TRITON TECHNOLOGY, INC.

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INTRODUCTION

This manual describes both the function and the operating procedures for the System 6 Mainframe Chassis. The Mainframe Chassis includes everything on the instrument itself except the plug-in instrument modules. As additional module types are installed, a separate manual for each will be supplied for inclusion in this binder.

ORGANIZATION

Section 1 covers the function of the System 6 and describes the various modules available for it. This section also provides information concerning the warranty and shipping requirements, should the System 6 need repair or service.

Section 2 provides safety instructions that should be read prior to using the System 6.

Section 3 describes and cross-references each Mainframe control, indicator, and connector, to a number located on a panel illustration.

Section 4 provides information on synchronization options which make it possible to use the system with other instruments such as electromagnetic flowmeters, without interference.

The Index provides easy access to information in the body of this manual (the manuals for each module type have their own indexes).

The Appendix provides in depth information pertaining to application of the instruments.

1. SYSTEM 6

1.1 FUNCTION

The Model 200, or System 6 Mainframe, houses Triton's physiological monitoring instruments. Its modular configuration allows maximum flexibility in designing instrument configurations for varied experimental protocols. Module types that are currently available include the Sonomicrometer, the Pulsed Doppler Flowmeter, the Dual Blood Pressure Amplifier, the Blood Pressure and dP/dt Amplifier, and the Doppler Displacement module. Installing these various modules makes it possible to simultaneously measure cardiac or blood vessel dimensions, bloodflow velocity, blood pressure, dP/dt, and electrograms. In addition, System 6 synchronizes with external Sonomicrometers, Pulsed Doppler Flowmeters, and Electromagnetic Flowmeters and thus can be linked with existing instruments to accomplish various protocols.

1.2 MODULE DESCRIPTIONS

The Sonomicrometer module is an ultrasonic instrument used to measure the time it takes for a sound burst to travel between a pair of small transducers implanted in the myocardium. This time span is a measure of the distance between the two transducers.

The Pulsed Doppler Flowmeter module uses ultrasonic sound bursts to measure the velocity of blood cells flowing through a region in a blood vessel.

The Dual Blood Pressure Amplifier module contains two identical channels for exciting a bridge-type transducer. This module amplifies, filters, and offsets the pressure signal to a level suitable for driving a recorder. In addition, this module will balance the transducer bridge and provide a pressure calibration reference.

The Blood Pressure and dP/dt Amplifier module consists of a single pressure amplifier identical to the Dual Pressure unit. In addition, it has a differentiator to generate the derivative of the pressure signal and a dP/dt calibrator.

The Doppler Displacement module uses a single transducer attached to the myocardium to monitor wall thickening displacements. Bursts of ultrasound are sent through the myocardium to measure thickening velocity. The velocity of the wall thickening is integrated to form a displacement signal. The module includes a displacement calibrator.

1.3 WARRANTY SERVICE--PACKING FOR SHIPMENT

If the System 6 should need repair or service, contact Triton Technology for instructions. The user should not attempt to repair the system as this will void any and all warranties. If the original container is not available, contact Triton Technology for an appropriate shipping container. Please use the following guidelines when returning an instrument:

1. **CALL TRITON TECHNOLOGY FOR A RETURN MERCHANDISE AUTHORIZATION**
   All equipment returns for warranty service must be accompanied by a Return Merchandise Authorization (RMA) number from Triton Technology. Place the RMA number on all paperwork and on the outside of the shipping container.

2. **PACK THE INSTRUMENT IN THE ORIGINAL CARTON**
   Ship the System 6 in the original custom-foamed, double-walled, re-usable carton. Wrap the System 6 in plastic prior to placing in the foamed container. If returning only a module, wrap in plastic and then pack it in a sturdy carton with at least 3" of foam or Styrofoam bead packing material on all sides.

3. **DESCRIBE THE PROBLEM AND NAME A CONTACT PERSON**
   Please enclose in the packing carton a detailed description of the problem. Also, include the name and phone number of a person familiar with the problem whom Triton can contact.

4. **INSURE THE SHIPMENT**
   Please remember to insure all shipments at replacement value.

5. Ship to Triton Technology, Inc.

   Sample Shipping Label:

> **Triton Technology, Inc.**
> **RMA number _____**
> **4616 Santa Fe Street**
> **San Diego, CA 92109**
> **USA**

1.4 PHYSICAL CHARACTERISTICS FOR SHIPPING

The System 6 Mainframe Chassis shipping weight is 42 pounds when packed in the standard 24x24x16-inch double-walled foamed shipping container. Add three pounds to the shipping weight for each installed module. The International "Volume Weight" is 54 pounds based on the standard container dimensions.

2. PREPARATION FOR USE

2.1 SAFETY INSTRUCTIONS

BEFORE CONNECTING THE INSTRUMENT TO A POWER SOURCE, CAREFULLY READ AND FOLLOW THESE SAFETY PRECAUTIONS

- **DO NOT OPERATE IN EXPLOSIVE ATMOSPHERE**
  To avoid explosion, do not operate the System 6 in an explosive atmosphere.

- **DO NOT INSTALL OR REMOVE MODULES WITH THE POWER ON**
  Always turn the power switch off (located on the rear panel of the Mainframe Chassis) before installing or removing any of the modules.

- **DO NOT REMOVE COVERS OR PANELS**
  To avoid personal injury, do not remove the covers or panels. Also, do not operate the system without the covers and panels properly installed. High voltages are developed within some chassis modules.

- **ALLOW ADEQUATE VENTILATION**
  The mainframe chassis is convection cooled with the rear panel of the chassis acting as part of the power supply heat sink. Therefore, allow at least 2 inches of free space from both the top and the back of the chassis. (It is normal for the upper part of the rear panel to feel warm due to heat conducted from the power supply heat sink.)

- **POWER SOURCE**
  The System 6 is intended to operate from a line voltage less than 250 volts AC. The system can be configured to run on 100, 120, 220 or 240 VAC, 50/60 Hz.

- **GROUNDING THE PRODUCT**
  The System 6 is grounded through a three-wire grounding conductor in the power cord.

- **DANGER ARISING FROM LOSS OF GROUND**
  Upon loss of the protective ground connection, all accessible conductive parts (including knobs and controls that appear to be insulated) may render an electrical shock.

- **POWER CORD**
  Use only the power cord and connector specified for the System 6. A three-wire power cord with a three-contact plug for USA 120 VAC is provided with each instrument to permit connection to both the power source and protective ground. To prevent electrical shock, insert this plug only into a power outlet that has a protective ground contact.

- **LINE FUSE**
  To avoid fire hazard, use only a fuseMain of the correct type, voltage rating, and current rating for the line voltage selected.

- **ANIMAL SAFETY**
  When measuring EKGs, always connect the reference ground to the animal from EKG REF on the Mainframe Chassis rear panel. The animal should not be otherwise grounded. Disconnect EKG REF from the animal when not in use.

2.2 AC POWER AND FUSEMAIN SELECTION

The System 6 is set for the line voltage in the country where it was shipped; changes should not be necessary. If, however, the instrument will be used in a different country or for any reason the AC power source needs to be changed, it will be necessary to first adjust the voltage selection card on the fuse block and possibly change the fuse. Use the following procedure to complete this task.

1. DETERMINE LOCAL LINE VOLTAGE
The instrument can operate at input voltages of 100 V, 120 V, 220 V, or 240 V nominal and at line frequencies from 50 Hz to 60 Hz.

2. OPEN FUSE COMPARTMENT
As illustrated in **Figure 1**, remove the power cord and slide the clear plastic window on the fuse block to the left. This exposes the fuse compartment.

3. REMOVE OLD FUSE
As illustrated in **Figure 2**, pull the small plastic lever labeled FUSE PULL to remove the fuse.

4. RE-ORIENT LINE-VOLTAGE-SELECT CARD IN FUSE BLOCK
*NOTE: The line-voltage-select card is pressed tightly into place. A fair amount of force is required to pull the card out. As shown in **Figure 3**, the card has four orientations.*

a) Pull the card out with a pair of needle nose pliers or a small wire hook inserted into the hole on the card.

b) Replace the card oriented for the voltage you require. The selected voltage will be legible face-up as the card is inserted.

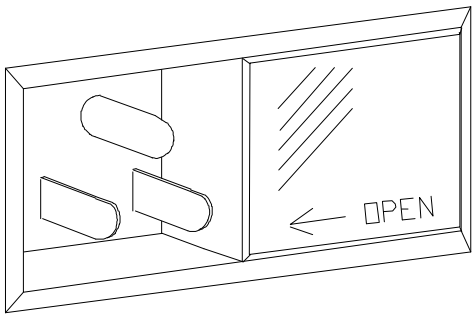

Figure 1 Remove Power Cord and Open Fuse Window

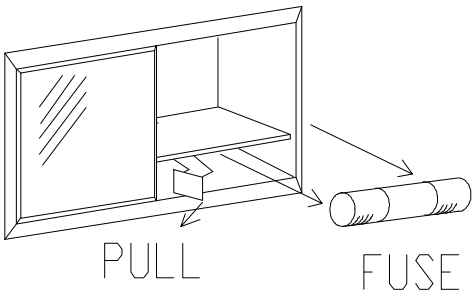

Figure 2 Remove Fuse

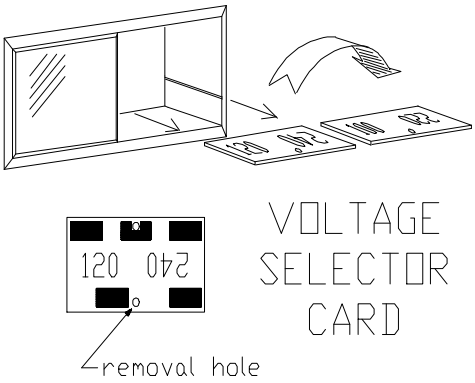

Figure 3 Select Line Voltage

5. INSERT NEW FUSE

a) Select the proper fuse from **Table 1 (page 7)**.

b) Push the plastic lever back in.

c) Snap the fuse into the fuse holder.

d) Slide the clear plastic cover over the fuse compartment and replace the power cord.

LINE VOLTAGE	FUSE RATING
100/120 VAC	1.5 Amp 3AG SLO BLOW
220/240 VAC	0.75 Amp 3AG SLO BLOW

Table 1 AC Fuse Ratings

2.3 INTERNAL POWER SUPPLY FUSE REPLACEMENT

All voltages from the System 6 power supply are fused internally, and the fuses are located on the power supply circuit board. If it is suspected that a power supply fuse has blown, contact Triton for additional information before replacing power supply fuses, as a blown fuse may indicate an internal problem. Use the instructions below and **Table 2** to identify and replace the fuse.

WARNING:
Turn power supply switch off and remove power supply cord before replacing internal fuses.

TO REPLACE POWER SUPPLY BOARD FUSES:

1. Remove the top cover which is held in place by five black Phillips-head screws.

2. The supply board lies in the upper rear corner of the chassis. The fuses are located along the top edge of the board and are labeled F1-F5. See **Table 2**.

3. Replace the blown fuse(s) with new ones and re-install the top cover.

All fuses are on the power supply circuit board USE ONLY 5 X 20 mm FAST-ACTING 250 V FUSES		
SUPPLY	FUSE NUMBER	FUSE RATING
33 VAC	F1	1.0 Amp
33 VAC	F2	1.0 Amp
+15 VDC	F3	2.0 Amp
15 VDC	F4	1.0 Amp
+5 VDC	F5	3.0 Amp

Table 2 DC Power Supply Fuse Ratings

3. MAINFRAME CHASSIS

3.1 FUNCTION

The Mainframe Chassis provides power, timing, and control to the six physiological monitoring modules. Along with these functions, the Mainframe Chassis also displays Sonomicrometer calibration distance, Doppler Flowmeter range, and pulsatile amplitude flow. In addition, signal output and external synchronization connectors are located on the Mainframe Chassis rear panel. The audio flow signal is also amplified in the Mainframe Chassis for both the front panel speaker and the rear panel stereo headphone jack. **Figures 4** and **4** on **pages 10** and **10** show the front and rear views of a typically configured System 6.

- **MODULE POWER**
  The Mainframe Chassis supplies ground, +5 VDC, +/-15 VDC and 33 VAC power from the internal AC power supply to all six module slots. In addition, each module case is grounded to the Mainframe Chassis through a banana jack on the module back.

- **TIMING**
  All timing is derived from a 60 MHz oscillator on the Mainframe Chassis mother board. signals for modules and other equipment are also generated on the motherboard. See the Section on OPTIONAL SYNCHRONIZATION *(page 22)* for more information.

- **CONTROL**
  It is possible to simultaneously collect data from all the modules. However, only one Sonomicrometer and one Doppler Flowmeter channel can be monitored on the Mainframe front panel displays at a time. The SONO CHANNEL SELECTOR SWITCH selects which Sonomicrometer channel is to be displayed while the FLOW CHANNEL SELECTOR SWITCH selects which Doppler Flow channel is to be displayed.

- **DISPLAY**
  Three LED displays on the Mainframe Chassis front panel are used to calibrate and operate the Sonomicrometer and Doppler Flowmeter modules:
  - Sonomicrometer calibration distance (3 digit LED)
  - Pulsed Doppler Flowmeter range setting (2 digit LED)
  - Pulsatile flow (20 LED bargraph - 10 red, 10 green)

- **OUTPUTS**
  The output signals for the modules are available on the back panel. There are six vertical columns of connectors, a column for each module. The connectors are marked with Sonomicrometer and Pulsed Doppler Flowmeter output references but they may, in fact, have different functions depending on the type of module installed. See the section on REAR PANEL MODULE OUTPUTS *(page 19)* for more information.

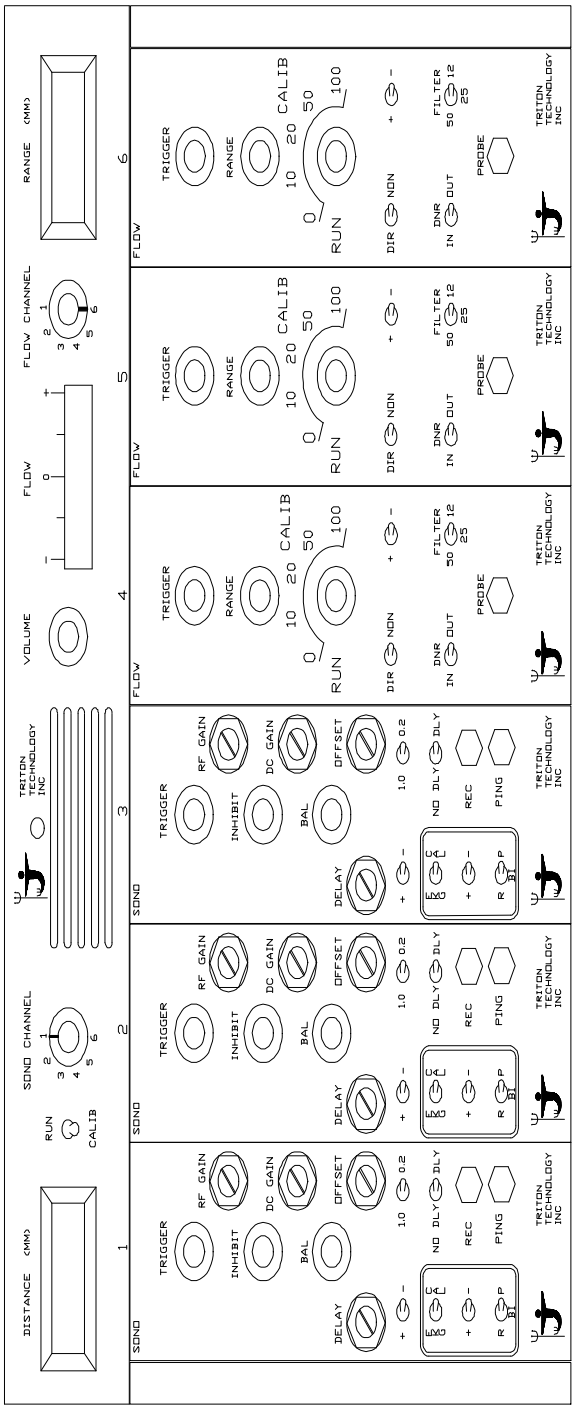

Figure 4 System 6 Front View

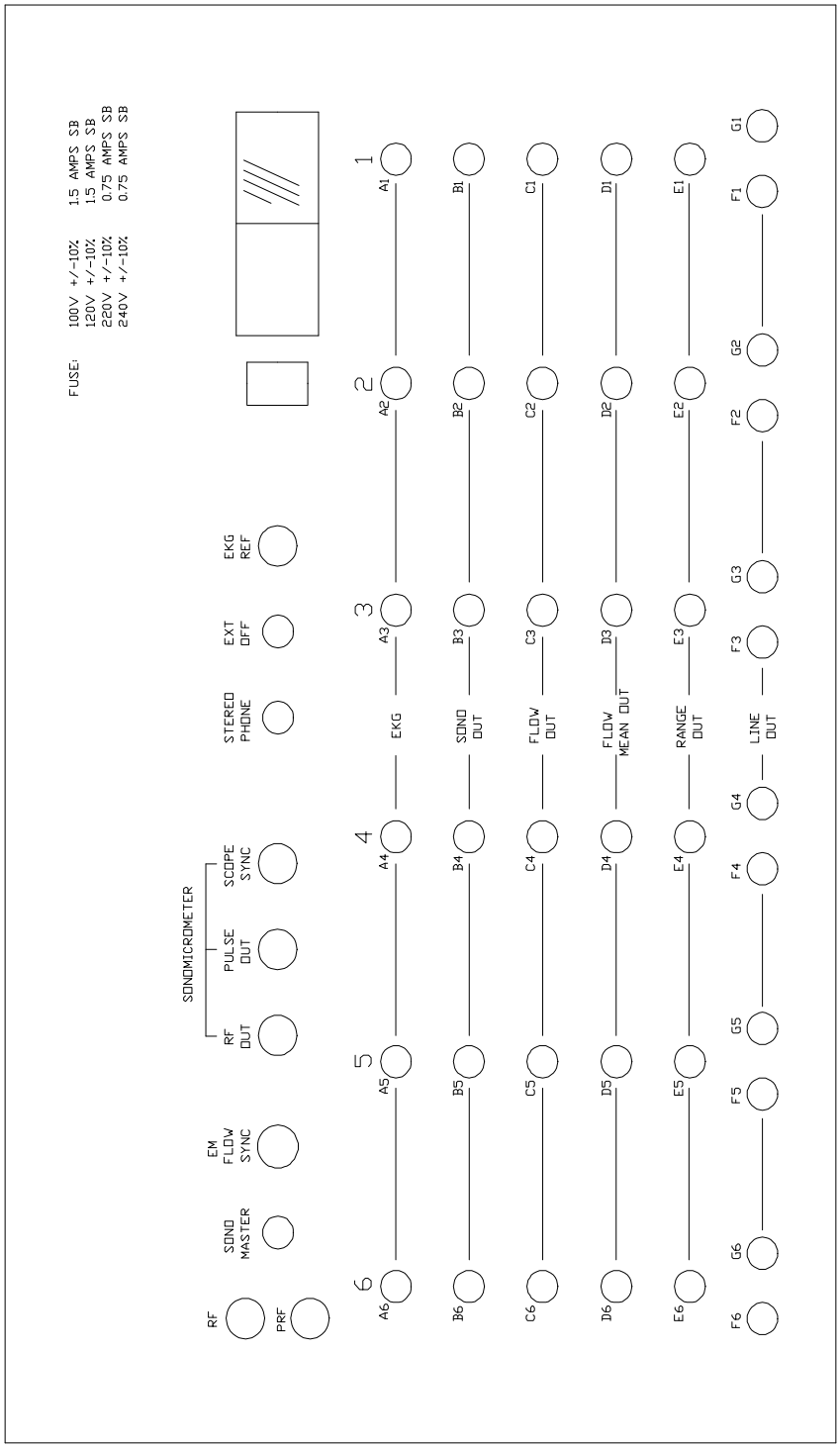

Figure 5 System 6 Rear View

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3.2 SPECIFICATIONS

DIMENSIONS - 24"H x 19"W x 15"D (61.0 x 48.3 x 38.1)cm
(standard 19" rack mount)

WEIGHT - 34 lbs (15.5 Kg)
Plus 3 lbs (1.4 Kg) per module

ENCLOSURE MATERIAL - BLACK ANODIZED ALUMINUM

MODULE SLOTS - SIX

POWER REQUIREMENTS - POWER SUPPLY CONFORMS TO INTERNATIONAL STANDARDS

LINE VOLTAGE RATINGS
(VAC ±10% @ 50-60 Hz):

100, 120

VAC - 1.5 A max

220, 240

VAC - 0.75 A max

SYNCHRONIZATION - FOR Model 100 FLOWMETER

RF -

20 MHz (TTL)

PRF -

31.25 KHz (TTL)

FOR Model 120 SONOMICROMETER

1302 Hz, +/-

15 V NOMINAL

FOR EM FLOWMETER

(VARIES, D

EPENDS ON FLOWMETER)

FOR NMR (NUCLEAR MAGNETIC RESONANCE)
GROUND SIGNAL FROM NMR TURNS SYSTEM CLOCK OFF IN THE SYSTEM 6

SYSTEM CLOCK - 60 MHz *(TTL oscillator)*

3.3 SYSTEM INTERCONNECTIONS

connectionsconnector types

FUNCTION	CONNECTOR TYPE
POWER	INTERNATIONAL 3-PRONG
EKG	PHONE JACK *
SONO OUT	PHONE JACK *
FLOW OUT	PHONE JACK *
MEAN OUT	PHONE JACK *
RANGE OUT	PHONE JACK *
LINE A OUT	PHONE JACK *
LINE B OUT	PHONE JACK *
SONO MASTER	PHONE JACK *
EM FLOW SYNC	STEREO PHONE JACK
STEREO PHONE	STEREO PHONE JACK
EXT OFF	PHONE JACK *
EKG REF	SINGLE BANANA JACK
SCOPE SYNC	BNC
RF OUT	BNC
PULSE OUT	BNC
20 MHz OUT	BNC
31.25 KHz OUT	BNC

** All phone jacks are standard 1/4" dia.*
(TIP=Signal, RING and SLEEVE=Gnd)

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3.4 FRONT PANEL CONTROLS

*The number preceding each item corresponds to its location on the MAINFRAME CHASSIS FRONT PANEL illustration (Figure **Error! Bookmark not defined.**, page **Error! Bookmark not defined.**).*

1 **DISTANCE (MM)**
A 3-digit LED displays the selected Sonomicrometer channel's calibration step in 1 mm or 0.2 mm steps and is used to calibrate the Sonomicrometer analog outputs on a chart recorder, data acquisition system, etc.

2 **RUN/CALIB**
In RUN mode, the Sonomicrometer produces dimension signals at SONO OUT.

In CALIB mode, the Sonomicrometer module generates a voltage at SONO OUT that steps with the INHIBIT control position. The INHIBIT control varies the calibration distance in 1 or 0.2 millimeter steps. This calibration voltage is in units of *volts per millimeter*. The DC GAIN control varies the voltage change per calibration step, and the OFFSET controls the output DC offset voltage.

3 **SONO CHANNEL**
The SONO CHANNEL selector determines which Sonomicrometer module sends its information to the DISTANCE display in the CALIB mode and to the back panel Sonomicrometer oscilloscope connectors: RF OUT, PULSE OUT, and SCOPE SYNC.

4 **POWER ON LAMP**
This red LED should be on whenever the power switch is on.

5 **SPEAKER**
The SPEAKER monitors the audio signals from the selected Doppler Flowmeter module. Plugging a stereo headphone into the rear panel headphone jack disables the SPEAKER.

6 **VOLUME**
The VOLUME controls the loudness of the audio Doppler signals from the selected flowmeter module. It controls the signal amplitude sent to both the SPEAKER and the STEREO PHONE jack. Plugging a stereo headphone into the rear panel phone jack disables the SPEAKER.

7 **FLOW (BAR-GRAPH DISPLAY)**
The pulsatile blood FLOW signal is displayed on the front panel with a horizontal LED bar graph display. Positive flow causes the green segments on the right-hand side to light. Negative flow causes the red segments on the left-hand side to light. Directional/Non-directional and polarity are controlled on the PDFM module by the DIR/NON and +/- switches. This display is active in both the RUN and the CALIB modes.

8 **FLOW CHANNEL**
The FLOW CHANNEL switch selects which Doppler Flowmeter channel is currently being monitored. Even though all modules operate simultaneously, only the selected module sends its information to the front panel displays.

9 **RANGE (MM)**

A 3-digit LED display displays the sampling RANGE of the selected Doppler Flowmeter channel. The RANGE is displayed in 0.5 mm steps. The maximum range depends on the ultrasonic frequency of the PDFM module selected: 20 MHz - up to 5.5 mm, 10 MHz - up to 11 mm, 5 MHz - up to 22 mm.

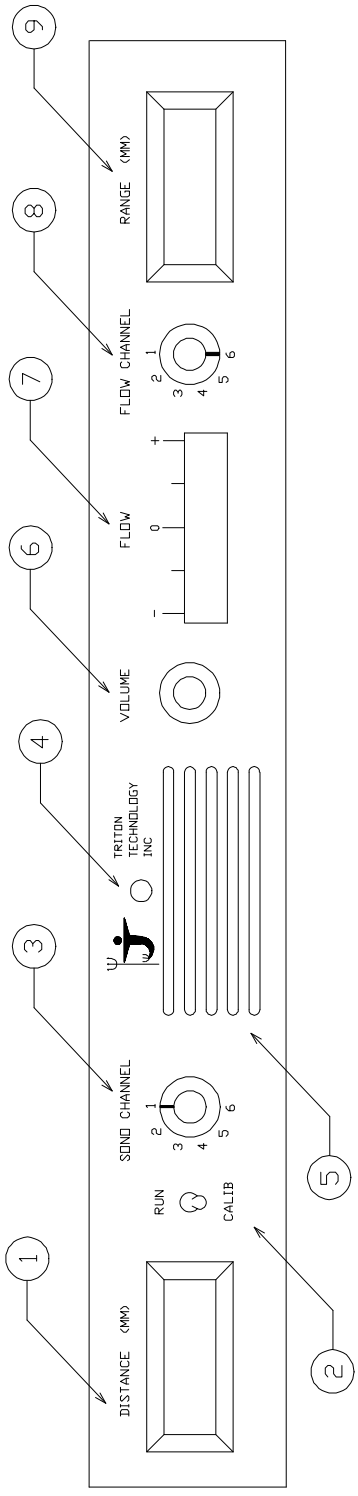

Figure 6 MAINFRAME CHASSIS FRONT PANEL

3.5 REAR PANEL CONTROLS & CONNECTIONS

The number preceding each item corresponds to its location on the MAINFRAME CHASSIS REAR PANEL illustration (Figure ***Error! Bookmark not defined.****, page* ***Error! Bookmark not defined.****).*

10 **RF (BNC CONNECTOR)**
The 20 MHz RF signal is available for with Triton's Model 100 Doppler Flowmeter.

PRF (BNC CONNECTOR)
The 31.25 KHz PRF pulse train is available for synchronization with Triton's Model 100 Doppler Flowmeter.

12 **SONO MASTER (PHONE JACK)**
The SONO MASTER makes it possible to synchronize with a Triton Technology Sonomicrometer Model 120.

13 **EM FLOW SYNC (PHONE JACK)**
The EM FLOW SYNC can synchronize external Electromagnetic Flowmeters (EM) with the System 6. prevents interference on recordings when EM Flowmeters are operated near the System 6. See the Section on EM FLOWMETER SYNCHRONIZATION *(page 22)* for more information.

14 **SONOMICROMETER - RF OUT (BNC CONNECTOR)**
The RF signal is a buffered version of the received ultrasonic signal from the selected Sonomicrometer module. The user should routinely monitor all the RF OUT signals for quality, amplitude, stability and triggering position on each Sonomicrometer channel during experiments.

15 **SONOMICROMETER - PULSE OUT (BNC CONNECTOR)**
In the RUN mode, the PULSE OUT is a *modified* TTL signal that tracks the first positive half-cycle of the RF signal when the Sonomicrometer is properly triggered. The signal is modified in that it remains slightly below TTL high until the end of the INHIBIT time. At the end of the INHIBIT time, the PULSE OUT rises and remains at TTL high until the triggering point, and then drops to low level. Therefore, the negative-going edge of the PULSE OUT tracks the RF signal.

In the CALIB mode, PULSE OUT steps from *left to right* across the oscilloscope screen as the INHIBIT control is turned clockwise. Conversely, PULSE OUT steps from *right to left* when turned counterclockwise.

16 **SONOMICROMETER - SCOPE SYNC (BNC CONNECTOR)**
The SYNC OUT is a positive-going TTL pulse train that synchronizes the oscilloscope to monitor RF and PULSE signals. This signal is normally 1302 Hz, but may be different if an EM Flowmeter module is installed.

17 **STEREO PHONE (PHONE JACK)**
The STEREO PHONE jack provides directional audio signals which can be monitored with stereo headphones. Positive flow sounds in the right ear and negative flow in the left. Inserting a phone plug in this jack disables the front panel speaker. The audio amplifier output impedance is low enough to operate most standard headphones.

18 **EXT OFF (PHONE JACK)**

Grounding the EXT OFF disables the System 6 master clock and prevents the System 6 from emitting RFI (radio frequency interference) signals. This feature is typically used with NMR (Nuclear Magnetic Resonance) equipment; however, any equipment that can provide a switched ground or "TTL low" output can be connected to the EXT OFF. A simple grounding switch can also be used at the EXT OFF for manually disabling the clock. The power supplies remain on and the system turns on instantly upon removal of the "ground".

19 **EKG REF**

When measuring EKGs, always connect the reference ground from the animal Animal SafetyEKG REF to the EKG REF on the rear panel of the Mainframe Chassis. The animal should not be grounded in any other way when making EKG measurements. Disconnect the EKG REF from the animal when not in use.

This ground reference is not connected directly to the System 6 chassis ground, but is *driven* to a virtual ground through high value resistors and an operational amplifier. Grounding in this manner actively suppresses low frequency noise, providing a good low noise signal ground reference. If the animal is accidently connected to a lethal voltage, the EKG REF looks like more than 1 Megohm resistance to ground. This decoupling from the Mainframe Chassis ground protects the animal from electrical shock. When not measuring EKGs, the best way to operate the System 6 is with the EKG REF disconnected from the animal, that is, *completely isolate* the animal from the chassis ground.

20 **ON/OFF (POWER SWITCH)**

The ON/OFF switches both sides of the AC line to the System 6 power supply.

21 **FUSED AC POWER RECEPTACLE**

The FUSE and POWER receptacles are combined with the LINE VOLTAGE SELECTOR. The power line receptacle is a standard IEC (International Electrotechnical Commission) type. The fuse receptacle accepts standard 3AG fuses.

22

The system uses a 3AG 1.5 amp slo-blow FUSE. (See Table 1 AC Fuse Ratings on page 7).

23 **LINE VOLTAGE SELECTOR**

The correct LINE VOLTAGE must be selected on the circuit card in the fuse housing. (See Figure 3 on page 3).

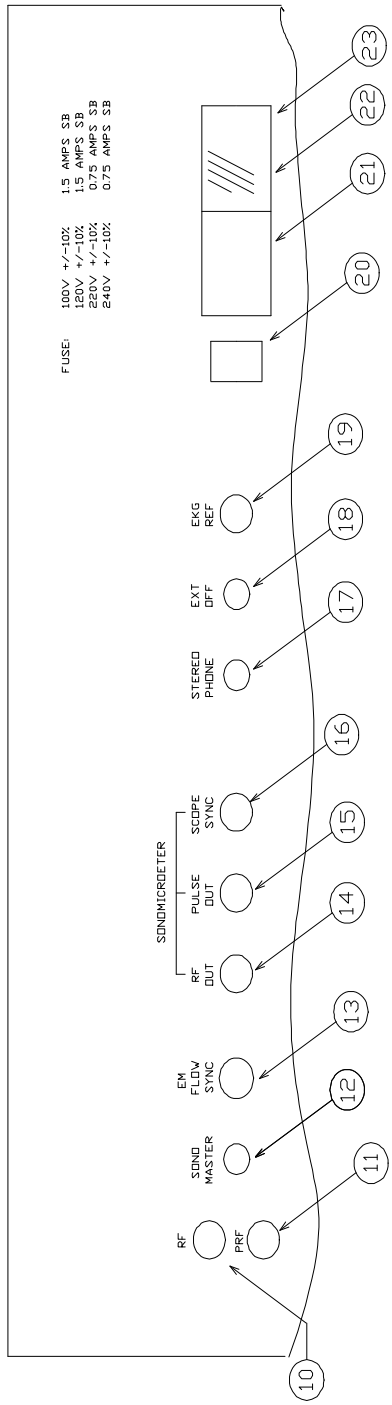

Figure 7 REAR PANEL CONTROLS & CONNECTIONS

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3.6 REAR PANEL MODULE OUTPUTS

*The number preceding each item corresponds to its location on the REAR PANEL MODULE OUTPUTS illustration (Figure **Error! Bookmark not defined.**, page **Error! Bookmark not defined.**).*

***Note:** Each of the 6 module slots has 7 back panel output connectors labeled A through G. For example, C3 is the "C output" of "module 3". For convenience, these output connectors are also silkscreened with the names of their function when either a Sonomicrometer module or a Pulsed Doppler Flowmeter module is in place. The descriptions below identify the functions using other available modules.*

39 A1-A6 "EKG" (PHONE JACK)

MODULE	OUTPUT FUNCTION
SONOMICROMETER	EKG
PDFM	
DUAL PRESSURE	PRESS 'A' OUT
DP/DT	PRESS OUT
DOPPLER DISP.	

40 B1-B6 "SONO OUT" (PHONE JACK)

MODULE	OUTPUT FUNCTION
SONOMICROMETER	SONO OUT
PDFM	
DUAL PRESSURE	MEAN PRESS 'A' OUT
DP/DT	MEAN PRESS OUT
DOPPLER DISP.	

49 C1-C6 "FLOW OUT" (PHONE JACK)

MODULE	OUTPUT FUNCTION
SONOMICROMETER	
PDFM	FLOW OUT
DUAL PRESSURE	
DP/DT	dP/dt OUT
DOPPLER DISP.	DISPLACEMENT OUT

50 D1-D6 "MEAN FLOW OUT" (PHONE JACK)

MODULE	OUTPUT FUNCTION
SONOMICROMETER	
PDFM	MEAN FLOW OUT
DUAL PRESSURE	PRESS 'B' OUT
DP/DT	
DOPPLER DISP.	

51 E1-E6 "RANGE OUT" (PHONE JACK)

MODULE	OUTPUT FUNCTION
SONOMICROMETER	
PDFM	RANGE OUT
DUAL PRESSURE	MEAN PRESS 'B' OUT
DP/DT	
DOPPLER DISP.	

52 F1-F6,G1-G6 "LINE OUT" (PHONE JACK CONNECTOR)

MODULE	OUTPUT FUNCTION
SONOMICROMETER	
PDFM	LINE OUT
DUAL PRESSURE	
DP/DT	
DOPPLER DISP.	

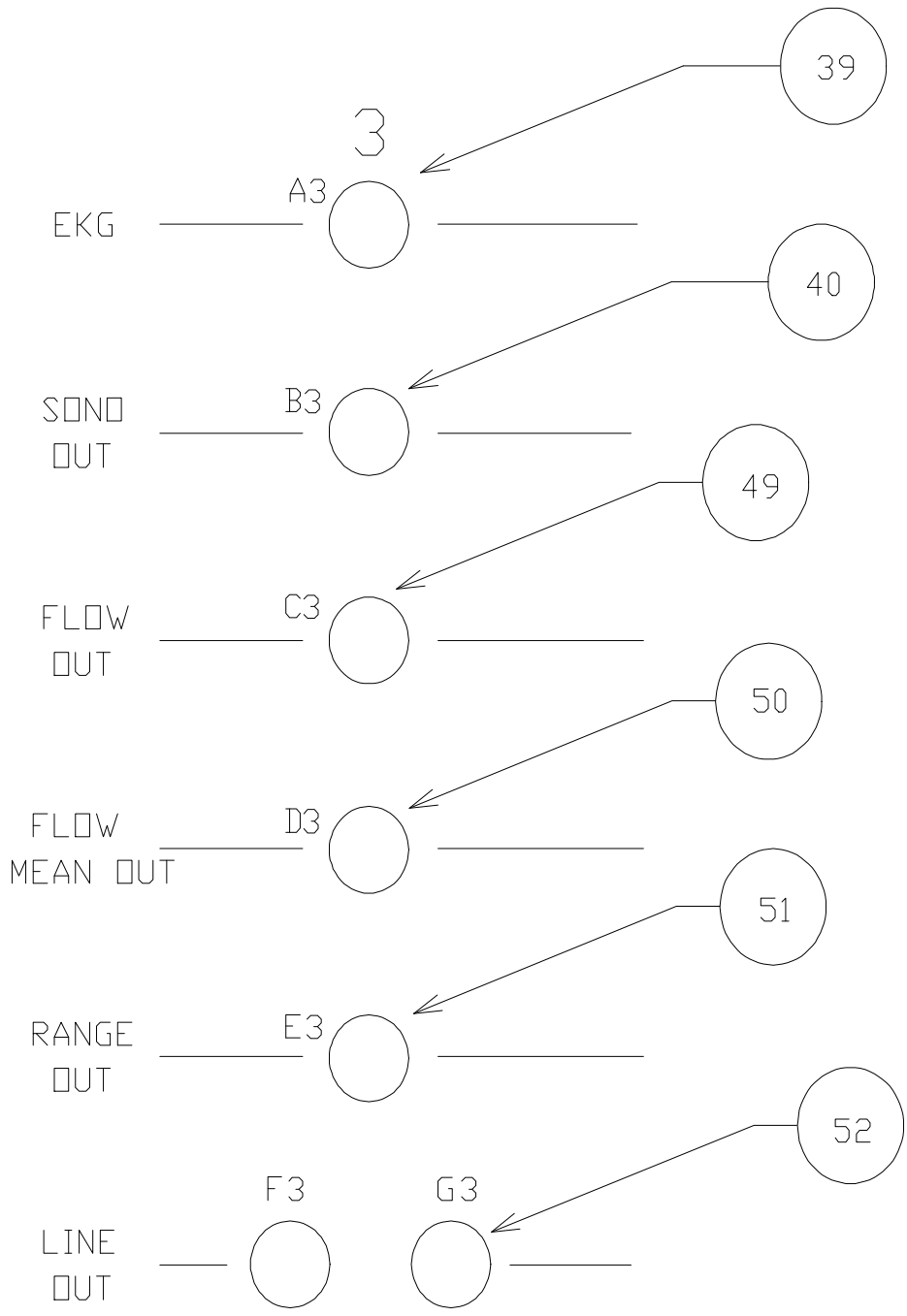

Figure 8 REAR PANEL CONTROLS & CONNECTIONS *(See note on page 198)*

4. SYNCHRONIZATION OPTIONS

4.1 EM FLOWMETER SYNCHRONIZATION

The Sonomicrometer module generates high energy pulses as a normal consequence of its operation. These pulses radiate into the area around the System 6, causing electromagnetic interference (RFI/EMI) in most Electromagnetic (EM) Flowmeters.

Many EM Flowmeters have provisions for external so that two or more Flowmeters may be synchronized together. The System 6 timing circuits can synchronize the timing of many types of EM Flowmeters, using a flowmeter's external synchronization input. The System 6 acts as the "master" and the EM Flowmeter is "slaved" to it. The System 6 timing circuits generate the proper waveforms, frequencies, and phase relationships. The phase of the sync signal(s) is arranged such that the Sonomicrometer "pingers" are not fired during the Flowmeter "read" times. The net result of this synchronization is that the baseline noise of the flow trace with the Sonomicrometers synchronized will be comparable to that of the EM Flowmeter when operating alone.

PLUG-INS

EM Flowmeters from different manufacturers operate at different frequencies and thus have different timing requirements. Therefore, no one synchronization circuit will work for all brands of EM Flowmeters. It is necessary to have separate EM Flowmeter synchronization for each make of EM Flowmeter. These plug-ins go into DIP sockets on the System 6 motherboard. See Appendix A for a list of synchronizable EM Flowmeters and operating frequencies.

4.2 RECEIVER SYNCHRONIZATION

The Sonomicrometer channels are time-multiplexed so that only one module is transmitting or "pinging" at any given time. This prevents interference between Sonomicrometer channels. A Sonomicrometer receiver, however, is not limited to receiving signals from its own pinger. The Mainframe Chassis motherboard has a field of jumper plugs that determine which pinger a receiver detects. Properly setting these jumpers will synchronize a receiver in any one module to the pinger in another module. This arrangement makes various triangulation measurements possible.

Receiver synchronization makes it possible, for example, to "PING" a double-lensed transducer in the ventricular septum, and simultaneously "RECEIVE" from two transducers implanted in the free-walls of the left and right ventricles.

Another possibility is to "PING" an epicardial transducer overlying several other transducers in the myocardium in order to measure function at various depths through the ventricular wall.

See Appendix B for receiver synchronization programming information.

4.3 MULTIBOX SYNCHRONIZATION

For some experimental protocols, the user may wish to record more than the six Sonomicrometer channels available from System 6. If this user has a Triton Technology Model 120 Sonomicrometer available, it may be slaved to the System 6. The System 6 has eight time slots

available for non-interfering synchronization. These eight time slots may be allocated between the two systems in any combination, but the recommended combination is to have four channels of Sonomicrometer in the System 6 with a four-channel Model 120 slaved to it for a total of eight channels.

In order for to occur properly, both the System 6 and the Model 120 should have the same Pulse Repetition Frequency (PRF) and clock frequency. There are several possible clock and PRF frequencies in Model 120 Sonomicrometer units depending on the flow sync, etc. The Model 120 timing card may need to be modified or replaced for proper synchronization.

The System 6 internal timing will also need to be programmed for proper synchronization. Because of the number of possible timing combinations it will be necessary for the user to contact Triton Technology, Inc. for specific instructions.

APPENDIX A FLOWMETER SYNCHRONIZATION

System 6 can synchronize with several different makes and types of bloodflow meters. As delivered, the System 6 will synchronize with the Triton Technology Model 100 Pulsed Doppler Flowmeter. Plug-in modules are available which make it possible to synchronize with most of the commonly used electromagnetic (EM) flowmeters. In addition, the System 6 will synchronize with the Transonic ultrasonic transit time flow meter.

Table A1 lists the common flowmeters, their synchronization frequencies, and the associated Sonomicrometer sampling frequencies (PRF). Contact Triton for information on synchronizing other flowmeters.

The System 6 Sonomicrometers and their associated wiring radiate electromagnetic energy each time they "ping". In addition, the System 6 Pulsed Doppler Flowmeter generates bursts of radio frequency (RF) energy. This radiated energy may cause interference with EM flowmeters. In order to prevent interference, an external flowmeter may be electronically synchronized with the System 6. All the flowmeters listed in **Table A1** have provisions for plug-in synchronization modules which may be purchased from Triton. These modules plug into the motherboard of System 6. Installation instructions are supplied with the modules. Sine-wave EM flowmeters such as the Skalar from Holland and the Biotronix 613 do not appear to require synchronizing.

EM FLOWMETER	TIP TYPE	RING FREQ (Hz)	SONO FREQ (Hz)	FREQ
STATHAM 2200, 2202	EM	5209	1302	1302
ZEPEDA W5RD	EM	977	489977	
BIOTRONIX 610	EM	4465	4465 (INVERTED)	1116
CAROLINA 501	EM	7813	489977	
TRANSONIC (ULTRASONIC)	TRANSIT TIME	7813	489977	

Table A1 Common flowmeter synchronization frequencies

APPENDIX B SONO RECEIVER SYNCHRONIZATION

System 6 is designed with eight time slots for Sonomicrometer measurements. This time-multiplexing prevents interference between Sonomicrometer channels. The timing for each module slot is determined by a group of programming jumpers on the motherboard.

Any Sonomicrometer channel receiver may be synchronized with any timing slot. The pingers, on the other hand, are normally timed by their module position. (ie. module 1 pinger fires on timing slot 1, module 2 pinger fires on timing slot 2, etc.)

The receiver timing is determined by jumper plugs in six sockets on the mainframe motherboard. The programming can be changed by moving the factory installed jumper to the correct position for the desired timing. The ability to synchronize more than one receiver from a single pinger makes it possible to do triangulation measurements.

One simple application of alterable receiver timing is the measurement of two dimensions with one transmitting crystal and two receiving crystals. For example, a double-lensed transducer is pinged from channel 1 as shown in **Figure B1**. A receiver crystal is placed on either side. One receive crystal is connected to channel 1 as usual. The second receive crystal is connected to the channel 2 receiver but the channel 2 receiver is synchronized to the channel 1 timing. As a result, two distances are measured simultaneously with respect to a common point. This approach has been used to simultaneously measure left and right ventricular minor axis dimensions. The double lens is placed in the ventricular septum and an epicardial patch transducer is placed on both the left and right ventricular *free* walls.

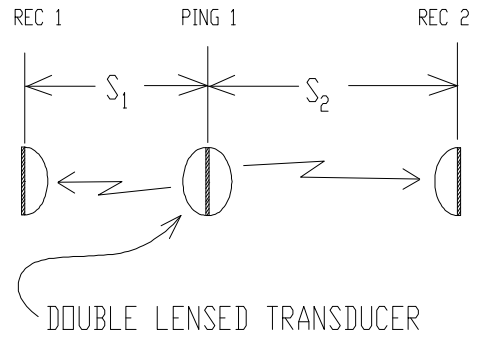

Figure B1 Measuring two distances with three transducers

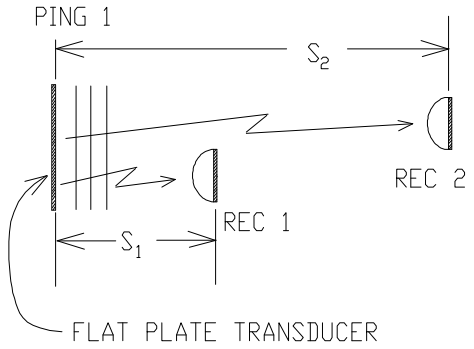

Figure B2 Measuring several distances

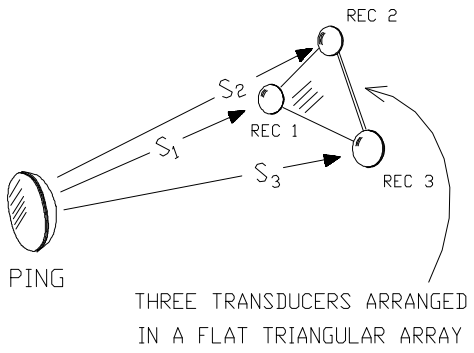

Figure B3 Multiple distances in three dimensions

A similar example is shown in **Figure B2**. In this case, a large, flat-plate transducer is pinged, projecting a wide sound beam through the muscle. Multiple receiver crystals are placed at different distances from the flat plate transducer. The individual distances are measured when the corresponding receivers are synchronized to the flat-plate transducer's pinger. This configuration has been used to measure ventricular wall thickening at different depths. A large flat epicardial

patch transducer is pinged. Receivers are placed directly under the flat plate at different depths to study transmural thickening vs. depth.

The example just described may be extended to three-dimensional arrays as shown in **Figure B3**. The position of the pinger relative to the plane of a fixed triangular array of receivers can be determined in X, Y, and Z coordinates. This approach has been used to study wall thickness and transmural shear. A 10 mm right triangle shaped array was sutured to the epicardium and the motion of a sub-endocardial pinger was measured in normal and ischemic myocardium.

For more information on these subjects refer to the following papers and abstracts or contact Triton Technology, Inc.:

Gallagher KP, Osakada G, Hess OM, Koziol JA, Kemper WS, Ross J Jr: Subepicardial segmental function during coronary stenosis and the role of myocardial fiber orientation. Circ Res 50:352-359, 1982.

Osakada G, Sasayama S, Kawai C, Hirakawa A, Kemper WS, Franklin DL, Ross J Jr: The analysis of left ventricular wall thickness and shear by ultrasonic triangulation technique in the dog. Circ Res 47:173-181, 1980.

Kemper WS, Sasayama S, McKown D, Ross J Jr, Franklin DL: Ultrasonic triangulation technique for assessment of ventricular wall thickness and myocardial shear in vivo. Proc of 28th Conf Eng Med Bio, New Orleans, 1975. (abstract)

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