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POOL DATA ACQUISITION SYSTEM DOCUMENTATION

Scott B. Robinson¹
Laurie A. Blanchard²
Robert Soares¹

¹Thermal and Mountain Medicine Division
²Biophysics and Modeling Division

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U.S. Army Research Institute of Environmental Medicine
Natick, MA 01760-5007

Report Documentation Page

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SYMBOLS/ACRONYMS/ABBREVIATIONS

Ω	Ohms (resistance)
$^{\circ}\text{C}$	Degrees Celcius
μA	Microamps
μV	Microvolts
A	Amps
AC	Alternating current
A/D	Analog to digital
Acq. AI	Acquire Analog Input
ASCII	American Standard Code for Information Interchange
CPU	Central processing unit
D/A	Digital to analog
DAQ	Data Acquisition
DC	Direct Current
DMM	Digital Multimeter
ET	Elapsed Time
exe application)	Executable file (stand alone PC-compatible
GUI	Graphical user interface
HF	Heat flow
HF _abd	Abdominal heat flow
HF _calf	Calf heat flow
HF _fa	Forearm heat flow
HF _finger	Finger heat flow
HF _foot	Foot heat flow

HF_hand	Hand heat flow
HF_head	Head heat flow
HF_pect	Pectoral (chest) heat flow
HF_spare	Spare heat flow
HF_subsc	Subscapular (back) heat flow
HF_thigh	Thigh heat flow
HF_tri	Triceps heat flow
ln	Natural log
mA	Milliamps
ms	Milliseconds
mV	Millivolts
MAX	Measurement and Automation Explorer
MWST	Mean Weighted Skin Temperature
NI	National Instruments
PXI	<u>P</u> CI <u>e</u> X <u>t</u> ensions for <u>I</u> nstrumentation
RH	Relative humidity
SOP	Standard operating procedure
T_abd	Abdominal temperature
T_calf	Calf temperature
T_fa	Forearm temperature
T_finger	Finger temperature
T_foot	Foot temperature
T_hand	Hand temperature
T_head	Head temperature
T_pect	Pectoral (chest) temperature

T_{spare}	Spare temperature
T_{subsc}	Subscapular (back) temperature
T_{thigh}	Thigh temperature
T_{tri}	Triceps temperature
TTL	Transistor-transistor logic
T_a	Ambient temperature
TBX	Terminal block
T_{dp}	Dew-point temperature
T_{es}	Esophageal temperature
T_{re}	Rectal temperature
T_{sk}	Skin temperature
V	Volts or voltage
VI	Virtual Instrument

INTRODUCTION

This report describes a data acquisition system developed to obtain body temperature measurements for human volunteers during cold exposure. Since acceptable commercial systems are not available, this system was custom-built to acquire data using National Instruments hardware components and LabVIEW 6.0 Developmental Software. The system works by integrating signals collected by hardware devices, and the software processes/manipulates by using Virtual Instruments (VI's). This report provides detailed documentation for the construction and operation of the data acquisition system. This report is intended to allow a technician to duplicate or modify this system, given general background knowledge in National Instrument's LabVIEW graphical programming language.

General requirements for this system are that it be highly accurate, precise, and expandable for future studies. The system also needs to function within the environmental temperatures of the protocol. Based on the requirements noted above, the hardware chosen for this system consists of the PXI-1006 14-slot chassis, PXI-8176 Controller/CPU, (six) PXI-2503 analog input modules, (six) PXI-2605 24-channel terminal blocks, and PXI-4060 Digital Multimeter (DMM). The PXI system was chosen for its flexibility in integrating with other systems, its high degree of accuracy (resolution), and its potential for future expansion.

Data collection for this system is achieved by sampling analog signals at regular intervals from thermistors (placed in the air, on the skin, and in the subject's esophagus and rectum) and user input controls, and modifying them within the custom software to obtain real-time measurements. Four-wire heat flow disks (Concept Engineering, Old Saybrook, CT) are used to acquire skin temperature (T_{sk}) and heat flow (HF). Voltage is measured across two (white/black) of the four wires, and resistance will be measured across the other two wires (red/yellow).

The software Graphical User Interface (GUI) is designed to be user-friendly, with minimal user input configurations to manage. The GUI is designed to provide immediate numerical indication of skin and core temperatures, as well as environmental conditions. The interface is also designed to provide both a graphical history of data, as well as a numerical history in tabular form. Therefore, the last data point can be viewed immediately, a historical table of all data can be scrolled through, and trends in data can be tracked graphically. The interface is required to have start and stop testing buttons and the ability to monitor or monitor/record data to disk, all clearly marked and easy to locate. The system is designed to run continuously throughout testing without the need for an operator to constantly monitor the system. Besides the start, stop, and monitor controls, the system is developed with the ability to enter unique file names and select predetermined "event-markers" to identify various stages of testing.

Finally, data are secured by opening the destination file, appending data to this file, and closing this file each time data are collected. This method ensures that data are not lost during power failure or if the software is corrupted. Data are collected every 15 seconds. This method of data collection ensures that random access memory (RAM) is available and does not stress system resources.

MATERIALS

- (1) National Instruments LabVIEW 6.1 developmental software package
- (1) PXI-1006 14-slot chassis
- (1) PXI-4060 digital multimeter
- (1) PXI-8176 chassis controller/CPU
- (6) PXI-2605 24-channel terminal block
- (6) PXI-2503 analog input modules
- (1) Fluke 27 digital multimeter

METHODS

MEASUREMENTS

The system is developed to obtain data from thermistors, platinum resistance thermometers (PRTs), and dew-point sensors. Therefore, the system needed to have the ability to measure voltages and resistances with a high degree of accuracy and reliability. Four-wire heat flow disks are used to obtain skin temperature and heat flow. Voltages are measured across two of the four wires to obtain heat flow, and resistance is measured across the other two wires to obtain skin temperature. Once the measurement has been made, the values are then manipulated in the software by the program's subVIs (Figures 1-4) for scaling dew point temperature (T_{dp}) and water temperature (T_{water}) measurements, heat flow scaling in accordance with calibration values, obtaining an average value of skin temperature, and conversion of data to °C, respectively. Esophageal temperature (T_{es}) and Rectal Temperature (T_{re}) are also linearized with VI in Figure 4. The dew-point sensor and quartz thermometer each output voltages of 1 mV/°C, respectively. Each are scaled by 100, respectively, to obtain actual temperatures in °C. The VI shown in Figure 1 handles the scaling of these two measurements.

PROGRAMMING DESIGN

In order to keep data flowing smoothly and allow LabVIEW programmers to update/conceptualize the code without difficulty, the program is designed in a neat and concise manner consistent with standards for programming in a data flow language. The main portion of the program is built within a "while loop" and, once initiated, will run continuously until the user clicks the stop button, which is a "stop if true" Boolean. Upon activating this button, the activity within the loop will cease, and data will stop being collected. The program collects data, manipulates them as desired, and writes to disk within this main loop. Outside the loop is a VI (Figure 5) that opens a file, obtains an initial time and date stamp, acquires a file name according to the users text input string entry entitled filename (Figure 6), writes a series of predetermined "headers" for each spreadsheet column, and then passes this information into the loop that writes these data to the beginning of the spreadsheet. Data collected from this point on append to the end of each row to eliminate the potential for overwriting data.

The program consists of two main scan engines: one acquiring measures of resistance and the other voltage. Resistance measurements are taken on the PXI::14::INSTR module, and voltage measurements are taken on the PXI::13::INSTR

module. To ensure sequential scanning in the proper order, com0 on the PXI::14::INSTR terminal block is wired directly to the com0 of the PXI::13::INSTR terminal block. This ensures that all devices wired into both terminal blocks are sampled at nearly the same time ($\pm 10\text{-}20$ ms).

The engines start with identifying the NI Switches and initiating them for scanning, followed by the “NI Switch Trig configure” VI. The program flow continues by configuring the “NI Switch” to continuously scan, then identifies the list of channels to be measured. The built-in PXI-4060 digital Multimeter (DMM) is then identified, initialized, and then configured for measurement. Resolution, range, and type of measurement (voltage/resistance) are configured at this point. The measurement period and scan delays are then configured, followed by initiation of the NI Switch and then the initiation of the NIDDM. At this point, the DMM is ready to acquire samples. The “NIDMM Fetch” VI acquires the data and passes the array into successive subVIs (Figures 7-8) that will manipulate the raw data and place it (them?—data?) into a larger array, which will be passed into a while loop containing a “Figure 8” VI (do you mean a literal Figure 8? Use Fig 8 caption wording to clarify. Change others in this paragraph...). At several points between the data manipulation VIs and the Build Array VI, data are pulled off and plotted graphically in 2D form. In particular, the voltages collected are passed through the “Figure 2” VI that multiplies each value by a predetermined calibration value to obtain heat flow. Within the other scan engine, collected resistances are passed through the “Figure 4” VI, which multiplies each value within the array by the linearization equation. To obtain a measure of Mean Weighted Skin Temperature (MWST), values are pulled off the array, destined for the final build array VI, and passed through the “Figure 3” VI, which takes predetermined skin temperature sites and multiplies them by their weighted percentage of the entire skin surface area. The data are then routed back to the final build array VI that is eventually passed to the spreadsheet for recording (Equation 2—verify against equation pg 5). Following the “NIDMM Fetch” VI, all of the data have been collected for that period, and the error clusters, associated with the scanning, continue on to abort scanning by the DMM and close the NI Switch. The switches and DMM remain idle until the next scan. Scans are programmed to acquire data at 15-second intervals using the “Wait Until Next ms Multiple” VI, with the value “15000” wired to the input constant.

The data table displayed on the front panel is generated by pulling off the array of data destined for the “Figure 9” VI and converting the array of numbers to an array of strings wired to a pre-formatted table.

Each group of samples has an associated timestamp to indicate the exact hour, minute, and second that the data were acquired. Timestamps are handled by acquiring hours, minutes, and seconds from the CPU clock time and writing them in separate columns of a spreadsheet. A running time is also acquired by taking the absolute value of a “Figure 10” VI and subtracting the time acquired at zero.

A simple event marker is placed on the front panel, with selectable values from 0-5 indicating phases of testing. The control will write the number to each row. The values indicate the following phases: 0 = Baseline; 1 = Enter Water; 2 = Begin Exercise; 3 = Stop Exercise; 4 = Exit Water; 5 = Recovery.

The GUI was designed to display real-time data in the form of numerical indicators, 2D graphs, and historical table format.

All data collected are displayed on the front panel in table format with the last four samples collected in continuous view. The table contains vertical and horizontal scrollbars to view the entire data set collected. The table "headers" are linked to the VI in Figure 5 via the/a(?) property node(s?) and will update each column if the function within "Figure 5" VI is altered. The spreadsheet column titles are listed in the table below (Table 1).

PHYSICAL CONNECTIONS/WIRING

Due to the numerous wires needing to be interfaced with the NI PXI's terminal blocks, care needed to be taken to ensure that all connections were made accurately. A system was devised to arrange all the skin thermistors in correct order and organize voltage and resistance measurements on different terminal blocks. The skin temperature wires 0-11 (red/yellow) for each heat flow disk are connected to channels 0-11 on the PXI::14::INSTR terminal block (Table 2). The heat flow wires 0-11 (white/black) for each heat flow disk are connected to channels 0-11 on the PXI::13::INSTR terminal block (Table 3). T_{re} , T_{es} , and T_a are also recorded on PXI::14::INSTR terminal block on channels 12-14. T_{dp} and T_{water} are connected to the PXI::13::INSTR terminal block on channels 12 and 13.

Connection to the system involves attaching the "male-end" of the harness to the "female-end" of the Deutsch connectors. There are four connections to be made: (1) upper body heat flow disks, (2) lower body heat flow disks, (3) T_{es} probe, and (4) T_{re} probe. All other measurement devices (i.e., T_a , T_{dp} , and T_{water}) are "hard-wired" into the terminal block.

Cable extensions for skin and core temperatures were connected to the railings of the pool to enable monitoring of subject data during computer tests outside the pool. In addition, another set of cable extensions for T_c and T_{es} probes were run across the ceiling of the chamber and down the far wall, accessible to monitor subjects that require re-warming in the Jacuzzi.

USER INTERFACE DESIGN

The GUI was designed to meet all of the needs of the investigators and display data (both numerically and graphically) in a simple manner. It was also designed to give the investigators enough control and user input fields to record events in real-time, while remaining aesthetically pleasing. Figure 6 shows the layout of the program's interface and displays skin temperatures, and esophageal and rectal temperatures in 2-D graphical form (temperature versus time). The display shows tracings for the entire course of the experiment, as well as data in numerical form, both in real-time and in a historical tabular format. T_{sk} is plotted on one graph, and T_{re} and T_{es} are plotted together on another.

The front panel also contains buttons to initiate data recording, cease data recording, and to mark events. In addition, the front panel has input boxes for entry of

alphanumeric characters that are also written to a spreadsheet. Input fields include file name, subject ID #, weight, height, treadmill speed, and treadmill depth. The event marker control allows the user to select a value from 0-5 (using an up/down scroller) indicating the following: 0 = Baseline; 1 = Enter Water; 2 = Begin Exercise; 3 = Stop Exercise; 4 = Exit Water; 5 = Recovery. These values are passed into the spreadsheet for each collection.

Air temperature, dew-point temperature, and calculated mean weighted skin temperature are displayed numerically in real-time (Figure 6).

As previously mentioned, a log of collected data (in tabular format) is visible, displaying the last four samples acquired. The table is modified so that the top-most row of data is the most current and incoming data will append to the file.

The intention of the project was that the entire program be written out as an executable (.exe) file to avoid manipulation/corruption of the backside code. As of the time this document was written, software version issues have prevented us from doing this.

DATA SECURITY/VALIDATION

Several measures are taken in the design of this system to ensure the integrity of the data. The system is designed to acquire samples at 15-second intervals, with the user-option to monitor (without recording) or record/write data in ASCII format to disk (C:\unique_filename.txt) immediately after acquiring the sample. Thus, if the system/equipment were to fail during a test, data will still be recoverable up to the failure point, given the data file has not been corrupted. In addition, the system will time-stamp each sample (HH:MM:SS) and record a user-selectable event marker to identify phases of testing. Subject ID number will also be able to be entered by the user to assist in identifying test results when analyzing data at a later point.

EQUATIONS

Steinhart and Hart Thermistor Linearization Equation: (1)

$$T = 1 / (0.001462064 + 0.000239335 * \ln(R) + 0.000000096 * (\ln(R))^3) - 273.15$$

Mean Weighted Skin Temperature Equation: (2)

$$MWST = T_{\text{forearm}} (0.07) + T_{\text{triceps}} (0.07) + T_{\text{pectoral}} (0.14) + T_{\text{hand}} (0.07) + T_{\text{subscapular}} (0.14) + T_{\text{thigh}} (0.28) + T_{\text{calf}} (0.17) + T_{\text{foot}} (0.06)$$

FIGURES/TABLES

Figure 1. Scalers for Dew-Point Temperature and Water Temperature

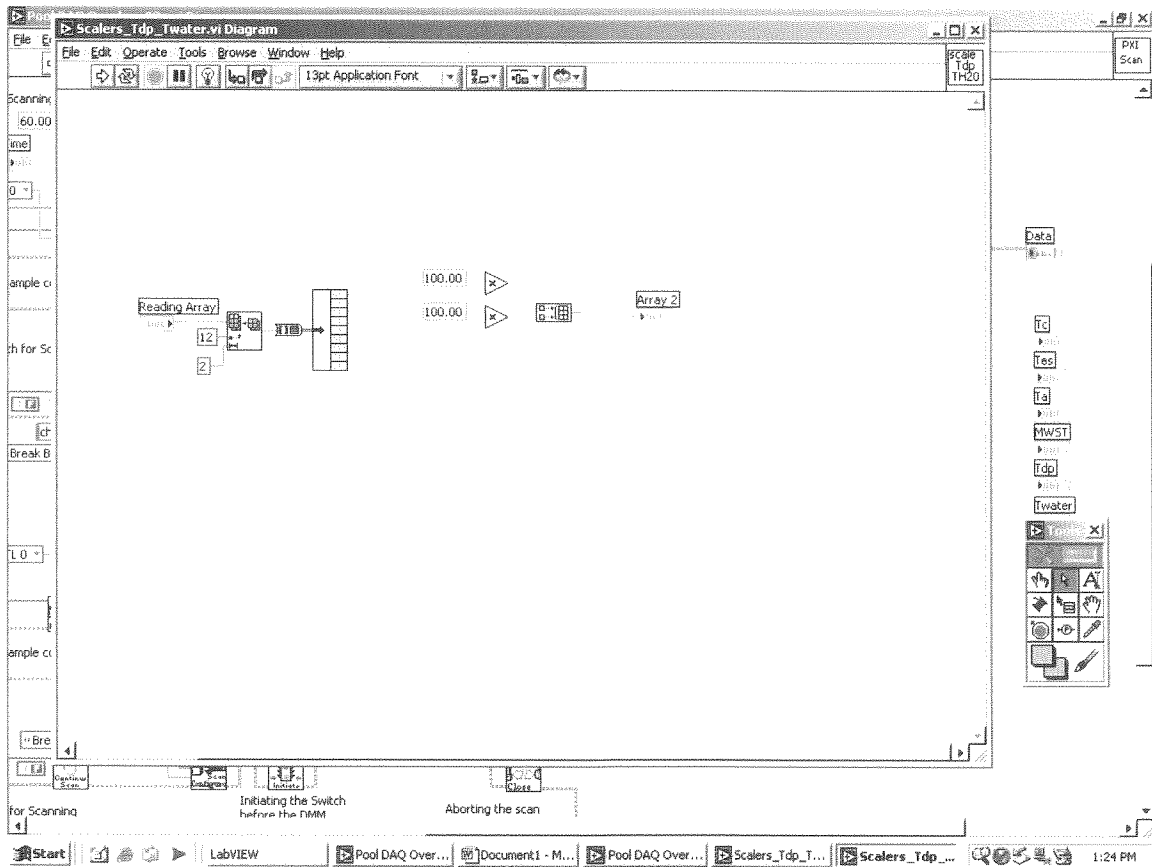


Figure 2. Scale Heat Flow

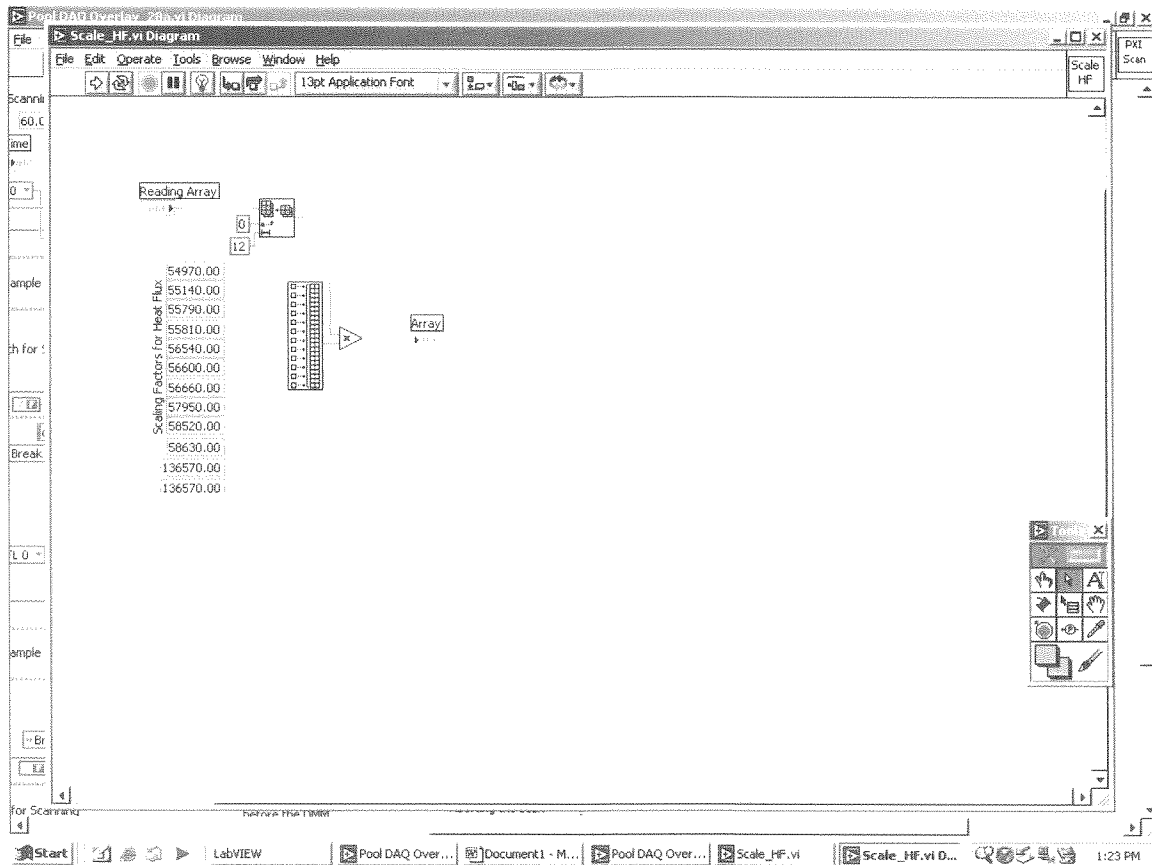


Figure 3. Mean Weighted Skin Temperature (MWST) VI

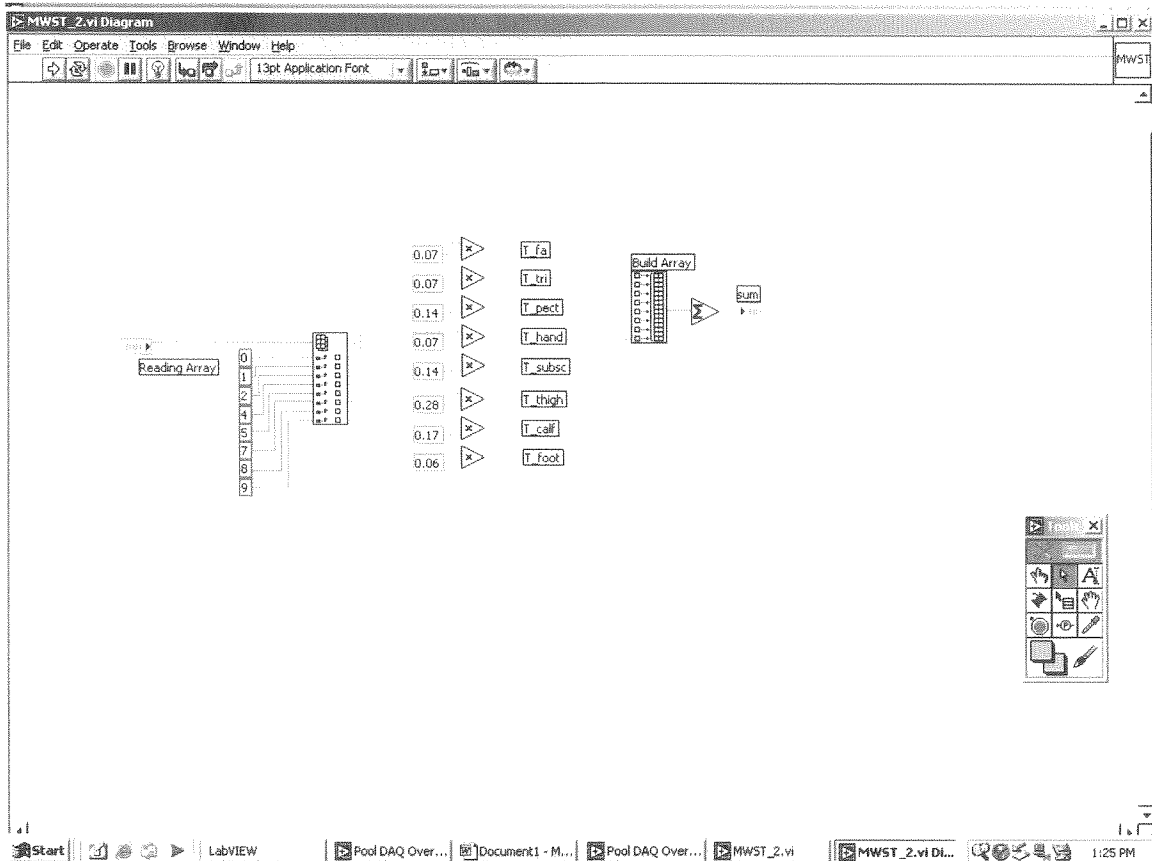


Figure 4. Linearize THM's VI

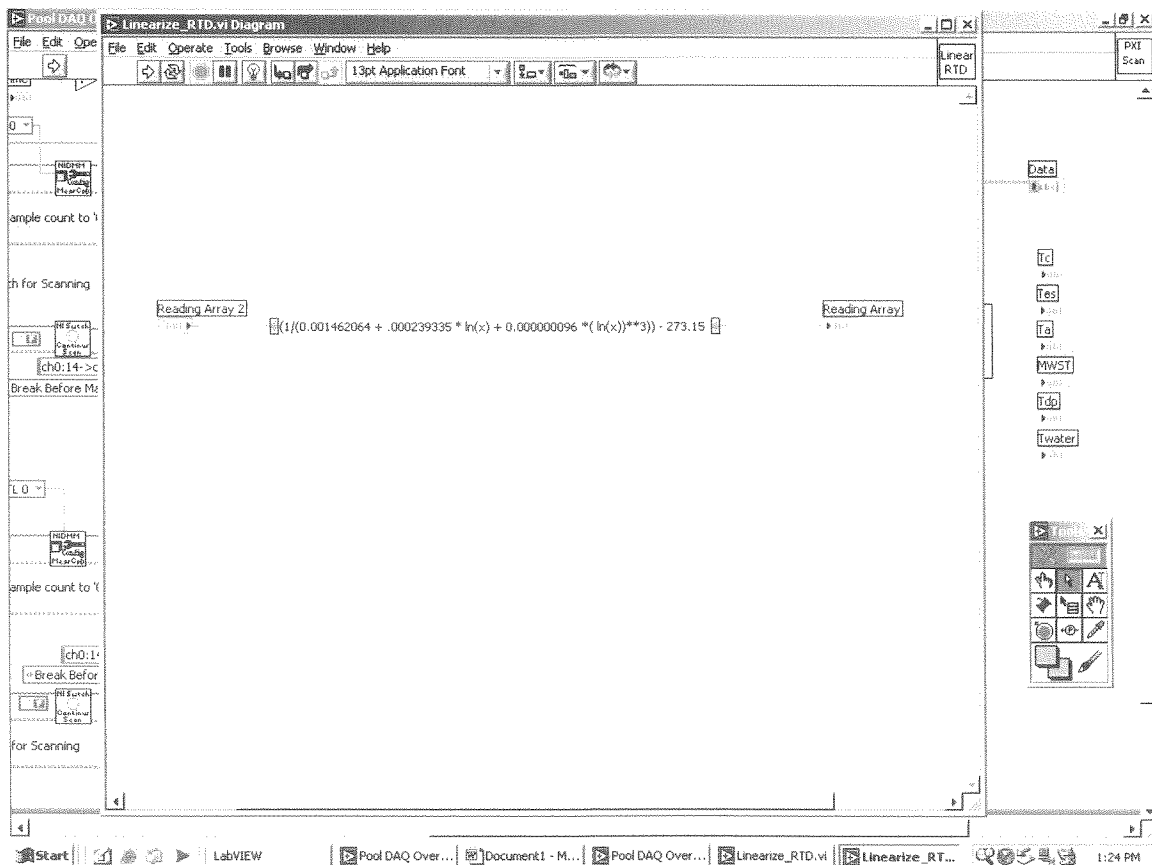


Figure 5. Column Labels VI

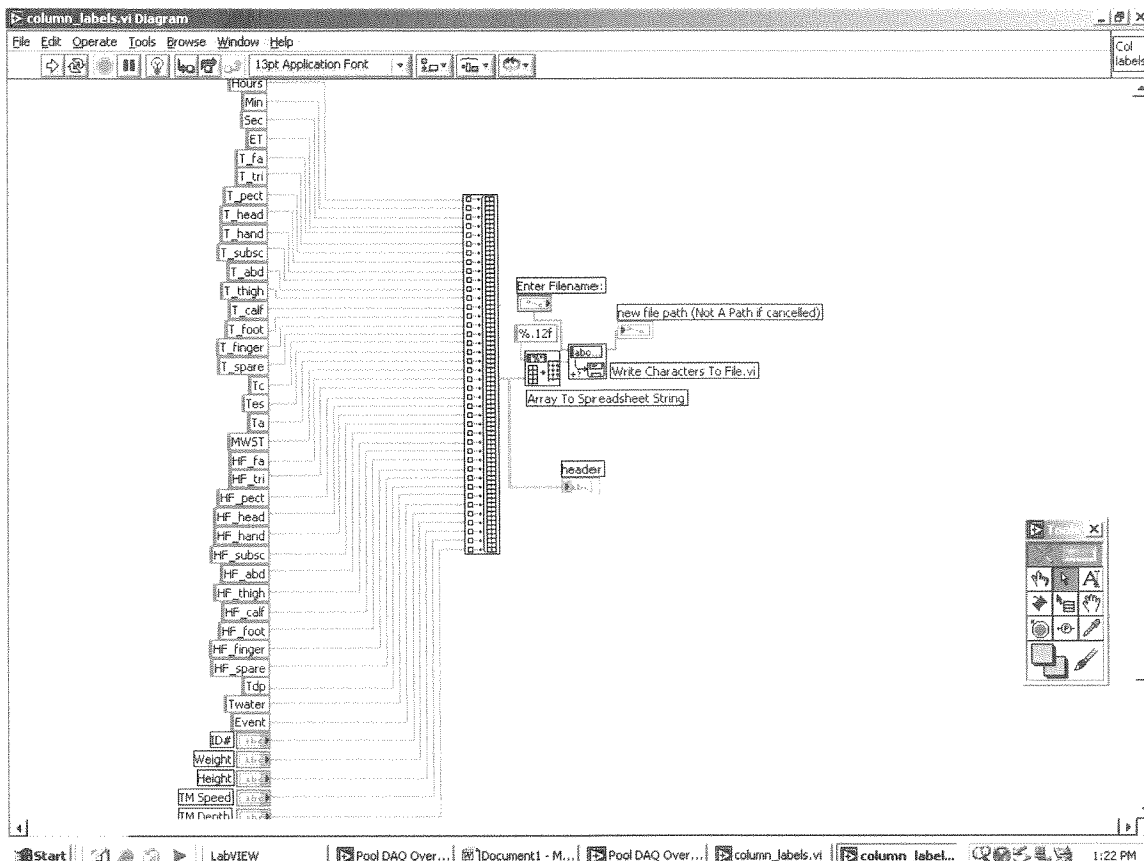


Figure 6. Pool DAQ VI (Front Panel)

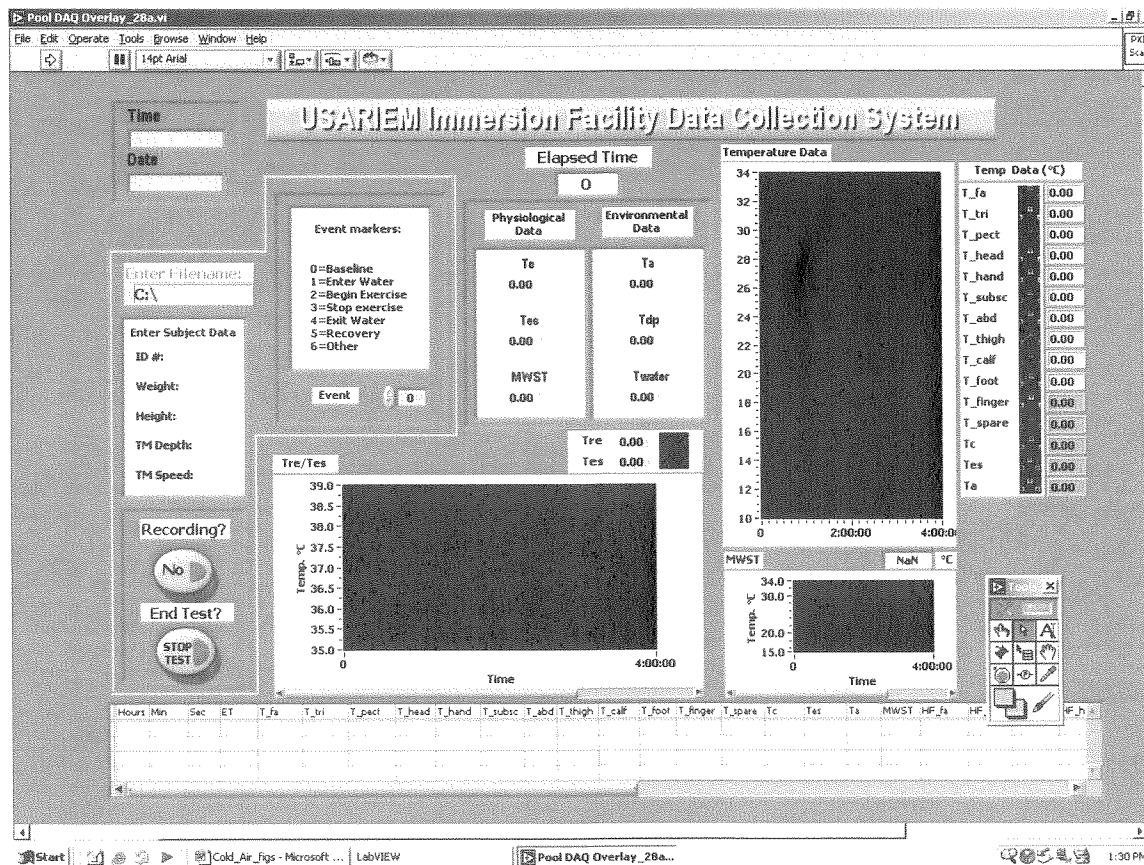


Figure 7. Pool DAQ VI (Lower Left View)

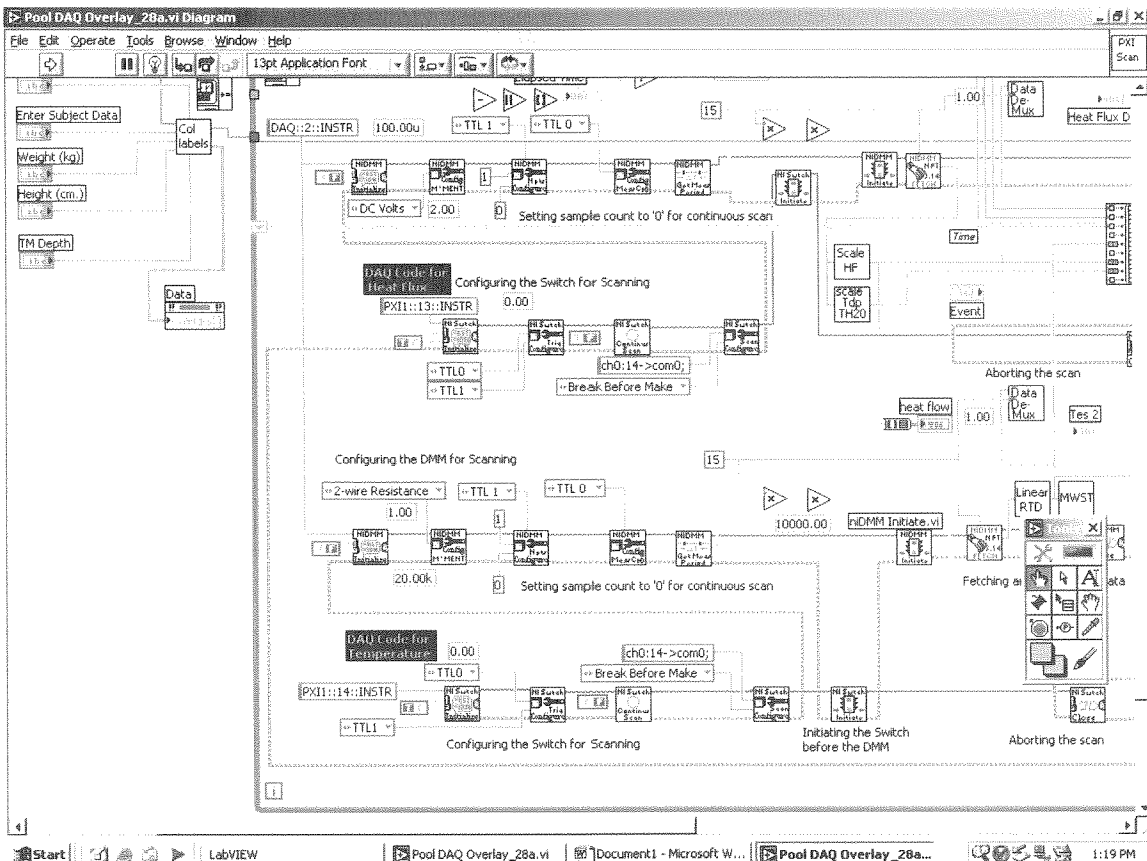


Figure 8. Pool DAQ VI (Lower Right View)

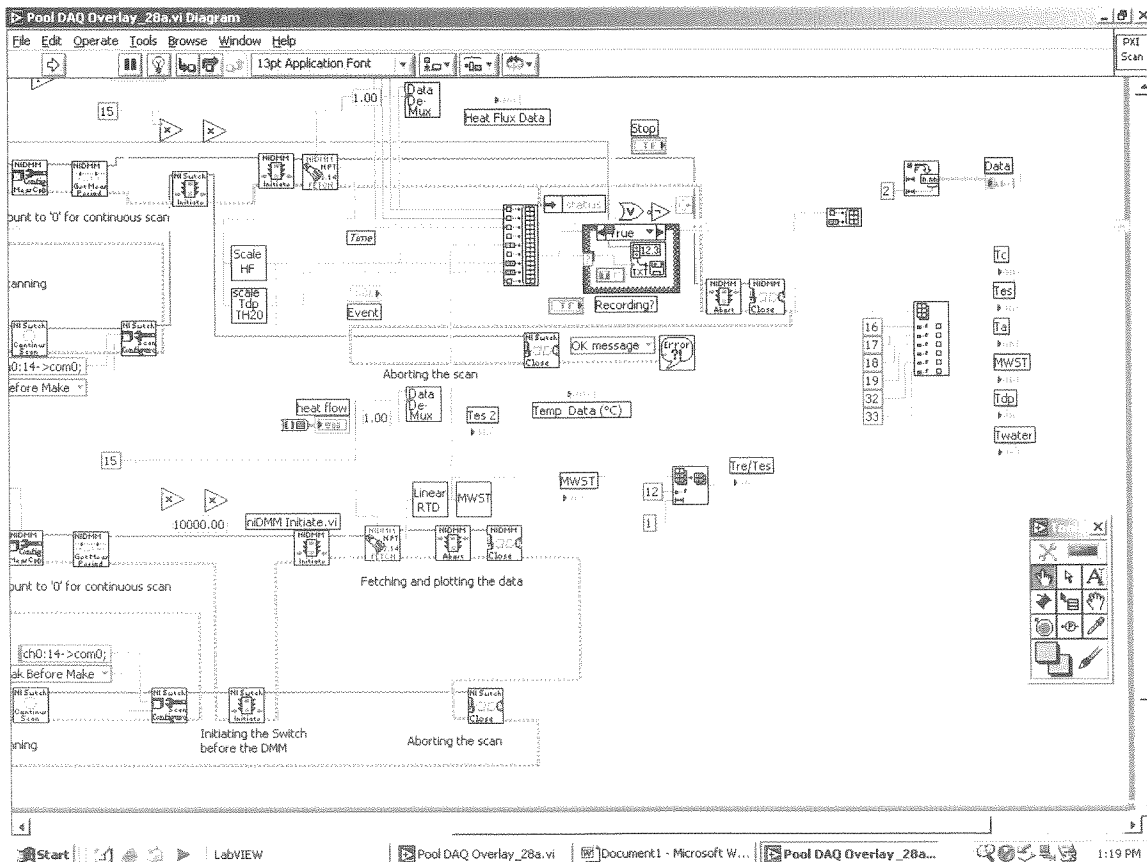


Figure 11. Pool DAQ VI (Upper Left View)

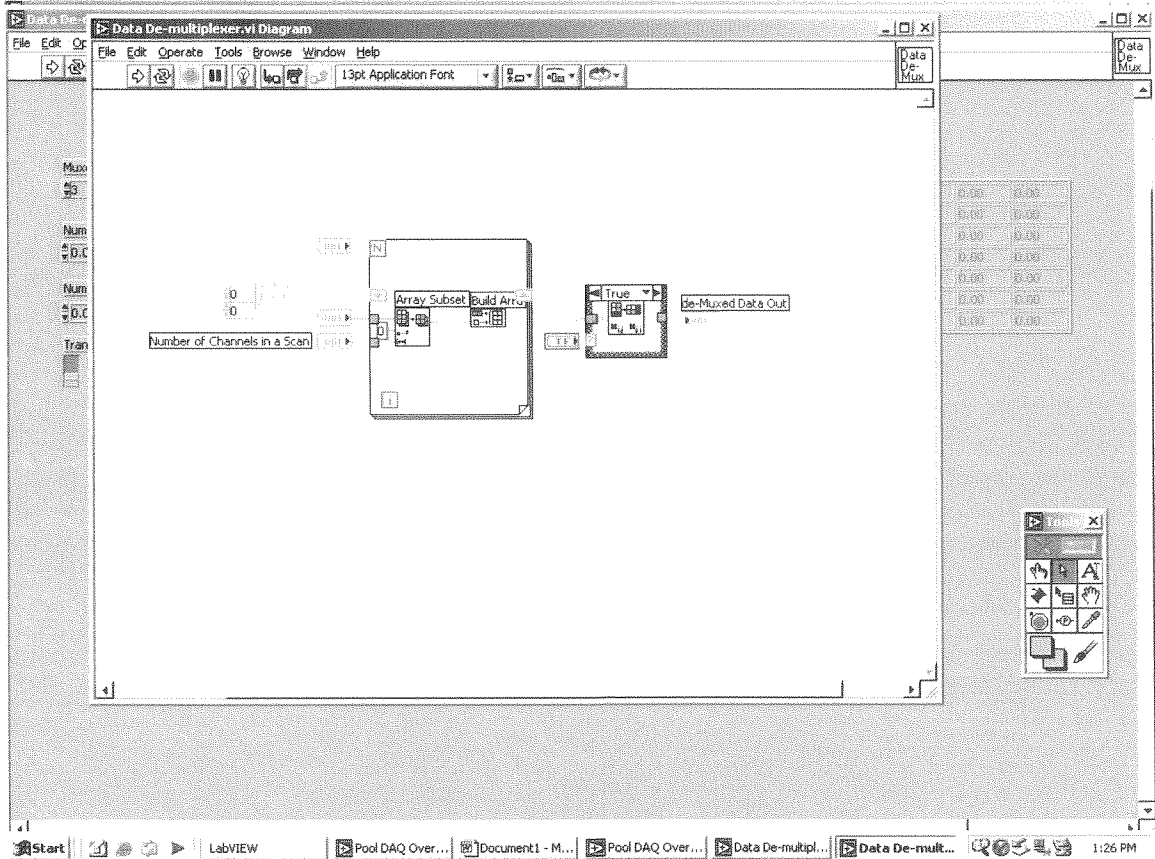


Figure 12. Data De-Multiplexer VI

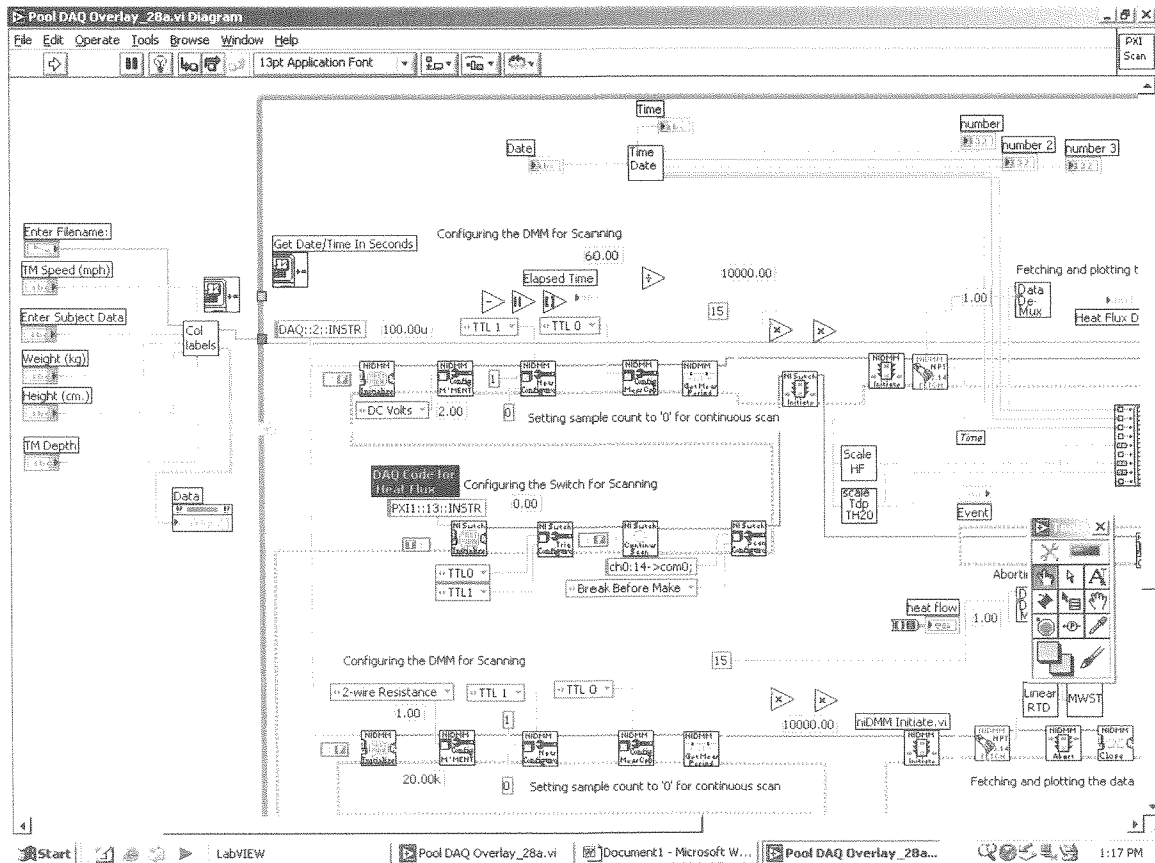


Table 1. Spreadsheet Labeling Scheme.

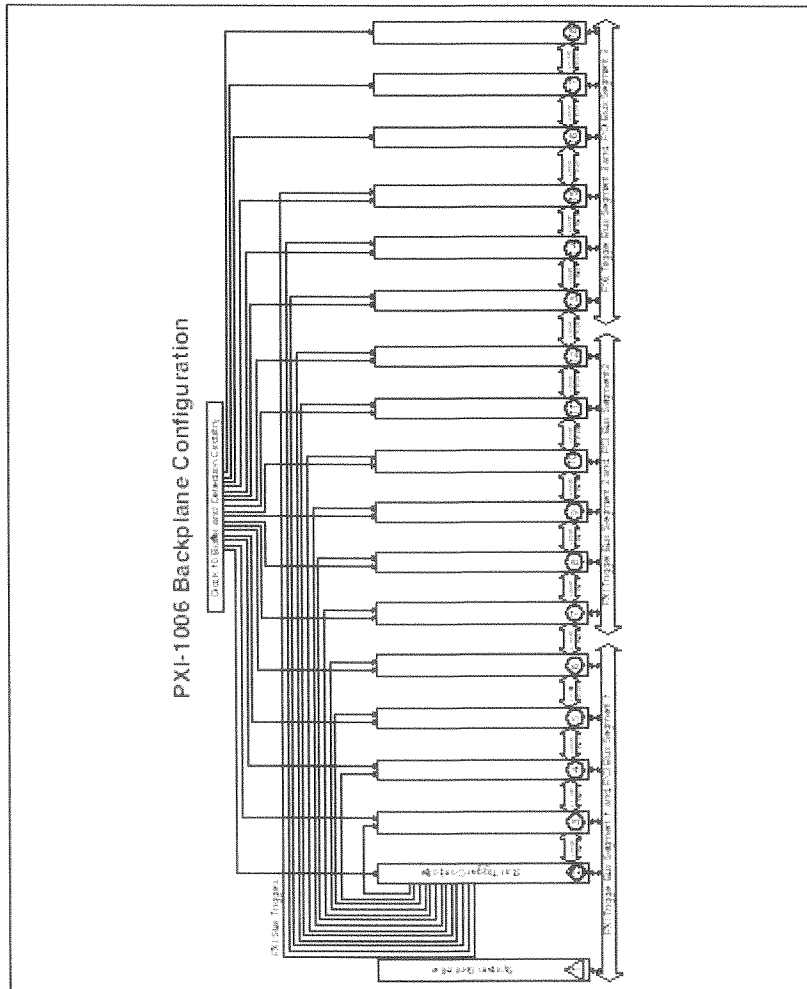
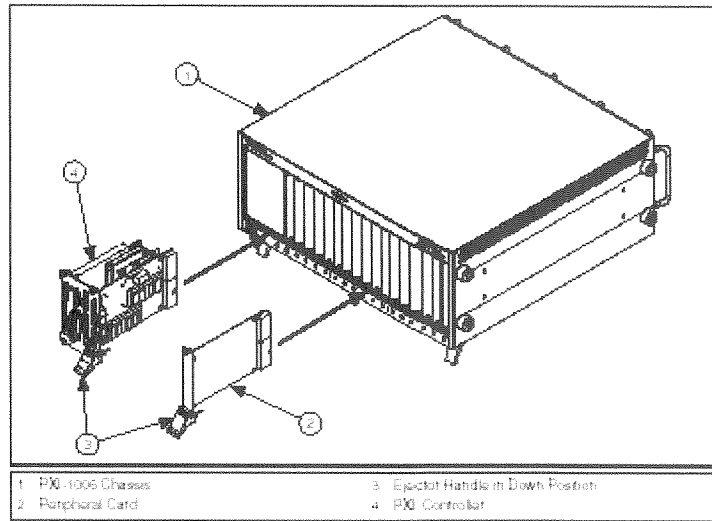
Column	Label
1	<i>Hour</i>
2	<i>Min</i>
3	<i>Sec</i>
4	<i>ET</i>
5	<i>T_fa</i>
6	<i>T_tri</i>
7	<i>T_pect</i>
8	<i>T_head</i>
9	<i>T_hand</i>
10	<i>T_subsc</i>
11	<i>T_abd</i>
12	<i>T_thigh</i>
13	<i>T_calf</i>
14	<i>T_foot</i>
15	<i>T_finger</i>
16	<i>T_spare</i>
17	<i>Tc</i>
18	<i>Tes</i>
19	<i>Ta</i>
20	<i>MWST</i>
21	<i>HF_fa</i>
22	<i>HF_tri</i>
23	<i>HF_pect</i>
24	<i>HF_head</i>
25	<i>HF_hand</i>
26	<i>HF_subsc</i>
27	<i>HF_abd</i>
28	<i>HF_thigh</i>
29	<i>HF_calf</i>
30	<i>HF_foot</i>
31	<i>HF_finger</i>
32	<i>HF_spare</i>
33	<i>Tdp</i>
34	<i>Twater</i>
35	<i>Event</i>
36	<i>ID</i>
37	<i>Weight</i>
38	<i>Height</i>
39	<i>TM_Speed</i>
40	<i>TM_Depth</i>

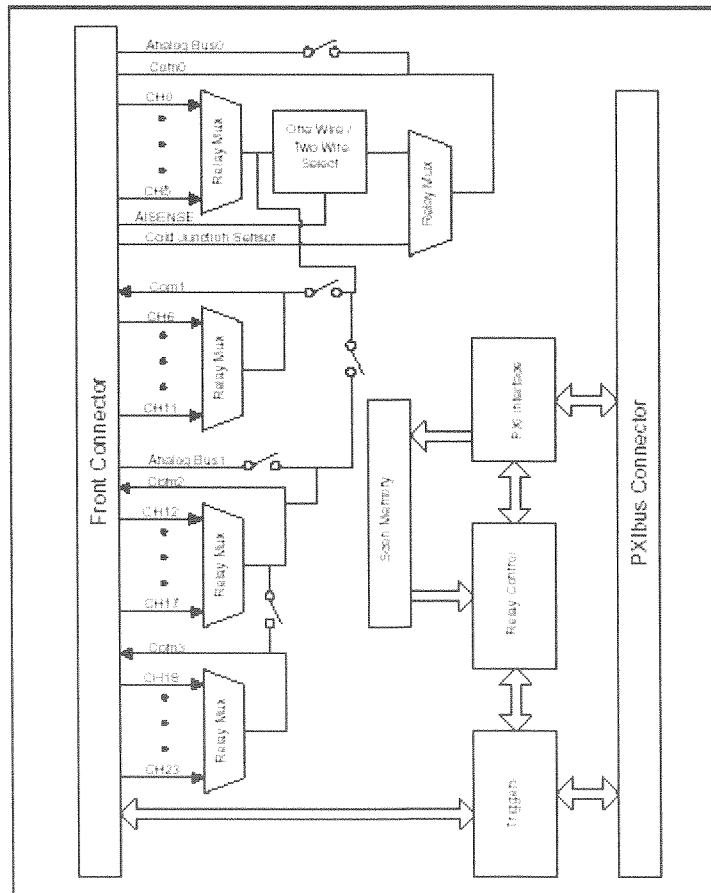
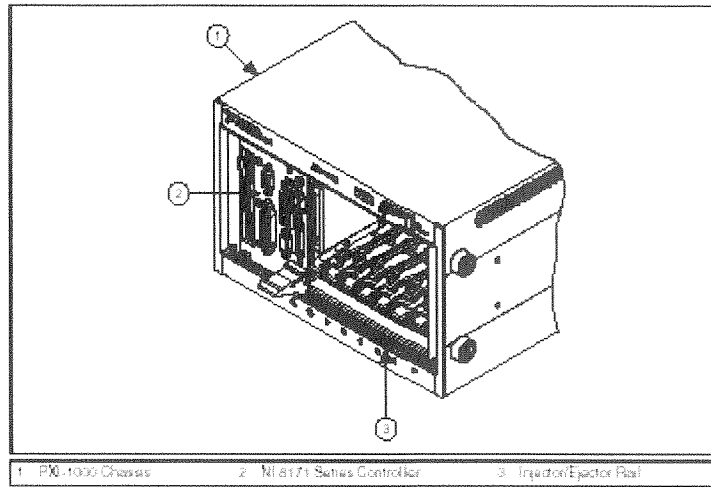
Table 2. PXI-2503 Analog Input Module with PXI-2605 Terminal Block PXI::14::INSTR.				
Channel	Measurement	Terminal	Wire color	Connector and Pin #
0	HF_fa	+	white/brown	M26Deutsch1 A
		-	white/yellow	M26Deutsch1 B
1	HF_tri	+	red/green	M26Deutsch1 E
		-	red/yellow	M26Deutsch1 F
2	HF_pect	+	white/black	M26Deutsch1 J
		-	green	M26Deutsch1 K
3	HF_head	+	white/black/red	M26Deutsch1 N
		-	white/purple	M26Deutsch1 P
4	HF_hand	+	orange	M26Deutsch1 T
		-	black	M26Deutsch1 U
5	HF_subsc	+	white/brown	M26Deutsch2 A
		-	white/yellow	M26Deutsch2 B
6	HF_abd	+	red/green	M26Deutsch2 E
		-	red/yellow	M26Deutsch2 F
7	HF_thigh	+	white/black	M26Deutsch2 J
		-	green	M26Deutsch2 K
8	HF_calf	+	white/black/red	M26Deutsch2 N
		-	white/purple	M26Deutsch2 P
9	HF_foot	+	orange	M26Deutsch2 T
		-	black	M26Deutsch2 U
10	HF_finger	+	white/orange	M26Deutsch1 X
		-	blue	M26Deutsch1 Y
11	HF_spare	+	white/orange	M26Deutsch2 X
		-	blue	M26Deutsch2 Y
12	Tdp	+	red	
		-	black	
13	Twater	+	red	
		-	black	

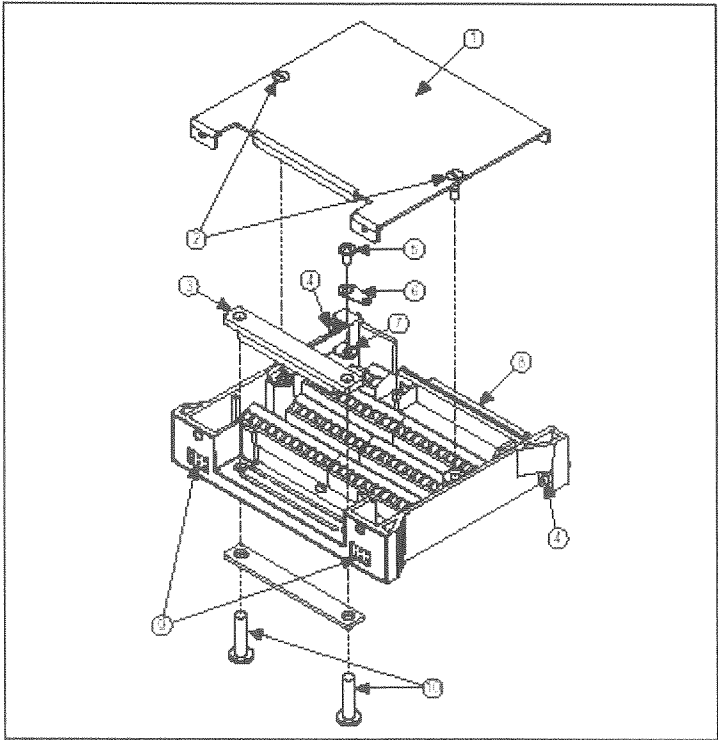
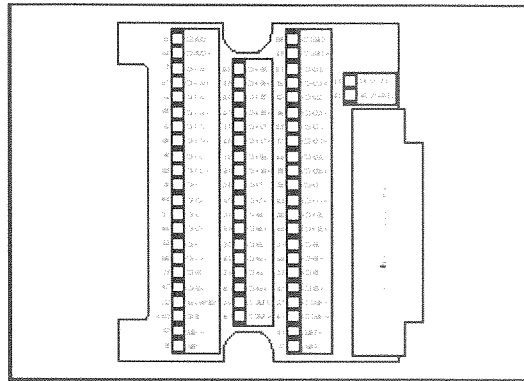
Table 3. PXI-2503 Analog Input Module with PXI-2605 Terminal Block PXI::13::INSTR.				
Channel	Measurement	Terminal	Wire color	Connector and Pin #
0	T_fa	+	purple	M26Deutsch1 C
		-	white/gray	M26Deutsch1 D
1	T_tri	+	white/blue	M26Deutsch1 G
		-	brown	M26Deutsch1 H
2	T_pect	+	white/red	M26Deutsch1 L
		-	white/green	M26Deutsch1 M
3	T_head	+	tan	M26Deutsch1 R
		-	yellow	M26Deutsch1 S
4	T_hand	+	pink	M26Deutsch1 V
		-	gray	M26Deutsch1 W
5	T_subsc	+	purple	M26Deutsch2 C
		-	white/gray	M26Deutsch2 D
6	T_abd	+	white/blue	M26Deutsch2 G
		-	brown	M26Deutsch2 H
7	T_thigh	+	white/red	M26Deutsch2 L
		-	white/green	M26Deutsch2 M
8	T_calf	+	tan	M26Deutsch2 R
		-	yellow	M26Deutsch2 S
9	T_foot	+	pink	M26Deutsch2 V
		-	gray	M26Deutsch2 W
10	T_finger	+	red/black	M26Deutsch1 Z
		-	red	M26Deutsch1 a
11	T_spare	+	red/black	M26Deutsch2 Z
		-	red	M26Deutsch2 a
12	Tc	+	red	M3Deutsch3 a
		-	black	M3Deutsch3 c
13	Tes	+	red	M3Deutsch4 a
		-	black	M3Deutsch4 c
14	Ta	+	red	M3Deutsch5 a
		-	black	M3Deutsch5 c

Table 4. Transducer Wiring.				
Measurement	Sensor	Scaling factor	Wire color	Connector and Pin #
T_fa	1822	Steinhart and Hart equation	red	F26Deutsch1 C
			yellow	F26Deutsch1 D
T_tri	1834	Steinhart and Hart equation	red	F26Deutsch1 G
			yellow	F26Deutsch1 H
T_pect	1832	Steinhart and Hart equation	red	F26Deutsch1 L
			yellow	F26Deutsch1 M
T_head	1823	Steinhart and Hart equation	red	F26Deutsch1 R
			yellow	F26Deutsch1 S
T_hand	1840	Steinhart and Hart equation	red	F26Deutsch1 V
			yellow	F26Deutsch1 W
T_subsc	1826	Steinhart and Hart equation	red	F26Deutsch2 C
			yellow	F26Deutsch2 D
T_abd	1829	Steinhart and Hart equation	red	F26Deutsch2 G
			yellow	F26Deutsch2 H
T_thigh	1838	Steinhart and Hart equation	red	F26Deutsch2 L
			yellow	F26Deutsch2 M
T_calf	1835	Steinhart and Hart equation	red	F26Deutsch2 R
			yellow	F26Deutsch2 S
T_foot	1839	Steinhart and Hart equation	red	F26Deutsch2 V
			yellow	F26Deutsch2 W
T_finger	1018	Steinhart and Hart equation	red	F26Deutsch1 Z
			yellow	F26Deutsch1 a
T_spare	1021	Steinhart and Hart equation	red	F26Deutsch2 Z
			yellow	F26Deutsch2 a
HF_fa	1822	54970	white	F26Deutsch1 A
			black	F26Deutsch1 B
HF_tri	1834	55140	white	F26Deutsch1 E
			black	F26Deutsch1 F
HF_pect	1832	55790	white	F26Deutsch1 J
			black	F26Deutsch1 K
HF_head	1823	55810	white	F26Deutsch1 N
			black	F26Deutsch1 P
HF_hand	1840	56540	white	F26Deutsch1 T
			black	F26Deutsch1 U
HF_subsc	1826	56600	white	F26Deutsch2 A
			black	F26Deutsch2 B
HF_abd	1829	56660	white	F26Deutsch2 E
			black	F26Deutsch2 F
HF_thigh	1838	57950	white	F26Deutsch2 J
			black	F26Deutsch2 K
HF_calf	1835	58520	white	F26Deutsch2 N
			black	F26Deutsch2 P
HF_foot	1839	58630	white	F26Deutsch2 T
			black	F26Deutsch2 U
HF_finger	1018	136570	white	F26Deutsch1 X
			black	F26Deutsch1 Y
HF_spare	1021	136570	white	F26Deutsch2 X
			black	F26Deutsch2 Y
Tc	YSI 44000 series	Steinhart and Hart equation	black	F3Deutsch3 a
			red	F3Deutsch3 c
Tes	YSI 44000 series	Steinhart and Hart equation	gray	F3Deutsch4 a
			gray	F3Deutsch4 c
Ta	YSI 44000 series	Steinhart and Hart equation	black	F3Deutsch5 a
			red	F3Deutsch5 c

DIAGRAMS







- | | | |
|------------------------------|----------------------|-----------------------------|
| 1 Cover | 5 Ground Lug Screw | 8 Connection to Switch Card |
| 2 Cover Screws (captives) | 6 Ground Solder Lug | 9 Analog Bus Connectors |
| 3 Strain Relief Bar | 7 Chassis Ground Lug | 10 Strain Relief Screws |
| 4 Chassis Contraction Screws | | |

COMPONENT SPECIFICATIONS

PXI-1006

(Do you want a one-liner here, as in PXI-4060 below, to be consistent? Or leave this blank and delete from other sections?)

Electrical

AC Input

Input voltage range: 90-264 VAC

Input frequency range: 47-63 Hz

Over-current protection: 10 A circuit breaker

Maximum steady state operating current: 10 A

Line regulation: $\pm 0.1\%$ over operating line range

Efficiency: 70%-80% typical

Power disconnect: The (standby) power switch causes the power module to supply DC power to the CompactPCI/PXI backplane. The rear-panel D-sub connector facilitates remote inhibiting operation. The (standby) switch must be in the On position prior to use of remote inhibit. The power cord provides main power disconnect.

DC Output

Maximum usable power: 600 W

DC current capacity (IMP)

Load regulation

Maximum ripple and noise: 1% ripple, 1% noise

20 MHz bandwidth

Over-current protection: 105%-140% of rated output current; automatic recovery

Over-voltage protection: 3.3 V, 5 V clamp at 122%-134% of output voltage

+12 V and -12 V clamp at 110%-120% of output voltage

Power supply/fan unit MTTR: Replacement in less than 5 minutes

Cooling

Module cooling system: Forced air circulation (positive pressurization) via three 140 cfm fans with HI/AUTO speed selector

Voltage IMP (Steady-State Current)

+3.3 V 60 A

+5 V 60 A

+12 V 9 A

-12 V 1.8 A

Voltage Regulation

+3.3 V 0.4% or 20 mV max

+12 V 0.4% or 20 mV max

+5 V 0.4% or 20 mV max

-12 V 0.4% or 20 mV max

Slot airflow direction: P1 to P2, bottom of module to top of module
Module/power supply cooling intake: Three rear fans
Module cooling exhaust: Along both sides and top of chassis
Power supply cooling system: Forced air circulation via integrated fan
Power supply cooling exhaust: Along upper left side
Power supply/fan unit: Replacement in less than 5 minutes

Electromagnetic Compatibility (Can these lines below be brought together?)

EMC/EMI: CE, C-Tick and FCC Part 15
(Class A) compliant
Electrical emissions: EN 55011 Class A @ 10 m.
FCC Part 15A above 1 GHz
Electrical immunity: Evaluated to EN 61326:1998,
Table 1 (Bring up to above line?)

Note: This device should be operated only with shielded cabling for full EMC and EMI compliance. See the Declaration of Conformity for this product for any additional regulatory compliance information.

Safety

Designed in accordance with IEC 61010-1, EN 61010-1, UL 3111-1, and CAN/CSA C22.2 No. 1010.1 for electrical measuring and test equipment
Installation Category II
Pollution Degree 2

Environmental

Operating temperature: 0°-50°C
Storage temperature: -20°-70°C
Operating relative humidity: Maximum 80% for temperatures up to 31°C, decreasing linearly to 50% at 40°C
Functional shock (operating): MIL-T-28800E CLASS 3, Half-Sine Shock Pulse, 11 ms duration, 30 g peak
Operating location: Indoor use only
Random vibration
Operational1: 5-500 Hz, 0.31 gRMS
Non-operational1: 10-500 Hz, 2.46 gRMS
EMC emissions: FCC Class A compliant and EN 55011 Group 1 Class A Compliant
EMC immunity: Refer to DOC supplied with chassis for compliance to relevant directives
Altitude: 2 km (1.24 mi) max

Backplane

Size: 3U-sized; one system slot (with three system expansion slots) and 17 peripheral slots
Compliant with IEEE 1101.10 mechanical packaging
PXI Specification Revision 2.0 compliant
Accepts both PXI and CompactPCI (PICMG 2.0 R3.0) 3U modules
Backplane bare-board material: UL 94 V-0 recognized

Backplane connectors: Conform to IEC 917 and IEC 1076-4-101, and are UL 94 V-0 rated

Mechanical

Weight: 13.2 kg (29.2 lb.)

Maximum module weight: 1.8 kg (4 lb.)

Materials: Sheet aluminum (5052-H32 and 3003-H14) and cold, rolled steel finish

Unpainted aluminum: Conductive clear conversion coating

Cold rolled steel: Clear chromate zinc plating

Paint: Polyurethane enamel

PXI-4060

This section lists the specifications of the NI PXI/PCI-4060. These specifications are guaranteed between 15° and 35°C, unless otherwise specified.

Electrical

DC Voltage (4th level heading?)

Accuracy (% of reading \pm μ V) (5th level headings? Change all that apply...)

Range	24 Bit/Bit (25 °C \pm 1 °C)	94 Day (25 °C \pm 10 °C)	1 Year (25 °C \pm 10 °C)	Tempo (% of reading) (°C \pm μ V/°C)
250 mV	$\pm 0.02\% \pm 1.25 \mu\text{V}$	$\pm 0.21\% \pm 1.25 \mu\text{V}$	$\pm 0.24\% \pm 1.25 \mu\text{V}$	$\pm 0.01\% \pm 48 \mu\text{V}$
25 V	$\pm 0.02\% \pm 1 \mu\text{V}$	$\pm 0.21\% \pm 1 \mu\text{V}$	$\pm 0.24\% \pm 1 \mu\text{V}$	$\pm 0.01\% \pm 48 \mu\text{V}$
2 V	$\pm 0.02\% \pm 1 \mu\text{V}$	$\pm 0.14\% \pm 1 \mu\text{V}$	$\pm 0.17\% \pm 1 \mu\text{V}$	$\pm 0.009\% \pm 5 \mu\text{V}$
200 mV	$\pm 0.02\% \pm 0.5 \mu\text{V}$	$\pm 0.14\% \pm 0.5 \mu\text{V}$	$\pm 0.17\% \pm 0.5 \mu\text{V}$	$\pm 0.009\% \pm 1 \mu\text{V}$
20 mV	$\pm 0.02\% \pm 0.5 \mu\text{V}$	$\pm 0.14\% \pm 0.5 \mu\text{V}$	$\pm 0.17\% \pm 0.5 \mu\text{V}$	$\pm 0.009\% \pm 1 \mu\text{V}$

Accuracy numbers are for 1°C steps with no zero or no input bias. The effects of full-scale and zero-scale errors, temperature variation, linearity, and noise.

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Noise Rejection (5th level head?)

NMRR (10 Hz filter setting, 50/60 Hz powerline frequency $\pm 1\%$): 80 dB

DC ECMRR (with a 1 k Ω imbalance in HI lead): 140 dB

AC ECMR (RDC to 50/60 Hz) (with a 1 k Ω imbalance in HI lead): 150 dB

Input Characteristics (5th level head?)

Input bias current: 1 nA max

Input resistance: >1 G Ω (2 V, 200 mV, 20 mV ranges); 1 M Ω (250 V, 25 V)

DC Current

Accuracy (% of reading \pm μ A)

Range	24 Hour (25 °C ± 1 °C)	90 Day (25 °C ± 10 °C)	1 Year (25 °C ± 10 °C)	Tempo (% of reading) (°C × μA/°C)
20 mA	±0.15% ± 10 μA	±0.85% ± 10 μA	±0.42% ± 10 μA	±0.035% ± 1 μA
200 mA	±0.15% ± 10 μA	±0.85% ± 10 μA	±0.42% ± 10 μA	±0.035% ± 1 μA
10 A*	±1.1% ± 1 mA	±0.55% ± 1 mA	±0.055% ± 1 mA	±0.01% ± 0.1 mA

Accuracy numbers are for 5 1/2 digits with auto-zero on and include the effects of full scale and zero scale errors, temperature variation, linearity, and noise.
* Requires 10 A shunt, 0.5% mV/A

Input Characteristics (5th level head? Check below indented heads...)

Maximum input: 200 mA/250 V

Input protection: Fuse F1 500 mA/250 V fast fusing

Shunt resistor: 1 Ω

Burden voltage: <400 mV at 200 mA DC

Additional AC Errors

Frequency-dependent errors

Range	24 Hour (25 °C ± 1 °C)	90 Day (25 °C ± 10 °C)	1 Year (25 °C ± 10 °C)	Tempo (% of reading) (°C × mV/°C)
250 V*	±0.6% ± 25 mV	±0.2% ± 80 mV	±0.25% ± 68 mV	±0.01% ± 20 mV
25 V	±0.6% ± 9 mV	±0.1% ± 20 mV	±0.18% ± 20 mV	±0.01% ± 20 mV
2 V	±0.2% ± 8 mV	±0.5% ± 11 mV	±0.80% ± 11 mV	±0.01% ± 2 mV
200 mV	±0.16% ± 22 mV	±0.1% ± 120 mV	±0.18% ± 120 mV	±0.01% ± 0.11 mV
20 mV	±0.28% ± 10 μV	±0.8% ± 170 μV	±0.9% ± 13 μV	±0.05% ± 12 μV

Accuracy numbers are for 5 1/2 digits and include the effects of full scale and zero scale errors, temperature variation, linearity, and noise, applies for and below 219% of input range. Accuracy may be affected by source impedance, cable capacitance, magnetic absorption, or slew rate.
* The NI 400 can only range to 300 V

Noise Rejection

AC CMRR at 50/60 Hz (with a 1 kΩ imbalance in HI lead): >80 dB

Input Characteristics

Input resistance: 1 MΩ

Bandwidth: 20 Hz-25 kHz

Additional AC Errors

Frequency-dependent errors

Accuracy (% of reading ±mA)

Input Characteristics

Maximum input: 200 mA/250 V

Input protection: Fuse F1 500 mA/250 V fast fusing

Shunt resistor: 1 Ω

Burden voltage: <400 mV at 200 mA AC

Resistance

Accuracy (% of reading $\pm \Omega$)

Range	24 Hour (25 °C \pm 1 °C)	90 Day (25 °C \pm 10 °C)	1 Year (25 °C \pm 10 °C)	Tempo (% of reading) \pm 10 °C
Extended resistance (\geq 2 M Ω)	$\pm 0.1\% \pm 0.1 \Omega$	$\pm 0.1\% \pm 0.1 \Omega$	$\pm 0.1\% \pm 0.1 \Omega$	$\pm 0.025\% \pm 0.1 \Omega$
2 M Ω *	$\pm 0.12\% \pm 0.1 \Omega$	$\pm 0.07\% \pm 0.1 \Omega$	$\pm 0.06\% \pm 0.1 \Omega$	$\pm 0.025\% \pm 0.1 \Omega$
20 k Ω	$\pm 0.12\% \pm 0.1 \Omega$	$\pm 0.07\% \pm 0.1 \Omega$	$\pm 0.06\% \pm 0.1 \Omega$	$\pm 0.025\% \pm 0.1 \Omega$
20 k Ω	$\pm 0.06\% \pm 0.05 \Omega$	$\pm 0.04\% \pm 0.3 \Omega$	$\pm 0.027\% \pm 0.3 \Omega$	$\pm 0.02\% \pm 0.02 \Omega$
2 k Ω	$\pm 0.06\% \pm 0.05 \Omega$	$\pm 0.04\% \pm 0.3 \Omega$	$\pm 0.027\% \pm 0.2 \Omega$	$\pm 0.02\% \pm 0.02 \Omega$
20 Ω	$\pm 0.06\% \pm 0.05 \Omega$	$\pm 0.04\% \pm 0.3 \Omega$	$\pm 0.027\% \pm 0.2 \Omega$	$\pm 0.02\% \pm 0.02 \Omega$

Accuracy numbers are for the 4-wire resistance measurement. $\pm 0.1 \Omega$ digits with auto-zero subtract the effects of full-scale and zero-scale errors, temperature variation, humidity, and noise.
 * With auto-zero on or while scanning, and when large resistance with capacitance leads to measured additional delay time is required.

Measurement modes

Resistance: 2-wire or 4-wire resistance

Extended resistance: 2-wire resistance only

Maximum lead resistance: 10 Ω (200 Ω range); 1 k Ω (all other ranges)

Test current: 100 μ A for 200 Ω , 2 k Ω , 20 k Ω ranges; 1 μ A for 2 M Ω , 200 k Ω ranges;

1 μ A and 1 M Ω in parallel for extended resistance measurements

Additional error for 2-wire resistance: 0.6 Ω

Diode Testing

Accuracy (% of reading $\pm \mu$ V)

Range	24 Hour (25 °C \pm 1 °C)	90 Day (25 °C \pm 10 °C)	1 Year (25 °C \pm 10 °C)	Tempo (% of reading) \pm 10 °C
1 V	$\pm 0.05\% \pm 1 \mu$ V	$\pm 0.04\% \pm 1 \mu$ V	$\pm 0.03\% \pm 1 \mu$ V	$\pm 0.02\% \pm 1 \mu$ V

Accuracy numbers are for $\pm 0.1 \Omega$ digits and include the effects of full-scale and zero-scale errors, temperature variation, humidity, and noise.

Test current: 100 μ A

General Specifications

Settling time: Affected by source impedance and input signal changes

Warm-up time: 30 minutes for measurements accurate within specifications

Bus type:

PCI: Slave

PXI: Slave

CompactPCI: Slave

Altitude: Up to 2,000 m; at higher altitudes the installation category must be de-rated

Working voltage: 300 V maximum between either input terminal and earth ground

Power requirement: +5 VDC, 250 mA in operational mode

Safety

Designed in accordance with IEC 61010-1 and UL 3111-1 for electrical and testing equipment. Reinforced insulation. Indoor use only.

Installation Category: II

Pollution Degree: 2

Physical

Dimensions

PCI: 10.8 by 17.5 cm (4.25 by 6.9 in)

PXI: 10 by 16 cm (3.9 by 6.33 in)

Environmental

Operating temperature: 0°-55°C

Storage temperature: -20°-70°C

Relative humidity: 10%-90% non-condensing

PXI-8176

This section lists the electrical, mechanical, and environmental specifications of the NI 8171 series embedded computers.

Electrical

Voltage (V)	Current (A)	
	Typical	Maximum
+3.3	1 A	4 A
+5	3.8 A	6 A
+12	0.01 A	0.05 A
-12	0 A	0 A

Physical

Board dimensions: PXI 3U-size module 8.1 by 13 by 21.6 cm (3.2 by 5.1 by 8.5 in)

Slot requirements: One system slot plus three controller expansion slots

Compatibility: Fully compatible with PXI specification

MTBF: 169,000 h

Weight: 1.18 Kg (2.6 lb) typical

Environmental

Operating temperature: 0°-55°C

Storage temperature: -20°-70°C

Relative humidity: 10% to 90% non-condensing

Note: For full EMC compliance, you must operate this device with shielded cabling.

In addition, all covers and filler panels must be installed. Refer to the Declaration of Conformity (DoC) for any additional regulatory compliance information for this product. To obtain the DoC, click **Declaration of Conformity** at ni.com/hardref.nsf/. This Website lists the DoCs by product family.

PXI-2605

Physical

Cold-junction sensor

Accuracy1: 0.5° from 15°-35°C; 0.9° from 0°-15°C; and 35°-55°C

Repeatability: 0.2° from 15°-35°C

Output: 198.54 mV-19.58 mV from 0°-55°C

Dimensions: 8.4 by 10.7 by 2.0 cm (3.3 by 4.2 by 0.80 in)

Max voltage (signal + common mode): Each input should remain within 30 Vrms or 60 VDC of ground and all other channels to eliminate the possibility of hazardous shock.

PXI-2503

General

Input Characteristics

Number of relays available as channels: 24

Common mode voltage

Channel to channel: 30 Vrms/60 VDC

Channel to earth: 30 Vrms/60 VDC

Maximum allowed voltage—Differential Mode or Single ended

AC: 30 Vrms

DC: 60 VDC

Maximum switching capacity—Differential Mode or Single ended

DC: 1 A @ 30 VDC

Maximum switching power per differential channel or single ended: 60 VA, 30 W

Contact on resistance (initial): 100mΩ

Contact material: Gold-clad silver alloy

Transfer Characteristics

Thermal E.M.F. (Differential): <2 μV

Maximum Frequency Bandwidth 50ΩTermination

Worst case channel: 35 MHz

Channel to channel crosstalk/isolation

Differential: 50ΩTermination

Frequency	Crosstalk
10 KHz	> 100 dB
100 KHz	> 80 dB
1 MHz	> 55 dB
10 MHz	> 30 dB
35 MHz	> 25 dB

Dynamic Characteristics

Maximum operating speed: 200 cycles/s

Relay operate time (@ 20°C): 3 ms typical, 5 ms max

Relay release time (@ 20°C): 1.5 ms typical, 5 ms max

Expected life:

Mechanical (@ 180 cpm): 5 x 10⁷ operations

Electrical at maximum load: 2 x 10⁶ operations

PXI Bus Interface

Slave

PXI Trigger Bus

Trigger Lines: 8

Star Trigger: 1

Power Requirement

+5 V

Typical: 370 mA

Maximum: 700 mA

Physical

Dimensions: 10 by 16 cm (3.9 by 6.3 in.)

Weight: 0.118 kg (0.4 lb.)

I/O Connector: 68-pin male SCSI

Environmental

Operating Temperature: 0°-50°C

Storage Temperature: -55°-150°C

Relative Humidity: 5%-85% non-condensing

Shock and Vibration

Functional Shock

MIL-T-28800E Class 3 (30 g half sine shock pulse)

Also meets IEC 60068-2-27

Random Vibration

MIL-T-28800E, MIL-STD-810E Category 1

Operational: 5-500 Hz, 0.3 grams

Non-operational: 5-500 Hz, 2.4 grams

Certifications and Compliances

CE Mark Compliance

This product meets applicable EU directives as follows:

Safety Isolation: low-voltage safety, EN 61010-1:1993

EMC Directive Immunity: EN 50082-1:1992

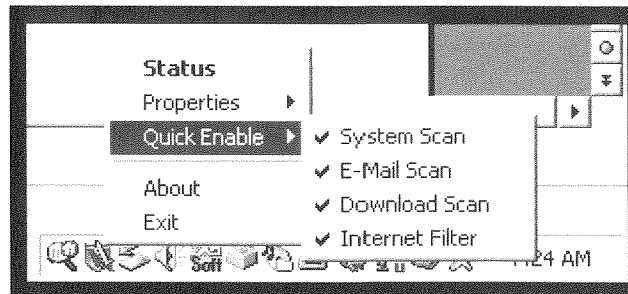
Emissions: EN 55011:1991, Group 1 Class A at 10 m

KNOWN SYSTEM ISSUES

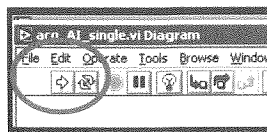
There are no known deficiencies associated with this system. INSERT THIS SENTENCE ELSEWHERE--NOT WORTH A SEPARATE SECTION/PARAGRAPH?

STANDARD OPERATING PROCEDURE FOR POOL DATA ACQUISITION SYSTEM (PXI)

1. Turn on UPS power switch.
2. Turn on PXI chassis power switch.
3. Turn on computer (**Password: *******).
4. Turn on monitor.
5. Disable all McAfee scans. Right click on the McAfee icon on the lower MS toolbar. Move over “quick enable,” and click on all items with a check mark to the left of it. Ensure that no items have a check mark next to it.



6. Disable all screen savers and power managers.
7. Launch Pool_DAQ.vi application from desktop shortcut. Program is located on C:\.
8. Maximize window.
9. Enter unique filename.
10. Enter two-digit subject number (e.g., 01, 02, 13).
11. Press “run” button (located on navigation bar) when ready to monitor data. (Note: data are being monitored but not recorded. The “record” button must be pressed to acquire data.)



12. Press “record” button to record data to spreadsheet.
13. Toggle the “Event Marker” control to record different phases of testing during experiment.
14. Press “stop” button to end both monitoring and recording.
15. Find file C:\your_unique_filename.txt and copy to Zip disk.
16. Close program, shutdown computer, and then turn off power on PXI chassis.

REFERENCES

1. National Instruments Corporation. *National Instruments DAQ PXI E Series User Manual*. Austin, TX: 1999.
2. National Instruments Corporation. *National Instruments LabVIEW 6.1 Developers Suite*. Austin, TX: 2002.
3. National Instruments Corporation. *National Instruments LabVIEW Basics I and II Development Course Manual*. Austin, TX: 2002.
4. National Instruments Corporation. *National Instruments LabVIEW Measurements Manual*. Austin, TX: 1999.
5. National Instruments Corporation. *National Instruments Measurement and Automation Catalog 2003*. Austin, TX: 2000.
6. National Instruments Corporation. *National Instruments PXI-1006 User Manual*. Austin, TX: 2001.
7. National Instruments Corporation. *National Instruments PXI-2503 User Manual*. Austin, TX: 1998.
8. National Instruments Corporation. *National Instruments PXI-2605 User Manual*. Austin, TX: 1999.
9. National Instruments Corporation. *National Instruments PXI-4060 User Manual*. Austin, TX: 2000.
10. National Instruments Corporation. *National Instruments PXI-8176 User Manual*. Austin, TX: 2002.