Table of Contents

Problem Statement

Gases such as carbon monoxide, carbon dioxide, and certain refrigerants can pose a serious threat to employees in the workplace and the general public. Increased levels of these gases can lead to fines from the Environmental Protection Agency (EPA) as well as intervention from the Occupational Safety and Health Administration (OSHA). OI Analytical currently has a Specific Air Monitor (SAM) product line to monitor the concentration of these gases; however, they have lacked the manpower to update this product for several years. As a result, the SAM unit is no longer a major player in this specialized area of chemical detection. Here at Dynamic Design, we would like to take the opportunity to extend the existing unit. Therefore, we have defined our problem statement as follows:

"How can Dynamic Design revitalize OI Analytical's SAM unit product line by adding features and functionality while minimizing cost to the customer?"

I. Functional Requirements

Power Inverter Board
- Convert 24V DC to 115V AC for the pump inside the main unit
- Shield main board and peripheral interface board from interference

Peripheral Interface Board
- Breakout all necessary signals for external use
- Restrict board size to fit within existing main unit

Remote Monitor
- Display sampling channels and PPM levels
- View current SAM unit settings

Windows CE Board
- Monitor CO_2 levels on each channel
- Provide GUI interface

Expansion Module
- Monitor temperature around sample area
    - Temperature range
    - Max. distance sensor can be from expansion module
    - Max size of sensor
- Restrict board size

II. Conceptual Block Diagram

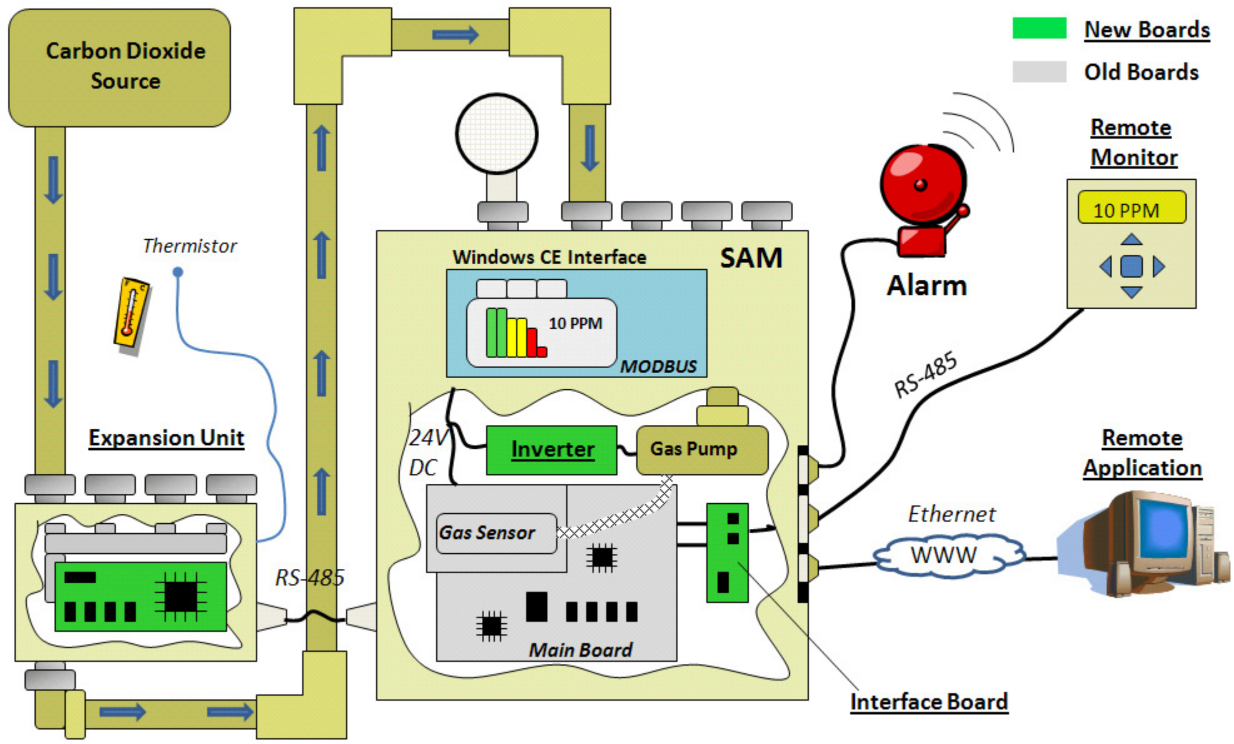


Figure 1 - Conceptual Block Diagram

Our conceptual block diagram shows a high-level view of the project components. In the center, the top of the main unit shows the zero intake for calibrating the SAM. The four adjacent intakes pull in carbon dioxide samples from separate areas. From here, the samples move through the gas pump. A small sample is sent through the gas sensor where calculations are performed to determine the concentration of CO_2 in the sample. The main board then converts this analog concentration to a digital value and displays it on the LCD screen. If the concentration level falls above or below thresholds established by the user, four outputs from the main unit will generate a corresponding output current. This allows up to four remote alarms to be connected to the main unit, or one for each main channel.

From the main unit, the expansion unit allows for one channel on the main unit to extend into eight channels. Smart controls inside this unit handle switching for the solenoids that drive each channel. These units can be daisy chained to create a scalable number of total channels; however, this project will only incorporate controls for up to 16 total channels.

On the other end of the main unit, the remote configuration application will allow the SAM unit to be programmed over an internet connection. This will provide a thin client interface that will model the display on the main unit. The final major component is the creation of the standalone remote monitor. To currently retrieve data for each channel, the main unit must be visited and the values must be recorded by hand. This remote monitor can be placed in a control room or similar area a distance from the main unit, allowing the CO_2 levels to be checked without visiting the main unit.

III. Performance Requirements

Power Inverter Board

- Convert 24V DC to 115V AC
  - Frequency of 60Hz
- Protect electrical system
  - Incorporate fuse
  - Shield board

Peripheral Interface Board

- Provide 24V DC connector to the internal unit
- Provide multiple RS-485 connections including line termination

Remote Monitor

- View SAM unit settings
  - Keypad for user interface
  - Tabs for GUI to step through command tree
- Communicate with SAM unit
  - Modbus 4-wire method

Windows CE Board

- View and alter SAM unit settings
- Control Modbus slaves

Expansion Module

- Provide up to 8 additional gas sample channels
  - Communication via Modbus over RS-485
- Monitor temperature around sample area
  - Communicate with microprocessor
  - Thermistor incorporating signal conditioning
- Restrict board size
  - Must fit within existing enclosure

IV. Technology Survey Assessment

LCD Screen	Pros	Cons
EA DIP204J-4NLW	• Easy to read • Serial Interface	• Most expensive of the three options
NHD-0420H1Z-FL-GBW-3V3	• Cost less than the LCD screen above	• Harder to read • Parallel interface
EA DOGM162E-A	• Least expensive option • Smaller form	• Less Display Space

We have chosen the LCD screen EA DIP204J-4NLW because it is easier to read under various lighting conditions. For the other options, the green LCDs with black lettering are difficult to read in low light.

Micro-controller	Pros	Cons
PIC18F4520	• OI Analytical currently uses this microcontroller • Cost less than the PIC24	• Possibility of product getting discontinued
PIC24HJ128GP210-I/PT	• More versatility • Readily available	• Price per 100 is more expensive than PIC18
MSP430FE425AIPM	• Costs the least of the three options	• Team members have no experience with this

We chose the PIC 18 microcontroller because this is the product that OI Analytical currently uses. This was requested by OI to reduce cost.

5 Volt Regulator	Pros	Cons
PT78ST105S-ND	• OI Analytical currently uses this regulator • Current rating of 1.5A	• Expensive compared to the other voltage regulators
512-LM336Z5	• Programmable from 4-6 volts	• Low amp rating
LM4040D50IDCKR	• Very precise – 1% error	• Low amp rating

We chose to use the PT78ST105S-ND because of the high current rating. We need the extra current for the fan-out problem faced by powering all of the components within the SAM unit.

RS485 Driver	Pros	Cons
LTC491CS#PBF	• Full Duplex • OI Analytical currently uses this chip	• More expensive than the other two ($5.88 each)
SN75HVD3082EDGK	• Small SOIC package available	• Half Duplex
AM26LS32ACD	• Very precise • Least expensive	• Half Duplex

Once again, we will use the chip that OI Analytical currently uses. The full duplex will allow us more versatility when transmitting and receiving messages over the R S-485 line.

3-8 Decoder	Pros	Cons
DM74LS138M	• Designed for high speed communications • 5V input • Currently used by OI	• Not available on Digikey's website
SN74ALS137AD	• 5V input	• Expensive ($2.40 each)
CD74ACT138MG4	• Inexpensive ($0.60 each) • 5V input • Designed for high speed communications	• None at this time

We have decided to go with the CD74ACT138MG4 for our decoder. We chose this one over OIs current decoder because of availability and that it is also cost less than the DM74LS138M. This CD74ACT138MG4 is also designed for high speed communications and should fit our needs well.

Instrumentation Amp	Pros	Cons
LT1789CS8-10#PBF	• Familiar with this IA from a previous project. • Low power draw (95uA) • 2.2 – 36V supply voltage • Cheapest of the three options ($6.38 each)	• 100uV offset voltage • 1 input channel
INA128UG4	• 50uV offset voltage	• 2.25-18V power supply voltage range

		• 1 input channel
INA2141UA	• 2 input channels	• Expensive ($8.95 each)

We have chosen the LT1789CS8-10#PBF Instrumentation amp because of the low cost and our familiarity with the product. We have used this IA for the exact same application in another project.

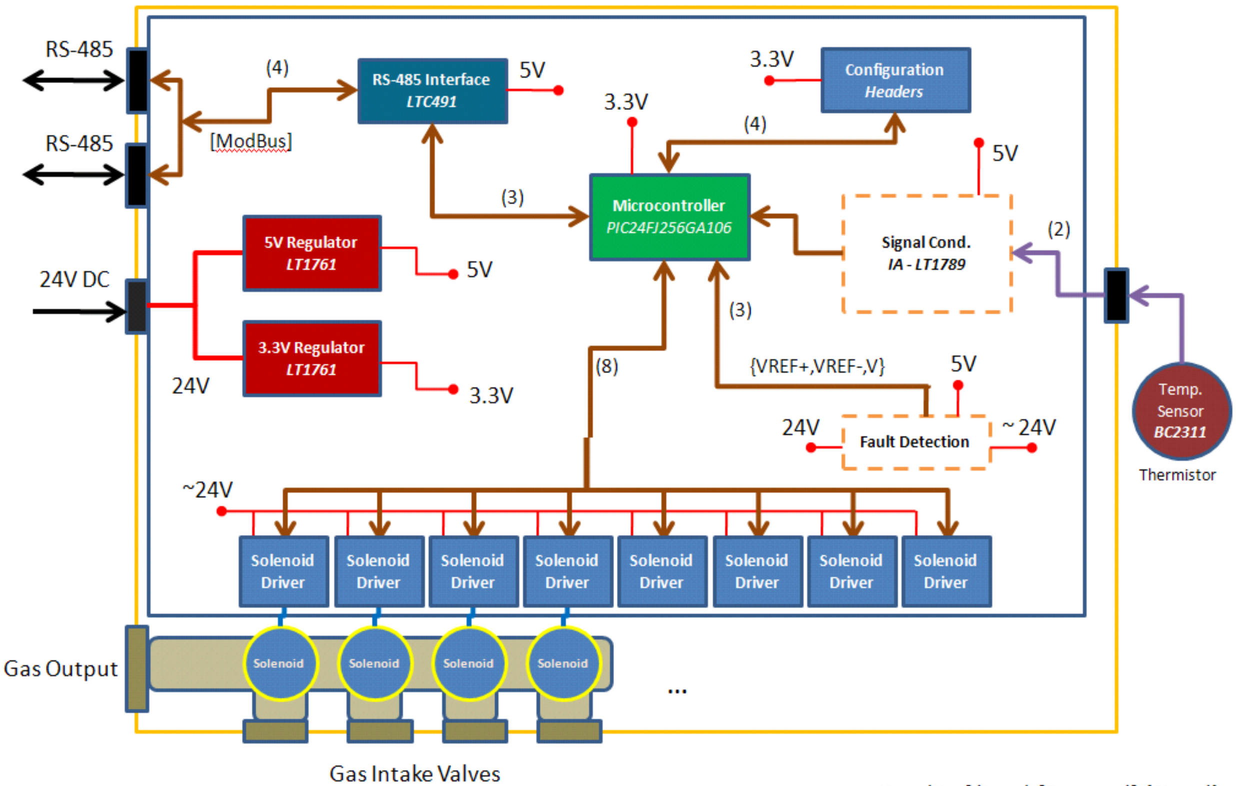
Thermistor	Pros	Cons
BC2311-ND	• Small form factor • Inexpensive ($0.68 each)	• Exposed Bead Design • 10k
DS125	• Wide Temperate range	• No cost available yet. RFQ is needed
3455RC 01000235	• Enclosed Thermistor • Wide temperature operation range	• Very expensive ($56.09 each)

At this point we have decided to use the BC2311-ND at this time because of its low cost and availability. We are still actively researching other options that would perform in an exposed environment.

V. Detailed Functional Block Diagrams

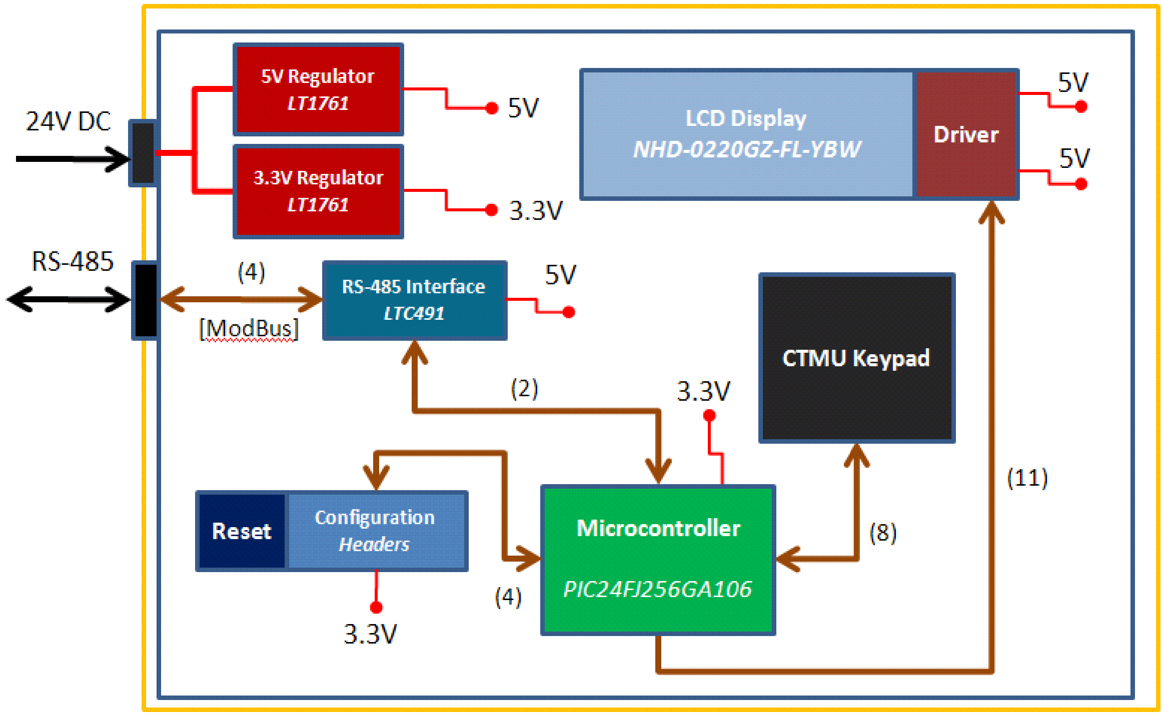
The following diagrams will provide a more detailed overview than the conceptual diagram. These diagrams will map the general process flow and provide component-specific details when applicable.

Expansion Unit



Key: (# of lines),[Protocol],{Signal}

Standalone Remote Monitor



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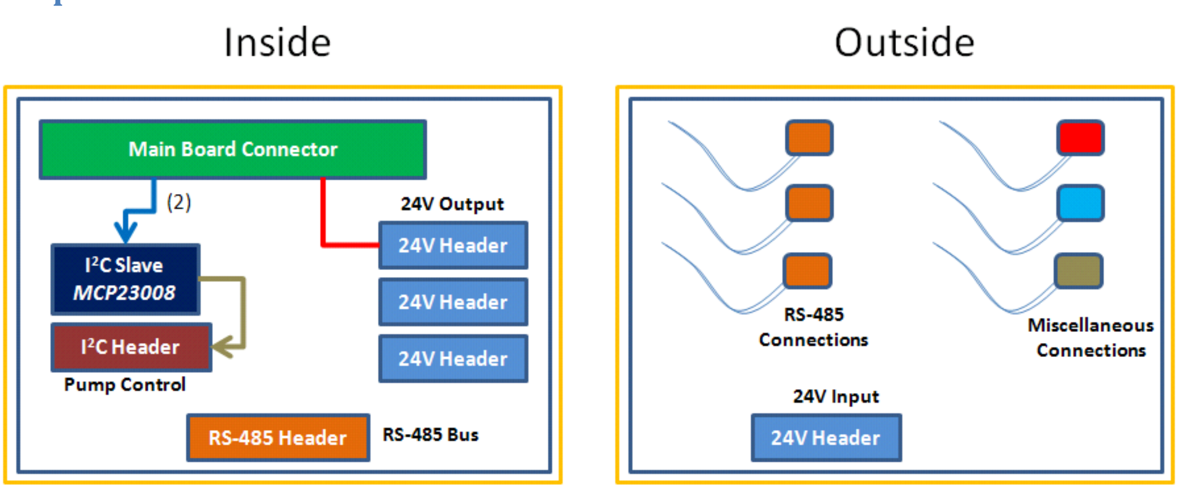
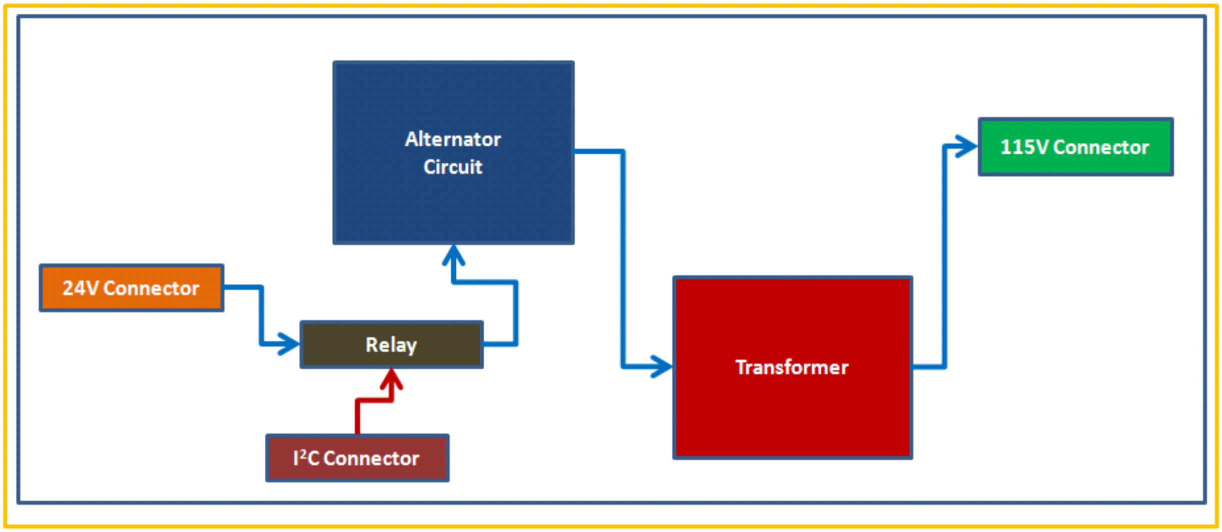
Peripheral Interface Board



Key: (# of lines),[Protocol],{Signal}

Power Inverter Board



VI. Deliverables

Dynamic Design has listed the fifteen deliverables for this project in Table XXX.

Table 1. List of Deliverables.

#	Deliverable	Member Responsible	Due Date
1	Test Plan	Tam Bui	9/2/2009
2	Functional Block Diagrams	Bryan Sonnier	9/4/2009
3	GUI Mockups	Julian Coleman	9/11/2009
4	Preliminary PCB Schematics	Jonathan Tindall	9/21/2009
5	Software Flowcharts	Julian Coleman	9/25/2009
6	Preliminary PCB Layouts	Jonathan Tindall	9/28/2009
7	Critical Design Review	Bryan Sonnier	10/2/2009
8	Final PCB Schematics	Jonathan Tindall	10/5/2009
9	Final PCB Layouts	Jonathan Tindall	10/12/2009
10	Bill of Materials	Bryan Sonnier	10/19/2009
11	Fully Documented Source Code	Julian Coleman	10/30/2009
12	Final Test Results	Tam Bui	11/19/2009
13	User Manual	Bryan Sonnier	11/27/2009
14	Final Prototype Demonstration	Julian Coleman	12/10/2009
15	Final Project Documentation	Bryan Sonnier	12/11/2009

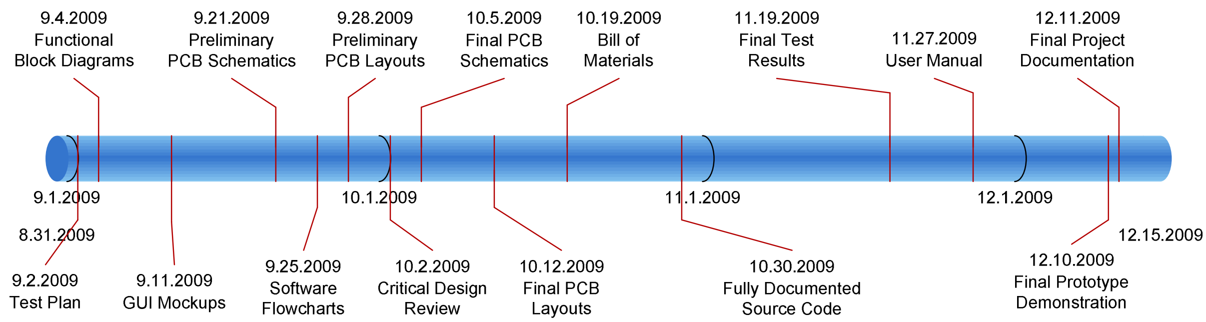


Figure 2. Deliverables Timeline.

The following section defines each deliverable, including a detailed description of the assumptions made during the project planning process. Any of these deliverables and their specifications is subject to change pending a written agreement between Dynamic Design and OI Analytical.

Test Plans

One test plan will be submitted that details the testing procedures for each system component. This will ensure the functionality and reliability of each peripheral and of the system as a whole. The test plans will initially consist of a list of setup requirements. This may include pin connections, voltage levels, or environmental conditions. A second list will be included mentioning all limits at which a test would fail. The conditions may include over voltage, over current, or invalid signals. Once the setup and limit requirements are established, the testing process will be described. Each test will be described in full detail so that a novice engineer could correctly apply the same tests to determine if a unit functions correctly. This deliverable will be submitted in both hardcopy and softcopy format.

Inverter

The inverter will be tested to ensure that the output matches the specifications for the diaphragm pump on the SAM unit. Both loaded and unloaded conditions will be tested. A test of the inverter's circuit protection will be performed to ensure that a current large enough to damage the system's power supply will disable the inverter. Finally, a test will be performed to obtain the average amount of power consumed by the inverter while operating the pump.

Peripheral Interface

Tests on the I^2C communication lines will be performed to ensure that the voltage levels are within tolerance of the I^2C components. Connectivity and resistance tests will ensure that there is an acceptably low amount of resistance from the interface board.

Remote Monitor

The RS-485 communication system will be tested to ensure proper differential voltage, correct timing requirements, and implementation of OI Analytical's modified Modbus protocol. The signals and timing to the LCD display will be tested to ensure compatibility with the device. Tests on the CTMU will ensure the monitor will respond while within the operating temperature and sense touch from a variety of technicians. The total power consumed by the device will also be verified. Triggering all available functions to induce a crash will allow for software testing, which may include entering arbitrary strokes on the keypad. Finally, the remote monitor will be tested to ensure that it is capable of being flashed both locally using the PicKit2 or remotely over the RS-485 communication system.

Expansion Module

Like the remote monitor, the RS-485 communication system will be tested. Also, the test engineer will check the current of each solenoid when activated as well as a failing condition, such as multiple solenoids being open. Measured temperature and voltage data will be tested for accuracy from the microprocessor, ADC input, and pre-amp input at middle, minimum, and maximum values. The total power consumed by the device will also be obtained. Finally, the expansion module will be tested to ensure it can be flashed both locally using the PicKit2 or remotely over the RS-485 communication system.

Windows CE

The RS-485 communication system will also be tested here. Similar to the remote monitor, software testing will be performed by triggering all available functions of the device to induce a crash, which may include random stokes to the interface. The remote configuration application will also be tested in the same manner.

System

As with the individual units, software testing will be performed as an integrated system by triggering all available functions on the remote monitor and Windows CE board. The entire system must function within the designated range of operating temperatures. Finally, all calibration, safety and miscellaneous tests required by OI Analytical are to be performed.

Functional Block Diagrams

Functional block diagrams will be created for the power inverter, peripheral interface, expansion module, and remote monitor. These diagrams will show the integration of the current hardware with the hardware developed by Dynamic Design. Color may be employed to distinguish components from one another or to identify lines for communication and power. The active components required for each system such as displays, keypads, and chips will be displayed and labeled with part numbers.

Power connections will have appropriate voltages labeled at the connection point of components. Likewise, communicate lines between devices will have labels containing the physical standard (RS-485, RS-232) as well as the communication protocol used. The number of physical lines may need to be aesthetically abbreviated. The diagrams will be created using Microsoft PowerPoint 2007. Dynamic Design will submit these functional block diagrams in both hardcopy and softcopy forms.

GUI Mockups

The GUI mockups will provide OI Analytical a visual representation of the user interface that will be implemented on the Window CE interface board. The mockup will be created using Microsoft PowerPoint 2007. Visual Studio 2005 will be utilized in the development of the GUI mockup for the Windows CE interface. The mockup will include an interface that employs tabs to identify each of the primary categories. It will retain the look and feel of the current OI Analytical interface. To facilitate the development of a GUI that is parallel to their current model, logos, buttons, and text, data provided by OI Analytical will be used in the GUI mockup and final system. This deliverable will be submitted as both a hardcopy and softcopy.

Software Flow Charts

Flow charts will be created for the software of the expansion module, remote monitor and Windows CE board. The charts will describe the operation of non-library functions within each program by using Microsoft Visio shapes with inserted explanatory text. Algorithms used within any functions will be mentioned and fully detailed if possible. The flow charts will be created in Microsoft Visio and be will be submitted in .vxd format. Additionally, a hard copy will be submitted on sectionalized 8.5x11 sheets of paper. Sections will be created based on program flow and aesthetic appeal, and continuing sections will use page markers to identify the previous/next page and connection.

Preliminary Schematics

Schematics will be created and submitted for the remote monitor, expansion module, power inverter, and peripheral interface board. They will be created with the schematic capture program in Multisim. Schematics will be printed on 8.5 x 11 sheets of paper and may employ subcircuits to achieve this format in a visually pleasing manner. Subcircuits will have input and output labels as well as a meaningful subcircuit title. The schematic grid will consist of blocks X mils in size. All symbols created while developing the circuit will be submitted via the Multisim user database in the softcopy format of the schematic. Additionally, symbols from OI Analytical's current library may be used to aid schematic development. This deliverable will be submitted in both softcopy and hardcopy format. Hardcopy printouts will be printed in landscape orientation.

Preliminary PCB Layouts

PCB layouts will be created and submitted for the remote monitor, expansion module, power inverter, and peripheral interface board. PCB layouts will be created in National Instrument's Ultiboard software. Layouts will be printed on 8.5 x 11 sheets of paper. The grid of the layouts will consist of blocks X mils in size. Trace widths will be sufficient to carry the expected current of each circuit; a ground plane may also be employed in the PCB design. All footprints created while developing the circuit will be submitted via the Ultiboard user database in the softcopy formats of the layouts. Additionally, footprints from OI Analytical's current library may be used to aid layout development. Dynamic Design will provide gerber (.gbr) files of all layers of each PCB in softcopy format. Also, 1:1 scale printouts of all PCB layers on each board will be submitted in hardcopy format. Hardcopy printouts will be printed in landscape orientation. Additional PCB designs for a CTMU touch pad may also be provided.

Bill of Materials

The bill of materials (BoM) for each developed unit (remote monitor, expansion module, peripheral interface, and inverter) will list all components employed in designing the PCB boards, including the cost of the PCB board itself. Each BoM and will consist of project-relevant component information that may include, but is not limited to, capacitive/resistive value, quantity, designator, part number, cost of single unit, cost of one hundred units, vendor, material, tolerance, temperature rating, pin count, and package. Each BoM will be created in a Microsoft Excel 2007 spreadsheet with column labels varying based on the manufacturer's provided information. The only costs listed for each component will be those from the designated distributor. This deliverable will be submitted in both softcopy and hardcopy format. An example of this format is shown in Figure XXX.

Remote Monitor BoM								
Component	Manuf. Part #	Distributor	Distributor. Part #	Resistance	Material	Surface Mount	Size	
Resistor	120F	Mouser	120F-320	120Ω	Ceramic	Yes	0805	
Resistor	120F	Mouser	240F-320	240Ω	Ceramic	Yes	0805	
Component	Manuf. Part #	Distributor	Distributor. Part #	Capacitance	Package	Surface Mount	Type	
Capacitor	XY450	Digi Key	XY450-RT	450nF	A	Yes	Tantalum	
Capacitor	XY1000	Mouser	XY1000-RT	1uF	A	Yes	Ceramic	
Capacitor	XY100	Mouser	XY100-RT	100nF	B	Yes	Ceramic	
Component	Manuf. Part #	Distributor	Distributor. Part #	Input Voltage				
LCD	LCD420	Mouser	LCD34-GH	5V				
Keypad	KEY540	Mouser	234-KEY	3.3V				
PIC24	PIC24FJ45	Mouser	PIC24-FJ45	5V				

Figure 3. Example Bill of Materials.

Critical Design Review

Dynamic Design will give a critical design review (CDR) during week nine of the development stage of SAMURAI. The CDR will update OI Analytical of the project status. It will be held at a location to be determined by week seven of the development stage; factors such as demonstration requirements and audience size must be considered. The presentation will last thirty minutes and will be recorded for further review and archiving.

A PowerPoint presentation will be given listing the current project progress. The presentation will also state the time and budget status using scheduled performance and cost performance indices. Remaining work and technical challenges will also be listed and described. In addition to a presentation, Dynamic Design will also demonstrate any functioning hardware created by that point.

Representatives from OI Analytical can attend the meeting, as well individuals from the academic community. A hardcopy of the presentation will be available upon request with at least twenty-four hour notice given to Dynamic Design. This printout and the recorded video will be submitted to OI Analytical in softcopy format.

Test Results

Once all of the tests have been performed on the system, the results will be recorded in a professionally formatted document listing all measurements and incongruities found for each test. This document will justify the results of each test. A comparison between the test results and the expected results will determine if the new components meet the project requirements. Test results will include photos, charts, tables, and graphs where applicable. This deliverable will be submitted in softcopy (.docx) and hardcopy formats.

Final Schematics

The final schematics will retain the same requirements as the initial schematics. This will contain the final revisions of the modules used during the final presentation.

Final PCB Layouts

The final PCB layouts will retain the same requirements as the initial PCB layouts. This will contain the final revisions of the modules used during the final presentation.

Fully Documented Source Code

Source code will be delivered for the remote monitor, expansion module, and Windows CE board. Non-library classes, functions, and variables will be documented and titled. Also, preexisting code for the sensor board and main board will not be included in this deliverable.

Creation of a class will start with a block comment that gives the name of the class, a short description of its use, and the functions it contains. Vital class variables may include a single line comment. Similarly, the created functions will begin with a block comment detailing the function name, a short description, a list of arguments, argument types, optional arguments, and the return value. As with classes, important variables will be commented. Single line comments will also be interjected for important steps within a function.

C and C++ source files will include a header file for each source file. Both header and source files will include a leading block comment with authoring information. Header information will include the name of the company that owns the software (OI Analytical), the date the file was created, the last modification date, a list of contributing authors, and a summary of the operation of the code.

For each unit the software components will be categorized into the following folders: project build, source files, header files, supporting documentation, and additional includes. The project build folder will contain the MPLab and Visual Studio files. The additional includes folder will contain the libraries of precompiled code used in the project. Due to the length and nature of source code, the developed source code for the three modules will be submitted in softcopy format and, upon request, in hardcopy format. The submission will also include a list of software and hardware required for the code to function and will be included in the softcopy submission if possible.

Additionally, the front- and back-end of the remote monitor will be done within the same project using MPLAB. The expansion module's firmware will also be written using MPLAB. The front- and back-end of the remote monitor will be programmed within the same project using Microsoft Visual Studio 2005. The code will be designed to run on Windows CE 6.0 and will be written in C++.

User Manual

Dynamic Design will update OI Analytical's SAM user manual to include the upgraded features and functionality. Additional hardware explained in the upgraded user manual will include the expansion module and the remote monitor. As with the current manual, only information about setup, proper use, and warnings will be covered. The user guide will not include schematic or source code level descriptions of any unit. The manual should allow a novice technician that has never used the hardware to setup and operate the equipment correctly. Dynamic Design will ensure that the upgraded sections will match the look of the current manual. This user manual will be submitted in both softcopy and hardcopy format.

Final Prototype Demonstration

The final prototype demonstration will be given by Dynamic Design at the end the development stage of the SAMURAI project. The full functionality of each module and the integrated system will be presented. Representatives from OI Analytical can attend this demonstration, as well as individuals from the academic community. The location will set within two weeks of the demonstration date and will consider factors such as demonstration requirements and audience size. The presentation and demonstration will be expected to last between one and two hours; it will be recorded for further review and archiving.

Dynamic Design will present a PowerPoint presentation fully describing the work performed and the functional units created. At the culmination of the presentation, the functionality of each unit and the full system will be demonstrated. A hardcopy of the PowerPoint presentation will be available upon request, and the recorded video will be submitted to OI Analytical with the PowerPoint file in softcopy format.

Final Project Documentation

The final project documentation will include a composite of information relating to the project. The project summary, full descriptions of each unit, explanations of all tests performed and their results, all deliverables submitted, project timelines, abbreviated source code, relevant sections of component datasheets, unit schematics and unit PCB layouts will be included. This final project documentation should allow a novice engineer to obtain a full grasp of SAMURAI's scope. This documentation will also serve as a reference for future modifications to the SAM unit and its peripherals. This deliverable will be submitted in both softcopy and hardcopy format.

Sponsor Requirements

OI Analytical has no additional requirements for the completion of this project outside of the previously defined scope. Any additional requirements must be agreed upon by Dynamic Design and OI Analytical in writing.

VII. Milestones

The following list describes events that show significant project progress:

- Approval of the completed test plan.
- Approval of the initial hardware designs.
- Approval of the final hardware designs.
- Acceptance of Windows CE application.
- Acceptance of the remote configuration application.
- Acceptance of the remote monitor unit.
- Acceptance of the expansion module application.
- Acceptance of the final test results.
- Acceptance of the fully functional working prototype.
- Acceptance of the final project documentation, including user manuals, test plan, and test results.

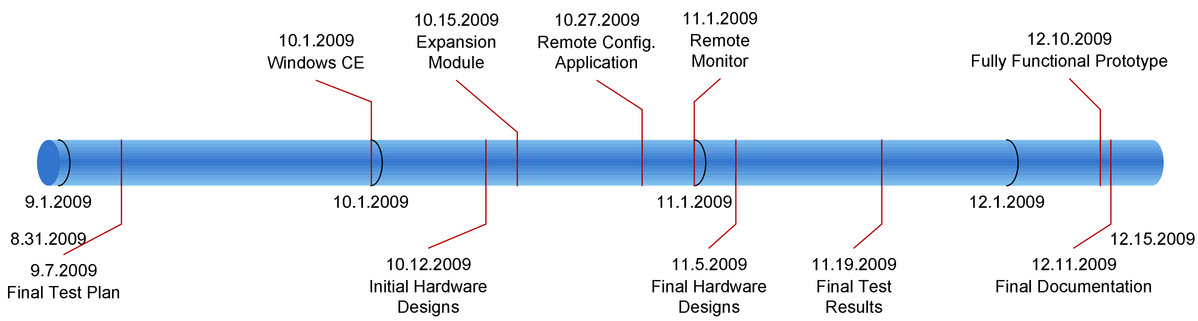


Figure 4 - Milestones Timeline

VIII. Gantt Chart

Our preliminary Gantt chart shows the approximate duration for each phase of our project. We have planned a start date of August 31, 2009, and project our final demonstration date as November 13, 2009, with all required documentation submitted by December 4, 2009.

ID	Task Name	Start	Finish	Duration
1	Research	8/31/2009	9/7/2009	8d
2	Design	9/8/2009	11/5/2009	59d
3	Fabrication	9/22/2009	11/14/2009	54d
4	Test	9/8/2009	11/19/2009	73d
5	Documentation	9/8/2009	12/9/2009	93d
6	Wrap-Up	11/8/2009	12/11/2009	34d