MAC®5000
Resting ECG Analysis System
Service Manual

2017803-003 Revision C

GE Medical Systems
Information Technologies

gemedical.com

NOTE: The information in this manual only applies to MAC 5000. It does not apply to earlier software versions. Due to continuing product innovation, specifications in this manual are subject to change without notice.

Contents

For your notes

1 Introduction

For your notes

Manual Information

Revision History

Each page of the document has the document part number and revision letter at the bottom of the page. The revision letter identifies the document's update level.

The revision history of this document is summarized in the table below.

Table 1. Revision History, PN 2017803-003

Revision	Date	Comment
A	25 September 2003	Initial release of this document.
B	27 October 2003	Made editorial changes throughout the manual.
C	13 August 2004	Made editorial changes throughout the manual.

Manual Purpose

This manual supplies technical information for service representative and technical personnel so they can maintain the equipment to the assembly level. Use it as a guide for maintenance and electrical repairs considered field repairable. Where necessary the manual identifies additional sources of relevant information and or technical assistance.

See the operator's manual for the instructions necessary to operate the equipment safely in accordance with its function and intended use.

Intended Audience

This manual is intended for the person who uses, maintains, or troubleshoots this equipment.

Warnings, Cautions, and Notes

The terms danger, warning, and caution are used throughout this manual to point out hazards and to designate a degree or level or seriousness. Familiarize yourself with their definitions and significance.

Hazard is defined as a source of potential injury to a person.

Term	Definition
DANGER	Indicates an imminent hazard which, if not avoided, will result in death or serious injury.
WARNING	Indicates a potential hazard or unsafe practice which, if not avoided, could result in death or serious injury.
CAUTION	Indicates a potential hazard or unsafe practice which, if not avoided, could result in minor personal injury or product/property damage.
NOTE	Provides application tips or other useful information to assure that you get the most from your equipment.

Safety Messages

Additional safety messages may be found throughout this manual that provide appropriate safe operation information.

DANGER
Do not use in the presence of flammable anesthetics.

WARNINGS
This is Class 1 equipment. The mains plug must be connected to an appropriate power supply.

Operate the unit from its battery if the integrity of the protective earth conductor is in doubt.

CAUTIONS
This equipment contains no serviceable parts. Refer servicing to qualified service personnel.

U.S. Federal law restricts this device to the sale by or on the order of a physician.

Responsibility of the Manufacturer

GE Medical Systems *Information Technologies* is responsible for the effects of safety, reliability, and performance only if:

- Assembly operations, extensions, readjustments, modifications, or repairs are carried out by persons authorized by us.
- The electrical installation of the relevant room complies with the requirements of the appropriate regulations.
- The equipment is used in accordance with the instructions for use.

General

The intended use of this device is to record ECG signals from surface ECG electrodes. This device can analyze, record, and store electrocardiographic information from adult and pediatric populations. This data can then be computer analyzed with various algorithms such as interpretive ECG and signal averaging for presentation to the user.

This device is intended for use under the direct supervision of a licensed health care practitioner.

Failure on the part of the responsible individual, hospital, or institution using this equipment to implement a satisfactory maintenance schedule may cause undue equipment failure and possible health hazards.

To ensure patient safety, use only parts and accessories manufactured or recommended by GE Medical Systems *Information Technologies*.

Contact GE Medical Systems *Information Technologies* for information before connecting any devices to this equipment that are not recommended in this manual.

If the installation of this equipment, in the USA, will use 240 V rather than 120 V, the source must be a center-tapped, 240 V, single-phase circuit.

Parts and accessories used must meet the requirements of the applicable IEC 60601 series safety standards, and/or the system configuration must meet the requirements of the IEC 60601-1-1 medical electrical systems standard.

The use of ACCESSORY equipment not complying with the equivalent safety requirements of this equipment may lead to a reduced level of safety of the resulting system. Consideration relating to the choice shall include:

- use of the accessory in the PATIENT VICINITY; and
- evidence that the safety certification of the ACCESSORY has been performed in accordance to the appropriate IEC 60601-1 and/or IEC 60601-1-1 harmonized national standard.

Equipment Symbols

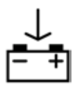
The following symbols appear on the equipment.

Type B equipment.

Type BF equipment, external defibrillator protected.

Alternating current. When illuminated, the green LED next to this symbol indicates AC power is connected.

Equipotential.



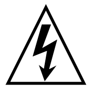
Charge the battery. The flashing amber LED next to this symbol indicates you must connect the system to AC power to re-charge the battery.

DO NOT throw the battery into the garbage.

Recycle the battery.

Consult accompanying documents.

Classified with respect to electric shock, fire, mechanical, and other specified hazards only in accordance with UL 2601-1, CAN/CSA C22.2 No. 601-1, CAN/CSA C22.2 601-2-25, EN 60601-2-25, EN 60601-1-1.



In Europe, this symbol means dangerous or high voltage. In the United States, this symbol represents the caution notice below:

CAUTION

To reduce the risk of electric shock, do NOT remove cover (or back). Refer servicing to qualified personnel.

M15287-16A

96A, 97A, 98A, 99A, 100A, 101A, 102A, 103A, 108A, 181A

Service Information

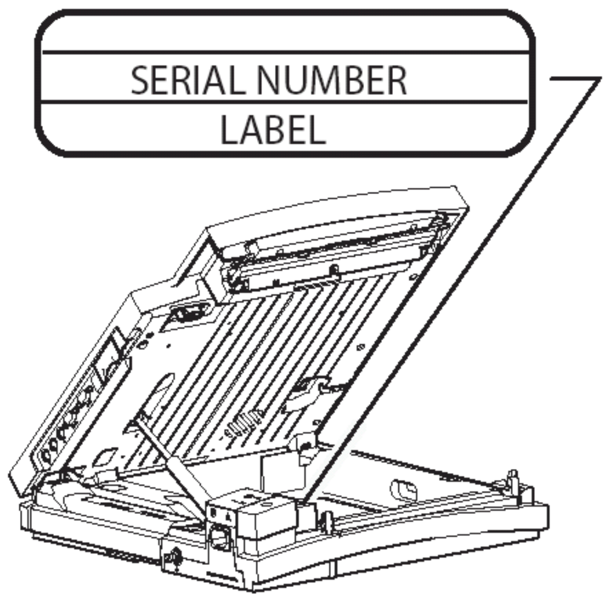
Service Requirements

Refer equipment servicing to GE Medical Systems *Information Technologies* authorized service personnel only. Any unauthorized attempt to repair equipment under warranty voids that warranty.

It is the user’s responsibility to report the need for service to GE or to one of their authorized agents.

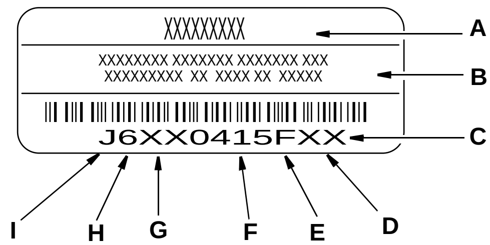
Equipment Identification

The Serial Number tag is located inside the device where shown below.



Every GE Medical Systems *Information Technologies* device has a unique serial number for identification. The serial number that appears on the device may be in one of two formats, A or B as follows.

Format A



MD1113-022C

Table 2. Equipment Identification – Format A		
Item	**Name**	**Description**
A	name of device	MAC 5000 resting ECG analysis system
B	manufacturer	GEMS-*IT*
C	serial number	Unique identifier
D	device characteristics	One or two letters that further describe the unit, for example: P = prototype not conforming to marketing specification; R = refurbished equipment; S = special product documented under Specials part numbers; U = upgraded unit
E	division	Division where device was manufactured.
F	product sequence number	Manufacturing number (of total units manufactured)
G	product code	Two-character product descriptor. WT = MAC 5000 resting ECG analysis system. **NOTE**: Earlier versions used MP and MH, see the serial tag on your device for the product code.
H	year manufactured	9 = 1999, 0 = 2000, 1 = 2001, (and so on)
I	month manufactured	A = January, B = February, C = March, D = April, E = May, F = June, G = July, H = August, J = September, K = October, L = November, M = December

Format B

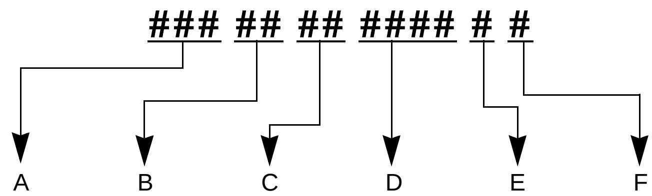


Table 3. Equipment Identification – Format B

A	[1]Product Code
B	Year Manufactured (00-99) 00 = 2000 01 = 2001 02 = 2002 (and so on)
C	Fiscal Week Manufactured
D	Production Sequence Number
E	Manufacturing Site
F	Miscellaneous Characteristic

1. This manual applies to MAC 5000 with Product Code AAY.

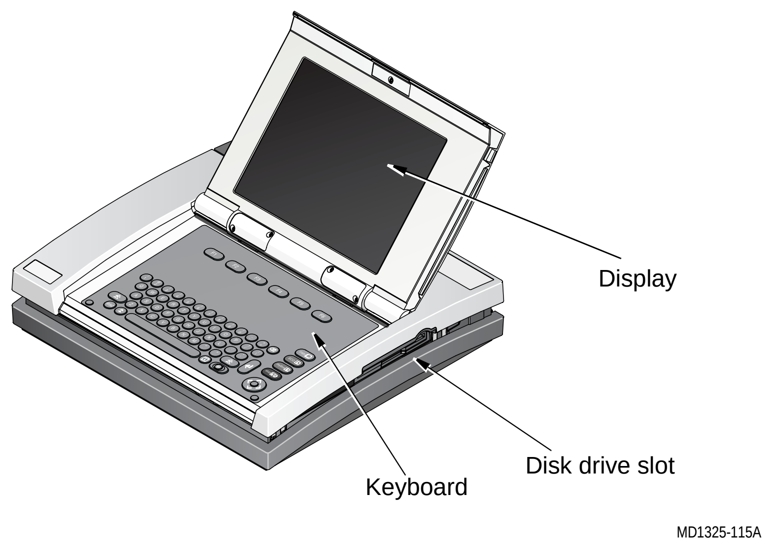
2 Equipment Overview

For your notes

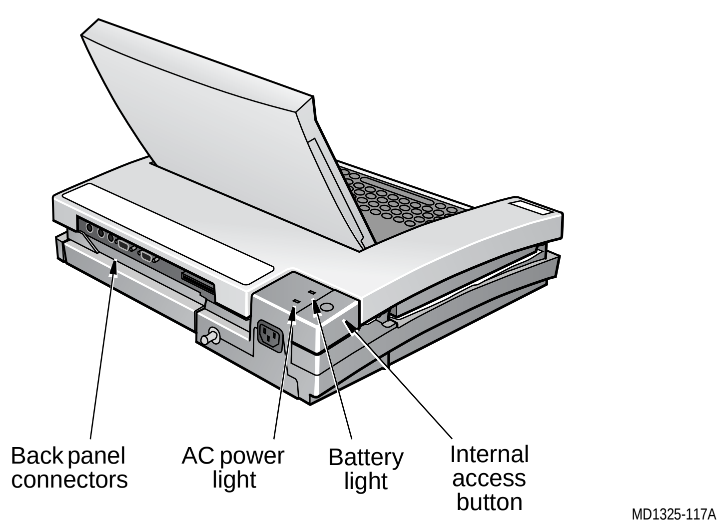
General Description

The MAC 5000 resting ECG analysis system is a 15 lead, 12 channel system with a 10.4 inch (264 mm) diagonal display, active patient cable, battery operation, and late potential electrocardiography. There are also options for communication capabilities.

Front View



Back View



Connector Identification

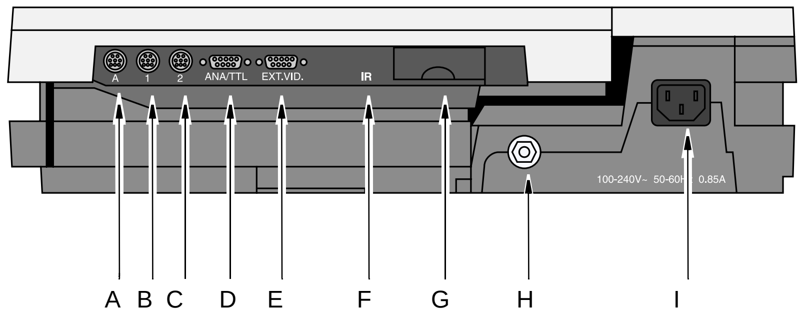


Table 4. Back Panel Connectors		
Item	**Name**	**Description**
A	**A**	Connect Bar Code Reader/ Card Reader / PS2 Style Keyboard
B	**1**	Treadmills or GE KISS pump (optional).
C	**2**	Connect a local transmission cable, serial line, or external modem (optional).
D	**ANA/TTL**	Connect a device requiring analog data or TTL trigger.
E	**EXT.VID.**	Connect an external video display.
F	**IR**	Point at a MAC 5000 or MUSE CV system's **IR** transceiver to transmit or receive ECG data.
G	card slot door	Lift to open the door and insert the software card into this slot to run the system.
H	ground lug	Connect non-grounded peripheral devices to ensure equipotential.
I	mains AC power	Insert the mains AC power cable.

Detailed Description

The MAC 5000 CPU PCB contains all of the circuitry for the MAC 5000 resting ECG analysis system except for the power supply, acquisition module, keyboard and display.

The board contains the following:

- Clock 24 MHz for FPGA (Field-Programmable Gate Array)
- SDRAM (holds both code and data) also acts as video frame memory
- SmartMedia Flash (holds FPGA configuration and system code)
- CRT video DAC's
- External 12 Volt Power Switch
- Acquisition Module Transceiver / Power Switch
- Printhead Power Switches and Pixel Test Circuit
- Switch Mode Power Supplies
  - 3.3 Volt for Logic, LCD
  - 5 Volt for Logic, Printer, Floppy Drive
  - 12 Volt for LCD backlight, External Com Port Power
  - Battery Charger
  - -12 Charge Pump for Analog Circuits
- Linear Power Supplies
  - 1.8 Volt (SA-1110 Core)
  - 2.5 Volt (FPGA Core)
  - 2.5 Volt Reference
  - 3.3 Volt for System Supervisor (Moe Stooge)
  - 12 Volt for Analog Circuits
- Crystals
  - 32 kHz Real Time Clock
  - 32 kHz (SA-1110)
  - 3.6864 MHz (SA-1110)
  - 4 MHz (4 devices, 1 for each Stooge)
- StrongARM CPU (SA-1110) Containing:
  - 32 bit StrongARM RISC (Reduced Instruction Set Computer) processor core 2.1 MIPS (Million Instructions Per Second)
  - SDRAM (Synchronous Dynamic Random Access Memory) Controller
  - MMU (Memory Management Unit)
  - LCD Controller
  - Parallel I/O Ports
  - UARTs (Universal Asynchronous Receiver/Transmitter)

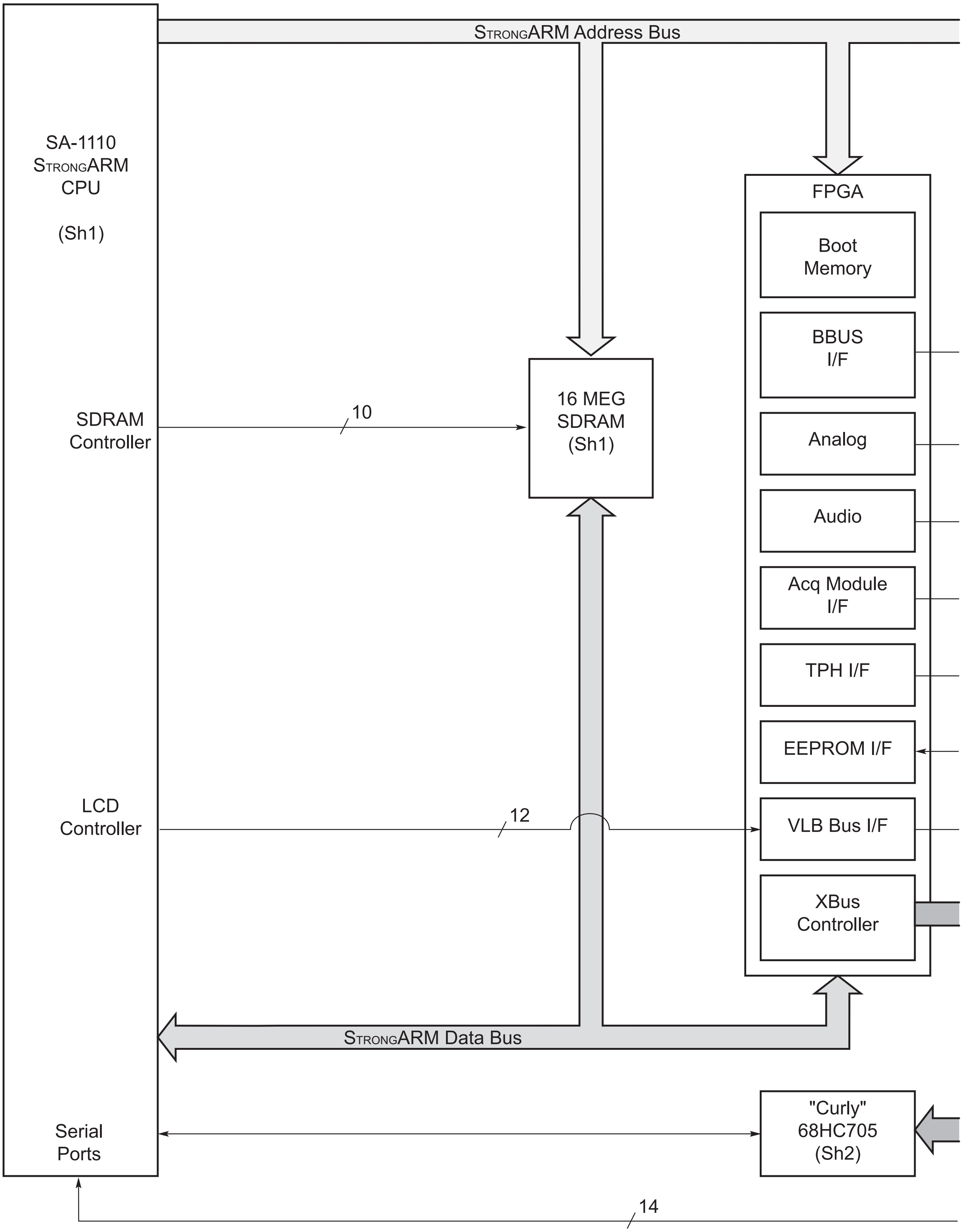
- FPGA Containing:
  - StrongARM Boot ROM emulation
  - XBus Controller
  - Video Waveform Scroller
  - Interrupt Controller
  - System Interrupt Generator
  - Acquisition Module Interface
  - Thermal Printhead Interface
  - Serial EEPROM Interface
  - BBus Controller
  - Four PWM Analog Outputs
  - Beep Generator

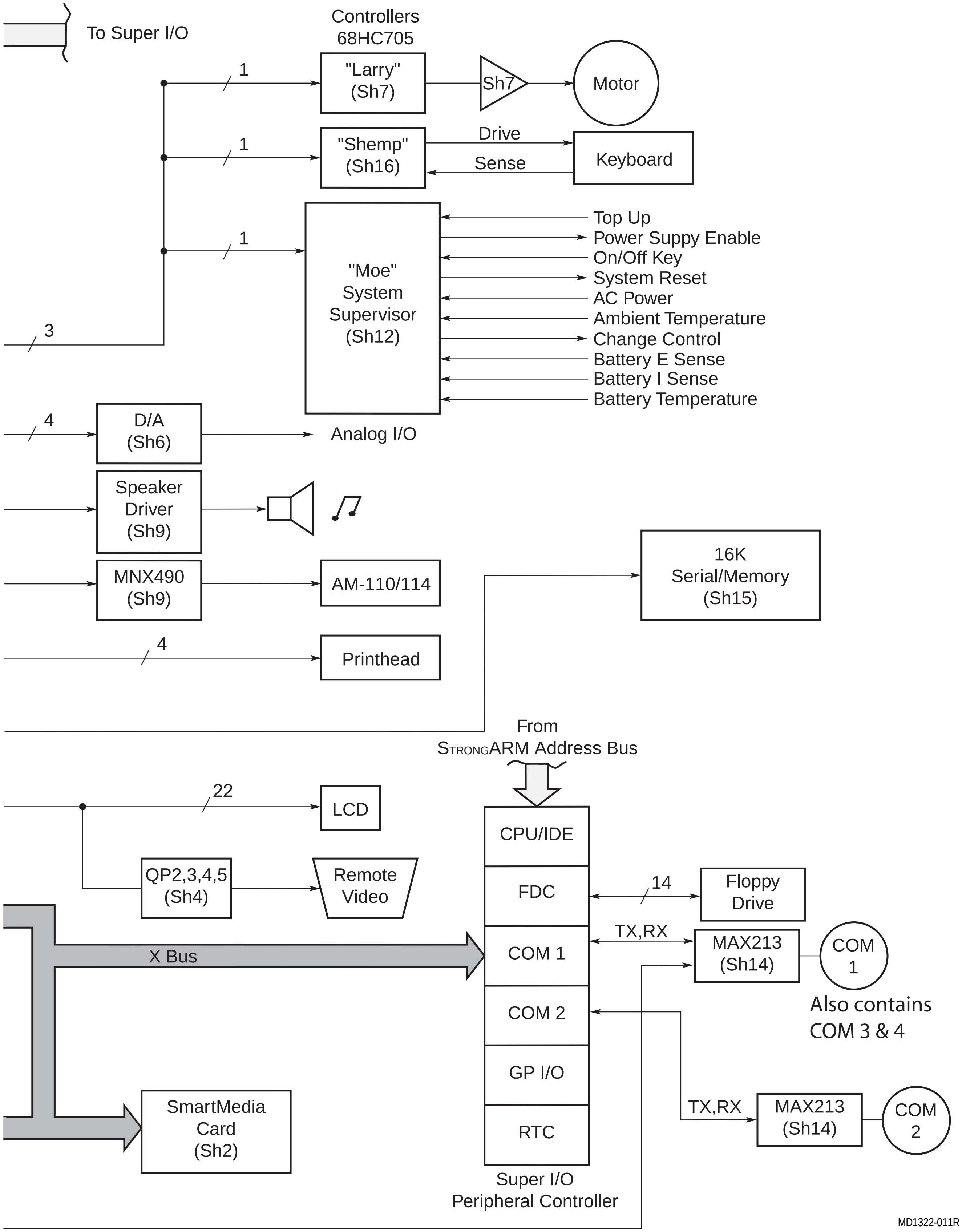
- A PC Super I/O controller containing:
  - A Floppy Disc Drive Controller
  - Two Serial Ports (one dual mode RS-232 / IrDA)
  - Clock/Calendar (Y2K compliant)
  - PS-2 Keyboard Port (for card and barcode readers)

- Four Peripheral Microcontrollers (The Four Stooges):
  - Bootstrap Control (Curly)
  - System Supervisor / Battery Charger-Gauge (Moe)
  - Printer Motor Controller / Analog Input (Larry)
  - Keyboard Interface (Shemp)

For your notes

Block Diagram




To Super I/O
Controllers
68HC705
"Larry"
(Sh7)
Sh7
Motor
"Shemp"
(Sh16)
Drive
Sense
Keyboard
"Moe"
System
Supervisor
(Sh12)
Top Up
Power Suppy Enable
On/Off Key
System Reset
AC Power
Ambient Temperature
Change Control
Battery E Sense
Battery I Sense
Battery Temperature
1
1
1
3
4
D/A
(Sh6)
Analog I/O
Speaker
Driver
(Sh9)
MNX490
(Sh9)
AM-110/114
16K
Serial/Memory
(Sh15)
4
Printhead
From
StrongARM Address Bus
22
LCD
QP2,3,4,5
(Sh4)
Remote
Video
CPU/IDE
FDC
COM 1
COM 2
GP I/O
RTC
14
Floppy
Drive
TX,RX
MAX213
(Sh14)
COM
1
Also contains
COM 3 & 4
X Bus
SmartMedia
Card
(Sh2)
TX,RX
MAX213
(Sh14)
COM
2
Super I/O
Peripheral Controller
MD1322-011R

For your notes

Theory of Operation

Power Supplies

The MAC 5000 requires several regulated voltages for operation of its various components. The Main Regulator provides most of the supply rails. The supply rails are:

+3V-C

MAC 5000 is never truly “off”. The system supervisor microcontroller (MOE) must constantly monitor the power key and perform battery charging/gauging. The clock/calendar in the Super I/O chip must also maintain time/date when the machine is off. These functions are powered from the +3V-C rail, which provides power continuously from the battery pack regardless of the state of the rest of the system. The Main Regulator produces +3V-C directly from the battery rail via an internal low current linear regulator. Only 5 mA are available from +3V-C, so it must be used sparingly.

NOTE

The MAX782’s low current regulator is dreadfully inefficient. Regulator Q current appears to be about 3x the load current. This makes conservation of load on +3V-C crucial.

+3V-M

Most of the MAC 5000 hardware runs from +3V-M. The MAX782 provides this rail from the battery via a PWM synchronous switching regulator. Moe controls +3V-M in tandem with +5V-M.

+3V-EMI (Electromagnetic Interference)

This is simply an RF-blocked feed from +3V-M. +3V-M load is contained within the CPU board. Power for devices for external functions is supplied by +3V-EMI. The isolation of +3V-EMI from +3V-M may be unnecessary as the concept has never been tested for its effect.

+5V-M

The MAC 5000 is not fully in the 3V age. The Super I/O, floppy diskette drive and thermal printhead all require 5V power. The MAX782 provides this rail via another PWM synchronous switching regulator.
Moe controls +5V-M in tandem with +3V-M.

+5V-EMI

Similar to +3V-EMI, this rail is an RF blocked feed from +5V-M, used to power devices for external functions. The isolation of +5V-EMI from +5V-M may be unnecessary as the concept has never been tested for its effect.

+18V

The Main Regulator’s 5V switching output also supports generation of a non-regulated 18V rail, which is used to provide power for the acquisition module. By providing the acquisition module with 11.5V linearly regulated power from the +18V rail of the main regulator rather than the main 12V regulator (U13), acquisition is not affected by excessive current draw from the printer motor or external loads on the COM ports (esp. KISS pump). The acquisition module's power requirements are modest, so efficiency is not a pressing concern and the lower efficiency of this approach is acceptable.

VCore

The StrongARM CPU operates its internal core logic at 1.8V, while its I/O ring runs at the system standard 3.3V. The Core Regulator, a low dropout linear regulator, drops +3V-M to 1.8V for use by the StrongARM.

+2.5V

The FPGA (Xilinx Spartan 2) operates its internal core logic at 2.5V, while its I/O ring runs at the system standard 3.3V. The +2.5V Regulator, a low dropout linear regulator, drops +3V-M to 2.5V for use by the FPGA.

+12V

The paper motor drive circuit, LCD backlight and external COM ports all require 12V. The Main Regulator's 18V output cannot provide sufficient current for all of the systems 12V loads, so a secondary 12V regulator is required. The Main 12V Regulator (U13), a switching buck regulator, provides the higher currents needed by these loads. A P-channel MOSFET (Q4) switch precedes the regulator to provide on/off control. Gate capacitor C54 slows the turn on/off time of the MOSFET switch to eliminate switching transients. The voltage divider created by R33,34 prevents the full supply rail from being impressed across Q4's gate when on. This protection is necessary, as the maximum Vgs of the MOSFET is less than the peak supply voltage.

REF2V5

The high power rails are neither precise nor quiet enough to be used as the reference for analog input/output or internal measurement circuits. The Analog Reference Regulator (U35), a 2.5V shunt regulator provides a quiet and stable reference voltage for such purposes. VREF is derived from +5V-EMI rather than +3V-EMI to minimize the change in reference current with changes in input rail voltage. The difference between 5V and 2.5V is three times greater than the difference between 3.3V and 2.5V. If the absolute ripple on both supplies is the same, the modulation of reference current will be 3 times less if power is derived from +5V.

VAna+, VAna-

The analog output circuitry is powered by a low current switched 12V rail, provided by the Main Regulator. VAna+ provides the positive supply for the output op-amps. A charge pump voltage inverter is provided to produce an approximate -11V rail for the op-amps. Although only the ECG output is bipolar, all output amplifiers are driven from VAna-.
A short circuit on either of the unipolar DC outputs could load VAna- sufficiently to affect the negative peak swing of the ECG output. The ECG and DC outputs are not required to operate correctly in the presence of abnormal loads.

Clocks

Super I/O and FPGA

Both of these devices uses the 24 MHz clock oscillator Y3 to drive their internal requirements for various clock frequencies. The main function of the Super I/O IC is the floppy drive interface and all the needed timing comes from this oscillator. The FPGA provides many functions including the acquisition interface, the printer interface, and the Stooges interface (Bbus) to name a few. The FPGA uses a built-in frequency doubler to raise this 24 MHz clock to 48 MHz for internal use, all other needed clock frequencies are derived from this clock.

CPU (StrongARM) / LCD Controller

The StrongARM processor provides its own clock and runs at 206.4 MHz. The processor also generates many other clocks for other functions housed in the same IC. All of these clocks are derived from a built-in clock synthesizer which uses an external 3.6864 MHz crystal. The SDRAM clock runs at 103.2 MHz. The LCD controller runs at 25.8 MHz. And all baud rates required by the internal serial ports are also derived from the clock synthesizer.

CPU (Stooges)

Each of the four Stooges has its own 4 MHz ceramic resonator for use in generating their respective clocks.

RTC (Real Time Clock)

The RTC of the system is provided as a part of the Super I/O controller. The timing for this function is derived from its own 32.768 kHz crystal.

CPU

The Intel StrongARM SA-1110 CPU, chosen for its high performance, low power consumption and high code density, is at the heart of MAC 5000. The SA-1110 is an advanced processor with many integrated peripherals (MMU, various caches, SDRAM controller, LCD controller, serial I/O, parallel I/O to name most but not all).

FPGA Internal Logic

All of the MAC 5000’s proprietary hardware is contained in a single Xilinx FPGA (Field Programmable Gate Array) that contains:

- StrongARM Boot ROM emulation
- XBus Controller
- Video Waveform Scroller
- Interrupt Controller
- System Interrupt Generator
- Acquisition Module Interface
- Thermal Printhead Interface
- Serial EEPROM Interface
- BBus Interface

- Four PWM Analog Outputs
- Beep Generator

The following descriptions give an overview of the FPGA's functionality. For detailed information on the internal circuitry, refer to the schematic. For a programmer's eye view of the FPGA, see the source file "hardware.h". Where appropriate, circuitry external to the FPGA is also described.

StrongARM Boot ROM Emulation

To improve performance and reduce cost, the MAC 5000 does not provide Flash execution memory. This makes it necessary to find another method to start the CPU. Just after the StrongARM SA-1110 processor is released from reset, it starts to fetch instructions from address 0 of memory enabled by Static Bank Select 0. Normally Bank 0 would be some ROM device that would contain StrongARM code. In this design, the FPGA provides RAM blocks that are used to emulate the boot ROM at bank 0. Early in system start-up after the bootstrap microcontroller (Curly) has configured the FPGA, Curly extracts instruction bytes from the SmartMedia card and presents them to the FPGA. Each instruction byte is loaded into the FPGA via the signal FRDY/BRDY. Curly asserts the SmartMedia FRE* signal while simultaneously driving the FRDY/BRDY signal to improve the transfer rate. Curly does not examine the instruction bytes, they are loaded from the SmartMedia card into the FPGA in a "flyby fashion". This process continues until all of the Boot Code (tag B2) is loaded into the Boot emulation RAM (Boot RAM) of the FPGA. A more complete explanation of the bootstrap process is presented in Curly's source code.

Although the Boot Code is written into the Boot RAM as byte wide data, the data as read by the SA-1110 will be as words 32 bits wide. The Boot RAM is far too small and Curly's read rate is far too slow to load all operating code from the card, so only the simple bootstrap program B2 is copied. This program contains code that allows the StrongARM to access the SmartMedia card directly through the FPGA. Once that initial bootstrap is loaded, Curly disconnects from the circuit (tri states all SmartMedia control lines) and releases the StrongARM processor from reset by removing the ARMRESET* signal. StrongARM execution begins and the remaining system code is read from the card at high speed. Curly then lies dormant until the next system start-up.

Board ID Register

It is necessary to identify versions/revisions of the CPU board automatically in the field. Curly provides a mechanism for identifying variations of CPU boards that require different start-up code. Depending on the board code read by Curly, any of up to eight different FPGA images and start-up code sets may be loaded. The board ID register contains a hardwired three bit code that tracks the FPGA image number, indicating to the StrongARM just which FPGA image has been loaded. Three additional FPGA inputs are reflected in this register to allow further refinement of the board identity. Resistors (R162 and R178 through R182) are used to program the board ID.

Board ID Code	Versions of the 801212 CPU Board assembly
000h	-001, -002, and -003
001h	-004 (not used) and -005 (this board)

XBus Controller

To reduce loading on the high speed processor address and data busses, a slow speed byte bus is provided for peripheral interface. The Super I/O controller and SmartMedia card are both located on this bus. Unlike the 3.3V only main data/address busses, XBus is compatible with both 5V and 3.3V logic. To maintain software compatibility with previous board versions, the low order address byte is not used by XBus. Starting XBus addressing with A8 also produces Super I/O addresses that easily map to their standard PC equivalents (simply append 0x00 to a datasheet Super I/O address offset to get a MAC 5000 Super I/O address offset).

Video Interface

Video Waveform Scroller – There are numerous ways of achieving a scrolling waveform, none of which is supported by standard LCD controllers. The MAC 5000 provides scrolling through FPGA hardware placed between the LCD controller output and the LCD panel input.

To produce the scrolling effect it is necessary to maintain two virtual image planes, one atop the other. Static (stationary) objects are drawn in the static plane, which appears nearest the viewer and may be either opaque or transparent. Dynamic (scrolling) objects are drawn in the dynamic plane, which appears behind the static plane and is always opaque, though not necessarily visible. The appearance of motion is achieved by continuously changing the start point for display of the dynamic plane from one video frame to the next.

Since the LCD controller does not support multiple image planes, it is necessary to pack two planes of image data into a single frame buffer. On the software side (during drawing) this is done by bit masking operations that allow separate manipulation of two virtual pixels in each byte of frame buffer memory. Each 8-bit byte holds a pair of pixels, one from the static plane and one from the dynamic plane.

On the hardware side, part of each frame buffer byte (the static plane) is played directly into the LCD after suitable color mapping. The remainder of the byte (the dynamic plane) is stored in a 1 line temporal buffer before being displayed. The amount of delay applied to the line buffer before merging it with the static image data determines its placement on the screen. By gradually changing the delay, the dynamic image can be made to scroll.

Color Lookup Table (CLUT) – Generally the dynamic plane is filled with waveforms and perhaps a few characters of text. The static plane often contains text messages, icons, buttons and graphics. The greater variety of object types displayed in the static plane demands a wider range of colors. For this reason, each video data byte is split asymmetrically into five bits of static pixel data and three bits of dynamic pixel data. This has come to be known as 5.3 format.

The 5.3 format provides a palette of 2^3=8 colors for dynamic objects and (2^5)-1=31 colors for static objects (1 of the colors is transparent, leaving 31 real colors). In practice, to "freeze" dynamic objects in the static plane requires that the 8 dynamic colors be replicated in the static color map, leaving only 31-8=23 new colors available for static objects. The FPGA implements a writeable CLUT (Color Lookup Table) to map the pixel values to sensible colors on the LCD. The CLUT provides 32 - 24-bit entries, providing access to the complete color space offered by the LCD panel. The color mapped LCD data is also fed to three external discrete 6-bit DAC's to create analog video for an external CRT.

Blank/Sync – External VGA monitors are supported with two styles of video sync signal as well as retrace blanking.

Video Sync – The horizontal and vertical sync pulses from the LCD controller are combined to produce a composite sync signal that is added to the video signal. The video sync signal may be disabled under software control to accommodate monitors that do not accept sync on green. The sync signal is applied to all three video guns to eliminate color shifting in systems that do not perform blank level video clamping.

TTL Sync – For monitors that do not accept sync on green, TTL logic level horizontal and vertical sync signals are provided. These may be enabled/disabled to implement a rudimentary "sleep" operation on Energy Star compliant monitors.

Blank – Unlike LC displays, CRT's emit light from more than just their active display surface. The electron beam is visible even during retrace and precautions must be taken to ensure that the guns are off in non-active areas of the display. To ensure black borders on external monitors (and reset the DC restore clamps in the video output buffers). The CLUT video passes through a gating register before leaving the FPGA. This allows the LCD DE (Display Enable) signal to force the guns to a blanking level during inactive portions of the display frame.

Interrupt Controller

On previous versions of the CPU board, the StrongARM processor SA-110 supported two external interrupts, FIQ (Fast Interrupt Request) and IRQ (Interrupt ReQuest). The FPGA expanded those inputs to service numerous sources of interrupts in the FPGA internal logic and Super I/O. Each interrupt source was routed to either the FIQ or IRQ pin and the FPGA provided each a writable enable bit and a readable status bit.

The StrongARM processor used in this design, the SA-1110, provides access to the FIQ and IRQ inputs of the interrupt controller via the GPIO (General Purpose Input/Output) lines. Although any of the GPIO lines can be used to generate an interrupt, GPIO lines GP0 and GP1 are reserved for FIQ and IRQ respectively. These two inputs are attached to the FPGA as in previous designs and the FPGA interrupt controller function is similar to that of previous board versions to minimize the impact on software design. For more detail on the operation of the interrupt mask/status registers, see the source file “hardware.h”.

System Interrupt Timer

A 1-kHz timer generates system interrupts (which may be routed to FIQ or IRQ) once every millisecond. This interrupt provides the foundation for all operating system timers.

Acquisition Module Interface

Overview – The MAC 5000 acquisition module communication protocol is different from previous generations in several key respects:

1. Acquisition module timing is synchronized to the system.

   There is no longer a need to play synchronizing games to get the system (especially the display and printer) operating at the same sampling rate as the acquisition module.

2. Data is framed and has checksum.

   Previous acquisition modules offered rudimentary error detection. This has finally been done nearly right. Each ECG data packet contains a checksum.

3. Commands do not interrupt the data stream.

   Previous generation acquisition modules required a cessation of sampling to transmit commands to the module. This cessation of sampling had the undesirable effect of breaking the acquisition stream for operations as simple as changing the line filter frequency or enabling or disabling the pace pulse detector. With the MAC 5000 this restriction is removed.

4. Buttons are supported.

   Button state is communicated to the system in each ECG data packet. This allows limited operator interaction with the machine via the acquisition module.

Details – A constant reference clock frequency of 1 MHz must be provided to the acquisition module for generation of its internal sampling clocks. To eliminate the need for data lines, command information is encoded on this reference clock by altering its duty cycle. The FPGA provides a serializer for the command bytes and clock generator/ modulator to transmit both the clock and command bits from the serializer. The reference clock duty cycle is nominally 50%. By altering the duty cycle, the DC content of the clock is changed. The acquisition module detects this change in DC level. The timing of these shifts in DC offset encode command data bits. A zero is encoded as a single shift in duty cycle from 50% to 25% lasting 31.25µs, followed by a refractory period of 468.8µs. A one is encoded as a pair of 31.25µs periods of 25% duty cycle separated by 93.75µs, followed by a 343.8µs refractory period. In either case the transmission of a single bit takes 500µs. A higher level protocol organizes commands as groups of 8 bits.

Data from the acquisition module is packed into 257 bit NRZ frames. The receive line idle state is high. The first bit of each packet is a zero and serves as the packet start bit. As with a UART, the start bit is discarded. The following 256 bits are received into a 16-word x 16-bit buffer for use by the StrongARM. The receive logic then looks for an idle period (analogous to a UART stop bit) of at least 125µs in length as an indicator that the link is again idle. Special marker words are inserted into the ECG data packet (words 5, 10 and 15) to guarantee there will never be a run of more than 80 bits of one's (or zeros for that matter), so there is no possibility of satisfying the idle period requirement in the middle of a data packet.

Because the acquisition module clock is supplied by the FPGA, receive timing errors are limited to phase uncertainty. By searching for the beginning of the start bit in a fashion similar to that used by a UART, the phase uncertainty is eliminated and the remainder of the packet may be received without further synchronization. In practice, the FPGA uses every edge in the receive data stream to re-sync its bit sampling circuit. It is possible for the ECG data to be all zeros or ones, so runs of as many as 80 zeros or ones could occur before a marker word is encountered in the data stream (which contains at least one “1” and one “0” to break any runs in the data).

The acquisition module supports a special “code update” mode for rapid reprogramming of its on-board code memory. To increase the update speed, the acquisition module echoes each uploaded code byte with a single reply word rather than the usual 16-word data packet. The FPGA receive logic provides a special one-word reception mode to accommodate this.

Thermal Printhead Interface

The StrongARM sends print data to the thermal print head through a buffered serial interface. The FPGA implements the data buffer, serializer, strobe/latch pulse generator and power switch gate drive pump. Special interlocks are implemented to prevent stuck strobe signals or printing when the battery voltage is critically low.

Each print line requires 1728 bits of data. To conserve FPGA resources, each line is divided into three chunks of 512 bits each, with one leftover chunk of 192 bits. The FPGA provides a single 16 word x 32 bit buffer (512 bits) to hold the print line data. After writing a chunk of data to the buffer, the StrongARM enables serialization of the data by reading one of two registers (to support the serialization of either a full 512 bit or partial 192-bit buffer). When the entire print line has been loaded, the StrongARM cues a print strobe by writing the required strobe width value to the strobe/latch pulse generator.

When the strobe register contains a non-zero value, the power switch gate pump produces a differential clock signal to drive an external diode voltage doubler (CR21-22, C171-173, R134). The output of the voltage doubler drives the gate of a power MOSFET (Q9) that provides power to the print head. R133 provides gate bleed off to ensure that Q9 turns off when the pump stops. C186 filters the doubler output to DC.

A special test mode is provided to allow testing of the thermal print head. In test mode, print head power is disabled and the strobe signal is driven continuously. This allows individual print dots to be driven with a small test current via a current source (Q10, R173, Z2) enabled by a level shifter (Q11, R174) driven from a StrongARM GPIO line. Half of the resulting printhead voltage drop (divider R154/155) may be measured to either determine the dot's resistance or at least determine if the dot is open.

Serial EEPROM Interface

A standard four-wire SPI interface is provided for connection to a serial EEPROM memory (CFGMEM). The StrongARM exchanges a byte of data with the EEPROM by writing a value to the interface register. Data is clocked at 4 MHz; quickly enough that no interrupt support is required. The StrongARM polls a ready bit to determine when the transfer is complete.

BBus Interface

There are several I/O functions poorly suited to direct control by the StrongARM, whether for reasons of software complexity or power consumption. These I/O functions are provided by three 68HC705 microcontrollers placed strategically around the board (Moe, Larry and Shemp). Each of these three microcontrollers must communicate with the StrongARM. BBus is a simple 1-wire point-to-point interface designed specifically for this purpose. The FPGA provides a single BBus transceiver and a 3-way bi-directional multiplexer to attach the three BBus microcontrollers. For more Bbus information see the microcontroller firmware source files. From the programmer's standpoint, BBus operates like SPI, where each transaction exchanges a single byte between the host and peripheral.

PWM Analog Outputs

Four PWM channels are provided for the generation of analog outputs. Three of the outputs are available on the Analog I/O connector; the fourth is available internally for future use (if any). One of the PWM channels provides 12-bit resolution at 6 kHz cycle rate; the other three provide 8-bit resolution at 96 kHz cycle rate. The StrongARM simply writes the desired value into a PWM data register and the output duty cycle changes on the next PWM cycle. External analog circuitry converts the PWM logic signals to smooth analog voltages. The 12-bit PWM channel is intended for ECG output and produces a swing of +10 to -10V. The two 8-bit channels provide a unipolar 10V output. Regardless of the resolution or swing range of each PWM channel, the FPGA treats the data value as a signed 16-bit number representing a voltage from +10V (0x7fff) to -10V(0x8000). Logic in each PWM channel ensures that the closest possible voltage is generated for each data value (ex. 0x8000 on an 8-bit channel produces zero volts output).

The FPGA PWM output signals contain a substantial amount of noise from +3V-M supply fluctuations. To reduce noise and establish an accurate reference level, the PWM signals are buffered by CMOS inverters (U16) that are powered from REF2V5. Although the CMOS inverters are powered by 2.5 Volts but are driven by 3.3 Volt logic, no problem exists as this is allowed with VHC logic. The PWM output signals are then low pass filtered (R79,C104, etc.) before being passed to the output amplifiers. The ECG output channel amplifier injects an offset current derived from REF2V5 to achieve bipolar operation. The DC outputs operate in unipolar fashion, eliminating the vexing MAX-1 offset problems. No zero calibration is required for the DC outputs. Since the ECG output is an AC signal, no offset adjust is required there either.

The output amplifiers provide additional low pass filtering (R71,C89, etc.). ESD (Electrostatic Discharge) protection and additional PWM carrier filtering is provided by 0.1µF filter capacitors. To prevent amplifier oscillation, blocking resistors are placed between the amplifier outputs and the filter capacitors.

Beep Generator

A simple tone generator with two volume levels provides system beeps and key clicks. Frequencies of 250 Hz, 500 Hz, and 1 kHz are provided at both low and high volume. The logic level output signal drives LS1 through an open collector transistor driver Q1. Full volume is achieved by driving the fundamental beep tone directly to the speaker. Half volume is achieved by gating the speaker signal with a 24 MHz square wave, reducing the amplitude by 50%.

SDRAM

Program code and working data is stored in a single 4MWord bank of 32-bit wide memory (16MBytes). This memory is made up of 2 64Mbit SDRAMs each 16 bits wide. Although the present design uses 64Mbit devices, 128Mbit and 256Mbit devices may also be used (i.e. the extra address line has been routed to the devices). All bus timing and refresh control is performed by the StrongARM processor. The SDRAM clock rate is ½ that of the StrongARM's CPU clock or 103.2 MHz. Since the clock rate is technically higher than 100 MHz the memory needs to be PC133 compliant. Although re-programmable via software, the present design uses memory with CAS3 data timing.

SmartMedia Card

FPGA configuration data and system software are stored on a SmartMedia card. The system can accommodate sizes from 2MBytes to 16MBytes (probably larger too as those sizes are announced). To reduce loading on the processor address/data busses, the SmartMedia card is accessed by the StrongARM via the isolated XBus. Special gating is provided in the FPGA for the SmartMedia CS pin to reduce susceptibility to accidental writes.

Serial EEPROM

System setup information, option enables and other machine specific data is stored in a 16KByte serial EEPROM. The SPI interface to the EEPROM is provided by the FPGA.

VGA LCD/CRT Interface

An internal backlit LCD is home for the MAC 5000's graphical interface. In addition, external VGA monitors are supported for stress applications. Control for a standard VGA format (640 x 480 pixels) LC display is provided by the FPGA. A connector is provided for an external CCFL (Counter-Current Flow Limit) backlight inverter as well as two digital controls for On/Off and brightness. While the FPGA is capable of directly driving the LCD, external hardware is required to generate the analog video levels expected by external VGA monitors.

LCD Panel EMI Reduction Components

To reduce EMI, 47pF capacitors have been added to all LCD digital lines. In addition, 49.9 Ω resistors have been added to the video clock and Sync lines.

CRT Video DAC / Sync / Buffers

A triple 6-bit video DAC supports external analog VGA monitors. Only one DAC/Level Shifter/Buffer will be described, as they are all identical in function. The video output is referenced to a filtered tap (FB25, C219) off the +3V-M supply rail and then level shifted back to ground.

Each DAC is comprised of six binary weighted resistors and a seventh blank/sync signal resistor. The FPGA LCD data outputs sink current through the 75Ω load resistor in proportion to their respective DAC resistors. The voltage across the 75 Ω load resistor represents the sum of all drive currents. Minor non-linearity is introduced in the DAC transfer function by the fact that the summing junction varies in voltage with DAC current.

The 3.3V referred video is shifted back to ground by a blocking capacitor. The shifted video signal is buffered (and further shifted) by emitter followers. Transistors clamp the negative excursions of the bases of the emitter followers to one diode drop above ground, so the most negative level at the emitter of the emitter followers is ground. Nominal full-scale swing is 1VP-P (blank to white).

Bias for the base of the clamp transistors is provided by a 1.4V bias supply consisting of a stack of two diode connected transistors (QP2). This 2Vbe bias exactly cancels the 2Vbe shift produced by the level clamp and output buffer. Since all transistors are of the same type their Vbe's track well enough to provide acceptable output offset.

Diode clamps to ground and +3V-EMI provide ESD protection for the VGA video and sync signals. The +3V-EMI rail is isolated from ESD transients by FB13.

Acquisition Module Transceiver / Power Switch

MAC 5000 acquires ECG data with a new generation CAM acquisition module. The FPGA provides the interface logic. Clocks and commands are transmitted to the acquisition module on a balanced RS485 line. Data is received similarly. Power to the acquisition module is provided by a software controlled linear regulator.

Transceiver

To reduce EMI and susceptibility to noise, the acquisition module link is implemented using RS-485 differential signaling. An RS485 interface device provides the single ended to differential conversion in both directions. Ferrite beads, capacitors and resistors are used to reduce EMI on both sides of the transceiver.

Acquisition Power Regulator / Switch

To reduce standby power consumption, acquisition module power is switchable. To protect the acquisition module from temporary brownouts on the main 12V supply, power is obtained from a parasitic winding on the main 5V regulator. This voltage is not well regulated, so a linear regulator (U14) is used to provide regulation. This regulator also sports an enable input which is used to disable power to the acquisition module when not in use. The regulator also has build in current limit and over temperature shutdown for protection.

COMM Port Power Switch / Current Limiter

Power for external peripherals such as a modem or the KISS vacuum electrode pump is available on the COMM connectors. Power may be turned on/off under software control and current limiting is employed to protect internal operations from excessive external loads. The current requirements and start-up conditions of the KISS pump require very high currents. U.L. limits power to external devices to 15 Watts for reducing the likelihood of fire during overload. The KISS and U.L. requirements conflict to a degree that a simple current limiter will not satisfy both needs therefore a special current limiter circuit had to be devised. Six Sigma project #27118 MAC 3000 Com Port Power Circuit project addressed this issue and is implemented in this design.

Since currents exceed 1 Ampere and the supply is 12 Volts a linear current regulator is impractical since the pass element would need a heatsink. The method chosen here was to use a FET (Q5) as a switch (a switch is either on or off and in both cases dissipates little power). In normal operation the ENIOPWR signal is driven high by software to activate the power switch. This signal saturates transistor Q3 which provides the gate drive for the dual FET Q5. Both P channel FETs of Q5 are used and therefore are connected in parallel. Return current from the load is sensed by shunt resistor R31 (0.1Ω). One stage of the quad opamp U4 is used as a differential amplifier to boost this current sensed signal. Another stage of U4 is used as an integrator which integrates the amplifier current limit signal before entering comparator U5. When the current exceeds the comparator threshold the open drain output of the comparator is used to remove the gate drive from Q3 which will in turn switch off the com port power. The function of the integrator is two fold. First it allows high surge currents to exist for a short time for starting the KISS pump. Secondly the integrator has a much longer recovery time due to diode CR6 which effectively changes the integration resistor from 100K Ω to 1Meg Ω. This long recovery time results in a low duty cycle when the load is a short circuit. The low duty cycle prevents FET Q5 from overheating when driving a short circuit.

Thermal Printhead Power / Pixel Test Hardware

The FPGA provides all the interface logic for the thermal print head. A MOSFET switch controls power. A charge pump voltage doubler driven by the FPGA provides that switch's gate drive.

Additional circuitry (currently unsupported) is supplied to allow the measurement of individual dot resistance for automatic strobe width compensation and blown dot detection. A switchable constant current source (6mA) applies a test current to the TPH power bus. Larry then measures the TPH power bus voltage (one of the four analog inputs he continuously monitors). By loading a single black dot into the print head it is possible to measure its resistance. A typical TPH has an average dot resistance of 650 Ω. Presuming negligible driver leakage current, a single enabled dot would drop 3.9V. While there are mitigating influences (off-pixel driver leakage current and on-pixel driver saturation voltage) that might make accurate pixel resistance measurements difficult, it is certainly possible to differentiate pixels of nominal resistance from those that are blown open.

Super I/O Peripheral Controller

A PC standard Super I/O peripheral controller provides floppy drive support, two serial channels (one IrDA compatible), and a clock/calendar.

Floppy Drive Support

The Super I/O provides support for a 3.5" 1.44MByte IBM format floppy diskette drive. The FPGA provides DMA-like interrupt support for the floppy controller. A special chip select supplies the DMA acknowledge signal that gates data to/from the Super I/O floppy controller via the XBus. To ensure no data is lost, the floppy DMA request is routed to the StrongARM's FIQ input.

RS-232 Serial Ports (one dual mode RS-232 / IrDA)

Four serial ports are provided on two back panel Mini-DIN 8 pin connectors. The Super I/O device provides two serial ports (COM1 and COM2) and two more (COM3 and COM4) are provided by the SA-1110 StrongARM processor. The COM2 serial port and modem handshake lines are found in the COM2 connector. COM1, COM3, and COM4 serial ports use pins in the COM1 connector. The COM2 serial port of the Super I/O device also supports the IrDA (Infrared Data Association) interface.

RS-232 level shifting is provided by two transceivers. Each produces the necessary drive voltages with internal charge pumps. The devices are rated to withstand ESD onslaught, so no external ESD protection is provided. The transceivers may be shut down under software control to conserve power.

Clock/Calendar

The Super I/O device provides a clock /calendar function. Backup battery power is provided by a “super” capacitor (C98) with sufficient storage capacity to power the clock for hours after main battery removal. This backup source provides sufficient time to exchange battery packs when necessary. Diode CR14 charges C98 when the main system power is up. R83 limits the charging current to a safe level.

PS2 Keyboard Port

External card / bar code readers may be connected to the MAC 5000 via a PS-2 compatible keyboard port. A small amount of 5V power is available at the connector to power the external device. Power faults are detectable. EMI and ESD protection are provided.

The Four Stooges

System management and some low level I/O functions are implemented in preprogrammed 68HC05 microcontrollers. Moving some I/O functions out into small processors relieves the StrongARM of burdensome real-time chores and moves the control hardware closer to the controlled devices, potentially reducing EMI. Localizing control also promotes reuse in future designs as the functions are self contained and reasonably portable.

Although there are four of these little fellows in the MAC 5000, each performing a different function, there is only one firmware image. By merging the code from each of the four functions into a single ROM image, cost and confusion are reduced. It is impossible to place a processor in the wrong spot on the board and a single pile of paperwork supports all of the MAC 5000's 68HC05 production volume. More detailed information may be found in the source code.

Start-up Self Identification

As each controller is released from reset, it executes a common "WhoAmI" routine to determine its identity on the board. Each controller's environment is uniquely and easily identified with a few port pin tests. Once the identity is discovered, the code jumps to the appropriate entry point in the unified image and microcontroller assumes the desired personality.

The flow for the "WhoAmI" routine is as follows:

- Run ChkMoe: Basically if the BBus (PD5) is low we are Moe. Since Moe controls the power supply for +3V-M which is off at the moment, the BBus pull-up resistors will actually pull the BBus lines low. This can only occur with Moe since all other Stooges are powered by +3V-M, Moe is powered by +3V-C instead.
- Run ChkCurly: First drive the BBus (PD5) low, if the IRQ line stays high we are Curly. Curly is the only Stooge that does not use the BBus and the connection from BBus (PD5) to the IRQ line is not necessary. Curly's IRQ pin is tied to +3V-M and is therefore always high.
- Run ChkShemp: If bit 4 of Port A is high, we are Shemp. At this point we are either Shemp or Larry. Shemp has pull-up resistors on Port A so bit 4 should be high. Larry on the other hand has uses Port A to drive a makeshift DAC. Since Port A is not being driven at the moment, bit 4 will be pulled to low via the common DAC resistor R136 which is grounded.
- We must be Larry. At this point we have eliminated all other Stooges.

BBus

Three of the four stooges (Moe, Larry and Shemp) communicate with the StrongARM via BBus connections. BBus is a single wire, half-duplex serial connection that places minimal hardware requirements on the microcontroller while yielding respectable bit transfer rates (~50KBps). A common set of BBus commands allow the StrongARM to access 128 bytes of RAM in each microcontroller. This dual port access allows the StrongARM to examine and modify internal variables in each controller while code is executing. This ability is used to allow the unalterable HC05 code to handle modest changes in hardware, such as changes in paper drive gearing or battery pack capacity.

Curly

Curly is responsible for configuring the FPGA and loading the first level bootstrap program into the Boot ROM emulated by the FPGA (see previous section titled 'StrongARM Boot ROM Emulation'). When Reset is released, Curly reads the PCB ID code from three port pins and then searches the SmartMedia card via the XBus data bus for a matching FPGA configuration image (pages with ID "Xn" where n is the 3-bit PCB ID code 1-8). Once located, the configuration image is loaded into the FPGA. The boot code is stored in the SmartMedia card in a special format that Curly understands and contains a small program that enables the StrongARM to read the SmartMedia card by itself. Once this first stage bootstrap program is loaded (SmartMedia ID of “Bn”, where n is the PCB ID), Curly will release the StrongARM from reset and Curly shuts off (effectively disappearing from the circuit) until the next system start-up. In this version of the CPU board the ID codes are X2 and B2.

Shemp

Similar in function to the ABus keyboard controller in MAX-1 architecture machines, Shemp scans the keyboard and queues key presses for the StrongARM. Unlike previous designs, key presses are reported both on press and release, allowing system software to implement auto-repeat as well as the continuous operation of treadmill control keys (up/down, faster/slower). A special key code indicates when all keys are up as a safeguard against stuck keys in the application software.

Unlike previous keyboard encoder designs, Shemp does not provide dedicated scan hardware for the shift and / or option keys. These keys are now located in the scan matrix. Careful placement of keys in the scan matrix allows simultaneous depression of the shift, option and other keys without interference.

Larry

Larry controls the paper drive motor and digitizes the analog inputs. The motor control functions are virtually identical to those offered by the 78310 processor in MAX-1 architecture machines, with an expanded speed control range (down to zero). Since Larry's code is not field-alterable, every motor control parameter is alterable via BBus. Hopefully this renders the code immune to minor changes in the printer drive train.

Motor Speed Control – Larry controls the motor speed by delivering a DAC controlled drive voltage to the motor windings. The 6-bit DAC is implemented using discrete, binary-weighted resistors directly driven by Larry's port pins. The DAC output voltage (approx. 300mV full scale) is compared to a filtered fraction of the applied DC motor voltage by comparator U29. If the motor feedback voltage is below the DAC voltage, the comparator turns on the motor via an H-Bridge driver. One motor terminal (which one is a function of motor direction) is always grounded. The other is alternately driven to either 12V or ground. The duty cycle of the drive signal determines the average applied voltage and therefore the average motor speed. The feedback voltage signal is the average of both motor terminals (R125 and R148 driving R123), with a 50:1 ratio, 15Vin = 300mV out, hence 15V full scale). Since one terminal is always zero (grounded) and the other is driven with a variable duty cycle between zero and 12V, the feedback signal is positive regardless of motor direction. C178 filters the switching noise from feedback voltage.

Note that the frequency and duty cycle of the motor drive signal are random. This serves to reduce EMI by spreading any emitted noise across a wide frequency spectrum. An RC snubber (R161 and C198) suppresses ringing on the motor lines.

Larry maintains precise motor speed control by comparing the frequency of the tachometer pulse train emitted by the motor's integral encoder to an internally generated reference frequency derived from Larry's resonator. Larry processes motor position information on both edges of both encoder signals for a total of 64 loop correction cycles per rotation of the motor shaft. This high angular sampling rate allows Larry to achieve accurate and smooth speed regulation down to zero speed.

Paper Jam / Pull Detection – Larry monitors the servo error variable to determine whether the servo loop is closed. If the error variable saturates "on" for more than a predetermined time it is assumed that the paper drive torque has become excessive, or the motor has stalled. This condition is reported as a Paper Jam Error.

Similarly, if the servo error variable saturates at "off" for more than a predetermined time, it is assumed that the someone is pulling on the paper with a force that exceeds the paper drive system torque, and as a result paper speed has been pulled out of regulation. This condition is reported as a Paper Pull Error.

Cue Hole Sensor

Cue and out-of-paper conditions are sensed via the thermal print head's integral optical cue sensor. Larry monitors the cue sensor's logic output.

Cue Hole Detection

Larry monitors the output of the cue sensor to detect the presence or absence of paper under the sensor, and hence the absence or presence of cue holes.

Paper Tracking Fault Detection

Larry monitors the cue sensor for abnormally long paper travel without encountering a cue hole. This condition is reported as a Paper Fault.

Paper Out Detection

Larry reports excessive paper travel without sensing paper as a paper out condition.

Analog Inputs

Larry digitizes four analog inputs at eight bits resolution each. Two inputs handle external analog signals, such as those produced by ergometers or analog output blood pressure monitors. Thermal printhead temperature is measured for use in compensating strobe pulse width to maintain constant print density over a wide range of thermal printhead temperatures. The output of the thermal printhead pixel test hardware is also digitized to allow the resistance measurements on individual print elements.

Moe

Moe is responsible for controlling and monitoring the battery, power supplies, on/off key, system reset and related functions. Moe runs continuously from +3V-C, even in the absence of AC power. This continuous operation is necessary for Moe to accurately monitor the battery state of charge and detect power key presses.

System Startup – When the system is off and the user presses the power key, Moe begins the startup sequence. If the battery contains sufficient charge, or if AC power is applied, the main CPU board power supplies (+3V-M and +5V-M) are enabled and after a suitable stabilization period SYSRESET* is released. Moe then keeps tabs on the system via a software watchdog that must be serviced by specific BBus activity from the StrongARM. Moe himself is monitored by a self contained MAX823 watchdog timer / brownout detector. Moe must constantly toggle the MAX823 watchdog input pin or suffer the consequences.

NOTE

> Moe presumes that the main power rails, which it controls, are off when it powers up. If Moe should malfunction while the system is already powered it is likely that the HC05 will incorrectly identify itself as Larry. Larry's default power-up state results in its port pins assuming a state that disables +3V-M. Since Larry does not service the watchdog chip (WDOG), another reset will follow within 2 seconds. As +3V-M is now down, Moe will be selected at the next restart.

When SYSRESET* is released, Curly configures the FPGA and starts the StrongARM from information stored in the SmartMedia card. Moe expects the StrongARM to request status via the BBus interface within a few seconds of startup. If that request doesn't arrive in time, Moe places the system back in reset and removes power.

In the event of main CPU failure that causes loss of function yet maintains Moe's watchdog function, a manual forced power-down function is provided. A continuous press of the power key for a period greater than 5 seconds will force the system to shutdown.

AC Power/Battery/Charger – Battery and system power management is entirely Moe's responsibility.

An off-the-shelf 28V 1A universal input power supply provides operating/ charging power for the MAC 5000. Located in the bottom of the chassis, the power supply is disconnected from the CPU board when the lid is open. The battery connection is maintained through the hinge so the CPU board is capable of operating for a limited time with the door open.

An LT1511 switchmode charge controller (Battery Charger) provides battery charge current. This device monitors both battery and power supply current draw and maintains both at safe levels. As system current draw increases, the Battery Charger automatically decreases battery charging current to maintain total power supply current below the design level (nominally 1A). Nominal charge current is also 1A, which is achievable only when the system is off.

Moe enables / disables the charger via CR7. When Moe pulls the CHRGTRL line low, CR7 sinks current from the Battery Charger's VC pin shutting down the error amplifier and disabling switching. R21 ensures that the charger remains off when Moe is starting up.

Lid Open Detection – A self-aligning connector routes power and motor signals from the power supply compartment to the CPU board. When the lid is closed the DOOROPEN signal is shorted to ground. When the lid is open a pull-up resistor ensures a high level on DOOROPEN. Moe monitors this line to detect lid open conditions that are reported to the system software to avoid misinterpretation of motor fault indications. When the door is open, the motor connections are lost and Larry receives no tachometer feedback from the motor. Without knowing the cause of the lost tachometer info, Larry can only respond with a paper jam condition. Moe's knowledge of the lid state is used to suppress this error message as well as prevent further print operations.

AC Power Monitor – Moe senses the presence of AC power through a voltage divider (R1, 8) which drives the under-voltage detection comparator in the Battery Charger (Vtrip = approx. 7V). The battery charger will not be enabled unless the DC power supply voltage is above approximately 21V.

Battery Pack – The MAC 5000 uses a 15-cell NiMH (Nickel Metal Hydride) battery pack with integral thermal sensor for charge termination detection and self-resetting thermal fuse for short circuit protection. Charge current and normal system operating power are obtained from the AC power supply. The charger circuitry monitors both battery charge current and power supply output current. The battery is always charged at the maximum rate possible but system power demands take precedence over charger demands. The charger automatically reduces charge current as required to keep the AC power supply output current within specified limits. In the extreme (during printing) charging ceases and energy is taken from the battery to meet peak system demands. When system power draw declines, all excess power supply capacity is once again delivered to the battery.

Battery Temperature Sensor – Moe uses a thermal sensor inside the battery pack to determine when to terminate charge. During normal charge, the electrical energy obtained from the power supply is stored in chemical reactions in the battery. When the battery reaches full charge there are no more reactants available in which to store chemical energy and the supplied charge power is converted directly to heat. The sudden rise in pack temperature caused by this release of heat is an indicator of full charge. When the rate of pack temperature rise exceeds a certain threshold, charge is terminated. This is the only normal charge termination mechanism. Abnormal conditions such as battery or ambient temperatures beyond spec, or excessive pack voltage, may also terminate charge. Once fully charged, the battery is maintained by low duty cycle charge current pulses.

Absurdly low voltage readings from the battery temperature sensor indicate an open thermistor. This is used as an indication that no battery pack is present.

The sole purpose for resistor R18 is to protect Moe's ADC (AN3) pin in the case where the temperature signal TBATTERY becomes inadvertently tied to VBATT+. This can easily occur since the two pins are adjacent. Should the short occur, resistor R18 will limit the current and Moe's internal protection diodes will clamp the voltage to +3V-C.

Battery Voltage Sensing – Moe continuously monitors battery voltage during operation. Excessively high pack voltages during charge will cause charge termination. If battery pack voltage falls below a predetermined threshold during operation, the battery gauge is immediately cleared to zero and the main CPU is notified of the critically low voltage. System software then initiates an orderly shutdown to protect the battery pack and prevent loss of date/time.

Ambient Temperature Sensor – Extreme ambient temperatures are not favorable for battery charging. Rapid changes in ambient temperature can cause premature or delayed charge termination by altering the pack's temperature. Moe monitors ambient temperature via the thermistor TEMP to ensure that charging occurs only within the "safe" temperature range as well as to minimize the effects of changing ambient temperature on charge termination (particularly to avoid premature termination, which would give a false "full" reading on the gas gauge).

The battery and ambient thermistors are the same type and value to ensure reasonable tracking. Capacitors C15 and C55 filter noise from the temperature sense lines.

Thermistor Bias Switch – To reduce quiescent power consumption when the system is turned off, a switch disables bias current to the battery and ambient thermistors. Q8, under control of MOE, switches the low side of the thermistor bias networks.

Charge Light – Moe provides power to the amber charge light in the power supply compartment. Moe communicates the current battery/ charger state via this light.

Four conditions may be indicated:

- Battery charged (light is off)
- Battery needs charge (light blinks twice per second)
- Battery is critically low (light blinks once per second)
- Battery is charging (light on continuously)

Note that f the battery is completely discharged so that the MAX783 VL output (+5V) falls out of regulation, the charge light will remain off.

The charge LED is contained in the power supply compartment and is disconnected from the CPU board when the cover is open. When the cover is closed electrical connections are re-established through the self-aligning connector. As the connections are made in random order, there is a possibility that the VPS and XChargeLED drive lines can connect before the power supply ground. This places a high potential across the LED drive circuit as the power supply attempts to return its output current through the LED. To prevent damage to the LED and driver, it is implemented as a constant current source with a large compliance voltage. Q7 provides the constant current drive, and derives LED operating power from the MAX782 (U26) VL output rather than from +3V-C. Q6 level shifts Moe's output to the level required to turn off Q7 during off periods.

Battery Gauge – Current flow into and out of the battery pack is monitored by Moe via a MAX472 Battery Current Monitor. By integrating the current flow, Moe is able to maintain a reasonable estimate of the battery pack's state of charge. Moe's A/D converter hasn't sufficient dynamic range to cover the full range of system currents at high resolution so some compromises must be made. The current monitor's full-scale range is set to a value that is likely to encompass normal operating currents. Peaks above this level (6Amps) are clipped. The effects of this clipping are minimal as such high density printing occurs for short periods of time and represents only a small portion of system energy consumption. Quantization error limits the ability to measure the small current that flows when the system is off. To compensate for this, Moe presumes a small constant quiescent current flow from the battery. This flow serves to drain the gauge at a rate estimated to mimic the self-discharge and system quiescent current draws.

Current monitor gain is set by R6 and is nominally 1.8A/V for a full-scale (3.3V) current of 6Amps. A low pass filter (R7 and C1) provides filtering to remove switching noise from the signal.

Untested "Nominal" Operating Time Specs

These specifications are affected by battery pack characteristics. While they are of interest, it is not possible to test them in production. These are "nominal specs" and are only guaranteed for a new battery pack of 3.5A capacity. As the following specs are for a system that is turned off, they are deliverable by the CPU regardless of other system components.

Nominal charge time:

5 Hours	
Max off time from gauge full till loss of clock:	1 Month
Max off time from gauge just empty till loss of clock:	3 Days
Max off time from panic shutdown till loss of clock:	1 Day
Maximum time from removal of live battery to loss of clock:	6 Hours

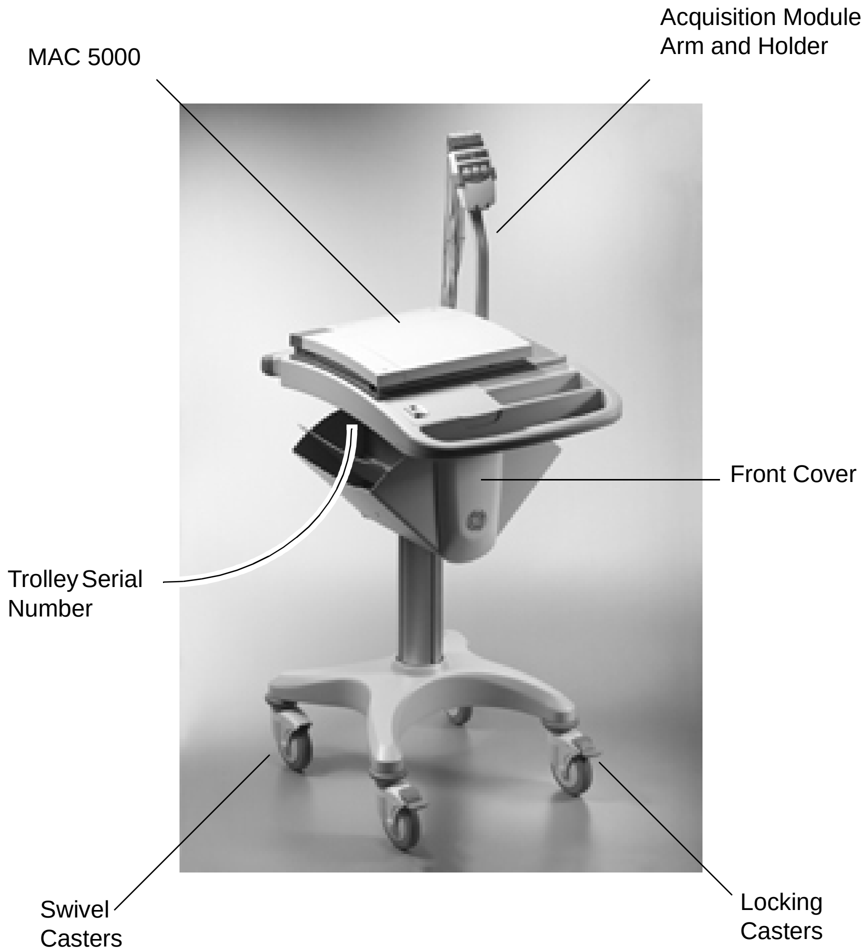
3 Installation

For your notes

Preparation for Use

General

Shown below is a completely assembled optional MAC 5000 Trolley. Use this picture for reference when installing trolley options.



NOTE

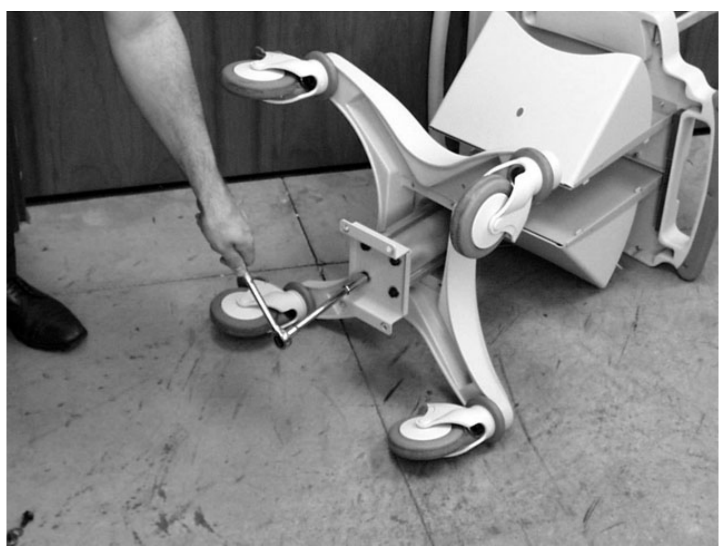
Because the optional Trolley is made by another vendor for GE Medical Systems *Information Technologies*, the serial number format is different from that shown in Chapter-1.

Trolley Height Adjustment

The optional MAC 5000 Trolley can be assembled for one of two heights, 92.07 CM (36.25 inches) or 84.45 CM (33.25 inches). The trolley is normally shipped at the 92.07 CM (36.25 inches) height but can be changed to fit your needs. To change to the lower height, use the following steps:

1. Tip the trolley on its side and using a 1/2 inch socket, remove the four outer 1/2 bolts and slide the base assemble up on the column.

2. Remove the remaining bolts and mounting plate.



3. Flip the mounting plate and reverse the procedure.

CAUTION
Do not over tighten. Over tightening the bolts may cause them to strip.

Installing the MAC 5000

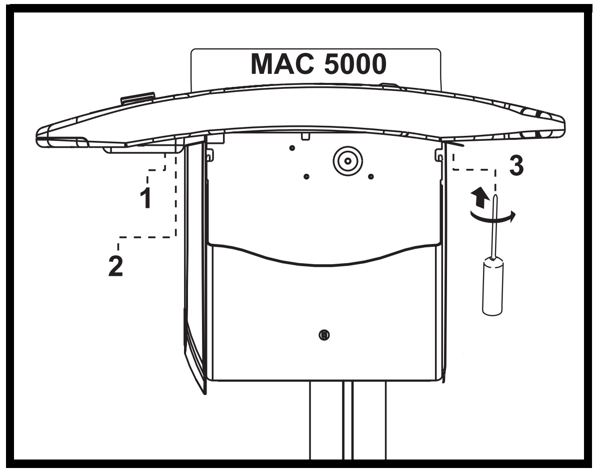
To secure the MAC 5000 to the trolley assembly, follow these steps:

1. Lock the wheels to prevent the trolley from rolling.

2. Remove the end panel by pulling out and up.

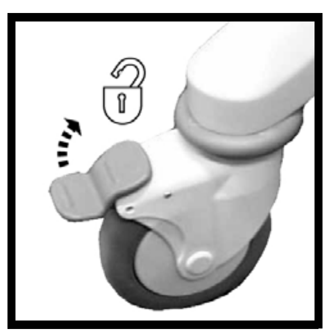
3. Place the unit on the trolley surface, then slide it on until the unit is firmly in place and under the tab at the rear of the on the tray.

4. Secure the MAC 5000 to the trolley by tightening the three captive screws located under the trolley tray.



5. Replace the end panel by pushing up and in until you hear a snap.

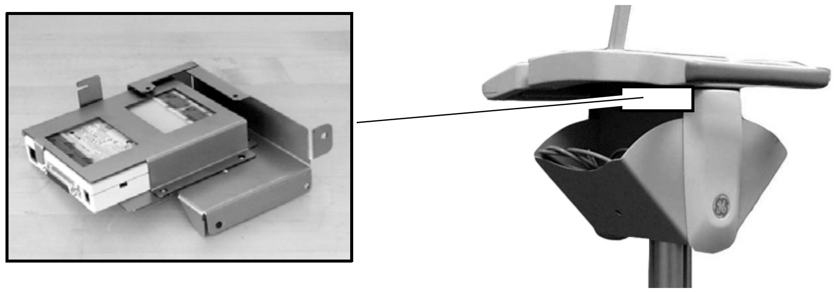
6. Unlock the wheels to allow free movement of the trolley.



Installing the Modem Kit

The modem and its mounting bracket comes assembled and ready to install on the trolley. To install a modem kit on the trolley, complete the following steps:

1. Find the modem mounting site located under the Acquisition Module support arm at the rear of the trolley where the kit is to be installed.



2. Slide the assembly up in place so that the bracket slot catches on the bracket lip.

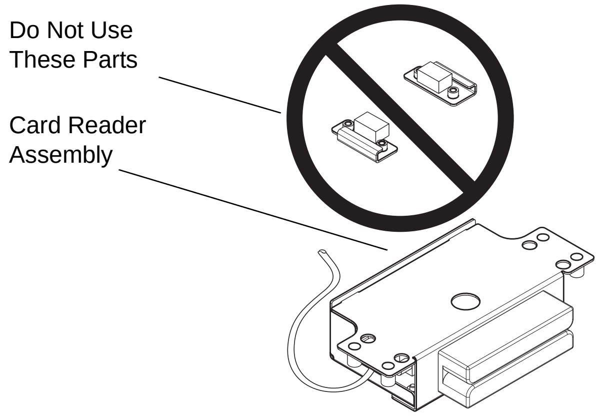
3. Tighten the three mounting screws to secure the modem to the trolley.

4. Plug the modem cable into connector port **2** on the MAC 5000.

5. Refer to the operator’s manual for information on using the modem.

Magnetic Card Reader Installation

The Magnetic Card Reader and its mounting bracket are assembled and ready to install on the trolley. Parts are included for two different trolley styles. Disregard and do not use the parts indicated in the following illustration.

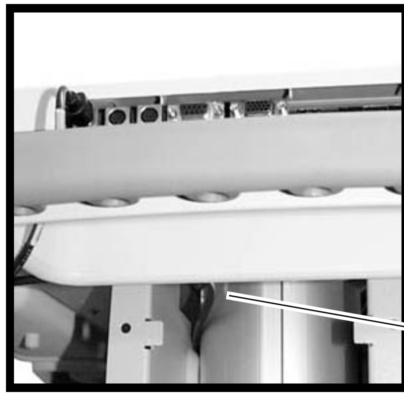


To install the Magnetic Card Reader and its mounting bracket on the trolley, complete the following steps:

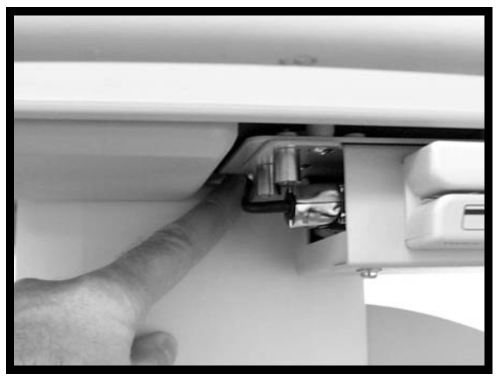
1. Remove both end panels by pulling out and up at the bottom.

2. Using a Phillips screw driver, fasten the Card Reader assembly under the front handle where the holes are provided.

3. Route the cable around the trolley column towards the rear as shown below.



4. At the front, hold the cable to the side so it clears the front panel as you replace the panel.

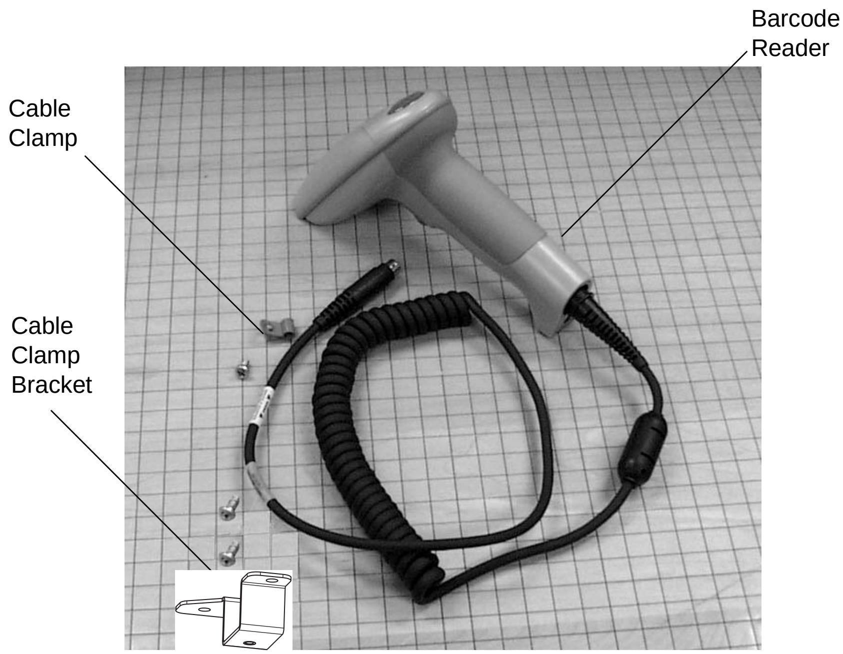


5. Plug the cable connector into port **A** then replace the back panel.

6. Refer to the MAC 5000 Operator's Manual for information on using the Magnetic Card Reader.

Bar Code Reader Installation

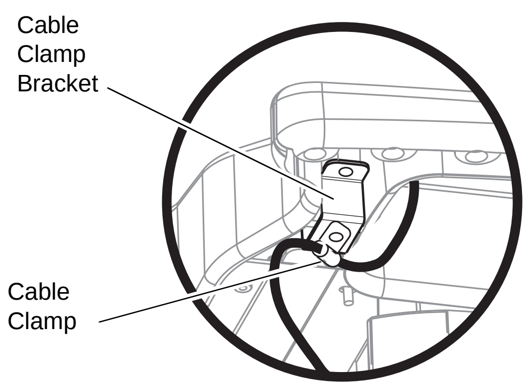
The Bar Code Reader and its mounting bracket are ready to install on the trolley. To install the Bar Code Reader and its cable mounting bracket on the trolley, complete the following steps:



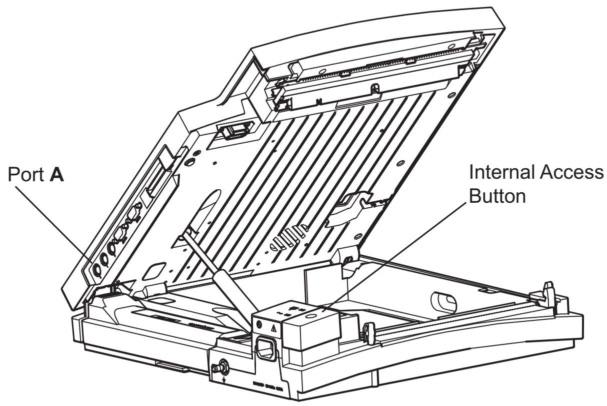
1. Fasten the cable clamp bracket to the underside of the rear handle using a Phillips screw driver and the self tapping screws provided.

   NOTE

   DO NOT overtighten. Overtightening the screw may cause the screw to strip and clamp to fail.



2. Press the Internal Access Button to open the MAC 5000, then plug the cable connector into port **A.** Opening the MAC 500 before attaching the cable clamp allows you to place the correct amount of slack to free the cable from stress when the MAC 5000 needs to be re-opened.



3. Next fasten the cable and clamp to the clamp bracket, then close the MAC 5000. Observe that there is enough slack to allow free movement of the cable when re-opening the MAC 5000.

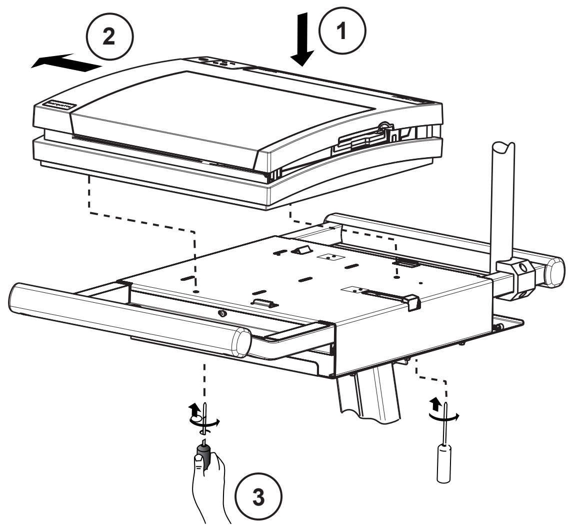

Correct amount of cable slack.


Not enough cable slack.

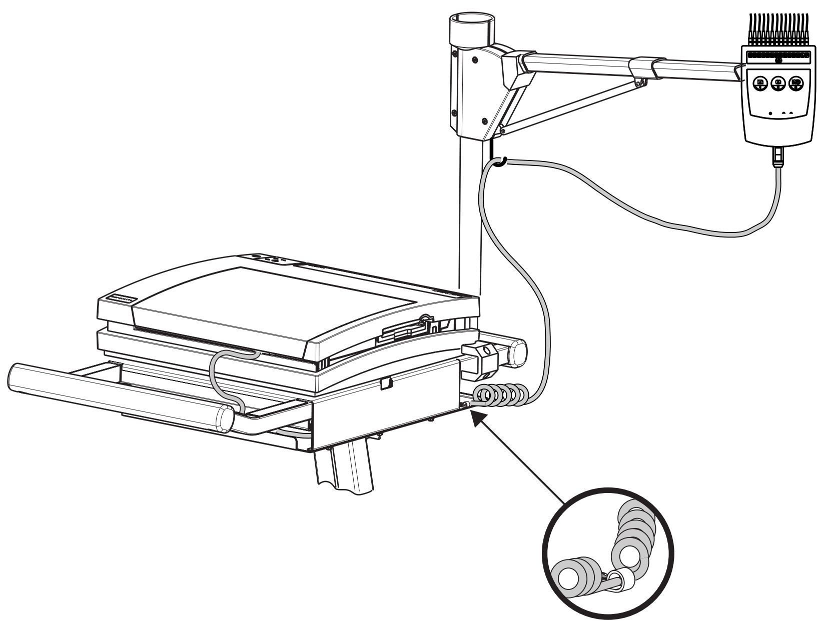
4. Refer to the MAC 5000 Operator's Manual for information on how to use the Bar Code Reader.

Type-S Trolley Assembly

1. To mount the MAC 5000 to the Type-S trolley, follow the steps in the illustration below.



2. Route patient cable through trolley and fasten with cable clamp as shown below.



MAC 5000 ST Requirements and Configuration

Following is a list of interface requirements and setup configurations required for the devices listed when used with the MAC 5000 ST option.

Compatible Blood Pressure Units

Colin - Model ST-780

Connection Requirements - Use cable PN 2008112-001 to connect from the MAC5000 port **1** to the Colin serial port. Use cable PN 2008111-001 to connect from the MAC5000 **ANA/TTL** port to the Colin QRS trigger input.

Device Configuration Requirements - None

MAC5000 Configuration Requirements - At the Main Menu complete the following in the order shown below:

- Select *System Setup*,
- Enter *System password*,
- *Exercise Test*,
- *Inputs/Outputs*,
- Change *Blood Pressure* to *Nipon-Colin*.

Sun Tech - Model Tango

Connection Requirements - Use cable PN 2008113-001 to connect from the MAC5000 port **1** to the Sun Tech serial port. Use cable PN 2008111-001 to connect from the MAC5000 **ANA/TTL** port to the Sun Tech QRS trigger input.

Device Configuration Requirements - At the Tango Main Menu complete the following in the order shown below:

- Select Utilities,
- Select Device,
- Scroll to ECG Trigger and press enter,
- Scroll to DIGITAL↑ and press enter,
- Scroll to EXIT and press enter,
- Scroll to Test Parameters and press enter,
- With Technique highlighted, press enter,
- Scroll to DKA and press enter,
- Scroll to EXIT and press enter,
- Scroll to EXIT and press enter to return to the display screen.

MAC5000 Configuration Requirements - At the Main Menu complete the following in the order shown below:

- Select *System Setup*,
- Enter *System password*,
- *Exercise Test*,

- *Inputs/Outputs*,
- Change *Blood Pressure* to *Suntech*.

Ergoline - Model Ergoline 900

Connection Requirements - Use cable PN 2008110-001 to connect from the MAC5000 port **1** to the Ergoline serial port. Use cable PN 2008115-001 to connect from the MAC5000 **ANA/TTL** port to the Ergoline QRS trigger input.

Device Configuration Requirements - See Ergoline 900 Operator's Manual.

MAC5000 Configuration Requirements - At the Main Menu complete the following in the order shown below:

- Select *System Setup*,
- Enter *System password*,
- *Exercise Test*,
- *Inputs/Outputs*,
- Change *Blood Pressure* to Ergoline Ergometer.

Compatible GE Medical Systems *Information Technologies* Treadmills

Model T2000

Connection Requirements - Use cable PN 2007918-001 (T2000) to connect from the MAC5000 port **1** to the treadmill serial port.

Device Configuration Requirements - None.

MAC5000 Configuration Requirements - Use the Edit Protocol application to set the protocol Test Type to *Treadmill in MPH* or *Treadmill in Km/H* for protocols that will be used with this treadmill.

Analog Treadmills

Connection Requirements - There are no cables available from GE Medical Systems *Information Technologies* to interface to analog treadmills. The customer is responsible for making the appropriate cable. Speed and grade signals for controlling analog treadmills are available on pins 2 (Slow Analog Output) and 8 (Fast Analog Output) of the **ANA/TTL** port. Pins 1, 4 and 5 are tied to ground.

Device Configuration Requirements - None.

MAC5000 Configuration Requirements - Use the Edit Protocol application to set the protocol Test Type to *Analog Treadmill in MPH* or *Analog Treadmill in Km/H* for protocols that will be used with this treadmill.

Configure pin 2 on the **ANA/TTL** port by selecting the following:

- *System Setup*,
- *Exercise Test*,

- *Inputs/Outputs*, and
- set *Slow Analog Output* to *Workload*.

Configure pin 8 on the **ANA/TTL** port by selecting the following:

- *System Setup*,
- *Exercise Test*,
- *Inputs/Outputs*, and
- set *Fast Analog Output* to *Workload*.

Bicycle Ergometers

Ergoline 800/900, Lode Ergometer

Connection Requirements - Use cable PN 2008109-001 (Ergoline 800), PN 2008114-001 (Ergoline 900), or PN 2007981-001 (Lode Ergometer), to connect from the MAC5000 **ANA/TTL** port to the ergometer analog control port.

NOTE For any other ergometer, the customer is responsible for making the appropriate cable.

Device Configuration Requirements - Refer to ergometer Operator's Manual.

MAC5000 Configuration Requirements - Use the Edit Protocol application to set the protocol Test Type to *Ergometer in Watts* or *Ergometer in KPM* for protocols that will be used with this Ergometer.

Configure pin 2 on the **ANA/TTL** port by selecting the following:

- *System Setup*,
- *Exercise Test*,
- *Inputs/Outputs*, and
- *Slow* Analog Output to *Workload*, or

configure pin 8 by selecting

- System Setup,
- Exercise Test,
- *Inputs/Outputs*, and
- *Fast Analog Output* to *Workload*.

For your notes

4 Maintenance

For your notes

Introduction

Recommended Maintenance

Regular maintenance, irrespective of usage, is essential to ensure that the equipment will always be functional when required.

WARNING
Failure on the part of all responsible individuals, hospitals or institutions, employing the use of this device, to implement the recommended maintenance schedule may cause equipment failure and possible health hazards. The manufacturer does not in any manner, assume the responsibility for performing the recommended maintenance schedule, unless an Equipment Maintenance Agreement exists. The sole responsibility rests with the individuals, hospitals, or institutions utilizing the device.

Required Tools and Supplies

In addition to a standard set of hand tools, you will need the items listed below.

Table 1. Tools and Supplies

Item	Part Number
#10 TORX driver	
Leakage current tester	MT-1216-02AAMI (for 220V) MT-1216-01AAMI (for 110V)
Multifunction micro-simulator	MARQ 1
Precision dust remover	
Lint-free soft cloth	TX609
PS2 style keyboard (Japan only)	

Inspection and Cleaning

Visual Inspection

Perform a visual inspection of all equipment and peripheral devices daily. Turn off the unit and remove power before making an inspection or cleaning the unit.

- Check the case and display screen for cracks or other damage.
- Regularly inspect all cords and cables for fraying or other damage.
- Verify that all cords and connectors are securely seated.
- Inspect keys and controls for proper operation.
  - Toggle keys should not stick in one position.
  - Knobs should rotate fully in both directions.

Exterior Cleaning

Clean the exterior surfaces monthly, or more frequently if needed.

1. Use a clean, soft cloth and a mild dish washing detergent diluted in water.
2. Wring the excess water from the cloth. Do not drip water or any liquid on the equipment, and avoid contact with open vents, plugs, or connectors.
3. Dry the surfaces with a clean cloth or paper towel.

Interior Cleaning

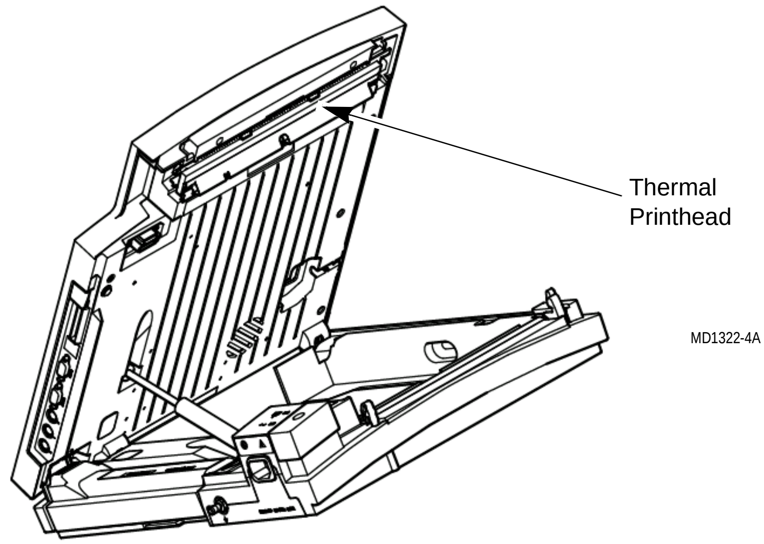
General

Check for dust buildup on the surfaces of the interior circuit boards, components, and power supply. Use commercially available compressed air to blow away the accumulated dust. Follow the manufacturers directions.

Thermal Printhead

Clean the thermal printhead every three months or more often with heavy use. A build-up of thermal paper coating on the printhead can cause light or uneven printing.

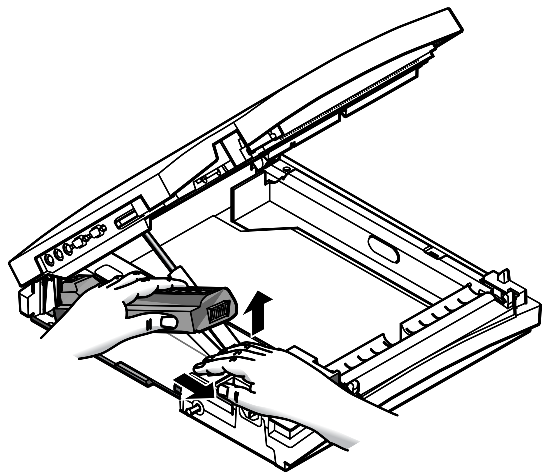
Use a solution containing alcohol on a nonwoven, nonabrasive cloth such as Techni-Cloth to wipe off the printhead. Do not use paper toweling, as it can scratch the printhead.



Battery and Patient Cable Replacement

Battery Replacement

1. Press the internal access button to open the unit.
2. Slide the battery release button in the direction of the arrow and lift the battery out.

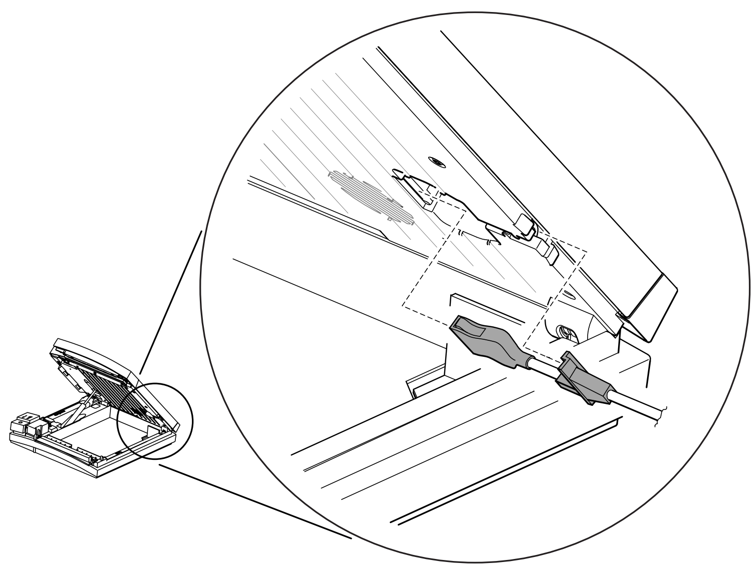


MD1325-112B

3. Install a new battery and close the unit.

Patient Cable Replacement

1. Press the internal access button to open the unit.
2. Press the connector release tabs and pull the connector loose.
3. Pull the cable from the retaining tabs.



MD1322-006

4. Reassemble the cable by reversing the above steps.

Disassembly Guidelines

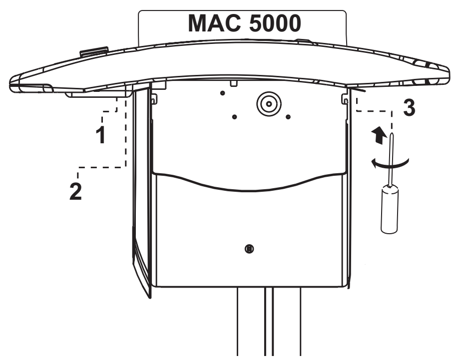
Preliminary Steps

Prior to disassembly, perform the following:

- If possible, process any ECGs remaining in storage.
- If possible, print out set-up for future reference.
- Disconnect the unit from the AC wall outlet and remove the power cord from the unit.
- Remove the battery.
- Remove the chart paper.
- Take strict precautions against electrostatic discharge damage.

Trolley Disassembly

1. Lock the wheels, remove the rear trolley panel then loosen the three captive screws located under the trolley.

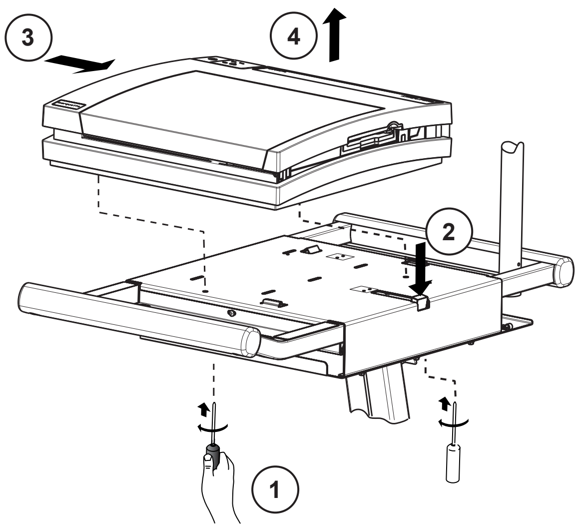


2. Pull the MAC 5000 up and up towards you.

3. Lift the unit from the trolley.

Type-S Trolley Disassembly

To dismount the MAC 5000 from the Type-S trolley, follow the steps shown in the illustration below.



Power Supply

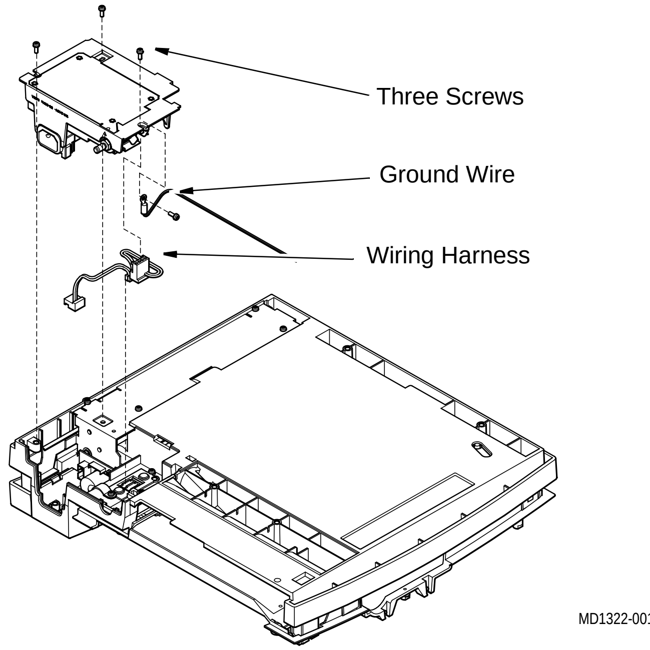
NOTE

A #10 TORX driver is required for disassembly and assembly of the Power Supply.

Removal

1. Turn the unit over so the bottom side is up.
2. Using a #10 TORX driver, remove the three screws holding the power supply in place.
3. Lift the power supply to expose the wiring harness and ground wire.

4. Remove P2 from J2 on the power supply assembly and the ground wire connection from the power supply chassis.



Reassembly

Reassemble the power supply reversing the steps for removal. Before replacing the screws, ensure that the ground wire is routed through the notch in the plastic and not pinched.

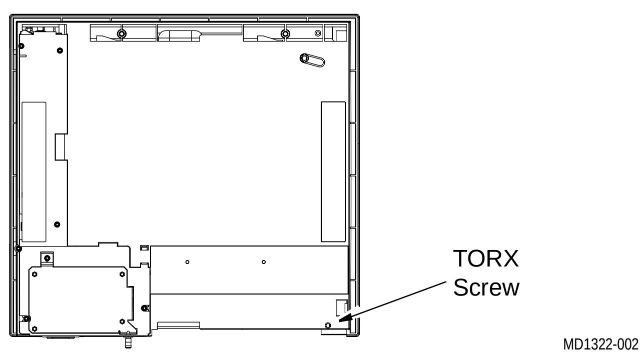
Top Cover

Removal

NOTE

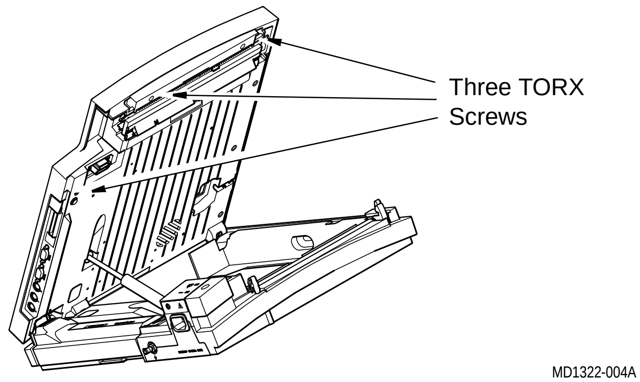
It is not necessary to remove the Power Supply prior to removing the top cover.

1. Turn the unit over so the bottom side is up and remove the TORX screw through the hole on the right rear corner of the unit. (This screw is only visible and accessible with the battery removed.)



2. Turn the unit right side up and press the internal access button and raise the top of the unit.

3. Remove three TORX screws.



4. Lower the top of the unit and lock in place.
5. Raise the display to the vertical position.
6. Gently lift the rear of the top cover free from the unit.

   NOTE

   The top cover holds the bezel that surrounds the rear panel connectors, so the bezel may fall free at this time.

7. At the front of the top cover, gently pull the thin strip of plastic free from under the keyboard. The entire top assembly is now loose.

   NOTE

   It may be helpful to rotate the top cover 45 degrees to provide a larger opening to clear the display.

8. Carefully lift the top assembly up and clear of the raised display.

Reassembly

1. Raise the display to the vertical position.
2. Make sure the bezel surrounding the rear panel connectors is in place. Make sure the release mechanism for the Smartmedia card functions properly.
3. Lower the top cover down around the display and set in position.
4. Snap the rear of the top cover in place and then, gently pulling on the thin plastic strip at the front of the top cover, position it in place under the keyboard assembly.
5. Replace the screws removed in disassembly.

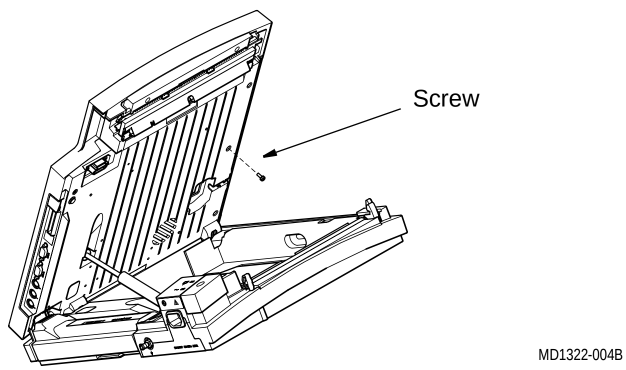
Display/Keyboard Assembly

Removal

1. Remove the top cover following the procedures above.
2. Label the three cables connecting the display/keyboard assembly to the main PCB. Disconnect these cables from the main PCB.

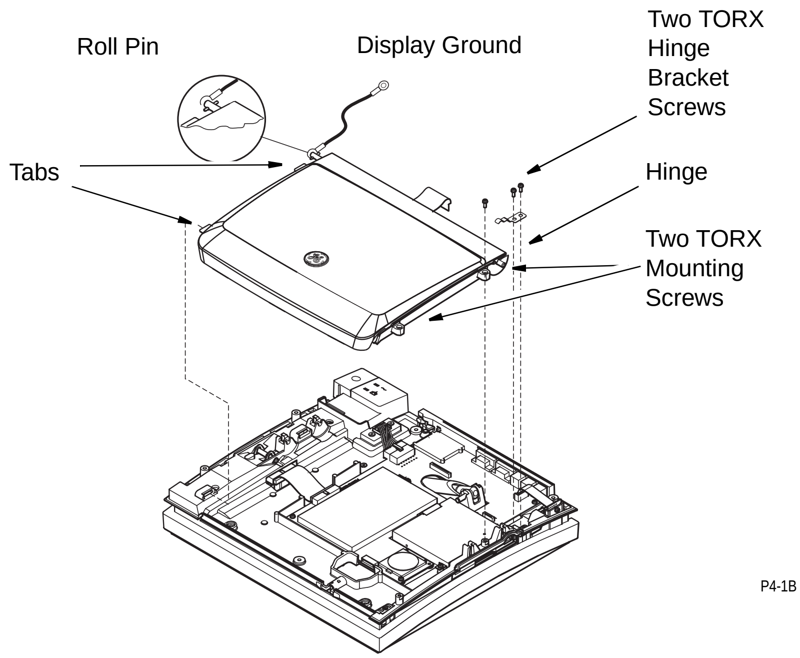
   NOTE

   Two of these cables have locked connectors that must be lifted up to release the cables.
3. Press the internal access button and raise the top of the unit. Remove one screw on the inside, near the front edge of the top.



4. Working from the outside of the top, remove the two TORX mounting screws located on the right side of the assembly.
5. Remove the two TORX screws from the hinge bracket.
6. Remove the screw from the display ground at the left of the hinge rod.

7. Slide the display hinge (metal rod) to the left to release it from the mounting detent.

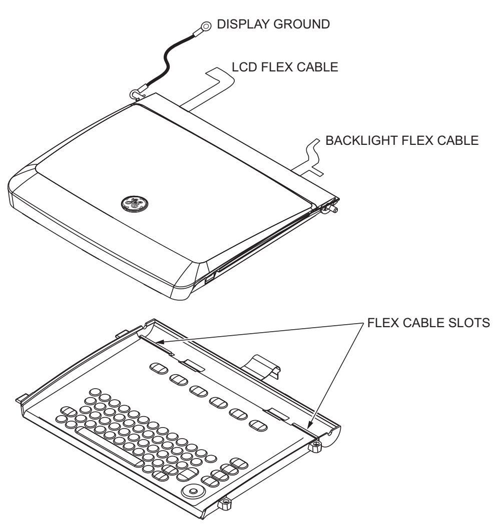


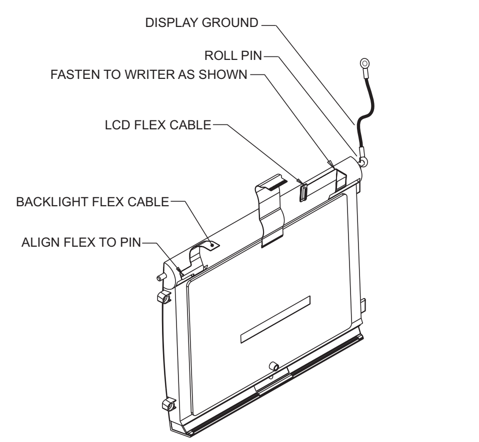
8. Slightly lift up on the right hand side of the display/keyboard assembly, and pull the assembly to the right to free the tabs from their mounting slots. Do not lift the right side of the display too high or the plastic tabs may be damaged.
9. When free from the main unit, the display/keyboard assembly can be separated in to two pieces allowing replacement of either the keyboard or display assembly.

NOTE

Further disassembly of the LCD assembly is not recommended. Replace as complete assembly.

Display/Keyboard Reassembly





1. Insert both flex cables through flex cable slots and position them as shown.
2. Tilt the display/keyboard assembly to the left and with the roll pin of the hinge (metal rod) parallel to the left hinge base, insert the rod into the left hinge base and lower the display/keyboard assembly in place.
3. Slide tabs into their mounting slots and set the display/keyboard assembly in place.
4. Connect the three cables from the display/keyboard assembly to the main PCB. Be sure to lift the locks up prior to attempting to insert the cables into the connectors.
5. Slide the display hinge (metal rod) to the right until it locks into the right hinge base.
6. Replace the hinge bracket with the two TORX screws removed earlier.
7. Replace the screw and display ground at the left of the hinge rod.
8. Replace the two TORX mounting screws on the right side of assembly.

Reassembly

1. Raise the display to the vertical position.
2. Make sure the bezel surrounding the rear panel connectors is in place. Make sure the release mechanism for the Smartmedia card functions properly.
3. Lower the top cover down around the display and set in position.
4. Snap the rear of the top cover in place and then, gently pulling on the thin plastic strip at the front of the top cover, position it in place under the keyboard assembly.
5. Replace the screws removed in disassembly.
6. Assure that the Nand Card is fully inserted into the card slot.

Main PCB

Removal

1. Remove the top cover and display/keyboard assemblies following the procedures above.
2. Disconnect all remaining cable connections to the main PCB. These include cables to the
   - power supply
   - printhead
   - battery connect PCB
   - diskette drive

3. With a Phillips screw driver, remove the mounting screws holding the main PCB in place. They are located around the outside edges of the main PCB.
4. Lift the main PCB from the unit.

Reassembly

1. Reassemble the main PCB, top cover and display/keyboard assemblies by reversing the steps for removal.
2. Install the battery and paper, then power on the unit and verify that the
   - serial number and printhead resistance (label on printhead) is correct
   - setup parameters meet user's requirements.

Printhead Replacement

Removal

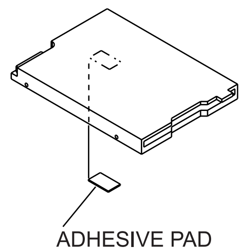
1. Remove the top cover following the procedure above.
2. Using a Phillips head screw driver, remove the two screws that hold the printhead to the printhead mounting plate.
3. Open the writer assembly, disconnect and remove the printhead.

Reassembly

1. Record the resistance value of the new printhead.
2. Connect the new printhead to the ribbon cable.
3. Hold the new printhead FIRMLY in place against the two metal tabs on the printhead mounting plate, then tighten the two screws.
4. Replace the top cover and power up the unit.
5. Go to the Setup menu and enter the new printhead resistance value.
6. Run a Writer Test test (See Chapter 5).

Diskette Drive Removal/Replacement

1. Remove the top cover and display/keyboard assembly following the procedures above.
2. Remove the cable from the diskette drive to the main PCB.
3. Remove two flat head screws holding the diskette drive to its mounting brackets. Loosen, but do not remove two TORX mounting screws holding the mounting brackets in place.
4. Detach the diskette drive and lift from the unit.
5. Apply the adhesive pad to the replacement diskette drive and position the drive in the unit. Insert and loosely attach the two screws.



6. The mounting screws MUST be tightened in the following order:
   - Tighten the two TORX mounting screws,
   - Next tighten the two screws holding the drive to the mounting bracket.
7. Connect cable to the main PCB.
8. Replace the display/keyboard assembly and the top cover following procedures above.

Writer Roller/Carriage Assembly

Removal

1. Remove the power supply assembly following procedures above.
2. Inside the power supply compartment, disconnect the cable that connects to the writer assembly.
3. Open the unit to access the paper compartment. Move the paper size bracket to the A4 position to expose one of the writer assembly mounting screws.
4. Remove the screw and return the paper size bracket to the 8.5 x 11 position.
5. Close the unit and turn it over so the bottom side is up.
6. Remove the four screws located on the underside of the writer roller/carriage assembly and lift the writer from the bottom of the unit.

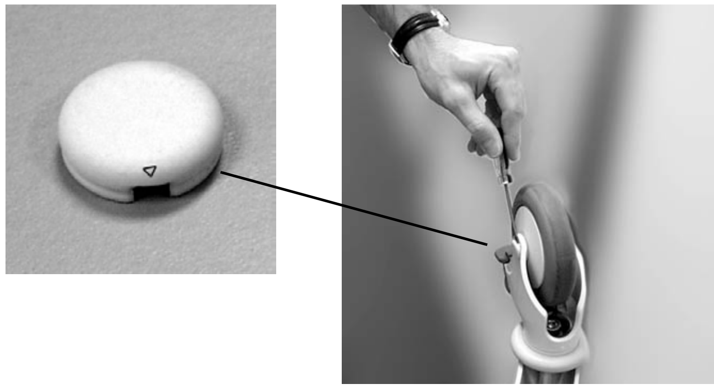
Reassembly

Reassemble the writer roller/carriage assembly by reversing the above procedures.

Trolley Casters

Removal

1. Remove the MAC 5000 and all loose items from the trolley and then place the trolley on its side.
2. Locate the slot under the arrow on the bearing dust cap and using a small blade screwdriver, pry the cap from the caster to be removed.



3. Using an Allen wrench, remove the wheel shaft and wheel from the caster.

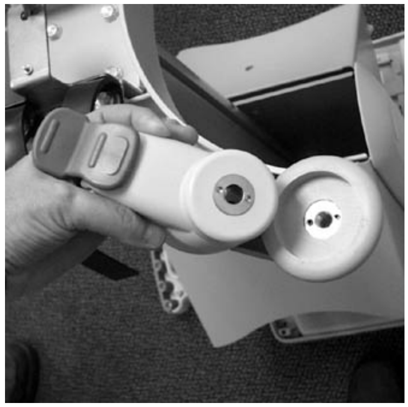
4. Using an Allen wrench, remove the bolt holding the caster to the trolley.

Reassembly

1. Install the replacement caster on the trolley.

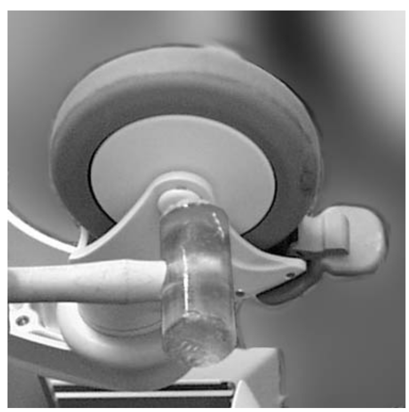
   NOTE

   Ensure that the pins align with the holes on the fixed caster before fastening to the trolley.



2. Install the wheel and attach with the wheel bearing shaft and nut.

3. Using a small mallet, tap the bearing dust covers back in place.



4. Set trolley upright and push to check alignment and free movement of casters.
5. Replace MAC 5000.

Domestic Electrical Safety Tests

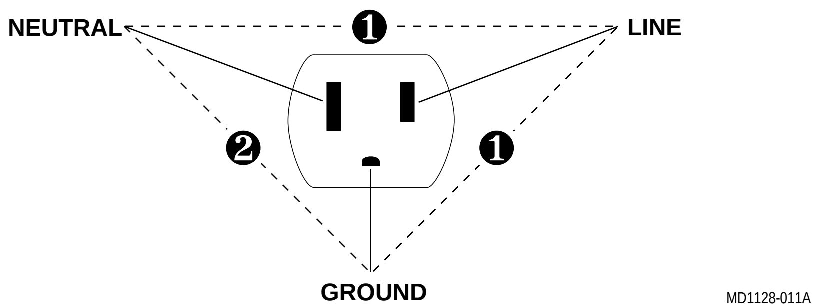
AC Line Voltage Test

This test verifies that the domestic wall outlet supplying power to the equipment is properly wired. For international wiring tests, refer to the internal standards agencies of that particular country.

120 VAC, 50/60 Hz

Use a digital voltmeter to check the voltages of the 120-volt AC wall outlet (dedicated circuit recommended). If the measurements are significantly out of range, have a qualified electrician repair the outlet. The voltage measurements should be as follows:

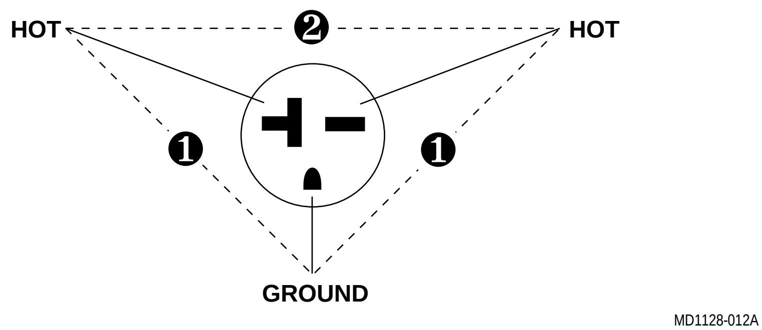
1. 120 VAC (± 10 VAC) between the line contact and neutral and between the line contact and ground.
2. Less than 3 VAC between neutral and ground.



240 VAC, 50/60 Hz

Use a digital voltmeter, set to measure at least 300 VAC, to check the voltages of the NEMA 6-20R, AC wall outlet (dedicated circuit recommended). If the measurements are significantly out of range, have a qualified electrician repair the outlet. The voltage measurements should be as follows:

1. 120 VAC (± 10 VAC) between either “hot” contact and ground.
2. 210 to 230 VAC between the two “hot” contacts.



Leakage Tests

The leakage tests are safety tests to ensure that the equipment poses no electrical health hazards. Use the table below to determine which tests apply to the unit under test and the maximum allowable leakage currents. For international leakage limits, refer to the internal standards agencies of that particular country.

If the unit under test fails the leakage tests, do not allow the customer to use the equipment. Call Tech Support for assistance. (See the “How to Reach Us” page in the front of the manual.)

We recommend that you perform these tests:

- Before applying power for the first time
- Every 6 months as part of routine maintenance
- Whenever internal assemblies are serviced

NOTE

The accuracy of the leakage tests depends on the properly-wired wall outlet. Do not proceed until you verify the integrity of the power source.

WARNING

Total system leakage must not exceed 300 microamperes.

Table 2. Leakage Tests and Maximum Allowable Leakage Currents

Test	Maximum Current (μA)
1. Ground-wire-leakage-to-ground	300
2. Chassis-leakage-to-ground	100
3. Patient-cable-leakage-to-ground	*10
4. Patient-cable-leakage-into-patient-leads-from-120 V ac	*20

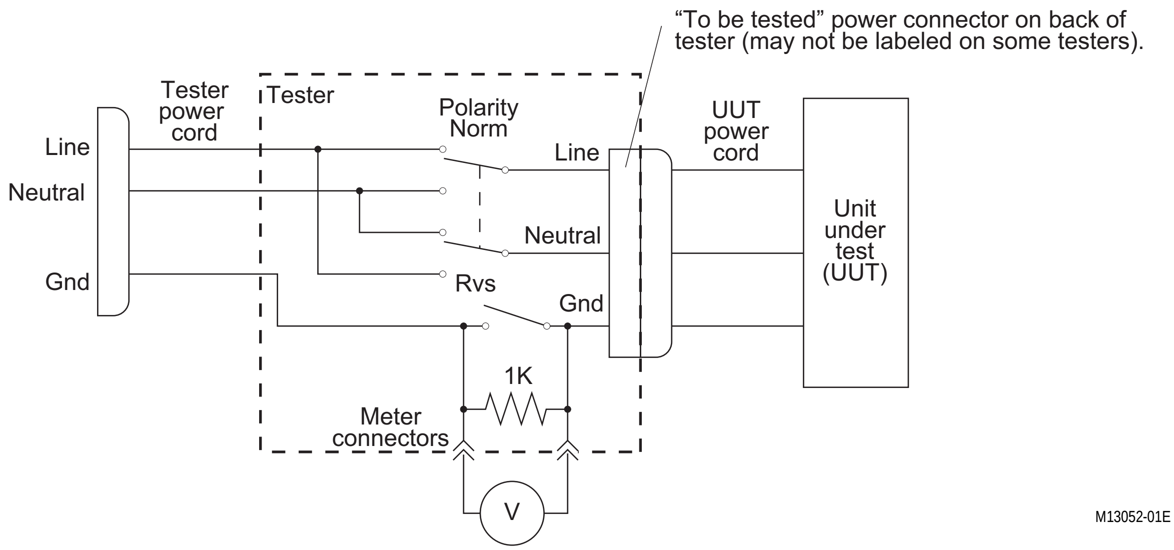
NOTE

Maximum Current readings for Tests 3 & 4 apply to the MAC 5000 at 120 VAC only and do not apply to other equipment.

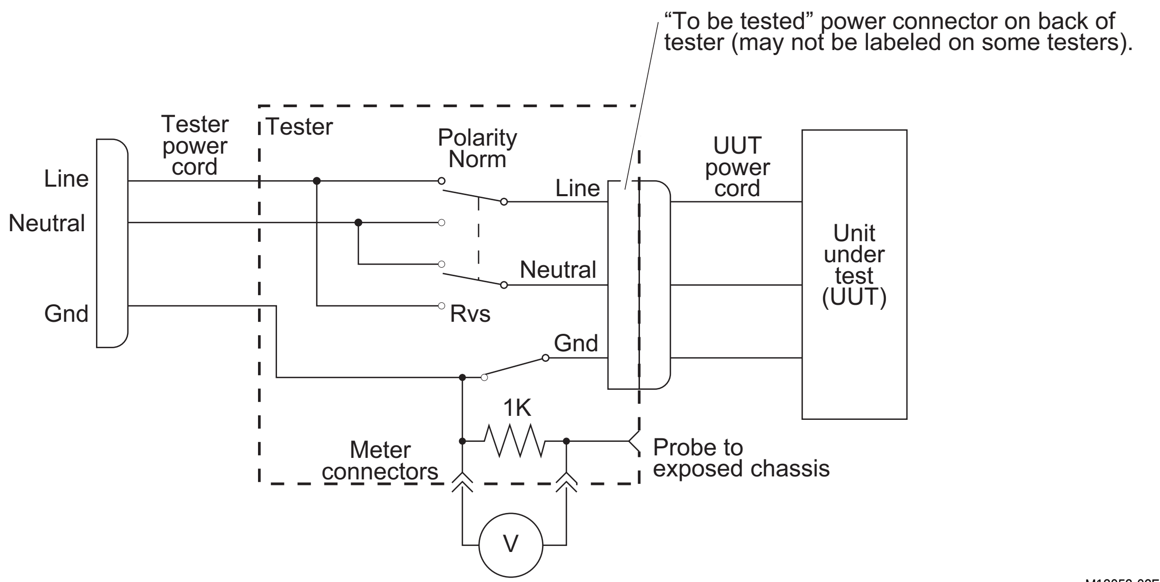
Leakage Test Diagrams

These diagrams show only a representation of how a typical leakage current tester functions. Follow the instructions provided with the leakage current tester that you use.

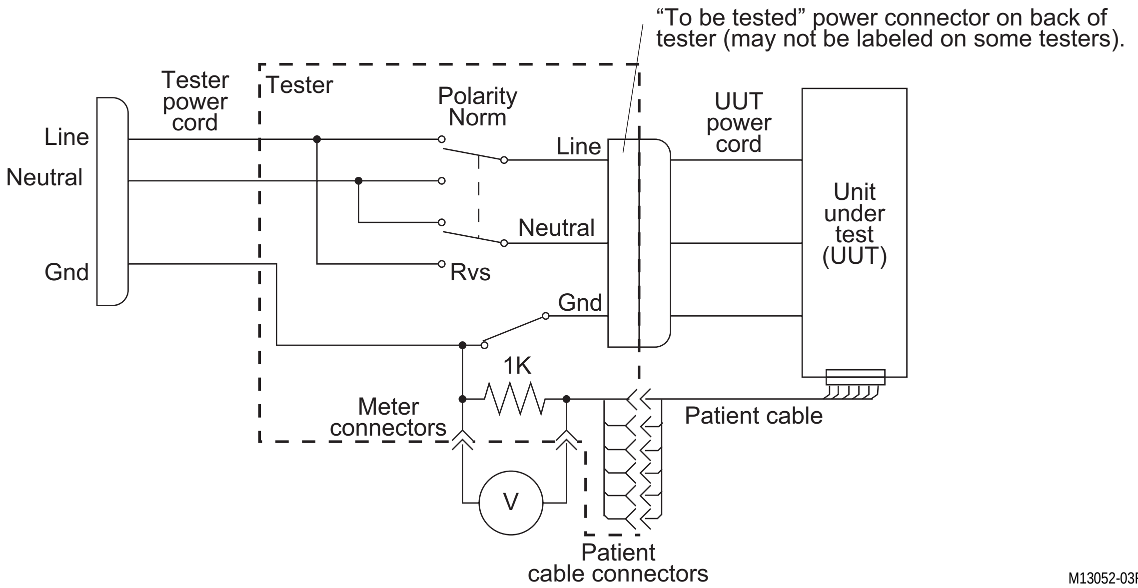
Test #1 - Ground-wire-leakage-to-ground



Test #2 - Chassis-leakage-to-ground

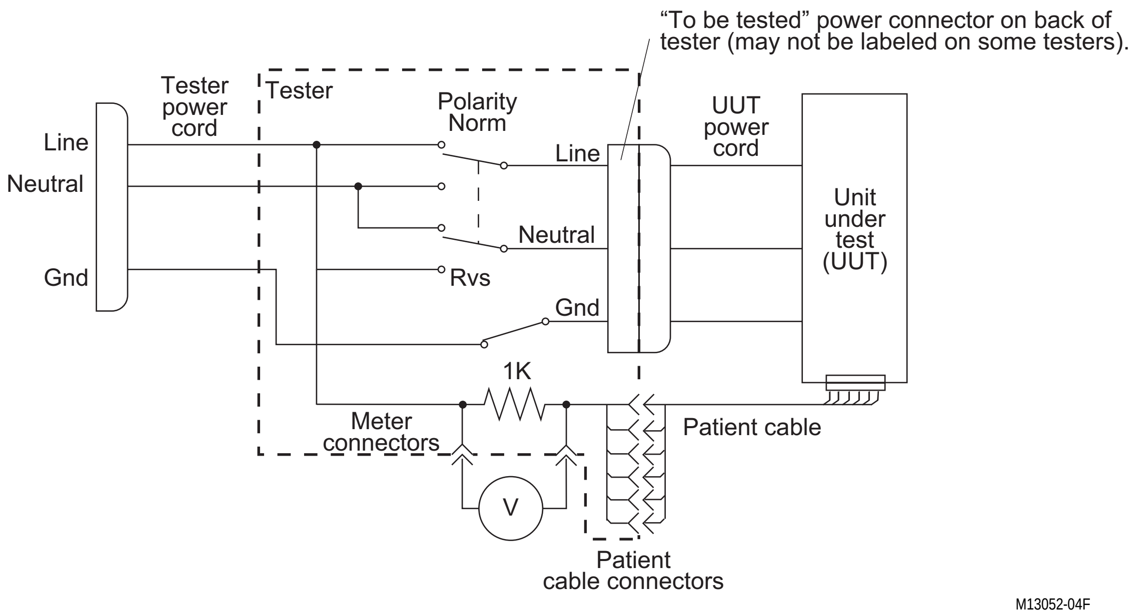


Test #3 - Patient-cable-leakage-to-ground



Test #4 - Patient-cable-leakage-into-patient Leads-from 120 VAC

During this test, line voltage is applied to the patient cable connectors. To prevent erroneous readings, do not allow the leadwires to contact conductive materials such as metal handles, and do not place the leadwires on the floor.



Ground Continuity

This test verifies that there is continuity (less than 200 mΩ resistance) between all the exposed metal surfaces, which have the potential to become energized, and the ground prong on the mains AC power cord. If the metal surfaces are anodized or painted, scrape off a small area in an inconspicuous area for the probe to make contact with the metal.

- Use a digital multimeter to check ground continuity from the AC line cord ground pin to exposed metal surfaces. (i.e. rear panel ground lug, ANA/TTL, and EXT. VID.)
- If the measurements are significantly out of range, check for breaks in the power cord or in the internal connections within the unit.

For your notes

5 Troubleshooting

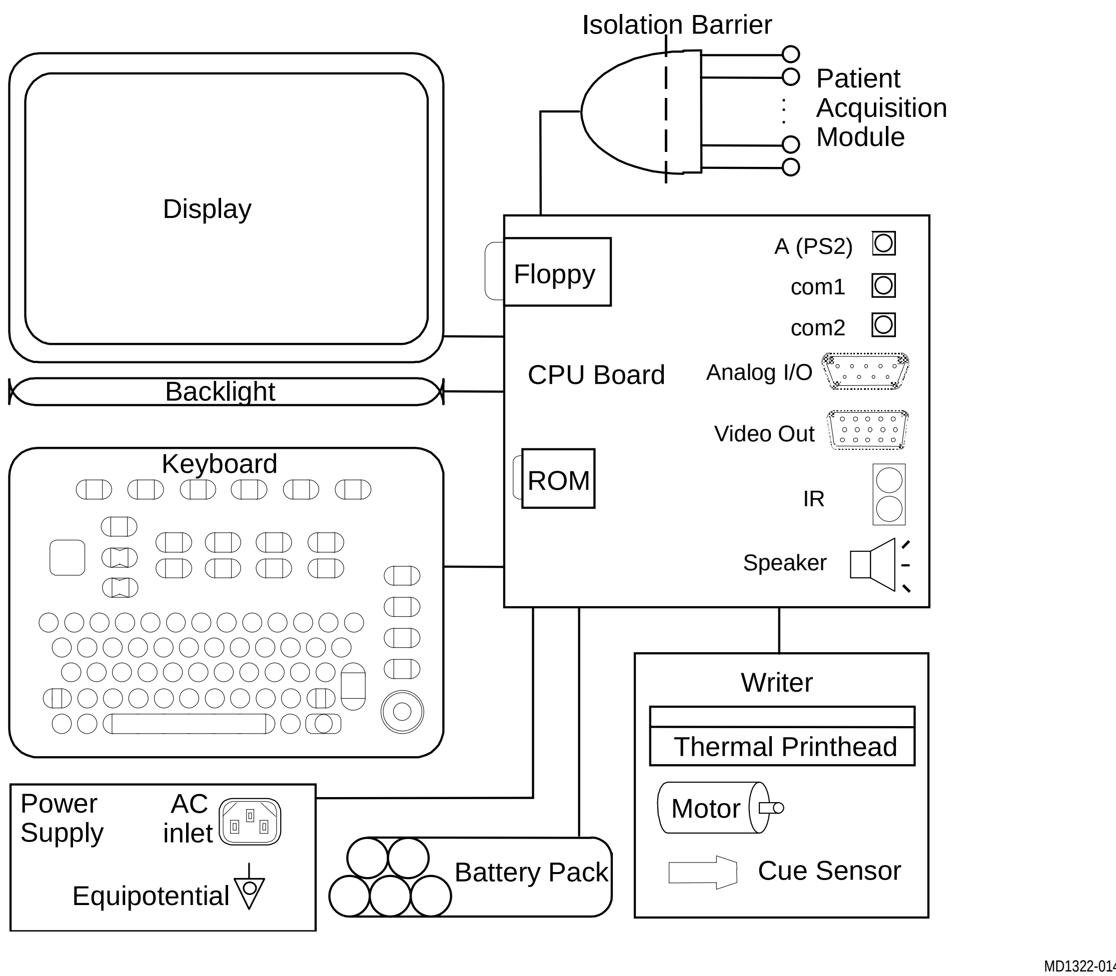
For your notes

Assembly Descriptions

Introduction

The troubleshooting information in this chapter helps you narrow service problems to one of the replaceable assemblies. These assemblies, illustrated in the block diagram, are discussed in more detail in the individual assembly chapters along with replacement procedures.

Assembly Block Diagram



General Fault Isolation

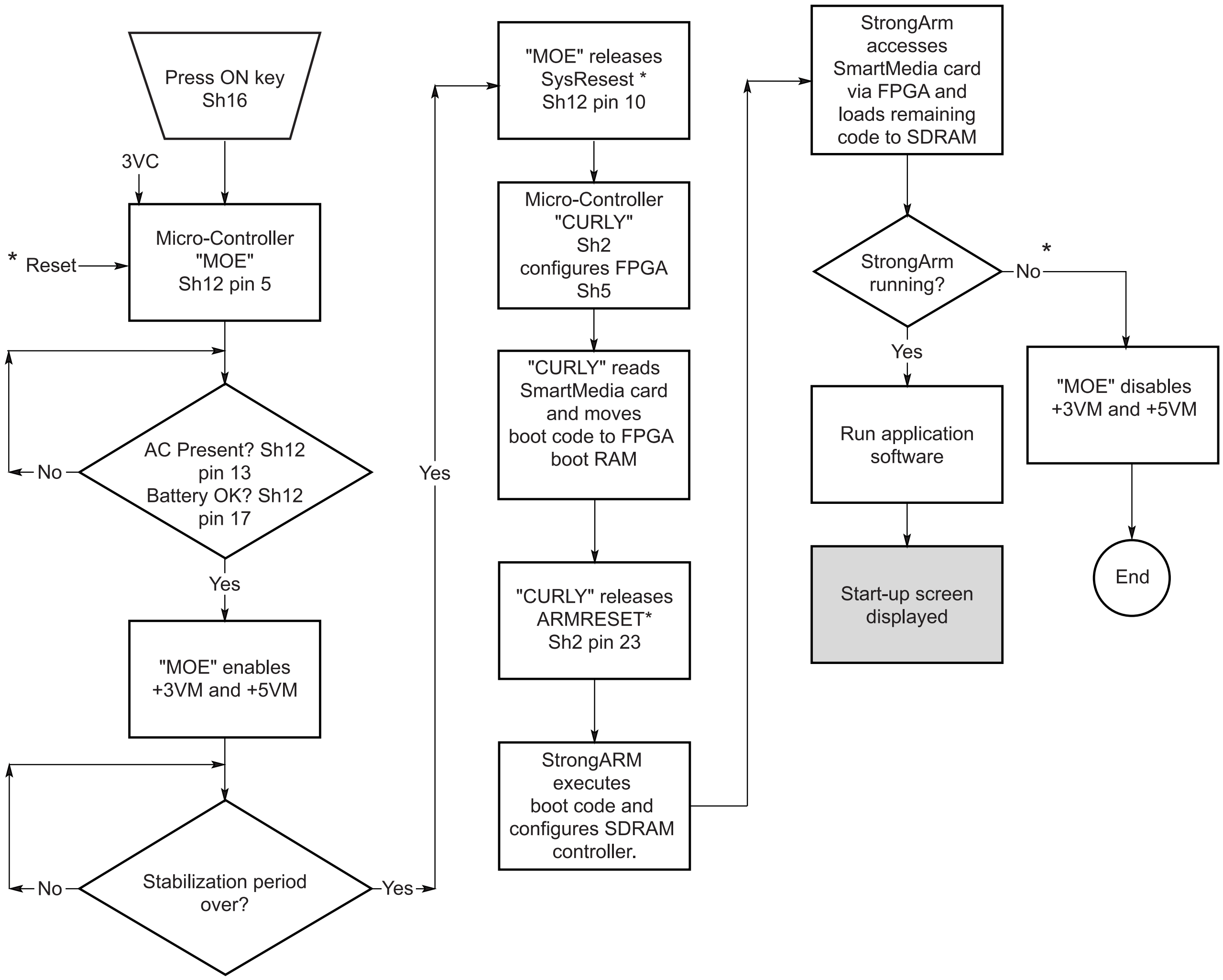
Power-up Self-test

See the MAC 5000 Operator's Manual, Equipment Overview: Getting Started to verify operation.

On power-up, the system automatically runs an internal self-test. If all circuits test good, the start up screen displays. If the equipment is not working properly, ask yourself the following questions.

- Is the unit turned on?
- Have there been any changes in the use, location, or environment of the equipment that could cause the failure?
- Has the equipment hardware or software been modified since last use?
- Is operator error the cause of the problem? Try to repeat the scenario exactly and compare that to the proper operation of the equipment described in the manual.
- Is the battery installed?
- When connected to the AC wall outlet, does the green AC power light glow?
- Is the writer door closed?
- Is the software card installed?

Power-up Flow Chart



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Poor Quality ECGs

Poor quality ECGs can be caused by factors in the environment, inadequate patient preparation, hardware failures related to the acquisition module, leadwires, cables, or problems in the unit.

Use a simulator to obtain an ECG report. If the report is good, the problem is external to the unit.

Visual Inspection

A thorough visual inspection of the equipment can save time. Small things—disconnected cables, foreign debris on circuit boards, missing hardware, loose components—can frequently cause symptoms and equipment failures that may appear to be unrelated and difficult to track.

NOTE

Take the time to make all the recommended visual checks before starting any detailed troubleshooting procedures.

Table 1. Visual Inspection List

Area	Look for the following problems
I/O Connectors and Cables	Fraying or other damage Bent prongs or pins Cracked housing Loose screws in plugs
Fuses	Type and rating. Replace as necessary.
Interface Cables	Excessive tension or wear Loose connection Strain reliefs out of place
Circuit Boards	Moisture, dust, or debris (top and bottom) Loose or missing components Burn damage or smell of over-heated components Socketed components not firmly seated PCB not seated properly in edge connectors Solder problems: cracks, splashes on board, incomplete feedthrough, prior modifications or repairs
Ground Wires/Wiring	Loose wires or ground strap connections Faulty wiring Wires pinched or in vulnerable position
Mounting Hardware	Loose or missing screws or other hardware, especially fasteners used as connections to ground planes on PCBs
Power Source	Faulty wiring, especially AC outlet Circuit not dedicated to system (Power source problems can cause static discharge, resetting problems, and noise.)

Diagnostic Tests

Introduction

Verify that the MAC 5000 resting ECG analysis system operates properly by running the diagnostic tests. These tests check the operation of the display screen, speaker, keyboard, thermal writer, battery, and communication. Detailed information displays on screen.

Loading the System Diagnostics

1. Select *Main Menu* on the Resting screen.
2. Select *More*.
3. Select *System Setup*.
4. At the prompt type the word “system”, the password set at the factory, then press the **Enter** key. If the password was not changed, the *System Setup* menu appears. If the menu does not appear, use the master password. If the system’s unique password is inaccessible, create one following the instructions in “Substitute Master Password” later in this section.
5. When the *System Setup* menu displays, hold down **Shift** and press **F5** (**Shift** + **F5**).
6. Type **prod** at the service password prompt.
7. The *System Diagnostics* menu appears.

Substitute Master Password

If you do not have access to the system’s password, you can create a master password as follows.

1. At the prompt for the system password, enter meimac. A random 6-digit number displays on the screen. For example, 876743.
2. Write the number down and create a new 6-digit number by adding alternating digits from the random number as follows. Add:
   - first and third digits,
   - second and fourth digits,
   - third and fifth digits,
   - fourth and sixth digits,
   - fifth and first digits, and
   - sixth and second digits.

   Disregard the 10s column when adding the digits. The new number from the example above would be 440020.
3. Enter the new number, then press the **Enter** key. The *System Setup* menu displays. This process only works once, so you should reprogram the password permanently.

4. Go to the *Basic System* menu.
5. Select *Miscellaneous Setup*.
6. Select the *System password* line and type the new password in the space.
7. Press the **Enter** key.
8. Select *Save Setup* from the *System Setup* menu.
9. Select *To system*.

System Diagnostics Main Menu

Use the arrow pad control to highlight a menu item, then press the **Enter** key to select it. The tests and test menus contain on-line prompts and/or instructions.

- *Display Tests*
- *Speaker Test*
- *Keyboard Test*
- *PS2 Port Test*
- *Writer Tests*
- *Battery Tests*
- *Communication Tests*
- *Acq. Module Tests*
- *Analog I/O Tests*
- *Floppy Drive Tests*
- *Exit System Diagnostics* (reboots the system)

Display Tests

Run the screen *Display Tests* to verify that all the screen pixels are working and that the brightness and contrast samples appear to be within normal range. There are no screen display adjustments. The screen *Display Tests* are as follows.

Pixel Verification Test

Use the arrow pad control to move the bar across the screen and look for any missing pixels on the display.

Press the **F1** key to turn on all of the pixels simultaneously.

Press the **Enter** key to exit the test.

Grey Scale Test Patterns

The first test pattern (used in manufacturing to verify the screen intensity) shows two squares, one bright and one dim. Press any key to activate the next display.

The second test pattern shows 32 color levels. Check for problems with the overall pattern. (If the system does not have the color option, various grey scale patterns display.)

Press the **Enter** key to exit the test.

Speaker Test

Use the arrow pad to select *Loud* or *Soft*. Press the **Enter** key to produce a loud or soft tone. (The tone level difference is minimal.)

Highlight *Return* and press the **Enter** key to return to the *System Diagnostics* menu.

Keyboard Test

Press each key and verify that the key is highlighted on the screen and also displayed at the top of the screen. (It is normal for a dim background image to remain on the screen when you select the next key.) The numeric value that displays at the top of the screen is the scan code representation of the pressed key.

NOTE

The display shows keys in the upper part of the screen that are only available with the MAC 5000 ST keyboard.

- Check both of the **Shift** keys by pressing each in combination with a letter to display a capital letter.
- Press the center of arrow pad control and verify that the word *IN* displays on screen. Press **arrows** to change the displayed arrow position. A beep sounds with each arrow press.
- Press the **Shift** key and the **F6** key to exit the test.

PS2 Port Test

Use the following steps to complete the PS2 Port Test:

1. Turn **OFF** the mains power switch on the MAC 5000.
2. Connect a PS2 style keyboard to the PS2 port.
   (See Chapter 2, Connector Identification.)
3. Turn **ON** the Mains power switch on the MAC 5000.
4. Follow the Keyboard Diagnostic Test procedure.
   (Characters typed on the PS2 keyboard will be displayed on the MAC 5000 Keyboard Test screen if the PS2 port is working.)

Writer Tests

Run the writer tests to check the motor speed control, paper speed, paper tracking, paper cueing, and print head quality. During the tests, make the following general checks.

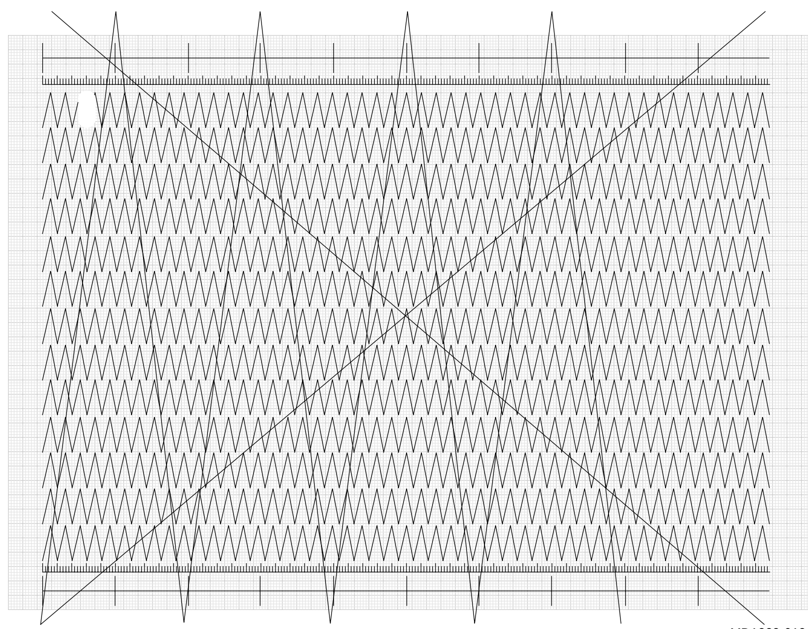
- The first character printed should not be distorted. This checks start-up speed.
- The writer should not skew or crush either edge of the paper.
- The large triangles and diagonal lines printed across the pages should be straight and uniform, without curves or wavering.
- The perfs should align with the tear bar on the door after cueing.
- Paper travel should be smooth.

C-Scan Tests 1, 2, & 3

These tests are combinations of test pattern I and the roller test. They are used by the writer vendor.

50 mm/s Test Pattern I, 25 mm/s Test Pattern I, & 5 mm/s Test Pattern I

These test patterns check the motor speed control and the paper speed. Verify that the length of the printout from start to finish is 250 mm ± 5 mm. Use the grids located on the top and bottom of the page for reference. Do this for each of the three tests.



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Roller Test

(Uneven darkness can appear if AC power is on during this test.)

- After cueing, printing should start at approximately 13–14 mm on the page.

- The pattern appears as diagonal light and dark wavy bands.

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- Isolated light spots indicate a flat spot on the roller.
- A white line across the length of the page indicates a missing print head dot.
- Dark lines across the width of the page indicate gear tolerance problems.
- Lines too close together at the start of the test indicate an incorrect start-up speed.

Test Pattern II

A combination of Test Pattern I and Roller tests. The first three pages consist of a series of triangular waveforms and various hashmarks. The fourth page is a partial roller test.

Test Pattern II Continuous

Test Pattern II runs continuously until stop is pressed.

Continuously Run Out Paper

This test is used in manufacturing to test how well the unit self-corrects tracking problems.

Battery Tests

NOTE

Verify that a functional floppy disk is inserted in the unit before proceeding with the battery tests. Test results can only be saved on a floppy disk and printed once the tests are complete. Failure to insert a floppy disk will result in loss of test results.

Battery Status

Displays, and constantly updates, the following information:

- Percent of charge remaining
- Battery voltage
- Battery current
- Battery temperature
- Maximum and minimum battery temperature
- Ambient temperature
- Maximum and minimum ambient temperature
- Current battery charging status

Battery Discharge Test

This test charges the battery to full capacity, if necessary, then monitors a discharge cycle. Follow the instructions on screen. After the battery is discharged, the device will shut off. Plug the device back in to print the results.

Monitored information, written to the floppy disk, includes:

- Discharge rate (in mAH)
- Battery temperature
- Battery charge status
- Percent of charge remaining

Battery Charge Test

This test completely discharges the battery, if necessary, then monitors a charge cycle. Monitored information, written to the floppy disk, includes:

- Charge rate (in mAH)
- Battery temperature
- Battery charge status
- Percent of charge

Print Charge/Discharge Test Results

Prints the results of the last discharge or charge test to the writer.

Communication Tests

COM Port Loopback Test

The *Communications Port Loopback Test* sends various ASCII characters out the COM port's transmit lines and expects the same character to return in it's receive lines. Upon completion of the test, the word *Passed* or *Failed* appears, depending on the results.

For each of the options listed (COM1, COM2, COM3, and COM4) perform the following steps,

1. Select an option and press the **Enter** key.
2. Follow the instructions on screen and install loopback jumpers in the selected serial port.
3. Remove the loopback jumpers when the test is complete.

Modem Test

Connect a modem to **COM 2** and select the *Modem Test*. The test returns the modem ID number, firmware rev, and current parameter settings. If communication with the modem is unsuccessful, the ID and firmware rev display *N/A*.

Acquisition Module Test

Follow the instructions on screen.

NOTE

A shorting bar is required to perform this test.

- Tests if the front end is powered
- Tests if the front end is communicating
- Displays the front end lead wire noise
- Indicates when one of the three front end buttons is pressed
- Displays software version of acquisition module

Analog I/O Tests

Analog Output Test

Follow the instructions on screen to monitor the analog outputs using an oscilloscope. The outputs monitored are:

- +12V
- DC Output 1
- DC Output 2
- ECG Output
- TTL Trigger Output

Four sets of outputs are possible. Select the output sets using the arrow pad.

Analog Input Test

Follow the instructions on screen to connect a DC voltage to the DC input pins of the **ANA/TTL** connector. The voltage of the DC input displays.

DCOut Loopback Test

Follow the instructions on screen to connect the DC Outputs to the DC Inputs. The test sends all possible values out the DC Outputs and confirms that the correct values are read from the DC Inputs. A pass/fail result displays.

ECGOut/QRSTrigger Loopback Test

Follow the instructions on screen to connect the ECG Output and TTL Trigger Output to the DC Inputs. The test sends all possible values out the ECG Output and a square wave out the TTL Trigger Output. It confirms that the correct values are read from the DC Inputs. A pass/fail result displays.

Floppy Drive Tests

Follow the instructions on screen. A read/write test is performed on a formatted floppy disk and a pass/fail test result is displayed. Try another disk if this test fails. If this test continues to fail, contact GE Medical Systems-*Information Technologies* for service.

NOTE

The following test and the resultant values are for manufacturing use only and NOT intended for service of this device.

A head radial alignment and Azimuth alignment test is performed using an Accurite test disk (part number is displayed on screen). Alignment test values will be displayed.

Diskette Format Failure

Unformatted diskettes may cause the message "*Please insert a data diskette*" to appear and not allow the MAC 5000 to force a format. Remove the diskette from the MAC 5000 and format the diskette on a PC. After formatting, try it on the MAC 5000 again. If it fails again, replace the diskette and repeat the procedure.

Equipment Problems

ECG Data Noise

If the acquired ECG data displays unacceptable noise levels:

- Verify proper electrode placement.
- Verify proper electrode application. (Perspiration and dead skin must be removed from the electrode site.)
- Check for defective or out of date electrodes.
- Check for defective, broken, or disconnected leadwires.
- Check the patient's position. The patient should remain motionless during the acquisition of a resting ECG.

Missing ACI-TIPI Report

- ACI-TIPI is disabled.
  - Enable ACI-TIPI.
- The selected report is *without interpretation*.
  - Select *Interpretation* for the report.
- The ACI-TIPI required information is not entered.
  - Make sure the age range, gender, and chest pain complaints are entered.
- The patient was entered as pediatric.
  - Make sure you enter an age range less than 16.
- The original ECG was acquired in an electrocardiograph without the ACI-TIPI option.

No BP from External Device

- Check setup.
  - If Suntech, check protocol on Tango.
- Check cables (Serial and TTL).
- Check TTL trigger.

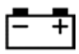
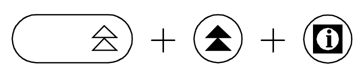
Treadmill/Ergometer Does Not Move

- Check protocol.
- Check cables.
- Check input / output settings.
- Check Emergency Stop switch.

System Errors

The following errors may occur while you are operating this system. You may be required to perform some action.

If you perform the recommended actions and the condition still remains, contact authorized service personnel. See “How to Reach Us” to find out how to contact GE Medical Systems *Information Technologies*.

Problem	Cause	Solution
 appears on the screen.	No battery is installed in the system.	Install a battery and connect the system to an AC wall outlet to charge the battery.
 flashes intermittently.	The battery charge is low.	Connect the system to an AC wall outlet to charge the battery.
 appears on the screen.	The writer door is open.	Close the writer door.
The system does not power up when operating from battery power.	The battery is empty.	Connect the system to an AC wall outlet to charge the battery.
The system shuts down when operating from battery power.	Battery is empty, or the *Automatic Shutdown* feature is enabled.	Connect the system to an AC wall outlet to charge the battery, or power on the system.
“X” Lead disconnected message appears.	Electrode(s) disconnected.	Reconnect the electrode(s).
MODEM ERROR. The remote device is not responding. Would you like to retry?	Modem not connected. (If wireless option, client bridge not connected.)	Connect and retry.
	(Wireless option only) MAC 5000 is not within range of access point.	Relocate MAC 5000 to within range of access point and retry transmission.
Cannot use the system because *Device Password* does not work.	*Device Password* has been changed or has not been adequately communicated to the staff.	Override the *Device Password* prompt by pressing the following keys at the same time: 

153A, 154A, 209A

NOTE

For information about troubleshooting the MobileLink Standard Security option, see “MobileLink Installation & Troubleshooting Guide” (PN 2002783-060).

For information about troubleshooting the MobileLink Ultra High Security option, see “MobileLink UHS Installation & Troubleshooting Guide” (PN 2020300-051).

Frequently Asked Questions

Maintenance

NOTE

See Operator's Manual for complete *System Setup* information.

Save Setups

Q: How do I save changes I have made to the System Setups?

A: Check the following:

- Return to Menu by pressing the **esc** key or selecting *More* from the menu until you see *System Setup*.
- Select *System Setup*.
- Select *Save Setup*.
- Select *To System*.
- You can select *Main Menu* to exit *System Setup*.

Storing ECGs

Q: Why won't any of the ECGs I perform save to the floppy diskette?

A: Check the following:

- Check that the diskette is fully inserted into the drive.
- Make sure you are using high-density (HD) 3.5" diskettes.
- Verify that the diskette is not write-protected.
- Try a new diskette.
- If your system is not set up to automatically save records, you must manually save by pressing *Store*.

Format a Disk

Q: How do I format a diskette in the MAC 5000?

A: When you insert a new diskette into the MAC 5000 the system will automatically format the diskette. If you are using a previously-used diskette, and want to reformat it, you can format it at a PC.

Cleaning

Q: Should I clean the MAC 5000?

A: Clean the exterior surfaces of all the equipment and peripheral devices monthly, or more frequently if needed.

- Use a clean, soft cloth and a mild dishwashing detergent diluted in water.
- Wring the excess water from the cloth. Do NOT drip water or any liquid on the writer assembly, and avoid contact with open vents, plugs, and connectors.
- Dry the surfaces with a clean cloth or paper towel.

Battery Capacity

Q: What is the capacity of the battery?

A: We recommend that the MAC 5000 be plugged into a wall outlet whenever it is not in use. However, the life of the battery is approximately 100 ECGs and one-page reports or six hours of continuous operation (without printing).

System Setup

Location Number

Q: When entering in the patient data, how do I get the Location field to automatically populate with the same number?

A: The *Location* number can be set in *System Setup* to save you from entering it for each test.

- Go to *System Setup*.
- Select *Basic System*.
- Select *Miscellaneous Setup*.
- Arrow down to *Location* and type in the number you want set as your default. Then press **Enter**.
- Press the **esc** key until you return to *System Setup*.
- Select *Save Setup*.
- Select *To System*.
- You can select *Main Menu* to exit *System Setup*.

Patient Questions

Q: How do I change what questions I see when I am entering the patient data?

A: The patient questions you see on the *Patient Data* window when starting a test were set up in *System Setup*.

- Go to *System Setup*.
- Select *Basic System*.
- Select *Patient Questions*.
- Select the patient questions you want to include when entering the patient data for a test.
- Press the **esc** key until you return to *System Setup*.
- Select *Save Setup*.
- Select *To System*.
- You can select *Main Menu* to exit *System Setup*.

Passwords

Q: Can you set up a password for the *Delete* function that is different than the *System Setup* password?

A: No. The password for the *System Setup* and the *Delete* function are the same.

Clinical

Report Format

Q: How do I change the way an ECG looks when it prints out?

A: Do the following steps.

- Go to *System Setup*.
- Select *ECG*.
- Select which type of ECG report you want to change:
  - *Resting ECG Reports*
  - *Pediatric ECG Reports*
  - *15 Lead Reports*
- Select unconfirmed reports from the menu.
- Find the report type you want the MAC 5000 to print.
- Place the number of copies you want in the appropriate column.
- If you want the MAC 5000 or 12SL interpretation included on the ECG, put the number of copies you want in the “with” column.
- If you do not want the MAC 5000 interpretation to print on the ECG, put the number of copies you want in the “without” column.
- Click view report type, to see the examples of the report formats.
- Press the **esc** key until you return to *System Setup*.
- Select *Save Setup*.
- Select *To System*.
- You can select *Main Menu* to exit *System Setup*.

Hi-Res and Phi-Res

Q: What is the difference between the Hi-Res and Phi-Res functions?

A: Hi-Res looks at the entire complex, whereas Phi-Res focuses on the P wave.

Editing

Q: Can you edit the interpretation at the MAC 5000, and then transmit the edited record to the MUSE system as an unconfirmed record?

A: If you edit demographic information only the record is still transmitted to the MUSE system as an unconfirmed record. However, if you edit the interpretation, the data will not be saved unless the record is confirmed at the MAC 5000. The record is transmitted to the MUSE system as a confirmed record as well.

Entering Patient Data

Q: Do I have to enter all the Information I see on the Patient Data screen?

A: In System Setup/Basic System/Patient Questions you can require that the patient identification number, or medical record number) be entered. It is not a requirement to enter any other data. However, we recommend that you enter the patient name and identification number, at the least. If you are transmitting to the MUSE system you will want to enter the Location number as well. If an emergency situation dictates that you must complete the test. without entering the patient data, make sure you edit the record to add the missing information before you transmit it to the MUSE system.

Transmission

Losing Fields When Transmitting

Q: Why do I lose the Referring MD and Technician names off of my reports when I transmit records to the MUSE system?

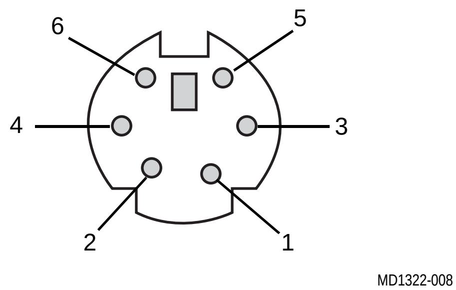
A: Your MAC 5000 may be transmitting to the SDLC modem on the MUSE system instead of the CSI modem. Check in System Setup to make sure you are transmitting to the MUSE system CSI phone number.

Input and Output Connectors

The following pages detail the input/output signals for those connectors. The pin-by-pin descriptions identify the signal names and pin outs for each connector on the unit.

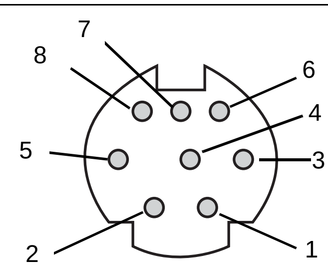
A Pins (J1)

Table 2. A Pins (J1)

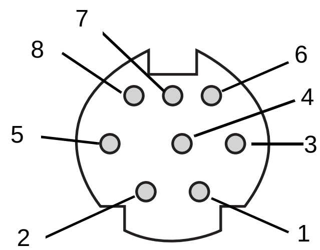
Pin	Name	
1	Data	
2	NC	
3	Ground	
4	+5V	
5	Clock	
6	NC	

COM1 (COM3/4) Pins (J3)

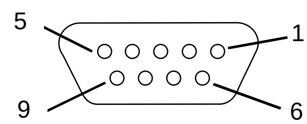
Table 3. COM1 (COM3/4) Pins (J3)

Pin	COM1 Signal	COM3/4 Signal	
1	RTS	COM3 TxD	
2	CTS	COM3 RxD	
3	TxD		
4	Ground		
5	RxD		
6	DTR	COM4 TxD	
7	+12V		
8	DSR	COM4 RxD	

COM2 Pins (J5)

Table 4. COM2 Pins (J5)		
Pin	**Name**	
1	RTS	
2	CTS	
3	TxD	
4	Ground	
5	RxD	
6	DTR	
7	+12V	
8	DSR	

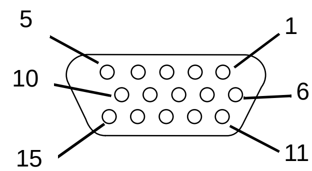
Analog Pins (J6)

Table 5. Acquisition Module Connector (J6)		
Pin	**Name**	
1	+12V	
2	DC Output 1	
3	TTL Trigger Output	
4	Ground	
5	Ground	
6	DC Output 2	
7	DC Input 1	
8	ECG Output	
9	DC Input 2	

EXT. VID. Pins (J7)

Table 6. External VGA Video (J7)

Pin	Name
1	Red Video
2	Green Video
3	Blue Video
4	Ground
5	Ground
6	Ground
7	Ground
8	Ground
9	NC
10	Ground
11	Ground
12	NC
13	Horizontal Sync
14	Vertical Sync
15	NC



CPU PCB Input/Output Signals

Battery Pack/Monitor, J2	
Pin No.	**Signal**
1	18V Battery Power
2	18V Battery Power
3	Battery Temperature Sense
4	3V Temperature Sense Power
5	Battery Ground
6	Battery Ground

LCD Backlight, J4	
Pin No.	**Signal**
1	12V Power
2	12V Power
3	12V Power
4	Ground
5	Ground
6	Brightness Select
7	Backlight Enable
8	NC
9	Ground
10	Ground

Keyboard, J8	
Pin No.	**Signal**
1	NC
2	NC
3	NC
4	NC
5	NC
6	Sense4
7	Sense2
8	Sense1
9	Sense0

Keyboard, J8 (Continued)	
10	Sense3
11	Sense5
12	Sense6
13	Sense7
14	Drive0
15	Drive1
16	Drive2
17	Drive3
18	Drive4
19	Ground
20	Power Key
21	Drive5
22	Drive6
23	Drive7
24	Drive8
25	Drive9
26	Drive10

LCD, J10	
Pin No.	**Signal**
1	Ground
2	Pixel Clock
3	Hsync
4	Vsync
5	Ground
6	R0 (LSB)
7	R1
8	R2
9	R3
10	R4
11	R5 (MSB)
12	Ground
13	G0 (LSB)
14	G1
15	G2
16	G3

LCD, J10 (Continued)	
17	G4
18	G5 (MSB)
19	Ground
20	B0 (LSB)
21	B1
22	B2
23	B3
24	B4
25	B5 (MSB)
26	Ground
27	Data Enable
28	3V Power
29	3V Power
30	NC
31	NC

Power Supply/Motor, J11	
Pin No.	**Signal**
1	Motor Encoder B
2	5V Power
3	Motor A
4	Motor Encoder A
5	Ground
6	Motor B
7	NC
8	28V Power
9	Ground
10	Battery Charge LED
11	28V Power
12	Ground
13	Door Open Detect
14	Ground

Thermal Printer, J12	
Pin No.	**Signal**
1	Thermal Printer Power
2	Thermal Printer Power
3	Thermal Printer Power
4	Thermal Printer Power
5	Thermal Printer Power
6	Thermal Printer Power
7	Thermal Printer Power
8	Ground
9	Ground
10	Ground
11	Ground
12	Ground
13	Ground
14	Ground
15	Cue Sense
16	NC
17	5V Main Power
18	Ground
19	Data Strobe
20	Data Strobe
21	Data Strobe
22	Data Strobe
23	Data Load
24	Data Clock
25	Print Head Temperature
26	Pixel Data

Floppy Disk Drive, J13	
Pin No.	**Signal**
1	5V Power
2	Index
3	5V Power
4	Drive Select 0
5	5V Power
6	Disk Change
7	NC
8	Media Sense 0
9	Media Sense 1
10	Motor Select 0
11	NC
12	Direction
13	NC
14	Step
15	Ground
16	Write Data
17	Ground
18	Write Gate
19	Ground
20	Track 0
21	Ground
22	Write Protect
23	Ground
24	Read Data
25	Ground
26	Head Select

Acquisition Module, J14	
Pin No.	**Signal**
1	Power
2	Ground
3	TX+ (RS485)
4	TX- (RS485)
5	RX+ (RS485)
6	RX- (RS485)
7	NC
8	NC
9	NC
10	NC

For your notes

6 Parts List

For your notes

Ordering Parts

General Information

The FRU parts lists in this chapter supply enough detail for you to order parts for the assemblies considered field serviceable. To order parts, contact Service Parts at the address or telephone number on the, “How to Reach Us...,” page provided at the beginning of this manual.

Field Replaceable Units

The following items may not be assigned separate manufacturing part numbers because they are normally part of a larger assembly. Since they are considered field replaceable units (FRUs), they have specific service part numbers so they can be ordered and replaced by service technicians. Contact Tech Support for FRU information for assemblies used on previous configurations.

NOTE

Verify part numbers before ordering service parts (field replaceable units). See the tech memo series for this product for changes or additions to this list.

Field Replaceable Units	
Item	**Part Number**
Battery Assembly	900770-001
Power Supply Assembly	421117-001
PCB, MAC 5000 CPU	801212-005
Keyboard Assembly	421115-XXX
Disk Drive, 3.5 inch Laptop Floppy	2001377-001
Cover, Disk Drive	417468-002
Display Assembly	2019106-001
***** Top Cover ***** Label Top Cover *** NOTE:** Top Cover & Label must be ordered together.	2017413-001 2008167-001
Printhead	422397-001
Writer Assembly	421108-006
Roller Assembly	422396-006
Writer Release Button	2005920-001
Leaf Spring	417565-001
Gas Cylinder	416015-001
Battery/LED Circuit Board	801222-001
MAC 5000 Country Modem PTO Option Class	MAC5000_MODEM
Country Specific	2005264-0XX
MAC 5000 CAM14 PTO Option Class	MAC5000_CAM14
Kit CAM14 Resting ECG W/AHA Adapter	901142-001
Kit CAM14 Resting ECG W/IEC Adapter	901142-002
MAC5000 Keyboard PTO Option Class	MAC5000_KEYBRDS

NOTE:
Because MAC 5000 keyboards are available in various styles, the letter X is used here in the place of the number as follows:

X = 1 = current style keyboard

X = 2 = current style ST keyboard

Field Replaceable Units (Continued)	
Item	**Part Number**
Keyboard Assembly, English	421115-X01
Keyboard Assembly, German	421115-X02
Keyboard Assembly, French	421115-X03
Keyboard Assembly, Spanish	421115-X04
Keyboard Assembly, Swedish	421115-X05
Keyboard Assembly, Italian	421115-X06
Keyboard Assembly, Japanese	421115-X07
Keyboard Assembly, Dutch	421115-X08
Keyboard Assembly, Norwegian	421115-X09
Keyboard Assembly, Danish	421115-X10
Keyboard Assembly, Czech	421115-X11
Keyboard Assembly, Hungarian	421115-X14
Keyboard Assembly, Polish	421115-X15
Power Cord Generic PTO Option Class	POWERCORDS
Power Cord 125V 6FT Stress	80274-006
Power Cord 125V 6FT SE	80274-004
Power Cord CONT Euro 10A 250V 8FT	401855-001
Power Cord British 10A 250V 8FT	401855-002
Power Cord Italian 10A 250V 8FT	401855-003
Power Cord Israeli 10A 250V 8FT	401855-004
Wire Harness 10A 125V 6.5FT	401855-005
Wire Harness 10A 250V 6.5FT	401855-006
Power Cord Swiss 10A 250V 8FT	401855-007
Power Cord Indian 10A 250V 8FT	401855-008
Danish 220VAC/50HZ,STRESS	401855-009
Power Cord Australian 10A 250V 8FT	401855-010
Power Cord 10A 8FT CONT Euro Stress	401855-101
Power Cord 10A 8FT British Stress	401855-102
Power Cord Italian 10A 8FT Stress	401855-103
Power Cord Israeli 10A 8FT Stress	401855-104
Power Cord Swiss 10A 8FT Stress	401855-107

Field Replaceable Units (Continued)	
Item	**Part Number**
Power Cord Indian 10A 8FT Stress	401855-108
Wire Harness 10A 125V 6.5FT	401855-005
Wire Harness 10A 250V 6.5FT	401855-006
Power Cord Swiss 10A 250V 8FT	401855-007
Power Cord Indian 10A 250V 8FT	401855-008
Danish 220VAC/50HZ,Stress	401855-009
Power Cord Australian 10A 250V 8FT	401855-010
Power Cord 10A 8FT Cont Euro Stress	401855-101
Power Cord, Danish 10A 8FT Stress	401855-109
Power Cord AUST 10A 8FT Stress	401855-110
Power Cord 16A, Euro	401855-201
Power Cord 13A, British	401855-202
Power Cord 16A, Italian	401855-203
Power Cord 16A, Israeli	401855-204
Power Cord 15A AUST	401855-210
Cord Power Stress 125V 15A 12FT	405535-002
Cord Power RA 125V 13A 10FT	405535-006
Cord Power 18-3 SJT	5509-001
Power Cord RA 125V 13A 12FT	405535-001
Power Adapter 230VAC/DC ME	414582-222
Power Adapter 240VAC/DC AA	414582-224
Power Adapter 240VAC/DC, UK	414582-225
Power Cord European Adapter 1FT	415359-001
Power Adapter 100VAC/DC Japanese	414582-223
Barcode Scanner Kit, English	2018626-001
Barcode Scanner Kit, German	2018626-002
Barcode Scanner Kit, French	2018626-003
Barcode Scanner Kit, Spanish	2018626-004
Barcode Scanner Kit, Swedish	2018626-005
Barcode Scanner Kit, Italian	2018626-006
Barcode Scanner Kit, Norwegian	2018626-009

Field Replaceable Units (Continued)	
Item	**Part Number**
Barcode Scanner Kit, Danish	2018626-010
Barcode Scanner Kit, Czech	2018626-011
Barcode Scanner Kit, Hungarian	2018626-014
Barcode Scanner Kit, Polish	2018626-015
Magnetic Card Reader Kit, English	2018627-001
Magnetic Card Reader Kit, German	2018627-002
Magnetic Card Reader Kit, French	2018627-003
Magnetic Card Reader Kit, Spanish	2018627-004
Magnetic Card Reader Kit, Swedish	2018627-005
Magnetic Card Reader Kit, Italian	2018627-006
Magnetic Card Reader Kit, Norwegian	2018627-009
Magnetic Card Reader Kit, Danish	2018627-010
Trolley Caster Fixed (Anti-Static)	2017784-002
Trolley Caster Swivel (Anti-Static)	2017785-002
Trolley Caster Kit (Anti-Static)	2024418-001
North American MobileLink Ultra High Security Assembly	2023922-001
North American MobileLink Assembly	2014403-002
European MobileLink Assembly	2014403-003

For your notes

Appendix A – Abbreviations

For your notes

Standard Abbreviations

A

A	ampere
A-ang	antianginal
A-arh	antiarrhythmic
A-coa	anticoagulants
A-hyp	antihypertensive
A1 - A4	auxiliary leadwires
AAMI	American Association of Medical Instrumentation
ABP	ambulatory blood pressure
ac, AC	alternating current
ACLS	Advanced Cardiac Life Support
A/D	analog-to-digital
Adj	adjustable
AG	automotive glass
Ah	ampere hours
AHA	American Heart Association
Al	aluminum
AllRam	all RAM
AllSec	all sector
AllTrk	all track
ALT	alternate
Alt-Off	alternate offset
am, AM	acquisition module, ante meridiem
AM-1	acquisition module-1
AM-1M	acquisition module-1 modified
AM-2	acquisition module-2
AM-3	acquisition module-3
AM-4	acquisition module-4
amp	ampere
Ampl	amplifier
AMU	ambulatory monitoring unit
ANA	analog
ANLG	analog
AnsrTone	answer tone
A/O	Analog Output
ASCII	American Standard Code for Information Interchange
ASSY	assembly
Attn	attention
AUG	August
AUST	Australian
AUSTRALN	Australian
Auto	automatic
AutoRhym	automatic rhythm
AUX	auxiliary
aVF	augmented left leg lead
avg	average
aVL	augmented left arm lead
aVR	augmented right arm lead
AWG	American Wire Gage

B

Bd	board, baud
BDGH	binding head
BetaB	beta blockers
BKSP	backspace
BLK	black
BLU	blue
Blvd	boulevard
BP	blood pressure
BPM	beats per minute
BRIT	Britain
BRN	brown
BSI	British Standards Institute
Btu	British thermal unit

C

CalcBlk	calcium blockers
CAPOC	Computer Assisted Practice of Cardiology
CASE	Computer Aided System for Exercise
Catoprl	Catopril
Cauc	Caucasian
Cer	ceramic
CFM	cubic feet/minute
CGR	computer graphic record
Ch, CH	channel
C/L	center line
CLK	clock signal
Clonid	Clonidine
cm	centimeter
cm^2	square centimeters
Cmd	command number
CMMR	common mode rejection ratio
CMOS	complementary metal-oxide semiconductor
c/o	in care of
COM1	communications port 1
COM2	communications port 2
ComLink	communications link
Comp	composition
Confrmd	confirmed
Cont, CONT	Continental, continued
Coumadn	Coumadin
CPR	cardiopulmonary resuscitation
CPU	central processing unit
CR	diode
CRC	cyclic redundancy check
CRD	cord
crt, CRT	cathode ray tube
CSA	Canadian Standards Association
CTRL	control

D

D/A	digital to analog
DA	damping relay
dac, DAC	digital-to-analog converter
DAN	Danish
Dat/Tim	date/time

dBm	decibel (referenced to 1 milliwatt into 600 ohms)
dc, DC	direct current
DD	double density, day
DDD	Digital Diagnostic Diskette
DEC	Digital Equipment Corporation, December
Del	delete
DEMO	demonstration
DES	designation
DevId	device identification
Diag	diagnostic
Digital	Digitalis
Digitox	Digitoxin
Digox	digoxin
Digoxin	Digoxin-Lanoxin
DIP	dual in-line package
Dirctry	directory
Diurt	diuretics
DOB	date of birth
DOS	disk operating system
DP	diametral pitch
DPST	double-pole, single-throw
DRAM	dynamic RAM
DR/DT	digital recording/digital transmission
DSKTP	desktop
Dysopyr	Dysopyramide

E

E	enable, vector electrode site, vector lead
ecg, Ecg, ECG	electrocardiogram
ECO	Engineering Change Order
EDIC	Electrocardiograph Digital Information Center
EEPROM	electrically erasable programmable ROM
e.g.	for example
EGA	enhanced graphics adapter
EMF	electromotive force
EMI	electromagnetic interference
ENG	English
EOF	end of file
EPIC	Electronic Patient Information Chart
EPLD	electrically programmable logic device
EPROM	eraseable, programmable, read-only memory
ESD	electrostatic discharge
etc, etc.	et cetera
EURO	Europe, European
EXP	Expanded

F

F	fuse, Farad, female
F1-F5	function keys 1 through 5
Fax	facsimile
FCC	Federal Communications Commission
FE	front end
FILH	fillister head
FLH	flat head
FLRAM	flash RAM

FR	French
FrntEnd	front end
FSK	frequency shift keying
ft	foot, feet
Furosem	Furosemide

G

g	gram, acceleration due to gravity
GB	Great Britain
GERM	German, Germany
GND	ground, digital ground (dc common)
GRN	green
GRY	gray

H

H	high, vector electrode site, vector lead
HDLC	high-level data link control
Hex, HEX	hexagon, hexadecimal
HH	hour
HiRes	high-resolution
Hr	hour
Hydral	Hydralazine
Hz	Hertz (cycles per second)

I

I	on, input, vector electrode site
I, II, III	limb leads
IC	integrated circuit
ID	identification
i.e.	that is
IEC	International Electrotechnical Commission
in	inch
IN	input
inc, inc., INC	incorporated
Info	information
Ins	insert
I/O	input/output
I/P	input
ISA	industry standard architecture
Isosorb	Isosorbide
IT	Italian, Italy

J

JAN	January
JIS	Japan Industrial Standards

K

k, K	kilo, 1000, 1024
Kb, KB	kilobyte
kg, Kg	kilogram
kHz, KHz	kilohertz
kV, KV	kilovolt
Kyb	keyboard

L

L	line
L1	level one
L2	level two
LA	left arm
lb	pound
LCD	liquid crystal display
Lcl Line	local line
Ld Grps	lead groups
LED	light-emitting diode
LH	left hand
Lidoca	Lidocaine
LL	left leg
Loc	location
LocPc	Local MAC PC
LogRetry	log retry
Ltd	limited

M

m	meter
M	megabyte, metric, vector electrode site, vector lead, male
mA	milliamperes
MAC	Microcomputer Augmented Cardiograph
mains voltage	voltage of a supply mains between 2 line conductors of a polyphase system or voltage between the line conductor and the neutral of a single-phase system
max	maximum
Measure	measurements
Med	medications
MEM	memory
MF	metal film
MHz	megahertz
min	minutes, minimum
Misc	miscellaneous
mm	millimeter
MM	minute
MMM	month
mm/mV	millimeter per millivolt
mm/s	millimeter per second
Modem	modulator/demodulator
MOS	metal oxide semiconductor
MPE	metallized polycarbonate expitaxial
ms	milliseconds
MS-DOS	Microsoft Disk Operating System
MTBF	mean time between failures
mtg	mounting
MTR	MOTOR
MUSE	Marquette Universal System for Electrocardiography
mux	multiplexer
mV	millivolt
mVR	minus (inverted) aVR

N

N	neutral

n/a	not available
NA	not applicable
NC	no connection
Nitrate	nitrates
NLQ	near letter quality
NMI	non-maskable interrupt
NMOS	N-channel metal-oxide semiconductor
No	number
NO	normally open
norm	normal
nS	nanoseconds
NSR	Normal Sinus Rhythm

O

O	off, original
OE	other errors
OEM	original equipment manufacturer
OH	off-hook relay
OneSec	one sector
ORG	orange
Orig	original
OUT	output
oz	ounce

P

P	P wave (section of the ECG waveform)
p-p	peak-to-peak
PA	P wave amplitude
Params	parameters
Passwds	passwords
PatData	patient data
PatInfo	patient information
PATN	patient
PC	printed circuit, personal computer
PCB	printed circuit board
pF	picofarad
Pgm	program
PgmId	program identification
Phenoth	Phenothiazide
Phenytn	Phenytoin
PID	patient identification digit
PLCC	plastic leadless chip carrier
PM	power module
pm, PM	post meridiem, preventive maintenance
PM-2	Power Module-2
PM-3	Power Module-3
pn, PN	part number
PNH	pan head
PPA	P wave amplitude
PR	ECG signal interval
Pro-Off	progressive offset
Procain	Procainamide
PROM	programmable read-only memory
Propran	Propranolol
PSK	phase shift keying

PSU	power supply unit
Psych	psychotropic
PUP	pull-up signal
PVC	polyvinyl chloride
PWM	pulse-width modulation
PWR	power
PWR CRD	power cord

Q

Q	transistor
QA	quality assurance, Q wave amplitude
QAD	Quality Assurance Deviation
QAM	quadrature amplitude modulation (phase and amplitude modulation)
QC	quality control
QD	Q wave duration
QRS	QRS complex (portion of ECG waveform), interval of ventricular depolarization
QT	QRS interval
QTC	QRS interval
QTY	quantity
Quinid	Quinidine

R

R	resistor, red, reset
RA	right angle, right arm or R wave amplitude
RAM	random access memory
RC	resistor capacitor
RD	R wave duration
Ref	reference, refresh
REN	Ringer Equivalence Number
Reserp	Reserpine
REV	revision
RevdBy	reviewed by
RevXmit	reverse transmission
rf	radio frequency
RFI	radio frequency interference
RGB	red, green, blue
RI	ring indicate
RL	right leg
RMR	Rhythm and Morphology Report
ROM	read only memory
RPA	R wave amplitude
RPD	R wave duration
rpt, Rpt	report
RTC	real time clock
RTI	relative to patient input
RTN	return
RVS	reverse
R/W	read/write

S

12SL	12 simultaneous leads
s, S	second, select, switch

SA	s wave amplitude
SB	slow-blow
SCL	safe current limits
SD	schematic diagram, S wave duration
SE	serial input/output errors
sec	second
sec.s	seconds
SEER	Solid-state Electronic ECG Recorder
SING	Singapore
SP	Spanish
SPA	S wave amplitude
SPDT	single-pole, double-throw
SRAM	static RAM
ST-T	ST-T wave (section of the ECG waveform)
standrd, Standrd	standard
STD	standard
STE	ST segment displacement at the end
STJ	ST segment displacement at the J point
STM	ST segment displacement at the mid-point between STJ and STE
stmts, Stmts	statements
supply mains	permanently installed power source
SVT	power cord type; 300 V
sw, SW	switch, software
SW	Swedish, Sweden

T

T Tone	touch tone
TA	T wave amplitude
Tant	tantalum
TDML	treadmill
TE	timeout errors
Tech	technical
Thiazid	Thiazide
TM	trademark
Tot	total
TP	test point
TPA	T’ wave amplitude
TRAM	Transport Remote Acquisition Monitor
Tricyli	Tricylic antidepressant
TTL	transistor-transistor logic, TTL levels
TVS	transient voltage suppressor

U

UE	undefined errors
uF	microfarad
UL	Underwriters’ Laboratory, Inc
Unconf	unconfirmed
UUT	unit-under-test

V

v, V	volt, volts
V1-V6	precordial leads
V123	V1, V2, V3
V3R	precordial lead

V456	V4, V5, V6
V4R	precordial lead
V ac	volts, alternating current
V dc	voltage, direct current
VA	volt-amperes
Var	variable
VDE	Verband Deutscher Elektrotechniker (German regulatory agency)
Vent.	ventricular
VF	ventricular fibrillation
VGA	video graphics array
VIA	versatile interface adapter
VIO	violet
Volt	voltage
VRAM	video RAM
vs	versus

W

w/	with
W	watt
Warfar	Warfarin
WHT	white
WI	Wisconsin

X

x	by (as in "8-1/2 x 11")
XCV	transceiver
X,Y,Z	orthogonal leads

Y

Y	year, yellow
yr	year
yrs	years
YY	year

Symbols

↑	SHIFTed or alternate function
μ	micro
μF	microfarad
μs, μsec	microsecond
68K	68000
&	and
#	number
°C	degrees Celsius
°F	degrees Fahrenheit
Ω	Ohm, ohm
%	percent
®	registered
>	greater than
<	less than
±	plus or minus
*	An asterisk after a signal name indicates the signal is active at its relatively lower potential, or "active-low." Signals without the asterisk suffix are active at their relatively higher potential, or "active-high."
12SL	12 simultaneous leads

Appendix B – Technical Specifications

For your notes

Technical Specifications

Display	
Item	**Description**
Type	264mm (10.4 in.) diagonal graphics backlit AM LCD
Resolution	640 x 480 pixels, with waveform enhancement
Displayed Data	Heart rate, patient name, ID, clock, waveforms, lead labels, speed, gain and filter settings, warning messages, prompts and help messages

Computerized Electrocardiograph	
Item	**Description**
Instrument Type	15 lead (14 channel) microprocessor-augmented, automatic electrocardiograph
Analysis Frequency	500 samples/s (sps)
ECG Storage	150 ECG's (typical), 200 (maximum) on removable media (1.44 MB, 3.5" diskette)
Digital Sampling Rate	4000 samples/s/channel
Analysis	Pediatric and vectorcardiography Optional: 12SL analysis, HI-RES and PHI-RES late potential analysis
Pre-acquisition	Provides 10 s of instantaneous ECG acquisition
Dynamic Range	AC differential: ±5 mV DC offset: ±320 mV
Resolution	4.88 µV/LSB @ 250 sps, 1.22 µV/LSB @ 500 sps
Frequency Response	–3 dB @ 0.01 to 150 Hz
Common Mode Rejection	>140 dB (123 dB with AC filter disabled)
Input Impedance	>10 MΩ @ 10Hz, defibrillator protected
Patient Leakage Current	<10 µA
Pace Detection	750 µV @ 50 µs duration, Orthogonal LA, LL and V6
Special Acquisition Functions	Disconnected lead detection, electrode impedance, AC noise, baseline wander, and muscle tremor
Communication	MAC and MUSE system compatible RS-232 Optional: Modem, FAX, and wireless transmission, remote retrieval (remote query)

Writer	
Item	**Description**
Type	Thermal dot array
Speeds	5, 12.5, 25, 50 mm/s (same as display)
Number of Traces	3, 6, 12, or 15 user-selectable (same as display)
Sensitivity/Gain	2.5, 5, 10, 20, 10/5 (split calibration) mm/mV (same as display)
Speed Accuracy	± 2%
Amplitude Accuracy	± 5%
Resolution	Horizontal 1000 dpi @ 25 mm/s, 200 dpi vertical
Paper Type/Size	Thermal z-fold, perforated, 215.9 mm x 276.4 mm (8.5 in. x 11 in.) fanfold, 300 sheets per pack

Keyboard	
Item	**Description**
Type	Sealed elastomer with soft function keys, alphanumeric keys, writer controls and TrimPad cursor controls

Electrical	
Item	**Description**
Power Supply	AC or battery operation
AC Input Voltage Current Frequency	 100-240 VAC, +10, -15% 0.5 A @ 115 VAC, 0.3 A @ 240 VAC, typical 50/60 Hz, ±10%
Battery Type	User replaceable, 18V @ 3.5 AH ±10%, rechargeable NiMH pack
Battery Capacity	100 single-page reports (typical) or 6 hours continuous operation (without printing)
Battery Charge Time	Approximately 4.5 hrs. from total discharge with display off. NOTE: Cannot charge battery at or above 45° C (best if below 40° C)

Vectorcardiography	
Item	**Description**
Report Formats	Vector loops of component vectors (P, QRS, ST-T)
Sensitivity	20, 40, 80, 160 mm/mV
Time Resolution	2 ms

Hi-Res and PHi-Res Signal-Averaged Electrocardiography	
Item	**Description**
Frequency Response/Input	-3 dB @ 0.01 and 250 Hz
Frequency Response/Output Upper Limit Lower Limit	 250 Hz 0.01, 25, 40 or 80 Hz
Sensitivities Raw Data and Template Average Beat Filtered Signals and Vector Magnitude	 20 mm/mV 20 mm/mV and 50 mm/mV 1 mm/µV
Analysis Sampling Rate	1000 samples per second per channel
Digital Sampling Rate	4000 samples per second per channel
High/Low Pass Filters	Spectral filter using Fast Fourier Transform (FFT)
ADC Resolution	1.22 µV/LSB
Analysis Resolution	0.1525 µV/LSB

Physical [1]	
Item	**Description**
Height	9.4 cm (3.7 in) with display closed
Width	38.1 cm (15.0 in)
Depth	35.1 cm (13.8 in)
Weight	6.8 kg (15 lb) without paper

1. without trolley

Environmental	
Item	**Description**
Operating Conditions Temperature Relative Humidity Atmosphere Pressure	 10° C to 40° C (50° F to 104° F) [1] 20% to 95% RH noncondensing 700 to 1060 hPa

Environmental (Continued)	
Item	**Description**
Transport/Storage Conditions Temperature Relative Humidity Atmosphere Pressure	 -40° C to 70° C (-40° F to 158° F)* 15% to 95% RH noncondensing 500 to 1060 hPa
Disposal Batteries Device	 Disposing of battery by fire or burning will cause the battery to explode. The battery is recyclable. Follow local environmental guidelines concerning disposal and recycling. Batteries may be returned to GE Medical Systems *Information Technologies* service for recycling. Recyclable.

1. Paper discoloration may occur at higher temperatures.

Safety	
Item	**Description**
Certification	UL 2601-1 classified UL classified for CAN/CSA C22.2 No. 601.1 CB certified for IEC 601-1 CE marking for Council Directive 93/42/EEC concerning Medical Devices Meets applicable AAMI EC-11 requirements
Type of Protection Against Electrical Shock	Class 1, internally powered
Degree of Protection Against Ingress of Liquids	Ordinary
Handling of Disposable Supplies and Other Consumables	Use only parts and accessories manufactured or recommended by GE Medical Systems *Information Technologies*. Follow manufacturer's instructions for use for disposable/ consumable products. Follow local environmental guidelines concerning the disposal of hazardous materials.
Patient Mode of Operation	Continuous
Patient Leakage Current	<10 µA
Degree of Protection Against Electrical Shock	Type BF defibrillation protection for the patient cable (acquisition module)
Maintenance Frequency	Daily visual inspection and routine cleaning (if needed) performed by user. Use a commercially available, industrial strength disinfectant cleaner on any part of the equipment (other than electrodes) which comes into direct contact with the patient. Every six months routine maintenance checks and test procedures performed by qualified technical personnel.
Repair Guidelines	Calibration instructions, equipment descriptions, and all other information which will assist qualified technical personnel in repairing those parts of the equipment designated as repairable is available in the field service manual for the equipment. We will make available upon request circuit diagrams and component parts lists for printed circuit boards deemed repairable by qualified technical personnel.

For your notes

Appendix C – Electromagnetic Compatibility

For your notes

Electromagnetic Compatibility (EMC)

Changes or modification to this system not expressly approved by GE Medical System could cause EMC issues with this or other equipment. This system is designed and tested to comply with applicable regulation regarding EMC and needs to be installed and put into service according to the EMC information stated as follows.

WARNING
Use of portable phones or other radio frequency (RF) emitting equipment near the system may cause unexpected or adverse operation.

WARNING
The equipment or system should not be used adjacent to, or stacked with, other equipment. If adjacent or stacked use is necessary, the equipment or system should be tested to verify normal operation in the configuration in which it is being used.

Guidance and Manufacturer's Declaration – Electromagnetic Emissions

The MAC 5000 is intended for use in the electromagnetic environment specified below. It is the responsibility of the customer or user to ensure that the MAC 5000 is used in such an environment.

Emissions Test	Compliance	Electromagnetic Environment - Guidance
RF emissions CISPR11	Group 1	The equipment uses RF energy only for its internal function. Therefore, its RF emissions are very low and are not likely to cause any interference in nearby electronic equipment.
RF emissions CISPR11	Class A	The equipment is suitable for use in all establishments including domestic establishments and those directly connected to the public low-voltage power supply network that supplies buildings used for domestic purposes.
Harmonic Emissions EN 61000-3-2	Class A	
Voltage fluctuations/ Flicker emissions EN 61000-3-3	Complies	

Guidance and Manufacturer's Declaration – Electromagnetic Immunity

The MAC 5000 is intended for use in the electromagnetic environment specified below. It is the responsibility of the customer or user to ensure that the MAC 5000 is used in such an environment.

Immunity Test	EN 60601 Test Level	Compliance Level	Electromagnetic Environment - Guidance
Electrostatic discharge (ESD) EN 61000-4-2	± 6 kV contact ± 8 kV air	± 6 kV contact ± 8 kV air	Floors should be wood, concrete or ceramic tile. If floors are covered with synthetic material, the relative humidity should be at least 30%.
Electrical fast transient/burst EN 61000-4-4	± 2 kV for power supply lines ±1 kV for input/output lines	± 2 kV for power supply lines ±1 kV for input/output lines	Mains power should be that of a typical commercial or hospital environment.
Surge EN 61000-4-5	± 1 kV differential mode ± 2 kV common mode	± 1 kV differential mode ± 2 kV common mode	Mains power should be that of a typical commercial or hospital environment.
Voltage dips, short interruptions and voltage variations on power supply input lines EN 61000-4-11	<5% U_t (>95% dip in U_t) for 0.5 cycles 40% U_t (60% dip in U_t) for 5 cycles 70% U_t (30% dip in U_t) for 25 cycles <5% U_t (>95% dip in U_t) for 5 sec	<5% U_t (>95% dip in U_t) for 0.5 cycles 40% U_t (60% dip in U_t) for 5 cycles 70% U_t (30% dip in U_t) for 25 cycles <5% U_t (>95% dip in U_t) for 5 sec	Mains power should be that of a typical commercial or hospital environment. If the user of the MAC 5000 requires continued operation during power mains interruptions, it is recommended that the MAC 5000 be powered from an uninterruptible power supply or a battery.
Power frequency (50/60 Hz) magnetic field EN 61000-4-8	3 A/m	3 A/m	Power frequency magnetic fields should be at levels characteristics of a typical location in a typical commercial or hospital environment.

NOTE

Ut is the AC mains voltage prior to application of the test level.

Guidance and Manufacturer’s Declaration – Electromagnetic Immunity

The MAC 5000 is intended for use in the electromagnetic environment specified below. It is the responsibility of the customer or user to assure that the MAC 5000 is used in such an environment.

Immunity Test	EN 60601 Test Level	Compliance Level	Electromagnetic Environment – Guidance
			Portable and mobile RF communications equipment should not be used closer to any part of the equipment, including cables, than the recommended separation distance calculated from the equation applicable to the frequency of the transmitter. **Recommended separation distance**
Conducted RF EN 61000-4-6	3 Vrms 150 KHz to 80 MHz	3 V rms	$d = 1.2\sqrt{P}$
Radiated RF EN 61000-4-3	3 V/m 80 MHz to 2.5 GHz	3 V/m	$d = 1.2\sqrt{P}$ 80 MHz to 800 MHz $d = 2.3\sqrt{P}$ 800 MHz to 2.5 GHz
			where P is the maximum output power rating of the transmitter in watts (W) according to the transmitter manufacturer, and *d* is the recommended separation distance in meters (m). Field strengths from fixed RF transmitters, as determined by an electromagnetic site survey[a], should be less than the compliance level in each frequency range[b]. Interference may occur in the vicinity of equipment marked with the following symbol: 

NOTE 1: At 80 MHz and 800 MHz, the higher frequency range applies.
NOTE 2: These guidelines may not apply in all situations. Electromagnetic propagation is affected by reflection from structures, objects, and people.

[a] Field strengths from fixed transmitters, such as base stations for radio (cellular/cordless) telephones and land mobile radio, AM and FM radio broadcast, and TV broadcast cannot be predicted theoretically with accuracy. To assess the electromagnetic environment due to fixed RF transmitters, an electromagnetic site survey should be considered. If the measured field strength in the location in which the equipment is used exceeds the applicable RF compliance level above, the equipment should be observed to verify normal operation. If abnormal performance is observed, additional measures may be necessary, such as re-orienting or relocating the equipment.

[b] Over the frequency range 150 KHz to 80 MHz, field strengths should be less than 3 V/m.

Recommended Separation Distances

The table below provides the recommended separation distances (in meters) between portable and mobile RF communication equipment and the MAC 5000.

The MAC 5000 is intended for use in the electromagnetic environment on which radiated RF disturbances are controlled. The customer or the user of the MAC 5000 can help prevent electromagnetic interference by maintaining a minimum distance between portable and mobile RF communications equipment (transmitters) and the MAC 5000 as recommended below, according to the maximum output power of the communications equipment.

	Separation Distance in Meters (m) According to Frequency of Transmitter			
Rated Maximum Output Power of Transmitter in Watts	**150 kHz to 80 MHz outside ISM bands** $d = 1.2\sqrt{P}$	**150 kHz to 80 MHz in ISM bands** $d = 1.2\sqrt{P}$	**80 MHz to 800 MHz** $d = 1.2\sqrt{P}$	**800 MHz to 2.5 GHz** $d = 2.3\sqrt{P}$
0.01	0.12	0.12	0.12	0.23
0.1	0.38	0.38	0.38	0.73
1	1.2	1.2	1.2	2.3
10	3.8	3.8	3.8	7.3
100	12	12	12	23
NOTE 1: At 80 MHz and 800 MHz, the separation distance for the higher frequency range applies.				

For transmitters rated at a maximum output power not listed above, the recommended separation distance [d] in meters (m) can estimated using the equation applicable to the frequency of the transmitter, where P is the maximum output power rating of the transmitter in watts (w) according to the transmitter manufacturer.

NOTE

These guidelines may not apply in all situations. Electromagnetic propagation is affected by absorption and reflection from structures, objects, and people.

Compliant Cables and Accessories

WARNING
The use of accessories, transducers and cables other than those specified may result in increased emissions or decreased immunity performance of the equipment or system.

The table below lists cables, transducers, and other applicable accessories with which GE Medical Systems claims EMC compliance.

NOTE
Any supplied accessories that do not affect EMC compliance are not included.

Part No.	Description	Maximum Lengths
900770-001	MAC Pac Battery	NA
900995-001	CAM 14	NA
2016560-001	Cable Assembly Host MAC 5000	1.7m
2016560-003	Cable Assembly Host MAC 5000ST	5.4m
901142-001	Kit CAM 14 Resting W/AHA Adaptors	NA
901142-002	Kit CAM 14 Resting W/IEC Adaptors	NA
400073-001	Serial Comm. Cable 8 Pin Mini DIN	6.1m
416070-001	External Video Cable	1.8m
700520-002	Analog/TTL Interface Cable	3.0m
2007918-001	Treadmill Cable MAC 5000ST to T2000	6.0m
405535-006	Power Supply Cord US 13A 125V	3.0m
401855-001	Power Supply Cord European 10A 250V	2.5m
401855-002	Power Supply Cord British 10A 250V	2.5m
401855-003	Power Supply Cord Italian 10A 250V	2.5m
401855-004	Power Supply Cord Israeli 10A 250V	2.5m
401855-007	Power Supply Cord Swiss 10A 250V	2.5m
401855-008	Power Supply Cord Indian 10A 250V	2.5m
401855-010	Power Supply Cord Australian 10A 250V	2.5m
2005264-XXX	MAC 5000 External Modem Kit	NA
2018626-XXX	MAC 5000 Barcode Scanner Kit	NA
2018627-XXX	MAC 5000 Magnetic Card Reader Kit	NA

Part No.	Description	Maximum Lengths
2014403-XXX	MAC 5000 Wireless Kit	NA
2023922-XXX	MAC 5000 Secure Wireless Kit	NA

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