Computer Science

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Remote Monitoring and Control of a Building

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Remote Monitoring and Control of a Building

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This report is submitted in partial fulfillment of the requirements for the Bachelor's degree in Computer Science. All material in this report which is not our own work has been identified and no material is included for which a degree has previously been conferred.

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Abstract

This paper is a thesis investigating the possibilities to create a system for controlling and monitoring a remote object, for instance a building. It involves data acquisition, monitoring, alarm and controlling. Also, it introduces the LabVIEW product line as well as the G programming language to the reader. Great weight has been put into an investigation in SMS communication. The workplace has been Enator Teknik Karlstad, a subdivision of TietoEnator, during the spring semester of 2000.

The work has resulted in a working application for monitoring temperature and noise. The measured values are displayed on a screen. Functionality for logging data to disk has been added, as well as the possibility to view monitoring in real-time through a web browser interface. Some functionality for alarming as well as for control according to the results of the SMS Investigation has also been implemented.

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1 Introduction

This report describes “Project Z”. A research and programming assignment at TietoEnator, serving as a Bachelor’s Project in Computer Science at University of Karlstad, spring semester of 2000. This report guides the reader through the goals, data acquisition, the LabVIEW environment, design, interactions, messaging service and SMS investigation, events, detailed design, conclusions and results analysis. All acronyms are listed in Appendix A.

1.1 Background

Enator Teknik wants to show its work with a demonstrating example of measurement, control, regulation and communication. An interesting object to build this example would be around a building.

1.2 Problem

Administration of a building often means work within the building, even though it concerns matters that could be remotely controlled. The existing systems are stationary, demand special communication software or are meant for alarm purposes only.

2 Goals

2.1 Purpose

To design and implement a system for survey and control of a remote building

- With a PC, where the only requirements are a web browser and an Internet connection.
- With a GSM phone and SMS messaging.

2.2 Expected results

- A fully functional application running on the computer where all data inputs are gathered, and the capability of measuring and controlling all the units listed in the system specification. All data will be graphically representated on the computer screen in some appropriate way.
- The capability of viewing the screen of the PC running the application in a web browser using an Internet connection.
- An investigation of the necessary steps in adding SMS functionality to the application in 1. This includes functions such as sending SMS messages when a certain event occurs, and also the capability to send back a SMS message to the computer with some command telling it how it should respond to this event.

2.3 Time Plan

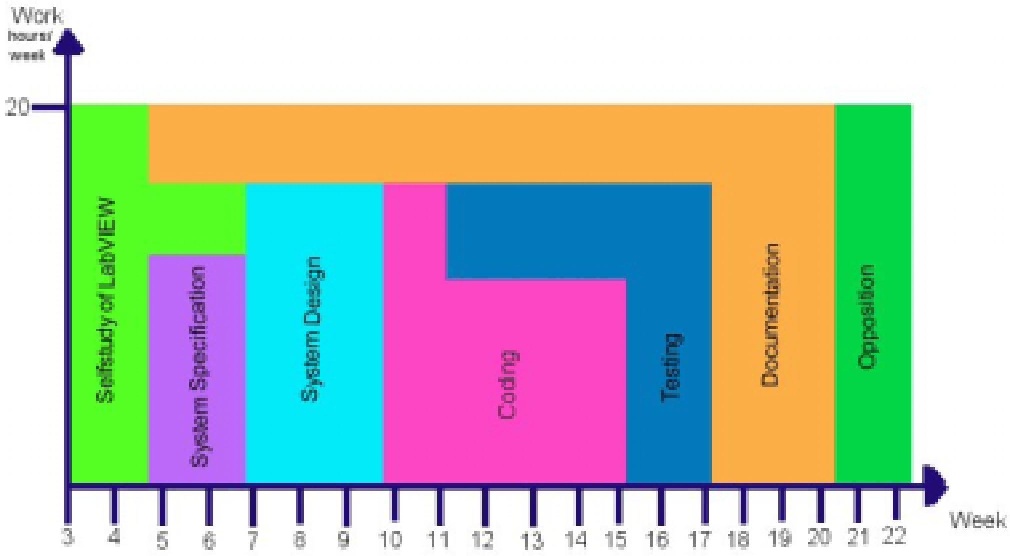


Fig. 2.1 Time Plan

3 Data Acquisition and Monitoring

This assignment is much about measuring and monitoring data. To acquire data, special hardware is needed. The data acquisition will be handled in the LabVIEW environment, described in chapter 4.

3.1 About DAQ

DAQ, short for Data Acquisition, is the process of measuring and storing external data to a computer, and used in an application. The LabVIEW environment has good support for this and is described more in detail in chapter 4. A DAQ Functions Subpalette, i.e. a set of tools, is included in LabVIEW. It provides the programmer with many instruments for analogue and digital I/O as well as for calibration and configuration of external devices. NI-DAQ is the device driver layer between the operating system and the DAQ boards, described below. Fig 3.1 [1] shows the relationship between LabVIEW, NI-DAQ and the DAQ hardware.

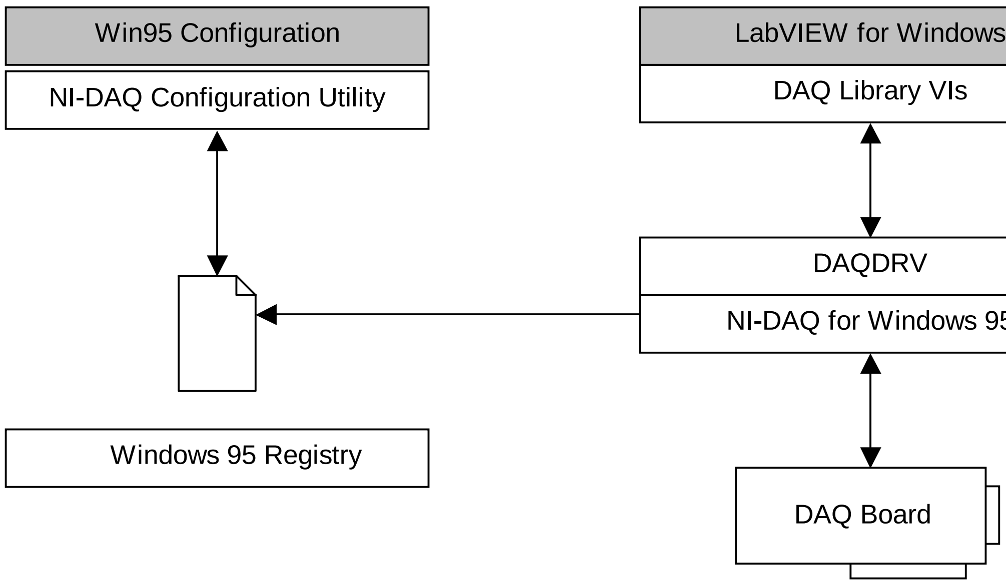
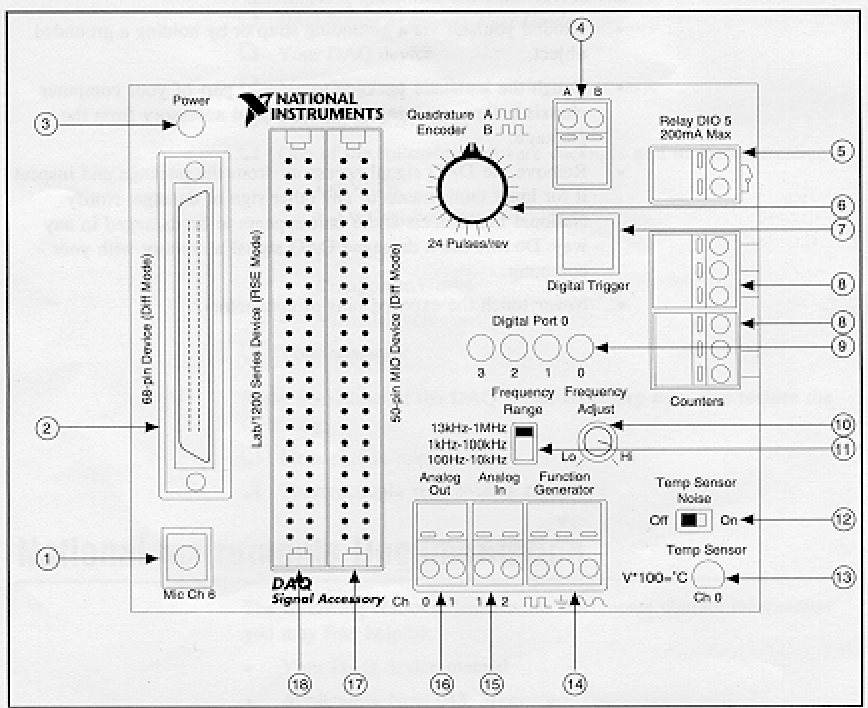


Fig. 3.1 Data Acquisition Model

A DAQ Board is a PCI card for connecting external measuring and/or controlling devices to a computer. The device we are using is called the DAQ Signal Accessory, which is used for demonstrating PC-based data acquisition and control. See Fig 3.2 [6].

Fig. 3.2 DAQ Signal Accessory



1	3.5 mm Mono Microphone Jack	10	Function Generator Frequency Adjust Knob
2	68-Pin Device Connector	11	Function Generator Frequency Range Selector
3	Power LED Indicator	12	Noise Generator Switch
4	Quadrature Encoder Output	13	IC Temperature Sensor
5	Quick Connect Terminal for Relay DIO 5	14	Quick Connect Terminals for Function Generator
6	Quadrature Encoder Knob	15	Quick Connect Terminal for AI Channels 1 and 2
7	Digital Trigger Push-Button Switch	16	Quick Connect Terminal for AO Channels 0 and 1
8	Quick Connect Terminals for Counters	17	50-Pin MIO Device Connector
9	Digital Port LEDs	18	Lab/1200 Series Device Connector

3.2 Monitoring

The goals specified in chapter 2 must be limited and clearly specified. Below are brief descriptions of the assignment.

- **What is to be measured?**
  - Temperature and Noise

- **When is data sampled?**
  - User specified logging and screen update interval.

- **Where does monitoring take place?**
  - Measurement in the same room as the computer, since the cable to the DAQ Signal Accessory measures only about one meter.
  - Logging unto user specified file path.

- **Why monitor?**
  - Measurement to demonstrate simple monitoring.
  - Logging to be able to view old data.

- **How to monitor?**
  - With a LabVIEW user interface and instruments.
  - With a DAQ Board and DAQ Signal Device connected to a PC.
  - With a Web Server for remote survey.
  - With a Message Service for alarm purposes, and possibly remote controlling.

3.3 Future Applications

Since the outcome of this project is for demonstration purposes only, no extra features are added to the system. In the future, however, several applications can be thought of, for example:

- Analogue measure of temperature inside and outside the house.
- Analogue measure of humidity, again inside and outside the house.
- Digital measure of alarm status (on/off?), and control of this.
- Digital measure of coffee-machine status (on/off?), and control of this as well.
- Control of lighting remotely.
- A variety of other applications.

4 LabVIEW Introduction

LabVIEW does not differ much from any other modern program development environment like C/C++ or BASIC, except for one important aspect. Other programming languages use text-based source code. In LabVIEW, the programmer uses a completely graphical language, G. Programs are created as block diagrams and are called Virtual Instruments (VIs). As any other programming language, LabVIEW comes with extensive libraries of functions to be used for (almost) any kind of program. LabVIEW has libraries for data acquisition, analysis, presentation and storage etc. Also included are tools for setting breakpoints, viewing the data flow while running the program and run-time stepping to make debugging and program development easier.

Though LabVIEW is a general-purpose programming system, *it is designed specifically for data acquisition and instrument control*.

The reason why LabVIEW programs are called virtual instruments is because their appearence and functionality can imitate that of an actual instrument. This is why TietoEnator has chosen LabVIEW for this assignment.

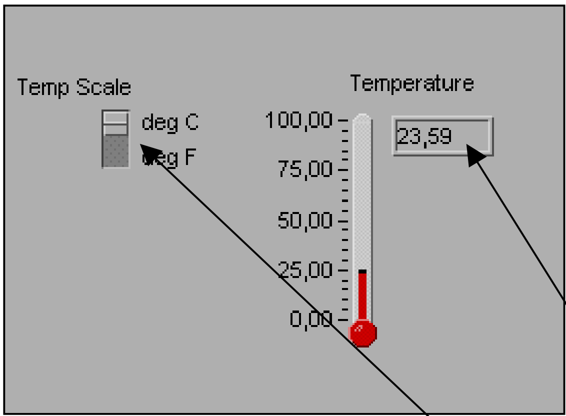
A VI consists of three different parts:

- An interactive user interface called the front panel. This simulates the panel of a real physical instrument. It can consist of knobs, buttons, graphs, and a lot more controls and indicators. Data can be entered by keyboard or by mouse and the results are shown via some indicator, like a text-field.
- A dataflow diagram, which is similar to the source code in a text-based programming language. This block diagram is constructed in G and provides a graphical solution to the programming problem.
- Icon connections are used to specify what inputs and outputs the VI should have, so the instrument can be used from other VIs.

A VI is hierarchical and modular. This means that you can use them either as top-level programs or as subprograms within other VIs. A VI used as a subprogram is called a sub-VI.

With these features, LabVIEW can really be called a modular language. When programming in LabVIEW you usually divide your problem into smaller and smaller parts until there remains only a series of small and simple subtasks. Then you build a VI for each subtask and combine these in another block diagram to accomplish the larger task. In the end you have a top-level VI which is the final application.

Here comes a simple example of a LabVIEW VI, *Thermometer.vi*.



1 2 *Fig. 4.1 Front Panel* 3 4

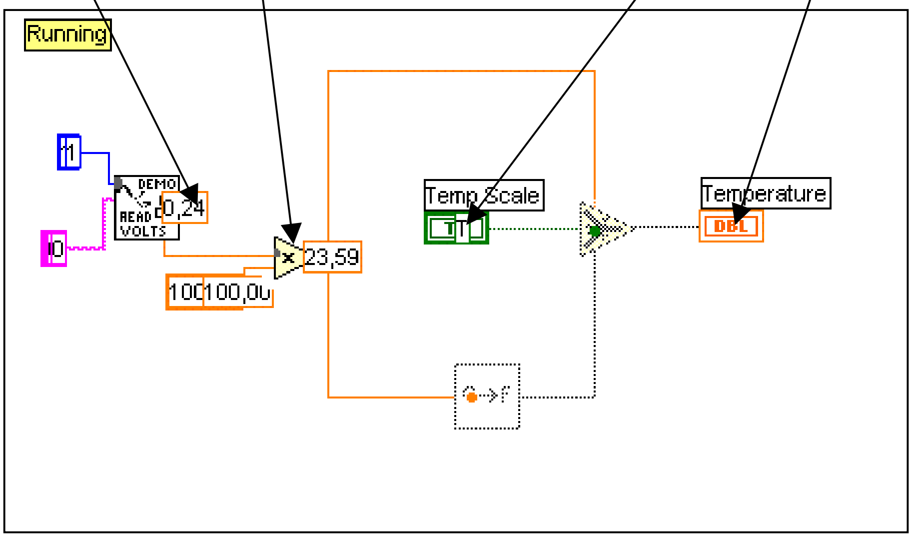


Fig. 4.2 Dataflow Diagram

Solid proof for the age-old theorem ‘0,24*100,00 = 23,59’.

1. ReadVolts Demo SubVI generates (in some manner) a value, with indata 1 and 0, 0,24.
2. The value is multiplied with 100,00 => 23,59.
3. Temp Scale is set to “deg C” so the result of C->F (Celsius to Fahrenheit) is not used.
4. Temperature is displayed, 23,59.

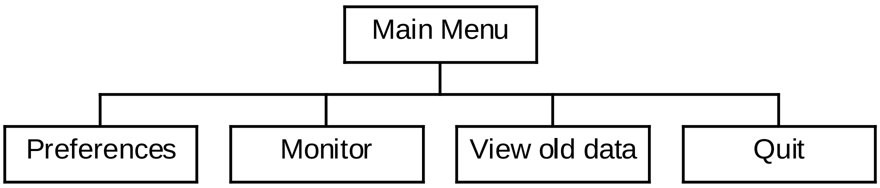
5 System Design

This system will consist of three parts, namely the LabVIEW Core, the Message Handler (with or without SMS) and the Web Server. Since SMS functionality is more or less an investigation only, we cannot specify exactly how it will work, nor can we guarrantee that it will. Any solutions in this field will be added to the model as the project proceeds.

5.1 The LabVIEW Core

LabVIEW is used for measuring from a DAQ Signal Accessory, connected to a PC with a DAQ Board. Data is acquired and processed within the VIs and SubVIs. The data is then presented in one or more panels. Also see chapter 4. A window hierarchy will be used, see Fig 5.1.

Fig. 5.1 System Survey



Main Menu	Menu with the alternatives below.
Preferences	System settings.
Monitor	Monitoring.
View old data	Logging analyser.
Quit	Exit application.

Table 5.1 Parts of System Survey

5.2 Message Handler

Preferably, two-way message communication with a cellular phone is used. A solution for both sending alarms and receiving commands to and from the LabVIEW Core. This is an investigation, and depending on the result different functions will be added. This will be documented later in section 7.1. Another alternative could be sending simple e-mails (*SendMail.vi*), which of course is easier to accomplish, since the Internet Toolkit for LabVIEW has this functionality. When controlling though, SMS would seem slightly more convenient. The controller may not want to take his computer everywhere. The cellular phone is always at hand.

When relevant events occur in the LabVIEW Core, see section 8.2, the Message Handler will be handling these. Depending on the settings, and, of course, the results of our SMS investigation, messages may be sent to an alarmee (*SendMail.vi* & *SendSMS.vi*). The alarmee, if able to, can also send messages to the Message Handler (*GetMail.vi*). This is not only for controlling purposes, as it can be used for requesting current data as well. The LabVIEW Core will regularly check with the Message Handler for incoming commands from the controller and handle these according to a pre-specified manner.

5.3 Web Server

The Internet Developers Toolkit for G will be used. It includes the G Web Server, which can present VIs as web pages, with or without interaction. Technically, this works as a CGI, to which we *could* send information such as pressing a button or turning a knob. There are two solutions for this, either a frame-oriented page or an image map, any will do. Note though that the VI runs much smoother on a Netscape Navigator browser, where much less flickering occurs (than in Internet Explorer, that is). Controlling is not the issue here though, because the viewer is only supposed to watch the monitoring.

5.4 System Architecture

Here is an explanation of the integration of the parts mentioned above. LabVIEW Core might be a misleading term, since all parts are made in LabVIEW. The term was however named before we knew this could be realized. What is named Core is mainly the menu structure and the monitoring instruments (as well as review old data). The Web Server is a prefabricated instrument controlled either from the Core, or from the LabVIEW scroll-down menu (under Project->Internet Toolkit, accessible through any VI). The Message Handler is only used from the Core (in monitoring mode), and is an automatic feature, if enabled. Message Handler is an instrument, consisting of its own "core" and subfunctions for communicating with the hardware and sending and receiving messages.

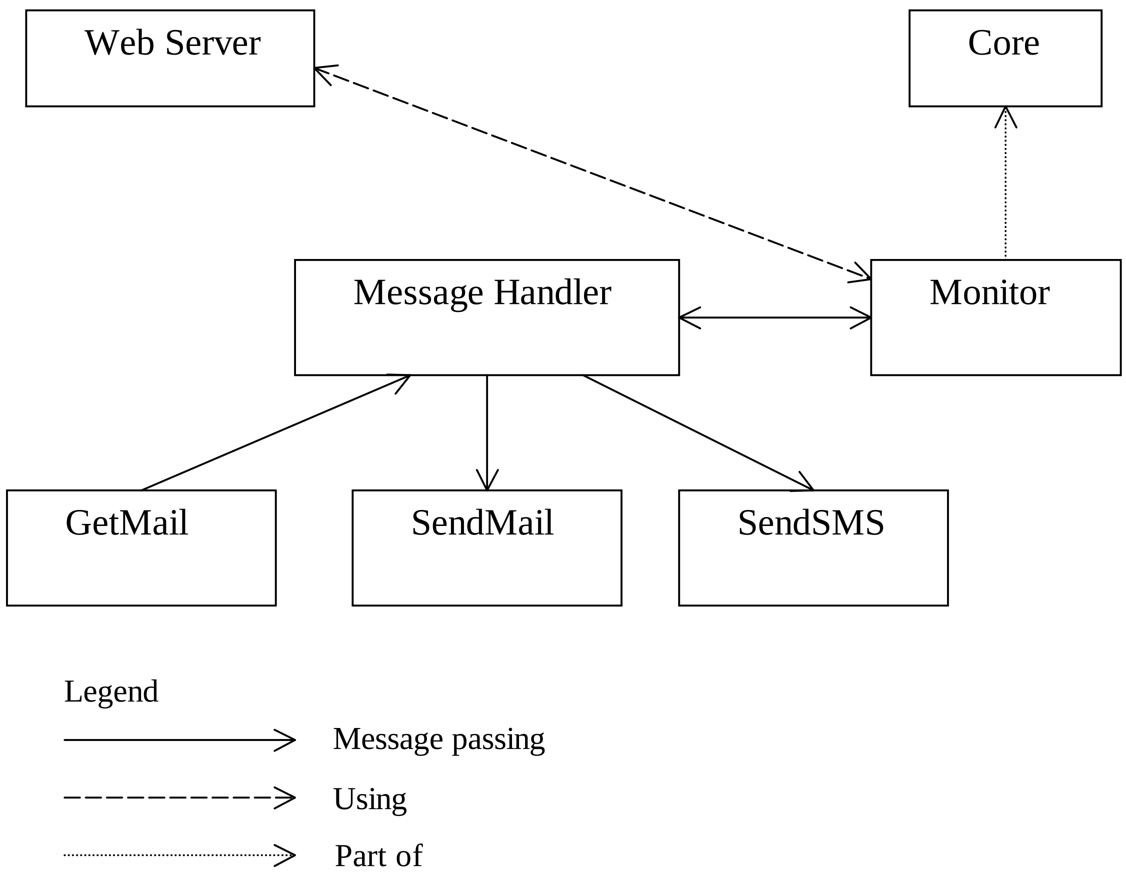


Fig. 5.2 Architecture

6 User – System Interactions

6.1 Local Interactions

Here we will discuss what the user can do with the front panel of our application. As seen above in section 5.1: ”The LabVIEW Core,” a menu structure is used. The user presses buttons (with a mouse) or enters values in text fields (with a keyboard, or maybe a mouse). Every window will be descibed separately.

6.1.1 Welcome

The user starts the program here, pressing Menu button. See B.1.

6.1.2 Main Menu

Four buttons: Monitor, View Old Data, Preferences and Quit. When the user selects from the first three, a new window will pop up (with selected contents). The Quit button, of course, quits the application. See B.2.

6.1.3 Monitor

Four buttons with LEDs: these are booleans showing the current state. A lit LED means true and an unlit means false. The buttons are Noise Logging, Temperature Logging, Noise Alarm and Temperature Alarm. When the user selects one of these, it toggles and logging or alarm is turned on or off. One button is controlling the HTTP Server, not seen in the screenshot. When the button is pressed the HTTP Server starts. When unpressed, the server is stopped. Finally, one Exit button for quit monitoring. The user can also set the axis values of the charts, by editing these (must turn off Autoscale first though). See B.3.

6.1.4 View Old Data

Text-fields for specifying date and time interval to review. The possibility to choose noise or temperature is done with a toggle switch. The “Go!” button reads data from disk and presents a chart of this data to the user. The scaling is also adjustable with textfields. The Exit button exits the window. See B.4.

6.1.5 Preferences

Text-fields for altering global settings for the program. Save button saves changes to memory and disk, and closes window. Cancel exits without saving. See B.5.

6.2 Remote Interactions

6.2.1 WWW

The project specification clearly states *no interaction on the web page*. From a sheer security oriented point-of-view this is quite logical, since *anyone* can view a web page. This *anyone* is however not supposed to control our application. Password protection is an alternative and if TietoEnator wants this they can add this later on. If so, the G Web Server, as already described, supports interaction through CGI. For now, only a continuosly running view of Monitor.vi is displayed (if active, that is).

6.2.2 Messaging

As with WWW, messaging is insecure, but not as accessible. We have not added authentication to the messages, but this can be added later. Controlling is possible only through email for now, as described in the next chapter, 7.

7 Messaging Service

7.1 Investigation for SMS Functionality

7.1.1 About SMS

The following text is a good description of SMS, translated from Swedish, see ref. [8].

“One of the most interesting functions in the GSM standard is SMS. SMS uses available time in the control channels from the base stations to inject messages. These messages can be of any format, but with a maximum length of 160 characters. SMS messages are shown in the mobile phone’s display, and can be read and written by pressing the telephone’s keys. Even though the function is useful, it is limited. Connected to a computer with a keyboard, SMS is an efficient and very useful messaging system.

SMS, which is an additional advantage of the GSM standard, besides data and fax, offers:

- 160 characters long messages.
- Guarranteed delivery.
- Acknowledgement of delivery.
- Receiving and sending can be done during a telephone conversation.
- Individual or group sending.

How are these advantages useful? The first area of use is messaging. SMS can send messages to any mobile phone. If the phone is turned off, the message is saved by the operator and is sent as soon as the phone is turned on. When the message has been received it is saved in the phone’s SIM card. The receiver can choose when and how he wants to read the message.

To make SMS messaging more efficient you can connect your phone to a laptop or desktop computer. Messages can then be written from the keyboard, which simplifies the usage of SMS. They can be sent from a computer with common communication software. For simple, short messages there are gateways, that translates SMS to fax so the message can be sent to a fax machine instead. They can also be sent to e-mail adresses. The only limit is 160 characters, which in the example above also must include fax number or e-mail adress.

SMS is becoming more frequent in using to prescribe on information services such as weather's forecast or stock exchange ratings. The information can be ordered or automatically transmitted with wanted time interval.

The presentation of the information is today adapted for the phone's display. But as the connections to laptop computers gets more common, these services will become even more sofisticated. In today's standard software, SMS is an excellent tool to send short messages. Alternatively, SMS can be a low cost option for data transmission."

7.1.2 SMS Investigation Results

The application we are to develop needs some kind of alarm feature. An alarm must be instantly read by the alarmee, therefore SMS suits this particular task excellent. One could think of the corporate manager having vacation on some tropical island and then suddenly a fire breaks out at his office. He just might want to be aware of this immediately! What then is needed adding this kind of functionality to the application? What is also needed for adding the possibility for the user (manager or not) to control the application remotely by his/her phone? We will try to answer these questions in this chapter.

There are two plausible answers for both questions, either to use an available software package or to develop SMS functionality. Since *we* are only investigating, the main purpose for *us* is to track down, test and evaluate available applications. If none would prove suitable, TietoEnator might have to develop something of their own for SMS. Further below is found descriptions of software found on the Internet, shareware or freeware, or other commercial products tested.

Also needed is some kind of messaging hardware device. Since SMS is mainly a GSM phone feature such a phone would be useful. The plan was to use a Nokia 8210, supplied by TietoEnator. A description of the phone is found at Nokias web site [7].

Since the target environment uses Windows 95, infrared support must be added to the operating system, as well as an infrared adapter. Infrared support is achieved through the Infrared Monitor, downloadable for free from Microsofts webpages. The external device in use is a SIR Infrared Adapter IR Mate IR-210B for Desktop PC. We will not discuss the technical aspects of this product, because it is not important. (It works therefore it is good).

7.1.3 Software

Nokia has developed a software package for this particular phone called *"PC Suite for Nokia 8210"*, which has some SMS functionality. It works great, really, however there is no way for us to communicate to and from the PC Suite from an external application, which we must do in order to handle these in LabVIEW. The messages received by the phone are displayed nicely on the screen, but cannot be saved to disk (and thus not read by any other programs), nor is there any DDE or OLE support, which would enable communication with other programs. This software package is thus *not* suitable for our needs, to send and receive messages from another program. We did however find some other software packages, described below.

- *Pager Center*, which in Europe is called *SMS Centre*, both work alike and is just the same program with different settings for different network providers. Both are shareware, with evaluation time. However this is not a suitable product, since Pager Center is designed for North American market and SMS Centre for United Kingdom market. Even if a special solution for Sweden is arranged, currently supported network providers are listed in [9], the software is limited for sending SMS only. A nice feature though is the ability to communicate with the software from other programs, through the built-in API or command line arguments.

- *SMS Gateway* [10], which is supposed to manage all wanted features, to send and receive messages with a phone connected to the computer. However there are no default settings for the Nokia 8210, which we *did* manage to communicate with, but never in a correct way. The phone was responding, but we didn't know the correct settings* (if any) to establish a lasting connection. If another (supported) telephone is used this application would be just what we're looking for. It has built-in DDE and OLE support, which LabVIEW loves. Virtual Instruments could be programmed for alarm and remote control using a GSM phone. Unfortunately, since we had no such phone available we have not done these. They would, however, not be too complicated if and when such a phone is available. Another drawback (besides us not having a supported phone) was the severe impact on system performance, the computer was "glued". This is maybe related to the communication problems we experienced with our phone.
- *TDK Globalpulse* [11] has support for *sending* messages through DDE, and saving messages from phone. However, this saving procedure is manual and unfortunately that's not appreciated from our point of view. Also it did not seem to work with the specific phone, we suppose due to lack of IR connectivity support.
- *Message Master Personal* [12] has lots of features, including support for sending and receiving short messages and built-in support for all Swedish network providers. It has furthermore support for communicating with other software applications, and with mobile phones through the infrared port. Like SMS Gateway, described above there are lots of pre-defined settings for several phones, although, again, not for *our* phone. Of the software listed here we would recommend TietoEnator to have a further look at this one. With the right phone, from the list below, there is enough to add SMS alarm *and* control features to this virtual instrument for control and survey of a remote building. NB. This is almost the same list as that for SMS Gateway.

* Without being too technical, these settings are in low-level hardware terms, such as ETSI Block/PDU Mode and Interface Initialization Strings.

Ericsson SH888
Falcom A1
Falcom A2
Nokia Card Phone 1.0
Nokia Cellular Data Suite
Nokia Communicator 9000
Nokia Communicator 9110
Nokia Data Card
Option FirstFone
SAGEM MC 850
Siemens M1
Siemens M20
Siemens SL10
UbiCom GSM Modul 232
WAVECOM

Table 7.1 Supported Phones in Message Master

7.1.4 Conclusions

Although we use Nokia Cellular Data Suite for the Nokia 8210, it did not make any signs of contact (with the program). So, with the "correct" phone, what are the procedures for adding SMS support to the application?

First, we need to write VIs for sending and receiving messages through the DDE Server provided by Message Master. Second, a uniform format for messages must be described. For instance, "TEMPLOG ON" might trigger the temperature logging. More of this in chapter 8.2: "Events in the LabVIEW Core." The alarm messages are not as strict and are set in the application preferences. Third, the program core needs to regularly check the phone (Message Master) for new messages and interpret these and act according to them.

All of the (useful or not) applications above are designed for use with mobile phones, which is a must when receiving messages. For sending purposes only, there are other solutions. One of which is a common modem, and a nice application with command line arguments, called *QuickSMS* [13], with which we actually made a virtual instrument for sending messages, see screenshot. This VI could easily be added to the Messaging Service of the whole application.

Another solution is to use an online service and some work-around tricks for the login procedures on the webpages, but that's not a very smooth way and it will stay a thought. Also is the possibility to send SMS to e-mail addresses (and vice versa). Though we didn't find any services for this, we recommend TietoEnator to do more research in this area, as it could be useful in combination with our e-mail functionality, see next chapter.

7.2 Other Messaging Services

7.2.1 About Email

Sending away letters over computer networks (usually *electronic mail* or briefly called *email*) is the most wellknown and commonly used communication service on computer systems. Today, millions of people have the possibility to use email and the popularity of this service grows day by day. Email offers some advantages in relation to classical communication: *very fast*, *inexpensive* and *simple*.

For sending messages, an SMTP server is used. These normally respond to the TCP port 25, and every domain with self-respect has one. Receiving messages can be done through different techniques, although the most common (and most insecure) is the POP3. These servers are usually on TCP port 110.

7.2.2 Email Service in the Application

As seen in section 7.1, messaging is to be used for alarming and controlling purposes. Messaging is ideal for the purpose of receiving commands since we can regularly check for email with the application. Email messaging is not, however, efficient for alarming purposes. The alarmee might not check his email every minute.

The email service will, seen from the outside, work like the SMS service. The Message Handler (*Message Handler.vi*) will be invoked from the LabVIEW Core at specific events, such as checking for commands (mail in this case) or sending alarms (in this case, also by mail). Settings for which messaging system to be used will be regulated in the preferences.

The email service knows which addresses to use, i.e. for destination and servers, as well as username and password for the user account. These settings are global variables also controlled in the preferences.

Communication will be performed through the subject field of the message header. Explanations of the syntax of this communication will be discussed in section 8.2.2, “Communication Syntax” below.

8 System Events

8.1 Data Flow

The DAQ Signal Accessory is quite simple. Without external devices connected to it, which we do not have, there is not much to measure. We can, however, do a few measurements.

- Room temperature, with the built-in thermometer in the DAQ Signal Accessory.
- There is also the possibility to generate a squareform or sine wave and display this. That's not very bound to the problem though, to control and survey a building.
- Additionally, the DAQ Signal Accessory has input for a microphone, which could be measured as well, perhaps simulating a noise detector.
- A set of LEDs can be lit by the user and thus simulating a control.

All measurements will be handled by the LabVIEW core and represented graphically in LabVIEW as well as on the web page. Control, i.e. an interface where the user can alter certain objects, such as lighting an LED, may be added to the LabVIEW interface, and possibly to the web page if password protected. An LED could represent anything, from a light to a burglar alarm.

These are the possibilities with a DAQ Signal Accessory, and thus what we are supposed to do: monitoring the Accessory for all possible measurements above.

Data history will be logged to text files, for later querys, such as "Give me the temperature from 2:00pm to 3:00pm the 23rd of May 2004". This kind of information could be viewed in LabVIEW or on the web page. Logging will, of course, be performed in a separate VI. More of this and the other VIs in the subsystem design will be discussed in section 9.2.

8.2 Events in the LabVIEW Core

8.2.1 Possible Events

Events are bound to timers. The LabVIEW Core, *Monitor.vi*, consists of timers regularly triggering different events. These are discussed below.

- The monitoring timer is used for updating the temperature and noise charts with data acquired from the DAQ Board and Signal Accessory. This is done every second, not changeable by the user. Alarm checking is made with the same interval. If an alarm occurs an LED is lit on the front panel showing this. The Message Handler is also invoked with the alarm as indata.
- A timer for mail (and/or SMS) checking is used in order to invoke the Message Handler without indata (actually, isAlarm is set to 'false'). Message Handler then checks for mail and returns commands from these mails. Preferably this is performed every minute. The syntax for interpretating these are descibed below in section 8.2.2.
- Two timers are used for logging, one for temperature and one for noise. The values of these are from the preferences set by the user.

8.2.2 Communication Syntax

Both email and SMS (at least, in theory) can be used for controlling, but how? We need some way to describe commands. We decided to use the subject field of an email for this purpose and thus we can use the same syntax for email and SMS controlling. The possible controls (for now) are listed below.

Command	Description
SET TEMPLOG ON/OFF	Toggles temperature logging on or off.
SET NOISELOG ON/OFF	Toggles noise logging on or off.
SET HTTPSERVER ON/OFF	Starts or stops webserver
GET NOISE	Requests for current noise value, the core then sends this as an alarm message.
GET TEMP	Requests for current temperature value, the core then sends this as an alarm message.

Table 8.1 Communication Syntax

9 Detailed System Design

9.1 System Analysis

Here we will discuss the data flow to, and from functions in use. The LabVIEW environment is based on “data flow,” and the components, called virtual instruments, can accept indata as well as generate outdata. These are represented as connectors and will be the parts focused on here.

Welcome.vi	displays a “welcome message.”
Menu.vi	displays the “Main Menu” of the System Survey
Monitor.vi	monitors temperature and noise, the “Monitor” of the System Survey.
Preferences.vi	handles all globals.
Olddata.vi	displays the “View Old Data” of the System Survey.
Templogger.vi	timestamps and saves current temperature value.
Noiselogger.vi	timestamps and saves current noise value.
LoadPrefs.vi	loads preferences from disk.
SavePrefs.vi	saves preferences to disk.
GetSeconds.vi	auxiliary date/time-string-to-seconds instrument.
MessageHandler.vi	sends and receives messages.
GetMail.vi	retrieves the first mail subject from POP server (if any).
SendMail.vi	sends mail with indata message as subject to specified destination.
SendSMS.vi	sends SMS with indata as message to specified GSM number.
globals.vi	used for data passing between virtual instruments.

Table 9.1 VIs in use

9.1.1 Message Passing and Global Variables

As seen in table 9.1, there is not much in- or outdata from the virtual instruments, this is mainly for esthetical purposes. All wiring makes the code unreadable, see B.6 (an early version of the *Menu.vi*). Therefore, we are using global variables to the greatest extent possible. There are however a few cases where message passing is more necessary:

- When certain help functions, such as *GetSeconds.vi,* are used, when the data is meant for use only inside the function.
- When indata can be different, such as in *SendMail.vi*, when the message alternates depending on which alarm is to be sent.

VI	Indata	Outdata
Welcome.vi	N/A	N/A
Menu.vi	N/A	N/A
Monitor.vi	N/A	N/A
Preferences.vi	N/A	N/A
Olddata.vi	N/A	N/A
Templogger.vi	N/A	N/A
Noiselogger.vi	N/A	N/A
LoadPrefs.vi	N/A	N/A
SavePrefs.vi	N/A	N/A
GetSeconds.vi	Date – string {YYYY-MM-DD}. Time – string {HH:MM:SS}.	Seconds – uint, since 1904-01-01 00:00:00.
MessageHandler.vi	Alarm command - string	Control command – string IsCommand – boolean
GetMail.vi	N/A	Command – string
SendMail.vi	Alarm – string	N/A
SendSMS.vi	Alarm – string	N/A
Globals.vi	N/A	N/A

Table 9.2 Data flow to and from the instruments

9.1.2 Instrument Individuality

As mentioned before, the globals.vi will be in use, connecting the various instruments as a whole. This reduces modularity. Furthermore, it is not completely safe trying to run for example *Monitor.vi* without first loading the preferences. *Monitor.vi* needs to know certain things about the measuring hardware mentioned in these settings and may otherwise generate unwanted errors.

9.2 Subsystem Analysis

Here we discuss the mechanisms within each subsystem. The conditions for invoking other virtual instruments and detailed discussion on functionality.

9.2.1 Welcome.vi

The purpose of this instrument is plainly to be a “start”-page of the application. Here settings will be loaded into memory, to *globals.vi*, from disk, if previously saved. When the user so desires the *Menu.vi* will be loaded when pushed the “Menu” button. See B.1.

9.2.2 Menu.vi

This consists of a loop, which waits for the “Quit” button to be pressed. Meanwhile the user can start the different subsystems from here: *Monitor.vi*, *Olddata.vi* and *Preferences.vi*, each one connected to a button, quite self-explainatory. See B.2.

9.2.3 Monitor.vi

First, two charts, one for temperature level monitoring and one for noise level monitoring is initialized to the current time, this is achieved by invoking the *GetSeconds.vi* with the current date and time. The charts are set to display the last 300 seconds. A chart update timer value is set from *globals.vi*.

Second, measuring is started. Logging and alarm can be turned on and off while measuring. If temperature logging is turned on (controlled with an LED button), every “temperature logging interval milliseconds” from *globals.vi* (preferably set in the preferences), the *TempLogger.vi* will be invoked. The same goes for noise logging and *NoiseLogger.vi*. Temperature is being averaged over a specific number of readings, from *globals.vi*, this in order to reduce faulty spikes and for nicer plotting.

While measuring, alarms may occur. These show themselves as LEDs on the screen and possibly as alarms to Message Handler. Eventually, the Message Handler is checked for remote commands. Indata to Message Handler (alarm message) is set to empty string that indicates no alarm.

Looking at B.3 we first notice the two graphs (charts) showing the last five minutes of monitoring temperature and noise. Noise is above, temperature below. The thermometer shows current temperature. Beside the charts, LEDs are lit if alarm, but only if the alarm buttons on the right are active (lit). The alarm button LEDs on the right also enables/disables alarms through Message Handler. The logging button LEDs toggles logging of monitoring data to disk. In this example, both the alarms and logging of noise are on. This would have resulted in a "Fire!" message (or what is specified) through mail or SMS if enabled by user.

9.2.4 Olddata.vi

This instrument does not perform anything until the user presses the "Go!" button. The user specifies a time interval with the "from" and "to" text-fields. Also specified is type of data and zooming interval on the y-scale. Values, within the specified date/time interval, are loaded from a file, specified in *globals.vi*, and sent to initialize a "XYchart". Values are stored in the form of [DATE][tab][TIME][tab][VALUE][end of line]. The date and time values are being converted to seconds with the *GetSeconds.vi*. Each time and logged data value is sent to the XYchart. The chart displays a curve of the specified interval. See B.4.

9.2.5 Preferences.vi

This instrument consists of text fields, where the user can edit settings. If “Save” button is pressed these are stored in *globals.vi* and then the *SavePrefs.vi* is invoked. The “Cancel” button exits preferences without updating or saving. See: B.5. Table 9.3 describes the settings that are used in this VI.

Limits	Max Temp	The limit when temperature is too high, for “heat alarm”.
	Min Temp	The limit when temperature is too low, for “chill alarm”.
	Max Noise	The limit when noise is too high, for “noise alarm”.
Channels	Temp Channel	The channel on the DAQ Board for temperature measurement.
	Microphone Channel	Same as above, but for noise measurement.
	Alarm Lamp	A value for the LEDs on the DAQ Board, not really a channel.
Logging	Temp Logging Interval	How frequent temperature data is saved to disk (ms).
	Temp Logging Filename	The disk location to save temperature data.
	Noise Logging Interval	How frequent noise data is saved to disk (ms).
	Noise Logging Filename	The disk location to save noise data.
E-mail	POP Username	The login name to the POP3 server.
	POP Password	The password to the POP3 server.
	POP Server	The host name or IP address of the POP3 server.
	SMTP Server	The host name or IP address of the SMTP server.
	Destination Adress	The email address of the alarmee.
	Checking Interval	How frequent email checking is done.
SMS	Phone no	The GSM number of the alarmee.
	QuickSMS	The file path to the QuickSMS software executable.
Alarm	Max Temp Message	Message received by an alarmee when “heat alarm” occurs.
	Min Temp Message	Same as above, for “chill alarm”.
	Max Noise Message	Again, as above, for “noise alarm”.
Get	Email	Checkbox, should we check for email commands?
	SMS	Checkbox, should we check for SMS commands? (for future purposes)
Send	Email	Checkbox, should we send email alarms?
	SMS	Checkbox, should we send SMS alarms?

Table 9.3 Preferences

9.2.6 Templogger.vi and Noiselogger.vi

These are treated together since they act similarly. The requested type will get actual data value and logging filename from *globals.vi*, set by the monitoring instrument and preferences. They are atomic actions, where we open-write-close the file in one transaction. The current date/time is stored together with the current value in the form of [DATE][tab][TIME][tab][VALUE][end of line] for easy reading.

9.2.7 LoadPrefs.vi

Preferences will be restored from a preferences file, name specified in *globals.vi*. The formatting will be [VALUE][end of line] for each setting. These are in turn loaded from the file and stored in *globals.vi*.

9.2.8 SavePrefs.vi

It is the complete opposite of LoadPrefs, yet very similar. Preferred values in *globals.vi* will be saved to the preferences file.

9.2.9 GetSeconds.vi

Splits the indata strings, date and time, to separate integers for year, month, day, hour, minute and second, converts to seconds with a built-in LabVIEW VI named “Date/Time to Seconds”. Returns the seconds as outdata to a calling instrument.

9.2.10 MessageHandler.vi

First, checks the indata Alarm, a string value. If not empty (we check this inside Message Handler), then we are dealing with an alarm. Alarm mail and/or SMS can be sent to user-defined address and/or phone number, if enabled. This is realised using *SendMail.vi* and/or *SendSMS.vi* with alarm message.

If the indata is empty, then we are *not* dealing with an alarm. Intead we check for email, using *GetMail.vi*, (and/or SMS if possible).

The instrument has an outdata parameter called isCommand, which is boolean. If mail (or SMS) is retrieved the command is extracted and returned. To mark that a command is retrieved, isCommand is set to true, otherwise it is set to false. The isCommand parameter is for outside use, putting the command check inside MessageHandler and thus saves (LabVIEW) programming space outside MessageHandler.

9.2.11 GetMail.vi

Logs onto a POP3 Server, using an add-on package called POP, found on National Instruments web page [14], with username and password from preferences. Retrieves the first message. Returns the subject line of this message.

9.2.12 SendMail.vi

Gets indata message, then logs on to a SMTP Server, using the Internet Toolkit SMTP instruments, and sends the message to the destination address specified in preferences.

9.2.13 SendSMS.vi

Uses the external program QuickSMS, discussed in section 7.1.2: “SMS Investigation Results”. Gets indata message, then invokes QuickSMS through command-line parameters with phone number from preferences and message.

9.2.14 Globals.vi

A global variable is a built-in G feature. When you create a global variable a special kind of VI is automatically created. You can either write to or read from a global variable. Writing to a global variable means the value of the global changes; reading from a global means you access the global as a data source. Global variables can be written and read by any VI in memory. The global variable (the VI) can hold many variables, much like a struct or record in other languages. Different global variables (VIs) can be used, we do not however use more than one.

“Global variables store data used by several VIs. Use global variables judiciously because they hide the data flow of your diagram. Although you need global variables in some applications, do not use them if you can structure your program using an alternate data flow method for transferring data.” [3]

Thus spoke the experts. We, however, find global variables *very* useful in this particular assignment. Of course, we could use message passing to and from the VIs, but this would *severly* decrease readability and creates a tangle of wires not at all pleasing to the eye. Extra caution is taken not to mess things up, not using global variables in suspicious places resulting in race conditions, i.e. one VI tries to read from a global when another tries to write at the same time. Since the graphical environment simplifies this, we find it safe using global variables

10 Conclusions and Results Analysis

10.1 Results As Expected?

The goals listed in the section 2.1 will be treated here. Have we done what is expected of us?

- We have a fully functional application, running on a computer. We collect data from inputs and represent them graphically on the computer screen in an appropriate way. The application is capable of measuring, and the user is capable of controlling the units listed in the system specification.
- The application can be viewed on the screen of a PC, using a web browser, preferably Netscape Navigator, and an Internet connection.
- We have investigated the necessary steps in adding SMS functionality to the application in 1. We have documented solutions for sending SMS messages when a certain event occurs and also the capability of sending SMS messages to the computer with commands controlling the application. Although we did only implement the sending procedures. Instead we have a fully functioning messaging service for sending and receiving emails.

10.2 Time Plan Accordance

We had, as seen in the chart in section 2.3, made a time plan. The question is, did we follow it? And if so, how accurate? If not, why?

First off, we did not start working until a week after the expected start, therefore the dates on the plan does not fully match reality. The self-study of LabVIEW took a little longer than expected. Initially, we did some background reading, then we learned more continuously. The system specification was finished quite early, nothing much to comment there. The design, however, was much done in parallell with the coding and testing, since LabVIEW works well with prototyping.

What we did not include in the time plan was the SMS investigation. This is mainly because we forgot it at first. It took almost half the period, and was done largely in parallell with all other events. The documentation has been performed as planned, continuosly.

10.3 Maintainability of the System

10.3.1 Performance

The computer we used in this project, a Pentium 166 (with 96 MB RAM), works, but would be considered the absolute minimum system requirements. We do not know exactly how fast a computer is needed. Perhaps a more modern OS would be in place as well (now running Windows 95).

10.3.2 Maintenance

If SMS functionality were to be added to the application, as described in this document, a demonstrating example of control and monitoring, very well worth its name, could be created. With the right resources many exciting add-ons could be made,. We hope our program is modular enough.

The logging procedures are quite diskspace consuming, especially when logging interval is fairly short. Perhaps some application for cleaning logs is convenient. For example deleting unneccessary data or maybe for backup purposes. This is beyond our jurisdiction, but keep it in mind.

10.4 Final words

It was a delightful experience coming in contact with the world of LabVIEW. LabVIEW is a very comfortable environment for developers who like to see fast results and a good overview of the coding. On the other hand, it makes you lazy and when you change to a more low-level kind of language you wonder where all those fancy features have gone.

Finally, thanks to TietoEnator for these months. It’s a nice place with nice people.

11 References

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[7] http://www.nokia.com/phones/8210/index.html, 2000-06-06.
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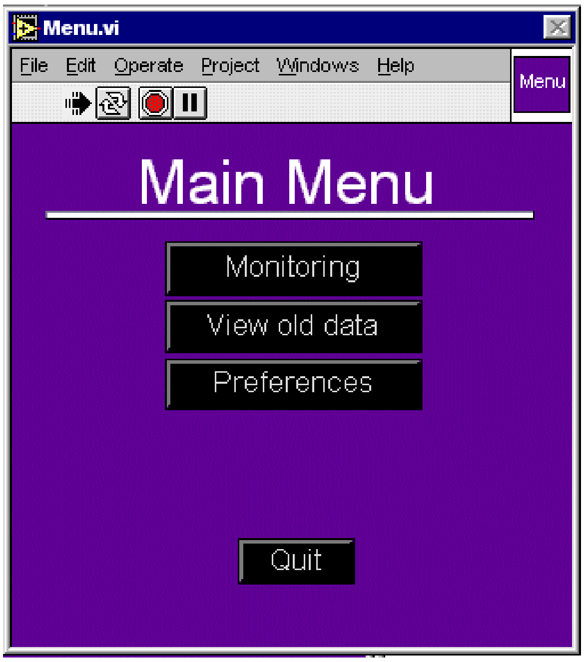
A Abbreviations

BASIC	**B**eginner's **A**ll-purpose **S**ymbolic **I**nstruction **C**ode
CGI	**C**ommon **G**ateway **I**nterface
DAQ	**D**ata **A**c**q**uisition
DDE	**D**irect **D**ata **E**xchange
ETSI	**E**uropean **T**elecommunications **S**tandards **I**nstitute
G	The **G**raphical Programming Language
GSM	**G**lobal **S**ystem for **M**obile Communications
I/O	**I**nput/**O**utput
IR	**I**nfra-**r**ed
LabVIEW	**Lab**oratory **V**irtual **I**nstrument **E**ngineering **W**orkbench
LED	**L**ight **E**mitting **D**iode
MB	**M**ega**B**yte
NB	**N**ota **b**ene
NI-DAQ	**N**ational **I**nstruments **D**ata **A**c**q**uisition
OLE	**O**bject **L**inking and **E**mbedding
OS	**O**perating **S**ystem
PC	**P**ersonal **C**omputer
PCI	**P**eripheral **C**omponent **I**nterconnect
PDU	**P**rotocol **D**ata **U**nit
POP3	**P**ost **O**ffice **P**rotocol **3**
RAM	**R**andom **A**ccess **M**emory
SIM	**S**ubscriber **I**dentity **M**odule
SIR	**S**ustained **I**nformation **R**ate
SMS	**S**hort **M**essaging **S**ervice
SMTP	**S**imple **M**ail **T**ransfer **P**rotocol
TCP	**T**ransmission **C**ontrol **P**rotocol
VI	**V**irtual **I**nstrument

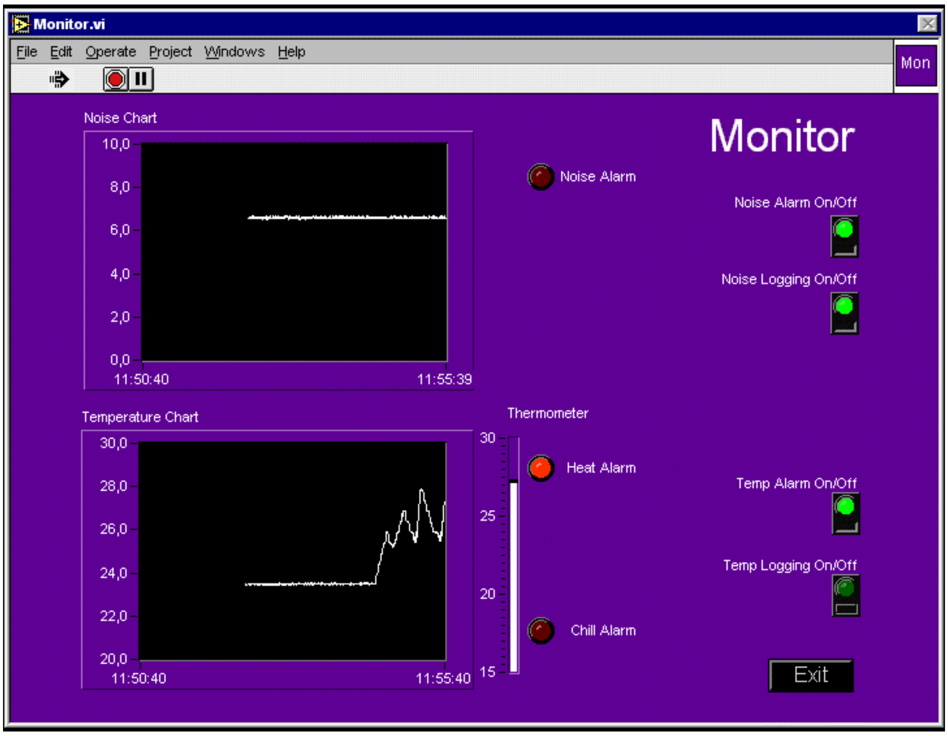
B Screenshots

B.1 Welcome.vi

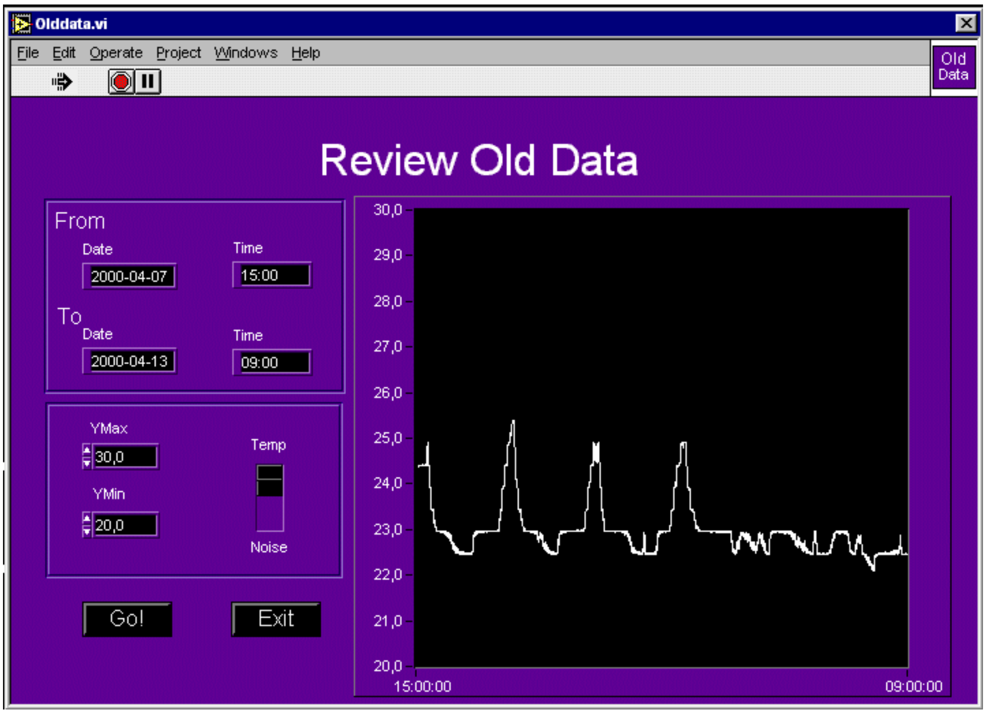
B.2 Menu.vi



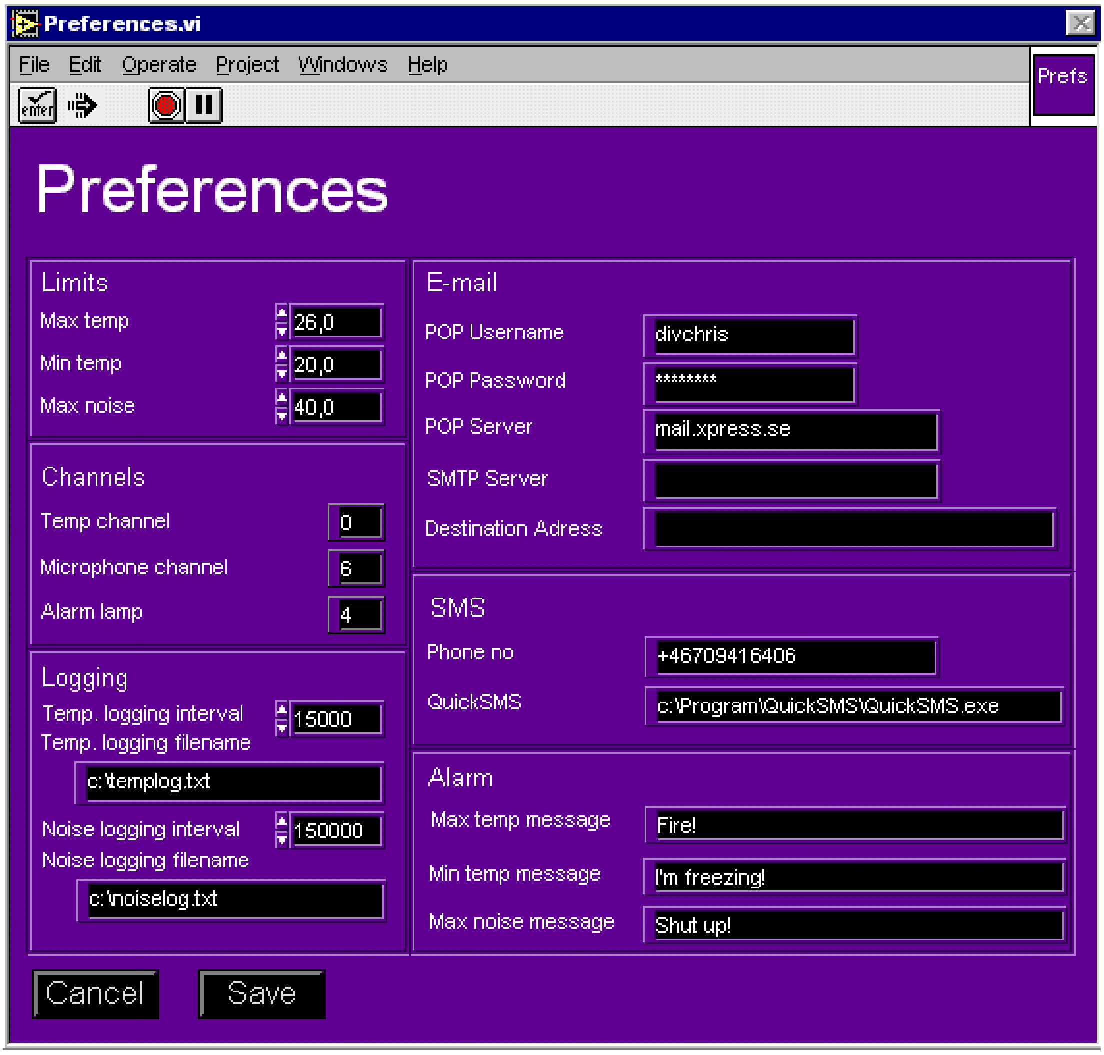
B.3 Monitor.vi



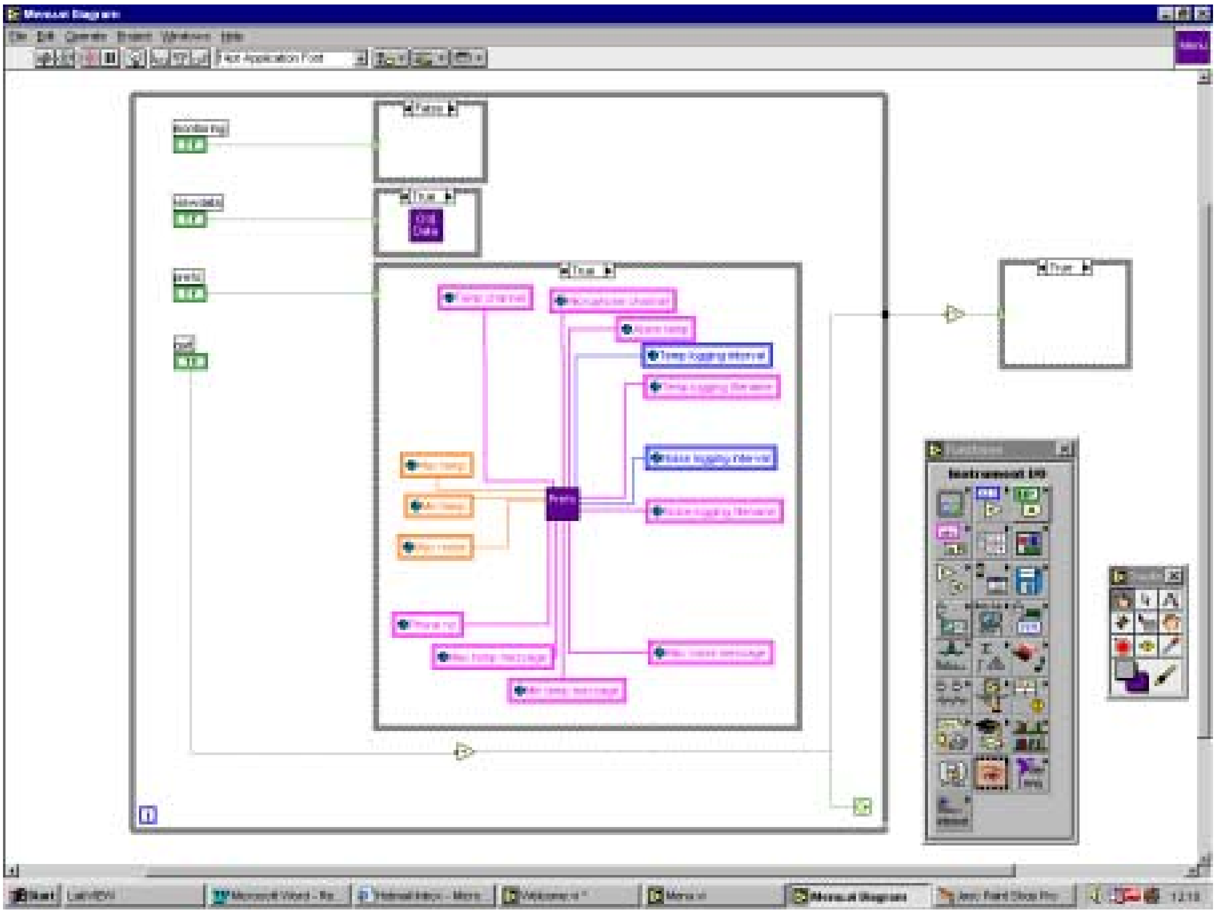
B.4 Olddata.vi



B.5 Preferences.vi



B.6 Menu.vi Diagram



B.7 Monitor.vi seen through a web browser