

**Model 1025
MR-compatible
Small Animal Monitoring
and Gating System**

Operation Manual

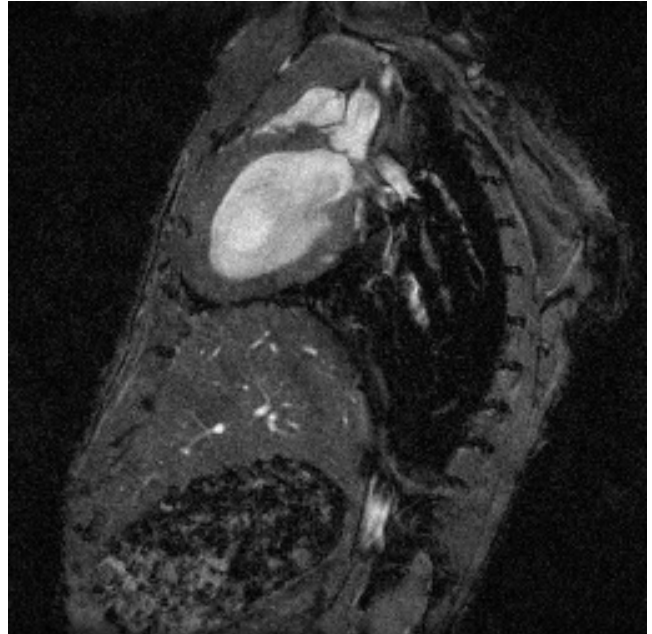
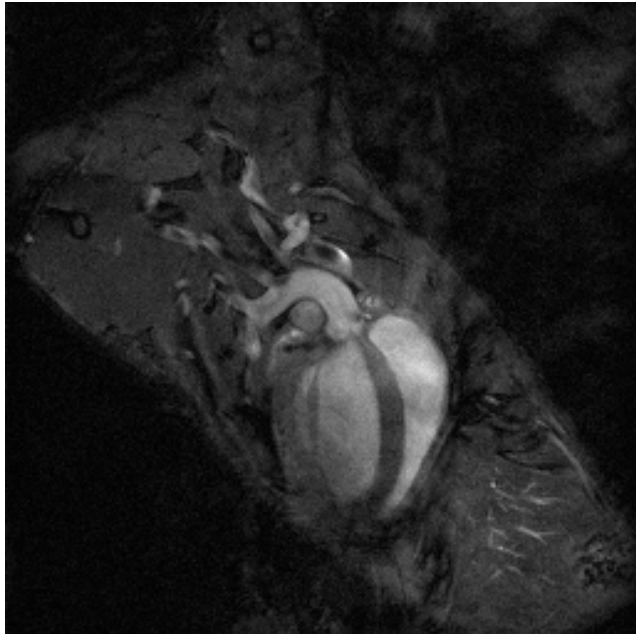


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Mouse aortic root study

9.4T vertical field
ECG and respiratory gated
90 second image, without contrast

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Introduction

This Operation Manual accompanies the release of Revision 6.23 of the PC software for SAI's MR-compatible Model 1025 Small Animal Monitoring and Gating System.

Each software release implements new features most of which resulted from user suggestions and comments. SA Instruments is grateful for our world wide user base. We thank our users for their help in developing this flexible tool which we hope will continue to be a valuable asset in the performance of their medical research.

The monitoring and gating system measures and records physiological parameters of small animals. It currently measures ECG, respiration (two ways), temperature (two ways), pressure including invasive blood pressure (two ways) and oxygen saturation. In addition there are four user auxiliary input channels which can be used as a data interface for equipment such as a stimulator, ventilator, additional probes, the MR scanner, etc.

The system generates an output trigger or gate based on a user defined algorithm composed of nearly any combination of the measurements. It also provides flexible control for a heater to regulate animal temperature.

New features with previous software releases included:

- Alarms for ECG, respiration and temperature
- Audible beeps for heart and respiration rate
- Waveform grid lines to facilitate measurements
- Time stamping to couple scanner operation with the measured physiological data set
- SnapShot to capture several seconds of data which can be viewed and printed with SnapView
- Extended capability for trend data files which can be viewed and reformatted using TrendMap
- Auto identification of 1025 and 1025L Monitoring and Gating Systems
- Auto track for respiration gates
- Gate indication can be displayed directly on the associated waveform
- Export raw data from SnapView
- 3-Lead ECG/Temperature Module
- Fiber Optic Temperature - up to 4 channels
- Pulse Oximetry
- Signal Breakout Module and WaveGrab software
- Universal Gating Module for use with clinical MR systems.
- Slow data mode for USER RESP analog input channel

Introduction

New features with this software release are the following:

- Fiber Optic Pressure measurement with sensor tip 0.4 mm OD – up to 3 channels
- Alarms feature has been extended to include Fiber Optic Temperature and Pulse Oximetry
- The system can interface to a capnograph with waveform and end-tidal CO₂ display and recording through the USER RESP analogue channel.

Chapters 3, 4 and 5 of the Operation Manual cover basic system operation. 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 9. The SnapView program to view SnapShot data files is covered in Chapter 10. Many advanced features such as the advanced gating menu, time stamping and inversion timing are discussed in Chapter 12. A troubleshooting guide with many useful tips is presented in Appendix C.

I encourage new users as well as those familiar with most of the system's capabilities to study the waveform examples in Appendix E. Valuable information on obtaining reliable triggers even when large artifacts are present in the ECG waveform can be found in Appendix C. The waveform examples and associated comments should help overcome most of the pitfalls present in monitoring and gating small animals in the MR environment.

Visit our web site www.i4sa.com for latest information on software and hardware upgrades and extended system capabilities.

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

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December 2009

Chapter 1

System Overview



Mouse long axis, bright blood

4.7 T horizontal
ECG and respiratory gated

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Chapter 1

System Overview

Monitoring and gating

The Model 1025 monitoring and gating system was designed specifically to meet the physiological monitoring and gating needs for anesthetized mice, rats and larger animals in the high field MR environment. 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, blood pressure, 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 MR images can be eliminated or greatly reduced by employing gating techniques during the acquisition of the MR image data. By synchronizing MR 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 MR data collection with the respiratory cycle. Typically the largest movement of the diaphragm and abdomen is during inspiration. Thus, selective acquisition of MR data during expiration can be effective in reducing breathing artifacts.

In some cases it is advantageous to employ gating combinations to trigger MR 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 1025 monitoring and gating system consists of data acquisition modules located near the animal and a Control/Gating Module connected to a PC located near the operator console. The PC displays multiple waveforms, measured values, trends and gating pulses, which can be used to trigger MR data collection. The data acquisition modules are controlled by menu driven software from the PC. The SAIL heater system can be used with the monitoring system to regulate the temperature of smaller animals in the magnet bore.

The **ECG/Temperature Module** resides in the magnet bore near the animal. It measures temperature with a small rectal probe, ECG using two or three leads connected to needle or surface electrodes and respiration from the movement of an ECG lead in the strong magnetic field. A rechargeable battery supplies module power. ECG, respiration and temperature measurements are amplified, digitized and transmitted out the magnet bore on an optical fiber to the Control/Gating Module. Measurements from this module can generate a cardiac and/or respiratory gating pulse and control a heater.

The Respiration/IBP Module resides on the gantry or just outside the magnet bore, but close to the animal. It measures respiration using a small pneumatic sensor. Invasive Blood Pressure is measured using a pressure transducer connected with tubing to an invasive line in the animal. These measurements can generate a cardiac and/or respiratory gating pulse. Auxiliary input channels allow the user to acquire, record,

System Overview

display and gate from user generated analog waveforms. Power is supplied from an external 12 V power supply or internal battery.

The **Fiber Optic Temperature Module** resides just outside the magnet bore near the Respiration/IBP Module. The module can accommodate up to 4 temperature channels. Fiber optic temperature probes extend into the bore and attach to the animal. A fiber optic output from the module can control the SAll air Heater Module

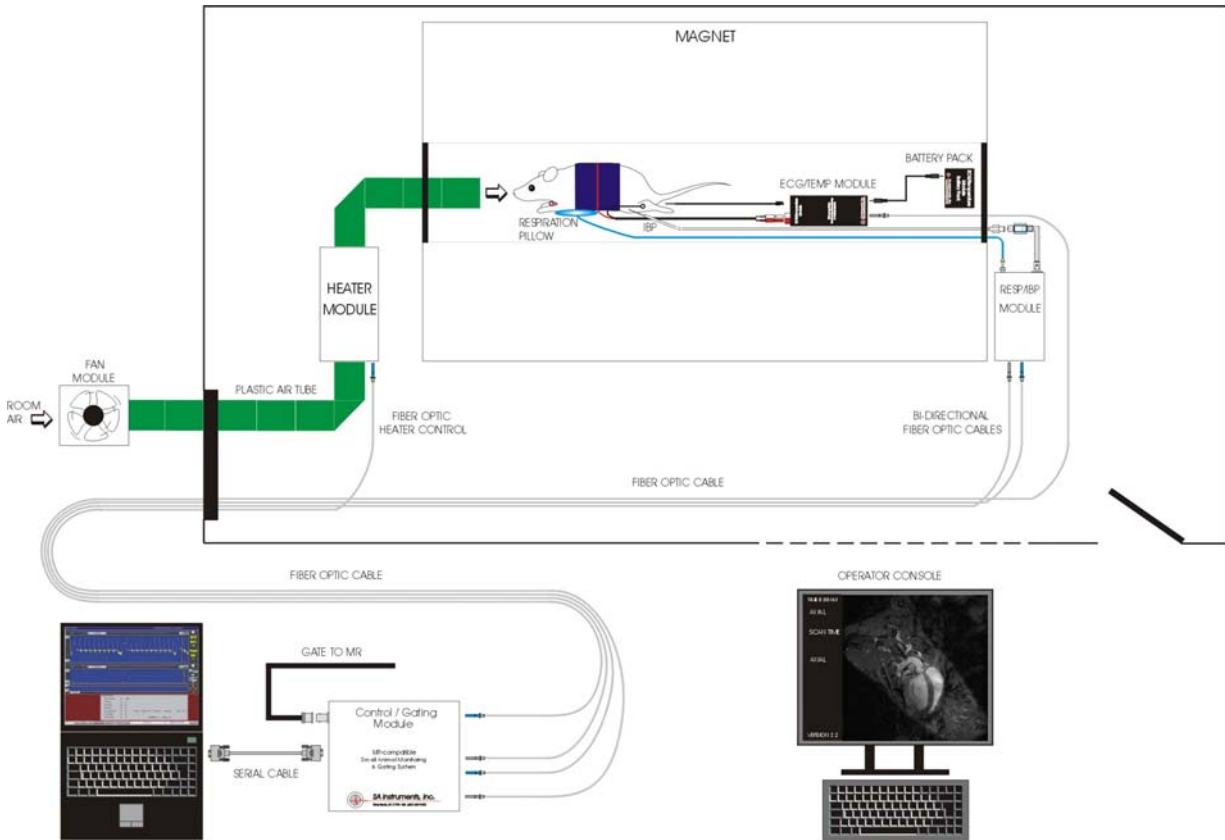
The **Pulse Oximeter Module** resides just outside the magnet bore near the Respiration/IBP Module. It measures oxygen saturation, heart rate, pulse distention, the plethysmogram waveform and provides a cardiac gate. A fiber optic oximetry sensor extends into the bore and attaches to the animal.

The **Fiber Optic Pressure Module** resides just outside the magnet bore near the Respiration/IBP Module. It measures pressure using a very small fiber optic pressure probe. The pressure waveform from this module can be used to generate a gating pulse for the MR scanner.

The **Control/Gating Module** resides outside the RF shielded room near the MR operation console. It receives data from the acquisition modules using optical fibers. The 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 and sent to the scanner. 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 allow the user to synchronize gating to other external devices such as a ventilator and/or the scanner's imaging sequence. A fiber optic output provides control for the Heater Module.

The **Heater System** supplies warm air in the magnet bore. A Fan Module located in the low fringe field of the magnet delivers cool room air to the Heater Module located near the magnet bore. The 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.

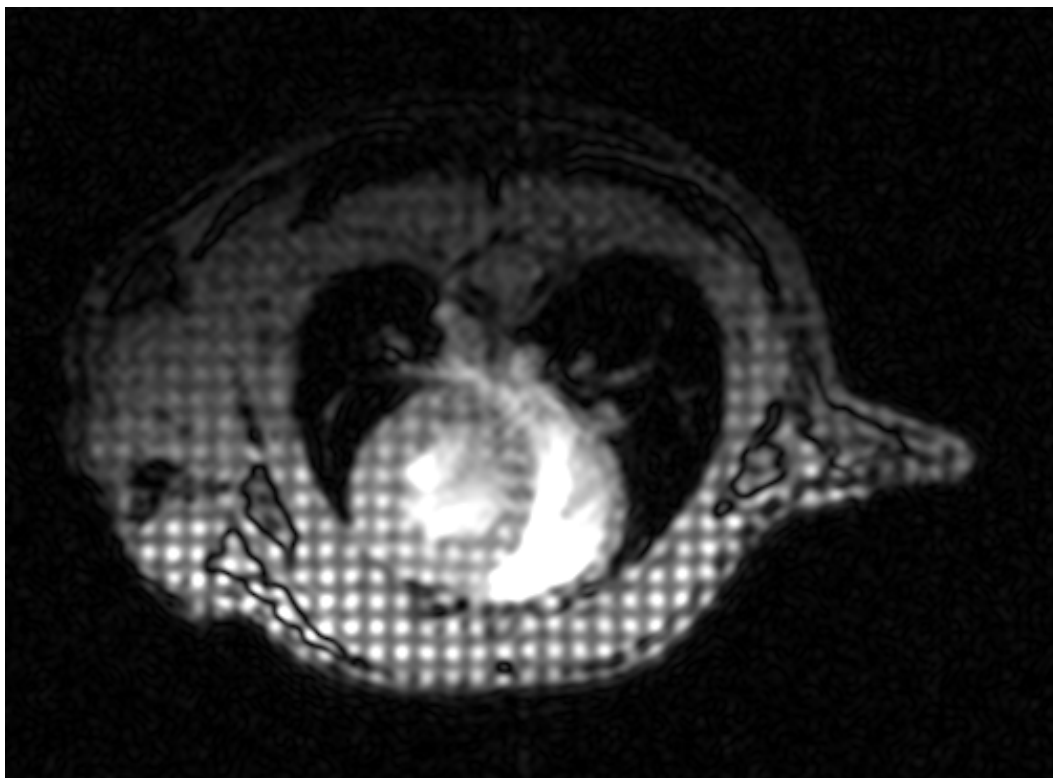
System Overview



System Overview

Chapter 2

System Setup



Mouse short axis, bright blood, double tagged

4.7 T horizontal
ECG gated

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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 click the TrendMap icon on the desktop (refer to Chapter 9). To view saved SnapShot data files click the SnapView icon on the desktop (refer to Chapter 10).

If the system was not supplied with a PC, install the software following the instructions on the inside cover of the CD. Specification requirements for the PC are listed in Appendix A. If a USB port is being used to communicate between the PC and Control/Gating Module, use the appropriate driver from the USB Serial Converter CD supplied with the system.

Windows can go to sleep and be difficult to awaken. Follow these instructions to disable hibernation on your PC:

Windows XP: click Start>Settings>Control Panel>Power Options and open the hibernate tab. Clear the hibernate check box.

Windows Vista: click Start>Control Panel>Power Options and select "Power Management Off".

Setting up the hardware

The Model 1025 has several optional functions. This manual assumes all functions are present with the system. Ignore those sections of the manual for options not present with your system. Refer to Appendix B for a list of major system components and accessories. Refer to Chapter 6 for instructions on setting up and testing Pulse Oximetry, Chapter 14 for Fiber Optic Temperature and Chapter 15 for Fiber Optic Pressure.

1. Locate the fiber optic cables (25SFOC-23 & 25DFOC-23) and fan air hose (FAH-20), which is the longer of two heater hoses. If the MR scanner has a RF room, it will be necessary to install the fiber optic cables and air hose passing through wave guides. Follow the color code on the fiber optic cables connecting gray plugs to gray receptacles and blue plugs to blue receptacles.
2. Connect the Control/Gating Module (720100) to the PC using the serial interface cable (CGIC-201).

System Setup

3. Power the Control/Gating Module with the external 12 VDC power supply (PS-2-12-CG).
4. Connect the Control/Gating Module to the ECG/Temperature Module (710100) using the simplex fiber optic cable. Connect to the port on the Control/Gating Module labeled “ECG/Temp” and to the ECG/T Module’s “Gray Fiber” port. Note no connection is made to the blue fiber port.
5. Connect the ECG/Temp Module Battery Pack (ETBP-108) to the ECG/Temperature Module using the ECG/Temp Module Battery Pack Cable (BPC-110). A red light should be visible in the fiber optic port labeled “gray fiber”. The battery pack should be connected to the ECG/Temp battery charger when not in use. The ECG/Temp battery pack charger is either internal to the Respiration/IBP module (731100) or external and line powered. If your system does not have a charger internal to the Respiration/IBP Module, an External ECG/Temp Battery Pack Charger (740100) has been supplied. It is not necessary to deep discharge the battery or to disconnect it from the charger after it is fully charged.
6. Connect the Control/Gating Module to either the Respiration/IBP Module or the Respiration Module (730100) using the duplex fiber optic cable. Connect the fibers to the fiber optic ports on the Control/Gating Module labeled “Resp/IBP”. Note: the Respiration/IBP and Respiration Modules are system options and at most only one will have been included with the system. If your system has the Respiration Module, follow the instructions listed for the Respiration/IBP Module. These modules have identical features with the exception of the IBP function.
7. Power the Respiration/IBP Module with the external 12 VDC power supply (PS-2-12), if line power is available near the magnet. If line power is not available near the magnet, the module can be operated on internal battery. In either case, the Respiration/IBP Module’s internal battery and the ECG/Temp Module Battery Pack should be charged before their initial use. If the Respiration/IBP Module is operated on internal battery, the module should be removed from the magnet and connected to the external 12 VDC power supply for charging whenever the monitoring system is not in use.

Caution: the 12 VDC supply is slightly magnetic and should be fix mounted in the fringe field of the MR magnet.

8. Position the Heater Module (76n100) near the magnet bore and connect it to AC power. Connect the fan air hose (FAH-20) (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 to the fiber optic receptacles on the Heater Module and Control/Gating Module labeled “Heater Control”.

9. Locate the Fan Module (77n100) in a low region of fringe field and connect to AC power and to the fan air hose. Note: In some situations it may be desirable to locate the Heater Module outside the magnet room or to locate the Fan Module in the magnet room (refer to Chapter 7).

Warning: the Fan Module is magnetic and must be fix mounted if located in the magnet room.

10. To provide a trigger to the MR system, connect a BNC cable (not supplied) from the MR scanner's gate input to the GATE connection on the Control/Gating Module. Note the Control/Gating Module is shipped from the factory with the gate output pulse configuration set to either "active low" or "TTL" based on your scanner's gating signal requirements. The gate output pulse configuration can be changed (refer to Chapter 3).

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: click Start>Control Panel>System>Device Manager>select continue in the permission window>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.

Testing the monitoring and gating system

The system can be tested using the Simulator (750100). Connect the Simulator to the ECG/Temp Module using the Simulator ECG leads (SEL-105) and the Simulator Temperature Cable (STC-105). The simulator generates an ECG waveform with respiration superimposed as well as a temperature reference.

System Setup

Turning on the Simulator power should result in ECG and E-resp™ waveforms and a temperature reading on the PC display. The ECG waveform appears after the offset voltage reaches 2.5 V (refer to Chapter 3-8). Adjust the simulator amplitudes, if necessary, to obtain heart and respiration rate readings and indications of gate detection. Turning on the gradient switch superimposes spikes on the ECG waveform. The effect should be barely noticeable on the PC display. The simulator is powered by an internal 9V battery, which is not rechargeable (refer to Chapter 8).

Caution: the Simulator battery is magnetic and should not be extended into the magnet bore

Open the SYSTEM INFO window and observe the 50/60 Hertz notch filter setting for the ECG/Temperature Module. Make certain the filter is set properly for your location (50 Hz in Europe, , 60 Hz in US, etc.) Some models of the ECG/Temperature Module make provision for the filter to be changed by the user (refer to Chapter 4).

Test the Respiration/IBP Module by connecting a Respiration Pillow Sensor (RS-301) to the pneumatic port on the Respiration/IBP Module. Lightly touching the pillow sensor should produce waveform deflections on the PC's Resp display. Connect an IBP Transducer (IBPX-A) to the IBP port on the Respiration/IBP Module . A yellow LED should flash indicating the need to zero the transducer and pressure on the transducer should produce waveform deflections on the PC's IBP3 waveform display.

Check communication from the PC to the Control/Gating Module by opening the GATING window and checking the Pulse Invert box next to E-Resp™. The red bar indicating respiration in the Resp Sweep display should switch or invert its position on the E-Resp™ waveform within 1 or 2 seconds.

Testing the heater system

Activation of the Fan Module power switch should produce air flow to the 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 ECG/Temp Module and observe a temperature reading on the PC monitor display. Select a set point higher than the measured temperature by opening the heater window (refer to Chapter 7). A yellow LED should pulse on the Heater Module indicating power being delivered to the heating element. Within several seconds, warm air should be present. Later chapters of the manual provide details on menu selections and settings. Refer to Appendix C for troubleshooting.

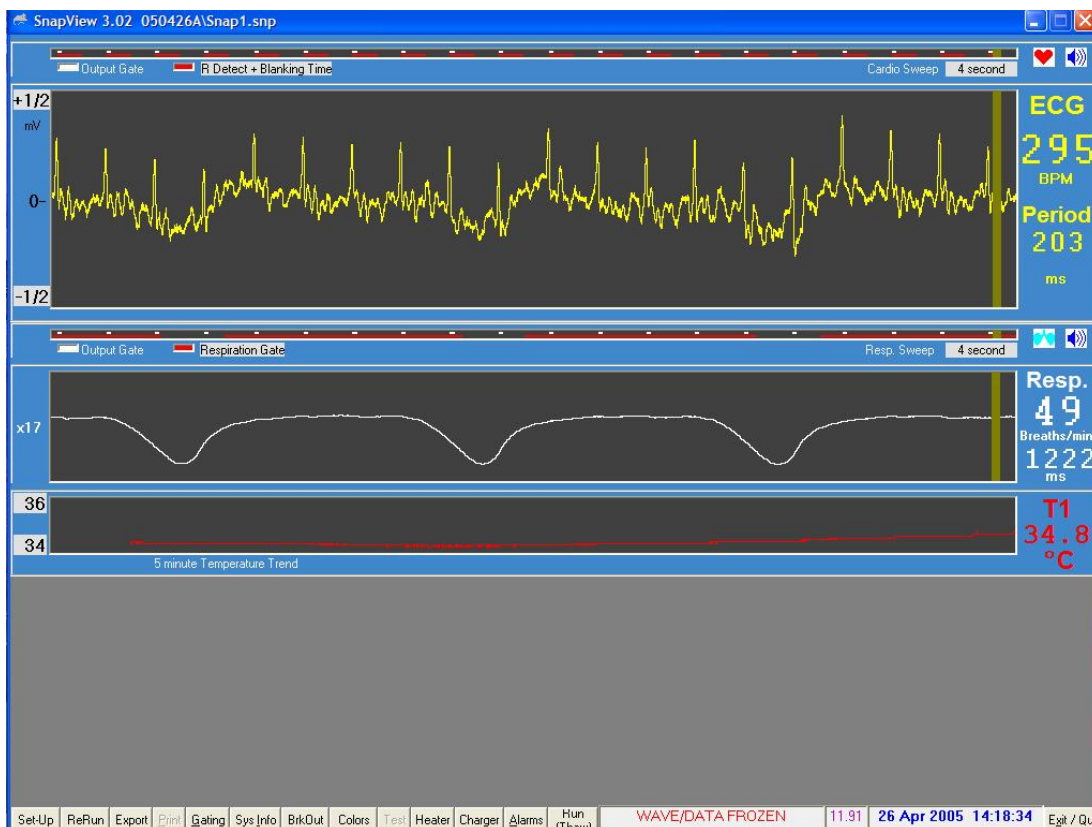
Step by step Instructions for monitoring and gating

Click the PC-sam icon on the desktop > select “Start Monitor with Selected Setup” to view the main monitor display screen. The “selected setup” should be “factory defaults” which includes ECG, respiration from the pillow sensor, temperature from the thermister probe and ECG gating. Refer to Chapter 3 to alter the monitor configuration.

Attach ECG electrodes and the thermister temperature probe to the animal following instructions in Chapter 4. Attach the pneumatic pillow respiration sensor to the animal following instructions in Chapter 5.

ECG and respiration waveforms along with temperature measurements should appear similar to those shown below. If your ECG waveform has negative rather than positive peaks, switch the electrodes at the red and white connectors on the ECG/Temperature Module.

Note the presence of small red bars above the peaks of the ECG waveform which indicate R-wave detection. Longer red bars appear above the respiration waveform which coincide with the animal’s expiration. White dots appear at the same time in both the Cardio and Resp Sweep displays whenever a gate is sent from the Control/Gating Module to the MR scanner.



System Setup

The heart and respiration rates are displayed to the right of the waveforms measured in beats or breaths per minute. The period displayed below each rate is the time interval in milliseconds for the cardiac or respiratory cycle. Refer to Chapter 3 for additional information regarding the main monitor display

Recommendations for daily operation

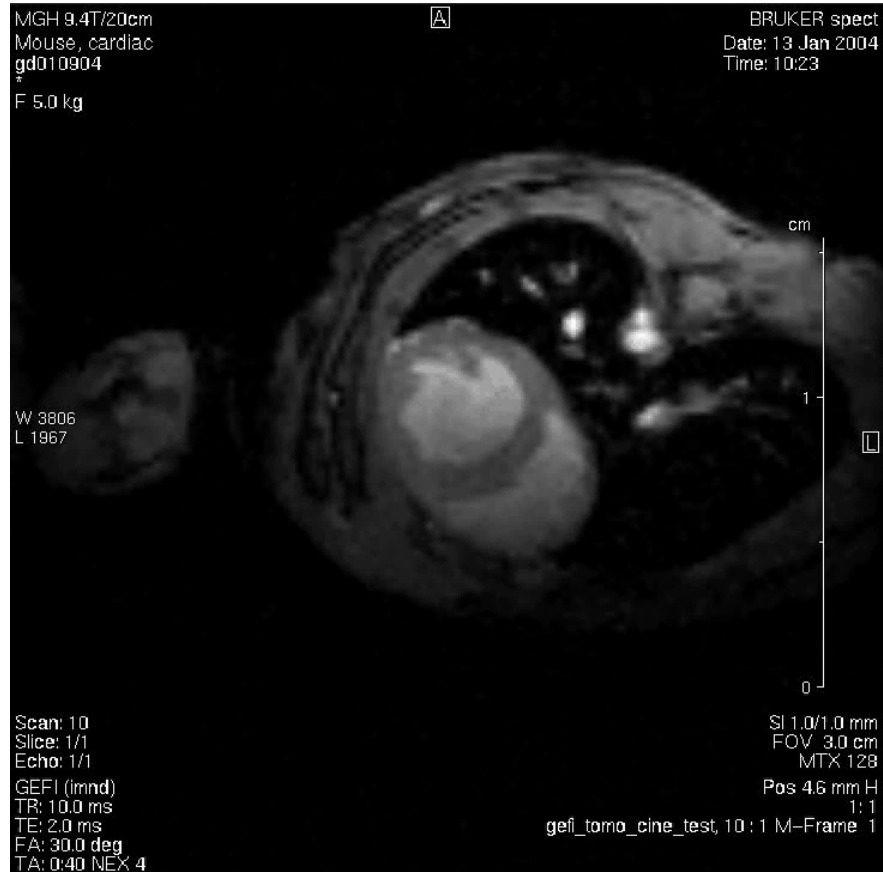
Connect the ECG/T Module Battery Pack to the charger at the end of the day. The battery pack can be left on the charger when not in use. It can not be over charged.

The Control/Gating Module can be powered on all the time.

The Respiration/IBP Module - a) if you have power in the magnet room, use the 12 V power supply provided. Make sure the power supply is not in a really strong fringe field. It will work in a strong field, but will have a shortened lifetime. The module has an internal battery. You can leave the battery switch and power switch in the on position all the time. b) if you do not have power in the magnet room, then you need to operate the module on internal battery and charge the battery overnight. Refer to Chapter 5.

The power to the Heater and Fan Modules should be turned off when not in use. FO Temperature 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 and oximetry probes.

Chapter 3
PC and Control/Gating Module



Mouse short axis, bright blood

9.4 T horizontal
ECG and respiratory gated

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Chapter 3

PC and Control/Gating Module

Overview

The Control/Gating Module, located near the operator's console, is connected to a PC to provide operator control as well as display and storage of waveforms, computed gates, measured values and trends.

The optical signal received at the Control/Gating Module from the ECG/Temperature Module is demodulated and separated into temperature and ECG 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 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.

The optical signal received at the Control/Gating Module from the Respiration/IBP Module is separated into respiration, User Resp and IBP or User IBP components before processing and display. Gates for each of the waveforms are determined automatically. Gate position in the respiratory or cardiac 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.

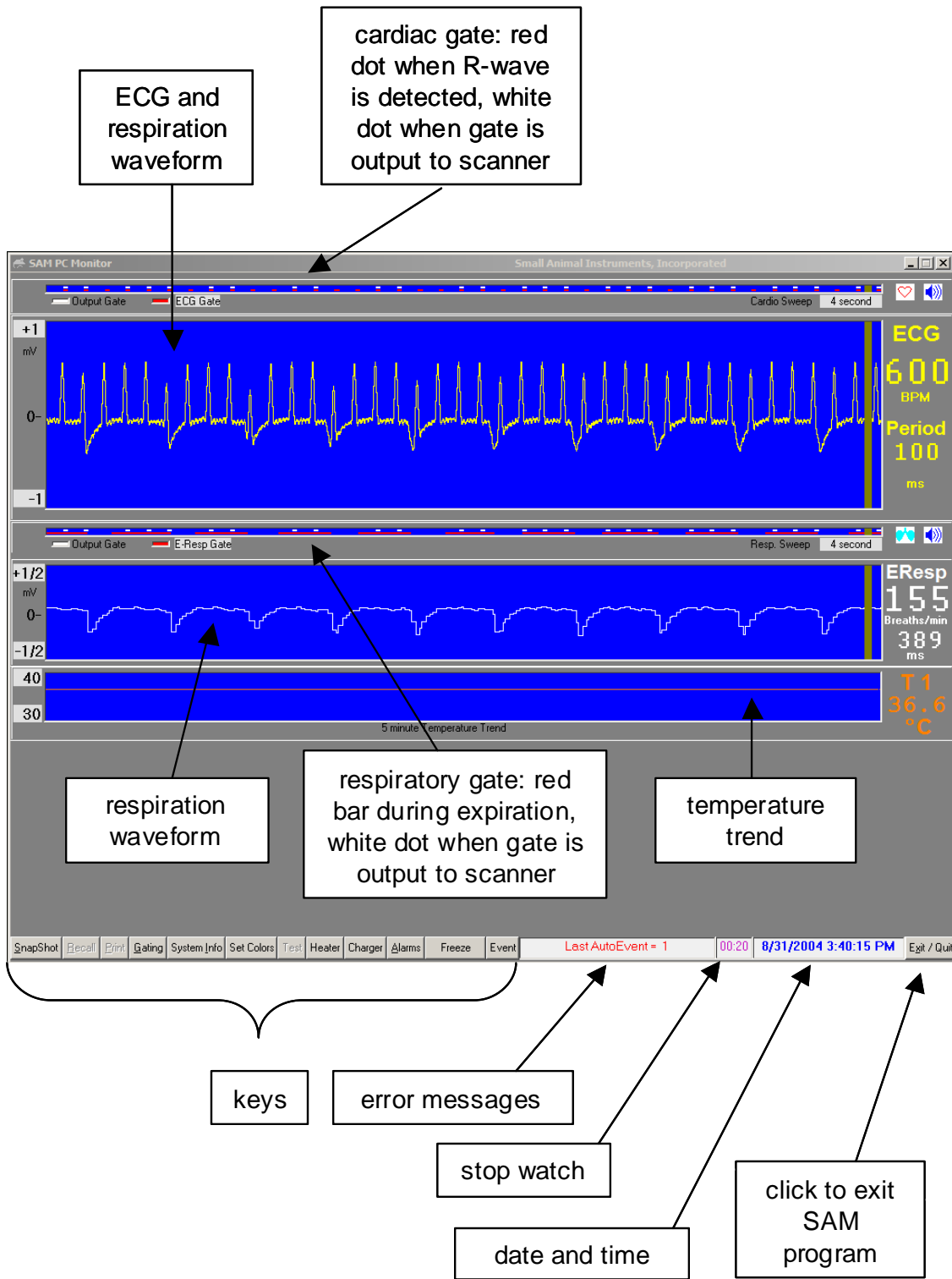
A typical monitor display configuration is shown on the next page. In this example, the parameters monitored are ECG, respiration and temperature. Detection of the R-wave (QRS complex) is indicated by the presence of a red dot on the cardio sweep display above the R-wave peak.

The respiration waveform dips during animal inspiration and 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.

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.

PC and Control/Gating Module



PC and Control/Gating Module

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 stop watch and the date and time.

The stop watch displays in hours and minutes. A bar flashes to indicate the stop watch is running. Click on the stop watch 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

The screenshot shows the SAN PC Monitor interface with three callout boxes:

- left click in waveform display to turn grids on/off**: Points to the grid area of the ECG waveform.
- heart beats when R-wave is detected, lung beats when inspiration is detected**: Points to the R-wave detection and E-Resp Gate waveforms.
- click to activate audio heart or respiration beat**: Points to the audio icons for ECG and E-Resp.

The interface displays three main waveforms:

- ECG**: Shows heart rate at 600 BPM and a period of 100 ms. The amplitude scale ranges from -1.5 to +1.5 mV.
- E-Resp**: Shows respiratory rate at 153 Breaths/min and a period of 386 ms. The amplitude scale ranges from -1/4 to +1/4 mV.
- T1**: Shows a 5-minute temperature trend with a current reading of 97.8 °F. The scale ranges from 86 to 104.

At the bottom, there are several control buttons: Snapshot, Recall, Print, Gating, System Info, Set Colors, Test, Heater, Charger, Alarms, Freeze, Event, LastAutoEvent = 1, 00:22, 9/1/2004 12:08:54 PM, and Exit / Quit.

Two additional callout boxes at the bottom explain controls for the temperature trend:

- click on shaded boxes to change amplitude and/or sweep time**: Points to the shaded amplitude and sweep time boxes for the ECG and E-Resp waveforms.
- click to switch between °C/°F**: Points to the temperature unit indicator.

PC and Control/Gating Module

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 oC and oF 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.

User Input channels

Up to four user auxiliary input channels are available, two digital (on/off) and two 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 (refer to Chapter 12). The analog channels allow user defined waveform information to be input for recording, display and gating.

The digital auxiliary channels are input through the Control/Gating Module at “AUX” (0 – 5 V) and “AUX GATE IN” (fiber optic signal). They are digitized at 1800 samples/second.

The analog auxiliary channels are associated with the Respiration/IBP Module. They are input at “User Resp” and “IBP3”. User Resp is digitized at one half the IBP rate of 900 samples/second. Refer to Chapter 5 for connector pin specifications and Chapter 12 for setup features.

PC and Control/Gating Module

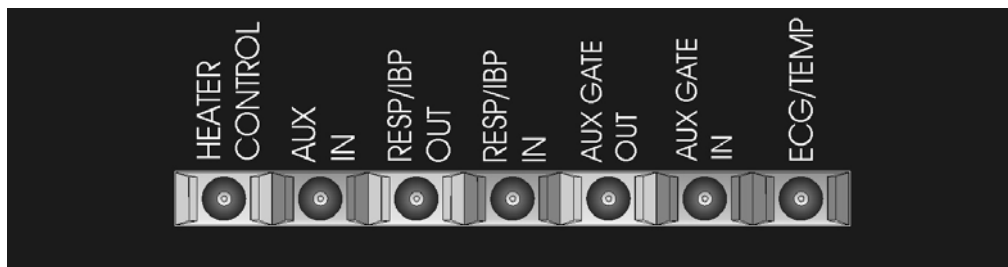
Control/Gating Module input/output connections

Electrical connections:



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

Fiber optic connections:



ECG/Temp	Input from the ECG/Temp Module
AUX GATE IN	fiber optic aux in, a user digital gate input channel
AUX GATE OUT	Gate or trigger pulse out
RESP/IBP IN	Input from Respiration/IBP Module
RESP/IBP OUT	Output to Respiration/IBP Module
AUX IN	not used
HEATER CONTROL	control signal for Heater Module

Gate output pulse signal configuration

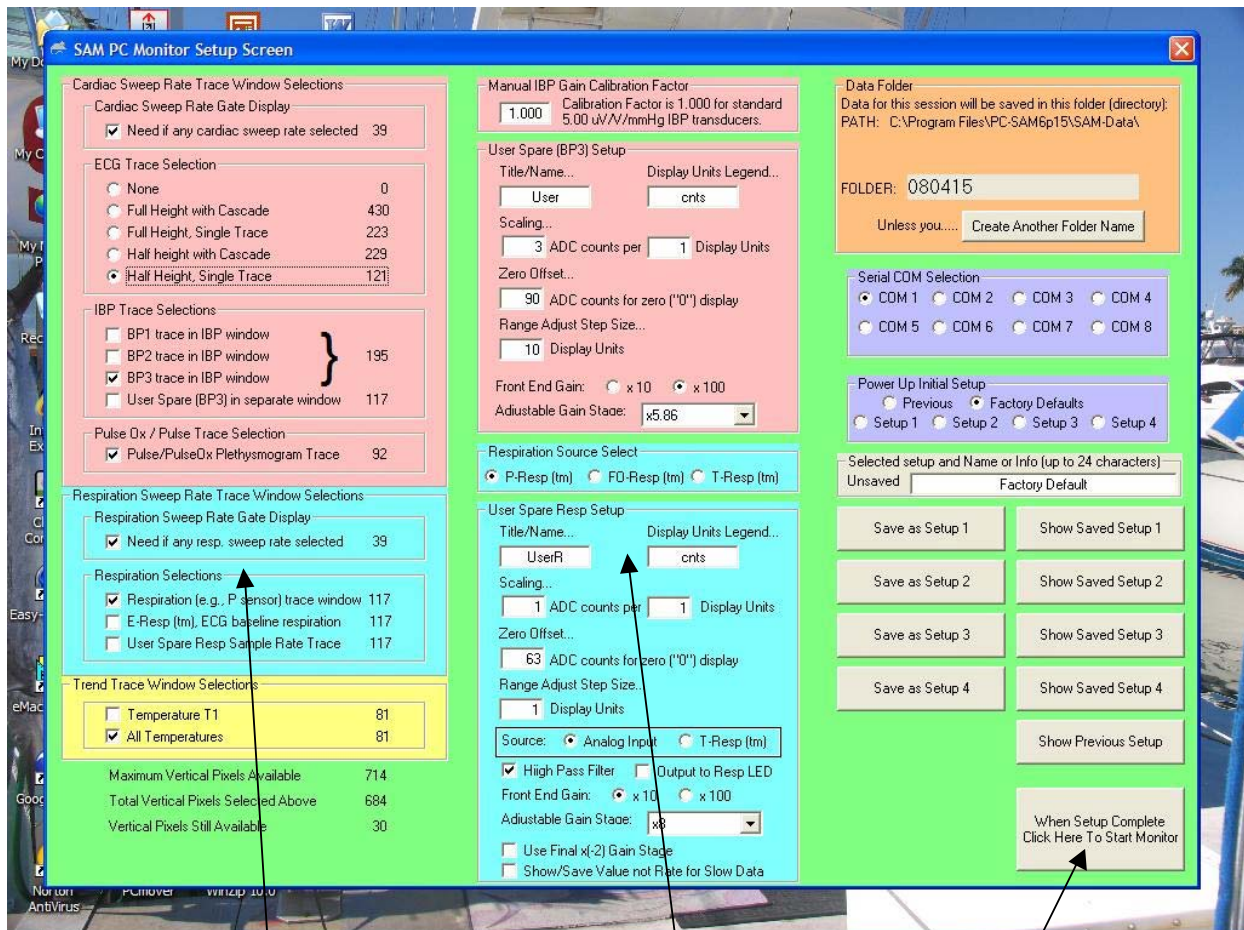
The Control/Gating Module is shipped from the factory with the gate output pulse configured appropriate for the user's anticipated scanner either TTL (H) or active low (L). The gate output pulse can be changed by removing the cover of the Control/Gating Module. The switch is located inside a small access hole in the RF shield.

PC and Control/Gating Module

Scanners manufactured by Bruker require active low (L) while those manufactured by Varian require TTL (H). 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.



make selections for waveform, gate and trend display

elect parameters for user defined analog inputs

click to start monitor

PC and 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 12).

The only currently valid selection for the respiration channel signal source is P-Resp. The other two choices FO-Resp and T-Resp are under development.

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

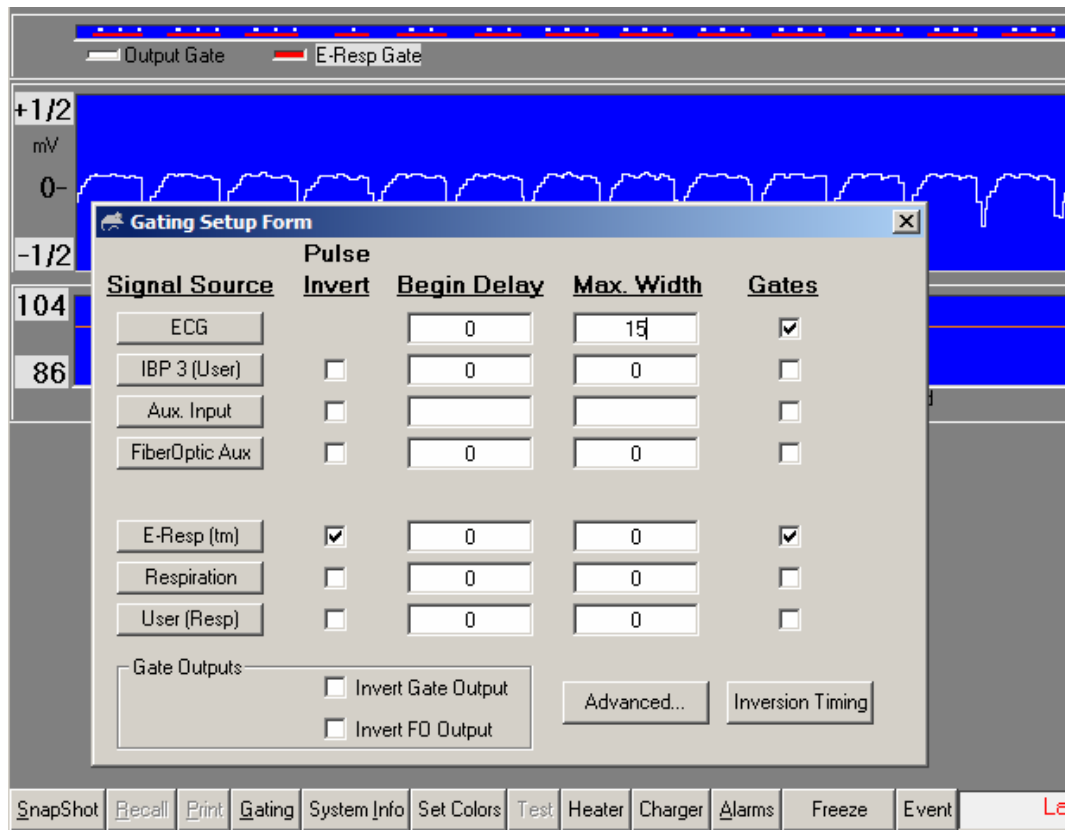
The SnapShot key in the lower left portion of the monitor causes storage of the last 36 seconds of monitor data. All data transmitted to the PC during the last 36 seconds is stored not just displayed data. Parameter values set by the PC (e.g. slew rates for R-wave detection, blanking time, gating selections,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

Data files can be viewed by double clicking SnapView on the desktop. 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 10).

PC and Control/Gating Module

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 12).

PC and Control/Gating Module

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. Use the high pass filter with low order numbers for large animals to reduce low frequency “T-wave” flow artifacts.

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 gradient vibrations. In that case, the blanking time should be set to exceed the MR scanner acquisition time by about 10 msec.

The screenshot displays the SAM PC Monitor software interface. The main window shows an ECG waveform with a heart rate of 600 BPM and a period of 100 ms. The R-DETECT SETUP window is open, showing the following settings:

- High Pass Filter: On, Order: Off
- R-Detect Blanking Period: Auto, R-R Period: Manual, 80 milliseconds
- Wave Feature Detection: Pos Peak, Neg Peak, Rising Edge, Falling Edge
- Positive Slope: 12, Samples = 6.7 ms, 200 uV minimum
- Negative Slope: 8, Samples = 4.4 ms, 98 uV minimum
- Detection Threshold: Auto, uV, 1001 uV Maximum

The GATING SETUP Form is also visible, showing the following settings:

Signal Source	Invert	Begin Delay	Max. Width	Gates
ECG	<input type="checkbox"/>	0	15	<input checked="" type="checkbox"/>
IBP 3 (User)	<input type="checkbox"/>			<input type="checkbox"/>
Aux. Input	<input type="checkbox"/>			<input type="checkbox"/>
FiberOptic Aux	<input type="checkbox"/>			<input type="checkbox"/>
E-Resp (tm)	<input checked="" type="checkbox"/>			<input type="checkbox"/>
Respiration	<input checked="" type="checkbox"/>	0	0	<input type="checkbox"/>
User (Resp)	<input type="checkbox"/>	0	0	<input type="checkbox"/>

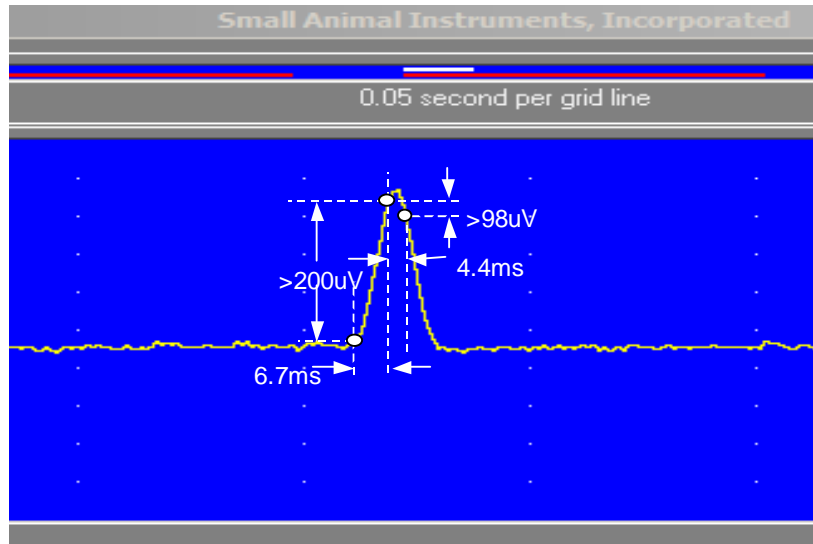
Annotations in the image include:

- A box labeled "select values for R-detection" pointing to the High Pass Filter and R-Detect Blanking Period settings.
- A box labeled "set blanking time" pointing to the R-R Period setting.
- A box labeled "click to open R-detect window" pointing to the ECG button in the GATING SETUP Form.

The interface also displays vital signs: ECG 600 BPM, Period 100 ms, EResp 154 Breaths/min, 384 ms, Resp. 0 Breaths/min, 888 ms, and T1 36.6 °C.

PC and Control/Gating Module

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 $200\mu\text{V}/6.7\text{ms}$ and a negative slope of $98\mu\text{V}/4.4\text{ms}$. The gate is generated at the end of the negative slope. In this example the R-wave is about $800\mu\text{V}$ 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.

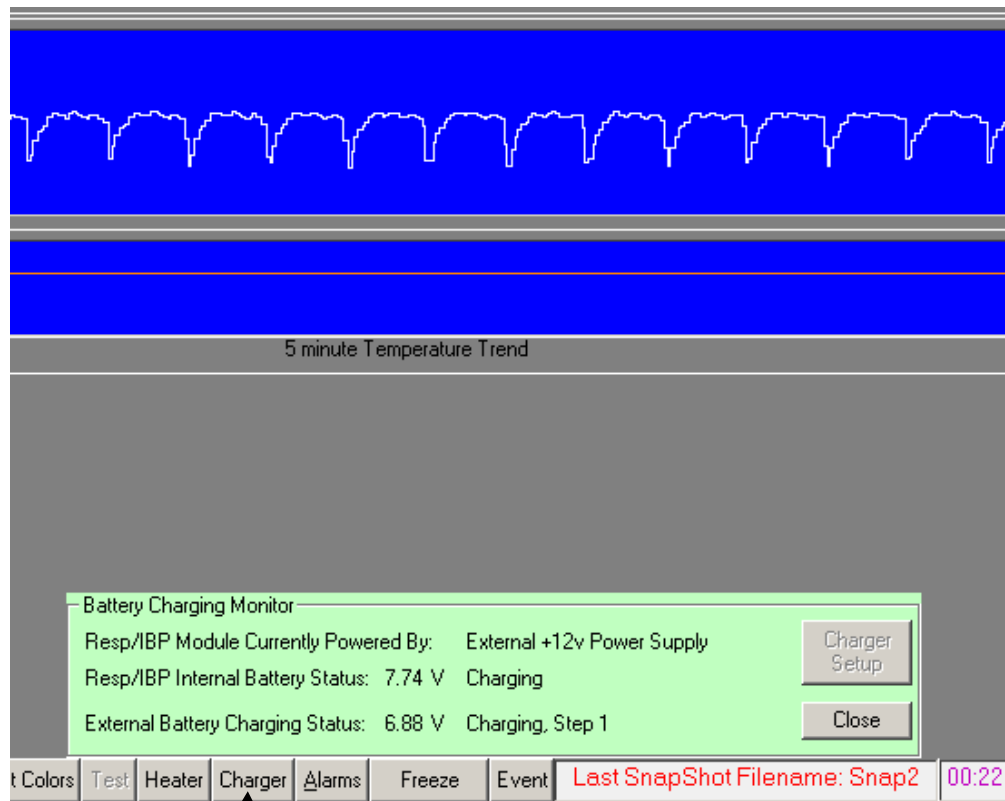
Select the amplitude(s): Determine the peak amplitude of the R-wave: usually $500\mu\text{V}$ to $1000\mu\text{V}$. In the case of mice with a rise and fall time selected of 6.7 and 4.4 ms respectively, we select rise & fall amplitudes of less than $6.7/7.5 = 90\%$ and $4.4/7.5 = 60\%$ of the peak amplitude. The system can be used to determine the amplitudes: set the amplitudes smaller than you expect, but large

PC and Control/Gating Module

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



click to display battery
charging window

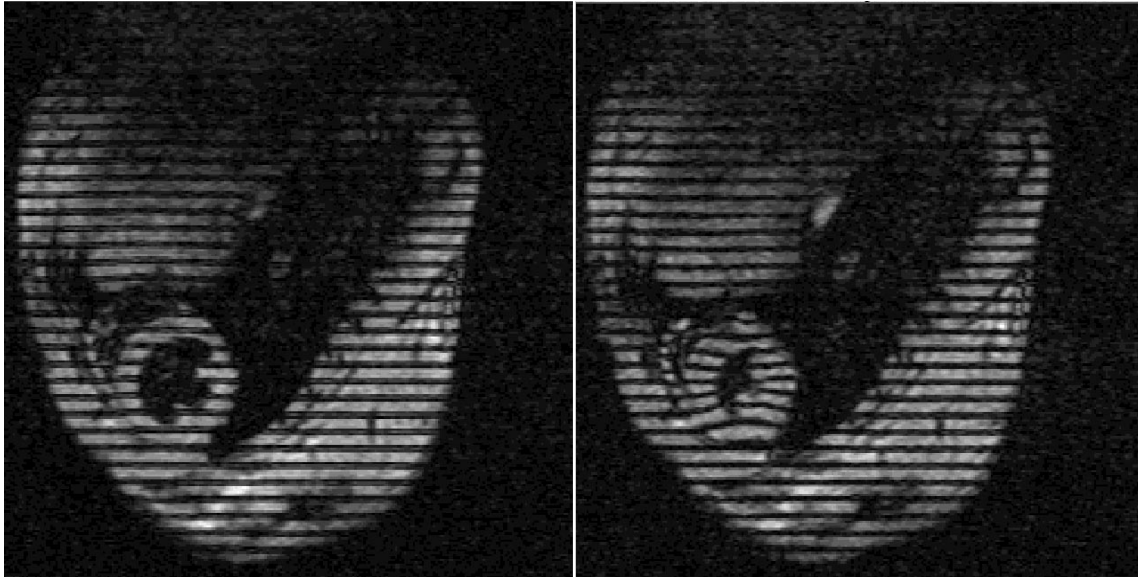
The CHARGER window reports the current status of the Respiration/IBP Module power, the internal battery and the external charging battery (i.e. the ECG/Temperature Battery Pack).

The Respiration/IBP Module can operate on +12 V or internal battery. However, the module can not charge an ECG/Temperature Module Battery Pack when operating from the internal battery. To charge an ECG/Temperature Module Battery Pack the Respiration/IBP Module must be connected to +12 V power. (refer to Chapter 5).

PC and Control/Gating Module

Chapter 4

ECG/Temperature Module



diastole

systole

Mouse short axis, black blood, tagged

4.7 T horizontal
ECG and respiratory gated

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Chapter 4

ECG/Temperature Module

Overview

The animal's electrocardiograph (ECG) is obtained from a pair of leads connected to sub-dermal needle electrodes, gold disk surface electrodes or pads. A respiration signal may be superimposed on the measured ECG waveform by closely coupling one of the ECG lead wires to the animal's abdomen. This coupling is accomplished by attaching the ECG lead wire to a cradle configured to conform to the animal's abdomen. As the animal breaths, the lead wire moves in the strong static magnetic field creating a signal (E-resp™) that is superimposed on the ECG waveform. Temperature is measured using a temperature probe in the animal's rectum.

ECG/Temperature Module signals are passed sequentially through an RF filter, amplifier and pulsed gradient filter before being combined and digitized. The digitized signal is transmitted out the magnet bore to the Control/Gating Module using a long fiber optic cable.

ECG/Temperature Modules beginning with RevE have both a fiber optic transmitter and receiver. Under normal operation, only the gray transmitter is used and no connection is made to the blue receiver.

Valuable information on generating reliable gates is presented in Appendix C Troubleshooting.

Positioning the ECG/Temperature Module

The ECG/Temperature Module powered by an external battery pack is positioned in the magnet bore close to the animal. It may be positioned near the head or near the tail. A rectal probe temperature extension cable is provided for use when the module is near the head. Because the module can move during gradient activity, it is very important to provide restraint by taping it to a stationary object. If the module vibrates during data collection, artifacts will be present on the ECG waveform. Do not tape the ECG/Temp Battery Pack to the ECG/Temperature Module.

Caution: The ECG/Temperature Module should be taped to eliminate unwanted movement from gradient vibration.

Attaching ECG electrodes

Electrode placement in mice is typically in or on the right front leg and left rear leg. For larger animals (rats and rabbits) it is best to avoid large electrode separation (due to detection of large blood flow artifacts). In the case of rats, the front legs work well, for rabbits a good location is under the front legs at the chest.

ECG/Temperature Module

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. Secure the electrode with tape. 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.

Attachment of electrode pads

Pad electrodes may be used by shaving the attachment site. 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 a small amount of electrode gel before taping the electrode.

Positioning ECG lead wires

ECG lead wires should be twisted with each other and as short as possible. Excess wire should be wrapped in a loop and taped to collapse or eliminate the loop. Wrap excess wire around two or three fingers creating a loop, then pull the loop into a line and tape. The wire bundle should then be taped to the animal holder to eliminate movement from gradient vibration and/or air flow. Movement of the ECG lead wires will create artifacts in the ECG waveform.

Caution: ECG lead wires should be twisted and unnecessary loops should be avoided. The lead wires should be taped to eliminate unwanted movement from gradient vibrations and/or air flow.

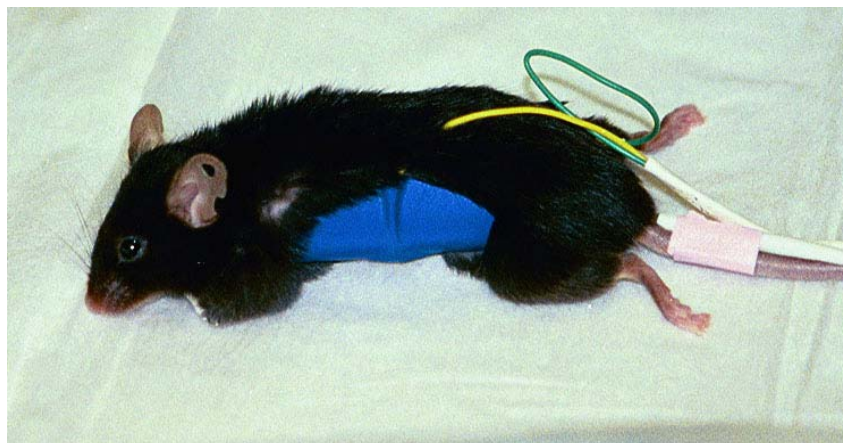
ECG lead wires can degrade tuning of the MR imaging coil. As a general rule, the lead wires should be routed as far away from the coil elements as practical.

E-resp™ with a cradle

The cradle allows one ECG lead to be closely coupled to the abdomen of the animal. As the animal breaths, the lead moves in the strong magnetic field creating a respiration voltage signal superimposed on the ECG waveform.

For mice, the cradle can be positioned on the back or under the stomach. The photo below shows the cradle positioned under the mouse. The cradle can be used in different configurations by removing and reapplying the tape.

ECG/Temperature Module

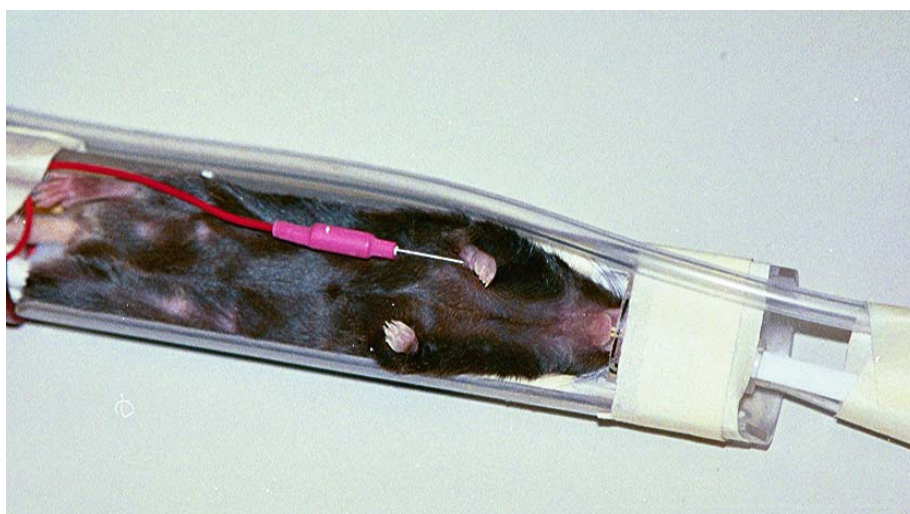


For rats, the lead does not need to extend around the entire cradle. The longer the length of wire attached to the cradle, the larger the respiration signal superimposed on the ECG waveform. At 4.7 T taping the lead on one half of the cradle gives a suitable signal. For higher field systems, less lead length coupled to the cradle may be desirable.

When a surface coil is used to image the liver or heart by positioning the coil under the animal's abdomen, an appropriate place for the E-resp™ cradle is around the spine. If a surface coil is used to image the spine, the cradle would be positioned from under the animal. When using a small whole body coil, it may be necessary to connect the leads to both front legs or both rear legs keeping the lead wires out of the imaging coil.

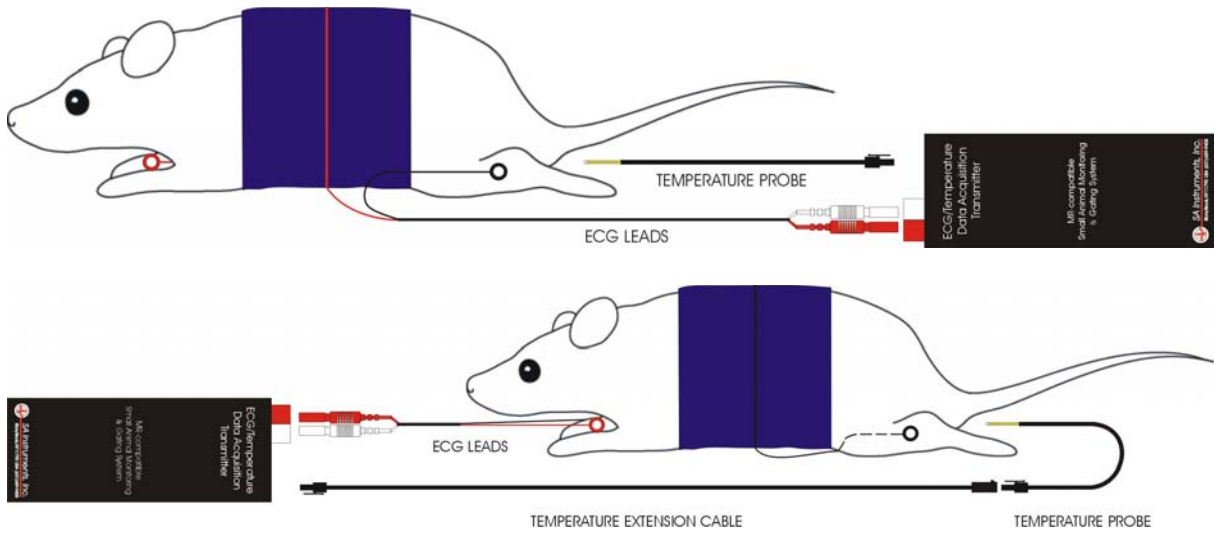
E-resp™ without a cradle

It is possible to obtain adequate coupling of an ECG lead wire to the animal's abdomen without the use of a cradle. The photo below shows a mouse without a cradle. In this case, an E-resp™ signal of 0.5 mVpp was obtained on a 9.4 T system.

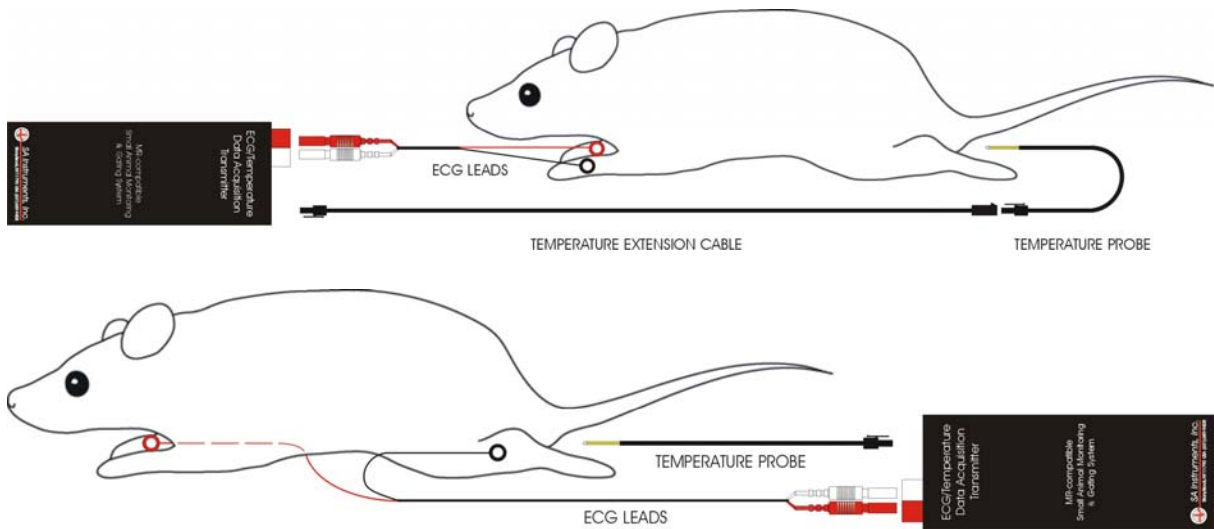


ECG/Temperature Module

With cradle



Without cradle



ECG/Temperature Module

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. The temperature probe extension cable can be used when the ECG/Temperature Module is near the animal's head. Clean the temperature probe with isopropyl alcohol.

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 temperature probe can occur if it develops a crack. Since the thermister in the tip of the probe operates at 5 V and a break lets conductive fluid from the animal make contact with the thermister wire, a small offset voltage can occur.

The offset voltage is displayed in the SYSTEM INFO window. It should be 2.5 V +/- 1.0 V for normal operation. If it 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 ECG/T Module (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 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.

Positioning the thermister temperature probe

The thermister temperature probe will distort the magnetic field for a few mm around the tip creating a small signal void in the MR image. This artifact is normally only a problem when imaging near the rectum. In that case the probe can be used as a skin probe near the animal's head.

Under some conditions it is possible for the thermister temperature probe to heat from interaction with the MR scanner's RF coil. Observation of the measured temperature will indicate if this happens. If a temperature rise is observed when the scanner begins to acquire data and the temperature decreases when the acquisition is complete, reposition the ECG/T Module, Battery Pack and cable. A position near the center line of the magnet bore is generally better than near the edge of the bore.

Charging the ECG/Temp Battery Pack

The ECG/Temp Battery Pack should be connected to the ECG/Temp battery charger when the system is not in use. The battery pack voltage is between 5.8 V and 6.5 V. A fully charged pack will operate for more than 15 hours. The battery pack voltage is displayed in the "System Info" window (refer to page 3-8).

ECG/Temperature Module

The ECG/Temp battery pack charger is either internal to the Respiration/IBP module or external and line powered. If your system does not have a charger internal to the Respiration/IBP Module, an External ECG/Temp Battery Pack Charger has been supplied. The battery pack will obtain a full charge in less than 2 hours. It is not necessary to deep discharge the battery or disconnect it from the charger after it is fully charged.

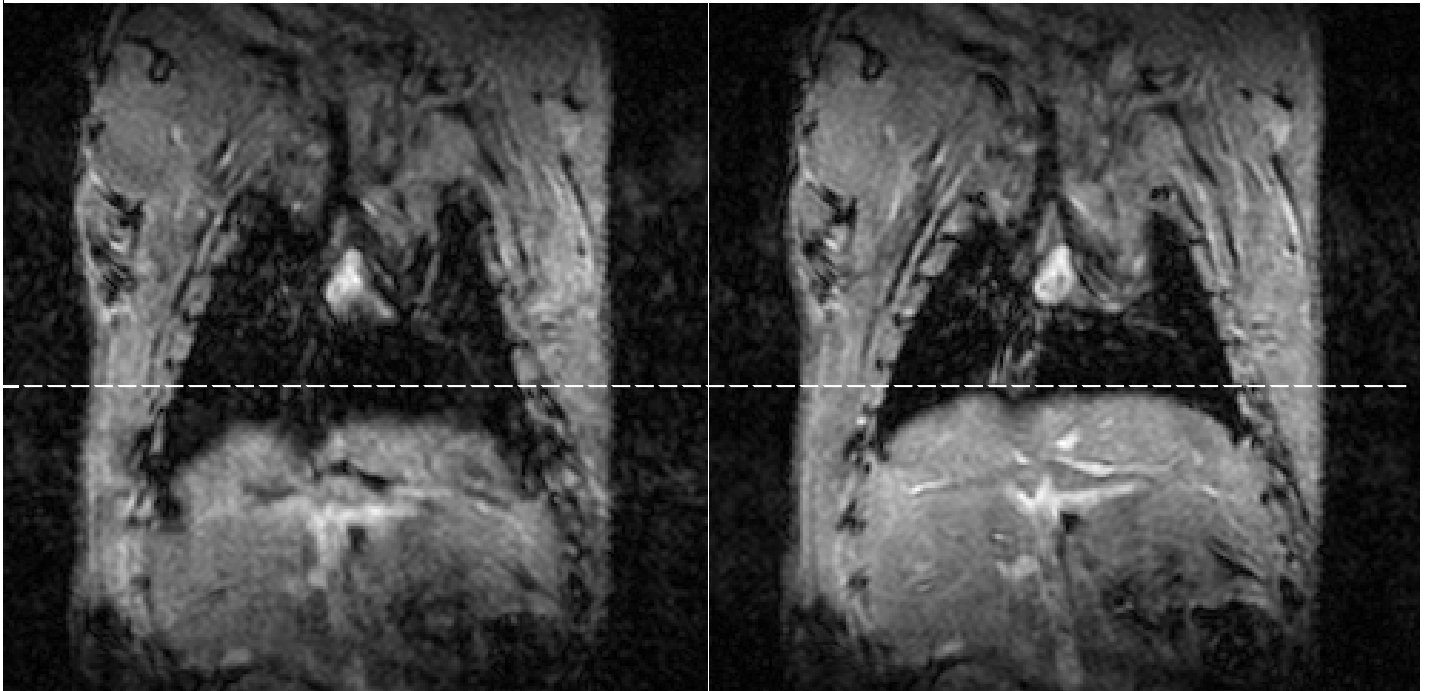
ECG/Temp Battery Pack Protection Circuit

Battery Packs with part number ETBP-108-PCC have an internal protection circuit. The circuit opens to protect the battery in the event it is connected to a short or if the battery voltage drops below a preset threshold.

Setting the 50/60 Hz notch filter

On some revisions, the notch filter is selected for 50 or 60 Hz using a screw near the Battery Pack Cable connection. For 60 Hz insert (remove) the screw for modules with RevC (RevD, RevE). The filter setting is reported in the SYSYEM INFO window on the PC.

Chapter 5
Respiration/IBP Module



inspiration

expiration

Mouse abdomen

4.7 T horizontal
ECG and respiratory gated

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Chapter 5 Respiration/IBP Module

Overview

The Respiration/IBP Module measures respiration (P-resp™) using a small pneumatic sensor and 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 Respiration/IBP Module. The other two IBP channels (IBP1 & IBP2) are battery-powered modules which daisy chain with duplex fiber optic cables from IBP3. The Respiration/IBP Module has auxiliary input capability to allow the user to input event markers or acquire, record, display and gate from user generated analog waveforms.

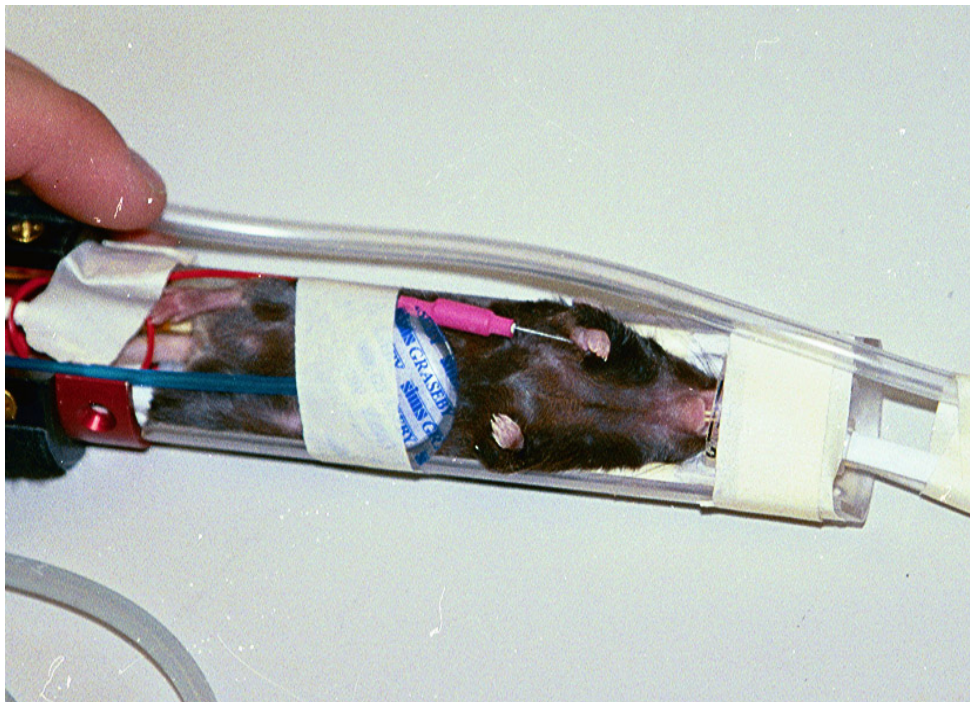
The module has bi-directional fiber optic communication to the Control/Gating Module and is powered from a 12 VDC external supply or by internal battery.

Caution: the 12 VDC power supply is slightly magnetic and should be fix mounted in the fringe field of the magnet.

IBP is an optional feature on the Model 1025. Systems with IBP have a Respiration/IBP Module. Those without IBP will have a Respiration Module. The Respiration Module will not have a connector labeled IBP3.

Attachment of the respiration pneumatic 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 Respiration/IBP Module at the pneumatic connector adjacent to the duplex fiber optic connection. It may be



Respiration/IBP Module

necessary to use one of the Respiration Extension Tubes (REST-3, RSET-8) to make the connection. A green LED flashes to indicate respiration is being detected. The respiratory waveform and gate pulses are transmitted to the Control/Gating Module over the fiber optic cable.

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.

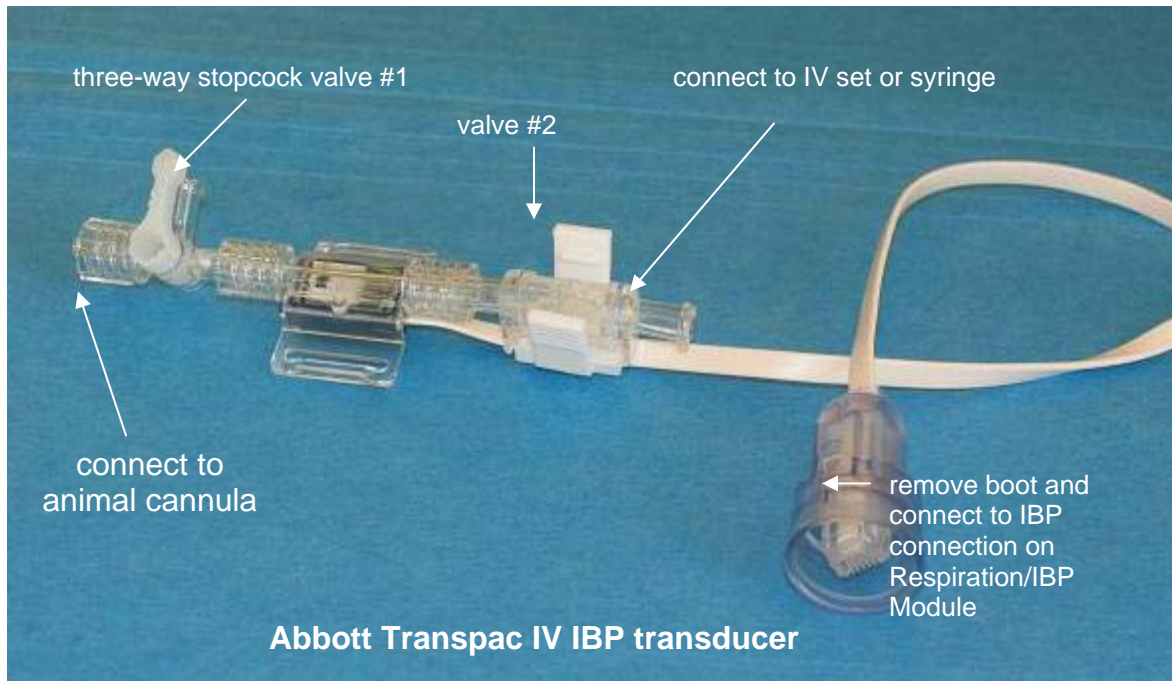
The respiration waveform exhibits a negative peak during inspiration. The gating algorithm detects the negative peak and produces a respiration gate during the peak. To gate on expiration, check the “invert” box for respiration in the GATING SETUP window (refer to Chapter 3 and example waveforms in Appendix E).

IBP transducers

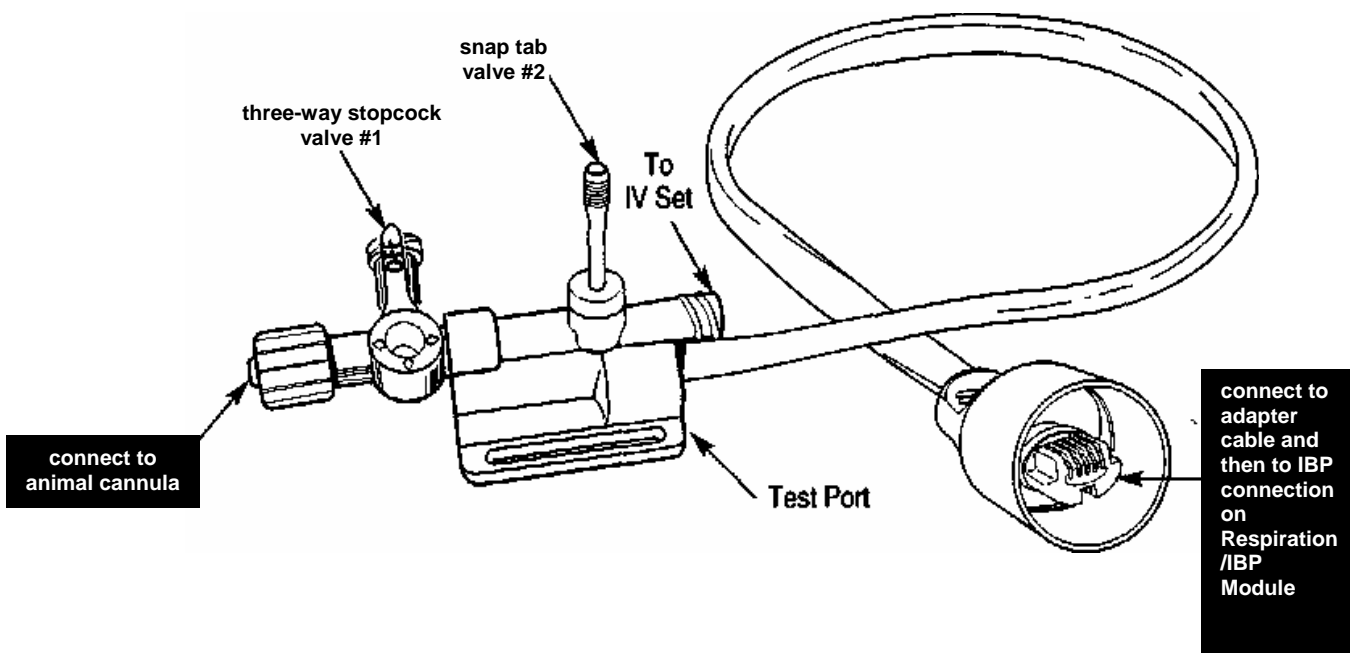
The Model 1025 is configured to operate using disposable invasive blood pressure transducers which meet the specification of $5\mu\text{V/V/mmHg}$. The following IBP transducers meet this specification and can be used with the Model 1025.

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

Respiration/IBP Module



The Abbott Transpac IV transducer can be connected directly to the Respiration/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.



Respiration/IBP Module

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 SAll Customer Service.

IBP transducers have an electrical connection (for the monitor), 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

Respiration/IBP Module

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 Respiration/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 Respiration/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.

Respiration/IBP Module

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.

Most IBP transducers provide a specified level of electrical isolation for the animal. However, if additional isolation is desired, the Respiration/IBP Module can be operated on internal 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 Respiration/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 Respiration/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.

Respiration/IBP Module

Charging the ECG/Temp Battery Pack

Using the Battery Pack Cable, connect the ECG/Temp Battery Pack to the Respiration/IBP Module jack labeled “ECG/TEMP BATTERY CHARGER”. A yellow LED will indicate the battery pack is charging. The yellow charging LED will turn off and the green LED will illuminate when the battery is fully charged. The battery pack should be connected for charging whenever the system is not in use. It is not necessary to deep discharge the battery pack or disconnect it from the charger when fully charged.

The ECG/Temperature Battery Pack can only be charged when the Respiration/IBP Module is connected to 12 VDC power. The battery pack can not be charged when the Respiration/IBP Module is operating on internal battery.

Caution: The ECG/Temp Battery Pack can only be charged when the Respiration/IBP Module is connected to 12 VDC power.

Open the CHARGER window and check the external battery charging status. If the Battery Pack is connected but not charging, check the Respiration /IBP Module power status in the CHARGER window. If it is not powered by external +12 V supply, make certain the power supply is connected to a power outlet, connected to the Respiration/IBP Module and that the power switch is in the on position.

Charging the Respiration/IBP Module Internal Battery

The Respiration/IBP Module has a built in battery charger for the internal battery. The internal battery is charged when the module is connected to 12 VDC power. If line power is available near the magnet, the 12 VDC power supply can always be connected to the Respiration/IBP Module. If line power is not available near the magnet, the module should be removed from the magnet and connected to the 12 VDC power supply for charging whenever the system is not in use. The battery will reach full charge in 2.5 hours.

The Respiration/IBP Module’s internal battery operates between 7.0 and 8.2 V. A fully charged battery will operate the Module for 10 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 CHARGER window (refer to Chapter 3) and the SYSTEM INFO window (refer to Chapter 12).

Spare channels for auxiliary data

Auxiliary analog input capability allows the user to acquire, record, display and gate from user generated analog waveforms. The capability exists for two analog channels. One channel sampled at the rate for respiration and a second channel sampled at the rate for blood pressure. IBP sampling is twice the sampling rate for respiration.

Respiration/IBP Module

The auxiliary channel sampled at the respiration rate is labeled "USER RESP". The channel sampled at the IBP rate uses the IBP (IBP3) connection on the Respiration/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 12).

The connector pin outs for user RESP and USER IBP are listed below. (pin 1 is the left hand pin):

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

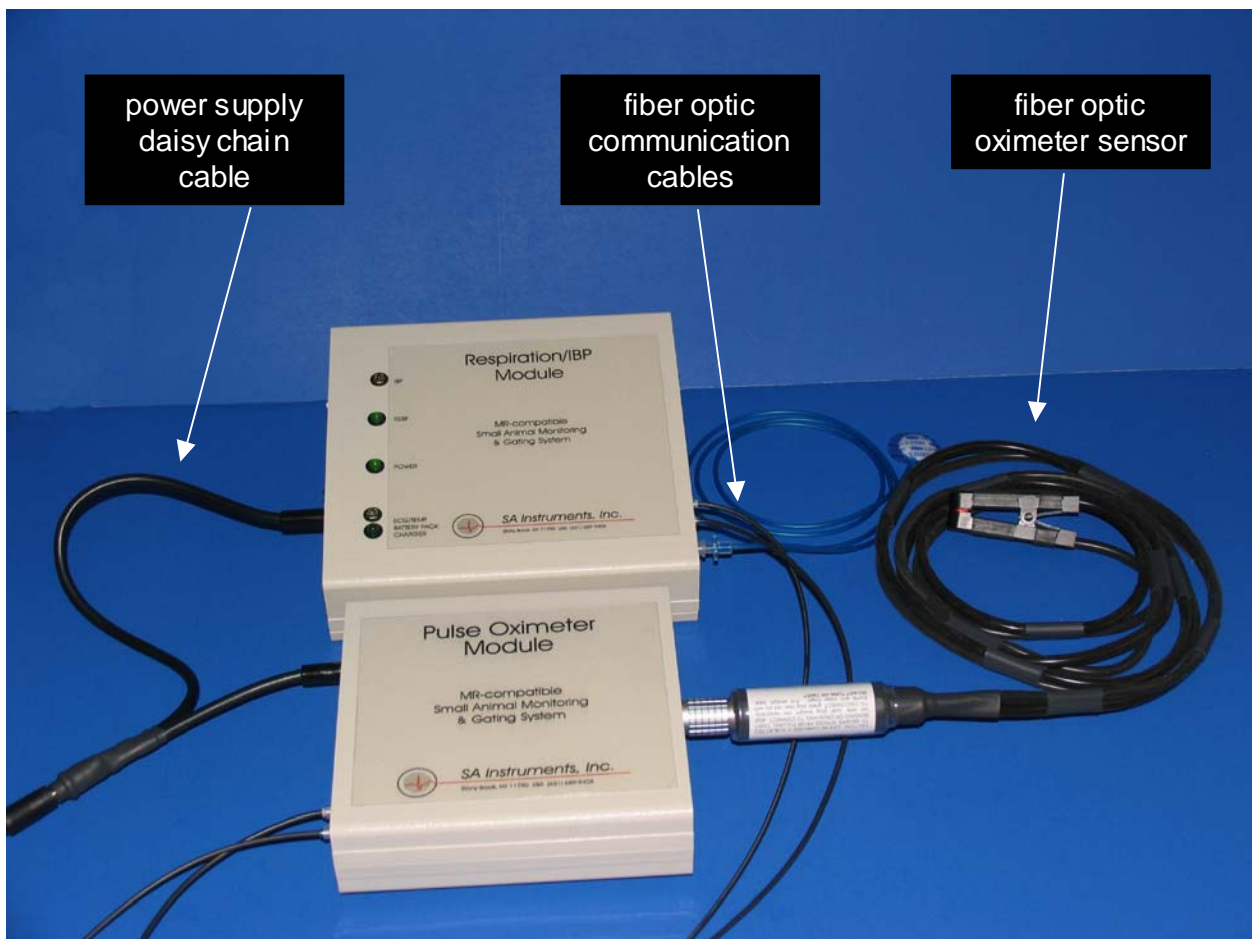
Chapter 6
Pulse Oximetry Module

Chapter 6

Pulse Oximetry Module

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 and measures the animal's heart rate.



Oximeter components and connections

The Pulse Oximeter Module is located next to the magnet bore and near the Respiration or Respiration/IBP Module. A fiber optic sensor extends into the bore and attaches to the animal. The module receives and sends data along with the Respiration/IBP and Fiber Optic Temperature Modules from and to the

Pulse Oximetry Module

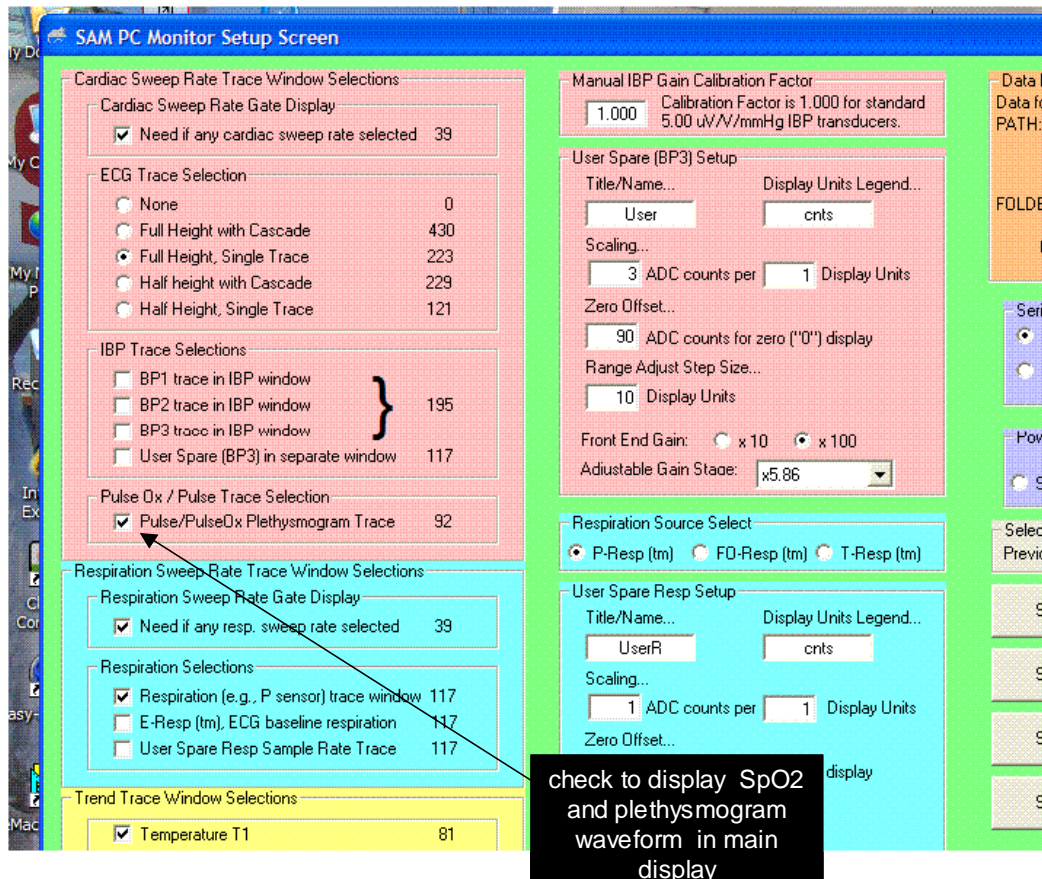
Control/Gating Module using fiber optic communication cables. It receives power from the Respiration Module's 12 VDC external power supply via a daisy chain cable or from a dedicated supply.

When the Oximeter Module is not present, the Respiration Module connects to the Control/Gating Module using a duplex fiber optic communication cable. The duplex cable has a one blue and one gray connector on each end. At the Respiration Module, the blue and gray connectors plug into the two fiber optic ports. In all cases the color of the connector matches the color of the port.

When the Oximeter Module is present, one of the fiber optic communication cables (it does not matter which one) is removed from the Respiration Module and connected to the Oximeter Module and a short simplex fiber optic cable is connected between the two modules. In all cases, the color of the connector must match the color of the port.

Display configuration

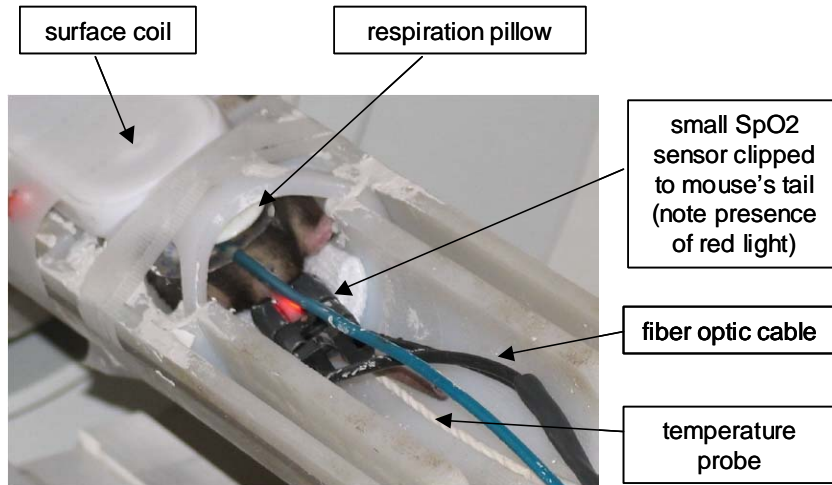
To add pulse oximetry to the monitor configuration, execute PC-sam and select the option to "open the MONITOR SETUP window". Select the Pulse Ox Plethysmogram Trace option as shown in the figure below.



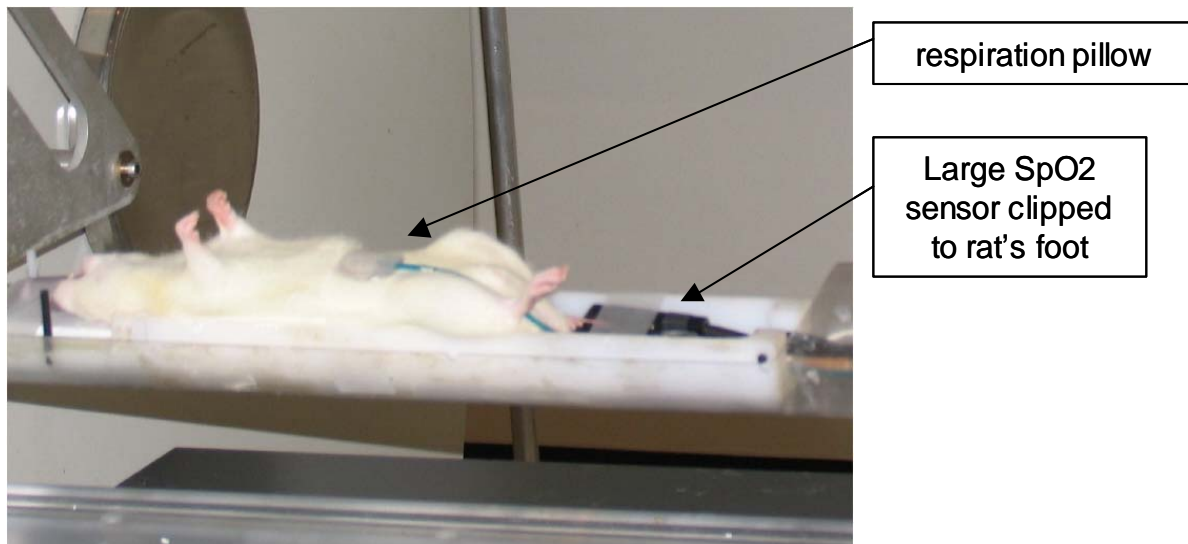
Pulse Oximetry Module

Attachment of fiber optic oximetry sensors

Small and large fiber optic clip on sensors are available. The clip on sensors are typically attached to the rat foot or the shaved mouse thigh. Other useful locations include the ankle, paw, wrist, tail, etc. For rabbits, the ear is often the location of choice.



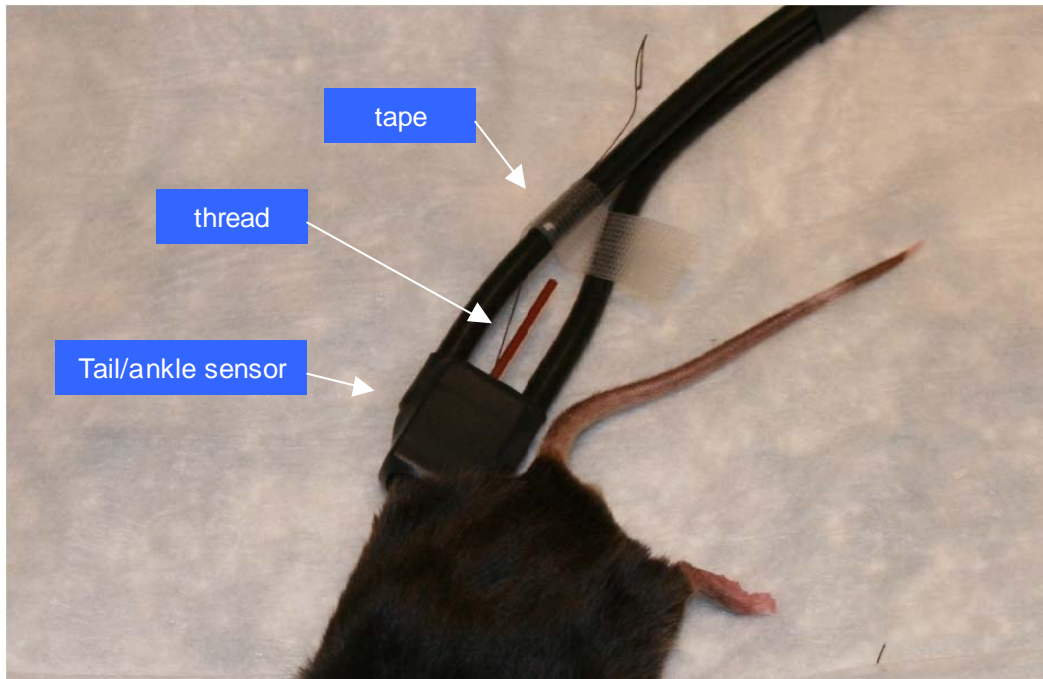
A black mouse is shown above prepared for MR with ECG, pulse ox, respiration and temperature sensors. The small pulse ox clip sensor is attached to the base of the tail.



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.

Pulse Oximetry Module



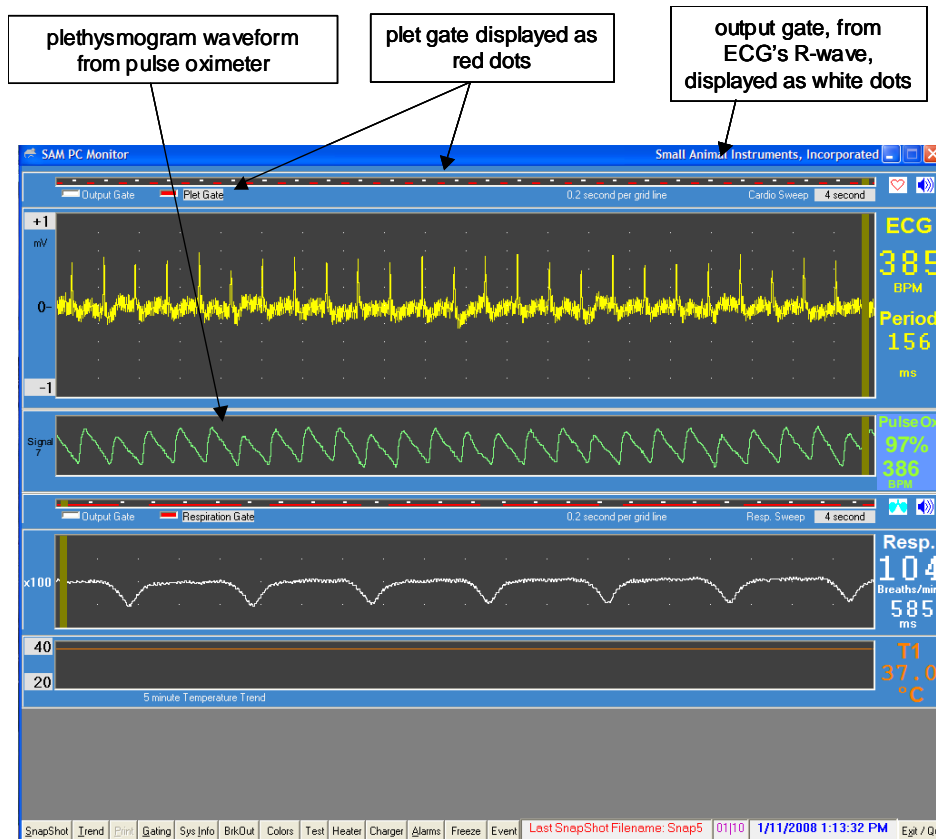
The mouse tail/ankle fiber optic sensor is shown above attached to the ankle of a black mouse. The sensor head holding the two fibers simply has a hole where the tail or ankle can be inserted. Note that the form does not apply pressure to the attachment site, so oximetry signals tend to be robust. In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

Pulse Oximetry Module



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 below 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.

Pulse Oximetry Module

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 screenshot shows the SAM PC Monitor software interface. The main display area shows a grid with a yellow horizontal line at 0 mV. The right side of the interface displays various physiological parameters: ECG, BPM, Period (ms), PulseOx (%), BPM, Resp. (Breaths/min), and T1 (°C). The bottom status bar shows a menu with options like Snapshot, Trend, Print, Gating, Sys Info, BrkOut, Colors, Test, Heater, Charger, Alarms, Freeze, Event, and a system message: ECG/T Communication Failure 00:00 1/27/2008 11:21:47 PM Exit / Quit.

1) Click Gating to display Gating Setup Form

2) Click Pulse/PulseOx to display PulseOx Controls window

3) Change value and click send to change the threshold value

Signal Source	Invert	Begin Delay	Max. Width	Gates
ECG	<input checked="" type="checkbox"/>	0	15	<input checked="" type="checkbox"/>
IBP 3 (User)	<input type="checkbox"/>	0	0	<input type="checkbox"/>
Pulse/PulseOx	<input type="checkbox"/>	0	0	<input type="checkbox"/>
Aux. Input	<input type="checkbox"/>	0	0	<input type="checkbox"/>
FiberOptic Aux	<input type="checkbox"/>			<input type="checkbox"/>

PulseOx Controls

PulseOx Gate Threshold: 11

Gating Setup Form

Gate Outputs: Invert Gate Output, Invert FD Output

Chapter 7

Heater System

Chapter 7

Heater System

Overview

The 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 °C can typically be obtained during MR examination.

Heater components

The SAll 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.

Heater System



Heater System

Heater control

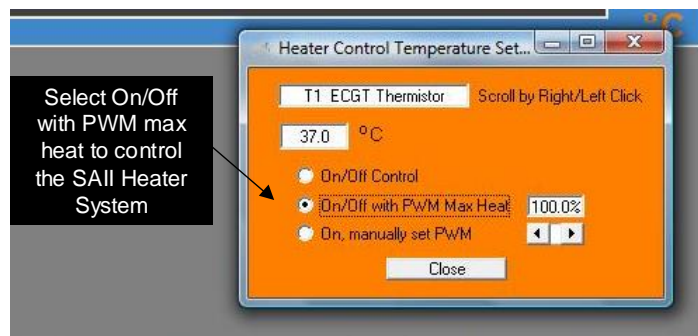
Clicking the Heater button at the bottom of the main waveform display in PC-sam opens the HEATER window. The window can be used to select which temperature probe will be used to control the heater, set the set point value and select the method of control.

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.

Selecting **on/off control** produces light from the "Heater Control" port of either the 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 SAll Heater System. The microprocessor in the SAll Heater Module detects continuous light and disables the heater element.

On/off control with manual control of the heater duty factor should be selected when using the SAll Heater System. 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 turn 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 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 HEATER window, select the temperature probe, select On/Off control with PWM max heat 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

Heater System

be used for insulation. 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 heater system on. Observe that the green power indicator is illuminated on the Heater Module. Also observe that the yellow heat indicator is flashing. If the heat indicator is not flashing check that the temperature measurement is lower than the set point. 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 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.

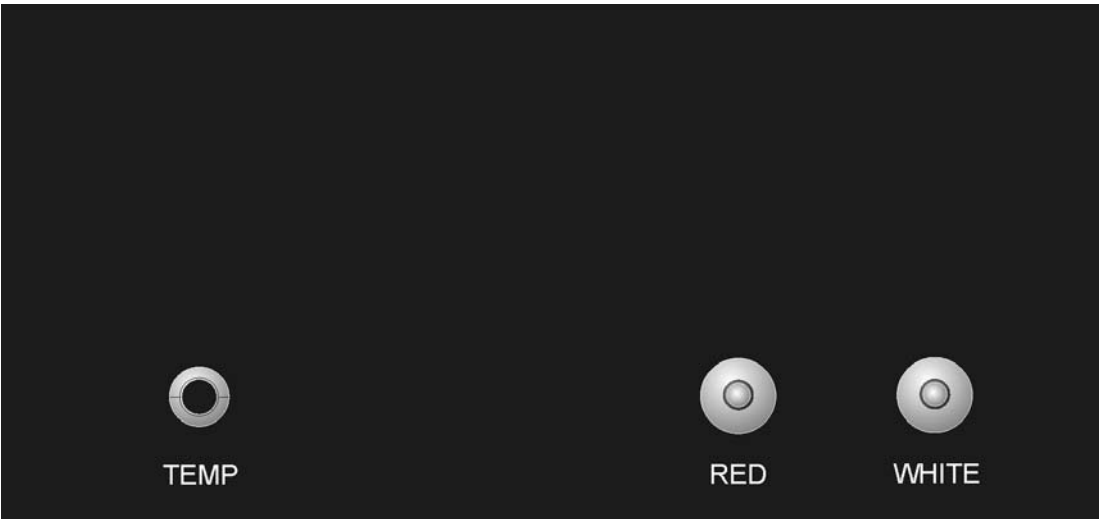
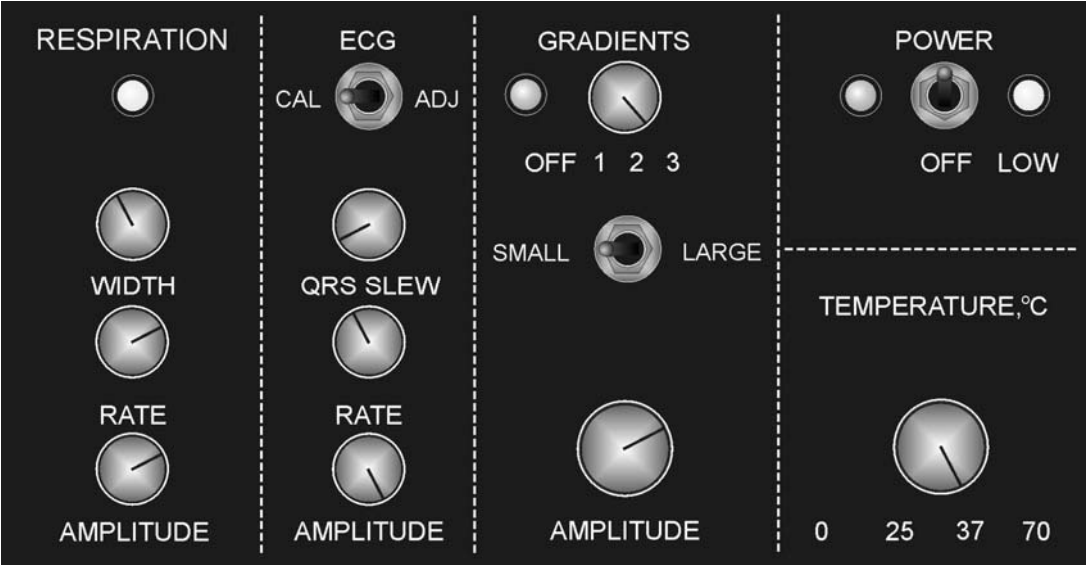
Chapter 8

Simulator

Chapter 8 Simulator

Overview

The simulator generates an ECG voltage waveform with respiration and gradient pulse interference superimposed. Connection to the ECG/Temperature Module is from the simulator rear panel connections with special simulator ECG leads to red and white labeled studs. The simulator also provides a reference temperature impedance. Connection to the ECG/Temperature module is from the rear panel with a special simulator temperature cable to the labeled phono jack.



Simulator

Operation

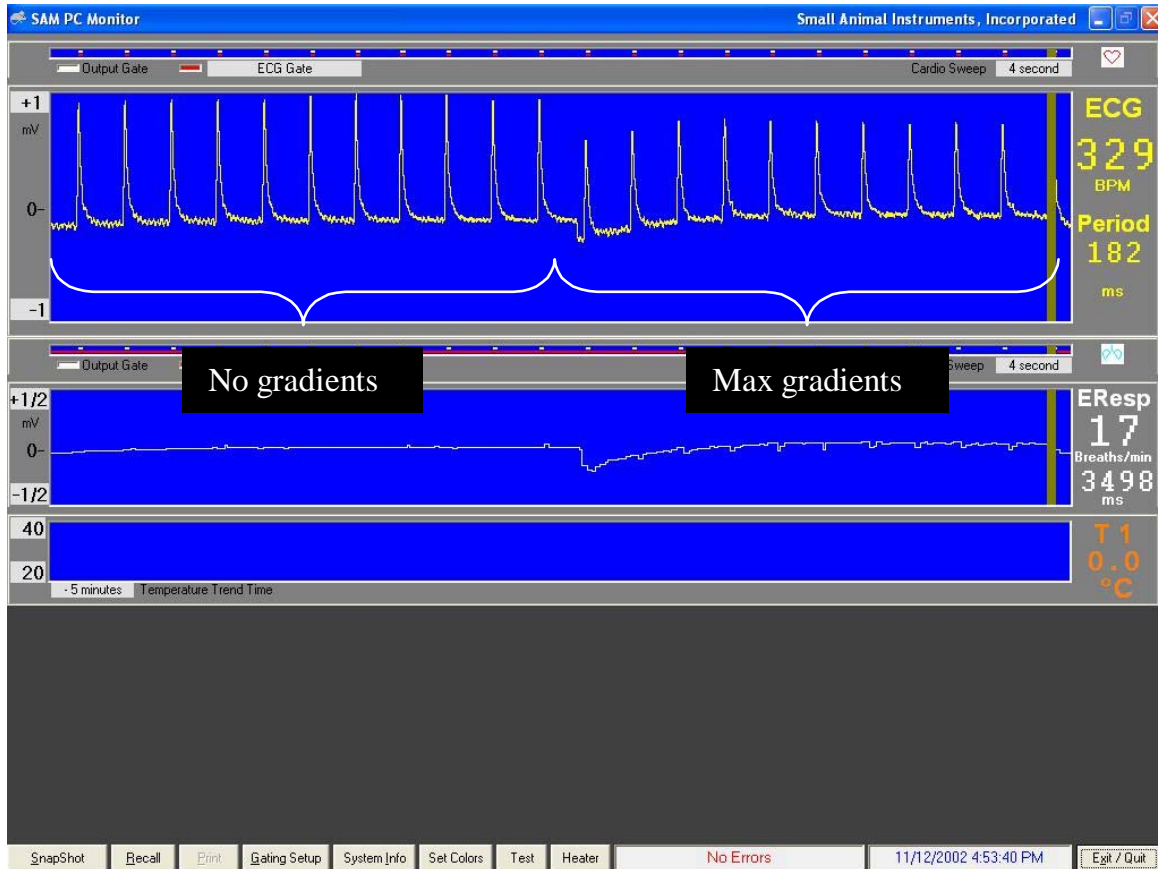
The Simulator is powered by a 9V internal battery. The power switch on the front panel activates the ECG and Respiration waveform. Green LEDs flash with the heart QRS and with respiration. A yellow LED flashes when the internal battery is low. Separate controls are provided for ECG rate and amplitude 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 (8.0 V). 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 batteries.

Simulator

Chapter 9

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 60 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. 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.

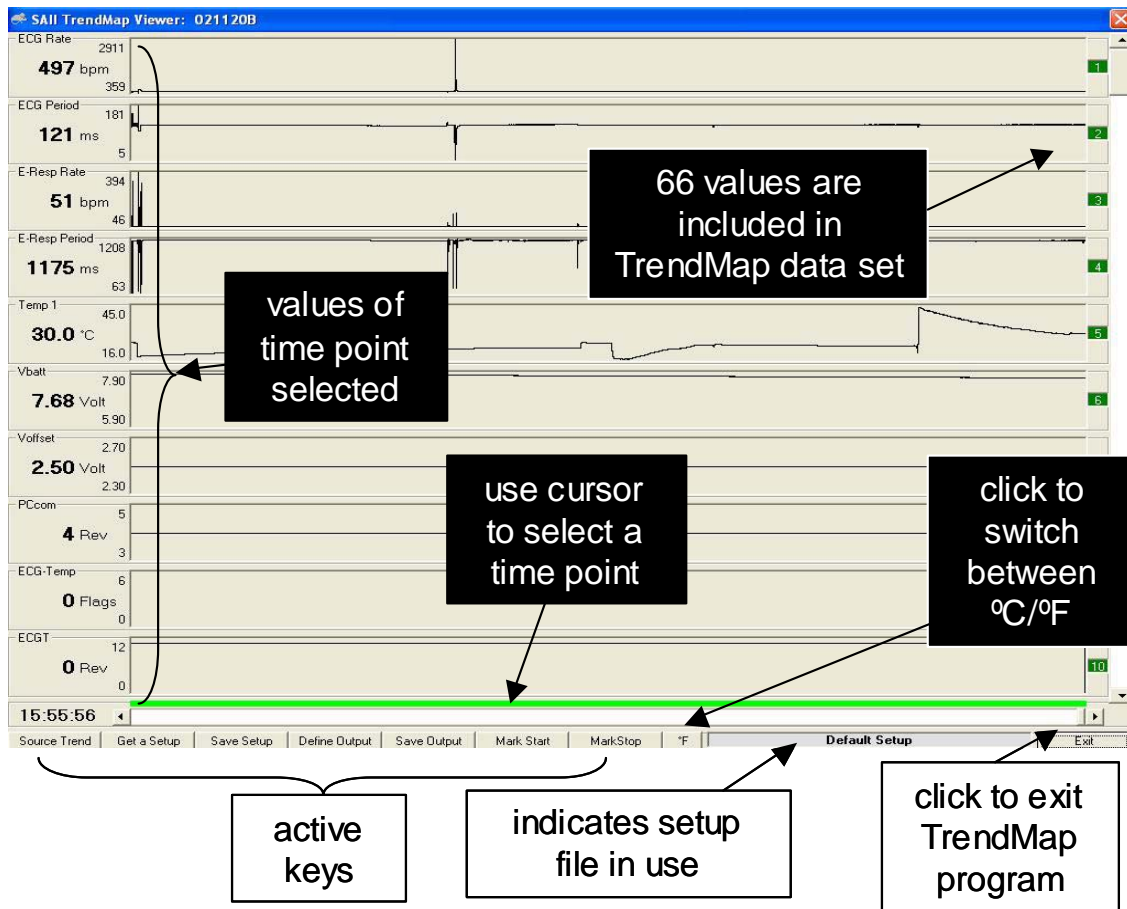
Events logged in PC-sam are recorded in the trend file as item 64 and can be viewed with TrendMap. Also AUX IN and Fiber Optic AUX IN are recorded in item 66.

TrendMap Viewer display

The TrendMap Viewer display is shown on the next page. More than 60 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 TRENDR 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 TRENDR 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

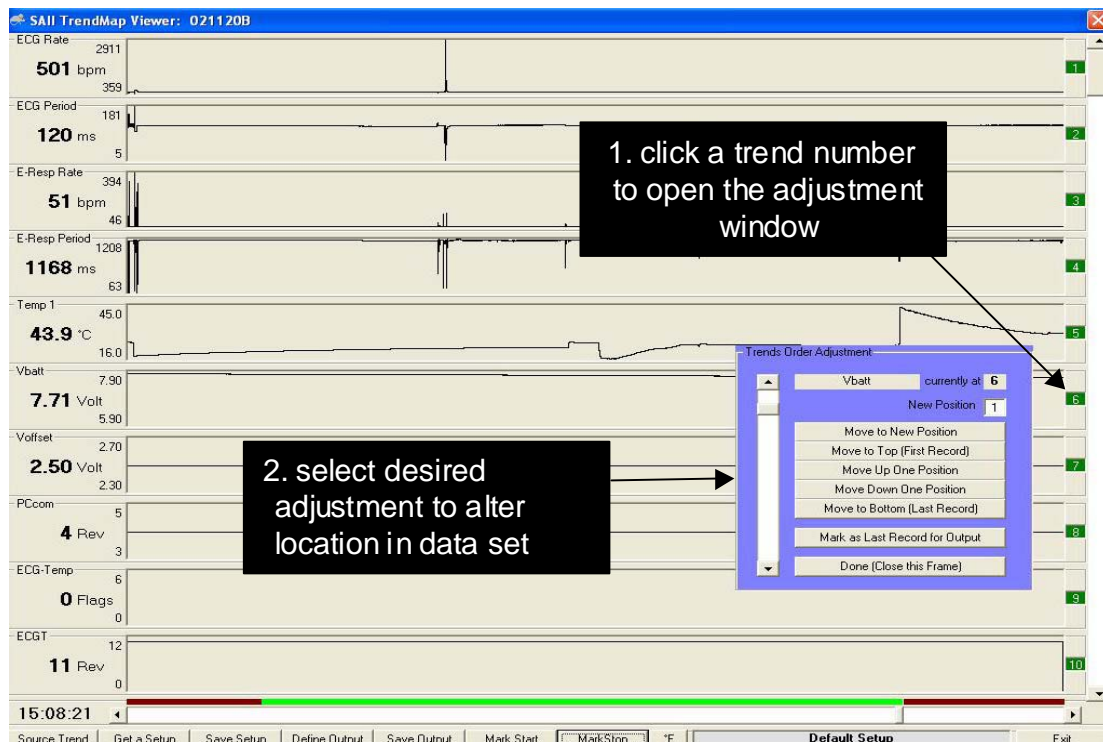
The window below allows opening of a TrendMap data set. The window opens when TrendMap is executed or when the Source Trend key is clicked.

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 screenshot shows the SAI1 TrendMap Viewer interface. On the left, a list of physiological parameters is displayed with their current values: ECG Rate (508 bpm), ECG Period (118 ms), E-Resp Rate (51 bpm), E-Resp Period (1180 ms), Temp 1 (20.7 °C), Vbatt (7.81 Volt), Voffset (2.50 Volt), PCcom (4 Rev), ECG-Temp (0 Flags), and ECGT (11 Rev). The main area shows a multi-trend plot with 10 individual data series. Trends 1 through 6 are highlighted in green, while trends 7 through 10 are highlighted in red. An 'Output File Setup' dialog box is open in the center, with the following settings: Name/Date Header Line (checked), Description Header Line (checked), Column Names Header Line (checked), Column Units Header Line (checked), No Time Column (unchecked), Time as Seconds From Start (checked), Time as HH:MM:SS (unchecked), 1 Seconds per Output Line, 6 Trends per Output Line, Comma Space (selected) for Column Delimiter, CR LF (selected) for End-Of-Line Delimiter, and '-1' (selected) for Replacement for 'Bad' [-1] Data. The dialog box has a 'Close Output File setup' button at the bottom. Four callout boxes provide instructions: 1. click to open output setup window (pointing to the dialog box), 2. make selections to define format of output file (pointing to the dialog box), 3. note data set selected for output is indicated as green (pointing to the green trends), and 4. click to save output (pointing to the 'Save Output' button in the bottom toolbar).

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 64. 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	ECG period	ms	R to R time interval from ECG leads
3	E-resp rate	bpm	Respiration rate from E-resp
4	E-resp period	ms	R to R time interval from E-resp
5	Temp 1	°C or F	temperature from channel 1
6	Vbatt	volts	battery voltage of ECG/Temp Battery Pack
7	Voffset	volts	offset voltage of ECG leads measurement
8	PCcom	Rev #	PC com software revision number
9	ECG-Temp	flags	proprietary data for service
10	ECGT	Rev #	ECGT software revision number
11	ETGate	Rev #	ETGate software revision number
12	RFcom	Rev #	RFcom software revision number
13	BP1 Sys	mmHg	IBP channel 1 systolic pressure measurement
14	BP1 Dia	mmHg	IBP channel 1 diastolic pressure measurement
15	BP1 Mean	mmHg	IBP channel 1 mean pressure
16	BP1 rate	bpm	heart rate from IBP 1 measurement
17	BP1 period	ms	heart period from IBP 1 measurement
18	BP2 Sys	mmHg	IBP channel 2 systolic pressure measurement
19	BP! Dia	mmHg	IBP channel 2 diastolic pressure measurement
20	BP2 Mean	mmHg	IBP channel 2 mean pressure
21	BP2 rate	bpm	heart rate from IBP 2 measurement
22	BP2 period	ms	heart period from IBP 2 measurement
23	BP3 Sys	mmHg	IBP channel 3 systolic pressure measurement
24	BP3 Dia	mmHg	IBP channel 3 diastolic pressure measurement
25	BP3 Mean	mmHg	IBP channel 3 mean pressure
26	BP3 rate	bpm	heart rate from IBP 3 measurement
27	BP3 period	ms	heart period from IBP 3 measurement
28	IBP	flags	proprietary data for service
29	IBP	Rev #	IBP software revision number
30	FOT4	°C or F	Temperature of fiber optic channel 4
31	FOT3	°C or F	Temperature of fiber optic channel 3
32	FOT2	°C or F	Temperature of fiber optic channel 2
33	FOT1	°C or F	Temperature of fiber optic channel 1
34	FOT Flags	flags	proprietary data for service
35	FOT Rev	Rev #	Fiber Optic Temperature Module software rev
36	EtCO2	mmHg	end tidal CO2 measurement
37	Insp CO2	mmHg	inspired CO2 measurement
38	FiO2	%	final inspired O2 measurement
39	CO2 rate	Resp/m	respiration rate from CO2 measurement
40	CO2 period	ms	respiration period from CO2 measurement
41	Pambient	mmHg	ambient pressure measurement
42	capnograph	flags	proprietary data for service
43	capnograph	Rev #	Capnograph software revision number

Item #	Label	Unit	explanation
44	USER Rate	cpm	rate from USER Resp channel
45	USER Period	ms	period from USER Resp channel
46	Resp Rate	resp/m	respiration rate from the pneumatic pillow input
47	Resp Period	ms	respiration period from the pillow input
48	Resp Gain	number	auto gain setting for the respiration channel
49	Resp	flags	proprietary data for service
50	Resp	Rev #	respiration software revision number
51	SpO2	% Sat	Oxygen saturation in % of hemoglobin
52	Ox Rate	bpm	heart rate from SpO2 waveform
53	Ox Period	ms	Heart period from SpO2 waveform
54	Ox Signal	level	auto gain level for oximeter measurement
55	Temp; 2	°C or F	temperature from channel 2
56	Oximeter	flags	proprietary data for service
57	Oximeter	Rev #	oximeter software revision number
58	Chg Vplus	volts	Respiration Module's operating voltage
59	Chg Vbint	Volts	voltage for the Resp Module's internal battery
60	Chg Vbext	Volts	voltage for an external battery being charged
61	Chg Ipwm	mA	Charging current for an external battery
62	Chg Flags	flags	proprietary data for service
63	Chg Rev	Rev #	battery charger software revision number
64	Event	text	users text message input
65	USER Gain	number	gain setting from USER Resp channel
66	Aux/FO in	flags	proprietary data for service

Note that as of the date of this manual, locations 36 through 43 and 55 are not active. These locations have been reserved for future implementation of the following additional modules: capnograph and a second channel of temperature.

Trends

Chapter 10

SnapView

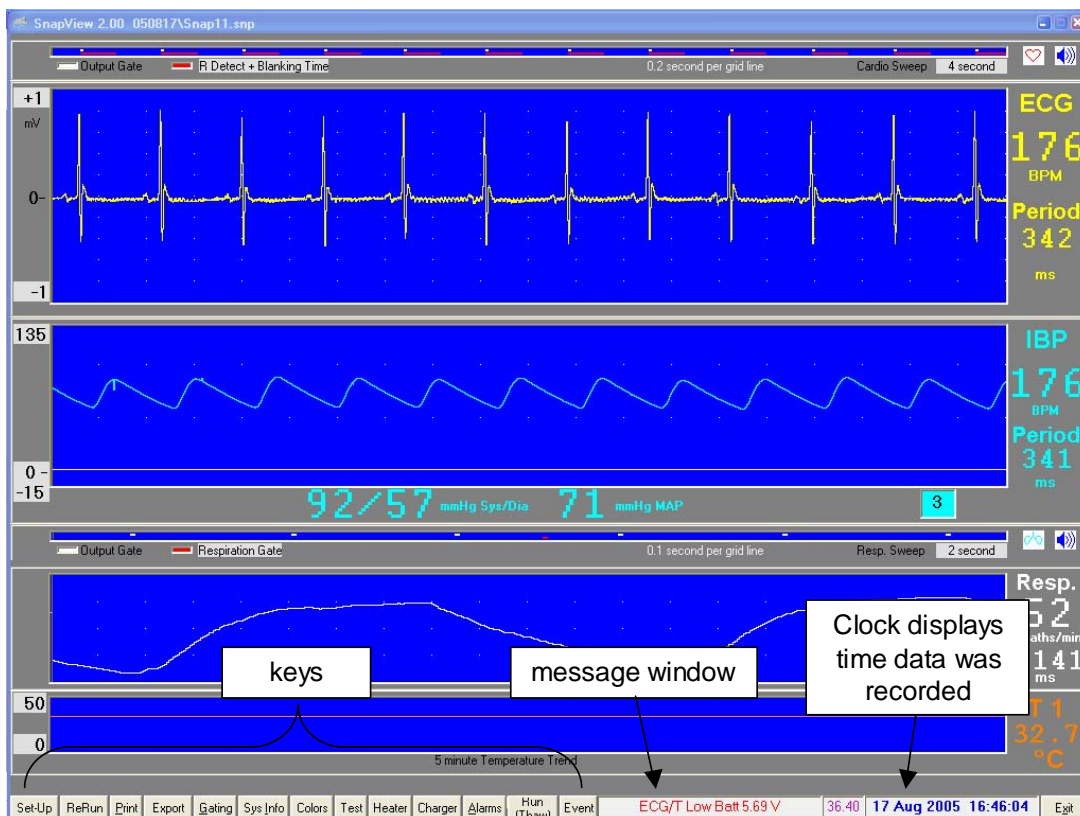
Chapter 10 SnapView

Overview

The SnapShot key in PC-sam causes storage of the last 36 seconds of monitor data. All data transmitted to the PC during the 36 second interval was stored. Parameter values set by the PC (e.g. slew rates for R-wave detection, blanking time, etc.) were stored once, at the time the SnapShot was taken.

SnapShot data files are viewed with SnapView. Double click the SnapView icon on the desktop to start the program. 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.

SnapView display

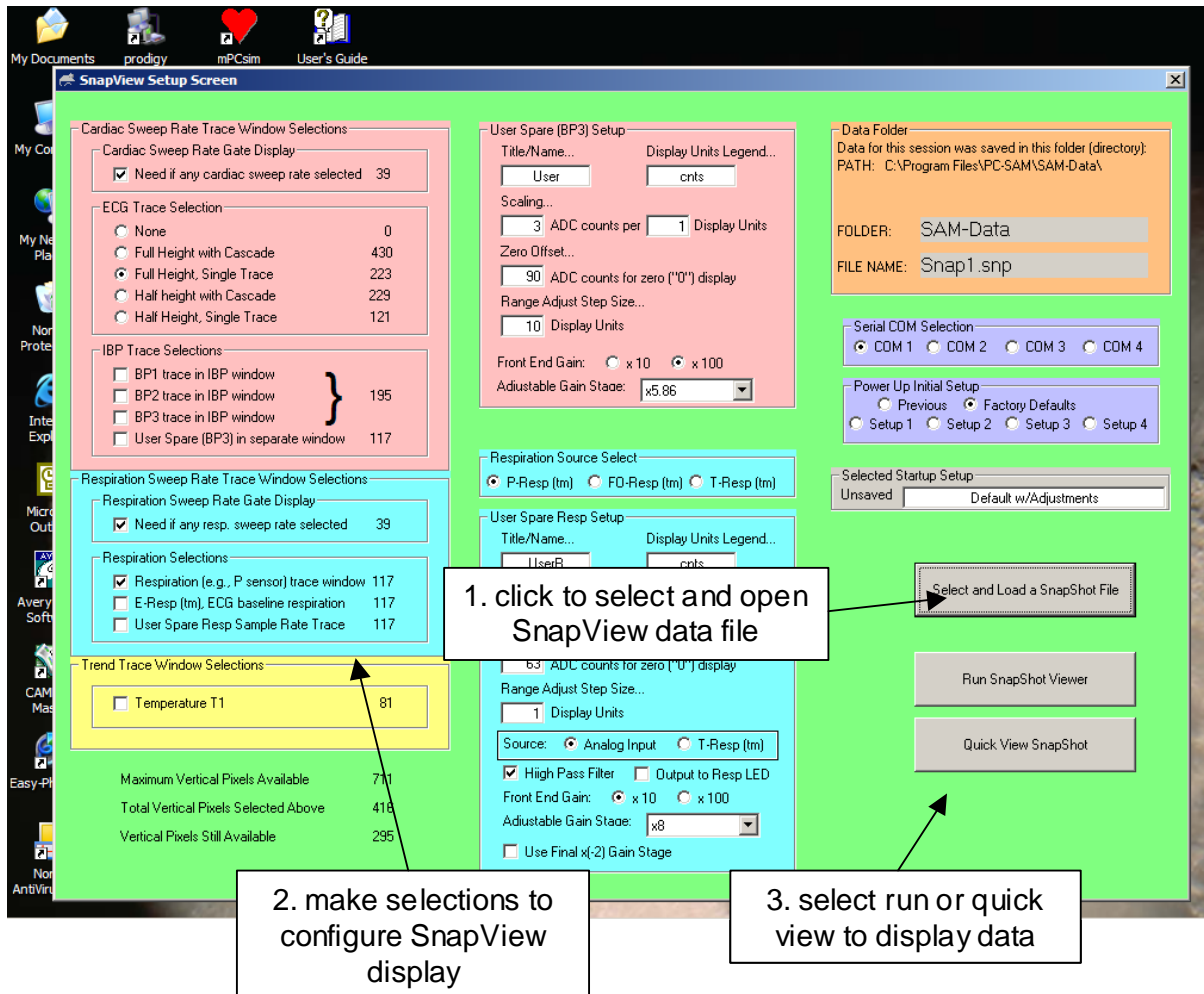


The SnapView display is shown here. The display is very similar to the monitor display of PC-sam. Most keys perform the same function as in PC-sam. The only differences are the Setup, ReRun, Print and Export keys.

SnapView

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 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 ECG (+/-512) and 17 other data points. The 17 data entries are IBP3, E-Resp, P-Resp, U-Resp, bad ETG, badRFB, GateBit, QRS, ECGgate, BP3gate, Erspgate, Prspgate, Urspgate, FOin, FOGate, AuxIn, Auxgate.

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.

SnapView

Chapter 11

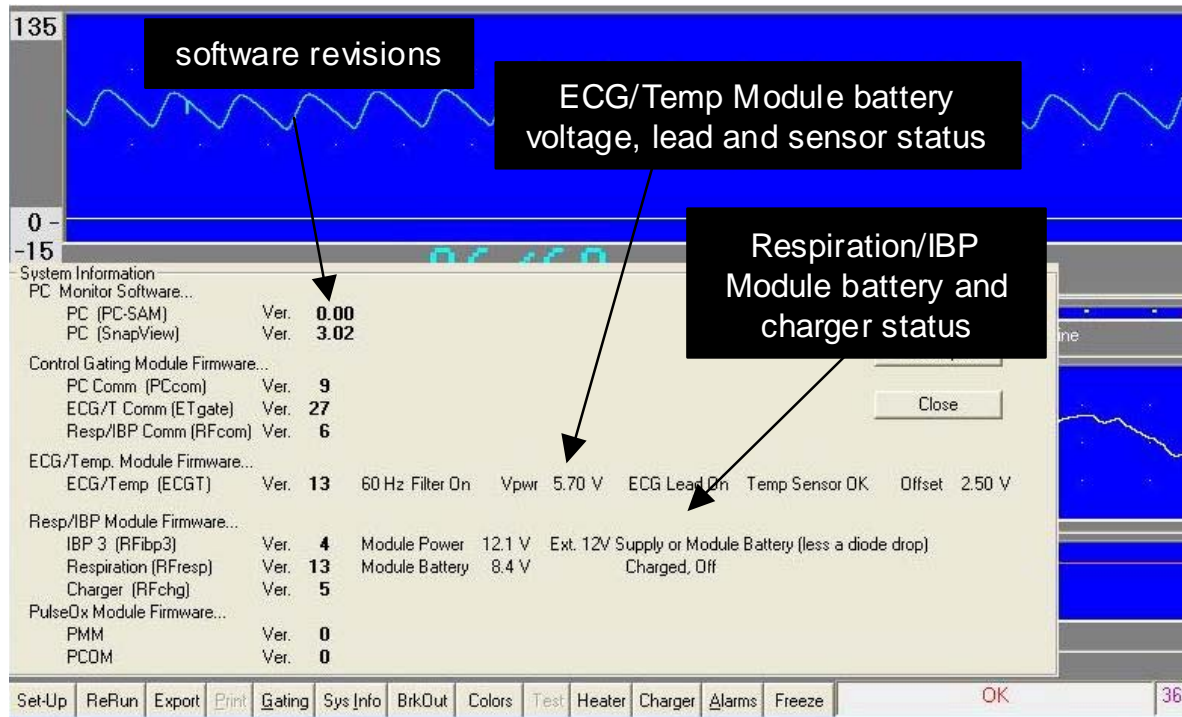
Additional Features

Chapter 11

Additional Features

System information window

The SYSTEM INFORMATION WINDOW lists software revisions and current status for the ECG/Temperature Module and the Respiration/IBP Module.



ECG/Temperature Module status includes the 50Hz/60Hz notch filter setting, battery voltage, ECG and temperature lead status and offset voltage.

The ECG/Temperature 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 (refer to Chapter 4) or if the temperature probe is defective.

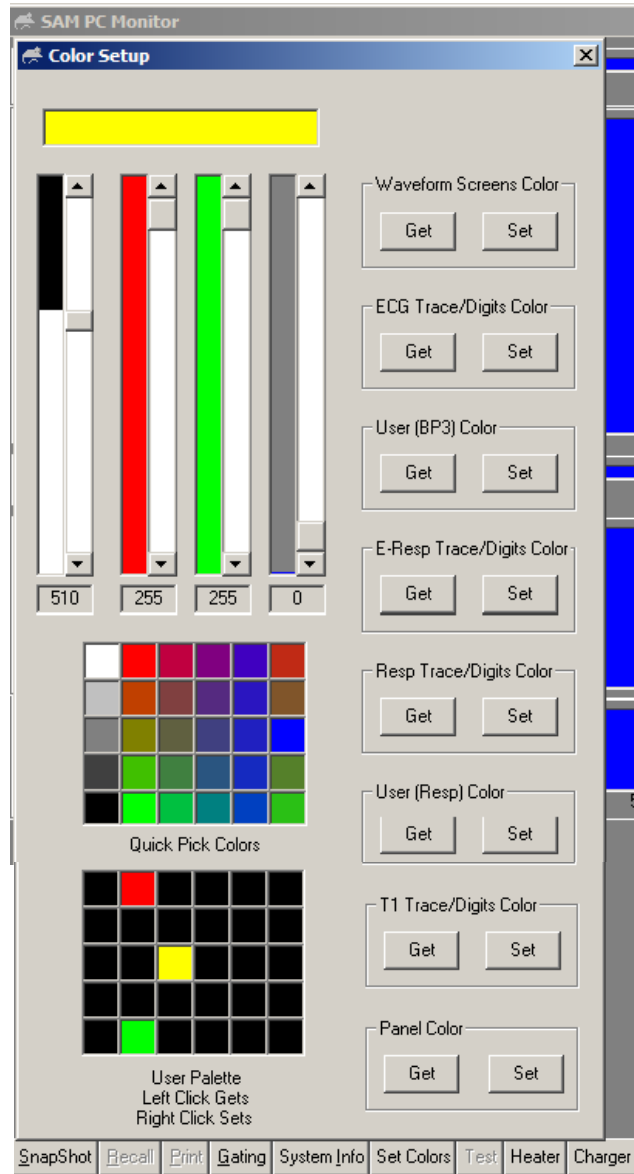
The Respiration/IBP Module status includes the modules power source (12V or internal battery) and status of the two internal battery chargers.

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

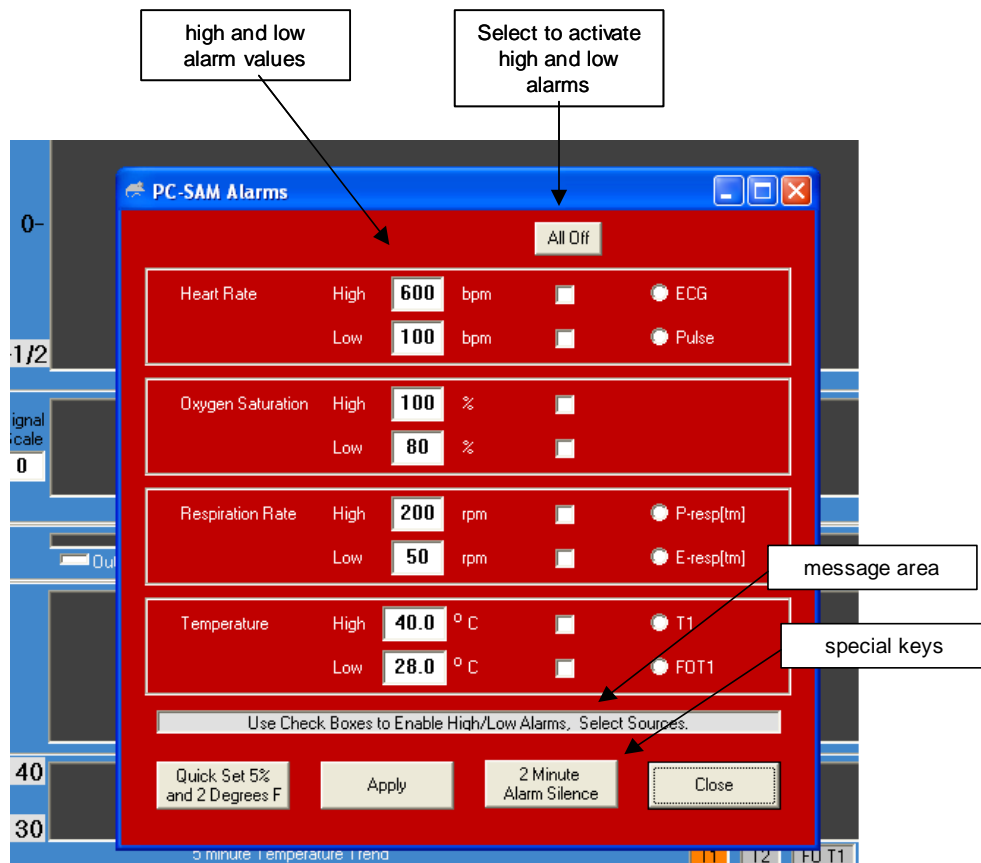


selected from Quick Pick or made from combinations of red, green and blue in the upper left of the window. Once colors have been constructed, they can be stored in the User Palette. Right click sets and left click gets.

ALARMS window

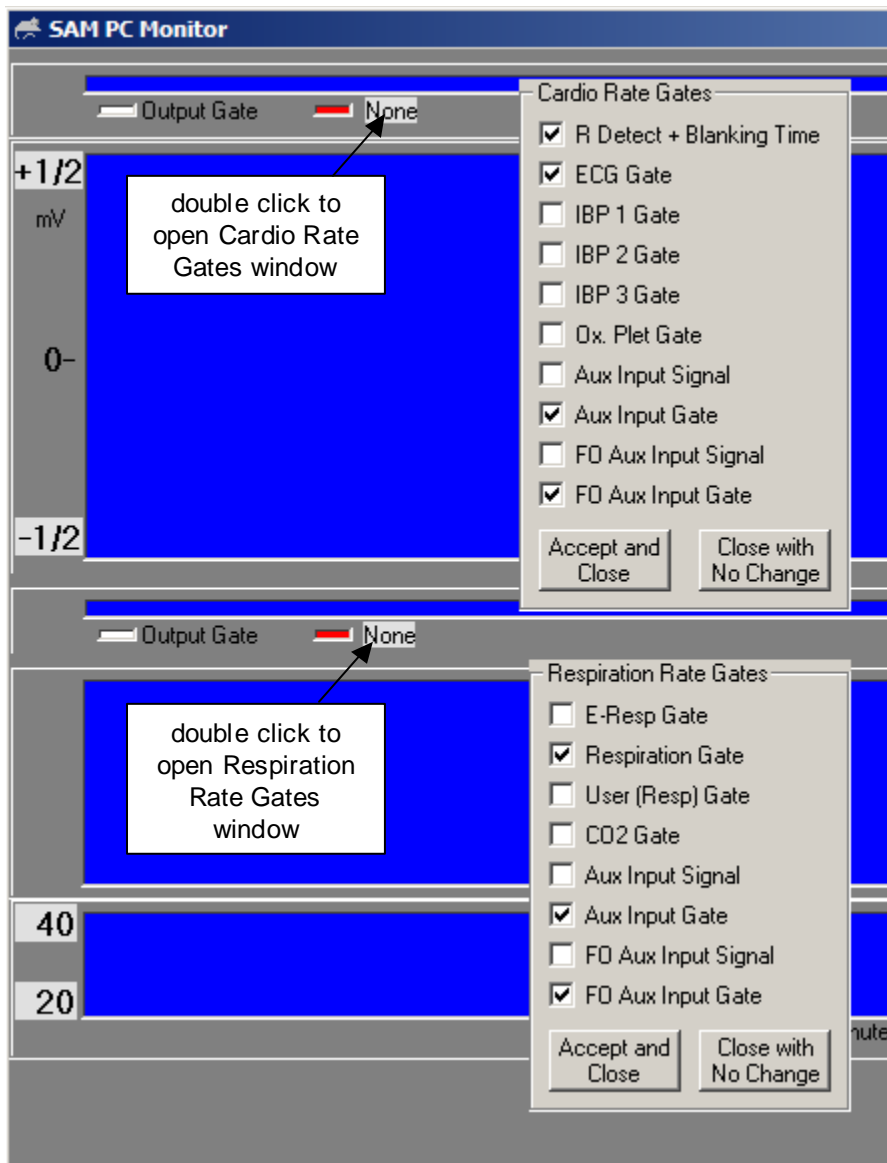
The alarms window allows high and low alarm limits to be set for heart rate, respiration rate and/or temperature. A check mark next to an alarm limit followed by clicking the Apply key will activate the alarm. When the measured value meets or exceeds the limit, an audible alarm sounds.

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 and respiration rate and 2 oF above and below the current temperature measurement.



Additional Features

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. Note that the Ox Pleth Gate is not active at this time.

An 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

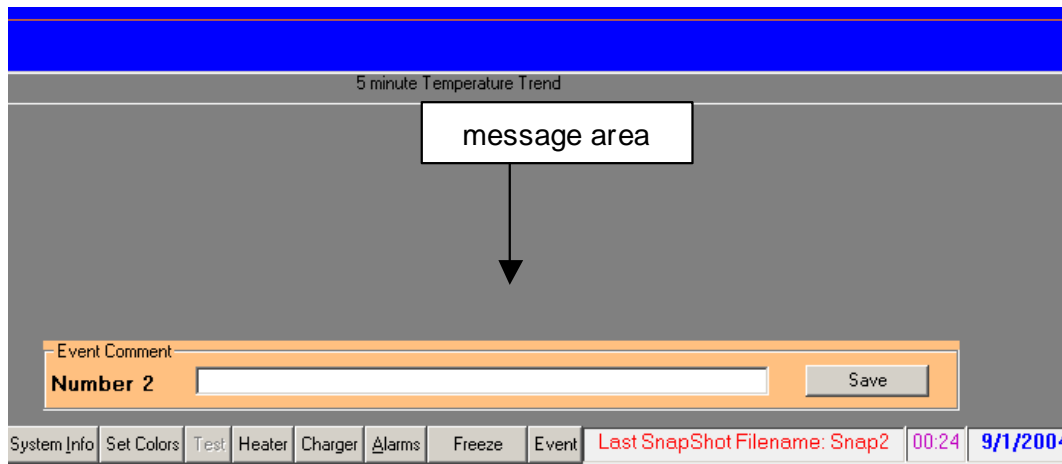
Additional Features

gate not Resp gate or User Resp gate. Also note the CO2 Gate is not active at this time.

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.

Additional Features

Chapter 12

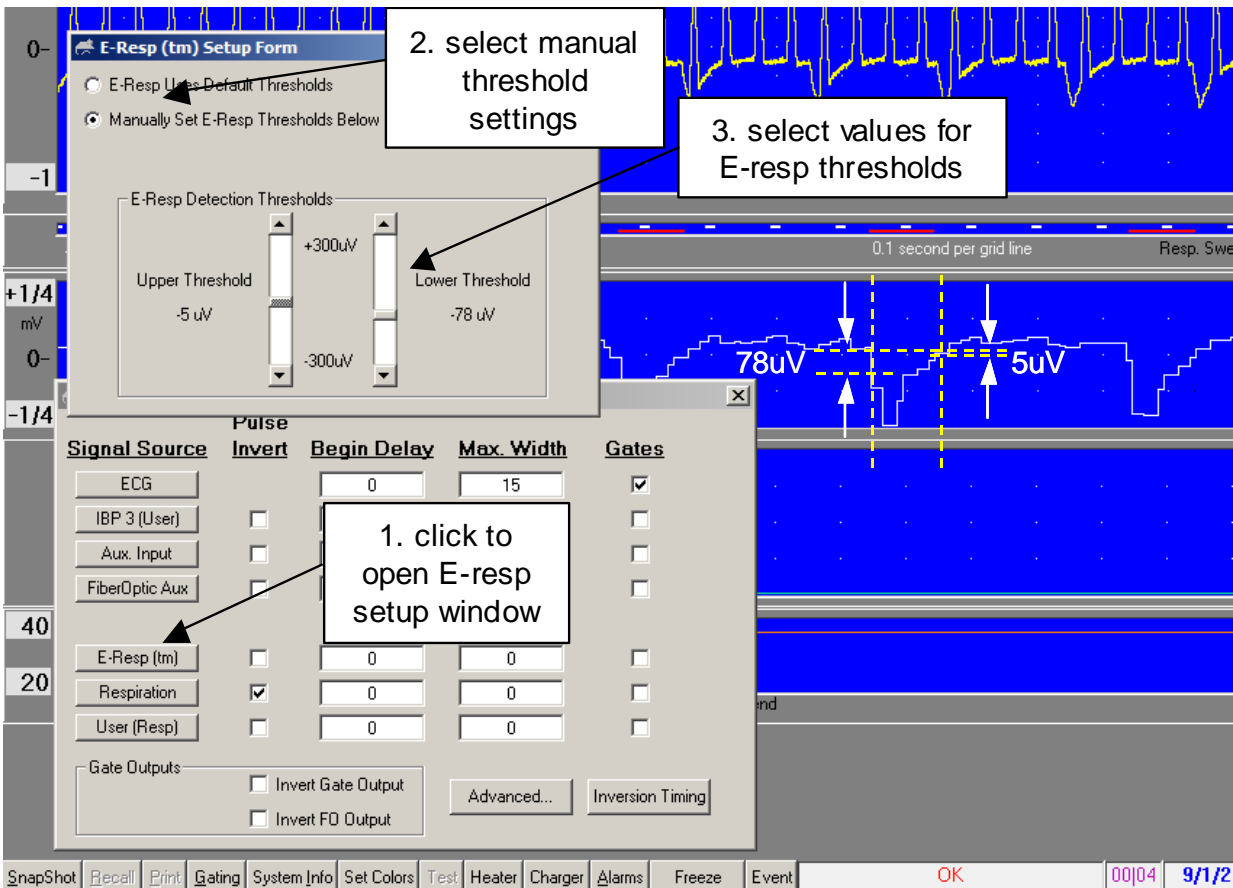
Advanced Features

Chapter 12 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 falls below the lower threshold of $-78\mu\text{V}$ and ends when the waveform rises above the upper threshold of $-5\mu\text{V}$.



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.

Advanced Features

The screenshot displays the SAM PC Monitor interface with two main waveform displays. The top display shows an ECG signal with a 0.1 second per grid line scale. Annotations include 'R-wave', 'R-F interval', 'inversion time', and 'R-R interval'. The bottom display shows a Respiration (EResp) signal with a 0.2 second per grid line scale. A 'Gating Setup Form' dialog box is open, showing the following settings:

Signal Source	Pulse Invert	Begin Delay	Max. Width	Gates	Apply To	Inversion Timing Time (ms)
ECG	<input type="checkbox"/>	0	15	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	1400
IBP 3 (User)	<input type="checkbox"/>	0	0	<input type="checkbox"/>	<input type="checkbox"/>	
Aux. Input	<input type="checkbox"/>	0	0	<input type="checkbox"/>	<input type="checkbox"/>	
FiberOptic Aux	<input type="checkbox"/>			<input type="checkbox"/>	<input type="checkbox"/>	
E-Resp (tm)	<input checked="" type="checkbox"/>	0	0	<input type="checkbox"/>	<input type="radio"/>	
Respiration	<input checked="" type="checkbox"/>	0	0	<input type="checkbox"/>	<input type="radio"/>	
User (Resp)	<input type="checkbox"/>	0	0	<input type="checkbox"/>	<input type="radio"/>	

The 'Inversion Timing' section includes a 'Time (ms)' field set to 1400 and a green 'On' button selected over 'On/Off'. Below this, there are radio buttons for 'No Resp', 'E-Resp (tm)', 'P-Resp (tm)', and 'User Resp'. A note states: 'Setup Delay/Width for desired "lead" location, then turn Inversion Timing Mode ON, for corrected gate timing. Inversion Timing is turned off for any setup changes.'

At the bottom of the dialog, there are checkboxes for 'Gate Outputs': 'Invert Gate Output' (unchecked) and 'Invert FD Output' (unchecked).

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.

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 ($70\text{ms} + 1400\text{ms} = 14 \times 105$). 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 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 Respiration/IBP Module
7. Signal gain

Advanced Features

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 Respiration/IBP 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 Respiration/IBP Module can be used as an IBP channel (IBP3) or as a user auxiliary analog input channel User IBP.

Advanced Features

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 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 Features

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-RespTM, 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-RespTM, 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

Advanced Features

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 Control/Gating Module. The background color in the value box indicates the status. White indicating the value has been sent to the 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.

Advanced Features

Chapter 13
Three Lead ECG/Temperature Module

Chapter 13

Three Lead ECG/Temperature Module

Overview

An ECG/Temperature Module with Three ECG lead inputs, rather than two, is available as an option for the model 1025 MR-compatible Monitoring and Gating System. The three lead module can provide improved ECG performance in situations where the environment has large 50 or 60 Hz radiation, where larger animals such as rats and rabbits are being monitored and/or when long lead lengths are employed.

The Three Lead ECG/Temperature Module can provide a more stable ECG waveform baseline than the two lead module. The module can also be used to correct intermittent "Lead Off" error conditions.

Setup and use

The three lead module can be used with the model 1025 as an exact replacement for the standard two lead module. It uses the same battery pack, battery pack cable and fiber optic cable. The only down side is that the three ECG leads must be connected to the animal rather than two and it is slightly larger.

ECG connections are color coded as red, white, and black. The red and white connections generate the EC signal on the three lead module as with the two lead module. Generally the best ECG signal is obtained using the red and white lead's connected to the animal's right front leg and left back leg. The black connection is the so-called "driven lead." It makes sure the animals and the ECG/Temperature module are at the same voltage potential. The black lead should be attached to one of the unused legs or paws. When using the three lead module with the simulator it is only necessary to make the red and white connections.

Three Lead ECG/Temperature Module

Revision G, December 1009

Chapter 14

Fiber Optic Temperature Module

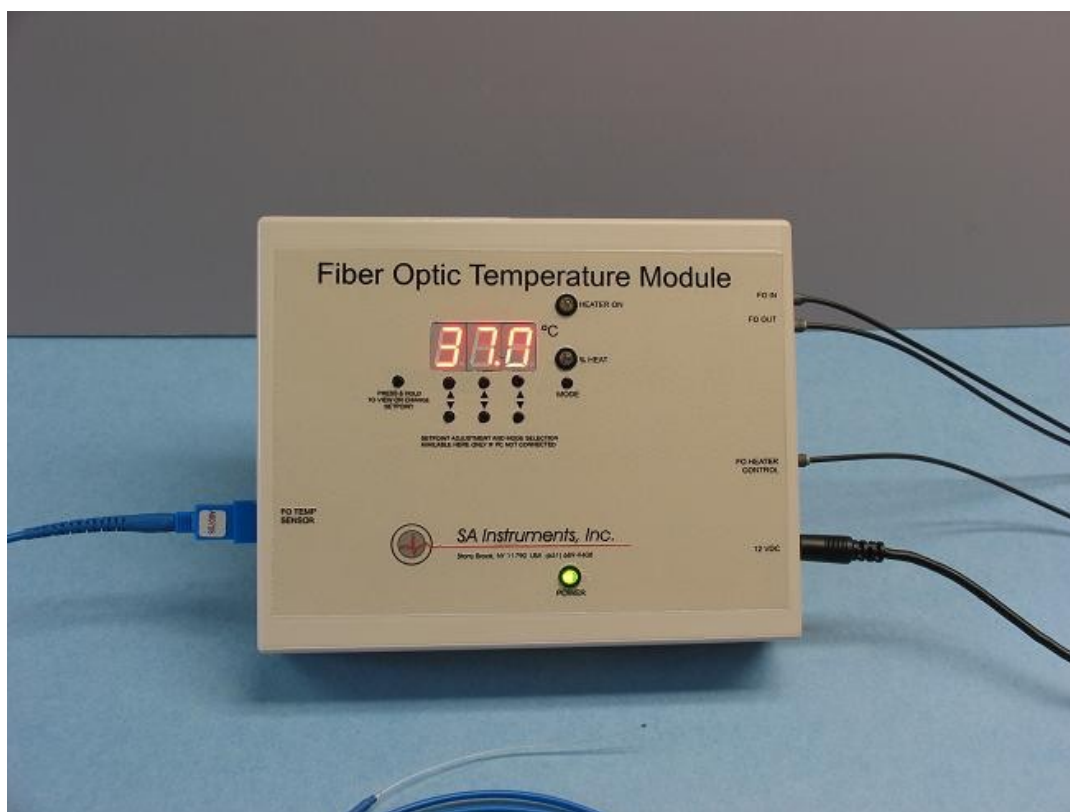
Chapter 14

Fiber Optic Temperature Module

Overview

Fiber optic temperature probes provide an alternative method to thermister temperature probes for measuring temperature in the MR environment. Fiber optic probes are not affected by the strong RF and magnetic fields of the MR scanner. They can not contribute to RF heating and they do not produce an artifact in MR images.

Components and connections



The Fiber Optic Temperature Module is located next to the magnet bore and near the Respiration or Respiration/IBP Module. One or more fiber optic temperature probes extend into the bore and attach to the animal. The module receives and sends data along with the Respiration/IBP and Pulse Oximeter Modules from and to the Control/Gating Module using fiber optic communication cables. It receives power from the Respiration Module's 12 VDC external power supply via a daisy chain cable or from a dedicated supply.

When the Fiber Optic Temperature and or Oximeter Modules are not present, the Respiration Module connects to the Control/Gating Module using a duplex fiber optic communication cable. The duplex cable has a one blue and one gray connector on each end. At the Respiration Module, the blue and gray connectors plug into the two fiber optic ports. In all cases the color of the connector matches the color of the port.

Fiber Optic Temperature Module

When one or more additional modules are present, one of the fiber optic communication cables (it does not matter which one) is removed from the Respiration Module and connected to one of the additional modules and short simplex fiber optic cables are connected between each of the modules. In all cases, the color of the connector must match the color of the port.

The temperature probe connects to the module by pushing the connector into the receptacle. To remove the probe depress the flat locking tab at the back of 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

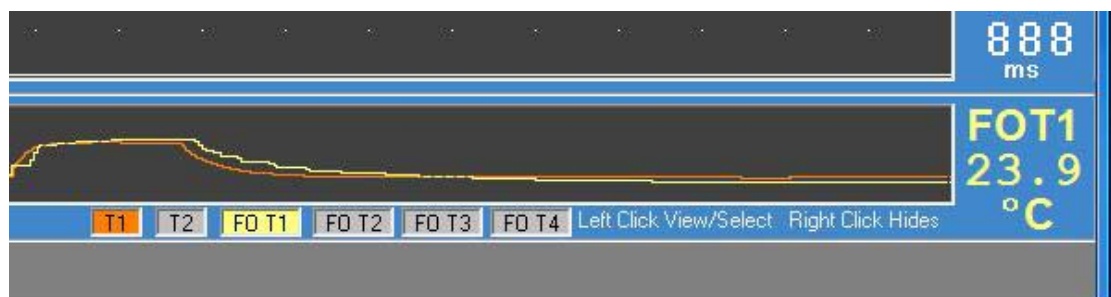
To add fiber optic temperature to the monitor configuration, execute PC-sam and select the option to “open the MONITOR SETUP window”. Select the “all temperatures” box at the lower left hand portion of the display.

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 are fragile and 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

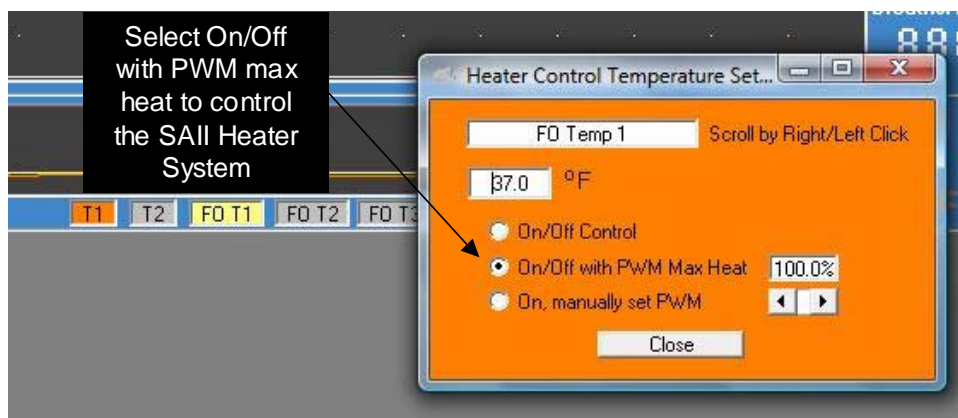


When the “all temperatures” selection is made in the MONITOR SETUP window, a row of buttons appears below the temperature trend in PC-sam’s main display. These buttons allow the user to select which temperatures are displayed in the trend and which current temperature is displayed in the digital display to the right of the trend. In the example above, both T1 and FOT1 have been selected and are present in the trend

Fiber Optic Temperature Module

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, set the set point value and to select the method of control. Use “On/Off with PWM Max Heat” to control the SA Instruments warm air Heater System. Refer to Chapter 7 for a detailed explanation of the Heater System.

The digital display on the Fiber Optic Temperature 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.

Fiber Optic Temperature Module

Chapter 15

Fiber Optic Pressure

Chapter 15

Fiber Optic Pressure

Overview

The Fiber Optic Pressure option for the Model 1025 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 a number of 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.

Fiber optic pressure sensors are not affected by the strong RF and magnetic fields of the MR scanner. They can not contribute to RF heating and they do not produce an artifact in MR images.

The Fiber Optic Pressure Module is located next to the magnet bore and near the Respiration or Respiration/IBP Module. A fiber optic pressure sensor extends into the bore and attaches to the animal. The module receives and sends data along with the Respiration/IBP and/or Pulse Oximeter and/or Fiber Optic Temperature Modules from and to the Control/Gating Module using fiber optic communication cables. It receives power from a dedicated supply.

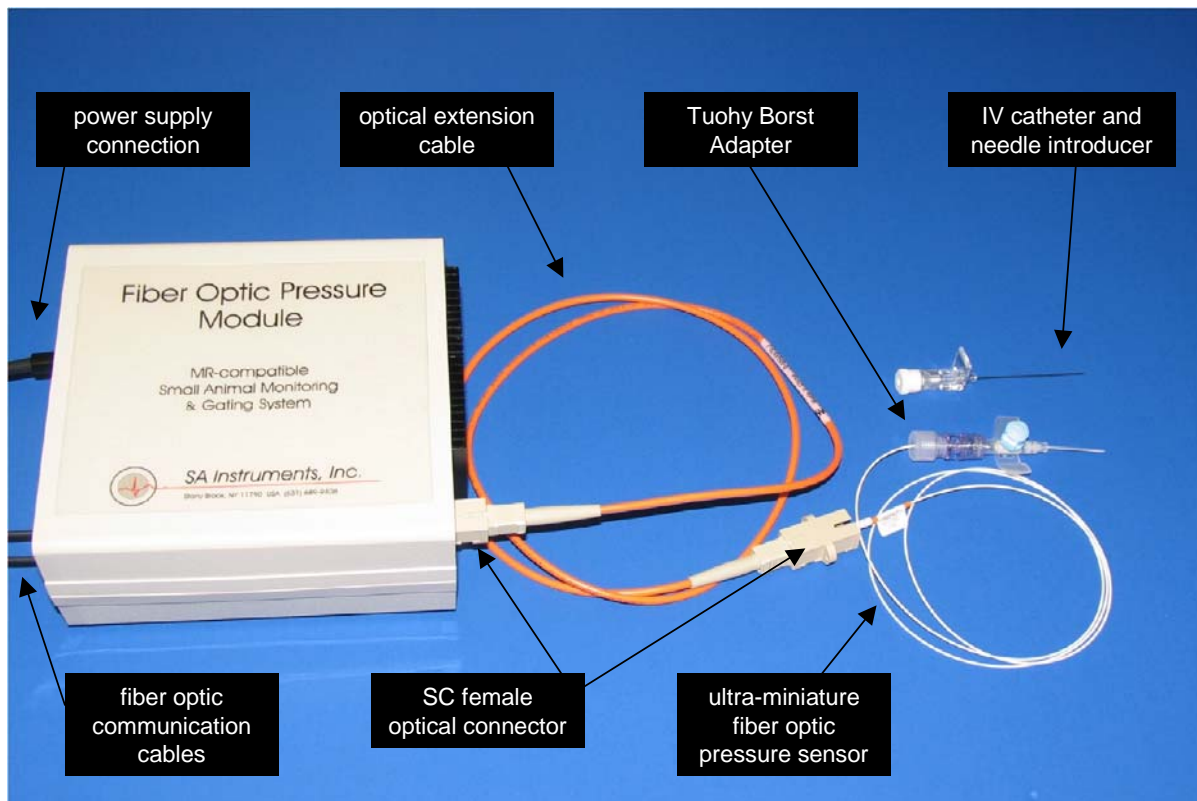
Sensor and extension connections

The pressure sensor connects to the module directly or 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.

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.

The fiber optic pressure sensor has a male SC connector that connects either to the port labeled “sensor” or to the extension cable’s female SC adapter.

Fiber Optic Pressure



Fiber optic communication cable connections

When the Fiber Optic Temperature and/or Oximeter and/or Fiber Optic Pressure Modules are not present, the Respiration Module connects to the Control/Gating Module using a duplex fiber optic communication cable. The duplex cable has a one blue and one gray connector on each end. At the Respiration Module, the blue and gray connectors plug into the two fiber optic ports. In all cases the color of the connector matches the color of the port.

When one or more additional modules are present, one of the fiber optic communication cables (it does not matter which one) is removed from the Respiration Module and connected to one of the additional modules and short simplex fiber optic cables are connected between each of the modules. In all cases, the color of the connector must match the color of the port.

Handling and cleaning fiber optic pressure sensors

The pressure sensors are 5' long with an 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. 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.



Fiber Optic Pressure

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.

Cleaning the SC female connectors

Clean the SC female connectors as follows:

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

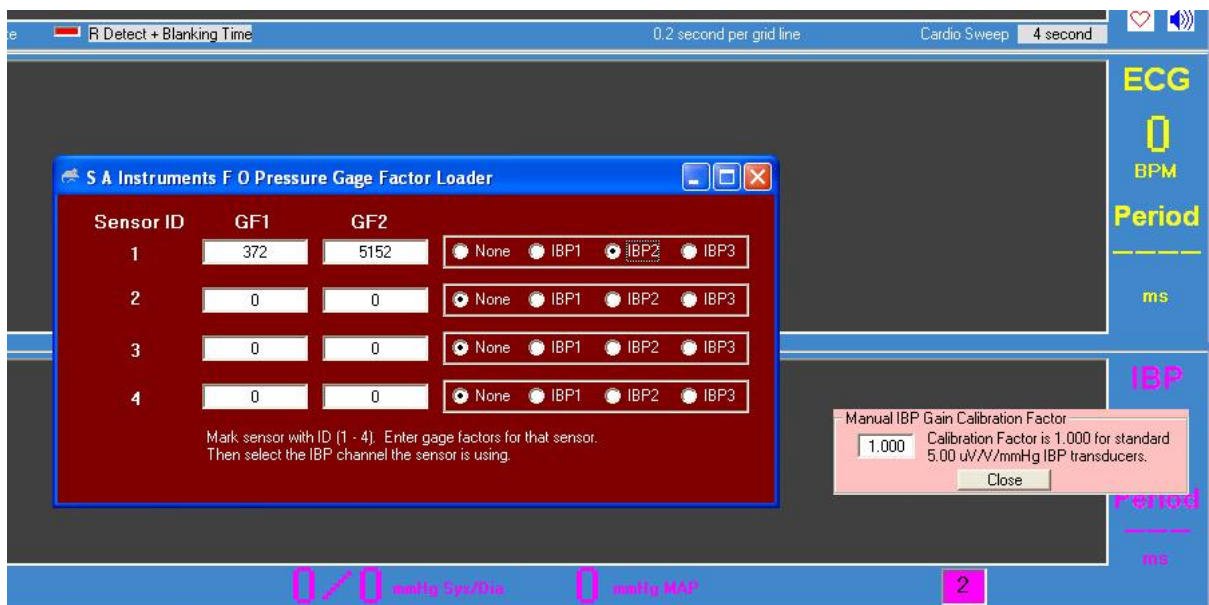
Fiber Optic Pressure

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.

Fiber Optic Pressure

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.

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

Fiber Optic Pressure

previous calibration parameters written to the EEPROM memory are automatically used to make the pressure measurement.

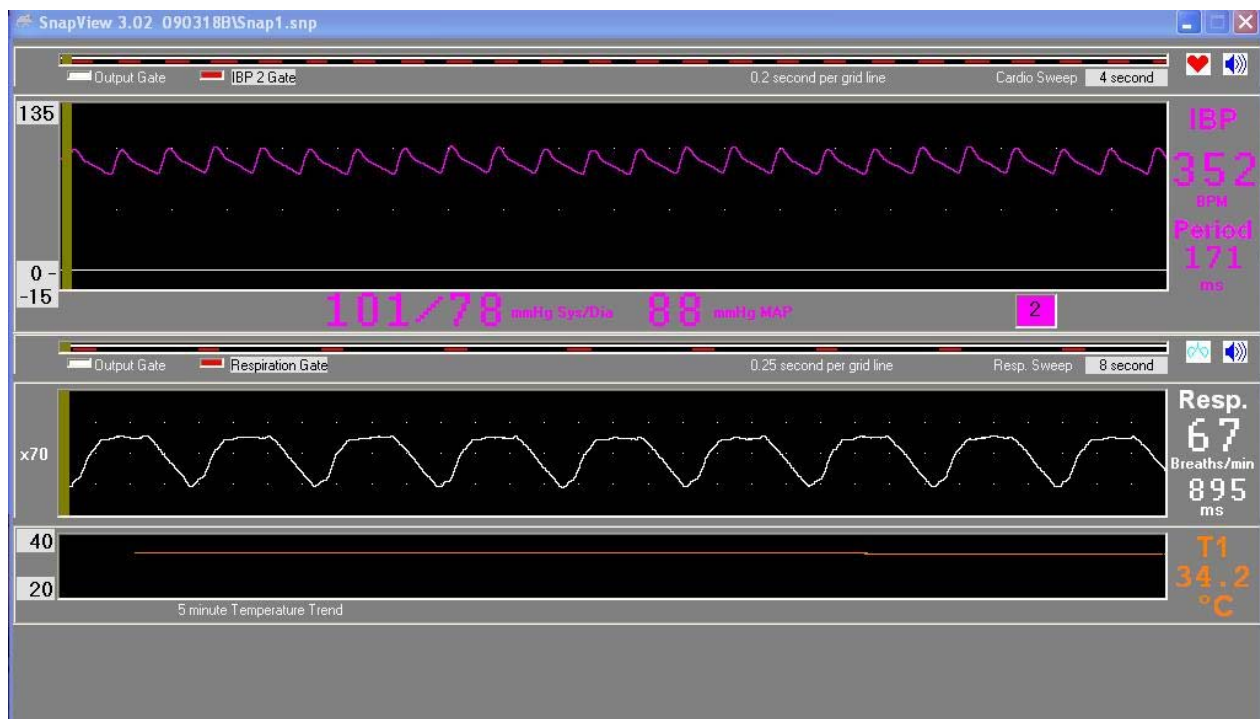
Inserting the fiber optic pressure sensor

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 below. 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.



Fiber Optic Pressure

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 gage 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 Trochy 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.

Fiber Optic Pressure

Chapter 16

Signal Breakout Module

Chapter 16

Signal Breakout Module

Overview

Physiological measurements and gates from the MR-compatible Model 1025 Monitoring and Gating System can be acquired by another data acquisition system or a PC using the Signal Breakout Module.

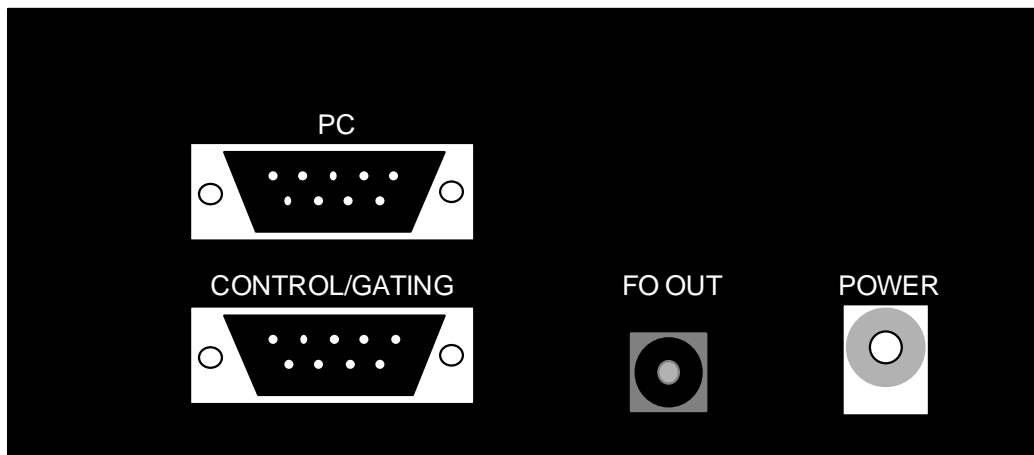
In order to maximize data transmission rate, SA Instrument's monitoring and gating systems send and receive densely packed data on the serial cable connecting between the Control/Gating Module and the PC. The Signal Breakout Module can be connected in the serial line to unpack the data and allow users 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.

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

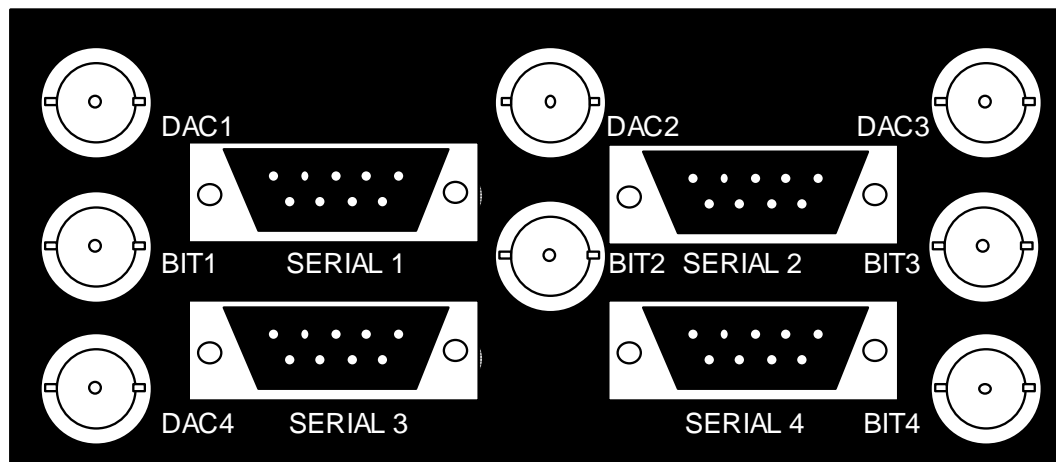


PC
Control/Gating
FO out
Power

Serial I/O connection to PC
Serial I/O connection to Control/Gating Module
Fiber optic connection for remote display
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

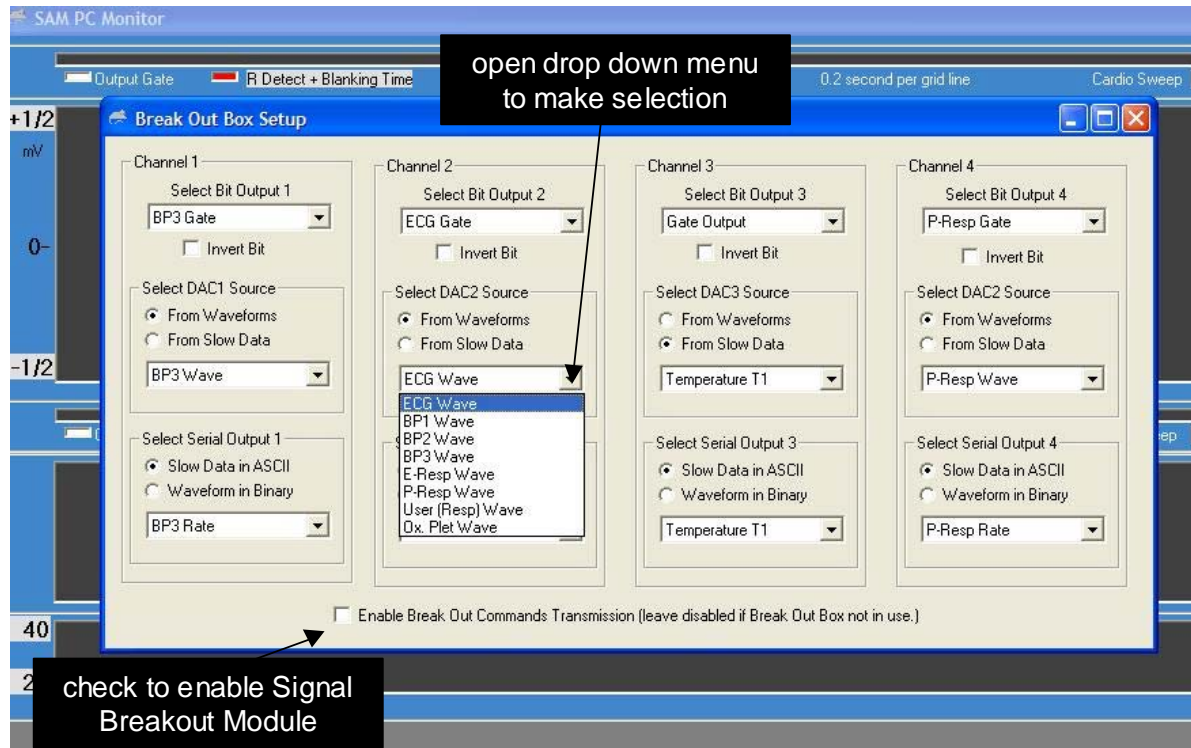
Setup and use

The Signal Breakout Module connects, using 9-pin D serial cables, to the PC and to the Control/Gating Module. It gets power either from a dedicated 12 VDC power supply or from the Control/Gating Module 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.

Signal Breakout Module



Capturing ASCII 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 waveform data from the serial output

Waveform data streams from the serial port at a rate of 1800 bytes per second. WaveGrab.exe can be used to capture the waveform data using a serial or USB PC port and write it as a text file. 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. You can set the com port, create a name for the text file, select the number of samples to collect and start or stop the capture process. Program status is displayed in a message box.

Signal Breakout Module

Chapter 17
Fiber Optic Universal Gating Module

Chapter 17

Fiber Optic Universal Gating Module

Overview

The Fiber Optic Universal Gating Module can be used to supply a gate pulse to imaging systems. It is always used to supply the gate pulse for clinical imaging systems. The module gets an input from the fiber optic AUX GATE OUTPUT of the Control/Gating Module. The fiber optic pulse is converted to both low level (2 mV) and high level (TTL) output pulses. The imager's ECG cable can be connected to ECG studs on the gating module to feed the low level gate to the imaging system. Alternatively, the high level gate can be obtained from the Module's BNC connection.

The module is non-magnetic and RF shielded, so when it is being used with a MR system it can be located in the magnet room. Power is supplied from an internal 9 V battery. The module has both power on and low battery indicator lights.

Controls and connections



Fiber Optic Universal Gating Module

Input	fiber optic gate light pulse
Output	2 mV pulse on RA, LA, RL, LL studs TTL pulse on BNC connector
Power switch	activates the 9 V internal battery, the power on and low battery LEDs

Setup and use

When used with a clinical MR system, the Fiber Optic Universal Gating Module is positioned near the patient gantry. A simplex fiber optic cable is connected between the Control/Gating Module's fiber optic AUX GATE output and the Universal Gating Module's fiber optic gate input. The Control/Gating Module is located outside and the Universal Gating Module is located inside the RF shielded room. So the simplex cable should pass through a wave guide installed in the room.

The optical gate signal is converted to an electrical signal by the Universal Gating Module. The electrical signal can be input to the clinical MR either by supplying the TTL signal to a gate input port (if available) or by supplying the 2 mV pulse to the scanner's clinical ECG cable. In either case, it maybe advantageous to change the gate width or invert the gate pulse using controls in PC-sam's GATING window.

Clinical scanners typically use both analog and digital filters to remove gradient interference from their ECG input. These filters necessarily add delay to the time the gate is received by the scanner. This delay can be quite large, a few 10s of msec. So, if a TTL gate input is available, it is preferred over input from the clinical ECG cable.

Caution: the 9 V battery should only be replaced with a battery obtained from SAll. Many 9 V batteries are magnetic and may be attracted by the MR magnet.

Chapter 18
Micro-Imaging MR Systems

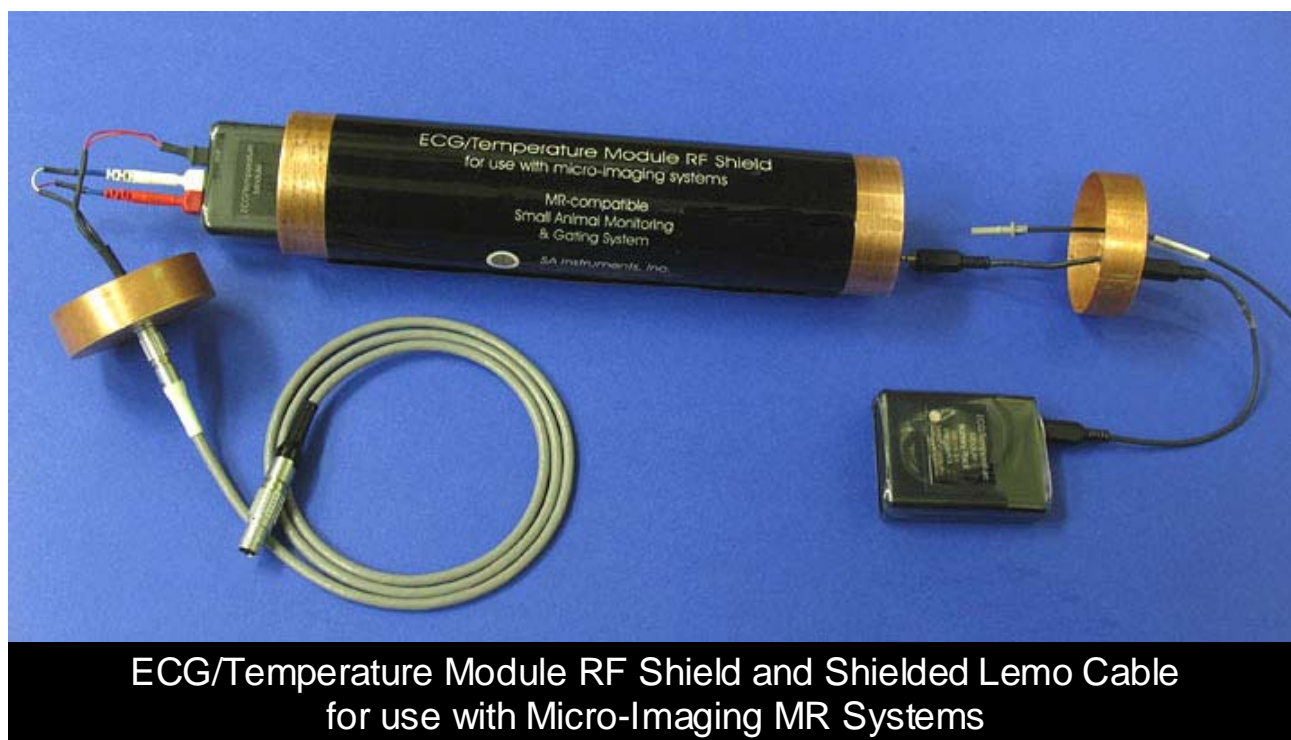
Chapter 18

Micro-Imaging MR Systems

Overview

Micro-imaging systems have a vertical bore with very limited space. A special “Micro-Imaging Kit” integrates the Model 1025 Monitoring and Gating System with these MR systems. The Micro-Imaging Kit effectively eliminates RF interference between the Micro-imaging MR system, the Model 1025’s ECG/Temperature Module and the external environment. The kit allows gated or ungated images free of RF artifact to be obtained while monitoring the physiological status of the mouse.

Micro-Imaging Kit



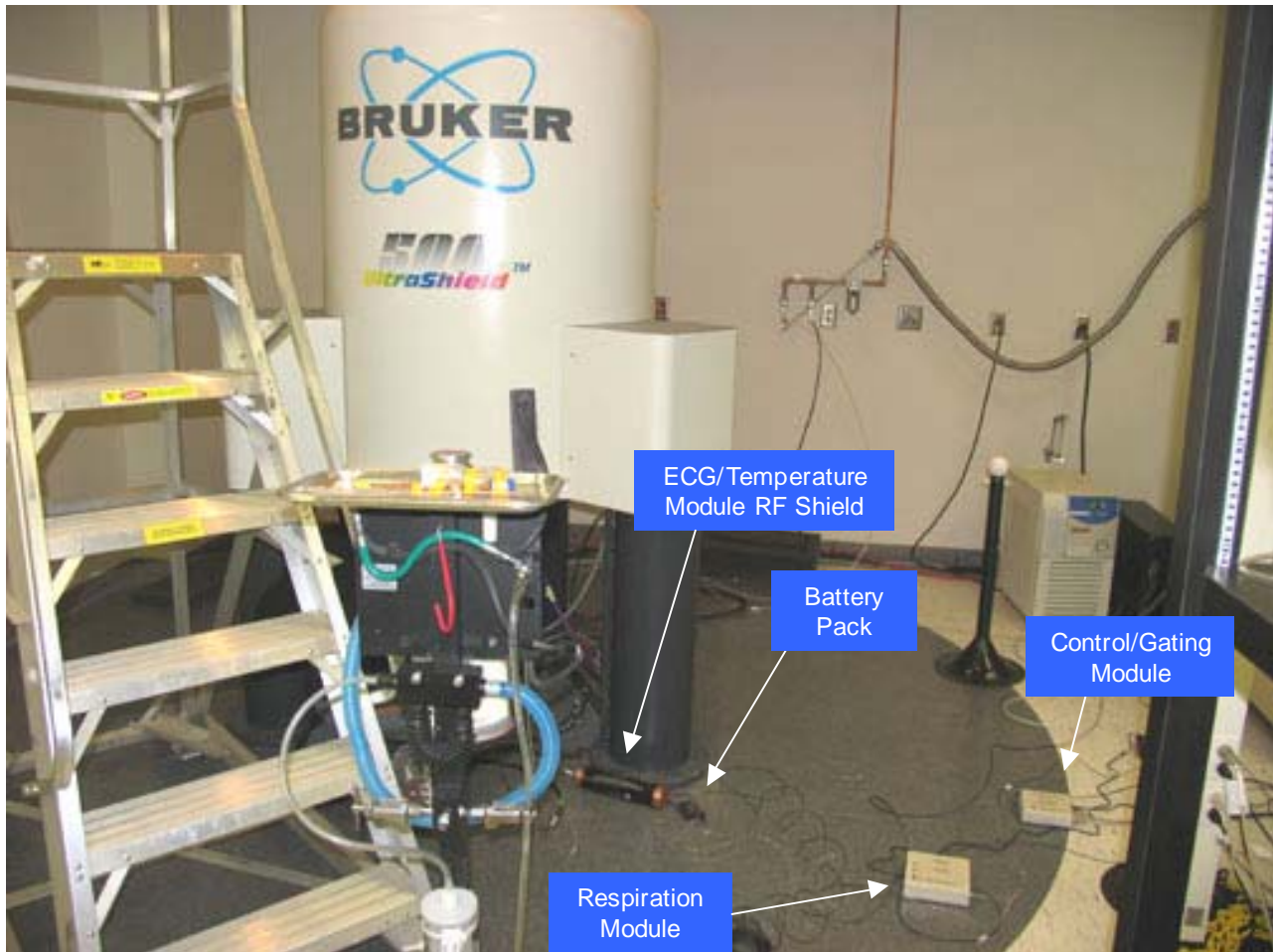
The Micro-Imaging Kit consists of an ECG/Temperature Module RF Shield, a shielded Lemo cable and an assortment of in-bore sensor and sensor extension cables.

The ECG/Temperature Module is placed inside the RF shield and connected to the Lemo cable, battery pack and fiber optic cable as shown in the picture above. The connection at the other end of the Lemo cable is connected to a Lemo receptacle mounted in the imaging probe.

The ECG/Temperature Module RF shield and shielded cable in effect place the ECG/Temperature Module inside the magnet’s RF shield allowing MR images to be free of RF induced interference from the external environment.

Micro-Imaging MR Systems

Micro-Imaging equipment setup

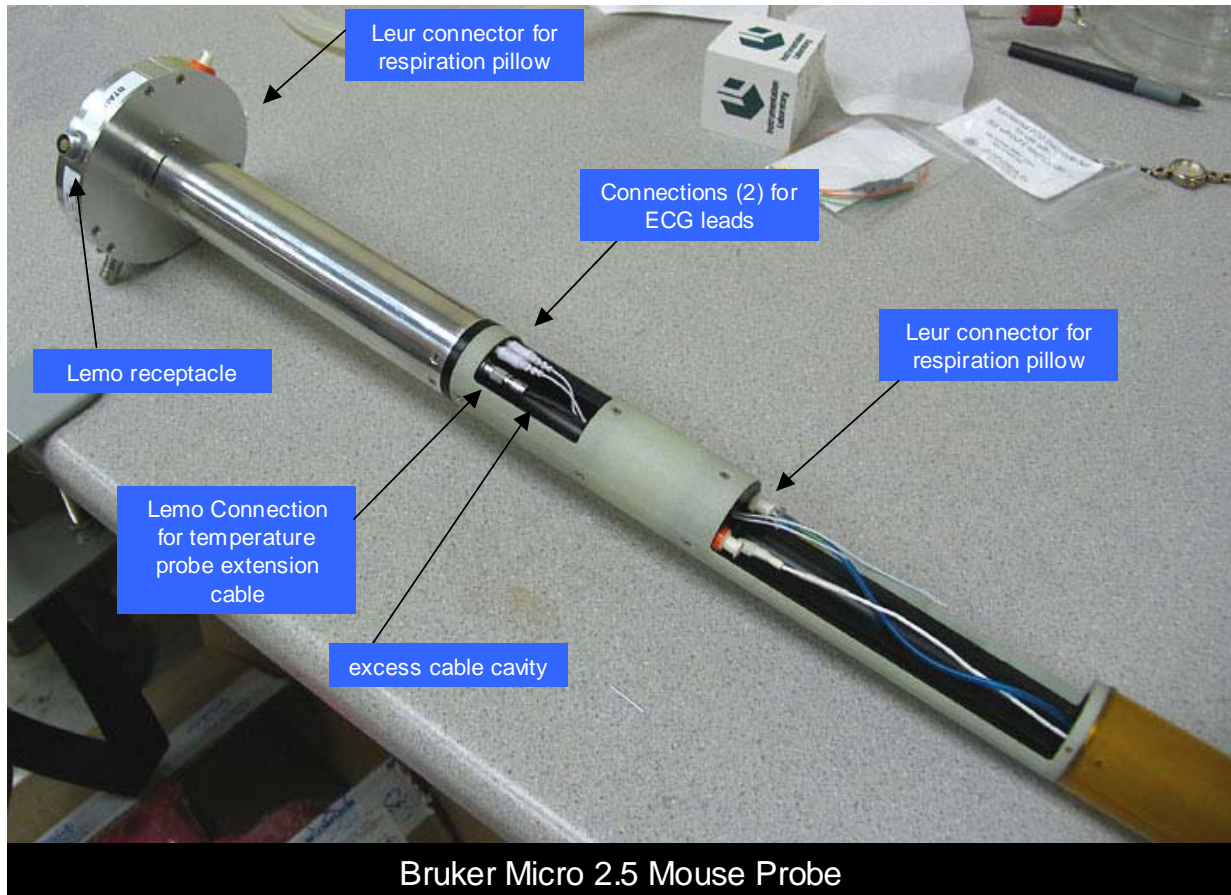


The equipment is implemented with the Micro-Imaging MR system as shown above.

The ECG/Temperature Module inside the ECG/Temperature Module RF Shield resides at any convenient location on the floor under the magnet. The Lemo cable connects the ECG/Temperature Module RF shield to the MR probe which is inserted in the magnet.

Respiration measurements using the pneumatic pillow are made by connecting extension tubing to the Respiration Module.

Bruker Micro 2.5 Mouse and Micro 2.5 AHS/RF Imaging Probes



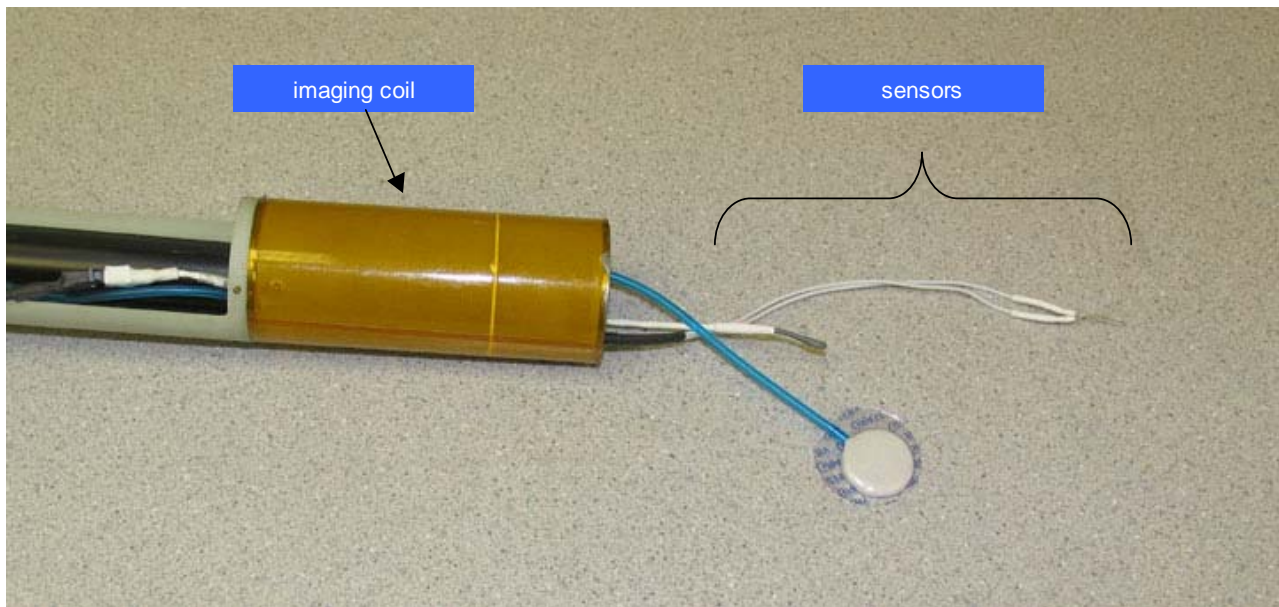
The Micro 2.5 Mouse probe is shown above with the Lemo and pneumatic respiration connectors mounted in the probe base.

Connections for ECG and temperature are made in the probe midsection. There are three ECG pins and a 3 pin Lemo receptacle in the midsection. A Lemo to Molex temperature extension cable (TPEC-110-10) connects to the Rectal Temperature probe (RTP-101-B). Two ECG pins closest to the 3-pin Lemo connect to either Subdermal ECG Needle Electrodes (RMEC-103-19), Gold Disk Electrodes (EGD-110-619) or 3M Red Dot electrodes (E3M-103-3). Note the ECG pin farthest from the 3-pin Lemo is not used. The respiration pillow sensor (RS-302-14) connects to the Leur connection inside the probe body.

Moving the ECG/Temperature Module RF Shield and Respiration Module with the probe allows physiological measurements to be observed during animal setup. After connecting the sensors to the internal probe connections, they can be extended through the coil in preparation for attachment to the mouse.

Micro-Imaging MR Systems

The temperature probe, ECG needle electrodes and rectal temperature probe are shown below in the extended position for connection to the mouse outside the imaging coil.



After connecting the sensors to the mouse and inserting the mouse into the coil, excess cable should be taped to eliminate a loop and placed in the cavity in the midsection. Likewise, excess pneumatic tubing should be placed in the cavity in front of the Leur connection. Be careful not to kink the pneumatic tubing.

The same set of sensors and temperature extension cable can be used with the Micro 2.5 AHS/RF probe.

Bruker Mini 0.5 AHS/RF Imaging Probe

The Mini 0.5 AHS/RF probe has the same connections for physiological monitoring as the Micro 2.5 probes. However, the Mini 0.5 probe is longer requiring the use of ECG (ETLEC-103-3), temperature (TPEC-109-3) and respiration (RSET-1/4) extension cables.

Micro-Imaging MR Systems

Bruker Micro-Imaging Kit Components

The following parts are supplied with the Bruker Micro-Imaging Kit (BMIK-110):

Part number	Description
ETS-110	ECG/Temperature Module RF Shield
ETCS-110	Cable, Shielded, Lemo 0B-1B, Micro-Imaging System
RMEC-103-19	Subdermal Needle Electrode set for mouse - 19"
EGD-110-619	Gold Disk Electrode set, 6mm – 19"
RS-302-14	Respiration Pillow Sensor – 14"
TPEC-110-10	Temperature Probe Extension Cable, Lemo – Molex – 10"
ETLEC-103-3	ECG Twisted Lead Extension set – 3"
RSET-1/4	Respiration Tubing Extension – 3"
TPEC-109-3	Temperature Probe Extension – 3"

Micro-Imaging MR Systems

Appendix A Specifications

ECG/Temperature:

ECG	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
Temp	Probe type	thermister, rectal
	Tip OD, mm	1.0
	Range	0 – 100 °C
	Accuracy	+/-0.2 °C, 10–70°C
Module	Power - battery	Rechargeable
	Battery life:	>15 hours
	Time to full charge	<2 hours
	Size: hxwx cm	2.1x5.1x14.0

Respiration/IBP:

Resp	Range	15 - 300 bpm
	Accuracy	1 count
IBP	Display range	0 – 300 mmHg
	Channels	3
Module	Auxiliary inputs	±5 V
	Power	+12 VDC & battery
	Battery life:	>8 hours
	Time to full charge	<3 hours
	Size: hxwx cm	4.2x15.8x15.0

Fiber Optic Temperature:

Temp	Probe type	fiber optic, rectal
	Tip OD, mm	1.0
	Range	20 – 60 °C
	Accuracy	+/-0.2 °C
Module	Power	12 VDC
	Number of channels	1 to 4
	Heater control	fiber optic PWM
	Size: hxwx cm	4.8x15.6x19.7

Specifications

Fiber Optic Pressure:

Temp	Probe type	fiber optic
	Tip OD, mm	0.4
	Range	0 – 300 mmHg
	Accuracy	1 count
Module	Power	12 VDC
	Number of channels	1 or 2
	Size: hxwxcm	3.8x13.3x12.5

Pulse Oximetry:

Rate	Range	40 - 900 BPM
	Accuracy	±1%
	Probe types	fiber optic
SpO₂	Range	0 – 100 %
	Accuracy	90 –100 ±2%
Module	Power	12 VDC
	Size: hxwxcm	3.8x13.3x12.5

Control/Gating:

Gating	R-wave to gate delay	selectable - 0 to 600 ms
	Expiration gate width and delay	selectable - 1 ms
		step size
Temp	Heater control	fiber optic PWM
	Size: hxwxcm	3.8x13.3x12.5

Heater System:

Heater	Heater control	fiber optic PWM
	power	115 – 230 VAC
	Size: hxwxcm	16.4x8.9x26.0
Fan	power	115 – 230 VAC
	Size: hxwxcm	6.4x18.0x18.4

PC requirements:

Software:	Windows	95, 98, NT, 2000, XP, Vista, 7
Hardware:		>1 GHz processor
		Serial or USB port* & CD
		Display resolution 1024 x 768 pixels or greater

Appendix B

System Components and Accessories

Part No.	Description
M1025OP-rev	Operation Manual, Model 1025 SAM & Gating System
M1025PCS-rev	PC-SAM Software CD
1025-CASE	Storage Case Model 1025 System
710100-xx-rev	ECG/Temp Module, 50 or 60 Hz
ETBP-108	ECG/Temp Module Battery Pack
BPC-110	ECG/Temp Module Battery Pack Cable
25SFOC-23	Simplex Fiber Optic Cable, 25 m
RMEC-103-10C	Subdermal ECG Needle Electrode set for mouse with cradle
RMEC-103-4	Subdermal ECG Needle Electrode set for mouse without cradle
RMEC-103-12C	Subdermal ECG Needle Electrode set for rat with cradle
RMEC-103-6	Subdermal ECG Needle Electrode set for rat without cradle
RMEC-104-10	Subdermal ECG Needle Electrode set for rabbit without cradle
EBS-103	Blue sensor pediatric electrode pads, 3/pack
E3M-103-3	ECG 3M Red Dot neonatal electrodes 3/pack
EGD-103-1012	Gold Disk Electrodes 10mm - Set
EGD-103-612	Gold Disk Electrodes 6mm - Set
EGEL-103	Electrode Gel
ETLEC-103-36	ECG twisted lead set 36"
RC-107-SM	E-resp Cradle-Small Mouse
RC-107-LM	E-resp Cradle Large Mouse
RC-107-RAT	E-resp Cradle-Rat
RTP-101-B	Rectal Temperature Probe - 7" (use with 710100 RevB)
RTP-103-B	Rectal Temperature Probe for rabbit
TPEC-109-7	Temperature Probe Extension Cable - 7"
TPEC-109-12	Temperature Probe Extension Cable - 12"
TPEC-109-36	Temperature Probe Extension Cable - 36"
TPC-200	Temperature probe covers
720100-rev	Control/Gating Module
CGIC-201	Control/Gating Module Serial Interface Cable
USB-20	USB to Serial Adapter Cable
PS-2-12	Power Supply, 12V
PSLC-2-E	Line Cord 230 VAC Europe
PSLC-2	Line Cord 115 VAC
730100-rev	Respiration Module
25DFOC-23	Duplex Fiber Optic Cable, 25 m
PS-2-12	Power Supply, 12V
PSLC-2-E	Line Cord 230 VAC Europe
PSLC-2-	Line Cord 115 VAC

Appendix B: System Components and Accessories

Part No.	Description
RS-301	Respiration Pillow Sensor
RSET-3	Respiration Extension Tubing 1 m
RSET-8	Respiration Extension Tubing 2.7 m
731100-rev	Respiration/IBP Module
IBPX-A	IBP Transducer Abbott Transpac IV
750100-rev	Simulator
SEL-105	Simulator ECG Leads
STC-105	Simulator Temperature Cable
M9001	MR-compatible Small Animal Heater System
761100-rev	Heater Module 115 VAC
760100-rev	Heater Module 230 VAC
771100-rev	Fan Module 115 VAC
770100-rev	Fan Module 230 VAC
FAH-20	Fan Air Hose 7 m
WAH-5	Warm Air Hose 1.6 m
CUF-2	Cuff, Heater Hose
HOS-x	Heater Hose (x feet long)
M92001	FORT Module (fiber optic receive/transmit conversion)
UGM-100	Universal Gating Module
15SFOC-23	Simplex Fiber Optic Cable, 15 m
740100	External ECG/Temperature Module Battery Pack Charger
910100-rev	3 Lead ECG/Temperature Module
RMEC-703-4	3 Lead ECG Needle Electrode Set for Mouse
RMEC-703-6	3 Lead ECG Needle Electrode Set for Rat
RMEC-703-10	3 Lead ECG Needle Electrode Set for Rabbit
EGD-705-612	3 Lead Gold Disk Electrode set, 6 mm
EGD-703-1012	3 Lead Gold Disk Electrode set, 10 mm
ETLEC-703-36	3 Lead ECG Twisted Lead Extension Cable 36" Long
810100	Fiber Optic Temperature Module
FOTS-5	Fiber Optic Temperature Sensor, 5 feet
580100	Pulse Oximeter Module
570100	Fiber Optic Clip Sensor, Large, 5 feet
560100	Fiber Optic Clip Sensor, Small, 5 feet
550100	Fiber Optic Mouse Tail/Ankle sensor, 5 feet
DCPC-2	Daisy Chain Power Cable, 2 modules
430100	Signal Breakout Module
830100	Fiber Optic Pressure Module
FOTS-5-PH-B	Fiber Optic Pressure Sensor, 0.4 mm OD

Appendix C Troubleshooting

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.	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.	No communication to the ECG/T Module	Check power to the ECG/T Module. Turn power switch off and on look for red light in the fiber optic driver.	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	11-1 4-1
ECG waveform but no heart rate display	R-detect parameters incorrect	Set correct values	3-9
Excessive artifacts on ECG without scanning	Movement of leads in magnet bore	Check for vibration or air flow. Tape leads or ECG/T module	4-2
Excessive artifacts on ECG while scanning	Movement of leads or module in magnet bore	Check for vibration. Tape leads & ECG/T module to restrain motion	4-2

Troubleshooting

Problem	Possible Cause	Corrective Action	See
Heater system has cold air blowing from the heater tube.	Wrong set point.	Check that the set point is greater than the measured temperature	7-4
Heater system has cold air blowing from the heater tube.	Power is not on.	Check power to the Heater Module. A green LED indicates power. Check AC connection.	7-1
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 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	7-1 7-3
No gate detected by MR scanner	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
No gate detected by MR scanner	Improper switch setting on Control/Gating Module.	Check for the presence of trigger output to the scanner (white dots in Cardio Sweep display). If trigger indication is present check gate output pulse signal characteristic switch setting is appropriate for the MR scanner.	3-2 3-5

ECG/T communication error

This error means the Control/Gating Module is not receiving valid data from the ECG/T Module. It can occur for one of the following reasons:

1. battery is discharged
2. faulty connection of the Battery Pack Cable at the Battery Pack or at the Module
3. fiber optic signal is not getting to the Control/Gating Module

The **Battery Pack voltage** can be checked with a digital volt meter or by connecting it to the Respiration Module's internal battery charger. If connecting to the Resp Module, open the CHARGER window and read the voltage on the last line. A fully charged battery be > 6.5V it will stop operating the module when it is less than 5.8 V. We issue the low voltage error message when the battery's voltage reached 6.0 V.

If the battery is OK, **test the ECG/Temperature Module's Battery Pack and cable** by holding the ECG/Temperature Module and Battery Pack with one hand so that the Battery Pack connections are visible. Connect the Battery Pack Cable with the other hand and observe red light in the module's fiber optic port. Gently move the cable at each connection. Any interruption of light from the fiber optic port would indicate a potential short in the cable or connections.

Check the fiber optic signal by observing the red light at the fiber optic driver on the ECG/T Module. Connect the fiber optic cable to the module and observe red light on the other end of the fiber. Connect the fiber to the Control/Gating Module at the port labeled ECG/TEMP. If the communication error persists, check for lint or blockage inside the ECG/TEMP port on the Control/Gating Module and or try another fiber optic cable (one of the fibers from the Respiration Module can be used for troubleshooting).

Check communication between the PC and Control/Gating Module

With the system running and with red bars for "R-detect + blanking time" open the R-detect setup window (right click on the ECG waveform display) and change the wave feature detection from "positive peak" to "negative peak". Within 2 seconds the red bars should disappear. Switch back to "positive peak" and in 2 seconds or less the red bars should again be displayed.

Determine if other features of the system are working? When pressing on the pillow, do you get red bars indicating inspiration (when the signal dips)? If you click the invert pulse box for respiration in the GATING SETUP window does the red bar switch to the expiration portion of the waveform (flat portion between the dips)? Since the ECG and respiration detection is performed by the Control/Gating Module, a response 1 to 2 seconds to changes in parameters from the PC is a test that communication is working.

Troubleshooting

No heat from heater

If the 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 Control/Gating Module. If the above are all true, and there is no red light, the problem must be a communication problem between the PC and Control/Gating Module. The problem has nothing to do with the Heater Module. It is confined to the PC, the Control/Gating Module and the cable between the two units.

If there is a red light then check the following:

1. Power is applied to the 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 SAIL’s Customer Service.

Low heat from heater

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

Using the 1.5 m tube from the 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 ECG/T module can be used to measure the temperature.

You can pretty well tell what the control electronics in the 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 thermistors located at the inlet and outlet of the 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.

Troubleshooting

Look inside the holes of the Heater Module. You will see a thermister at each end. The thermisters should stand erect and not be bent against the heat chamber. If the 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 Heater Module.

Gating Setup when large artifacts are present in the ECG waveform

The most common artifact in the ECG waveform is generated by vibrations of the ECG leads due to activation of the pulsed gradients during MR system data acquisition. When the MR scanner acquires imaging data, pulsed gradients are activated which generates acoustic noise, movement of the gradient insert and corresponding movement of the ECG leads. Vibration or movement of the ECG leads in the presence of the strong static magnetic field creates artifacts on the ECG waveform.

Many factors contribute to the size and extent of vibration artifacts on the ECG waveform. High field strength, long lead length, leads that are not taped and close coupling of the animal to the gradient insert all make vibration artifacts more extensive. However, in many cases it is not necessary to minimize the effects of vibration. It is usually possible to create accurate and reliable triggers even with the presence of large artifacts on the ECG waveform.

Follow these steps to generate accurate gating when large artifacts are present:

1. When the scanner is not acquiring data, check that each R-wave is detected and that no false gates are generated. i.e make certain a red dot (ECG gate) is present for each R-wave and that there are no extra red dots in the Cardio Sweep display. If this is not the case, adjust the R-detect parameters according to Chapter 3 of the Operation Manual.
2. Set the blanking time to 90% of the R-R interval. Note the R-R interval is displayed below the heart rate. Right clicking the ECG display will open the R-DETECT SETUP window.
3. Run a gated scan with the total slice acquisition time at least 20 msec less than the animal's R-R interval. It maybe useful to initially run a single slice scan to observe the effect of gradient vibrations on the ECG waveform. As you increase the number of slices, you will observe an increase in the width of the artifact following the trigger generated by the R-wave. Note that 5 to 10 msec are required for the vibrations to damp after the pulsed gradients are turned off. If

Troubleshooting

the total slice acquisition time is too long, a false trigger will be generated at the end of the blanking time.

As an example, consider the case of a cine field echo sequence run on an animal with a heart rate of 600 beats per minute (R-R interval of 100msec). Setting the blanking time to 90 msec will accommodate an arrhythmia rate of up to 10%. If the single slice acquisition time is 10 msec, then 8 slices can be acquired each at a different phase in the cardiac cycle. Note that if 9 slices are attempted, false gates will occur, as the vibrations ring down after the end of the blanking time, and the images will not be accurately gated.

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.

Charge the ECG/Temp Battery Pack when the system is not in use. The battery pack can be left attached to the charger after it is fully charged. There is no requirement to deep discharge the battery before charging.

Charge the battery in the Respiration/IBP Module when the system is not in use. The charger is internal to the module. The internal charger automatically charges the internal battery when the Respiration/IBP Module is connected to 12 VDC power.

Routine Maintenance

Appendix E

Sample Waveforms

This appendix presents the following waveform examples collected in the MR environment:

1. Mouse outside the MR magnet
2. Mouse with E-Resp™ cradle in 7.0 T
3. Mouse with E-Resp™ cradle in 7.0 T, ECG and respiratory gated spin echo sequence
4. Mouse without E-Resp™ cradle in 9.4 T, ECG and respiratory gated cine sequence
5. Rabbit in 4.7 T, ECG gated field echo sequence

Examples 1 and 2 exhibit how important temperature is on the physiology of the mouse and the effect of the strong static magnetic field on the ECG waveform.

Examples 1 and 2 were acquired with the same mouse and the same preparation. Example 2 was acquired thirty minutes after example 1. In that length of time the temperature of the mouse, which was not being regulated, dropped nearly 5 °C. With the drop in temperature the heart rate also decreased from 473 to 302 BPM.

Comparison of the ECG waveforms shows the signal contributions from flowing blood and from respiration. In this case we increased the respiration signal by intentionally coupling one of the ECG leads to the mouse's abdomen using an E-Resp™ cradle.

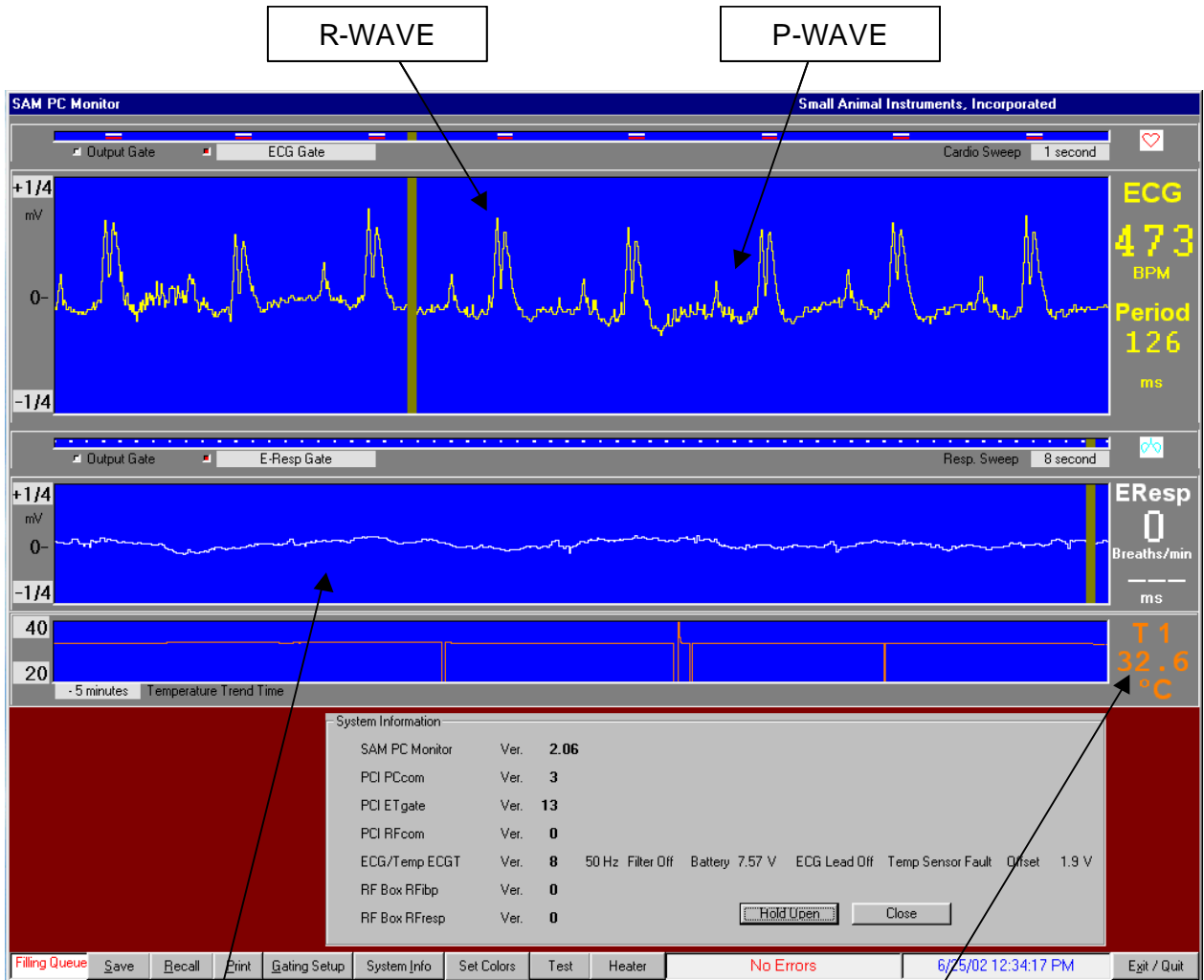
Example 3 shows us how to interpret scanner operation by observing the ECG waveform. Gradient interference is observed after each gate and we can clearly see the data acquisition time intervals for each slice in the sequence.

Example 4 shows ECG and respiratory gating during expiration. It also shows the correlation between E-Resp™ and P-Resp and that an E-Resp™ signal can be obtained without a cradle at high field.

Example 5 exhibits it is often beneficial to set R-detect parameters before the animal is inserted into the magnet. This is especially true with larger animals where flow artifacts can be relatively large.

Sample Waveforms

Mouse outside the MR magnet



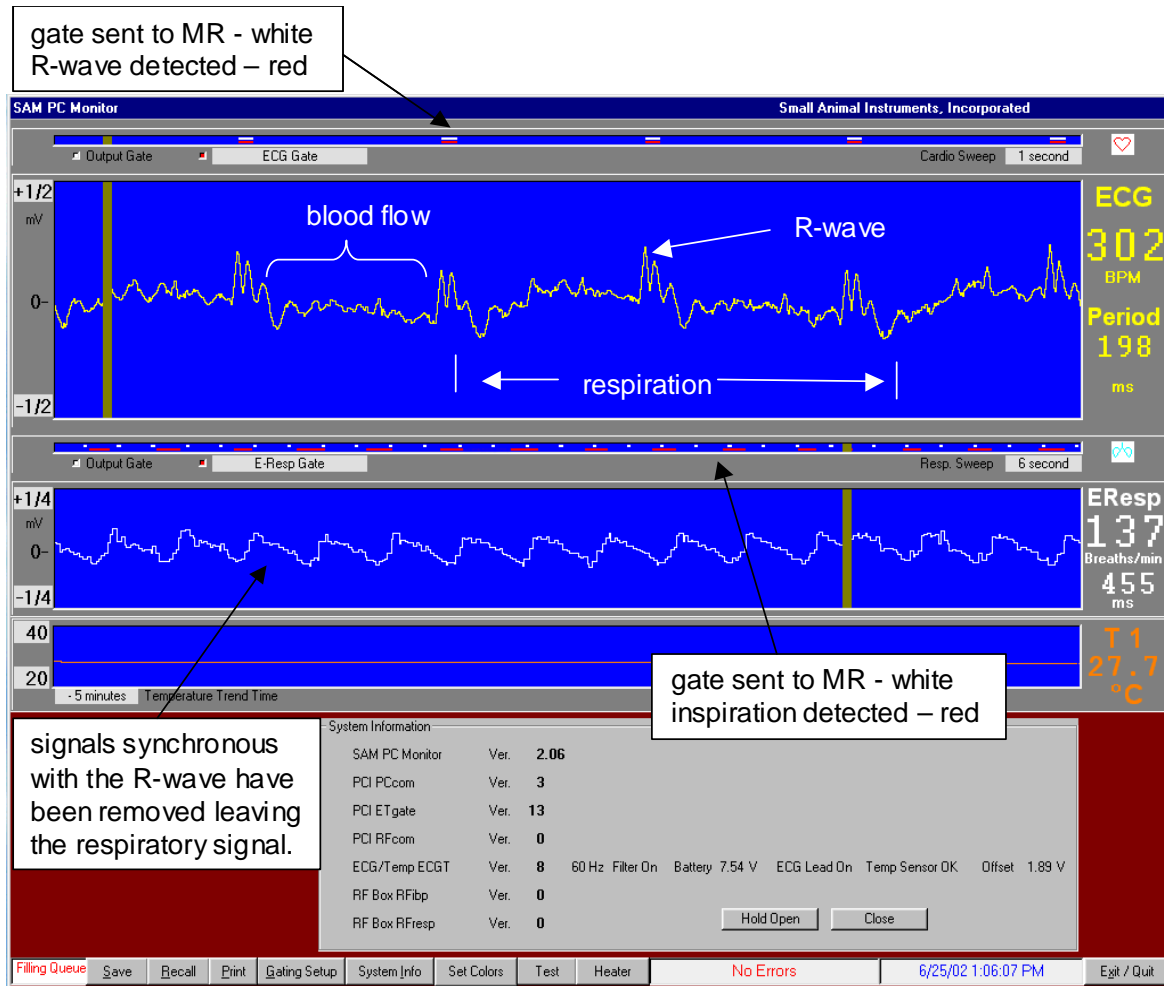
Note: the absence of an E-Resp™ respiratory signal outside the magnetic field

Note: the low temperature of the mouse results in a somewhat low heart rate.

The ECG waveform was obtained with sub-dermal right arm and left leg electrodes. The measured waveform does not contain signal contributions from respiration or blood flow outside the magnet.

Sample Waveforms

Mouse with E-Resp™ cradle in 7.0 T field



The measured ECG waveform has signals superimposed from respiration and blood flow. After the heart contracts (after the R-wave), flowing blood, which is ionic or charged, moving in the strong static magnetic field creates a signal synchronous with the R-wave (i.e. it is reproducible each heart beat).

The R-wave and other signals synchronous with the R-wave are removed from the measured ECG waveform to give the E-Resp™ waveform. Note because the sweeps are different, respiration in the ECG waveform appears compressed in the respiratory waveform.

Output gates are generated for each R-wave because ECG was selected as the only condition for the gating algorithm.

Sample Waveforms

Mouse with E-Resp™ cradle in 7.0 T MR ECG & respiratory gated spin echo sequence



This example, which does not show the best way to make gated images, is a good example of observing MR scanner operation from interference in the ECG waveform.

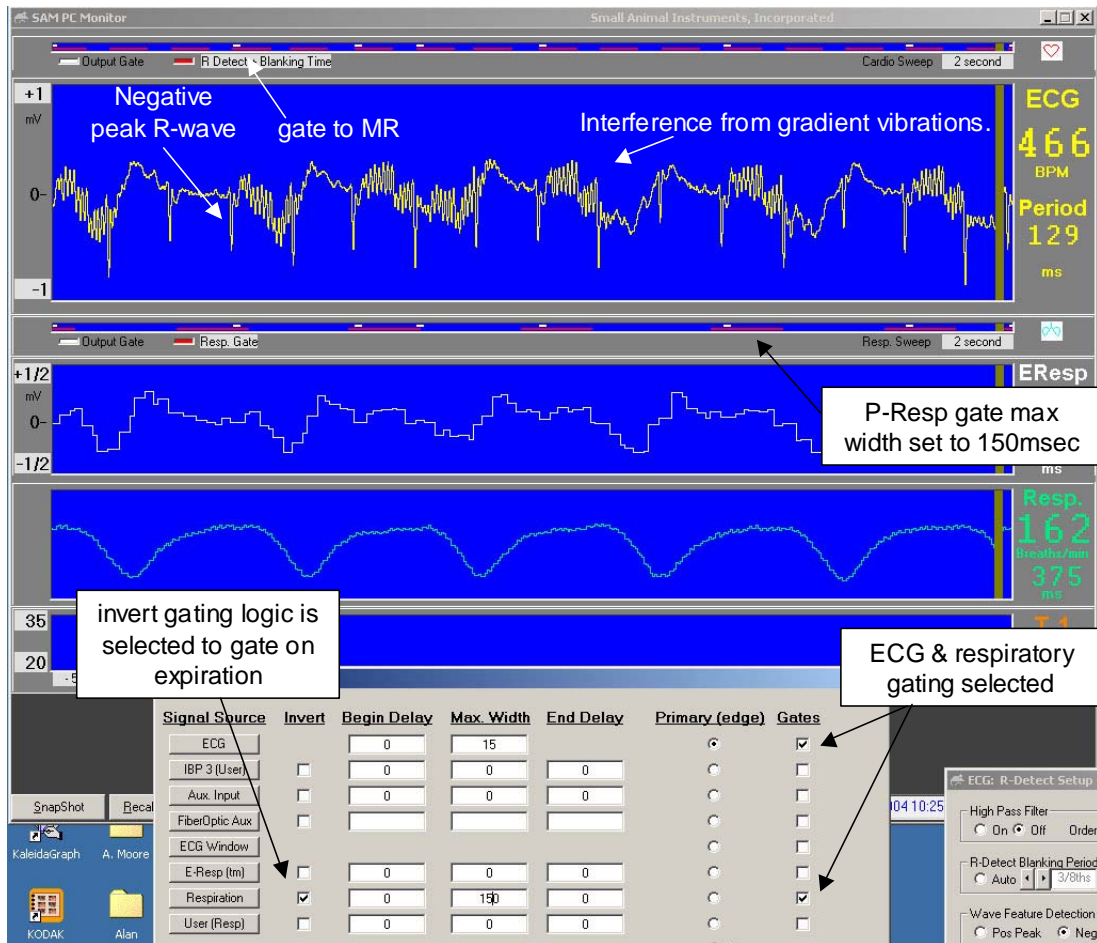
The measured ECG waveform has signals superimposed from respiration, blood flow and pulsed magnetic field gradients.

A gate for the MR scanner is generated by the first R-wave after detection of inspiration. The gate initiates MR scanner data acquisition for three images (slices). The gradient interference for a single slice lasts about 50 msec and the acquisition time between images is 130 msec. It is easy to conclude, from gradient interference present in the ECG waveform, that three images are being acquired during the respiratory cycle but not during the same cardiac cycle.

Note sometimes R-waves do not fall inside (coincide with) the inspiration window and therefore gates are not sent to the MR scanner.

Sample Waveforms

Mouse without E-Resp™ cradle in 9.4 T ECG and respiratory gated cine sequence

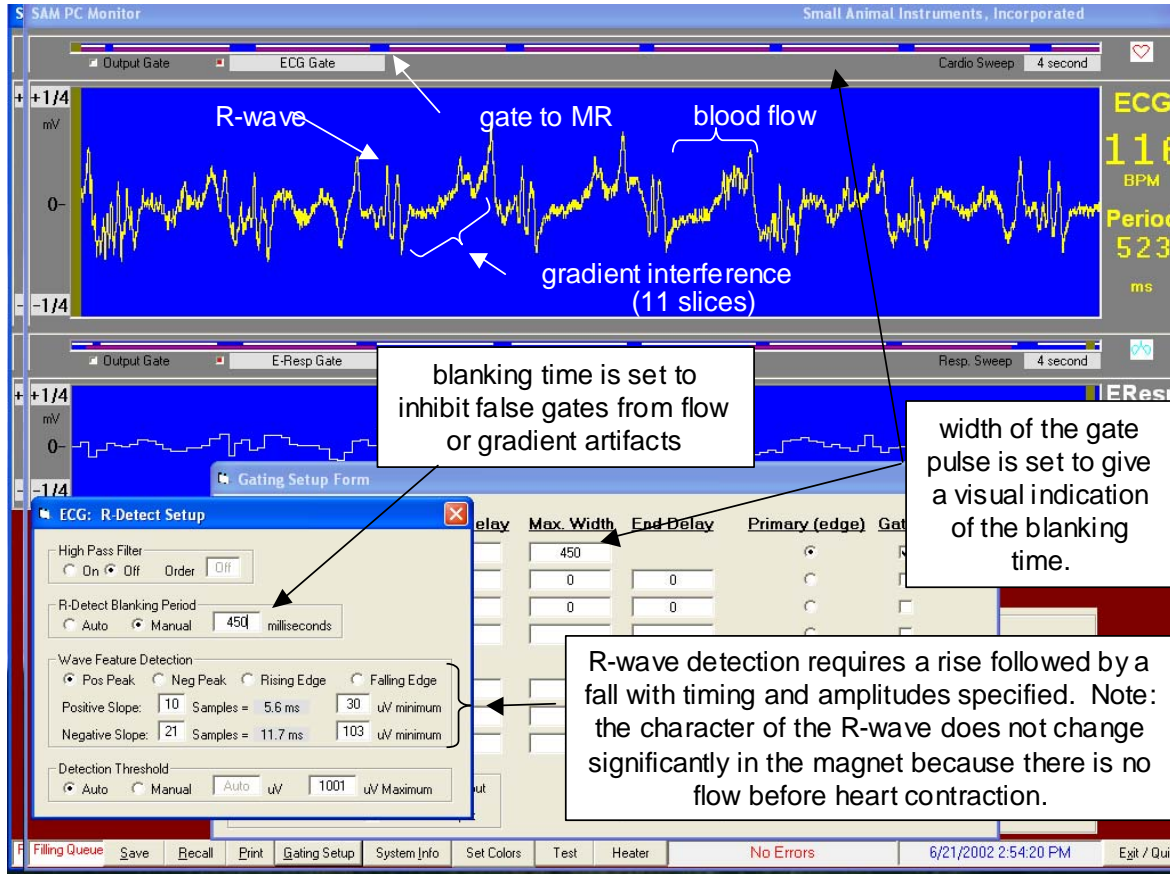


The measured ECG waveform has signals superimposed from respiration, blood flow and pulsed magnetic field gradients. The cardiac and respiratory sweep rates are the same, so it is easy to see the respiratory signal in the ECG waveform. An cradle was not used. Both E-Resp™ and P-Resp waveforms dip at inspiration. The P-Resp gate logic is inverted, displayed in the Resp sweep gate display and used with ECG gates to generate output gates to the MR. Note that a gate is sent to the MR only when the R-wave coincides with expiration.

As can be seen from the gradient interference in the ECG waveform, data acquisition following each gate is very nearly the R to R interval. However, the interference is not too large and R-detect parameters have been effectively set to discriminate between the R-wave and interference. Each R-wave is detected and there are no false triggers. If the interference had been larger, it could have been necessary to reduce the acquisition time and set the blanking time slightly longer than the acquisition time to eliminate false triggers.

Sample Waveforms

Rabbit in 4.7 T MR ECG gated field echo sequence



The ECG waveform was obtained with sub-dermal electrodes in the chest on either side of the heart. The measured ECG waveform has signals superimposed from blood flow and pulsed magnetic field gradients. Temperature and respiration were not measured.

In this example, blood flow artifacts in the magnet were very large making recognition of the R-wave very difficult. The R-wave is the stimulus that causes the heart to beat. Thus, the heart is stationary during the R-wave and blood flow occurs after the appearance of the R-wave. Blood flow only produces an artifact in the presence of a strong static field. Therefore it is beneficial to observe the R-wave and adjust detection parameters before placing the rabbit in the magnet.

In this example, blanking time is effectively used to block false gates. A visual indication of blanking time could also be made by selecting "R-detect + blanking time" from the cardio sweep gate selections (click on the gray box to rotate through selections).

Appendix F

Warranty, service and support

Warranty 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.