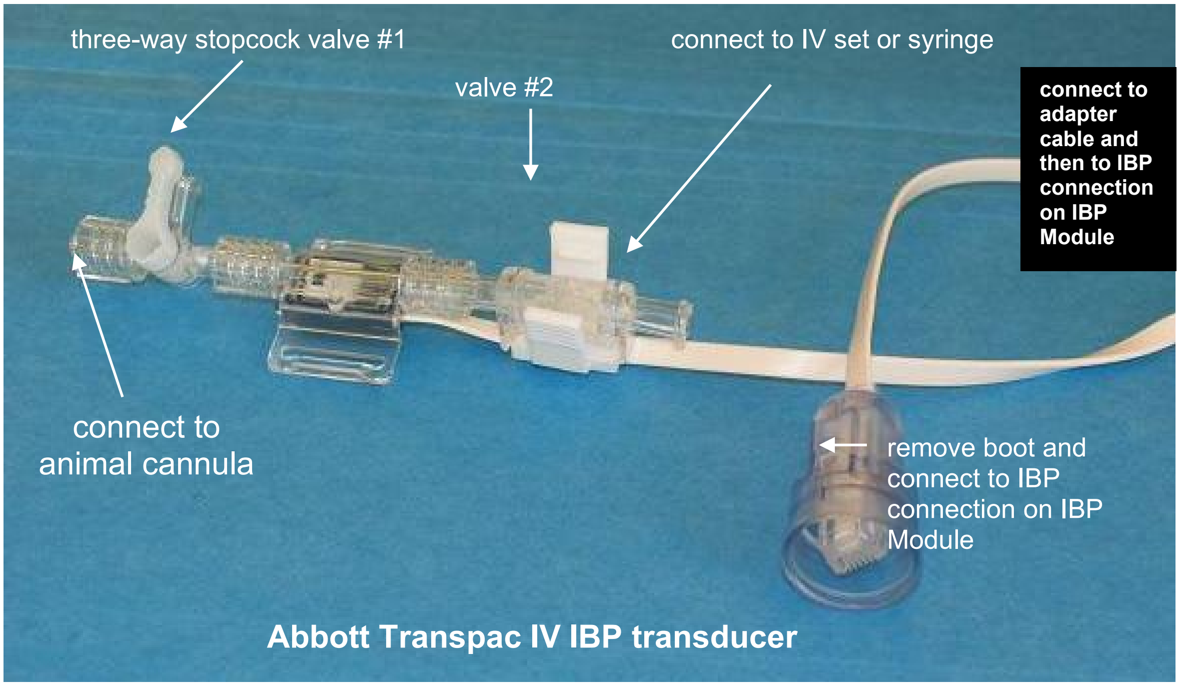
IBP transducers

The IBP Module is configured to operate using disposable invasive blood pressure transducers which meet the specification of 5µV/V/mmHg. The following IBP transducers meet this specification:

Transducer name	Manufacturer contact information
Abbott Critical Care Systems Transpac IV	Hospira, Inc. Lake Forest, IL 60045 (877) 946-7747, www.hospira.com
Baxter Edwards TruWave	Baxter/Edwards Lifesciences, LLC One Edwards Way Irvine, CA 92614 (949) 250-2500, www.edwards.com
Utah Medical Deltran IV	Utah Medical Products, Inc. 7043 South 300 West Midvale, UT 84047 (801) 566-1200, www.utahmed.com
Becton Dickinson Gabarith PMSET 1DT-XX	Becton Dickinson 1 Becton Drive Franklin Lakes, NJ 07417 (201) 847-6800
Braun Exadyn-Combitrans	B. Braun Carl-Braun-Strasse 1 D-34212 Melsungen Germany +49 5661710

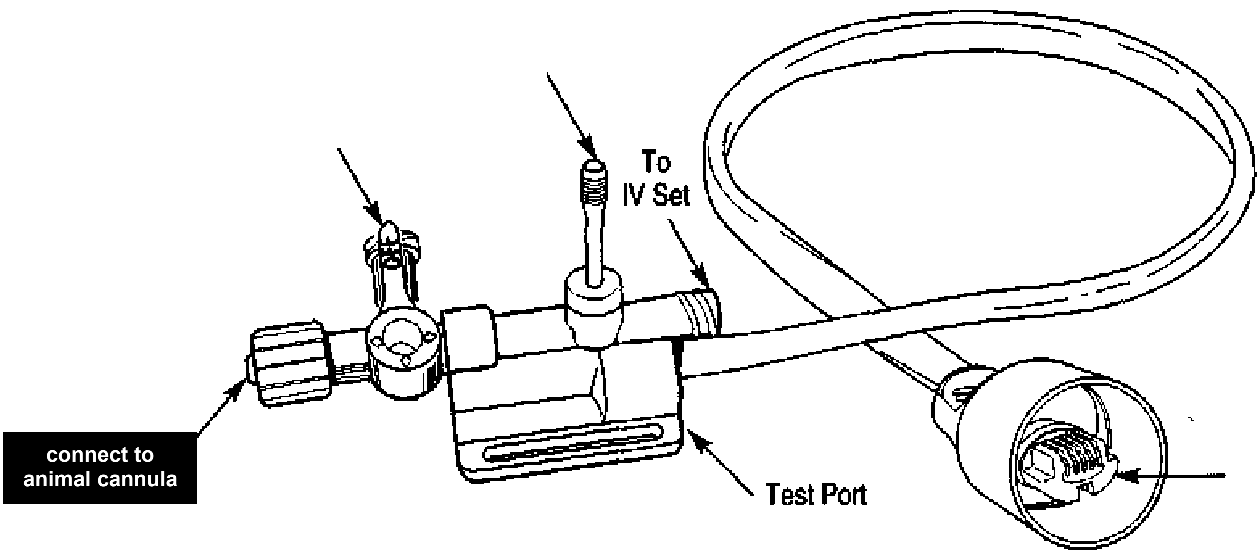
snap tab
valve #2

three-way stopcock
valve #1



Abbott Transpac IV IBP transducer

The Abbott Transpac IV transducer can be connected directly to the IBP Module at the IBP connection. If the transducer connector has a protective boot around it, remove the boot. The connection snaps into the receptacle and locks with the locking clip.



Invasive blood pressure transducers from other manufacturers can also be used with the system. However, an adapter cable will be required. Adapter cables can be obtained by contacting SAII Customer Service.

Invasive Blood Pressure

IBP transducers have an electrical connection (for the IBP Module), three fluid connections (for the animal, syringe and/or IV set) and two valves. A very small piezoelectric pressure sensor is located in the fluid pathway between the two valves. Pressure changes caused by the animal's blood in the tubing are converted to electrical signals by the transducer for display on the monitor.

Each manufacturer of IBP transducers provides detailed instructions for use. Please refer to those instructions for information in addition to that given below.

Transducer valves

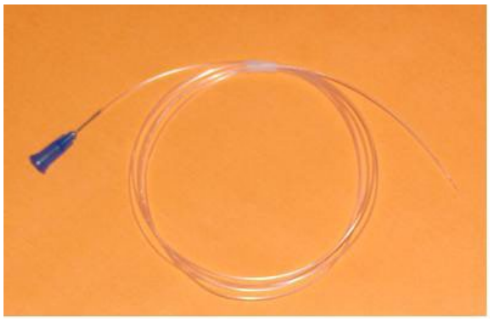
IBP transducers have two valves: a three position stopcock (valve #1) and a normally closed valve (valve #2).

The three position stopcock valve makes a connection between two of the three ports while blocking the third. The stopcock lever can be rotated to select which port is blocked.

The second valve is a normally closed flow through valve. Action by the operator is required to open the valve. In the case of the Abbott Transpac IV, pressing the plastic tabs between the thumb and fore finger will open the valve. In the case of the Baxter Edwards TruWave transducer, pulling the snap tab opens the valve. Note the IBP transducer manufacturer's instructions should be followed in the event the port attached to valve #2 is to be connected to an IV set for fluid delivery to the animal.

Animal cannula

A cannula inserted in the animal's vessel will allow blood to enter the blood pressure



tubing. Cannulas can be constructed in a number of ways using needles, tubing and Leur connectors.

A simple cannula can be made using PE50 tubing and a Leur stub (Harvard Apparatus part number NP 72-4439 www.harvardapparatus.com). The Leur stub has a female Leur connection on one end and a short 22 gage metal stub on the other end. The metal stub can be inserted into one end of a length of PE50 tubing to fabricate the cannula.

When using the IBP function in the MR environment, make certain the tubing is no longer than necessary to extend from the animal in the bore to the IBP transducer location at the entrance of the bore, typically 1 to 1.5 m.

Flushing the IBP transducer and cannula

Before insertion of the cannula in the animal, the IBP transducer and cannula must be flushed and filled with heparinized saline. The tube and cannula must be completely filled with fluid (i.e. no air bubbles). Failure to eliminate entrapped air can result in inaccurate blood pressure readings due to the compressibility of air.

Flush the transducer and cannula by connecting a syringe or elevated IV bag to the port at valve #2. Opening valve #2 allows fluid to pass through and out the end of the cannula. Air bubbles can be eliminated by raising or lowering and tapping on the tubing. Note the three-way stopcock should be positioned to block the port with no connection (open to air).

Making blood pressure measurements

The following steps to make IBP measurements should be integrated with animal handling and aseptic protocols established for your facility:

Connect the transducer with cannula to the IBP port on the IBP Module. If necessary use an adapter cable to make the connection. Select the IBP3 option in the monitor's SETUP MENU. A flat waveform should be present on the IBP portion of the monitor's display. The IBP waveform amplitude should change in response to pressure variations on the transducer.

Flush the transducer and cannula with heparinized saline solution. Remove all air bubbles.

When using the transducer in the MR environment, it should be constrained from moving in the magnet's fringe magnetic field. After positioning the IBP Module near the entrance to the magnet bore, tape the transducer to the canopy or bed near the entrance to the bore. Position the transducer at the level of the animal to maximize accuracy of Blood pressure measurements. Transducer offset changes with the magnetic field, so after securing the transducer it should be zeroed. Check to make certain air bubbles were not introduced.

Establish an invasive line in the animal by inserting the cannula according to the surgical protocol for your facility. Add additional heparinized saline if necessary to position the blood saline interface between the animal and the transducer. Repeat as necessary to keep blood from entering the transducer. A blood pressure waveform should be present on the monitor display.

Invasive Blood Pressure

Most IBP transducers provide a specified level of electrical isolation for the animal. However, if additional isolation is desired, the IBP Module can be operated on an external battery rather than mains power.

Zeroing the invasive pressure transducer

The transducer must be zeroed to ensure that accurate absolute pressure values are displayed. When the transducer is connected to the IBP Module, a yellow LED flashes to indicate zeroing is required. After securing the transducer in the magnet fringe field, follow these steps to zero the transducer:

1. Position the three-way stopcock valve to block the port connected to the animal cannula. This exposes the fluid in the transducer to atmospheric pressure.

2. Press the zero button on the IBP Module. The LED will turn off when the transducer is zeroed.

3. Position the three-way stopcock valve to block the port with no connection. This exposes the fluid in the transducer to the animal's blood pressure.

Calibrating the invasive pressure transducer

The IBP transducer can be calibrated using a manometer or other source of known pressure. The pressure source can be connected to the air port on the three-way stopcock valve. Some transducers (e.g. Baxter Edwards TruWave) provide a separate test port to allow verification of pressure readings without compromising sterility of the system. An IBP gain calibration factor is available in the PC-sam SETUP WINDOW to allow for adjustment of the readings.

Charging the IBP external battery

The IBP Module battery can be charged using an wall charger.. The internal battery is charged when the module is connected to 12 VDC power. The battery will reach full charge in approximately 2.5 hours.

The IBP Module's external battery operates between 7.0 and 8.2 V. A fully charged battery will operate the Module for 6 hours. A low battery warning is displayed on the PC when the battery is low. The module will operate for approximately 1.5 hours following the first indication of low battery. The battery voltage is displayed in the CHARGER window (refer to Chapter 3) and the SYSTEM INFO window (refer to Chapter 9).

Spare channel for auxiliary data

Auxiliary analog input capability allows the user to acquire, record, display and gate from a user generated analog waveform. The channel for auxiliary data uses the IBP (IBP3) connection on the IBP Module. Parameters to adjust waveform gain, scaling, offset, polarity and labeling are set in the MONITOR SETUP SCREEN (refer to Chapter 3) or by clicking on the associated waveform display (refer to Chapter 9).

The connector pin outs for USER IBP are listed below. (pin 1 is the right most pin when viewing the connector):

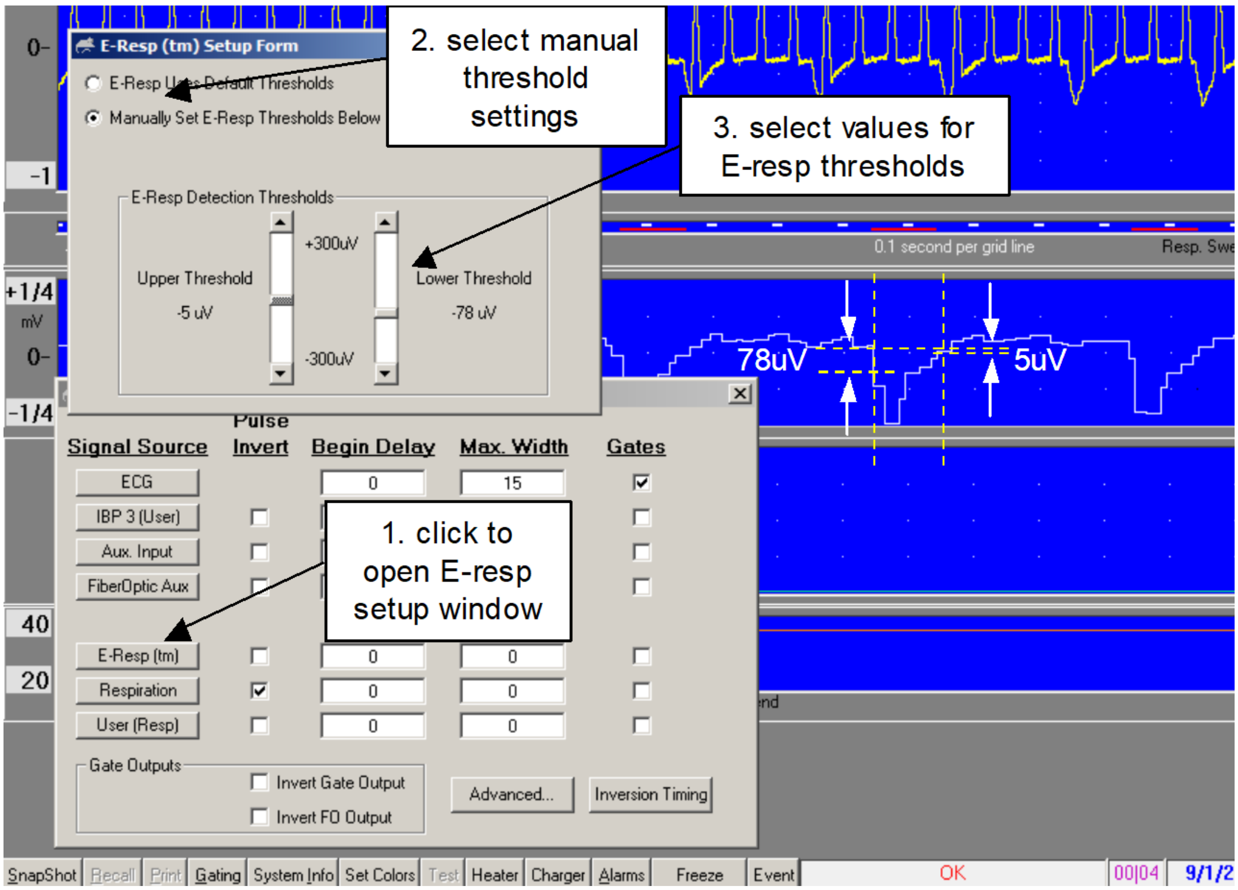
Pin 1 n/c
Pin 2 +5 VDC
Pin 3 Signal +
Pin 4 Signal –
Pin 5 ground
Pin 6 n/c

Chapter 15
Advanced Features

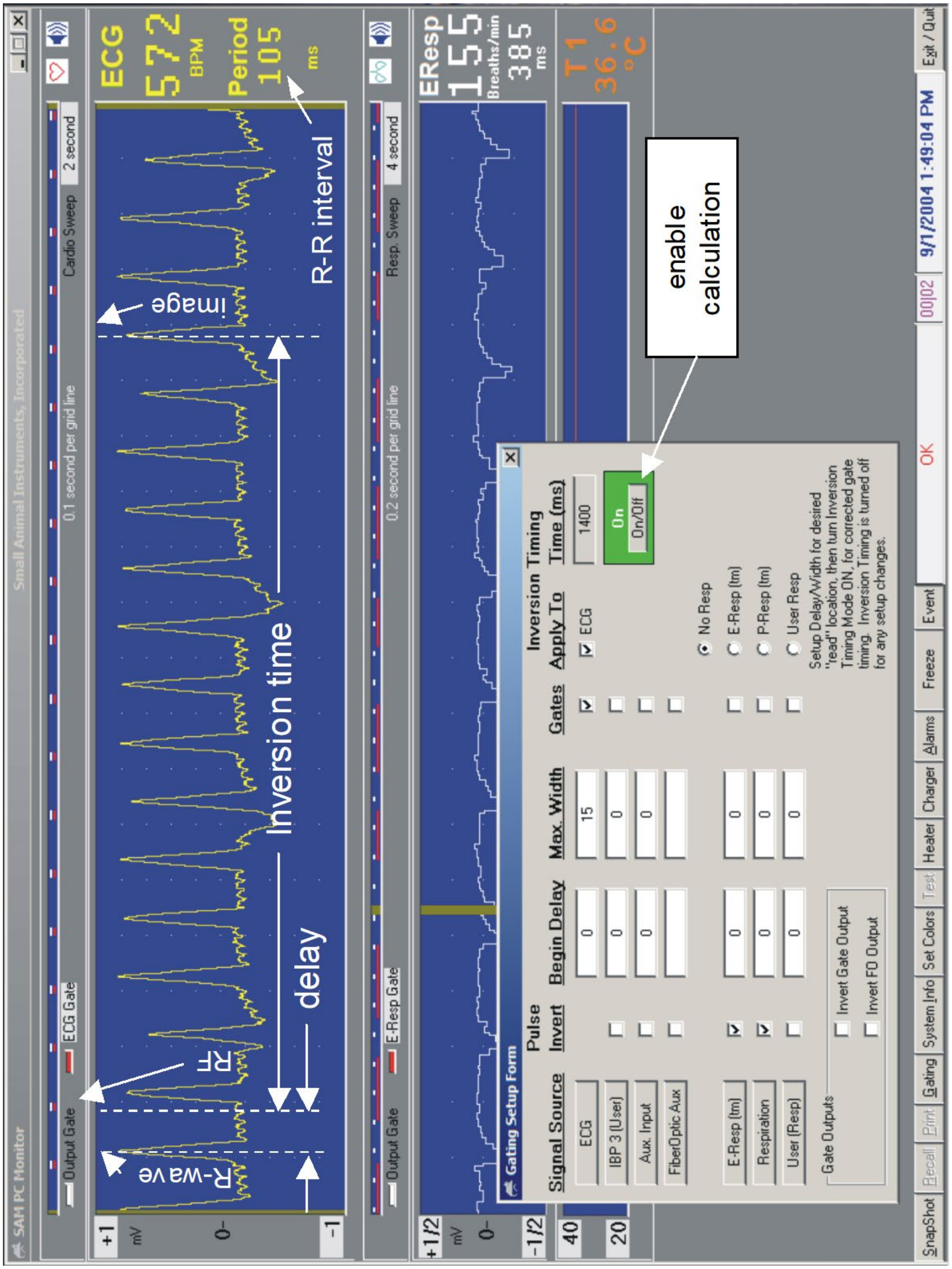
Manual E-Resp™ thresholds

Respiration waveform gates are generated automatically for E-Resp™, P-Resp™ and User Resp. However, in the case of the E-Resp™ waveform, the option also exists to manually set the thresholds for gate generation. The E-RESP SETUP window can be opened by clicking on the E-Resp button in the GATING SETUP window.

For the example shown, the pulse invert check has been removed in the gating setup menu. This allows detection of the dip with manual thresholds. The gate starts when the waveform fall below the lower threshold of -78µV and ends when the waveform rises above the upper threshold of -5µV.



Once the manual thresholds are set to detect inspiration, the pulse invert box can be selected to switch the gate to expiration. Gate position can also be adjusted using Begin Delay and Max Width settings.


R-wave
RF
delay
Inversion time
image
R-R interval
enable calculation
SAM PC Monitor
Gating Setup Form
Signal Source
Pulse Invert
Begin Delay
Max. Width
Gates
Inversion Timing
Apply To
Time (ms)
1400
On
On/Off
ECG
572
BPM
Period
105
ms
ERresp
155
Breaths/min
385
T1
36.6
°C
Setup Delay/Width for desired "read" location, then turn Inversion Timing Mode ON, for corrected gate timing. Inversion Timing is turned off for any setup changes.
9/1/2004 1:49:04 PM

Inversion timing

For certain imaging sequences, such as inversion recovery, the image data is acquired at a time later than the start of the pulse sequence. In those cases it may be desirable to generate a delayed gate to make certain the image is acquired at a specific position in the cardiac and/or respiratory cycle.

Parameters for the inversion timing calculation are entered from an expanded GATING SETUP window implemented by clicking the Inversion Timing key in the GATING SETUP window (refer to the PC-sam display on the previous page).

Consider a pulse sequence which applies a RF pulse 1400ms before readout of the image data. If the detected R-wave peak generates a gate to initiate the pulse sequence and thus the RF pulse, the image data will be acquired 1400ms later at a position in the cardiac cycle which depends on the heart rate or R to R period. For the example shown on the preceding page, the image would occur 35ms after a later R-wave peak assuming the heart rate does not change.

To position the image at the beginning of the cardiac cycle (at the R-wave), we perform an inversion timing calculation where the calculated gate delay plus the inversion time is the first integer multiple of the R to R period. For the example shown where the inversion time is 1400ms and the R to R interval is 105ms, the smallest integer which when multiplied by the R to R interval exceeds the inversion time is 14. In this case the calculated delay is 70ms (70ms + 1400ms = 14*105). Since the calculation is made on the fly, the calculated delay will automatically change with animal heart rate to ensure the image data is collected at the same position in the cardiac cycle.

The inversion timing delay calculation can be applied to ECG, respiration or both. The Pulse Invert, Begin Delay and Max Width controls are active during the calculation. Make the desired changes to these parameters, input the inversion time and click the On/Off key. Within 2 seconds, the delayed gate should appear on the monitor display and be output from the ERT Control/Gating Module.

USER RESP SETUP window

Right click on the User Resp waveform to open the USER RESP (USER SPARE RESP) SETUP window.

The following items can be set from the USER RESP window:

1. Labels for both waveform and scale
2. Scaling,
3. Offset,
4. Scale adjust step size
5. High pass filter,
6. The flashing LED on the IBP Module
7. Signal gain

The waveform and scale labels are set in real time. They appear on the monitor display as they are being entered in the USER RESP window.

The analog to digital converter (ADC) has 1024 bits. The user can select the scaling and offset between the ADC scale and the displayed scale. The displayed max and min scaled values can be changed by right and left clicking the values on the monitor display. The step size for this adjustment is set in the Range Adjust Step Size box.

Application of the high pass filter can be useful to remove a DC offset. Selecting “Output to Resp LED” flashes the USER RESP Module’s LED for each User Resp gate.

Analog Input should be selected for the signal Source. The other option T-Resp™ which generates a respiration signal from a temperature sensor is under development and has not been released.

Three gain stages allow overall signal gain to be set between 80 and nearly 20,000 with the option to change signal polarity. The middle gain stage can also be set to AutoGain to automatically track a signal of varying amplitude.

The User Resp software can interpret the waveform in the following ways:

- As a respiration waveform displaying respiration rate and period
- As a slowly changing analog value, like temperature, displaying the value of the measurement
- As a capnograph waveform displaying the respiration rate and end-tidal CO2.

To make the selection for how to interpret and display the information, execute PC-sam from the desktop and select the option to display the “full setup screen”, then make the selection at the bottom of the USER RESP SETUP window “Rate/Prd”. “value” or “Rate/EtCO2”. The corresponding measurements will be displayed to the right of the USER RESP waveform. The data will also be recorded in the Trend file.

User Resp gates are automatically generated for the User Resp waveform. The presence of gates generates values for User Resp respiration rate and period. The gates can be displayed on the respiratory sweep display and included in the algorithm for generation of output gates.

USER IBP SETUP window

Right click on the User IBP waveform to open the USER IBP SETUP window. The IBP connector on the IBP Module can be used as an IBP channel (IBP3) or as a user auxiliary analog input channel User IBP.

The following items can be set from the USER IBP window:

1. Labels for both waveform and scale
2. Scaling,
3. Offset,
4. Scale adjust step size
5. Signal gain

The waveform and scale labels are set real time. They appear on the monitor display as they are being entered in the USER IBP window.

The analog to digital converter (ADC) has 1024 bits. The user can select the scaling and offset between the ADC scale and the displayed scale. The displayed max and min scaled values can be changed by right and left clicking the values on the monitor display.

The step size for this adjustment is set in the Range Adjust Step Size box.

Two gain stages allow overall signal gain to be set between 10 and nearly 5,000.

User IBP gates are automatically generated for the User IBP waveform. The presence of gates generates values for User IBP rate and period. The gates can be displayed on the respiratory sweep display and included in the algorithm for generation of output gates.

AUTO EVENT window for time stamping

Left click the Event key to manually log an event in the trend file. Right click the Event key to open the AUTO EVENTS window. The auto events feature allows pulses on the Auxiliary Input to be counted and automatically logged in the trend file. The Auxiliary Input can be either the AUX IN or the FO AUX IN on the ERT Control/Gating Module. A FORT Module can be used to convert an electrical (TTL) signal to an optical signal for input into the FO AUX port (refer to Chapter 3). The event can be triggered from either the rising or falling edge of the pulse.

When enabled, the Auto Event Counter will either increment or decrement from the Start Count value to the Stop Count value. If the window is closed it will reappear when the Current Count reaches the Stop Count. An audible alert can optionally be issued when the Current Count reaches the Stop Count. Options exist to hold, reset or continue counting when the Stop Count is reached. The Apply key sends entered data to the counter software. The Restore key restores the last applied entry.

Note the user can set the Start Count, Stop Count and Current Count to create a non terminal state. To eliminate this condition make certain the Current Count can either increment or decrement to the Stop Count value.

ADVANCED GATING SETUP window

The advanced gating menu includes the following additional features:

1. End Delay for the gate generated by each signal except ECG
2. Primary, begin, hold and end conditions for each signal gate included in the construction of the output gate
3. Gate count condition logic

End delay allows the gate to be delayed from its otherwise normal end position.

Primary, begin, hold and end are logical conditions applied to the gates generated for each signal which are included in generation of the output gate.

When using the complex gating control, separate criteria are used for beginning and ending the output gate signal. The beginning of the output gate occurs when all the gate signals checked under Begin are logic high. If a Primary gate is selected, the beginning of the output gate occurs when all the Begin gates are high AND there is a low to high transition of the Primary gate. The end of the output gate occurs when ANY of the Hold gates (gates checked under Hold) goes low, OR when ALL of the End gates go low.

The possibilities for using this gating control are limited only by imagination when one considers the flexibility provided by two external gate inputs and two user definable analog inputs. However, typically, only a few items would be checked, and the end condition would be defined by either Hold or End, but not both (a column with no checks has no effect).

The gate counting feature allows a preset number of gates based on the above criteria to be output, followed by a blockage of outputs until the Gate Count reset condition is met. As an example, it could be set up to reset on expiration and use only the first ECG gate for imaging

Auto Track

The auto track feature provides an automatic way to adjust the respiration gate when the animal's respiration changes. The feature can be applied to E-Resp™, Resp or USER RESP. This feature is especially useful during long experiments when variations in either the animal's sedation or temperature cause respiration to change.

In the GATING SETUP window click a respiration button to display the AUTO TRACK window. Make certain the waveform of interest is selected as E-Resp™, Resp or USER RESP. Either or both of the parameters Begin Delay and Max Width can be automatically tracked. Enter the desired percentage of the measured respiration rate for one or both parameters and check the Enabled box

Note that the Apply and Cancel keys control the values entered for the auto track parameters. Pressing the Cancel key will display the previous value while pressing Apply sends the value to the ERT Control/Gating Module. The background color in the value box indicates the status. White indicating the value has been sent to the ERT Control/Gating Module. If the enabled box is not checked it does not matter if the parameter value has been sent or not as it will not be used to determine the gate position or width.

For the example shown above Auto Track has been selected to apply to Respiration. The respiration gate has been defined to be during the expiration portion of the waveform by checking Pulse Invert. Begin Delay and Max Width have been set to 5 and 50% of the respiration interval or 15.5 and 155 msec respectively. When changes occur in the animal's respiration rate, the two parameters will automatically track according to the parameter settings.

Chapter 16
Signal Breakout Module

Chapter 16
Signal Breakout Module

Overview

Physiological measurements and gates from the monitoring and gating system can be acquired by another data acquisition system or a PC using the Signal Breakout Module.

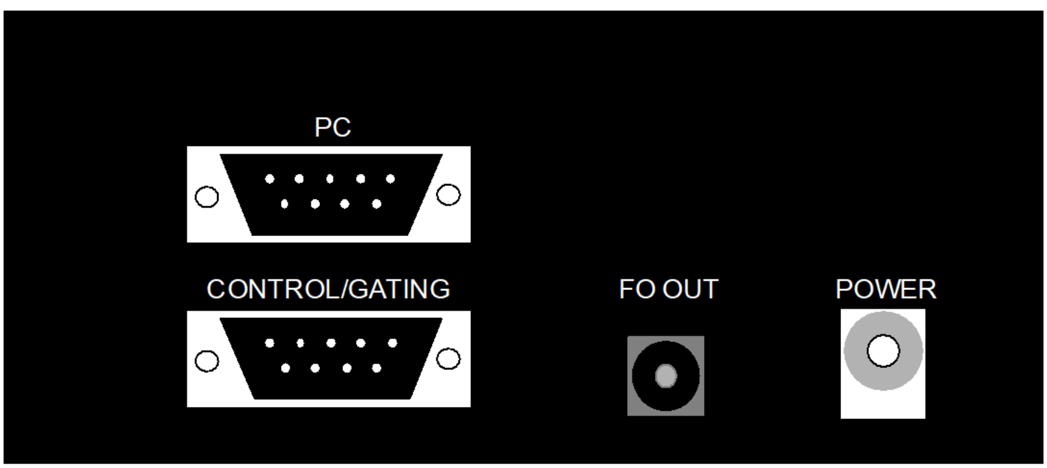
To maximize data transmission rate, SA Instrument's monitoring and gating systems send and receive densely packed data on the serial cable connecting between the Model 1025T and the PC. The Signal Breakout Module can be connected in the serial line to unpack the data and allow users access to the real time physiological measurements.

Data available from the Signal Breakout Module includes slow data such as heart rate, respiration rate, temperature, etc. as well as fast data including gates and waveforms. The module includes 4 channels each with 3 outputs which are user configurable. i.e. units have the ability for the user to assign which physiological parameters are available on each output. Multiple modules can be used to allow more than 4 channels.

The Signal Breakout Module also provides capability for a second remote display through a fiber optic output connection. The packed data which is output on the fiber optic connection can be converted by a FORT Module to an electrical signal at a remote location for input on the serial or USB port of a second PC. This second PC has all the display capabilities of PC-sam without the ability to control the system.

Input/output connections

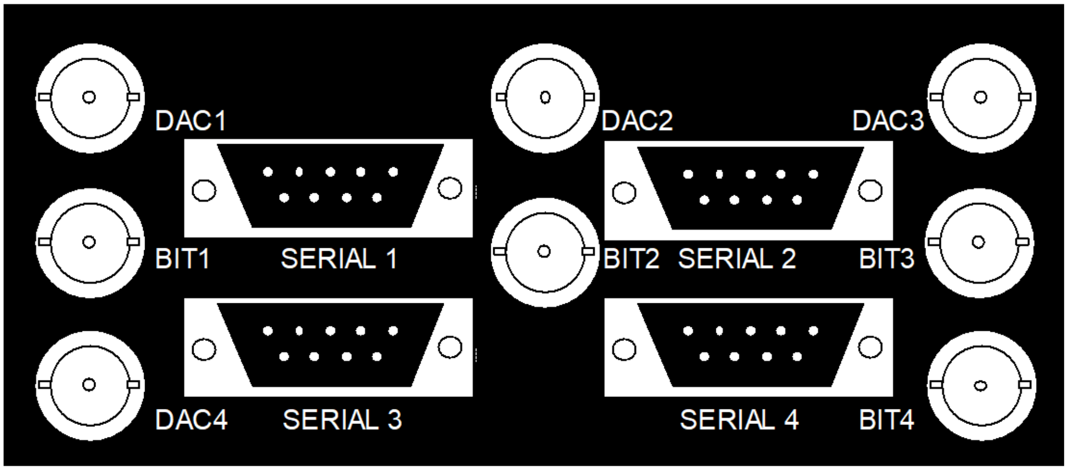
Power panel



PC	Serial I/O connection to PC
Control/Gating	Serial I/O connection to Model 1025T
FO out	Fiber optic connection for remote display
Power	12 VDC input

Signal Breakout Module

Physiological measurement output panel



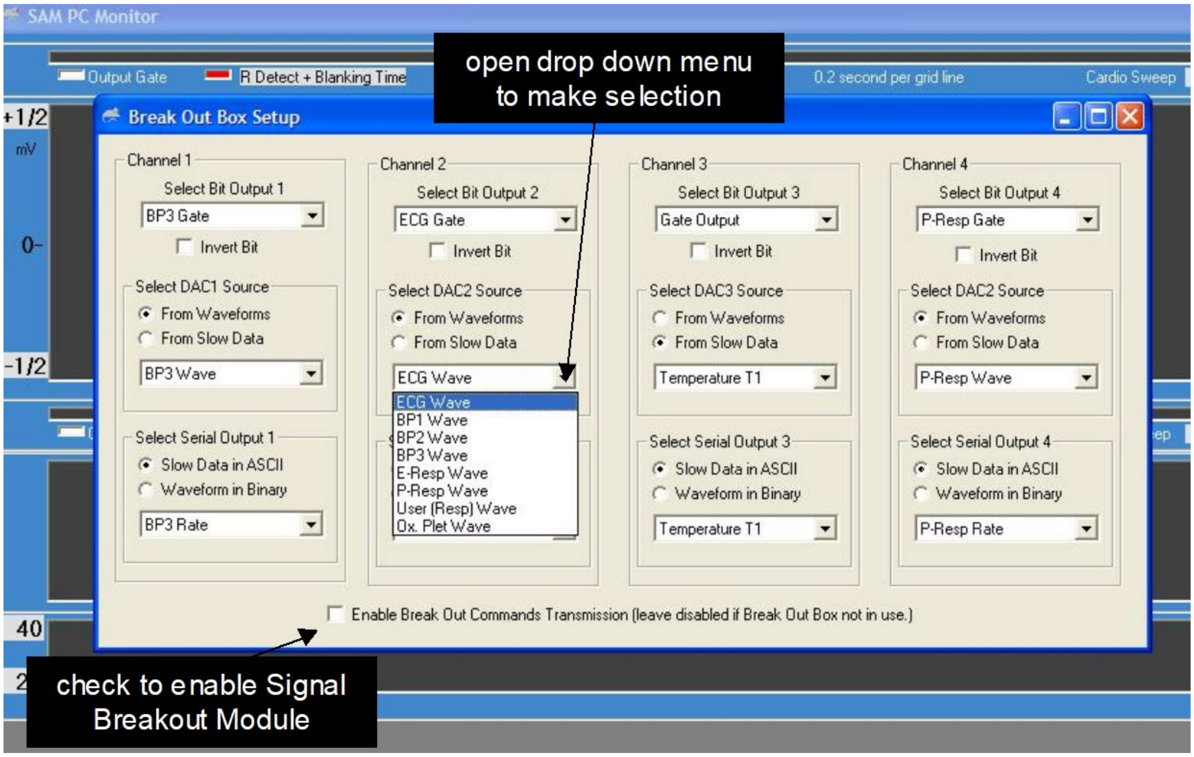
DAC1	Analog output 0 – 5 V channel 1
BIT1	Gate output 0 – 5 V channel 1
SERIAL 1	Serial output channel 1
DAC2	Analog output 0 – 5 V channel 2
BIT2	Gate output 0 – 5 V channel 2
SERIAL 2	Serial output channel 2
DAC3	Analog output 0 – 5 V channel 3
BIT3	Gate output 0 – 5 V channel 3
SERIAL 3	Serial output channel 3
DAC4	Analog output 0 – 5 V channel 4
BIT4	Gate output 0 – 5 V channel 4
SERIAL 4	Serial output channel 4

Setup and use

The Signal Breakout Module connects, using 9-pin D serial cables, to the PC and to the Model 1025T. It gets power from the PC over the serial cable or from a dedicated 12 VDC power supply. or from the Model 1025T using a daisy chain cable.

Clicking on the “BrkOut” key on the bottom of PC-sam’s main display opens the BREAKOUT window, shown on the next page. The window has 4 independent channels with drop down menus to set bit (gate), DAC (analog) and serial outputs for each channel. The bit channels can be inverted. For the DAC and serial outputs a selection between slow data or waveform data should be made before opening the drop down menu.

Note the box at the bottom of the BREAKOUT window. This box must be checked to enable PC-sam to send commands to the Signal Breakout Module.



Using multiple Signal Breakout Modules

More than one Signal Breakout Module can be used to output more than four parameters. Here are instructions for using two modules:

1. Connect the first module between the Model 1025T and the PC. Configure the 4 channels using the Breakout window in PC-sam. These settings are saved in EEPROM and will load on the next power up. You need to be sure the commands have made it to the Signal Breakout Module. Waiting ten seconds is probably adequate, but if you want to be sure, invert a gate bit from where you want it then invert it back. When you see it flip back all have been updated.

2. Connect the second module between the first module and the PC. This second module can now be configured using the Breakout window in PC-sam. The commands from the PC do not pass through to the second module. Instead the second module settings are those previously stored in EEPROM.

3. If you want to change the setup for the second module, remove the first and reprogram,

Signal Breakout Module data formats

Waveform data

ECG	900 sps, 1024 count,	512 = 0	5 µV/count
IBP1/2/3	450 sps, 1024 count	90 = 0	3 counts/mmHg
Plet	450 sps, 127 count,	64 = 0	
P-resp	225 sps, 127 count	64 = 0	
E-resp	225 sps, 127 count	64 = 0	
USER resp	225 sps, 1024 count	512 = 0	
CO_2	225 sps, 1024 count	0 = 0	100 counts per 1% CO_2

Slow data

Temperatures	14 bits,	ºF = count/100 + 32; ºC = count/180
Rates	14 bits,	1 BPM/count
Blood pressures	10 bits,	90 counts = 0 mmHg, 3 mmHg/count

Analog output of slow data

Data is shifted to a 12 bit value to maximize use of the output range: 0 – 5 V for 0 – 4096 counts.

Capturing ASCII slow data from the serial output

ASCII values from any of the 4 serial output channels can be read and displayed on a PC using HyperTerminal as follows:

1. Make an appropriate selection for the connection com number.

2. Set the following port settings: 115200 Bits per second, 8 Data bits, Parity None, Stop bits 1, Flow control None.

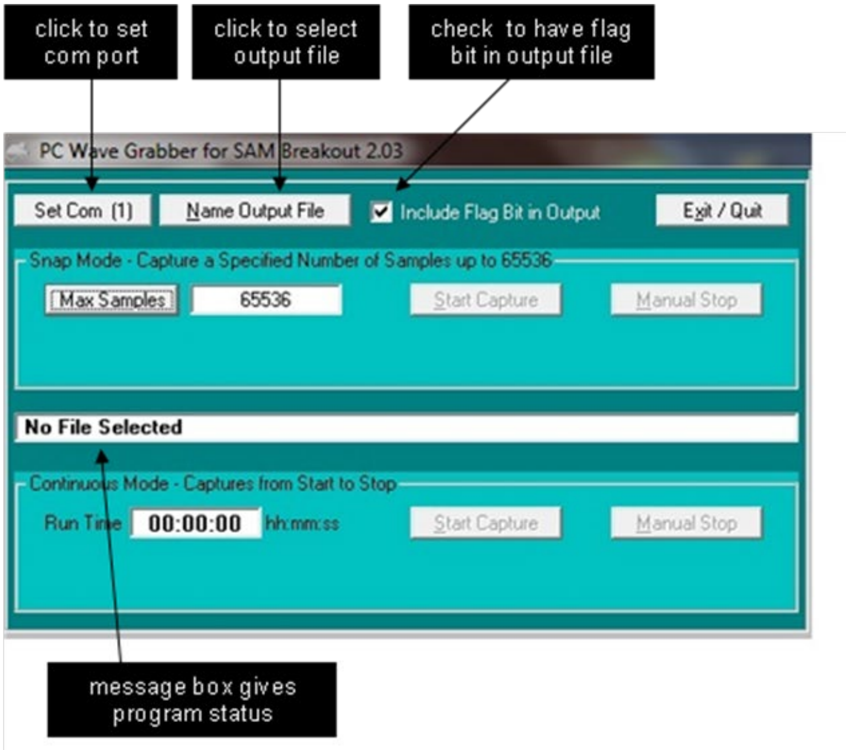
3. Select File>Properties>Settings>ASCII Setup>ASCII Receiving. Make certain the following are not checked: “Append line feeds…” and “Force incoming data to 7-bit ASCII”. Check “Wrap lines that exceed terminal width”.

Capturing ASCII waveform data from the serial output

Waveform data streams from the serial port at a rate of 1800 8 bit bytes per second. Waveform data is digitized using a 10 bit A/D, so 2 bytes contain a single measurement. WaveGrab.exe can be used to capture the waveform data using a serial or USB PC port and write it as a text file with 900 samples per second. The text file can then be imported into a spread sheet program such as Excel.

To run the software, click on the WaveGrab icon on the desktop. The first time WaveGrab is executed on a PC an authorization code is required to activate the software. The PC’s ID code must be transmitted to SA instruments and then an authorization code for that PC can be entered to activate WaveGrab.

Once activated, you can set the com port, create a name for the text file, select either the number of samples to collect or run continuous and start or stop the capture process. Program status is displayed in a message box.



WaveGrab version 2.03 has the important option to include a flag bit in the output. It is sometimes of benefit to synch data from the MR scanner or another source with the ECG, respiration and other waveforms. In that case, a bit from the scanner or another source can be input to the Model 1030 at the AUX BNC connection of the Model 1025T. In this case if you check to output the AUX GATE in the bit output and the waveform in the serial output or the BREAKOUT window and if the "include flag bit in the output" box is selected in the WaveGrab window then the flag/bit will be output with the waveform data (2 columns of data). This feature allows time stamping 2 or more waveforms so they can be synchronized for analysis.

The flag bit input at the AUX BNC should be a 5 V pulse >1 msec in duration. The bit can be displayed in PC-sam by selecting AUX Input in the Cardio Sweep display.

Capturing digital waveform data from the serial output

A 2 byte packet is output at 900 packets per second from the serial port. For ECG each packet is a measured data point. For IBP & plet the sample rate is 450 samples/sec and 2 packets are output with the same value. For respiration the sample rate is 225 samples/sec and 4 packets are output with the same value.

The first byte output for the packet has bit 7 = 0 and low bits 0-6. The second byte has bit 7=1, bit 6=1 if data is deemed stale, bit 5 contains the status of the bit out, and high bits 0-4.

To decode the digital waveform data do the following:
Read in byte by byte
If byte has bit 7 clear, save as low byte
If byte has bit 7 set and there was a previous stored low byte
Then the 2-byte packet is complete and can be decoded.

StaleFlag + HighByte and 64,	Stale flag is bit 6 of high byte
BitOut = HighByte and 32,	Bit output is bit 5 of high byte
IntVal=((HighByte and 31)*128)+LowByte	digital count decoded

Appendix A
Specifications

Model 1025T:

Parameters	ECG, temperature, respiration,
Auxiliary inputs	2, digital (on/off)
Gate output	any combination of waveforms and/or auxiliary inputs TTL or active low
Resp gate output	TTL (0 to 5 V)
Gate width and delay	adjustable, 1 ms step size
Heater control	fiber optic PWM
Power	12 VDC
Module size: hxwxd cm	5.7x12.9x13.3

ECG:

Electrode type	sub-dermal needles, gold disk surface and pads
Number of leads	3
Range:	40 - 900 BPM
Accuracy:	±1%
Input range:	-2.50 mV to 2.5mV
Input Impedance:	>10 MΩ @ 10 Hz
CMRR:	100 dB @ 60 Hz

Temperature (thermistor or fiber optic):

Rectal fiber optic	
Tip OD, mm	1.0, 1.5 or 3.0
Range	30– 45 ºC
Accuracy	+/-0.2 ºC
Rectal thermistor	
Tip OD, mm	1.0 or 3.0
Range	32– 42 ºC
Accuracy	+/-0.26 ºC

Respiration:

Probe type	pneumatic pillow
Range	13 - 300 bpm
Accuracy	1 count

Specifications

Multi-parameter Fiber Optic Module:

Parameters	temperature, SpO_2, pressure
Power	12 VDC
Module size: hxwxd cm	8.3x15.5x15.9

Fiber Optic Temperature:

Probe type	fiber optic, rectal
Tip OD, mm	1.0 and 3.0
Range	30 - 45 ºC
Accuracy	+/-0.2 ºC
Number of channels	up to 4

Fiber Optic Pressure:

Probe type	fiber optic
Tip OD, mm	0.3 and 0.4
Range	0 – 300 mmHg
Accuracy	1 count
Number of channels	1 or 2

Pulse Oximetry:

Probe type	fiber optic clip and tail/ankle large and small
Rate range	40 - 600 BPM
Rate accuracy	±1%
Probe types	fiber optic
SpO_2 range	0 – 100 %
SpO_2 resolution	1 count

IBP:

Sensor type	invasive blood pressure transducer
Display range	0 – 300 mmHg
Channels	1 to 3
Auxiliary inputs	2 analog 0 – 5 V
Module size: hxwxd cm	4.2x15.8x15.0

Air Heater System:

Heater control	fiber optic PWM
Heater power	100, 115 or 230 VAC
Heater size: hxwxd cm	16.4x8.9x26.0
Fan power	100, 115 or 230 VAC
Fan size: hxwxd cm	6.4x18.0x18.4

Single Pump Fluid Heater System:

Heater control	mixed water temperature 35 – 45 ºC ±0.1 ºC
Heater Module power	100/115/ 230 VAC
Heater Module size: hxwxd cm	16.4x8.9x26.0
Circulation Module power	12 VDC, 2.0 A
Circulation Module size: hxwxd cm	32x54x33

PC requirements:

Software: Windows	any version including 11
Hardware:	>1 GHz processor USB port Display resolution 1024 x 768 pixels or greater

Appendix B
System Components and Accessories

Part No.	Description
M1025TOP-rev	**Operation Manual, Model 1025T SAM & Gating System**
M1025PCS-rev	**PC-SAM Software CD**
1025T-CASE	**Storage Case Model 1025T System**
410100	**Model 1025T**
410200	**Model 1025T-FOT**
RMEC-703-4	Model 1025T Subdermal ECG Needle Electrode set for mouse, 3 lead
RMEC-703-6	Model 1025T Subdermal ECG Needle Electrode set for rat, 3 lead
RMEC-704-10	Model 1025T Subdermal ECG Needle Electrode set for rabbit, 3 lead
E3M-103-3	ECG 3M Red Dot neonatal electrodes 3/pack
EGD-705-612	Model 1025T Gold Disk Electrodes 6mm – 3 lead set for mouse
EGD-703-1012	Model 1025T Gold Disk Electrodes 10mm – 3 lead set for rat
EGEL-103	Electrode Gel
EPASTE-103	Electrode Paste
ETLEC-703-36	3 Lead ECG Twisted Lead Extension Cable 36” Long
RTP-101-B	Rectal Thermister Temperature Probe for mouse & rat – 3 mm OD tip 7" long
RTP-102-B	Rectal Thermister Temperature Probe for mouse & rat – 1 mm OD tip 7" long
RTP-103-B	Rectal Thermister Temperature Probe for rabbit – 4 mm OD tip 7" long
TPEC-109-7	Temperature Probe Extension Cable - 7"
TPEC-109-12	Temperature Probe Extension Cable - 12"
TPEC-109-36	Temperature Probe Extension Cable - 36"
FOTSC-6	Fiber Optic Temperature Sensor Type C, 0.040” tip OD, 6’ long
FOTEC-10	Fiber Optic Temperature Extension Type C, 10’ long
FOTSD-6	Fiber Optic Temperature Sensor Type D, 0.090” tip OD, 6’ long
FOTED-10	Fiber Optic Temperature Extension Type D, 10’ long
TPC-200	Temperature probe covers
RS-301	Respiration Pillow Sensor
RSET-3	Respiration Extension Tubing 3’ long
RSET-8	Respiration Extension Tubing, 8’ long
CGIC-201	Serial Interface Cable
PS-2-12	Power Supply, 12 V
PSLC-2-E	Line Cord 230 VAC Europe
PSLC-2	Line Cord 115 VAC
470100	**Multi-parameter Fiber Optic Module**
2FTDFOC-23	Duplex Fiber Optic Cable 24” long
FOTS-2	Fiber Optic Temperature Sensor Type A, 0.040” tip OD, 2’ long
FOTS-6	Fiber Optic Temperature Sensor Type A, 0.040” tip OD, 6’ long

System Components and Accessories

Part No.	Description
FOTS-9	Fiber Optic Temperature Sensor, 0.040” tip OD, 9’ long
FOTE-10	Fiber Optic Sensor Extension Cable, 10’ long
530100	Fiber Optic Pulse Ox Sensor, 6’ long with interchangeable collar
530110	Fiber Optic Pulse Ox Sensor, 9’ long with interchangeable collar
530202	Small Pulse Ox Clip for Mouse
530203	Large Pulse Ox Clip for Rat
530204	Small Pulse Ox Tail/Ankle Form for Mouse
530205	Medium Pulse Ox Tail/Ankle Form for Mouse
530206	Large Pulse Ox Tail/Ankle Form for Rat
530201	Transcranial Pulse Ox Form for Mouse
FOP-5-4	Fiber Optic Pressure Sensor, 0.016” tip OD, 5’ long
FOP-3-3	Fiber Optic Pressure Sensor, 0.012” tip OD, 3’ long
FOP-OEX-3	Fiber Optic Pressure Sensor Extension Cable 3’ long
FOP-OEX-10	Fiber Optic Pressure Sensor Extension Cable 10’long
FOP-TBA	Tuohy Borst Adapter
IVC-22A	22 gauge catheter
IVC-22B	22 gauge catheter with an injection port
810100	**Fiber Optic Temperature Module**
580100	**Pulse Oximeter Module**
830100	**Fiber Optic Pressure Module**
DCPC-2	Daisy Chain Power Cable for 2 modules
15SFOC-1	Simplex Fiber Optic Cable, 1’ long
731100-rev	**IBP Module**
IBPX-A	IBP Transducer Abbott Transpac IV
754100-rev	**Simulator**
SEL-705	Simulator ECG Leads
STC-105	Simulator Temperature Cable
M9001	**Air Heater System**
761100-rev	Air Heater Module 115 VAC
760100-rev	Air Heater Module 230 VAC
771100-rev	Fan Module 115 VAC
770100-rev	Fan Module 230 VAC
10SFOC-23	Simplex Fiber Optic Cable 30’ (10 m)
FAH-10	Fan air hose 10’ (3 m}
WAH-5	Warm air hose 5’ (1.5 m)
CUF-2	Cuff, heater hose

Part No.	Description
HOS-x	Heater hose (feet)
M9002	**Single Pump Fluid Heater System**
763100	WBH Heater Module 115 VAC
762100	WBH Heater Module 230 VAC
880200	Single Pump Circulation Module

Problem	Possible Cause	Corrective Action	See
No waveform on display. Trace frozen & communication error	Wrong com port selected	Select the correct com port in PC-SAM setup menu.	2-2 3-6
No waveform on display. Trace frozen & no communication error	No power to the Control/Gating Module or communication problem.	Check the power and serial connections	2-1
Sweeping waveform but no ECG signal.	Lead off.	Check lead attachment.	4-1
Sweeping waveform but no ECG signal.	Offset voltage too large	Check offset voltage in system info window. Check for faulty temp probe by disconnecting the probe from the ECG/T Module & check for needles in muscle	5-1 4-1
ECG waveform but no heart rate display	R-detect parameters incorrect	Set correct values	3-9

Problem	Possible Cause	Corrective Action	See
Air Heater system has cold air blowing from the heater tube.	Wrong set point.	Check that the set point is greater than the measured temperature	9-4
Air Heater system has cold air blowing from the heater tube.	Power is not on.	Check power to the Air Heater Module. A green LED indicates power. Check AC connection.	9-1
Air Heater system has cold air blowing from the heater tube.	Control signal not present.	Power indication OK, but Heat LED not flashing. Check the fiber optic connection to the Air Heater Module. Red light should be present in the end of the fiber to turn on the heater element. Check the temperature probe, set point and connections at the Control/Gating Module. Select "On/Off with PWM Max Heat" in HEATER window	9-1 9-3
No gate detected by the imaging system	Improper gating setup selection.	Check for the presence of trigger output to the scanner (white dots in Cardio Sweep display). If trigger is not present check selections in Gating Setup menu.	3-2 3-8
Fluid Heater system: No reading for heater output temperature.	Heater and/or FORT module not powered or communication port not set.	Check power and/or com port	10-3 10-5
Fluid Heater system: no reading for heating pad or animal temperature.	The temp probes are not set properly.	Select the temperature probes being used to make the measurements.	10-2

No heat from air heater

If the Air Heater Module is not generating heat and the yellow “heat” light does not flash, check the following settings:

1. The heater set point is large (70 °C)
2. The measured temperature displayed on the PC is less than the set point
3. The heater window has "on/off with PWM max heat" checked
4. The max heat value is large (100%).

Then check to see if there is a red light in the Heater Control fiber optic connection on the Model 1025T. If the above are all true, and there is no red light, the problem must be a communication problem between the PC and Model 1025T. The problem has nothing to do with the Air Heater Module. It is confined to the PC, the Model 1025T and the cable between the two units.

If there is a red light then check the following:

1. Power is applied to the Air Heater Module. If the green light is not on, check the switch and/or internal fuse.
2. Red light is present on the fiber optic cable connected to heater control.
3. The heater control fiber is seated in the connector (should snap in place).
4. Check inside the fiber optic connector for lint.

If still the yellow light does not flash, contact SAII’s Customer Service.

Low heat from air heater

If the yellow heat LED is flashing, but the temperature from the Air Heater Module is low, follow these instructions.

Using the 1.5 m tube from the Air Heater Module and the 7 m tube between the Fan and Heater, the temperature at the end (or just inside the end) of the outlet of the 1.5 m tube should be 55 °C. The Model 1025T thermister temperature probe can be used to measure the temperature.

You can pretty well tell what the control electronics in the Air Heater Module is doing by observation of the yellow heat LED. When the system is first turned on and with the Fan Module off (with set point very high and duty cycle to 100%) The yellow LED should flash continuously until the temperature just inside of the heater (inside the hole labeled Warm Air) rises to a standby level of about 40 °C. Once the temperature reaches the standby level, the yellow LED should only flash occasionally to maintain that temperature. When the fan is turned on, the processor senses a difference in temperature between the thermister located at the inlet and outlet of the Air Heater Module. In this case the processor allows the outlet temperature to rise to approximately 85 °C correspondingly the temperature at the end of the 1.5 m tube is about 55 °C. When that temperature is reached the yellow LED will flash only when current is required to maintain the temperature.

Look inside the holes of the Air Heater Module. You will see a thermister at each end. The thermister should stand erect and not be bent against the heat chamber. If the Air Heater Module was dropped during shipment, the heat chamber may be damaged. You might start with a cold system and without the Fan and then with the FAN to try to understand what is not working.

You can only get very low temperature if one of the following occurs:

1. Wrong voltage,
2. Fan not on or the processor thinks it is not on
3. Heat chamber housing cracked and leaking

Make certain the air hoses are connected properly. i.e. that the fan is not connected to the "Warm Air" port on the Air Heater Module.

PC-sam data files as diagnostic tools

Both SnapShot and Trend data files are extremely useful in troubleshooting. SnapShot files give a 36 second recording of all measured data while Trend data files continuously record system measurements once per second.

Trend data files are collected automatically in the background while PC-SAM is running. Each Trend file has an associated Events file. SnapShot data files are collected every time the SnapShot key is pressed. The SnapShot key is in the lower left of PC-SAM's main display. When the SnapShot key is pressed, the previous 36 seconds of all measured data are stored on the disk drive.

The factory default location for these files is

c;/ProgramFiles/PC-SAM/SAM-Data/
If the SAM-Data folder is not visible click on "compatibility files" at the top of the window.
If all else fails navigate to c:/users/SAII (or your user name)/AppData /Local/VirtualStore/ProgramFiles(x86)/PC-SAM/SAM-Data

Folders in SAM-Data are date encoded in the format yymmdd. If PC-SAM is opened more than once in a day a letter is appended to the folder name. Trend files have a ".trd" extension. Event files have a ".evt" extension. SnapShot files have a "'snp" extension.

These data files are not large. They can easily be attached to an e-mail. It can be very useful to send these data files with a description of your problem to service@i4sa.com.

Appendix D
Routine Maintenance

Clean the monitor's surfaces or probes with a soft cotton cloth moistened in a mild soap solution. If disinfection is required, wipe the surface with alcohol, sodium hypochloride or glutaraldehyde (Cidex, Metrucude, etc.). Follow the instructions provided by the manufacturer.

Water in the Single Pump Fluid Heater system should be replaced every 3 months or whenever contaminants are present. Water can be tap water or sterilized water. If using tap water, add 2 tablespoons of chlorine. Tap water can be sterilized by boiling it for a minute.

2Warranty Period

This product is warranted to be free from defects in material and workmanship for the following periods, commencing from the date of first use by the original end user:

- Labor - one (1) year
- Parts - one (1) year except accessories which are warranted for ninety (90) days

What is covered and what is not covered

Except as specified below, this warranty covers all defects in materials and workmanship in this product.

Accessories include batteries, ECG electrodes, respiration cradles, respiration pillows, extension cables and temperature probes.

The following are not covered by the warranty:

1. Personal Computer (the PC manufacturer's warranty applies).
2. Software or hardware upgrades.
3. Damage to or deterioration of the external cases
4. Any module which has been altered or on which the serial number has been defaced, modified or removed.
5. Damage, deterioration or malfunction resulting from:
    A. Accident, misuse, abuse or neglect;
    B. Failure to follow instructions supplied with the product;
    C. Shipment of the product (claims should be presented to the carrier);
    D. Repair or attempted repair by anyone not authorized by SA Instruments, Inc. to repair this product;
    E. Causes other than product defects, including lack of technical skill, competence or experience of the user.

Who may enforce the warranty

This warranty may be enforced by the original purchaser or to the present owner if the warranty has been properly transferred (contact SA Instruments, Inc.).

What we will pay for

We will pay all labor and material expenses for items covered by the warranty. Payment of shipping and insurance charges are discussed in the next section.

Warranty, service and support

How to obtain warranty service

1. If your system needs service during the warranty period, contact SA Instrument's Service Department at service@i4sa.com or (631) 689-9408. A service representative will provide technical support and help in diagnosing the failure.
2. In the event your system or part of your system needs to be returned for repair, the service representative will identify the closest repair facility and assign a return material authorization number (RMA). Defective components should be shipped freight and insurance prepaid to the repair facility. If necessary repairs are covered by the warranty, return ground shipment and insurance will be paid by SA Instruments, Inc. Let the service representative know if you require overnight shipment.
3. In the event estimated repair time is deemed to be excessive by SA Instruments, loaner equipment may be provided.

Limitation of liability and exclusion of implied warranties

Warranty terms:

1. SA Instrument's liability for any defective product is limited to repair or replacement of the product, at SA Instrument's option. No one is authorized to assume any greater liability on SA Instrument's behalf. SA Instruments, Inc. shall not be liable for damage to other products caused by any defects in SA Instrument's products, damages arising out to loss of use, loss of revenue or profits, or any other damages, whether incidental, consequential or otherwise.
2. All implied warranties or conditions, including but not limited to warranties or conditions of merchantability and fitness for a particular purpose, hereby are excluded.