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SCHOOL OF BIO AND CHEMICAL

DEPARTMENT OF BIOMEDICAL ENGINEERING

UNIT-1-VIRTUAL BIOINSTRUMENTATION – **SBM1402**

I Introduction

Historical perspective, advantages, block diagram and architecture of a virtual instrument, data-flow techniques, graphical programming in data flow, comparison with conventional programming

1.1 INTRODUCTION

An instrument is a device designed to collect data from an environment, or from a unit under test, and to display information to a user based on the collected data. Such an instrument may employ a transducer to sense changes in a physical parameter, such as temperature or pressure, and to convert the sensed information into electrical signals, such as voltage or frequency variations. The term instrument may also be defined as a physical software device that performs an analysis on data acquired from another instrument and then outputs the processed data to display or recording devices. This second category of recording instruments may include oscilloscopes, spectrum analyzers, and digital millimeters. The types of source data collected and analyzed by instruments may thus vary widely, including both physical parameters such as temperature, pressure, distance, frequency and amplitudes of light and sound, and also electrical parameters including voltage, current, and frequency.

Virtual instrumentation is an interdisciplinary field that merges sensing, hardware, and software technologies in order to create flexible and sophisticated instruments for control and monitoring applications. The concept of virtual instrumentation was born in late 1970s, when microprocessor technology enabled a machine's function to be more easily changed by changing its software. The flexibility is possible as the capabilities of a virtual instrument depend very little on dedicated hardware – commonly, only application specific signal conditioning module and the analog-to- digital converter used as interface to the external world. Therefore, simple use of computers or specialized onboard processors in instrument control and data acquisition cannot be defined as virtual instrumentation. Increasing number of biomedical applications use virtual instrumentation to improve insights into the underlying nature of complex phenomena and reduce costs of medical equipment and procedures.

1.2 History of Instrumentation Systems

Historically, instrumentation systems originated in the distant past, with measuring rods, thermometers, and scales. In modern times, instrumentation systems have generally consisted of individual instruments, for example, an electromechanical pressure gauge comprising a sensing transducer wired to signal conditioning circuitry, outputs a processed signal to a display panel and

perhaps also to a line recorder, in which a trace of changing conditions is linked onto a rotating drum by a mechanical arm, creating a time record of pressure changes. Complex systems such as chemical process control applications employed until the 1980s consisted of sets of individual physical instruments wired to a central control panel that comprised an array of physical data display devices such as dials and counters, together with sets of switches, knobs, and buttons for controlling the instruments. A history of virtual instrumentation is characterized by continuous increase of flexibility and scalability of measurement equipment. Starting from first manual-controlled vendor- defined electrical instruments, the instrumentation field has made a great progress toward contemporary computer-controlled, user-defined, sophisticated measuring equipment. Instrumentation had the following phases:

– Analog measurement devices

– Data acquisition and processing devices

– Digital processing based on general purpose computing platform

– Distributed virtual instrumentation

The first phase is represented by early "pure" analog measurement devices, such as oscilloscopes or EEG recording systems. They were completely closed dedicated systems, which included power suppliers, sensors, translators, and displays. They required manual settings, presenting results on various counters, gauges, CRT displays, or on the paper. Further use of data was not part of the instrument package, and an operator had to physically copy data to a paper notebook or a data sheet. Performing complex or automated test procedures was rather complicated or impossible, as everything had to be set manually.

Second phase started in 1950s, as a result of demands from the industrial control field. Instruments incorporated rudiment control systems, with relays, rate detectors, and integrators. That led to creation of proportional– integral–derivative (PID) control systems, which allowed greater flexibility of test procedures and automation of some phases of measuring process. Instruments started to digitalize measured signals, allowing digital processing of data, and introducing more complex control or analytical decisions. However, real-time digital processing requirements were too high for any but an onboard special purpose computer or digital signal processor (DSP). The instruments still were standalone vendor defined boxes.

In the third phase, measuring instruments became computer based. They began to include interfaces that enabled communication between the instrument and the computer. This relationship started with the general-purpose interface bus (GPIB) originated in 1960s by Hewlett-Packard (HP), then called HPIB, for purpose of instrument control by HP computers. Initially, computers were primarily used as off-line instruments. They were further processing the data after first recording the measurements on disk or type. As the speed and capabilities of general-purpose computers advanced exponentially general-purpose computers became fast enough for complex real-time measurements. It soon became possible to adapt standard, by now high-speed computers, to the online applications required in real-time measurement and control. New general-purpose computers

from most manufactures incorporated all the hardware and much of the general software required by the instruments for their specific purposes. The main advantages of standard personal computers are low price driven by the large market, availability, and standardization. Although computers' performance soon became high enough, computers were still not easy to use for experimentalists.

Nearly all of the early instrument control programs were written in BASIC, because it had been the dominant language used with dedicated instrument controllers. It required engineers and other users to become programmers before becoming instrument users, so it was hard for them to exploit potential that computerized instrumentation could bring. Therefore, an important milestone in the history of virtual instrumentation happened in 1986, when National Instruments introduced LabVIEW 1.0 on a PC platform. LabVIEW introduced graphical user interfaces and visual programming into computerized instrumentation, joining simplicity of a user interface operation with increased capabilities of computers. Today, the PC is the platform on which most measurements are made, and the graphical user interface has made measurements user-friendlier. As a result, virtual instrumentation made possible decrease in price of an instrument. As the virtual instrument depends very little on dedicated hardware, a customer could now use his own computer, while an instrument manufactures could supply only what the user could not get in the general market.

The fourth phase became feasible with the development of local and global networks of general purpose computers. Since most instruments were already computerized, advances in telecommunications and network technologies made possible physical distribution of virtual instrument components into telemedical systems to provide medical information and services at a distance.

Possible infrastructure for distributed virtual instrumentation includes the Internet, private networks, and cellular networks, where the interface between the components can be balanced for price and performance.

The introduction of computers into the field of instrumentation began as a way to couple an individual instrument, such as a pressure sensor, to a computer, and enable the display of measurement data on virtual instrument panel on the computer screen using appropriate software. The instrumental so contained buttons for controlling the operation of the sensor. Thus, such instrumentation software enabled the creation of a simulated physical instrument, having the capability to control physical sensing components.

1.3 Virtual Instrumentation

Virtual instrumentation achieved mainstream adoption by providing a new model for building measurement and automation systems. Keys to its success include rapid PC advancement; explosive low-cost, high-performance data converter (semiconductor) development; and system design software emergence. These factors make virtual instrumentation systems accessible to a very broad base of users.

Definition

A virtual instrumentation system is software that is used by the user to develop a computerized test and measurement system, for controlling an external measurement hardware device from a desktop computer, and for displaying test or measurement data on panels in the computer screen. The test and measurement data are collected by the external device interfaced with the desktop computer. Virtual instrumentation also extends to computerized systems for controlling processes based on the data collected and processed by a PC based instrumentation system.

1.4 Block diagram and architecture of a virtual instrument

A virtual instrument is composed of the following blocks:

- Sensor module
- Sensor interface
- Information systems interface
- Processing module
- Database interface
- User interface

Figure shows the general architecture of a virtual instrument. The sensor module detects physical signal and transforms it into electrical form, conditions the signal, and transforms it into a digital form for further manipulation. Through a sensor interface, the sensor module communicates with a computer. Once the data are in a digital form on a computer, they can be processed, mixed, compared, and otherwise manipulated, or stored in a database.

Then, the data may be displayed, or converted back to analog form for further process control. Virtual instruments are often integrated with some other information systems. In this way, the configuration settings and the data measured may be stored and associated with the available records. In following sections each of the virtual instruments modules are described in more detail.

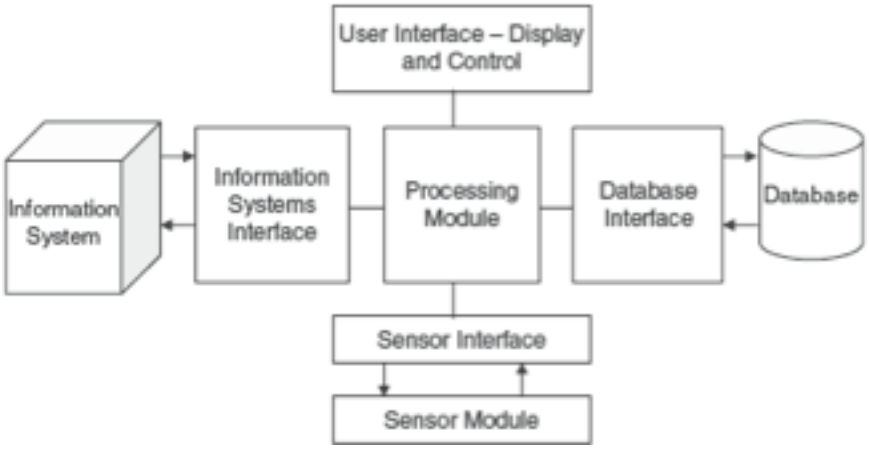


Fig 1: Architecture of a virtual instrument

- **Sensor Module**

The sensor module performs signal conditioning and transforms it into a digital form for further manipulation. Once the data are in a digital form on a computer, they can be displayed, processed, mixed, compared, stored in a database, or converted back to analog form for further process control. The database can also store configuration settings and signal records. The sensor module interfaces a virtual instrument to the external, mostly analog world transforming measured signals into computer readable form. A sensor module principally consists of three main parts:

- The sensor
- The signal conditioning part
- The A/D converter

The sensor detects physical signals from the environment. If the parameter being measured is not electrical, the sensor must include a transducer to convert the information to an electrical signal, for example, when measuring blood pressure.

The signal-conditioning module performs (usually analog) signal conditioning prior to AD conversion. This module usually does the amplification, transducer excitation, linearization, isolation, or filtering of detected signals.

The A/D converter changes the detected and conditioned voltage into a digital value. The converter is defined by its resolution and sampling frequency. The converted data must be precisely time- stamped to allow later sophisticated analyses. Although most biomedical sensors are specialized in processing of certain signals, it is possible to use generic measurement components, such as data acquisition (DAQ), or image acquisition (IMAQ) boards, which may be applied to broader class of signals. Creating generic measuring board, and incorporating the most important components of different sensors into one unit, it is possible to perform the functions of many medical instruments on the same computer.

- **Sensor Interface**

There are many interfaces used for communication between sensors modules and the computer. According to the type of connection, sensor interfaces can be classified as wired and wireless.Wired Interfaces are usually standard parallel interfaces, such as GPIB, Small Computer Systems Interface (SCSI), system buses (PCI eXtension for Instrumentation PXI or VME Extensions for Instrumentation (VXI), or serial buses (RS232 or USB interfaces).Wireless Interfaces are increasingly used because of convenience. Typical interfaces include 802.11 family of standards, Bluetooth, or GPRS/GSM interface. Wireless communication is especially important for implanted sensors where cable connection is impractical or not possible. In addition, standards, such as Bluetooth, define a self-identification protocol, allowing the network to configure dynamically and describe itself. In this way, it is possible to reduce installation cost and create plug-and-play like networks of sensors. Device miniaturization allowed development of Personal Area Networks (PANs) of intelligent sensors Communication with medical devices is also standardized with the IEEE 1073 family of standards. This interface is intended to be highly robust in an environment

where devices are frequently connected to and disconnected from the network.

- **Processing Module**

Integration of the general purpose microprocessors/microcontrollers allowed flexible implementation of sophisticated processing functions. As the functionality of a virtual instrument depends very little on dedicated hardware, which principally does not perform any complex processing, functionality and appearance of the virtual instrument may be completely changed utilizing different processing functions. Broadly speaking, processing function used in virtual instrumentation may be classified as analytic processing and artificial intelligence techniques.

Analytic functions define clear functional relations among input parameters. Some of the common analyses used in virtual instrumentation include spectral analysis, filtering, windowing, transforms, peak detection, or curve fitting. Virtual instruments often use various statistics function, such as, random assignment and bio statistical analyses. Most of those functions can nowadays be performed in real-time.

. Artificial intelligence technologies could be used to enhance and improve the efficiency, the capability, and the features of instrumentation in application areas related to measurement, system identification, and control. These techniques exploit the advanced computational capabilities of modern computing systems to manipulate the sampled input signals and extract the desired measurements. Artificial intelligence technologies, such as neural networks, fuzzy logic and expert systems, are applied in various applications, including sensor fusion to high- level sensors, system identification, prediction, system control, complex measurement procedures, calibration, and instrument fault detection and isolation. Various nonlinear signal processing, including fuzzy logic and neural networks, are also common tools in analysis of biomedical signals. Using artificial intelligence it is even possible to add medical intelligence to ordinary user interface devices. For example, several artificial intelligence techniques, such as pattern recognition and machine learning, were used in a software-based visual-field testing system.

- **Database Interface**

Computerized instrumentation allows measured data to be stored for off-line processing, or to keep records as a part of the patient record. There are several currently available database technologies that can be used for this purpose. Simple usage of file systems interface leads to creation of many proprietary formats, so the interoperability may be a problem. The eXtensible Markup Language (XML) may be used to solve interoperability problem by providing universal syntax. The XML is a standard for describing document structure and content. It organizes data using markup tags, creating self-describing documents, as tags describe the information it contains. Contemporary database management systems such SQL Server and Oracle support XML import and export of data. Many virtual instruments use DataBase Management Systems(DBMSs). They provide efficient management of data and standardized insertion, update, deletion, and selection. Most of

these DBMSs provided Structured Query Language (SQL) interface, enabling transparent execution of the same programs over database from different vendors. Virtual instruments usethese DMBSs using some of programming interfaces, such as ODBC, JDBC,ADO, and DAO.

- **Information System Interface**

Virtual instruments are increasingly integrated with other medical information systems, such as hospital information systems. They can be used to create executive dashboards, supporting decision support, real time alerts, and predictive warnings. Some virtual interfaces toolkits, such as LabVIEW, provide mechanisms for customized components, such as ActiveX objects, that allows communication with other information system, hiding details of the communication from virtual interface code. In Web based applications this integration is usually implemented using Unified Resource Locators (URLs). Each virtual instrument is identified with its URL, receiving configuration settings via parameters. The virtual instrument then can store the results of the processing into a database identified with its URL.

- **Presentation and Control**

An effective user interface for presentation and control of a virtual instrument affects efficiency and precision of an operator do the measurements and facilitates result interpretation. Since computer's user interfaces are much easier shaped and changed than conventional instrument's user interfaces, it is possible to employ more presentation effects and to customize the interface for each user. According to presentation and interaction capabilities, we can classify interfaces used in virtual instrumentation in four groups:

- Terminal user interfaces
- Graphical user interfaces
- Multimodal user interfaces and
- Virtual and augmented reality interfaces

Terminal User Interfaces

First programs for instrumentation control and data acquisition had character-oriented terminal user interfaces. This was necessary as earlier general-purpose computers were not capable of presenting complex graphics. As terminal user interfaces require little of system resources, they were implemented on many platforms. In this interfaces, communication between a user and a computer is purely textual. The user sends requests to the computer typing commands, and receives response in a form of textual messages.

Graphical User Interfaces

Graphical user interfaces (GUIs) enabled more intuitive human–computerinteraction, making virtual instrumentation more accessible. Simplicity ofinteraction and high intuitiveness of graphical user interface operations madepossible creation of user-friendlier virtual instruments. GUIs allowed creationof many sophisticated graphical widgets such as graphs, charts, tables, gauges,or meters, which can easily be created with many user interface tools.

Multimodal Presentation

In addition to graphical user interfaces that improve visualization, contemporarypersonal computers are capable of presenting other modalities suchas sonification or haptic rendering.

Multimodal combinations of complementarymodalities can greatly improve the perceptual quality of user interfaces.

Virtual Instruments versus Traditional Instruments

Stand-alone traditional instruments such as oscilloscopes and waveform generators are very powerful, expensive, and designed to perform one or more specific tasks defined by the vendor. However, the user generally cannot extend or customize them. The knobs and buttons on the instrument, the built-in circuitry, and the functions available to the user, are all specific to the nature of the instrument. In addition, special technology and costly components must be developed to build these instruments, making them very expensive and slowto adapt.

Table 1: Traditional Instruments Vs Virtual Instruments

Traditional Instruments	Virtual Instruments
Vendor defined	User-defined
Function specific,stand alone with limited connectivity	Application oriented system with connectivity to networks,peripherals, and applications
Hardware is the key	Software is the key
Expensive	Low cost , reusable
Closed, fixed functionality	Open, flexible functionality
Slow turn on technology	Fast turn on technology
Minimal economics of scale	Maximum economics of scale
High development and maintenance cost	Software minimizes development and maintenance cost

1.5 Advantages of VI

The virtual instruments running on notebook automatically incorporate their portable nature to the Engineers and scientists whose needs, applications and requirements change very quickly, need flexibility to create their own solutions. We can adapt a virtual instrument to our particular needs without having to replace the entire device because of the application software installed on the PC and the wide range of available plug-in hardware.

Performance

In terms of performance, LabVIEW includes a compiler that produces native code for the CPU platform. The graphical code is translated into executable machine code by interpreting the syntax and by compilation. The LabVIEW syntax is strictly enforced during the editing process and compiled into the executable machine code when requested to run or upon saving. In the latter case, the executable and the source code are merged into a single file. The executable runs with the help of the LabVIEW run-time engine, which contains some precompiled code to perform common tasks that are defined by the G language. The run-time engine reduces compile time and also provides a consistent interface to various operating systems, graphic systems, hardware components, etc.

Platform-Independent Nature

A benefit of the LabVIEW environment is the platform-independent nature of the G-code,

which is (with the exception of a few platform specific functions) portable between the different LabVIEW systems for different operating systems (Windows, MacOSX, and Linux). National Instruments is increasingly focusing on the capability of deploying LabVIEW code onto an increasing number of targets including devices like Pharlap OS-based LabVIEW realtime controllers, PocketPCs, PDAs, Fieldpoint modules, and into FPGAs on special boards.

Flexibility

Except for the specialized components and circuitry found in traditional instruments, the general architecture of stand-alone instruments is very similar to that of a PC-based virtual instrument. Both require one or more microprocessors, communication ports (for example, serial and GPIB), and display capabilities, as well as data acquisition modules. These devices differ from one another in their flexibility and the fact that these devices can be modified and adapted to the particular needs.

Lower Cost

By employing virtual instrumentation solutions, lower capital costs, system development costs, and system maintenance costs are reduced, increasing the time to market and improving the quality of our own products.

Plug-In and Networked Hardware

There is a wide variety of available hardware that can either be plugged into the computer or accessed through a network. These devices offer a wide range of data acquisition capabilities at a significantly lower cost than that of dedicated devices.

The Costs of a Measurement Application

The costs involved in the development of a measurement application can be divided into five distinct areas composed of hardware and software prices and several time costs. The price of the hardware and software was considered as the single largest cost of their most recent test or measurement system. However, the cumulative time costs in the other areas make up the largest portion of the total application cost.

Reducing System Specification Time Cost

Deciding the types of measurements to take and the types of analysis to perform takes time. Once the user has set the measurement specifications, the user must then determine exactly the method to implement the measurement system. The time taken to perform these two steps equals the system specification time.

Lowering the Cost of Hardware and Software

The price of measurement hardware and software is undoubtedly the most visible cost of a data-acquisition system. Many people attempt to save money in this area without considering the effect on the total development cost.

Minimizing Set-Up and Configuration Time Costs

Once the users have specified and purchased measurement hardware, the real task of developing the application begins. However, the user must first install the hardware and software, configure any necessary setting and ensure that all pieces of the system function properly.

Dataflow Programming

Lab VIEW follows a dataflow model for running VIs. A block diagram node executes when all its inputs are available. When a node completes execution, it supplies data to its output terminals and passes the output data to the next node in the dataflow path. Visual Basic, C + +, JAVA, and most other text-based programming languages follow a control flow model of program execution. In control flow, the sequential order of program elements determines the execution order of a program. For a dataflow-programming example, consider a block diagram that adds two numbers and then subtracts 50.00 from the result of the addition as illustrated in Fig. In this case, the block diagram executes from left to right, not because the objects are placed in that order, but because the Subtract function cannot execute until the Add function finishes executing and passes the data to the Subtract function. Remember that a node executes only when data are available at all of its input terminals, and it supplies data to its output terminals only when it finishes execution.

In the following example in Fig. 2.consider which code segment would execute first – the Add, Random Number, or Divide function. In a situation where one code segment must execute before another and no data dependency exists between the functions, the user can use other programming methods, such as error clusters, to force the order of execution.

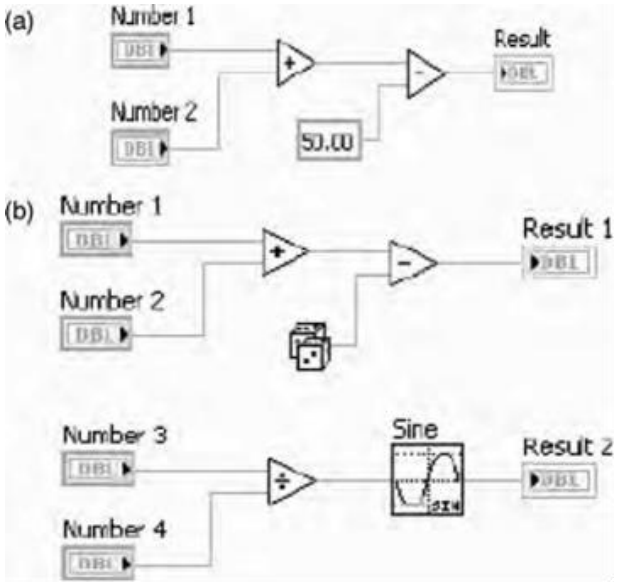


Fig. 2. Dataflow programming example

'G' Programming

The 'G' sequence structure is used to control execution order when natural data dependency does not exist. The user also can create an artificial data dependency in which the receiving node does not actually use the data received. Instead, the receiving node uses the arrival of data to trigger its execution. The programming language used in LabVIEW, called "G", is a dataflow language. Execution is determined by the structure of a graphical block diagram (the LV-source code) on which the programmer connects different function-nodes by drawing wires. These wires propagate variables and any node can execute as soon as all its input data become available. Since this might be the case for multiple nodes simultaneously, "G" is inherently capable of parallel execution. Multiprocessing and multi-threading hardware is automatically exploited by the built-in scheduler, which multiplexes multiple OS threads over the nodes ready for execution. Programmers with a

background in conventional programming often show a certain reluctance to adopt the LabVIEW dataflow scheme, claiming that LabVIEW is prone to race conditions. In reality, this stems from a misunderstanding of the data-flow paradigm. The afore-mentioned data-flow (which can be "forced," typically by linking inputs and outputs of nodes) completely defines the execution sequence, and that can be fully controlled by the programmer. The graphical approach also allows nonprogrammers to build programs by simply dragging and dropping virtual representations of the lab equipment with which they are already familiar. The LabVIEW programming environment, with the included examples and the documentation, makes it easy to create small applications. This is a benefit on one side but there is also a certain danger of underestimating the expertise needed for good quality "G" programming. For complex algorithms or large-scale code it is important that the programmer understands the special LabVIEW syntax and the topology of its memory management well. The most advanced Lab-VIEW development systems offer the possibility of building standalone applications.

1.6 Virtual Instruments

Virtual Instruments are front panel and block diagram. The front panel or user interface is built with controls and indicators. Controls are knobs, pushbuttons, dials, and other input devices. Indicators are graphs, LEDs, and other displays.

Front Panel

The front panel is the window through which the user interacts with the program. The input data to the executing program is fed through the front panel and the output can also be viewed on the front panel, thus making it indispensable.

Front Panel Toolbar controls and Indicators

The front panel is primarily a combination of controls and indicators, which are the interactive input and output terminals of the VI, respectively. Controls are knobs, push buttons, dials, and other input devices. Indicators are graphs, LEDs, and other displays. Controls simulate instrument input devices and supply data to the block diagram of the VI. Indicators simulate instrument output devices and display data the block diagram acquires or generates.

S. No	Icon	Name	Meaning
1		**Run**	Used to run a VI. The VI runs if the **Run** button appears as a solid white arrow as shown at the left. The solid white arrow also indicates the VI can be used as a subVI if a connector pane for the VI is created.
2		**Run**	While the VI runs, the **Run** button appears as shown at left if the VI is a top-level VI, meaning it has no callers and therefore is not a subVI.
3		**Run**	If the VI that is running is a subVI, the **Run** button appears as shown at left.
4		**Run**	The **Run** button appears broken, shown at left, when the VI that is created and edited contains errors. If the **Run** button still appears broken after wiring of the block diagram is completed, then the VI is broken and cannot run. On clicking this button, an **Error list** window is displayed, which lists all errors and warnings.
5		**Run Continuously**	The **Run Continuously** button, shown at left, is used to run the VI until one abortion or pause execution.
6		**Abort Execution**	While the VI runs, the **Abort Execution** button, shown at left, appears. Click this button to stop the VI immediately if there is no other way to stop the VI. If more than one running top-level VI uses the VI, the button is dimmed.
7		**Pause**	Click the **Pause** button, shown at left, to pause a running VI. Upon clicking the **Pause** button, LabVIEW highlights on the block diagram the location where the execution was paused, and the **Pause** button appears red. Click the button again to continue running the VI.

Fig 3: Front panel tool bars

Controls and Indicators :

Controls and Indicators are generally not interchangeable; the difference should be clear among the user. The user can "drop" controls and indicators onto the front panel by selecting them from a subpalette of the floating **Controls** palette window shown in Figure.

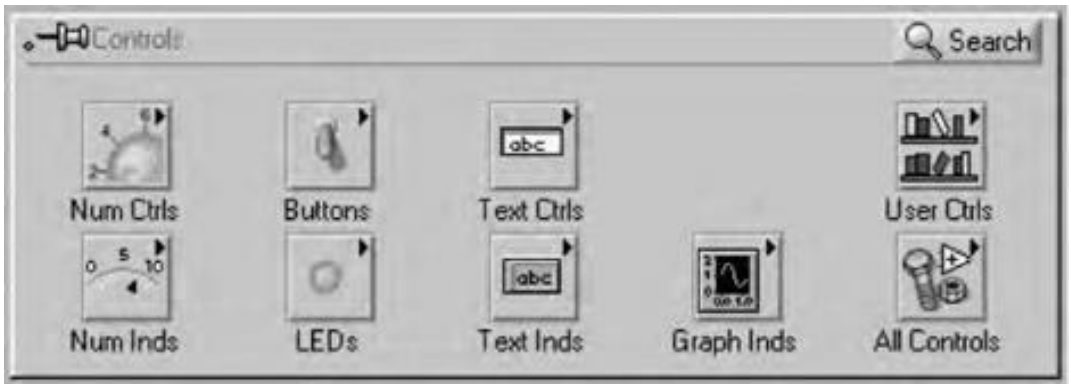


Fig 4: Controls and Indicators

Once an object is on the front panel, the user can easily adjust its size, shape, position, color, and other attributes. Controls and indicators can be broadly classified as:

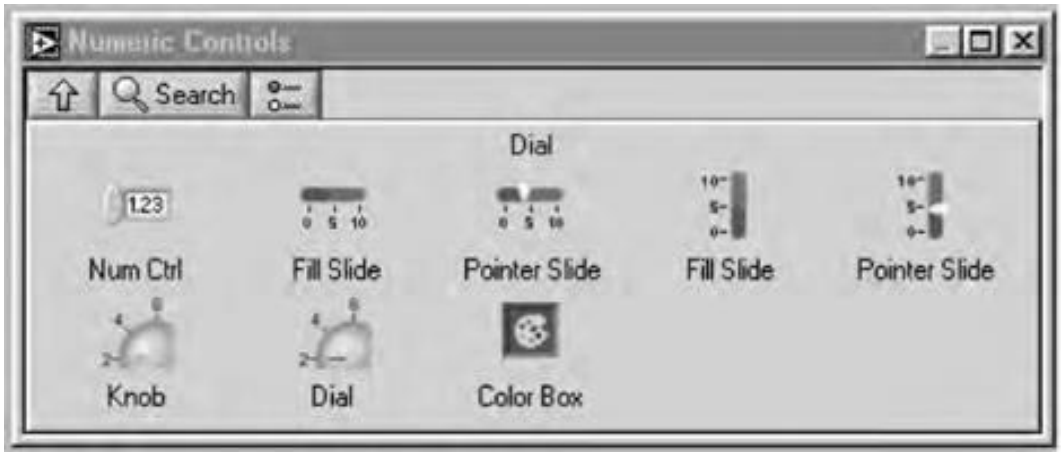
- Numeric controls and indicators
- Boolean controls and indicators

Numeric Controls and Indicators

The two most commonly used numeric objects are the numeric control and the numeric indicator, as shown in Fig. The values in a numeric control can be entered or changed by selecting the increment and decrement buttons with the Operating tool or double-clicking the number with either the Labeling tool or the Operating tool.

Boolean Controls and Indicators

The Boolean controls and indicators (Fig) are used to enter and display Boolean (True or false) values. Boolean objects simulate switches, push buttons, and LEDs. The most common Boolean objects are the vertical toggle switch and the round LED.



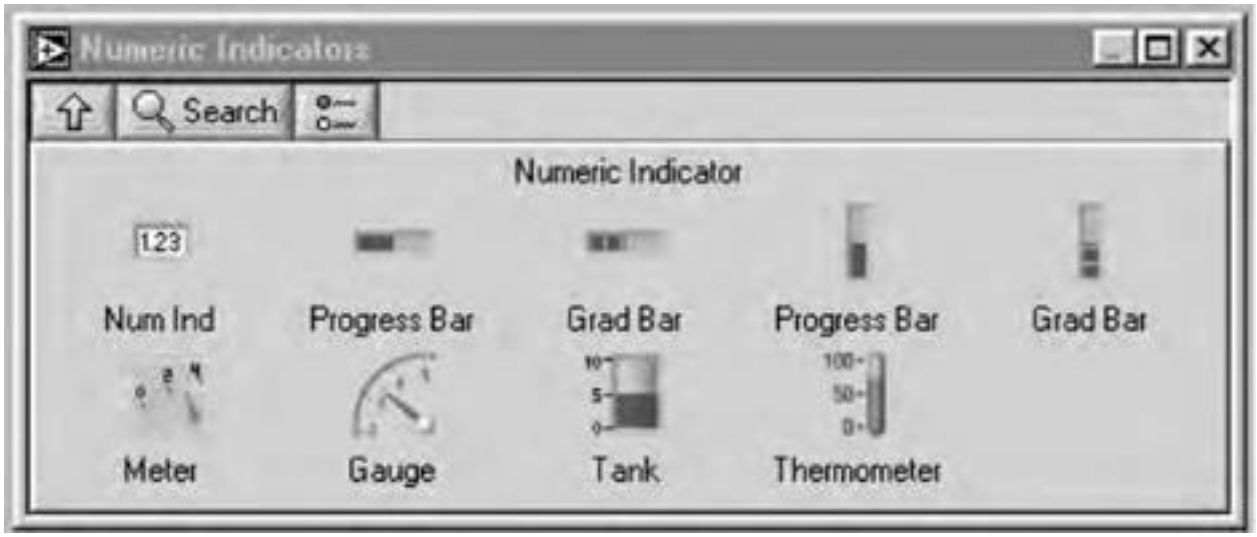


Fig 5: Numeric Control and Indicator

Block Diagram

The block diagram window holds the graphical source code of a LabVIEW'sblock diagram corresponds to the lines of text found in a more conventional language like C or BASIC – it is the actual executable code. The block diagram can be constructed with the basic blocks such as: terminals, nodes, and wires.

Terminals

Terminals are entry and exit ports that exchange information between the front panel and block diagram. Terminals are analogous to parameters and constants in text-based programming languages.

Types of terminals include control or indicator terminals and node terminals. Control and indicator terminals belong to front panel controls and indicators. When a control or indicator is placed on the front panel, LabVIEW automatically creates a corresponding terminal on the block diagram. The terminals represent the data type of the control or indicator. The user cannot delete a block diagram terminal that belongs to a control or indicator. The terminal disappears when its corresponding control or indicator is deleted on the front panel. The front panel controls or indicators can be configured to appear as icon or data type terminals on the block diagram. By default, front panel objects appear as icon terminals.

Control terminals have thick borders, while indicator terminal borders are thin. It is very important to distinguish between the two since they are not functionally equivalent i.e., control=input, indicator=output, and so they are not interchangeable.

Nodes:

Nodes are analogous to statements, operators, functions, and subroutines in standard programming languages. The AND and XOR functions represent one type of node. A structure is another type of node. Structures can execute code repeatedly or conditionally, similar to loops and Case statements in traditional programming languages. LabVIEW also has special nodes, called Formula Nodes, which are useful for evaluating mathematical formulas or expressions.

Wires

Wires connecting nodes and terminals hold a LabVIEW VI together. Wiresare the data paths

between source and destination terminals, they deliver data from one source terminal to one or more destination terminals. Wires are analogous to variables in text-based programming languages. If more than one source or no source at all is connected to a wire, LabVIEW disagrees and the wire will appear broken. This principle of wires connecting source and destination terminals explains why controls and indicators are not interchangeable; controls are source terminals, whereas indicators are destinations, or sinks. Each wire has a different style or color, depending on the data type that flows through the wire. The below Table shows a few wires and their corresponding types. By default, basic wire styles are used in block diagrams. To avoid confusion among the data types, the colors and styles are simply matched.

Block Diagram Toolbar

When a VI is run, buttons appear on the block diagram toolbar that can beused to debug the VI.

Table 2: Data type and representation

	Scalar	1D array	2D array	Color
Floating point number				Orange
Integer number				Blue
Boolean				Green
String				Pink

Table 3 :Dialogue box menu

S No	Icon	Name	Meaning
1	New...	New	The **New** button is used to create a new VI. The arrow on the **New** button is used to open a blank VI or to open the **New** dialog box.
2	Open...	Open	The **Open** button is used to open an existing VI. The arrow on the **Open** button is used to open recent files.
3	Configure...	Configure	The **Configure** button is used to configure the data acquisition devices. The arrow on the **Configure** button is used to configure LabVIEW.
4	Help...	Help	The **Help** button is used to launch the *LabVIEW Help*. The arrow on the **Help** button is used for other Help options, including the NI Example Finder.

Startup Menu

The menus at the top of a VI window contain items common to other applications, such as Open, Save, Copy, and Paste, and other items specific to LabVIEW. Some menu items also list shortcut key combinations (Mac OS).The menus appear at the top of the screen (Windows and UNIX).The menus display only the most recently used items by default. The arrows at the bottom of a menu are used to display all items. All menu items can be displayed by default by selecting Tools->Options

Palletes

LabVIEW has graphical; floating palettes to help the user to create and run VIs.LabVIEW has three often-used floating palettes that can be placed in a convenient spot on the screen: the Tools palette, the Controls palette, and the Functions palette. Controls and Functions Palettes. The Controls palette will often be used, since the controls and indicators that are required on the front panel are available. The user will probably use the Functions palette even more often, since it contains the functions and structures used to build a VI. The Controls and Functions palettes are unique in several ways. Most importantly the Controls palette is only visible when the front panel window is active, and the Functions palette is only visible when the block diagram window is active. Both palettes have subpalettes containing the objects to be accessed. As the cursor is passed over each subpalette button in the Controls and Functions palettes, the subpalette's name appears at the top of the window. If a button is clicked, the associated subpalette appears and replaces the previous active palette. To select an object in the subpalette, the mouse buttonis clicked over the object, and then clicked on the front panel or block diagram to place it wherever desired. Like palette button names, subpalette object name appear when the cursor is run over them.

To return to the previous("owning") palette, the top-left arrow on each palette is selected. Clicking on the spyglass icon the user can search for a specific item in a palette, and then the user can edit palettes by clicking the options buttons. There is another way to navigate palettes that some people find a little easier. Instead of having each subpalette replace the current palette, the user can pass through subpalettes in a hierarchical manner without them replacing their parent palettes.

Controls Palette

The Controls palette can be displayed by selecting Window->Show ControlsPalette or right-clicking the front panel workspace. The Controlspalette can also be tacked down by clicking the thumbtack on the top left corner of the palette. By default, the Controls palette starts in the Expressview. The Express palette view includes subpalettes on the top level of theControls and Functions palettes. The All Controls and All Functions subpalettes contain the complete set of built-in controls, indicators, VIs, and functions. The Advanced palette view includes subpalettes on the top level of the Controls and Functions palettes that contain the complete set of built in controls, indicators, VIs, and functions. The Express subpalettes contain Express VIs and other objects required to build common measurement applications. Click the Options button on the Controls or Functions palette to change to another palette view or format.

Functions Palette

The Functions palette is available only on the block diagram. The Functions palette contains the VIs and functions used to build the block diagram. The Functions Palette can be displayed by selecting the Windows->Show or right-clicking the block diagram workspace to display the Functions palette.

Fig : 6 Function Palette

Tools Palette

A tool is a special operating mode of the mouse cursor. Tools are used to perform specific diting and operation functions, similar to that used in a standard paint program.

Fig :7 Tool Palette

Table 4 : Tool Palatte Menu

S. No	Icon	Name	Meaning
1		Operating Tool	The Operating Tool is used to change values of front panel controls and indicators. Used to operate knobs, switches, and other objects with the Operating tool – hence the name. It is the only front panel tool available when the VI is running or in run mode.
2		Positioning tool	The Positioning tool selects, moves, and resizes objects.
3		Labeling tool	The Labeling tool creates and edits text labels.
4		Wiring tool	The Wiring tool wires objects together on the block diagram. It is also used to assign controls and indicators on the front panel to terminals on the VI's connector.
5		Color tool	The Color tool brightens objects and background by allowing the user to choose from a multitude of hues. Both foreground and background colors can be selected by clicking on the appropriate color area in the Tools palette. If an object is popped up with the Color tool, a hue from the color palette appears and the required color can be chosen.

References:

1. Jerome, Virtual Instrumentation Using LabView, PHI, 2010
2. https://www.youtube.com/watch?v=I8pc8-VcVFo
3. https://www.youtube.com/watch?v=90yKPBLmDJ4

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DEPARTMENT OF BIOMEDICAL ENGINEERING

UNIT-II-VIRTUAL BIOINSTRUMENTATION – **SBM1402**

II Programming Techniques

VIS and sub-VIS, loops & charts, arrays, clusters, graphs, case & sequence structures, formula modes, local and global variable, string & file input. Publishing measurement data in the web.

2.1 Loops & Charts:

LabVIEW offers two loop structures namely, the For Loop and While Loop to control repetitive operation in a VI. A For Loop executes a specific number of times; a While Loop executes until a specified condition is no longer true.

- **The FOR Loop**

A For Loop executes the code inside its borders, called its sub diagram, for total of count times, where the count equals the value contained in the count terminal. The count can be set by wiring a value from outside the loop of the count terminal. If '0' is wired to the count terminal, the loop does not execute.The iteration terminal contains the current number of completed loop iterations; 0 during the first iteration, 1 during the second, and so on, up to N-1 (where N is the number of times the loop executes).

Fig 1: Structure Palette

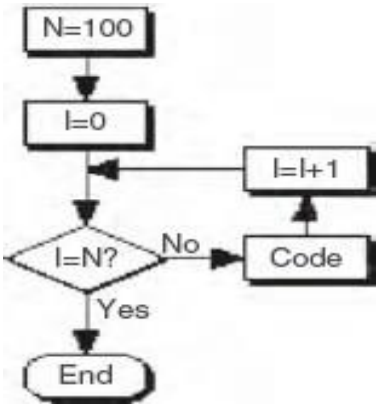

Fig 2: Flow chart of FOR loop

Fig 3: FOR Loop

The For Loop is located on the **Functions**->**All Functions**->**Structures**
The value in the count terminal (an input terminal), indicates how many times to repeat the sub diagram.
The iteration terminal (an output terminal), contains the number of iterations completed. The iteration count always starts at zero. During the first iteration, the iteration terminal returns 0.

- **The While Loop**

The While Loop executes the subdiagram inside its borders until the Boolean value wired to its conditional terminal is FALSE. LabVIEW checks the conditional terminal value at the end of iteration. If the value is TRUE, the iteration repeats. The default value of the conditional terminal is FALSE, so if left unwired, the loop iterates only once.

The While Loop is equivalent to the following pseudocode:

Do
Execute sub diagram
While condition is TRUE

It change the state that the conditional terminal of the While Loop checks, so that instead looping while true, we can have it loop unless it'strue. To do this, we pop-up on the conditional terminal, and select **"Stop ifTrue."**

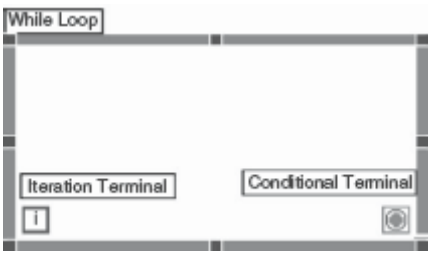

Fig 4: While loop terminals

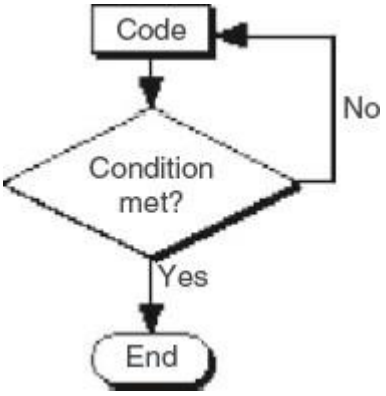

Fig 5: Flowchart of while loop

Do

Execute subdiagram

While condition is NOT TRUE

- The While Loop is located on the **Functions**>>**Execution Control** palette
- The section of code to be added inside the While loop is dragged or while loop encloses the area of code to be executed conditionally.

Condition Terminal

The While Loop executes the subdiagram until the conditional terminal, an input terminal, receives a specific Boolean value. The default behavior and appearance of the conditional terminal is **Stop If True**. When a conditional terminal is **Stop If True**, the While Loop executes its subdiagram until the conditional terminal receives a True value.

Iteration Terminal

The iteration terminal, an output terminal, contains the number of completed iterations. The iteration count always starts at zero. During the first iteration, the iteration terminal returns 0.

EXAMPLE 1

Problem statement: To find the sum of first 10 natural numbers using For Loop.

Block diagram construction:

– The For Loop is added from the structures sub palette on the functions Palette located on the block diagram.
– The count terminal is wired with the value 10 for 10 natural numbers.
– The iteration terminal is wired the greater than or equal to node from the Comparison subpalette from the Functions palette.
– The Boolean Output of the greater than or equal to is wired to the conditional terminal as in Fig.

Front panel construction:

– The control and indicator are added from the controls palette of the front panel. Using the labeling tool the Owned label is changed as input and output, respectively.
– The front panel with the result is shown in Fig. .

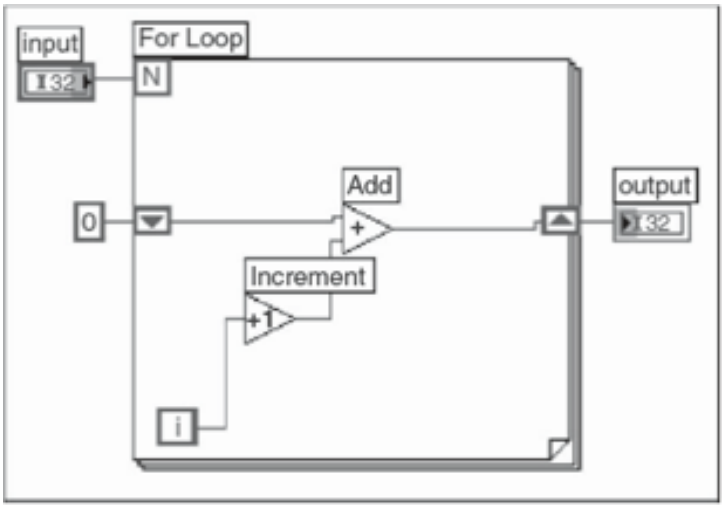

Fig 7: Block diagram of for loop example

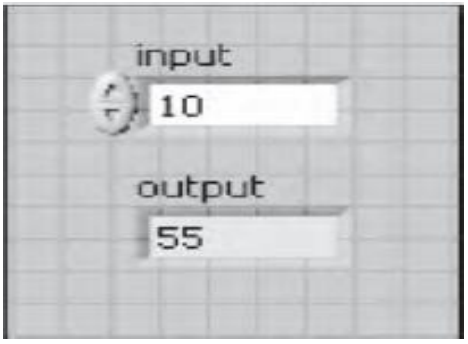

Fig 8: Front panel of For loop example

Example 2

Problem statement: To find the sum of first 10 natural numbers using while loop

Block diagram construction:

– The While Loop is added from the structures subpalette on the functions palette located on the block diagram.

– The count terminal is wired with the value 10 for 10 natural numbers.

– The iteration terminal is wired the greater than or equal to node from the comparison subpalette from the Functions palette.

– The Boolean Output of the greater than or equal to is wired to the conditional terminal of the While Loop as in Fig.

Front panel construction:

– The control and indicator are added from the controls palette of the front panel as in Fig. Using the labeling tool the Owned label is changed as input and output, respectively.

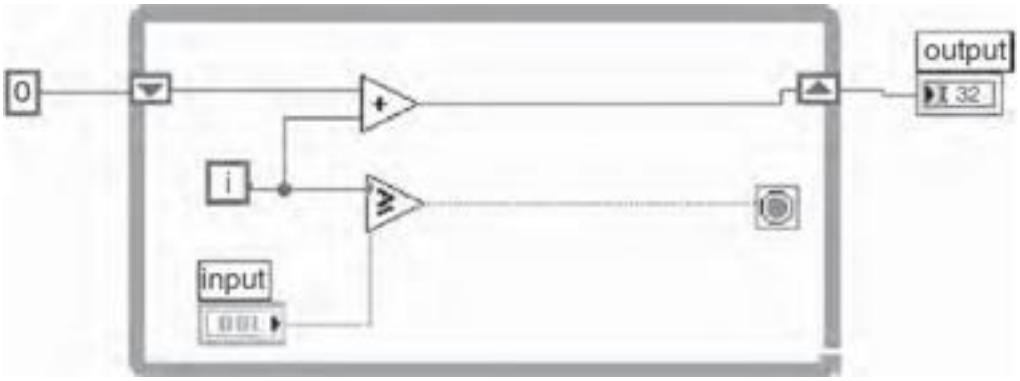

Fig 9: Block diagram of while loop for the above example

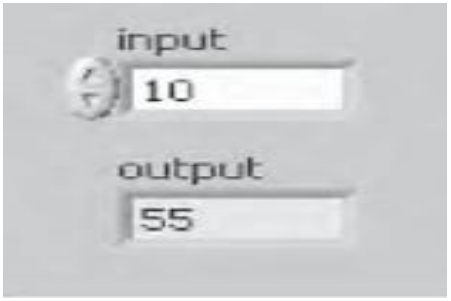

Fig 10: Front panel

2.2 Arrays:

A LabVIEW array is a collection of data elements that are all the same type similar to traditional programming languages. An array can have one or more dimensions, and has elements 2^{31}per dimension (memory permitting, of course). An array element can have any type except another array, a chart, or a graph.

Single and Multidimensional Arrays:

Single Dimensional Array:

Array elements are accessed by their indices; each element's index is in range 0 to N − 1, where N is the total number of elements in the array.The *first* element has index 0, the *second* element has index 1, and so on. Generally, waveforms are often stored in arrays, with each point in the waveform comprising an element of the array. Arrays are also useful for storing data generated in loops, where each loop iteration generates one element of the array.

Two steps are involved to make the controls and indicators for compound data types such as arrays and clusters.

Step 1. The array control or indicator known as the Array shell is created from the **Array** subpalette of the **Controls** palette available in the front panel
Step 2. The array shell is combined with a data object, which can be numeric, Boolean, or string (or cluster).Using the above two steps the created structure resembles

Index	0	1	2	3	4	5	6	7	8	9
10-element array	12	32	82	8.0	4.8	5.1	6.0	1.0	2.5	10

Fig11: Single Dimensional Array

Fig12: Array control and indicator

The user can also create array constants on the block diagram just like creating numeric, Boolean, or string constants. **Array Constant** can be chosen from the **Array** subpalette of the **Functions** palette. Then the data is placed in an appropriate data type (usually another constant) similar to that created on the front panel. This feature is useful when the user needs to initialize shift registers or provide a data type to a file or network functions. To clear an array control, indicator, or constant of data, the user can pop-on the index display.

Two-Dimensional Arrays

A two-dimensional, or 2D, array stores elements in a gridline fashion. It requires two indices to locate an element: a column index and a row index, both of which are zero-based in LabVIEW

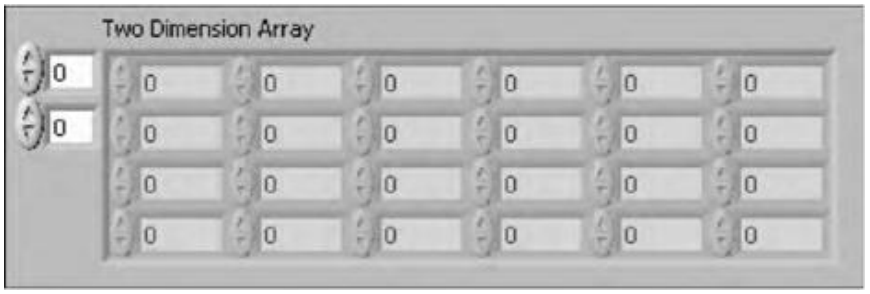

Fig13: 6*4 2D array

The user can add dimensions to an array control or indicator by popping up on its index display (not on the element display) and choosing **Add Dimension** from the Pop-up menu. In a 2D array of digital controls the user will have two indices to specify each element. The grid cursor of the Positioning tool can be used to expand the element display in two dimensions so that more elements can be seen. Unwanted dimensions can be removed by selecting **Remove Dimension** from the index display's Pop-up menu.

Creating Two-Dimensional Array

Two For Loops, one inside the other, can be used to create a 2D array on the front panel. The

inner For Loop creates a row, and the outer For Loop "stacks" these rows to fill in the columns of the matrix. In two For Loops creating a 2D array of random numbers using auto indexing

Autoindexing

The For Loop and the While Loop can index and accumulate arrays at their boundaries automatically, adding one new element for each loop iteration. This capability is called ***autoindexing***. One important thing to remember is that autoindexing enabled by default on For Loops but disabled by default on While Loops. The For Loop autoindexes, an array at its boundary. Each iteration creates the next array element. After the loop completes, the arraypasses out of the loop to the indicator; none of the array data are available until the Loop finishes. Notice that the wire becomes thicker as it changes to an array wire type at the Loop border.

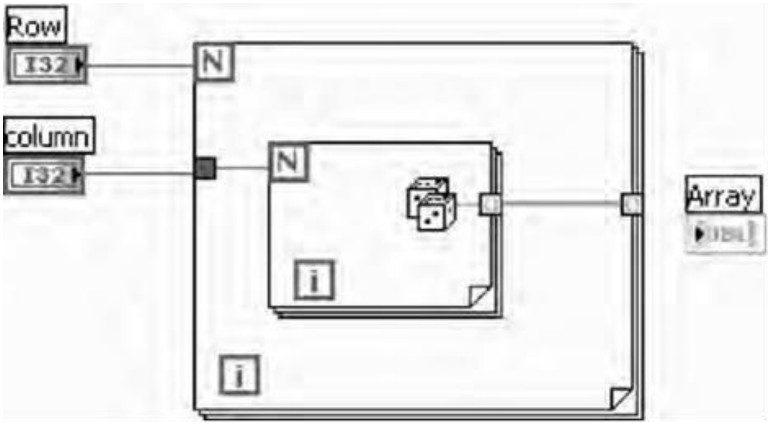

Fig14: For loop for creating 2 D array

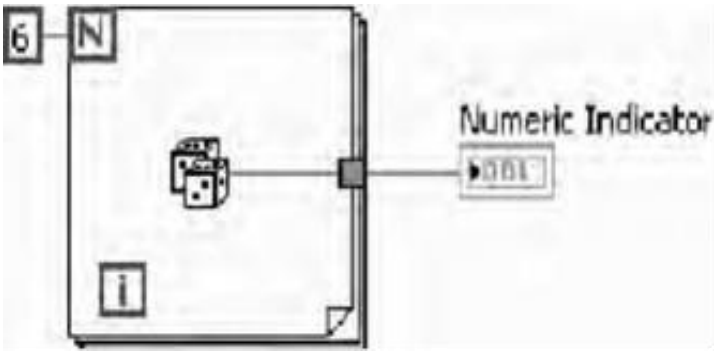

Fig15: Auto indexing disabled

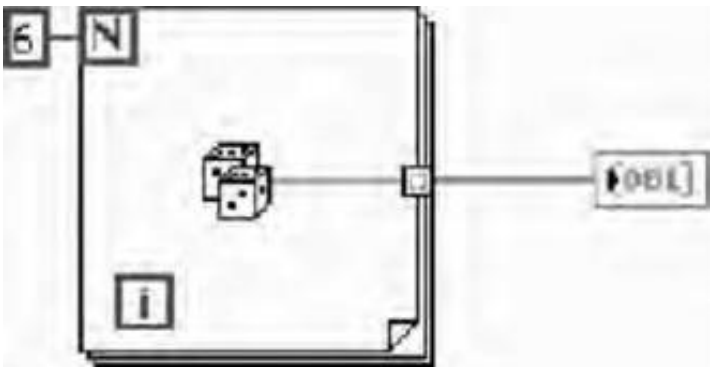

Fig16: Auto indexing enabled

To wire a scalar value out of a For Loop without creating an array, autoindexing must be disabled. This can be done by popping up on the tunnel (the square with the [] symbol) and choosing **Disable Indexing** from the tunnel's Pop-up menu. Since autoindexing is disabled by default, to wire array data out of a While Loop, the user must pop-up on the tunnel and select **Enable Indexing**. When autoindexing is disabled, only the last value returned from the **Random Number (0–1)** function passes out of the loop. Notice that the wire remains the same size after it leaves the loop. Pay attention to this wire size, because autoindexing is a common source of problems among beginners. Autoindexing also applies when the user is wiring arrays into loops. If indexing is enabled, the loop will index off one element from the array each time it iterates (note how the wire becomes thinner as it enters the loop). If indexing is disabled, the entire array passes in to the loop at once. Because For Loops are often used to process arrays, LabVIEW enables autoindexing by default when an array is wired into or out of them.

2.3 Clusters :

Cluster is a data structure that groups data. However, unlike an array, a cluster can group data of different types (i.e., numeric, Boolean, etc.); it is analogous to a struct in C or the data members of a class in C++ or Java.

Cluster elements can be accessed by *unbundling* them all at once or by indexing one at a time, depending on the function chosen; each method has its place. Unbundling a cluster is similar as unwrapping a telephone cable and having access to the different-colored wires. Unlike arrays, which can change size dramatically, clusters have a fixed size, or a fixed number of wires in them. The Unbundled By Name function is used to access specific cluster elements. Cluster terminals can be connected with a wire only if they have exactly the same type; in other words, both clusters must have the same number of elements, and corresponding elements must match in both data type and order. The principle of polymorphism applies to clusters as well as arrays, as long as the data types match.

Clusters are often used in error handling. The error clusters, **Error In.ctl** and **Error Out.ctl**, are used by LabVIEW to pass a record of errors between multiple VIs in a block diagram

Creating Cluster Controls and Indicators

A cluster is created by placing a **Cluster** shell (**Array & Cluster** subpalette of the **Controls** palette) on the front panel. Like arrays, objects can be added directly inside when they are pulled out from the **Controls** palette, or the user can drag an existing object into a cluster. **Objects inside a cluster mustbe all controls or all indicators**.

A cluster cannot have a combination of both controls and indicators; this is based on the status of the first object one place inside it. The cluster can be resized with the Positioning tool if necessary. The cluster can conform exactly to the size of the objects inside it, by popping up on the border(not inside the cluster) and choosing an option in the **Auto sizing** menu.

Creating Cluster Constants

If a cluster control or indicator is available on the front panel and if the user wants to create a cluster constant containing the same elements on the block diagram, then the user can either drag that cluster from the front panel to the block diagram or right-click the cluster on the front panel and select **Create**>>**Constant** from the shortcut menu.

Fig17: Cluster palette

Bundling Data

The **Bundle** function (**Cluster** palette) assembles individual components into a new cluster or allows us to replace elements in an existing cluster. The function appears as the icon at the left when one places it in the diagram window. Dragging a corner of the function with positioning tool can increase the number of inputs. When wired on each input terminal, a symbol representing the data type of the wired element appears on the empty terminal. The order of the resultant cluster will be the order of inputs to the **Bundle**. To create a new cluster the user need not wire an input to the center **cluster** input of the **Bundle** function. This needs to be wired only if elements are replaced in the cluster.

Fig18: Bundle Function

Unbundling Clusters

The **unbundled** function (**Cluster** palette) in Fig. 19 splits a cluster into each of its individual components. The output components are arranged fromtop to bottom in the same order they have in the cluster. If they have the same data type, the elements' order in the cluster is the only way to distinguish among them. Dragging a corner in the function with the Positioning tool can increase the number of outputs. The **Unbundled** function must be sized to contain the same number of outputs as there are elements in the input cluster, or it will produce bad wires. When an input cluster is wired to the correctly sized **Unbundled**, the previously blank output terminals will assume the symbols of the data types in the cluster example has been shown in Fig. LabVIEW does have a way to bundle and unbundled clusters using element names.

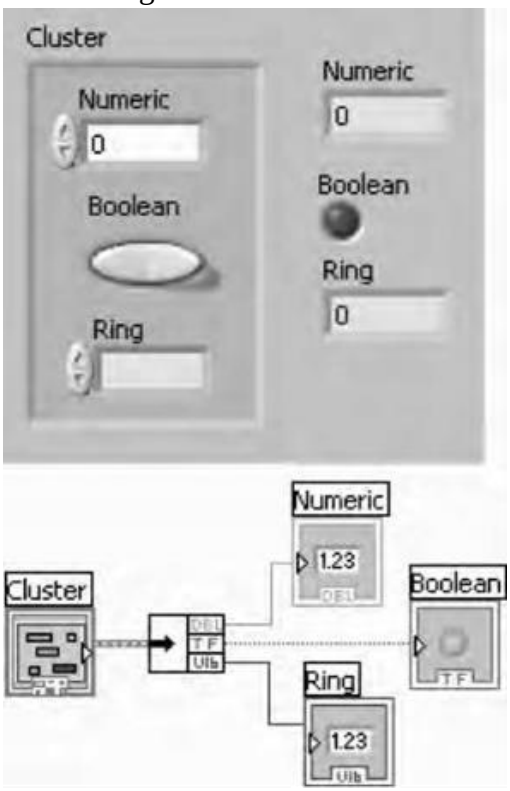

Fig19: Unbundle function

Bundling and Unbundling by Name

Sometimes there is no need to assemble or disassemble an entire cluster – the user just needs to operate on an element or two. This is accomplished using Bundle By Name and Unbundle By Name functions. Unbundle By Name, also located in the Cluster palette, returns elements whose name(s) are specified. There is no need to consider cluster order to correct Unbundle function size. The unbundle function is illustrated in Fig.

Bundle by Name, found in the Cluster palette, references elements by name instead of by position (as Bundle does). Unlike Bundle, we can access only the elements that are required. However, Bundle by Name cannot create new clusters; it can only replace an element in an existing cluster. Unlike Bundle, Bundle by Name's middle input terminal should be wired to allow the function know which element in the cluster has to be to replaced. This function is illustrated in Fig. All cluster elements should have owned labels when the By Name functions are used. As soon as

the cluster input of Bundle By Name or Unbundled By Name is wired, the name of the first element in the cluster appears in the name input or output.

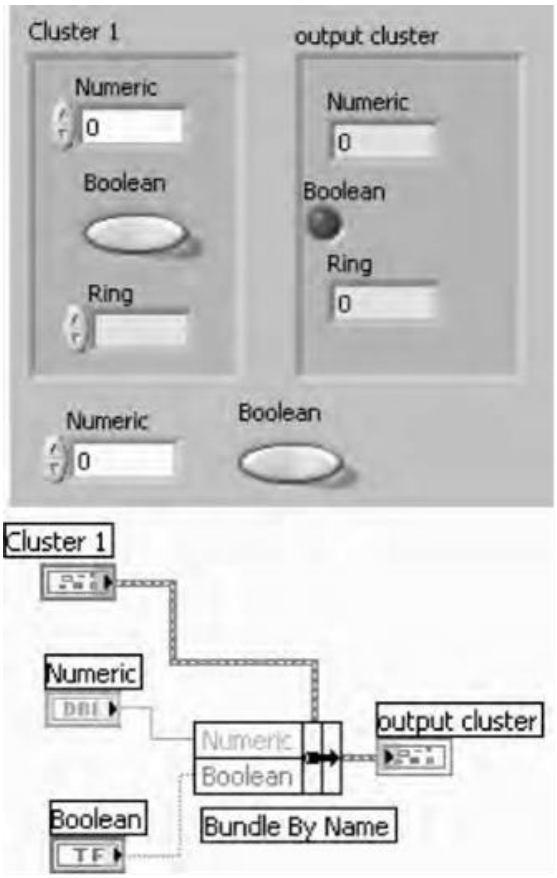

Fig20: Bundle by name

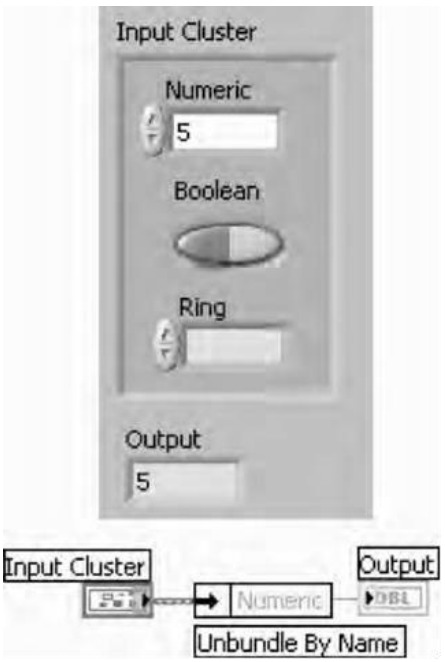

Fig21: Unbundle by name

2.4 Graphs:

The graphs located on the Controls_Graph Indicators palette include the waveform graph and XY graph. The waveform graph plots onlysingle-valued functions, as in $y = f(x)$, with points evenly distributed along the x-axis, such as acquired time-varying waveforms.

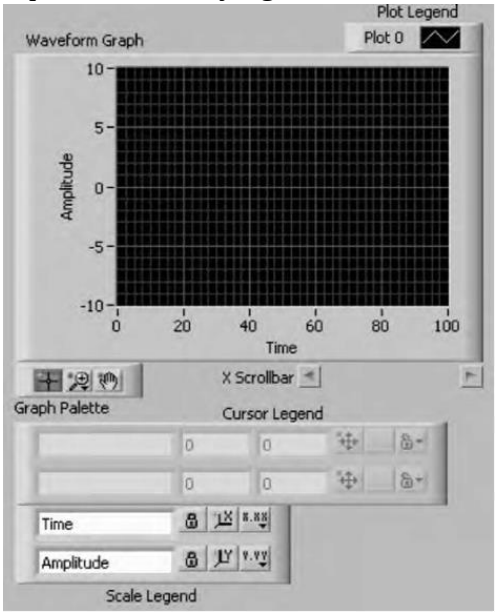

Fig 22: waveform graph

Single-Plot Waveform Graphs

The waveform graph accepts a single array of values and interprets the data as points on the graph and increments the x index by one starting at $x = 0$. The graph also accepts a cluster of an initial x value, and an array of y data.

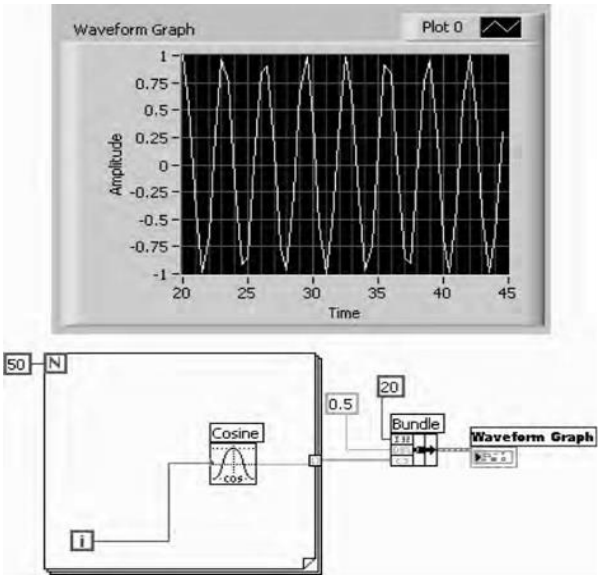

Fig 23: Single Plot Graph

Multiple-Plot Waveform Graphs

A multi plot waveform graph accepts a 2D array of values, where each row of the array is a single plot. The graph interprets the data as points on the graph and increments the *x* index by one, starting at $x = 0$. Wire a 2D array data type to the graph, right-click the graph, and select Transpose Array from the shortcut menu to handle each column of the array as a plot.

XY Graphs

XY graphs display any set of points, evenly sampled or not. Resize the plot legend to display multiple plots. Use multiple plots to save space on the front panel and to make comparisons between plots. XY and waveform graphs automatically adapt to multiple plots.

Single Plot XY Graphs

The single-plot XY graph accepts a cluster that contains an *x* array and a *y* array. The XY graph also accepts an array of points, where a point is a clusterthat contains an *x* value and a *y* value.

Multiplot XY Graphs

The multiplot XY graph accepts an array of plots, where a plot is a cluster that contains an *x* array and a *y* array. The multi plot XY graph also accepts an array of clusters of plots, where a plot is an array of points.

Waveform Charts

A plot is simply a graphical display of *X* versus *Y* values. Often, *Y* values in a plot represent the data value, while *X* values represent time. The waveform chart, located in the Graph subpalette of the Controls palette, is a special numeric indicator that can display one or more plots of data.

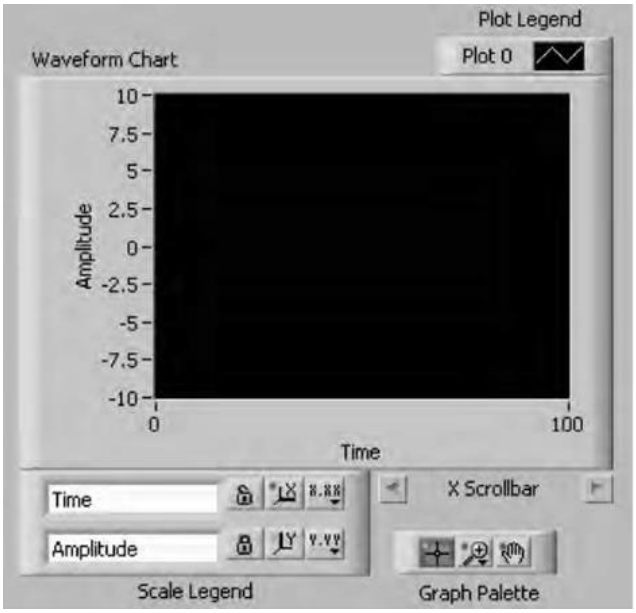

Fig24: Waveform chart and its component

Chart Update Modes

The waveform chart has three update modes – strip chart mode, scope chart mode, and sweep

chart mode. The update mode can be changed by poppingup on the waveform chart and choosing one of the options from the **Advanced**>>**update Mode**>>menu. Modes can be changed while the VI isrunning by selecting **Update Mode** from the chart's runtime Pop-up menu.The default mode is **Strip Chart**. The strip chart has a scrolling display similar to a paper strip chart . The scope chart and the sweep chart have retracing displays similar to that of an oscilloscope.

Strip Chart

A strip chart shows running data continuously scrolling from left to right across the chart.

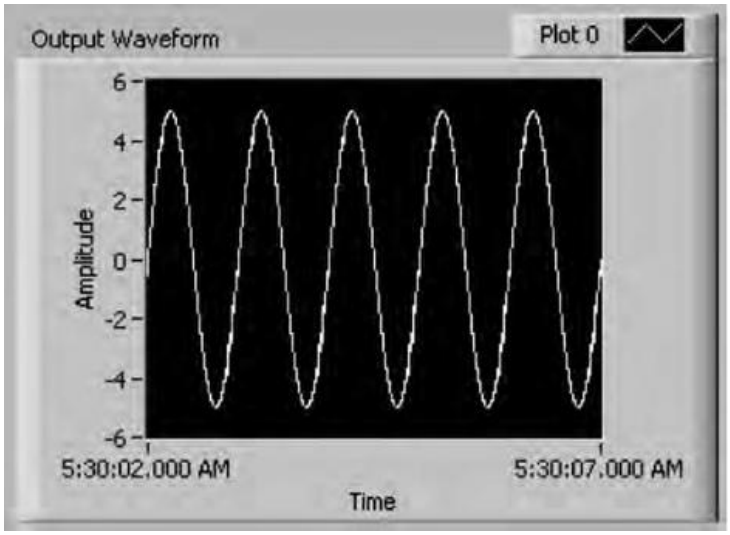

Fig:25 Strip chart

Scope chart:

A scope chart shows one item of data, such as a pulse or wave, scrolling part way across the chart

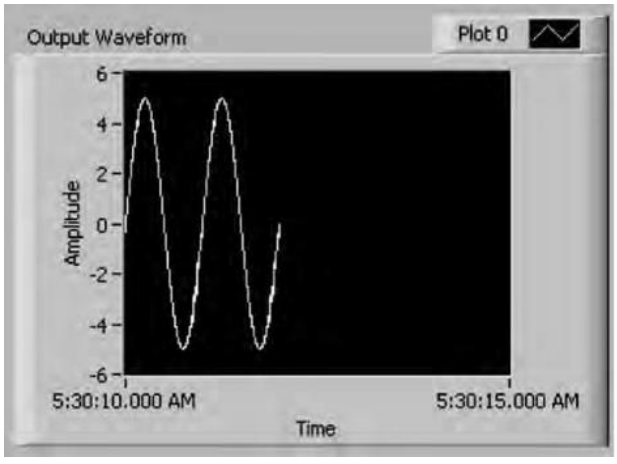

Fig: 26 Scope chart

Sweep Chart:

A sweep chart is similar to an EKG display. A sweep chart works similarly to a scope except it shows the older data on the right and the newer data on the left separated by a vertical line. The scope chart and sweep chart have retracing displays similar to an oscilloscope. Because there is less overhead in retracing a plot, the scope chart and the sweep chart display plots significantly faster than the strip chart.

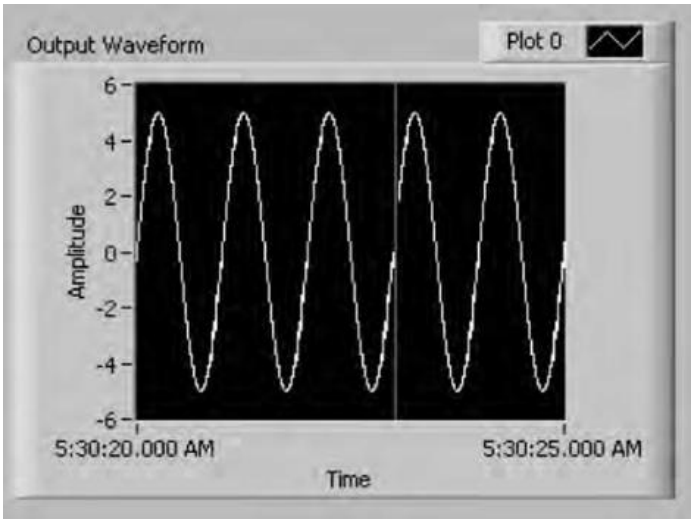

Fig:27 Sweep Chart

Wiring Charts

A scalar output can be wired directly to a waveform chart.

2.5 Strings

A string is a sequential collection of displayable or nondisplayable ASCII characters. Strings provide a platform-independent format for information and data. Often, strings may be used for displaying simple text message.

Some of the more common applications of strings include the following:

- Creating simple text messages.
- Passing numeric data as character strings to instruments and then converting the strings to numeric values.
- Storing numeric data to disk. To store numeric values in an ASCII file, the numeric values must be first converted to strings before writing the numeric values to a disk file.
- Instructing or prompting the user with dialog boxes. On the front panel, strings appear as tables, text entry boxes, and labels.

Creating String Controls and Indicators

The string control and indicator located on the Controls_Text Controls and Controls_Text Indicators palettes are used to simulate text entry boxes and labels. Using the Operating tool or labeling tool text data can betyped or edited in a string control. The Positioning tool is used to resize a frontpanel string object. The space occupied by a string object can be minimized byright-clicking the object and selecting the Visible Items_Scrollbar optionfrom the shortcut menu. The display types can be selected by right-clickinga string control or indicator on the front panel

String Functions

String Length returns the number of characters in a given string asshown in Fig 28.

Concatenate Strings concatenates all input strings into a single outputstring as shown in Fig 29.The function appears as the icon shown in block diagram in Fig 29.The function can be resized with the Positioning tool to increase the numberof inputs. In addition to simple strings, the user can also wire a 1D array ofstrings as input; the output will be a single string containing a concatenationof strings in the array.

String Subset accesses a particular section of a string. It returns the substringbeginning at offset and containing length which indicates the number

Fig:28 string length

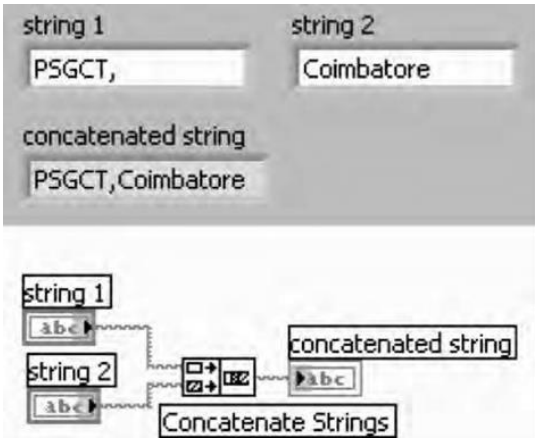

Fig 29: Concatenate Strings

Sequence Structures (Flat and Stacked Structures)

Determining the execution order of a program by arranging its elements ina certain sequence is called control flow. Visual Basic, C, and most other Fig. 30.

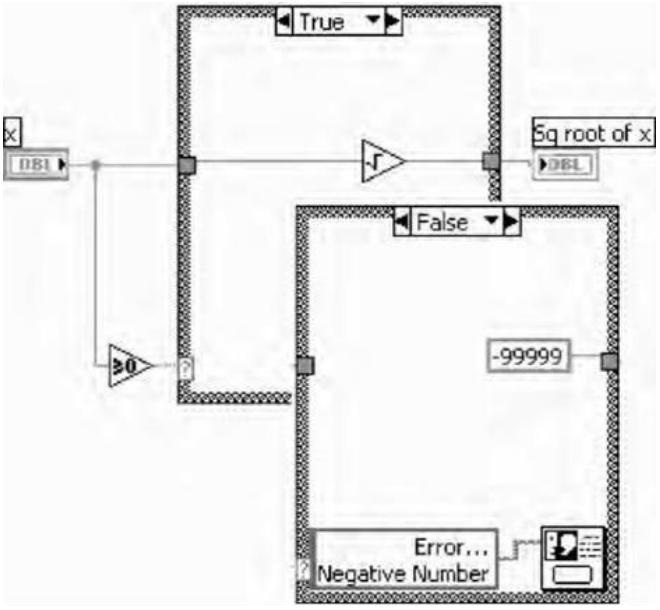

Fig30: Block diagram

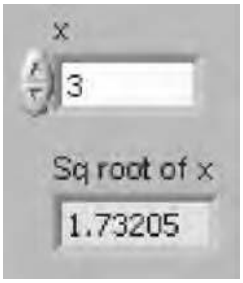

Fig 31: Front panel

procedural programming languages have inherent control flow because statementsexecutes in the order in which they appear in the program. LabVIEWuses the *Sequence Structure* to obtain control flow within a dataflow framework.A Sequence Structure executes frame 0, followed by frame 1,

then frame2, until the last frame executes. Only when the last frame completes dataleaves the structure.The Sequence Structure as shown in Fig. 30, looks like a frame of film.It can be found in the **Structures** subpalette of the **Functions** palette.Like the Case Structure, only one frame is visible at a time – the arrowsat the top of the structure can be selected to see other frames; or the topdisplay can be clicked to obtain a listing of existing frames, or the user canpop-up on the structure border and choose **Show Frame**. When a SequenceStructure is first dropped on the block diagram, it has only one frame; thus,it has no arrows or numbers at the top of the structure to designate whichframe is showing. New frames can be created by popping up on the structureborder and selecting **Add Frame After** or **Add Frame Before** as shownin Fig. 31.The Sequence Structure is used to control the order of execution of nodesthat are not data dependent on each other. Within each frame, as in the rest ofthe block diagram, data dependency determines the execution order of nodes.

2.6 The Formula Node

The *Formula Node* is a resizable box that is used to enter algebraic formulasdirectly into the block diagram. The Formula Node is a convenient text-basednode used to perform mathematical

operations on the block diagram. FormulaNodes are useful for equations that have many variables or are otherwisecomplicated and for using existing text-based code. The existing text-basedcode can be copied and pasted into a Formula Node rather than recreatingit graphically on the block diagram. This feature is found to be extremelyuseful when the user has a long formula to solve. For example, consider thefairly simple equation $y = x\square\square 3 + sin(x)$. Even for this simple formula, whenimplemented equation using regular LabVIEW arithmetic functions, the blockdiagram is a little bit harder to follow than the text equationsThe same equation can be implemented using formula node. With theFormula Node, the user can directly enter a formula or formulas, in lieu ofcreating complex block diagram subsections. The task is very simple; the usercan simply enter the formula inside the box. The input and output terminalsof the Formula Node can be created by popping up on the border of the nodeand choosing **Add Input** or **Add Output** from the Pop-up menu as illustrate
in Fig32. Then enter variable names into the input and output boxes.Names are case sensitive, and each formula statement must terminate witha semicolon (;). The equation is typed in the structure. Formula Nodes canalso be used for decision-making similar to case structure and select functiondiscussed in the previous sections.

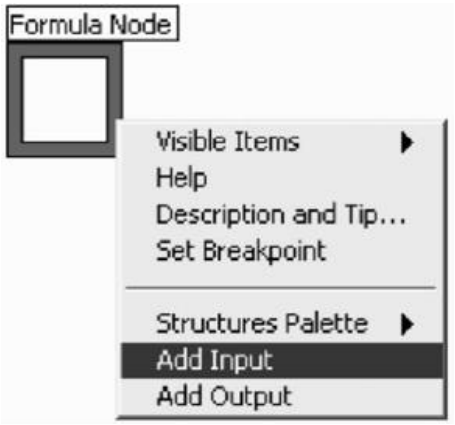

Fig32: Formula mode

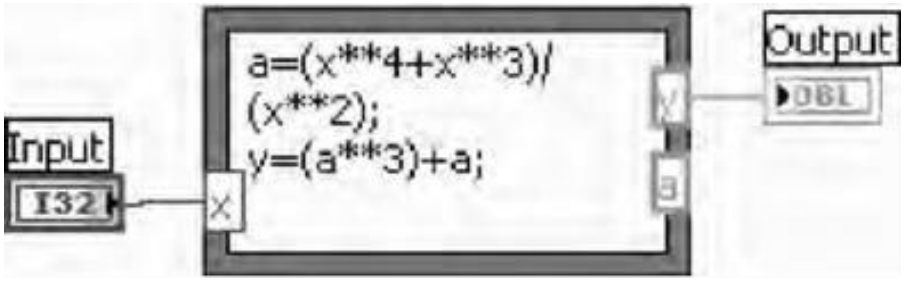

Fig33: Formula mode example

The inputis ‘x’ which is given as input to the Formula Node. The node computes thegiven function and returns the output in terms of ‘y’

2.7 Case Structures

The case structureis LabVIEW's method of executing conditional text, sort of like an"if–then–else"statement. It is located in the **Structures** subpalette of the **Functions** palette. The Case Structure, has two or more subdiagrams, orcases; only one of them executes, depending on the value of the Boolean,numeric, or string value wired to the *selector terminal*.If a Boolean value is wired to the selector terminal, the structure has twocases, FALSE and TRUE. If a numeric or string data type is wired to the selector, the structure can have from zero to almost unlimited cases. Initially only two cases are available, but number of cases can be easily added. More than one value can be specified for a case, separated by commas. In addition, the user can always select a "Default" case that will execute if the value wired to the selector terminal doesn't match any of the other cases. When a case structure is first placed on the panel, the Case Structure appears in its Boolean form; it assumes numeric values as soon as a numeric data type is wired to its selector terminal.Case Structures can have multiple subdiagrams, but the user can see only one case at a time, sort of like a stacked deck of cards. Clicking on the decrement(left) or increment (right) arrow at the top of the structure displays the previous or next subdiagram, respectively. The user can also click on the display at the top of the structure for a pull-down menu listing all cases, and then pop-up on the structure border and select **Show Case**. If a floating-point number is wired to the selector, LabVIEW rounds that number to the nearest integer value. LabVIEW coerces negative numbers to 0 and reduces any value higher than the highest-numbered case to equal the number of that case. The selector terminal can be positioned anywhere along the left border. If the data type wired to the selector is changed from a numeric to a Boolean, cases 0 to 1 change to FALSE and TRUE. If other cases exist (2 to n), Lab-VIEW does not discard them, in case the change in data type is accidental. However, these extra cases must be deleted before the structure can execute. For string data types wired to case selectors, the user should always specify the case values as strings between quotes.

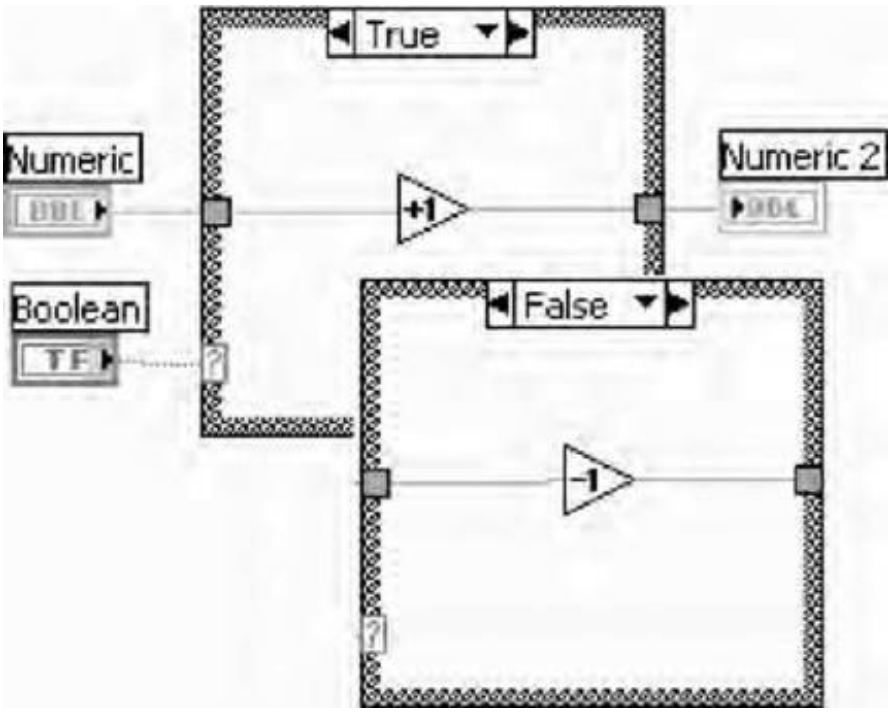

Fig 34: Boolean case structure

Boolean Case Structure

The following example is a Boolean Case structure shown in Fig34. The cases are shown overlapped to simplify the illustration. If the Boolean controlwired to the selector terminal is True, the VI increments the numeric value. Otherwise, the VI decrements the numeric value.

Integer Case Structure

The following example is an integer Case structure shown in Fig35. **Integer** is a text ring control located on the **Controls_Text Controls** palette that associates numeric values with text items. If the text ring control wired to the selector terminal is 0 (add), the VI decrements the numeric values. If the value is 1 (subtract), the VI increments the numeric values. If the text ring control is any other value than 0 (add) or 1 (subtract), the VI adds the numeric values, because that is the default case.

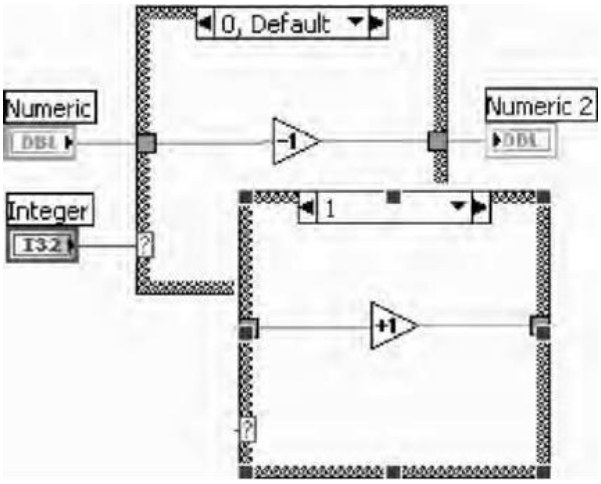

Fig 35: Integer Case Structure

String Case Structure

The following example is a string Case structure as shown in Fig36. If**String** is “Increment,” the VI increments the numeric values. If **String** is “Decrement,” the VI decrements the numeric values.

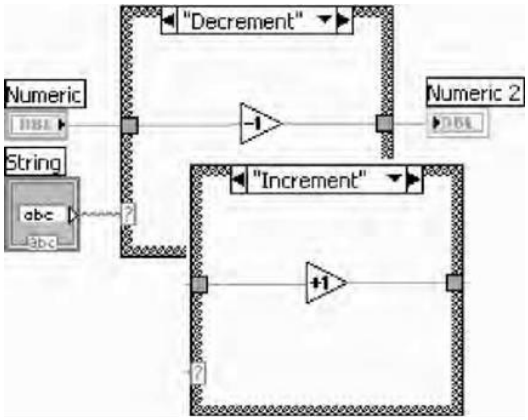

Fig 36: string case

Enumerated Case Structure

The following example is an enumerated Case structure as shown in Fig.37 An enumerated control gives users a list of items from which to select.

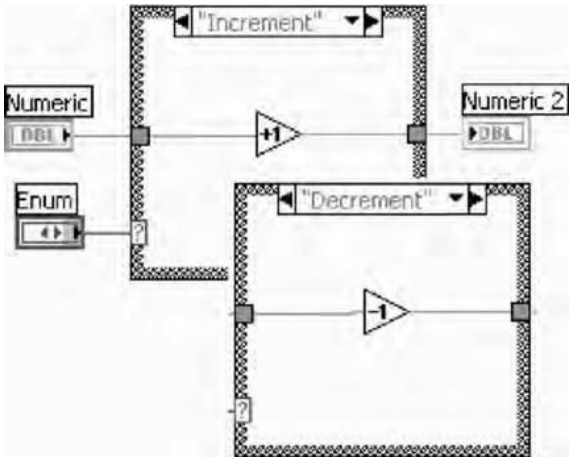

Fig:37 Enumerated case

The data type of an enumerated control includes information about the numeric values and string labels in the control. When an enumerated control is wired to the selector terminal of a Case structure, the case selector displays acase for each item in the enumerated control. The Case structure executes the appropriate case subdiagram based on the current item in the enumerated control. If Enum is “Increment,” the VI increments the numeric values. If Enum is “Decrement,” the VI decrements the numeric values.

Error Case Structure

When an error cluster is wired to the selector terminal of a Case structure, the case selector label displays two cases, Error and No Error, and the border of the Case structure changes color – red for Error and green for No Error. The Case structure executes the appropriate case subdiagram based on the error state. When an error cluster is wired to the selection terminal, the Case structure recognizes only the **status** Boolean of the cluster.

SEQUENCE STRUCTURES

A sequence structure contains one or more subdiagrams, or frames, that execute in sequential order. Within each frame of a sequence structure, as in the rest of the block diagram, data Dependency determines the execution order of nodes. There are two types of sequence structure the Flat Sequence structure and the Stacked Sequence structure. The Flat Sequence structure, shown as follows, displays all the frames at once and executes the frames from left to right and when all data values wired to a frame are available, until the last frame executes. The data values leave each frame as the frame finishes executing. Use the Flat Sequence structure to avoid using sequence locals and to better document the block diagram. When you add or delete frames in a Flat Sequence structure, the structure resizes automatically. To convert a Flat Sequence structure to a Stacked Sequence structure, right-click the Flat Sequence structure and select Replace with Stacked Sequence from the shortcut menu. If you change a Flat Sequence to a Stacked Sequence and then back to a Flat Sequence,

LabVIEW moves all input terminals to the first frame of the sequence. The final Flat Sequence should operate the same as the Stacked Sequence. After you change the Stacked Sequence to a Flat Sequence with all input terminals on the first frame, you can move wires to where they were located in the original Flat Sequence.

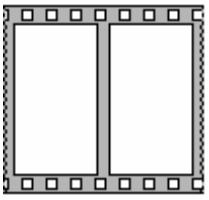

Fig:38 Flat sequence

Stacked Sequence Structure

The Stacked Sequence structure, shown as follows, stacks each frame so you see only one frame at a time and executes frame 0, then frame 1, and soon until the last frame executes. The Stacked Sequence structure returns data only after the last frame executes. Use the Stacked Sequence structure if you want to conserve space
on the block diagram. To convert a Stacked Sequence structure to a Flat Sequence structure, right-click the Stacked Sequence structure and select Replace»Replace with Flat Sequence from the shortcut menu. The sequence selector identifier, shown as follows, at the top of the Stacked Sequence structure contains the
current frame number and range of frames. Use the sequence selector identifier to navigate through the available frames and rearrange frames. The frame label in a Stacked Sequence structure is similar to the case selector label of the Case structure. The frame label contains the frame number in the center and decrement and increment arrows on each side. Click the decrement and increment arrows to scroll through the available frames. You also can click the down arrow next to the frame number and select a frame from thepull-down menu. Right-click the border of a frame, select Make This Frame, and select a framenumber from the shortcut menu to rearrange the order of a Stacked Sequence structure. Unlike the case selector label, you cannot enter values in the frame label. When you add, delete, or rearrange frames in a Stacked Sequence structure, LabVIEW automatically adjusts the numbers in the frame labels. To pass data from one frame to any subsequent frame of a Stacked Sequence structure, use a sequence local terminal shown .An outward-pointing arrow appears in the sequence local terminal of the frame that contains the data source. The terminal in subsequent frames contains an inward-pointing arrow, indicating that the terminal is a data source for that frame. You cannot use the sequence local terminal in frames that precede the first frame where you wired the sequence local.

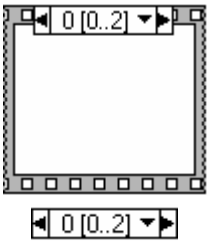

Fig 39: Stacked Structure

BASICS OF FILE INPUT/OUTPUT

File I/O records or reads data in a file. File I/O operations pass data to and from files. Use the fileI/O VIs and functions located on the Functions->All Functions»File I/O palette to handle all aspects of file I/O, including the following:

- Opening and closing data files
- Reading data from and writing data to files
- Reading from and writing to spreadsheet-formatted files
- Moving and renaming files and directories
- Changing file characteristics
- Creating, modifying and reading configuration files

LabVIEW can use or create the following file formats: Binary, ASCII, LVM, and TDM.

- **Binary**—Binary files are the underlying file format of all other file formats.
- **ASCII**—An ASCII file is a specific type of binary file that is a standard used by most programs. It consists of a series of ASCII codes. ASCII files are also called text files.
- **LVM**—The LabVIEW measurement data file (.lvm) is a tab-delimited text file you can open with a spreadsheet application or a text-editing application. The .lvm file includes information about the data, such as the date and time the data was generated. This file format is a specific type of ASCII file created for LabVIEW.
- **TDM**—This file format is a specific type of binary file created for National Instruments products. It actually consists of two separate files: an XML section contains the data attributes and a binary file for the waveform.

Use of Text Files

Use text format files for your data to make it available to other users or applications, if disk space and file I/O speed are not crucial, if you do not need to perform random access reads or writes, and if numeric precision is not important. Text files are the easiest format to use and to share. Almost any computer can read from or write to a text file.

Use of Binary Files

Storing binary data, such as an integer, uses a fixed number of bytes on disk. For example, storingany number from 0 to 4 billion in binary format, such as 1, 1,000, or 1,000,000, takes up 4 bytesfor each number. Use binary files to save numeric data and to access specific numbers from a fileor randomly access numbers from a file. Binary files are machine readable only, unlike text fileswhich are human readable. Binary files are the most compact and fastest format for storing data.

Use of Datalog Files

Use datalog files to access and manipulate data only in LabVIEW and to store complex data structures quickly and easily. A datalog file stores data as a sequence of identically structured records, similar to a spreadsheet, where each row represents a record. Each record in a datalog File must have the same data types associated with it. LabVIEW writes each record to the file as acluster containing the data to store.

A typical file I/O operation involves the following process,

1. Create or open a file. Indicate where an existing file resides or where you want to create a new file by specifying a path or responding to a dialog box to direct LabVIEW to the file location. After

the file opens, a refnum represents the file.
2. Read from or write to the file.
3. Close the file.
File I/O VIs and some File I/O functions, such as the Read from Text File and Write to Text File functions, can perform all three steps for common file I/O operations. The VIs and functions designed for multiple operations might not be as efficient as the functions configured or designed for individual operations.

LOCAL VARIABLES

- Local variables transfer data within a single VI and allow data to be passed between parallel loops
- They also break the dataflow programming paradigm.

Two ways to create
a local variable are right-click on an object's terminal and select Create->Local Variable.

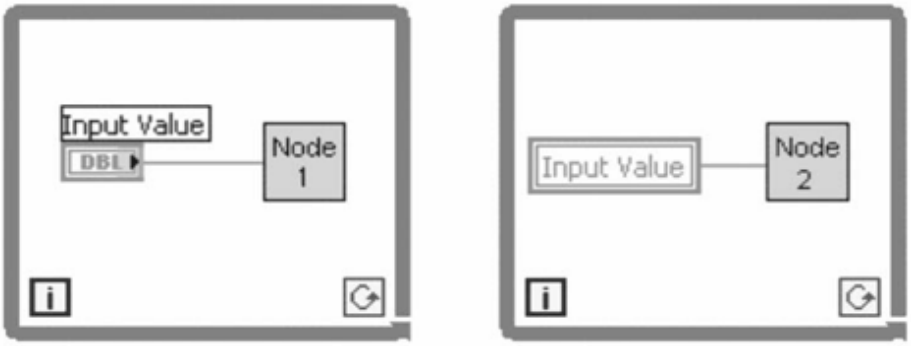

Fig 40: Local Variable

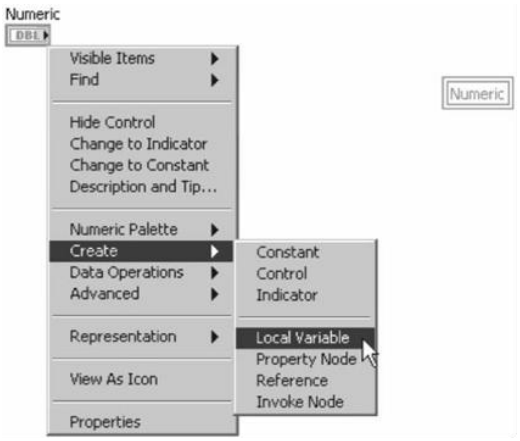

Fig41: Creating local variable

Another way is to select the Local Variable from the Structures palette. Create the front panel and select a local variable from the Functions palette and place it on the block diagram. The local variable node, shown as follows, is not yet associated with a control or indicator. To associatea local variable with a control or indicator, right-click the local variable node and select Select Item from the shortcut menu.

GLOBAL VARIABLES

- Global variables are built-in LabVIEW objects.

- use variables to access and pass data among several VIs that run simultaneously
- A local variable shares data within a VI; a global variable also shares data, but it shares data with multiple VIs.

For example, suppose you have two VIs running simultaneously. Each VI contains a While Loop and writes data points to a waveform chart. The first VI contains a Boolean control to terminate both VIs. You can use a global variable to terminate both loops with a single Boolean control as shown in Figure . If both loops were on a single block diagram within the same VI, you could use a local variable to terminate the loops.

When you create a global variable, LabVIEW automatically creates a special global VI, which has a front panel but no block diagram. Add controls and indicators to the front panel of the global VI to define the data types of the global variables. Select a global variable as shown inFigure42 .from the *Functions* palette and place it on the block diagram. Double-click the global variable node to display the front panel of the global VI. Place controls and indicators on this front panel the same way you do on a standard front panel. LabVIEW uses owned labels to identify global variables, so label the front panel controls and indicators with descriptive owned labels.

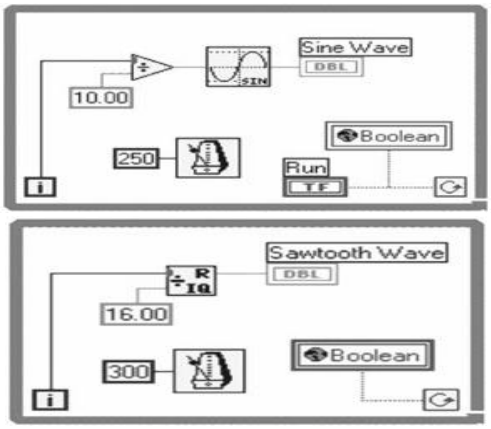

Fig:42 Global Variable

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3. Skolkoff, Basic concepts of LABVIEW 4, PHI, 1998

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UNIT – III-VIRTUAL BIOINSTRUMENTATION – SBM1402

III Data Acquisition

Data acquisition basics: Introduction to data acquisition on PC, Sampling fundamentals, Input/Output techniques and buses. ADC, DAC, Digital I/O, counters and timers, DMA, Software and hardware installation, Calibration, Resolution, Data acquisition interface requirements.

3.1 Introduction to data acquisition on PC

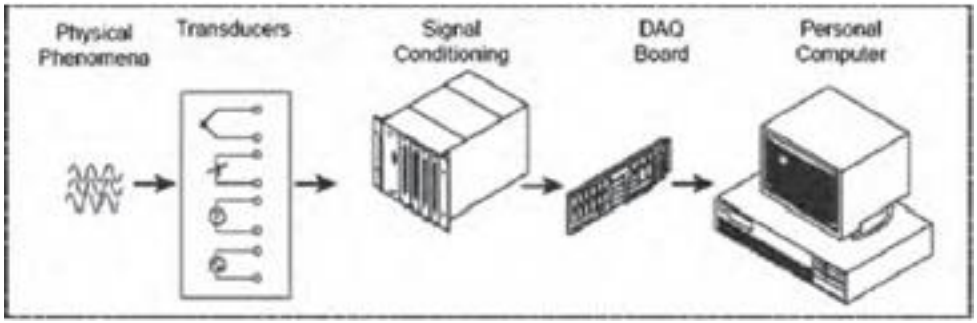

Fig 1:A general PC-based DAQ system with signal conditioning

PC-based data acquisition (DAQ) systems and plug-in boards are used in awide range of applications in the laboratory, in the field, and on the manufacturing plant floor. Typically, DAQ plug-in boards are general-purpose data acquisition instruments that are well suited for measuring voltage signals. However, many real-world sensors and transducers output signals that must be conditioned before a DAQ board can effectively and accurately acquire the signal. This front-end preprocessing, which is generally referred to as *signal conditioning*, includes functions such as signal amplification, filtering, electrical isolation, and multiplexing. In addition, many transducers require excitation currents or voltages, bridge completion, linearization, or high amplification for proper and accurate operation. Therefore, most PC-based DAQ systems include some form of signal conditioning in addition to the plug-in DAQ board and personal computer, as shown in Fig. 1.An instrument may be defined as a device or a system, which is designed to maintain a functional relationship between prescribed properties of physical variables and must include ways and means of communication to a human observer. The functional relationship remains valid only as long as the static calibration of system remains constant. On the other hand, the performance of a measurement system can be described in terms of static and dynamic characteristics. It is possible and desirable to describe the operation of a measuring instrument or a system in a generalized manner without resorting to intricate details of the physical aspects of a specific instrument or a system. The whole operation can be described in terms of functional elements. Most of the measurement systems contain three main functional elements such as the primary sensing element, variable conversion element, and data presentation element. Each functional element is made up of a distinct component or groups of components, which perform the required and definite steps in the measurement. These may be taken as basic elements, whose scope is determined by their functioning rather than their construction. Primary sensing element. The quantity under measurement makes its first contact with the primary sensing element of a

measurement system. In other words the measurand is first detected by primary sensor. This act is then immediately followed by the conversion of measurand into an analogous electrical signal performed by a transducer. A transducer in general, is defined
as a device which converts energy from one form to another. But in Electrical measurement systems, this definition is limited in scope. A transducer is defined as a device which converts a physical quantity into an electrical quantity. The physical quantity to be measured, in the first place is sensed and detected by an element which gives the output in a different analogous form. This output is then converted into an electrical signal by a transducer. This is true of most of the cases but is not true for all. In many cases the physical quantity is directly converted into an electrical quantity by a transducer. The first stage of a measurement system is known as a detector transducer stage. Variable conversion element. The output of the primary sensing element may be electrical signal such as a voltage, a frequency or some other electrical parameter. Sometimes this output is not suited to the system. For the instrument to perform the desired function, it may be necessary to convert this output to some other suitable form while preserving the information content of the original signal. For example, suppose output is in analog form and the next stage of the system accepts input signals only in digital form and therefore, an A/D converter will have to be used for converting signals from A/D form for them to be acceptable for the next stage of the system. Variable manipulation element. The function of this element is to manipulate the signal presented to it preserving the original nature of the signal. Manipulation here means only a change in numerical value of the signal. For example, an electronic amplifier accepts a small voltage signal as input and produces an output signal which is also voltage but of greater magnitude. Thus voltage amplifier acts as a variable manipulation element. It is not necessary that a variable manipulation element should follow the variable conversion element as shown in Fig.
It may precede the variable conversion element in many cases. In case, the voltage is too high, attenuators are used which lower the voltage or power for the subsequent stages of the system. As discussed earlier, the output of transducer contains information needed for further processing by the system and the output signal is usually a voltage or some other form of electrical signal. The two most important properties of voltage are its magnitude and frequency though polarity may be a consideration in some cases. Many transducers develop low voltages of the order

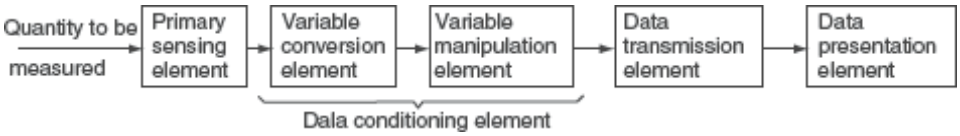

Fig 2: Functional elements of an instrumentation system

of mV and some even μV. A fundamental problem is to prevent this signal being contaminated by unwanted signals like noise due to an extraneous source which may interfere with the original output signal. Mother problem is that a weak signal may be distorted by processing equipment. The signal after being sensed cannot transmitted to the next stage without removing the interfering sources, as otherwise highly distorted results may be obtained which far from true. Many a times it becomes necessary to perform certain operations on the signal before it is

transmitted further. These processes may be linear like amplification, attenuation, integration, differentiation, addition and subtraction. Some nonlinear processes like modulation, detection, sampling, filtering, chopping and clipping, etc. are also performed on the signal to bring it to the desired form to be accepted by the next stage of measurement system. This process of conversion is called Signal Conditioning. The term signal conditioning includes many other functions in addition to variable conversion and variable manipulation. In fact the element that follows the primary sensing element in any instrument or measurement system is called Signal Conditioning Element. When the elements of an instrument are actually physically separated, it becomes necessary to transmit data from one to another. The element that performs this function is called a Data Transmission Element. For example, space-crafts are physically separated from the earth where the control stations guiding their movements are located. Therefore control signals are sent from these stations to space-crafts by complicated telemetry systems using radio signals. The signal conditioning and transmission stage is commonly known as Intermediate Stage.

In the signal conditioning stage, the signals are passed through a slew of steps like:

- Amplification
- Rectification
- Filtering
- Scaling

Data presentation element. The information about the quantity under measurement has to be conveyed to the personnel handling the instrument or the system for monitoring, control, or analysis purposes. The information conveyed must be in a form intelligible to the personnel or to the intelligent instrumentation system. This function is done by data presentation element. In case data is to be monitored, visual display devices are needed. These devices may be analog or digital indicating instruments like ammeters, voltmeters, etc. In case the data is to be recorded, recorders like magnetic tapes ,high speed camera and TV equipment, storage type C.R.T, printers, analog and digital computers, or microprocessors may be used. For control and analysis purpose microprocessors or computers may be used. The final stage in a measurement system is known as terminating stage. As an example of a measurement system, consider the simple bourdon tube

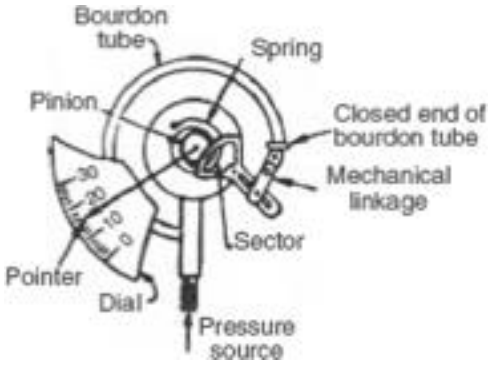

Fig 3:Bourdon tube pressure gauge

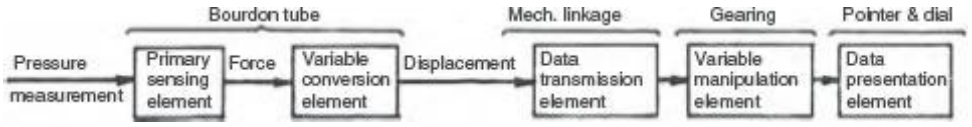

Fig 4:Schematic diagram of a Bourdon tube pressure gauge

Pressure gauge as shown in Fig. 3. This gauge offers a good example of a measurement system. In this case the bourdon tube acts as the primary sensing element and a variable conversion element. It senses the input quantity (pressure in this case). On account of the pressure the closed end of the bourdon tube is displaced. Thus the pressure is converted into a small displacement. The closed end of the bourdon tube is connected through mechanical linkage to a gearing arrangement. The gearing arrangement amplifies the small displacement and makes the pointer to rotate through a large angle. The mechanical linkage thus acts as a data transmission element while the gearing arrangement acts as a data manipulation element. The final data presentation stage consists of the pointer and dial arrangement; which when calibrated with known pressure inputs, gives an indication of the pressure signal applied to the bourdon tube. The schematic diagram of this measurement system is given in Fig. 4.When a control device is used for the final measurement stage, it is necessary to apply some feedback to the input signal to accomplish the control objectives. The control stage compares the signal representing the measured variable with a reference signal of the same form. This reference signal has a value the measured signal should have and is presented to a controller. If the measured signal agrees with the reference value, the controller does nothing. However, if there is a difference between the measured value and the reference value, an error signal is generated. Thus the controller sends a signal to a device which acts to alter the value of the measured signal. Suppose the measured variable is flow of a liquid, then the control device is a motorized valve placed in the flow system. In case the measured flow rate is too low than the preset flow rate, then the controller would cause the valve to open, thereby increasing the flow rate. If on the other hand, the flow rate were too high, the valves are closed. The operation of closing or opening of valve will cease when the output flow rate is equal to preset value of flow rate. The physical phenomenon, which is the signal from external world, faces signal abnormalities, so these have to be rectified in order to make the signal more effective.

3.2 Sampling fundamentals

A fundamental rule of sampled data systems is that the input signal must be sampled at a rate greater than twice the highest frequency component in the signal. This is known as the Nyquistcriterion. Stated as a formula, it requires that fs/2 >fa, where fs is the sampling frequency and fa is the signal being sampled. Violating the Nyquist criteria is called under sampling, and results in aliasing.

Filtering and Averaging

To get rid of aliasing, a type of low-pass filter has to be used, known as an anti-aliasing filter. Analog filters are absolutely mandatory, regardless of the sampling rate, unless the signal's frequency characteristics are known

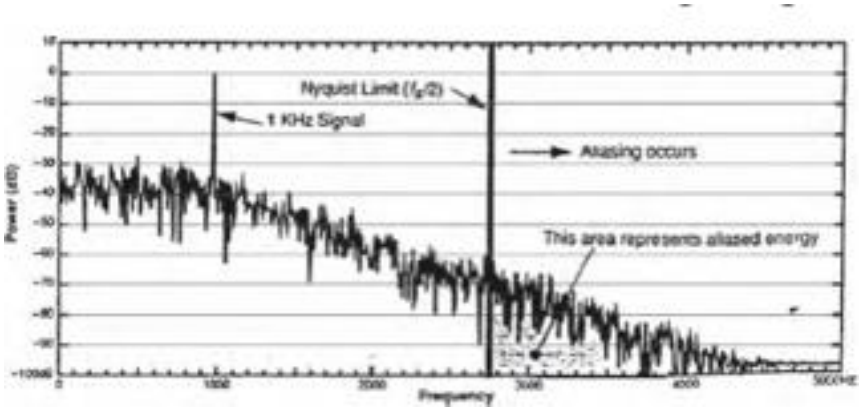

Fig 5:Power spectrum of a 1 kHz sine wave with low pass-filtered noise added

.In order to limit the bandwidth of the raw signal to *fs*/2 an analog filter isused. The analog filter can be in the transducer, the signal conditioner, on the A/D board, or in all three sections. The filter is usually made up of resistors, capacitors, and sometimes, operational amplifiers, in which case it is called an active filter. One problem with analog filters is that they are very complex and expensive. If the desired signal is fairly close to the Nyquist limit, the filter needs to cut off very quickly, which requires lots of stages, which depends on the order of the filter .Digital filters can augment, but cannot replace, analog filters. Digital filter VIs is included with the LabVIEW analysis VIs, and they are functionally equivalent to analog filters. The simplest type of digital filter is a moving averager, which has the advantage of being usable in real-time on a sample by-sample basis. One way to simplify the anti-aliasing filter problem is to oversample the input. If the A/D hardware is fast enough, the sampling rate is first increased and then a digital filter is used to eliminate the higher frequencies that are of no interest. This makes the analog filtering design problem simpler because the Nyquist frequency has been raised much higher, so the analog filter need not be sharp. The signal has to be sampled at a rate high enough to avoid significant aliasing with a modest analog filter, but sampling at too high rate may not be practical because the hardware is too expensive and extra data may overload the CPU. Figure 4.9 illustrates the occurrence of aliasing in a 1 kHz sine wave with low pass filtered noise in it. A potential problem with averaging comes up while handling nonlinear data. The process of averaging is defined to be the summation of several values, divided by the number. If the main concern is rejecting 60 Hz line frequency interference, an old trick is to grab an array of samples over one line period (16.66 ms). This should be done for every channel. Using plug-in boards with LabVIEW's data acquisition drivers, the user can adjust the sampling interval with high precision, making this a reasonable option. First, a simple experiment is set to acquire and average data from a noisy input. The sampling period is varied and checked for a null noise at each 16.66 ms multiple there is an attempt to average recurrent waveforms to reduce noise, the arrays of data that are acquired must be perfectly in-phase

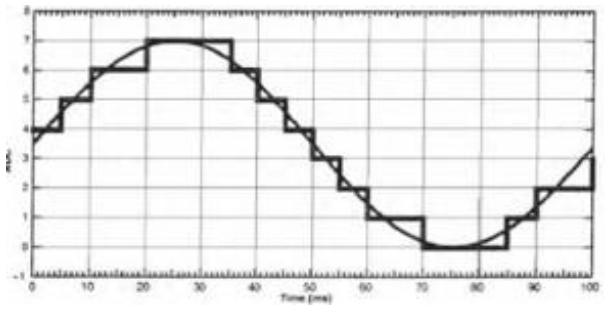

Fig 6:A sine wave and its representation by a 3-bit ADC sampling every 5 ms.

If a phase shift occurs during acquisition, then the waveforms will partially cancel each other or distort in some other way. Triggered data acquisition is the normal solution because it helps to guarantee that each buffer of data is acquired at the same part of the signal's cycle. Some other aspects of filtering that may be important to some of the applications are impulse response and phase response. For ordinary datalogging, these factors are generally ignored. But if the user is doing dynamictesting like vibration analysis, acoustics, or seismology, impulse and phase response can be very important. As a rule of thumb, when filters becom every complex (high-order), they cutoff more sharply, have more radical phase shifts around the cutoff frequency, and (depending on the filter type) exhibit ringing on transients. The best way to analyze filtering needs is to use a spectrum analyzer since we are able to know exactly what signals are present and what has to be filtered out. Some common methods used for filtering are:– A dedicated spectrum analyzer instrument (very expensive)– A digital oscilloscope with FFT capability (LabVIEW computes the power spectrum)

- Even a multifunction I/O board running as fast as possible with LabVIEW doing the power spectrum. Looking at the power spectrum in Fig. 4.10, some of the noise power is above the floor for the ADC and is also at frequencies above 2.75 kHz. This little triangle represents aliased energy and gives the user a qualitative feel for how much contamination the user can expect. It depends on the nature of the out-of-band noise.

3.3 Analog-to-Digital Control (ADC)

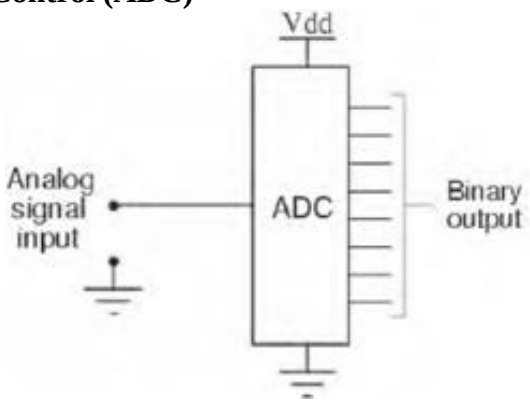

Fig 7:Analog-to-digital converter

Connecting digital circuitry to sensor devices is simple if the sensor devices are inherently digital in nature. witches, relays, and encoders are easily interfaced with gate circuits due to the

on/off nature of their signals. However, when analog devices are involved, interfacing becomes much more complex. Some mechanism is needed to electronically translate analog signals into digital(binary) quantities, and visa-versa. An analog-to-digital converter, or ADC, performs the former task while a digital-to-analog converter, or DAC, performs the latter. An ADC inputs an analog electrical signal such as voltage or current and outputs a binary number. In block diagram form, it can be representedas shown in Fig. 7.

Understanding Integrating ADCs:

Integrating ADCs provide high resolution A/D conversions, with good noise rejection. These ADCs are ideal for digitizing low band width signals, and are used in applications such as digital multimeters and panel meters. They often include LCD or LED drivers and can be used stand alone without a microcontroller host. The following section explains how integrating ADCs work. Discussions include single-, dual- and multislope conversions. Also, an in-depth analysis of the integrating architecture will be discussed. Finally a comparison against other ADC architectures will aid in the understanding and selection of integrating ADCs. Integrating analog-to-digital converters (ADCs) provide high resolution and can provide good line frequency and noise rejection. Having started with the ubiquitous 7106, these converters have been around for quite some time. The integrating architecture provides a novel and straightforward approach to converting a low bandwidth analog signal into its digital representation. These types of converters often include built-in drivers for LCD or LED displays and are found in many portable instrument applications, including digital panel meters and digital multimeters.

Single-Slope ADC Architecture

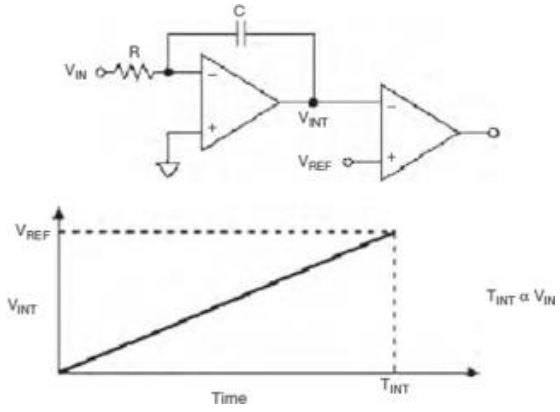

Fig 8:(a) Single-slope ADC circuit (b) Response of single slope ADC

The simplest form of an integrating ADC uses single-slope architecture (Figs. 8a, b). Here, an unknown input voltage is integrated and the value is compared against a known reference value. The time it takes for the integrator to trip the comparator is proportional to the unknown voltage (VINT/VIN).In this case, the known reference voltage must be stable and accurate to guarantee the accuracy of the measurement. One drawback to this approach is that the accuracy is also dependent on the tolerances of the integrator's R and C values. Thus in a

production environment, slight differences in each component's value change the conversion result and make measurement repeatability quite difficult to attain. To overcome this sensitivity to the component values, the dual-slope integrating architecture is used.

Dual-Slope ADC Architecture

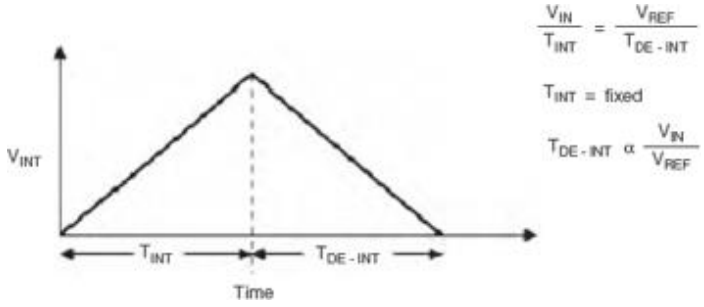

Fig 9:Dual slope integration

A dual-slope ADC (DS-ADC) integrates an unknown input voltage (VIN) for a fixed amount of time (TINT), then "disintegrates" (TDEINT) using a known reference voltage (VREF) for a variable amount of time (Fig. 9).

The key advantage of this architecture over the single-slope is that the final conversion result is insensitive to errors in the component values. That is, any error introduced by a component value during the integrate cycle will be canceled out during the de-integrate phase. In above equation form:

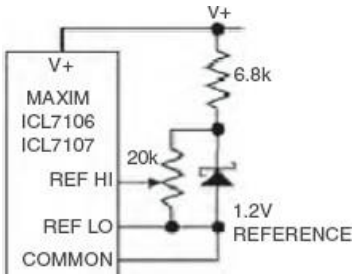

Fig 10:Dual Slope Converter

From this equation, it is found that the de-integrate time is proportional to the ratio of VIN/VREF. A complete circuit diagram of a dual-slope converter is shown in Fig. 10.As an example, to obtain 10-bit resolution, integration is performed for1024 (210) clock cycles, then disintegrated for 1024 clock cycles (giving a maximum conversion of two 210 cycles). For more resolution, increase the number of clock cycles. This tradeoff between conversion time and resolution is inherent in this implementation. It is possible to speed up the conversion time for a given resolution with moderate circuit changes. Unfortunately, all improvements shift some of the accuracy to matching, external components, charge injection, etc. In other words, all speed-up techniques have larger error budgets. Even in the simple converter in Fig. 4.1, there are many potential error sources to consider such as power supply rejection (PSR),common-mode rejection

(CMR), finite gain, over-voltage concerns, integrator saturation, comparator speed, comparator oscillation, "rollover," dielectric absorption, capacitor leakage current, parasitic capacitance, charge injection ,etc.

SAR ADC:

Successive-approximation-register (SAR) analog-to-digital converters (ADCs) represent the majority of the ADC market for medium to high resolution ADCs. SAR ADCs provide up to 5 Msps (mega samples per second) sampling rate with resolution from 8 to 18 bits. The SAR architecture allows for high performance, low power ADCs to be packaged in small form factors for today's demanding applications. It also provides an explanation for the heart of the SAR ADC, the capacitive DAC and also the high-speed comparator. Finally, the article will contrast the SAR architecture against pipeline, flash ADCs. SAR ADCs are frequently the architecture of choice for medium to-high-resolution applications with sample rates under 5 Msps. SAR ADCs most commonly range in resolution from 8 to 16 bits and provide low power consumption as well as a small form factor. This combination makes the mideal for a wide variety of applications, such as portable/battery-powered instruments, pen digitizers, industrial controls, and data/signal acquisition. As the name implies, the SAR ADC basically implements a binary search algorithm. Therefore, while the internal circuitry may be running at several megahertz (MHz), the ADC sample rate is a fraction of that number due to the successive-approximation algorithm.

Architecture:

Although there are many variations in the implementation of an SAR ADC, the basic architecture is quite simple (Fig. 11). The analog input voltage(VIN) is held on a track/hold. To implement the binary search algorithm, the N-bit register is first set to mid scale (that is, 100 00, where the MSB is set to "1"). This forces the DAC output (VDAC) to be VREF/2, where VREF is the reference voltage provided to the ADC. A comparison is then performed to determine if VIN is less than or greater than VDAC. If VIN is greater than VDAC, the comparator output is at logic high or "1"and the MSB of the N-bit register remains at "1." Conversely, if VIN is less than VDAC, the comparator output is logic low and the MSB of the register is cleared to logic "0." The SAR control logic then moves to the next bit down, forces that bit high, and does another comparison. The sequence continues all the way down to the LSB. Once this is done, the conversion is complete, and the N-bit digital word is available in the register. The y-axis (and the bold line in Fig. 4.33) represents the DAC output voltage. In the example, the first comparison shows that VIN <VDAC. Thus, bit 3 is set to "0." The DAC is then set to 01002 and the second comparison is performed. As VIN >VDAC, bit 2 remains at "1."

The DAC is then set to 01102, and the third comparison is performed. Bit 1 is set to "0," and theDAC is then set to 01012 for the final comparison. Finally, bit 0 remains at"1" because VIN>VDAC.

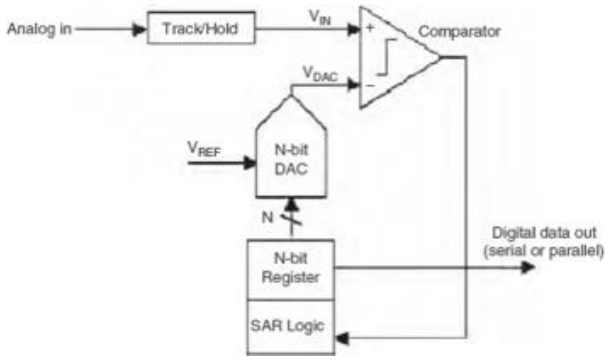

Fig 11:Simplified N-bit SAR ADC architecture

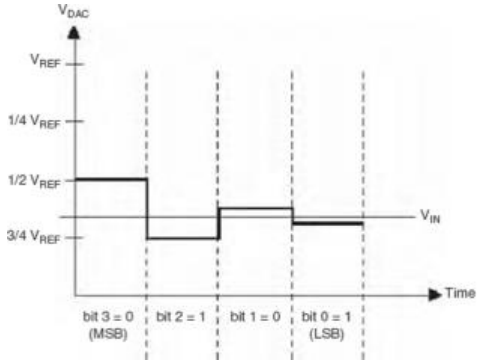

Fig 12: SAR operation

Four comparison periods are required for a 4-bit ADC. Generally speaking, an N-bit SAR ADC will require N comparison periods and will not be ready for the next conversion until the current one is complete. Thus, these types of ADCs are power and space-efficient. Some of the smallest ADCs available on the market are based on the SAR architecture. The MAX1115-MAX1118 series of 8-bit ADCs as well as their higher resolution counterparts, the MAX1086 and the MAX1286 (10 and 12 bits, respectively), fit in tiny SOT23 packages measuring 3mm by 3 mm. Another feature of SAR ADCs is that power dissipation scales with the sample rate, unlike flash or pipelined ADCs, which usually have constant power dissipation versus sample rate. This is especially useful in low-power applications or applications where the data acquisition is not continuous as in the case of PDA Digitizers.

3.4 DIGITAL TO ANALOG (DAC)

A digital to analog converter (DAC) converts a digital signal to an analog voltage or current output

Types of DACs

- Many types of DACs available.
- Usually switches, resistors, and op-amps used to implement conversion
- Two Types:
  - Binary Weighted Resistor
    - R-2R Ladder

Binary Weighted Resistor

Utilizes a summing op-amp circuit Weighted resistors are used to distinguish each bit from the most significant to the least significant Transistors are used to switch between Vref and ground (bit high or low)

- Assume Ideal Op-amp
- No current into op-amp
- Virtual ground at inverting input
- $V_{out} = -IR_f$

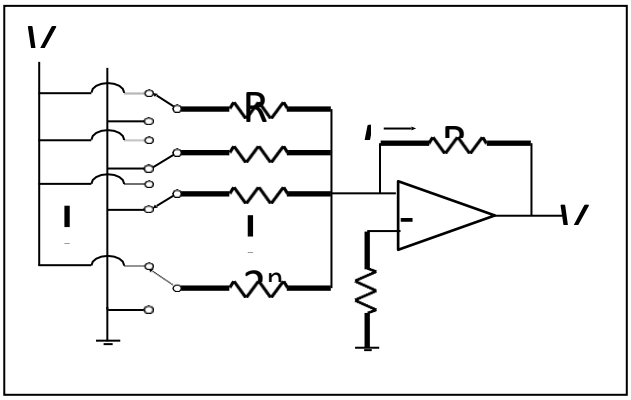

Fig 13: Binary Weighted Resistor

R-2R Ladder

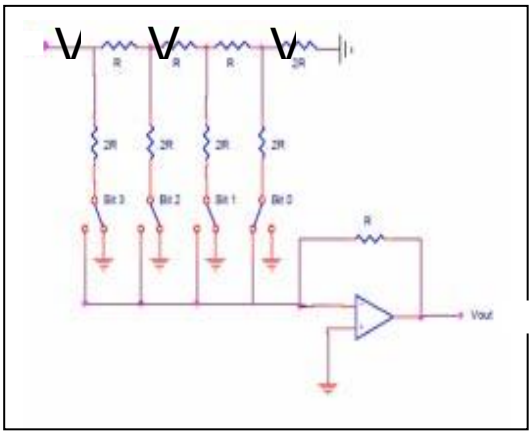

Fig 14: R-2R Ladder

Specifications of DACs

- Resolution
- Speed
- Linearity
- Settling Time
- Reference Voltages
- Errors

Resolution

- Smallest analog increment corresponding to 1 LSB change
- An N-bit resolution can resolve 2^N distinct analog

levels Common DAC has a 8-16 bit resolution

Speed

- Rate of conversion of a single digital input to its analog equivalent
- Conversion rate depends on
  - clock speed of input signal
  - settling time of converter
- When the input changes rapidly, the DAC conversion speed must be high.

Linearity

- The difference between the desired analog output and the actual output over the full range of expected values

Applications

- Digital Motor Control
- Computer Printers
- Sound Equipment (e.g. CD/MP3 Players, etc.)
- Electronic Cruise Control

Counters and Timers

A counter is a digital timing device. Typical applications of counters are event counting, frequency measurement, period measurement, position measurement, and pulse generation. A counter contains the following four main components:

- **Count Register**. Stores the current count of the counter. The user can query the count register with software.
- **Source**. An input signal that can change the current count stored in the count register. The counter looks for rising or falling edges on the source signal. Whether a rising or falling edge changes the count is software selectable. The type of edge selected is referred to as the active edge of the signal. When an active edge is received on the source signal, the count changes.

Whether an active edge increments or decrements the current
count is also software selectable.

- **Gate**. An input signal that determines if an active edge on the source will change the count. Counting can occur when the gate is high, low, or between various combinations of rising and falling edges. Gate settings are made in software.
- **Output**. An output signal that generates pulses or a series of pulses, otherwise known as a pulse train. When a counter is configured for simple event counting, the counter increments when an active edge is received on the source. In order for the counter to increment on an active edge, the counter must be started. A counter has a fixed number it can count to as determined by the resolution of the counter.

3.5 DMA

Direct **m**emory **a**ccess, a technique for transferring datafrom main memory to a device without passing it through the CPU.

Computers that have DMA channels can transfer data to and from devices much more quickly than computers without a DMA channel can. This is useful for making quick backups and for real-time applications. Some expansion boards, such as CD-ROM cards, are capable of accessing the computer's DMA channel.

Modes of operation

Burst mode

An entire block of data is transferred in one contiguous sequence. Once the DMA controller is granted access to the system bus by the CPU, it transfers all bytes of data in the data block before releasing control of the system buses back to the CPU, but renders the CPU inactive for relatively long periods of time. The mode is also called "Block Transfer Mode". It is also used to stop unnecessary data.

Cycle stealing mode

The cycle stealing mode is used in systems in which the CPU should not be disabled for the length of time needed for burst transfer modes. In the cycle stealing mode, the DMA controller obtains access to the system bus the same way as in burst mode, using **BR (Bus Request) and BG (Bus Grant) signals**, which are the two signals controlling the interface between the CPU and the DMA controller. However, in cycle stealing mode, after one byte of data transfer, the control of the system bus is deserted to the CPU via BG. It is then continually requested again via BR, transferring one byte of data per request, until the entire block of data has been transferred. By continually obtaining and releasing the control of the system bus, the DMA controller essentially interleaves instruction and data transfers. The CPU processes an instruction, then the DMA controller transfers one data value, and so on. On the one hand, the data block is not transferred as quickly in cycle stealing mode as in burst mode, but on the other hand the CPU is not idled for as long as in burst mode. Cycle stealing mode is useful for controllers that monitor data in real time.

Transparent mode

The transparent mode takes the most time to transfer a block of data, yet it is also the most efficient mode in terms of overall system performance. The DMA controller only transfers data

when the CPU is performing operations that do not use the system buses. It is the primary advantage of the transparent mode that the CPU never stops executing its programs and the DMA transfer is free in terms of time. The disadvantage of the transparent mode is that the hardware needs to determine when the CPU is not using the system buses, which can be complex.

Resolution

Resolution is important. The number of bits used to represent an analog signal determines the resolution of the ADC. The resolution on a DAQ device is similar to the marks on a ruler. The more marks a ruler has, the more precise the measurements are. The higher the resolution is on a DAQ device, the higher the number of divisions into which a system can break down the ADC range, and therefore, the smaller the detectable change. A 3-bit ADC divides the range into 23 or eight divisions. A binary or digital code between000 and 111 represents each division. The ADC translates each measurement of the analog signal to one of the digital divisions. Figure 11.19 shows a 5-kHz sine wave digital image obtained by a3-bit ADC. The digital signal does not represent the original signal adequately because the converter has too few digital divisions to represent the varying voltages of the analog signal. However, increasing the resolution to 16 bits to increase the ADC number of divisions from eight (23) to 65,536 (2^{16}) allows the 16-bit ADCto obtain an extremely accurate representation of the analog signal.

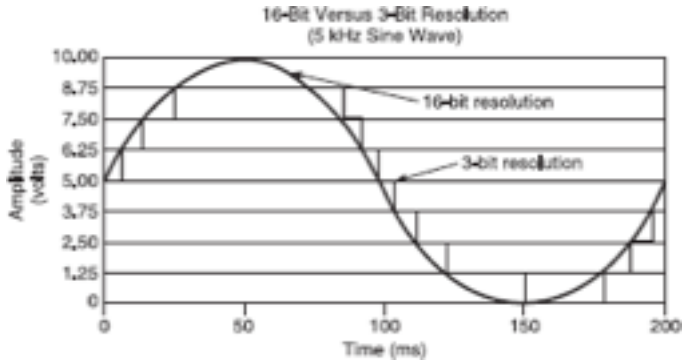

Fig : 3 bit and 16 bit resolution

Range refers to the minimum and maximum analog signal levels that the ADC can digitize. Many DAQ devices feature selectable ranges (typically 0 to 10 V or –10 to 10 V), so you can match the ADC range to that of the signal to take best advantage of the available resolution to accurately measure the signal. For example, in Figure 11.20, the 3-bit ADC in chart 1 has eight digital divisions in the range from 0 to 10 V, which is a unipolar range. If you select a range of – 10 to 10 V, which is a bipolar range, as shown in chart 2, the same ADC separates a 20 V range into eight divisions. The smallest detectable voltage increases from 1.25 to 2.50 V, and the right chart is a much less accurate representation of the signal.

Amplification or attenuation of a signal can occur before the signal is digitized to improve the representation of the signal. By amplifying or attenuating a signal, you can effectively decrease the input range of an ADC and thus allow the ADC to use as many of the available digital divisions as possible to represent the signal. For example, the below fig shows the effects of applying amplification to a signal that fluctuates between 0 and 5 V using a 3-bit ADC and a range of 0 to 10

V. With no amplification, or gain = 1, the ADC uses only four of the eight divisions in the conversion .By amplifying the signal by two before digitizing, the ADC uses all eight digital divisions, and the digital representation is much more accurate. Effectively, the device has an allowable input range of 0 to 5 V because any signal above 5 V when amplified by a factor of two makes the input to the
ADC greater than 10 V. The range, resolution, and amplification available on a DAQ device determine the smallest detectable change in the input voltage. This change in voltage represents one least significant bit (LSB) of the digital value and is also called the code width.

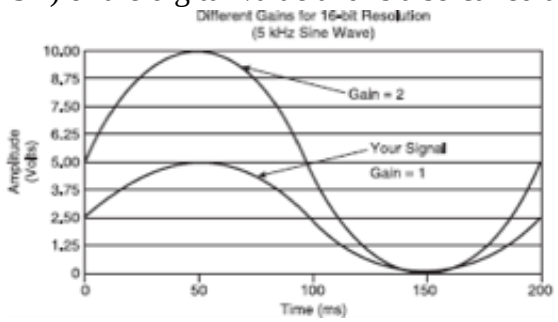

Fig : Effects of applying amplification in resolution using the following formula

$$C = D\left(\frac{1}{2^R}\right)$$

Where *C* is code width,
D is device input range, and *R* is bits of resolution.

Device input range is a combination of the gain applied to the signal and the input range of the ADC. For example, if the ADC input range is –10 to +10 V peak to peak and the gain is 2, the device input range is –5 to +5 V peak to peak, or 20 V. The smaller the code width, the more accurately a device can represent the signal. The formula confirms what you have already learned in the discussion on resolution, range and gain:

- Larger resolution = smaller code width = more accurate representation of the signal
- Larger amplification = smaller code width = more accurate representation of the signal
- Larger range = larger code width = less accurate representation of the signal

Hardware installation of DAQ Windows Configuration Manager

The Windows Configuration Manager keeps track of all the hardware installed in the computer, including National Instruments DAQ devices. If a Plug &Play (PnP) device, such as an E Series MIO device is available, the Windows Configuration Manager automatically detects and configures the device. If the device is a non-PnP device, or legacy device, the user must configure the device manually using the Add New Hardware option in the Control Panel. LabVIEW installs Measurement & Automation Explorer (MAX), which establishes all device and channel configuration parameters. After installing a DAQ device in the computer, the user must run this configuration utility.MAX reads the information the Device Manager records in the Windows Registry and assigns a logical device number to each DAQ device.

Channel and Task Configuration

Using Traditional NI-DAQ a set of virtual channels can be configured. A collection of property settings that include a physical channel, the type of measurement or generation specified in the channel name, and scaling information are also configured using this utility. In Traditional NI-

DAQ and earlier versions, virtual channels are a simple method to remember which channels are used for different measurements. NI-DAQmx channels are similar to the virtual channels of Traditional NI-DAQ. NI-DAQmx also includes tasks that are integral to the API. A task is a collection of one or more channels and the timing, triggering, and other properties that apply to the task itself.

Hardware Triggering

There are two ways to begin a DAQ operation:

1. Through a software trigger.
2. Through a hardware trigger.

With software triggering, the DAQ operation begins when the software function that initiates the acquisition executes. For example, the "Easy" DACVIs use software triggering.

Analog Input

Analog input is used to perform A/D conversions.

Digital Output

Measuring and generating digital values is used in a variety of applications, including controlling relays and monitoring alarm states.

DAQ Software

DAQ software is specialized software that has been developed specifically for use with data acquisition boards, cards and systems. This software can range from simple software used for one application such as data logging, or it can be extremely robust, offering a wide range of uses for measurement and control and laboratory applications. DAQ software in conjunction with a personal computer is used to control the data acquisition board's functions.

High-Level Functions

More elaborate functions provided by DAQ software includes acquiring, converting to engineering units, and displaying data graphically on a PC monitor; analyzing a complex analog input signal, providing linearization and cold junction compensation calculations for various types of thermocouple signals; or simultaneously sampling multiple channels of analog input data, comparing them, and plotting them in a three-dimensional presentation.

High-Level Mathematical Functions

FFT and frequency analysis, signal generation, mathematics, curve fitting and interpolation, along with time and frequency domain analysis, allow users to derive meaningful information from data.

Application Development

Whether the user is taking temperature measurements with an A/D board, analyzing signals using a stand-alone oscilloscope board, or measuring pressure with a sophisticated signal conditioner; using specialized application development DAQ software with the appropriate driver is ideal for the application. From data acquisition to instrument control, and image acquisition to motion control, application development software provides the tools to rapidly develop the acquisition system.

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IV Instrument Interfaces

Current loop, RS 232C/RS 485, GPIB, System basics, interface basics: USB, PCMCIA, networking basics for office & industrial application VISA & IVI, image acquisition & processing, Motion Control. ADC, DAC, DIO, DMM, waveform generator.

4.1 4–20mA Current Loop

Current-mode data transmission is the preferred technique in many environments, particularly in industrial applications. Most systems employ the familiar 2-wire, 4–20mA current loop, in which a single twisted-pair cable supplies power to the module and carries the output signal as well. The 3-wire interface is less common but allows the delivery of more power to the module electronics. A 2-wire system provides only 4mA at the line voltage (the remaining 16mA carries the signal). Current loops offer several advantages over voltage-mode output transducers:
– They do not require a precise or stable supply voltage.
– Their insensitivity to IR drops makes them suitable for long distances.
– A 2-wire twisted-pair cable offers very good noise immunity.
– The 4mA of current required for information transfer serves two purposes:
it can furnish power to a remote module, and it provides a distinction between zero (4 mA) and no information (no current flow).In a 2-wire, 4–20mA current loop, supply current for the sensor electronics must not exceed the maximum available, which is 4mA (the remaining 16mAcarries the signal). Because a 3-wire current loop is easily derived from the2-wire version, the following discussion focuses on the 2-wire version.

Need for a Current Loop
The 4–20mA current loop shown in Fig. 1 is a common method of transmitting sensor information in many industrial process-monitoring applications. A sensor is a device used to measure physical parameters such as temperature, pressure, speed, liquid flow rates, etc. Transmitting sensory information through a current loop is particularly useful when the information has to be sent to a remote location over long distances (1,000 ft, or more). The loop's operation is straightforward: a sensor's output voltage is first converted to a proportional current, with 4mA normally representing the sensor's zero-level output, and 20mA representing the sensor's full-scale output. Then, a receiver at the remote end converts the 4–20mA current back into a voltage which in turn can be further processed by a computer or display module. However, transmitting a sensor's output as a voltage over long distances has several drawbacks. Unless very high input-impedance devices are used, transmitting voltages over long distances produces correspondingly lower voltages at the receiving end due wiring and interconnect resistances. However, high-impedance instruments can be sensitive to noise pickup since the lengthy signal-carrying wires often run in close proximity to other electrically noisy system wiring. Shielded wires can be used to minimize noise pickup, but their high cost may be prohibitive when long distances are involved. Sending a current over long distances produces voltage losses proportional to the wiring's length. However, these voltage losses also known as loop drops" do not reduce the 4–20mA current as long as the transmitter an loop supply can compensate for these drops. The magnitude of the current in the loop is not affected by voltage drops in the system wiring since all of the current (i.e., electrons) originating at the negative (−) terminal of the loop power supply has to return back to its positive (+) terminal

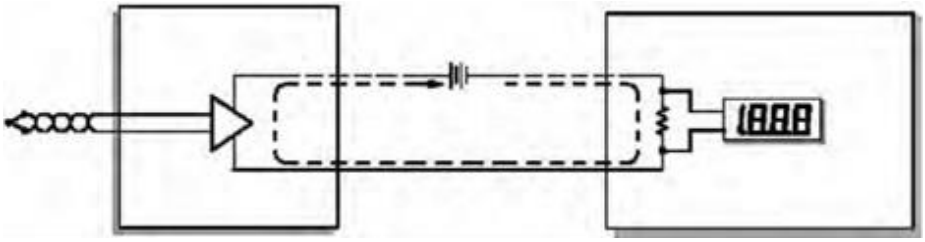

Fig1: Typical components in a loop

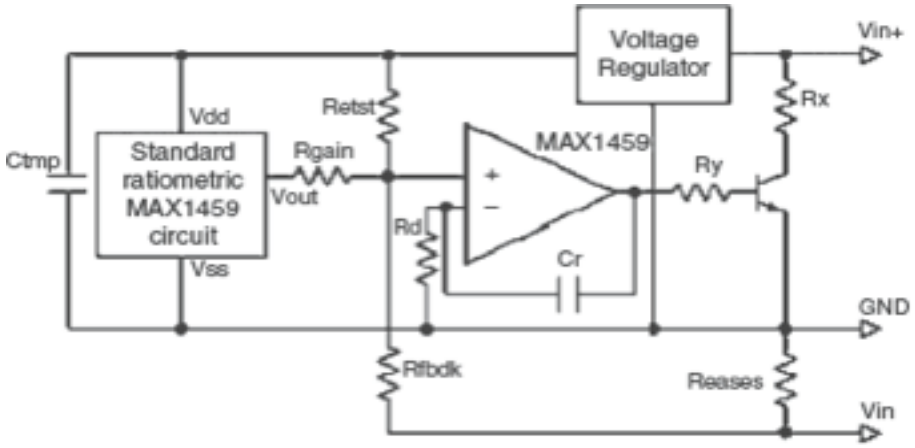

Fig2: 4-20 mA transmitter

Basic 2-wire Circuit

A voltage output should be converted to current when configuring a ratio metric 4–20mA circuit, because current-mode applications require a 4mA offset and 16mA span. This section presents the circuit details and results obtained from a current-loop configuration based on the MAX1459 sensorsignal conditioner. In principle, a voltage regulator is to be added, which converts the 10–32V loop voltage to a fixed 5V for operating the MAX1459. Figure shows the circuitry required for implementing a standard ratio metric version of the MAX1459 circuit. The voltage regulator can be any low-cost device whose quiescent current is sufficiently low for the 4mA budget.

Advantages of 4–20mA Current Loop

Current loops offer four major advantages such as:

– Long-distance transmission without amplitude loss

– Detection of offline sensors, broken transmission lines, and other failures

– Inexpensive 2-wire cables

– Lower EMI sensitivity

4.2 RS 232C/RS 485

The RS-232/485 port sequentially sends and receives bytes of information one bit at a time. Although this method is slower than parallel communication, which allows the transmission of an entire byte at once, it is simpler and can be used over longer distances because of lower power consumption. For example, the IEEE 488 standard for parallel communication states that the cable length between the equipments should not exceed 20m total, with a maximum distance of 2m

between any two devices. RS-232/485 cabling, however, can extend 1,200m or greater. Typically,

RS-232/485 is used to transmit American Standard Code for Information Interchange (ASCII) data. Although National Instruments serial hardware can transmit 7-bit as well as 8-bit data, most applications use only 7-bit data. Seven-bit ASCII can represent the English alphabet, decimal numbers, and common punctuation marks. It is a standard protocol that virtually all hardware and software understand. Serial communication is mainly using the three transmission lines: (1) ground, (2) transmit, and (3) receive. Because RS-232/485 communication is asynchronous, the serial port can transmit data on one line while receiving data on another. Other lines such as the handshaking lines are not required. The important serial characteristics are baud rate, data bits, stop bits, and parity. To communicate between a serial instrument and a serial port on computer, these parameters must match. The RS-232 port, or ANSI/EIA-232 port, is the serial connection found on IBM-compatible PCs. It is used for many purposes, such as connecting a mouse, printer, or modem, as well as industrial instrumentation. The RS-232protocol can have only one device connected to each port. The RS-485 (EIA-485 Standard) protocol can have 32 devices connected to each port. With this enhanced multidrop capability the user can create networks of devices connected to a single RS-485 serial port. Noise immunity and multi drop capability make RS-485, the choice in industrial applications requiring many distributed devices networked to a PC or other controller for data collection.USB was designed primarily to connect peripheral devices to PCs, including keyboards, scanners, and disk drives.RS-232 (Recommended standard-232) is a standard interface approved by the Electronic Industries Association (EIA) for connecting serial devices. In other words, RS-232 is a long established standard that describes the physical interface and protocol for relatively low- speed serial data

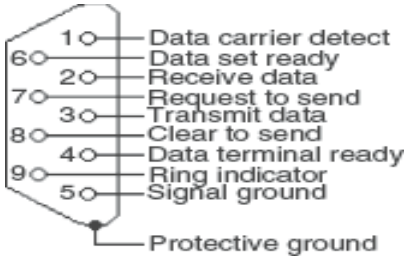

Fig 3: Pin diagram

Table: pin description

Pin Number	Signal	Description
1	DCD	Data carrier detect
2	RxD	Receive data
3	TxD	Transmit data
4	DTR	Data terminal ready
5	GND	Signal ground
6	DSR	Data set ready
7	RTS	Ready to send
8	CTS	Clear to send
9	RI	Ring indicator

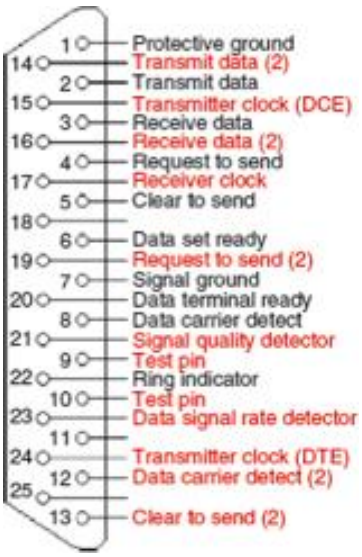

Fig 4: RS232c DB 25 pinout

Signal Descriptions

- TxD – This pin carries data from the computer to the serial device]
- RXD – This pin carries data from the serial device to the computer
- DTR signals – DTR is used by the computer to signal that it is ready to communicate with the serial device like modem. In other words, DTR indicates the modem that the DTE (computer) is ON.
- DSR – Similarly to DTR, Data set ready (DSR) is an indication from the modem that it is ON.
- DCD – Data carrier detect (DCD) indicates that carrier for the transmit data is ON.
- RTS – This pin is used to request clearance to send data to a modem.
- CTS – This pin is used by the serial device to acknowledge the computers RTS signal. In most situations, RTS and CTS are constantly on throughout the communication session.
- Clock signals (TC, RC, and XTC) – The clock signals are only used for synchronous communications. The modem or DSU extracts the clock from the data stream and provides a steady clock signal to the DTE. The transmit and receive clock signals need not have to be the same, or even at the same baud rate.
- CD – CD stands for Carrier detect. Carrier detect is used by a modem to signal that it has a made a connection with another modem, or has detected a carrier tone. In other words, this is used by the modem to signal that a carrier signal has been received from a remote modem.

RI – RI stands for ring indicator. A modem toggles (keystroke) the state of this line when an incoming call rings in the phone. In other words, this is used by an auto answer modem to signal the receipt of a telephone ring signal. The carrier detect (CD) and the ring indicator (RI) lines are only available in connections to a modem. Because most modems transmit status information to a PC when either a carrier signal is detected

RS485 Serial Communication

RS485 is an EIA standard for multipoint communications. It supports several types of connectors, including DB-9 and DB-37. RS-485 is similar to RS-422 but can support more nodes

per line. RS485 meets the requirements for a truly multipoint communications network, and the standard specifies up to32 drivers and 32 receivers on a single (2-wire) bus. With the introduction of "automatic" repeaters and high-impedance drivers/receivers this "limitation" can be extended to hundreds or even thousands of nodes on a network. The RS-485 and RS-422 standards have much in common, and are often confused for that reason. RS-485, which specifies bi-directional, half-duplex data transmission, is the only EIA standard that allows multiple receivers and drivers in "bus" configurations. RS-422, on the other hand, specifies a single, unidirectional driver with multiple receivers.

4.3 GPIB

The purpose of this section is to provide guidance and understanding of the General Purpose Interface Bus (GPIB) bus to new GPIB bus users or to provide more information on using the GPIB bus's features. GPIB Data Acquisition and Control Module provides analog and digital signals for controlling virtually any kind of a device and the capability to read back analog voltages, digital signals, and temperatures. The 4867 Data Acquisition and Control module is an IEEE-488.2 compatible device and has a Standard Commands for Programmable Instruments (SCPI) command parser that accepts SCPI and short form commands for ease of programming. Applications include device control, GPIB interfacing and data logging. The 4867is housed in a small 7 in.×7 in.

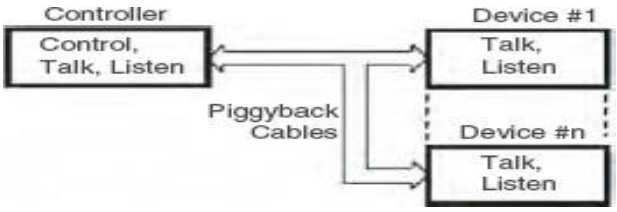

Fig 5: Block Diagram

Controllers have the ability to send commands, to talk data onto the bus and to listen to data from devices. Devices can have talk and listen capability. Control can be passed from the active controller (Controller-in-charge) to any device with controller capability. One controller in the system is defined as the System Controller and it is the initial controller-in-charge (CIC). Devices are normally addressable and have a way to set their address. Each device has a primary address between 0 and 30. Address 31 is the unlisten or untalk address.

Types of GPIB Messages

GPIB devices communicate with other GPIB devices by sending device dependent messages and interface messages through the interface system. **Device-dependent messages**, often called data or data messages, contain device-specific information, such as programming instructions, measurement results, machine status, and data files. **Interface messages** manage the bus. Usually called commands or command messages, interface messages perform such functions as initializing thebus, addressing and unaddressing devices, and setting device modes for remoteor local programming.The term "command" as used here should not be confused with somedevice instructions that are also called commands. Such device-specific commandsare actually data messages as far as the GPIB interface system itselfis concerned.

Physical Bus Structure

GPIB is a 24 conductor as shown in Fig 6Physically, the GPIB interface system consists of 16 low-true signal lines and eight ground-return or shield drain lines. The 16 signal lines, discussed later, are grouped into data lines(eight), handshake lines (three), and interface management lines (five).

Data Lines

The eight data lines, DIO1 through DIO8, carry both data and command messages. The state of the Attention (ATN) line determines whether the information is data or commands. All commands and most data use the 7-bitASCII or ISO code set, in which case the eighth bit, DIO8, is either unused or used for parity.

Handshake Lines

Three lines asynchronously control the transfer of message bytes between devices. The process is called a 3-wire interlocked handshake. It guarantees that message bytes on the data lines are sent and received without transmission error.

NRFD (not ready for data) – Indicates when a device is ready or not ready to receive a message byte. The line is driven by all devices when receiving commands by listeners when receiving data messages, and by the talker when enabling the HS488 protocol.

- NDAC (not data accepted) – Indicates when a device has or has not accepted a message byte. The line is driven by all devices when receiving commands, and by Listeners when receiving data messages.

- DAV (data valid) – Tells when the signals on the data lines are stable (valid) and can be accepted safely by devices. The Controller drives DAV when sending commands, and the Talker drives DAV when sending data messages. Three of the lines are handshake lines, NRFD, NDAC, and DAV, which transfer data from the talker to all devices who are addressed to listen. The talker drives the DAV line; the listeners drive the NDAC and NRFD lines. The remaining five lines are used to control the bus's operation.

  - ATN (attention) is set true by the controller-in-charge while it is sending interface messages or device addresses. ATN is false when the bus is transmitting data.

  - EOI (end or identify) can be asserted to mark the last character of a message or asserted with the ATN signal to conduct a parallel poll.

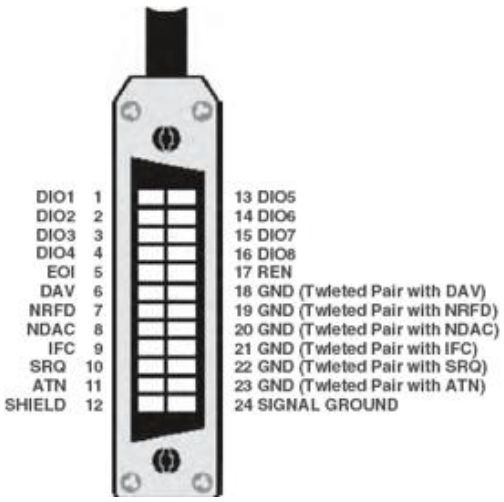

Fig :6 Bus structure of GPIB

4.4 USB

The USB is a medium-speed serial data bus designed to carry relatively large amounts of data over relatively short cables: up to about 5m long. It can support data rates of up to 12Mbs−1 (megabits per second), which is fast enough for most PC peripherals such as scanners, printers, keyboards, mice, joysticks, graphics tablets, low-res digital cameras, modems, digital speakers, low speed CD- ROM and CD-writer drives, external Zip disk drives, and soon. The USB is an addressable bus system, with a 7-bit address code so it can support up to 127 different devices or nodes. However, it can have only one host. So a PC with its peripherals connected through the USB forms a star Local Area Network (LAN).On the other hand any device connected to the USB can have a number of other nodes connected to it in daisy-chain fashion, so it can also form the

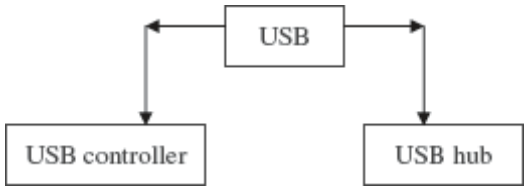

Fig 7: USB Structure

Most hubs provide either four or seven downstream ports, or less. Another important feature of the USB is that it is designed to allow hot swapping. Devices can be plugged into and unplugged from the bus without having to turn the power off and on again, re-boot the PC or even, manually start a driver program. A new device can simply be connected to the USB, and the PCs operating system should recognize it and automatically set up the necessary driver to service it.

Need for USB

The USB is host controlled. There can only be one host per bus. The specification in itself does not support any form of multi master arrangement. This is aimed at and limited to single point to point connections such as a mobile phone and personal organizer and not multiple hub, multiple device desktop configurations. The USB host is responsible for undertaking all transactions and scheduling bandwidth. Data can be sent by various transaction methods using a token-based protocol. One of the original intentions of USB was to reduce the amount of cabling at the back of PC. The idea came from the Apple Desktop Bus, where the keyboard, mouse and some other peripherals could be connected together (daisy chained) using the one cable. However, USB uses a tiered star topology, similar to that of 10BaseTEthernet. This imposes the use of a hub somewhere, which adds to greater expense, more boxes on desktop and more cables. However it is not as bad as it may seem. Many devices have USB hubs integrated into them. For example, keyboard may contain a hub which is connected to computer. Mouse and other devices such as digital camera can be plugged easily into the back of keyboard. Monitors are just another peripheral on a long list which commonly has in- built hubs. This tiered star topology, rather than simply daisy chaining devices together has some benefits. First power to each device can be monitored and even switched-off if an over current condition occurs without disrupting other USB devices. High, full and low speed devices can be supported, with the hub filtering out high speed and full speed transactions so lower speed devices do not receive them. Up to 127 devices can be connected to any one USB bus at any one given time. To extent devices simply add another port/host. While earlier USB hosts had two ports, most manufacturers have seen this as limiting and are starting to introduce 4 and 5 port host cards with an internal port for hard disks etc. The early hosts had one USB controller and thus both ports shared the same available USB bandwidth. As bandwidth requirements have increased, multiport cards with two or more controllers allowing individual channels are used.

Table: Pin connections

Pin connections	
Pin No.	Signal
1	+5V Power
2	– Data
3	+ Data
4	Ground

USB cables use two different types of connectors:
– Type A. Plugs for the upstream end.
– Type B. Plugs for the downstream end.

4.5 PCMCIA

Personal Computer Memory Card International Association (PCMCIA) is an international standards body and trade association founded in 1989developed a standard for small, credit card-sized devices, called PC Cards. Originally designed for adding memory to portable computers, the PCMCIA standard has been expanded several times and is now suitable for many types of devices. The inclusion of PCMCIA technology in PCs delivers a variety of benefits. Besides providing an industry standard interface for third-party cards (PC Cards), PCMCIA allows users to easily swap cards in and out of a PC as needed, without having to deal with the allocation of system resources for those devices. These useful features hot swapping and automatic configuration, as well as card slot power management and other PCMCIA capabilities –are supported by a variety of software components on the PCMCIA-based PC. In most cases, the software aspect of PCMCIA remains relatively transparent to the user. As the demand for notebook and laptop computers began skyrocketing in the late 1980s, users realized that their expansion options were fairly limited. Mobile machines were not designed to accept the wide array of available expansion cards that their desktop counterparts could enjoy

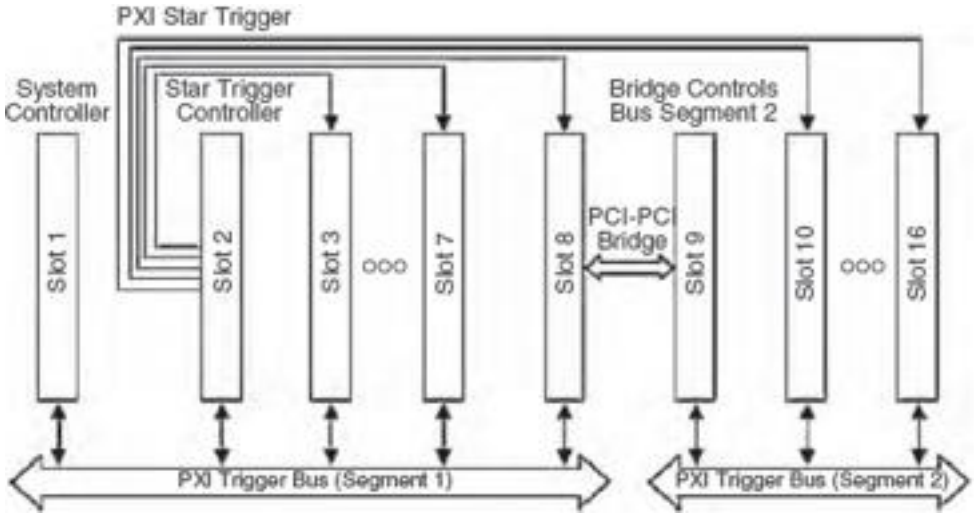

Fig 8: Triggering Architecture

Features of PCMCIA

– One rear slot, access from rear of PC
– Accept Type I/II/III Cards
– Comply with PCI Local Bus Specification Rev.2.2
– Comply with 1995 PC Card Standard
– Extra compatible registers are mapped in memory
– Use T/I 1410 PCMCIA controller
– Support PC Card with Hot Insertion and Removal
– Support 5V or 5/3.3V 16-bit PC Cards
– Support Burst Transfers to Maximize Data Throughput on both PCIBuses
– Supports Distributed DMA and PC/PCI DMA

Utilities of PCMCIA Card in the Networking Category

Under the networking category, typically PCMCIA slot supports 4 types of cards such as:

– LAN card
– Wireless LAN card
– Modem card
– ATA flash disk card

4.6 VISA

Virtual Instrumentation Software Architecture (VISA) is a standard I/O language for instrumentation programming. VISA by itself does not provide instrumentation programming capability. VISA is a high-level API that calls into lower level drivers. VISA is capable of controlling VXI, GPIB, or Serial instruments and makes the appropriate driver calls depending on the type of instrument being used. When debugging VISA problems, it is important to keep in mind that this hierarchy exists.

Fig9: VISA Architecture

The terminology related with VISA are explained as follows:

Resources. The most important objects in the VISA language are known as resources. Operations. In object-oriented terminology, the functions that can be used with an object are known as operations Attributes. In addition to the operations that can be used with an object, the object has variables associated with it that contain information related to the object. In VISA, these variables are known as attributes. There is a default resource manager at the top of the VISA hierarchy that can search for available resources or open sessions to them. Resources can be GPIB, serial message based VXI, or register-based VXI. The most common operations for message based instruments are read and write.

4.7 Waveform generator

Stand-alone traditional instruments such as oscilloscopes and waveform generators are very powerful, expensive, and designed to perform one or more specific tasks defined by the vendor. However, the user generally cannot extend or customize them. The knobs and buttons on the instrument, the built-in circuitry, and the functions available to the user, are all specific to the nature of the instrument. In addition, special technology and costly components must be developed to build these instruments, making them very expensive and slow to adapt.

References:

1. Jerome, Virtual Instrumentation Using LabView, PHI, 2010
2. Lisa K. Wells and Jeffrey Travis, LABVIEW for Everyone, PHI, 1997.
3. Skolkoff, Basic concepts of LABVIEW 4, PHI, 1998

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IV Application of VI

Fourier Transforms, Power spectrum, Correlation methods, windowing & flittering. Application in Process Control projects, Major equipments - Oscilloscope, Digital Multimeter, Pentium Computers, temperature data acquisition system, motion control employing stepper motor, Image acquisition and processing.

5.1 Fourier Transforms

LabVIEW and its analysis VI library provide a complete set of tools to perform Fourier and spectral analysis. The Fast Fourier Transform (FFT) and Power Spectrum VIs are optimized, and their outputs adhere to the standard DSP format.

FFT is a powerful signal analysis tool, applicable to a wide variety of fields including spectral analysis, digital filtering, applied mechanics, acoustics, medical imaging, modal analysis, numerical analysis, seismography, instrumentation, and communications.

The LabVIEW analysis VIs, located on the **Signal Processing** palette, maximize analysis throughput in FFT-related applications. This document discusses FFT properties, how to interpret and display FFT results, and how to manipulate FFT and power spectrum results to extract useful frequency information.

FFT Properties

The fast Fourier transform maps time-domain functions into frequency-domain representations. FFT is derived from the Fourier transform equation, which is

$$X(f) = \mathcal{F}\{x(t)\} = \int_{-\infty}^{\infty} x(t)\, e^{-j2\pi ft}\, dt \quad ,$$

where x(t) is the time domain signal, X(f) is the FFT, and ft is the frequency to analyze. Similarly, the discrete Fourier transform (DFT) maps discrete-time sequences into discrete-frequency representations. DFT is given by the following equation

$$X_k = \sum_{i=0}^{n-1} x_i\, e^{-j2\pi ik/n} \qquad \text{for } k = 0, 1, 2, \ldots, n-1$$

where x is the input sequence, X is the DFT, and n is the number of samples in both the discrete-time and the discrete-frequency domains. Direct implementation of the DFT, as shown in equation 2, requires approximately n complex operations. However, computationally efficient algorithms can require as little as n log2(n) operations.

$$\mathcal{F}\{x\} = X = X_{Re} + j\, X_{Im} = Re\{X\} + j\, Im\{X\}$$

An inherent DFT property is the following:

$$X_{n-i} = X_{-i}$$

FFT Standard Output:

The output format of the FFT VI can now be described with Xn-i. If the total number of samples, n, of the input sequence, x, is even, the format of the complex output sequence, X, and the interpretation of the results are shown in the below table.

Table 1: Output Format for Even n, k = n ÷ 2

Array Element	**Interpretation**
X[0]	DC component
X[1]	1st harmonic or fundamental
X[2]	2nd harmonic
.	.
.	.
.	.
X[k-2]	(k-2)th harmonic
X[k-1]	(k-1)th harmonic
X[k] = X[-k]	Nyquist harmonic
X[k+1]= X[n-(k-1)] = X[-(k-1)]	(k-1)th harmonic
.	
.	
.	
X[n-3]	-3rd harmonic
X[n-2]	-2nd harmonic
X[n-1]	-1st harmonic

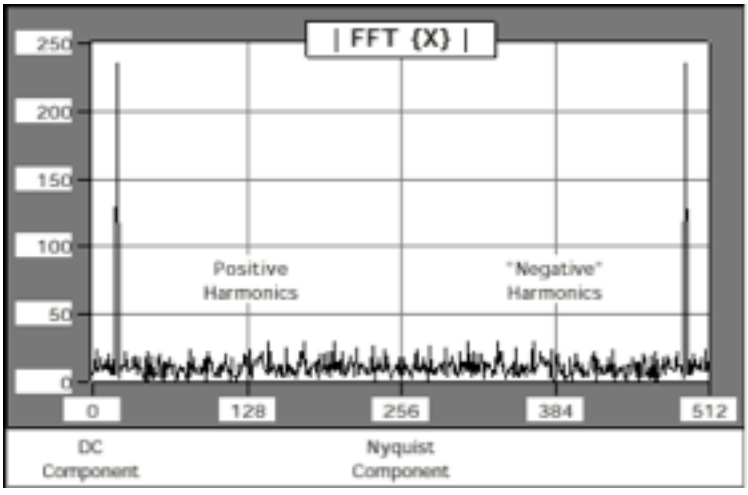


Fig 1 : Graph of table

If the total number of samples, n, of the input sequence, x, is odd, the format of the complex output sequence, X, and the interpretation of the results are shown in the below tableTable:2Output Format for Odd n, k = (n-1) ÷ 2

Array Element	**Interpretation**
X[0]	DC component
X[1]	1st harmonic or fundamental
X[2]	2nd harmonic
.	.
.	.
.	.
X[k-1]	kth -1harmonic
X[k]	kth harmonic
X[k+1]= X[n-k] = X[-k] kth	kth harmonic
. X[k+2]= X[n-(k-1)] = X[-(k-1)]	- (k-1)th harmonic
.	
.	
X[n-3]	-3rd harmonic
X[n-2]	-2nd harmonic
X[n-1]	-1st harmonic

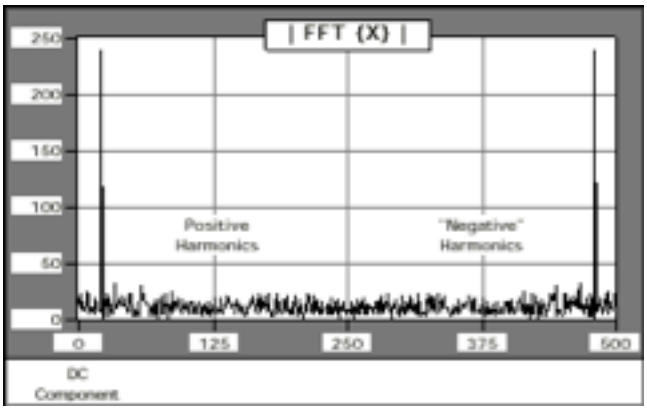


Fig 2 : Graph of table 2

Standard Output

Standard output is the format for even and odd-sized discrete-time sequences, described in Tables 1 and 2 of this document. This format is convenient because it does not require any further data

manipulation.To graphically display the results of the FFT, wire the output arrays to the waveform graph Fig : 2 Graph of table2. The FFT output is complex and requires two graphs to display all the information.

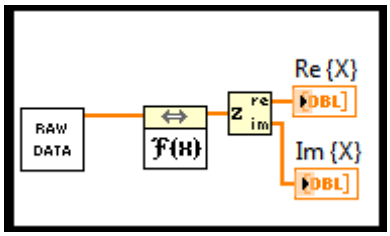


Fig 3 : Standard output by using VI

5.2 Power spectrum and Correlation:

The power spectrum reveals the existence, or the absence, of repetitive patterns and correlation structures in a signal process. These structural patterns are important in a wide range of applications such as data forecasting, signal coding, signal detection, radar, pattern ecognition, and decision-making systems. The most common method of spectral estimation is based on the fast Fourier transform (FFT).

In particular, the total power is given by

$$P_x(\omega) = \sum_{k=-\infty}^{\infty} r_x[k]\, e^{-jk\omega}$$

One can show that Px(w) is real, even and positive. The auto-correlation can be recovered with the inverse Fourier transform

$$r_x[k] = \frac{1}{2\pi} \int_{-\pi}^{\pi} d\omega\, P_x(\omega)\, e^{jk\omega}$$

Power spectrum – properties:

In particular, the total power is given by

$$r_x[0] = \frac{1}{N} \sum_{n=1}^{N} |x[n]|^2 = \frac{1}{2\pi} \int_{-\pi}^{\pi} d\omega\, P_x(\omega)$$

The power spectrum is sometimes called **spectral density** because it is *positive* and the signal power can always be*normalized* to *r*(0) =(2p)-1 .

Example: Uncorrelated noise has a constant power spectrum

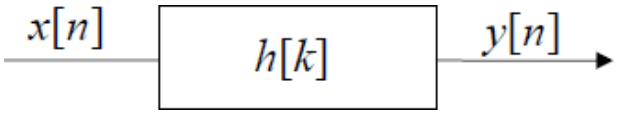
$$r[k]=\sigma^2\delta(k)$$

$$P_x(\omega)=\sum_{k=-\infty}^{\infty}\sigma^2\delta(k)e^{-jk\omega}=\sigma^2$$

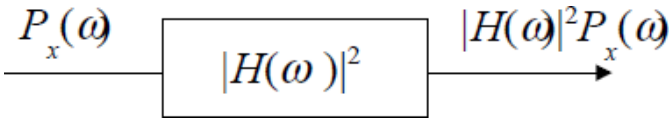
Hence it is also called **white noise**.

Effect of Filtering on Power Spectrum

A linear system with impulse response $h[k]$



Transforms the power spectrum as



Spectral Content

The power spectrum gives the spectral content of the data. To see that consider the power of a signal after filtering with a narrow bandpass filter around w 0.

$$\begin{aligned}E[|y[n]|^2]&=\frac{1}{2\pi}\int_{-\pi}^{\pi}d\omega P_y(\omega)\\&=\frac{1}{2\pi}\int_{-\pi}^{\pi}d\omega|H(\omega)|^2P_x(\omega)\\&=\frac{1}{2\pi}\int_{\omega_0-\Delta\omega/2}^{\omega_0+\Delta\omega/2}d\omega P_x(\omega)\\&\approx\frac{\Delta\omega}{2\pi}P_x(\omega_0)\end{aligned}$$

Power spectrum - properties

The power spectrum captures the spectral content of the sequence. It can be estimate directly from the Fourier transform of the data.

$$\hat{P}_x(\omega)=\frac{1}{N}|X(\omega)|^2$$

$$X(\omega)=\sum_{k=0}^{N-1} x[k]e^{-j\omega k}$$

5.3 Correlation methods

Correlation is a statistical technique that can show whether and how strongly pairs of variables are related.

Correlation Coefficient

The main result of a correlation is called the **correlation coefficient** (or "r"). It ranges from -1.0 to +1.0. The closer r is to +1 or -1, the more closely the two variables are related.

Cross and Auto-correlation

The cross-correlation is defined as

$$r_{yx}(k)=\sum_{n=-\infty}^{\infty} y^*[n]x[n+k]$$

Note that correlation is a convolution with opposite sign. It can be computed with the Fourier transform.

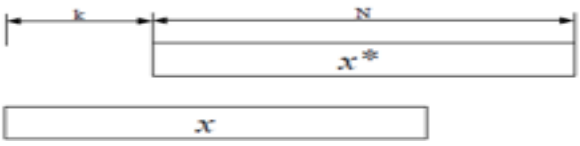
$$R_{xy}(\omega)=Y^*(\omega)X(\omega)$$

The auto-correlation is defined as

$$r_x(k)=\sum_{n=-\infty}^{\infty} x^*[n]x[n+k]$$

For a sample of finite length *N* this is typically normalized. We call this the sample auto-correlation

$$\hat{r}_x[k]=\frac{1}{N-k}\sum_{n=1}^{N-k} x^*[n]x[n+k]$$



Use xcorr() to compute cross of auto-correlation.

Auto-correlation properties

The auto-correlation is symmetric.

$$r_x[k] = r_x^*[-k]$$

The zero lag gives the total power of the signal

The auto-correlation has the power as an upper-bound

$$r_x[0] \geq |r_x[k]| \qquad r_x[0] = \sum_n |x[n]|^2$$

5.4 Windowing & flittering

Windowing is the process of taking a small subset of a larger dataset, for processing and analysis. A naive approach, the rectangular window, involves simply truncating the dataset before and after the window, while not modifying the contents of the window at all. However this is a poor method of windowing and causes power leakage.

Windowing of a simple waveform like cos ωt causes its Fourier transform to develop non-zero values (commonly called spectral leakage) at frequencies other than ω. The leakage tends to be worst (highest) near ω and least at frequencies farthest from ω.

If the waveform under analysis comprises two sinusoids of different frequencies, leakage can interfere with the ability to distinguish them spectrally. If their frequencies are dissimilar and one component is weaker, then leakage from the stronger component can obscure the weaker one's presence. But if the frequencies are similar, leakage can render them unresolvable even when the sinusoids are of equal strength. The rectangular window has excellent resolution characteristics for sinusoids of comparable strength, but it is a poor choice for sinusoids of disparate amplitudes. This characteristic is sometimes described as low-dynamic-range.

At the other extreme of dynamic range are the windows with the poorest resolution and sensitivity, which is the ability to reveal relatively weak sinusoids in the presence of additive random noise. That is because the noise produces a stronger response with high-dynamic-range windows than with high-resolution windows. Therefore, high-dynamic-range windows are most often justified in wideband applications, where the spectrum being analyzed is expected to contain many different components of various amplitudes.

In between the extremes are moderate windows, such as Hamming and Hann. They are commonly used in narrowband applications, such as the spectrum of a telephone channel. In summary, spectral analysis involves a tradeoff between resolving comparable strength components with similar frequencies and resolving disparate strength components with dissimilar frequencies.

That tradeoff occurs when the window function is chosen.

5.5 Application in Process Control projects

Software for Remote ON/OFF Control Experiment

The software for the Remote ON/OFF controller lab experiment is developed using LabVIEW. There are two distinct parts in the software:
1. ON/OFF controller server program and logic
2. Internet communication using DataSocket protocol
These parts will be explained in the following sections

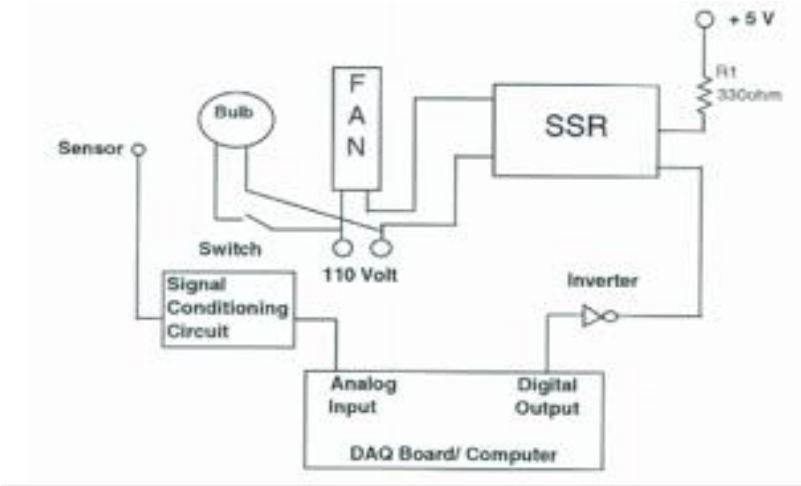


Fig 4: ON-OFF Temperature Control

ON/OFF Controller Server Program and Logic

The LabVIEW program on the server first reads the voltage from the analog input channel of the DAQ board and converts it to a temperature using the equation

$$Tout = 6\ Vin + 60$$

where Tout is the process temperature, and Vin is the input voltage from the DAQ board. The desired Set-point temperature value of the process is obtained from the client computer, and the Error is determined using the equation

$$Error = Set\text{-}point\ .\ Tout.$$

Based on the error and neutral zone High Limit and Low Limit, an ON/OFF controller logic is implemented using LabVIEW. In this logic, Digital Output Channel is the output logic value sent to the DAQ board which controls the fan through the SSR, Cooling Fan Indicators are the LED ON/ OFF indicators on the front panel of the LabVIEW VI that show the state of the fan, and Within Limits Indicator shows if the process is operating within the neutral zone. The Cooling Fan ON Indicator is also defined as a local read only variable which is used in the logic implementation.

The LabVIEW front panel of the server program VI

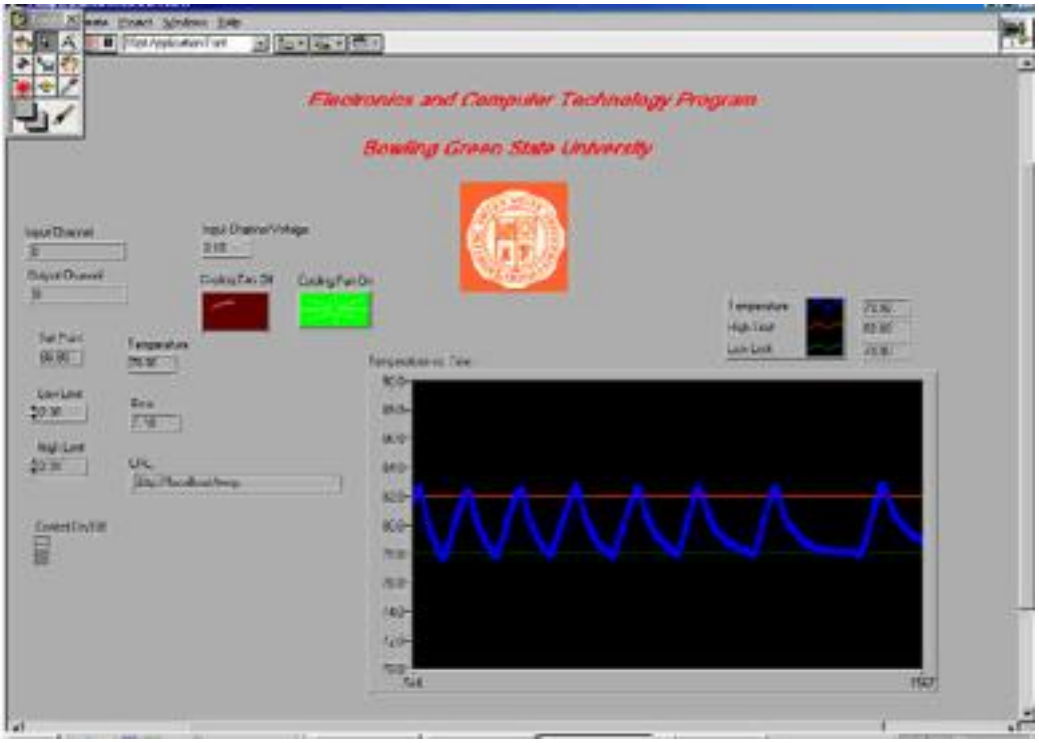


Fig 5: Server front panel Temperature data acquisition system

The hardware for server workstation consists of a PC with Pentium III, 550 MHz processor, 128 Mb RAM, Network Interface Card (NIC), National Instruments DAQ board. The server software includes Windows 98, NI-DAQ driver, LabVIEW 5.1 and NI-DataSocket Manager. The designed experiment is connected to the DAQ board. The server is assigned static IP address. The clients could be any PC.s with NIC that can run a LabVIEW program. The objective of the experiment is to maintain the temperature inside a wooden box at some desired set-point value, within neutral zone limits, using a two-state-controller mode. The wooden box is heated with a light bulb. The temperature is measured using LM335 solid-state The hardware for server workstation consists of a PC with Pentium III, 550 MHz processor, 128 Mb RAM, Network Interface Card (NIC), National Instruments DAQ board. The server software includes Windows 98, NI-DAQ driver, LabVIEW 5.1 and NI-DataSocket Manager. The designed experiment is connected to the DAQ board. The server is assigned static IP address. The clients could be any PC.s with NIC that can run a LabVIEW program. The objective of the experiment is to maintain the temperature inside a wooden box at some desired set-point value, within neutral zone limits, using a two-state-controller mode. The wooden box is heated with a light bulb. The temperature is measured using LM335 solid-state

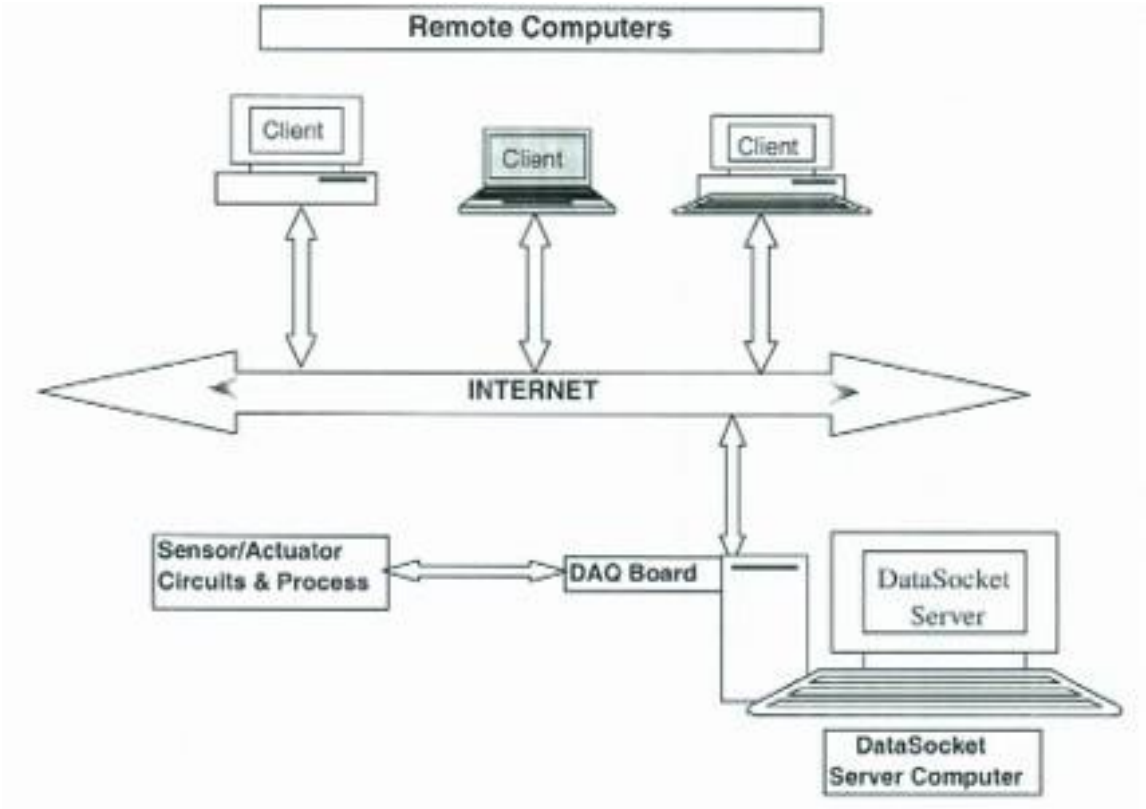


Fig 6: Temperature data Acquisition

Oscilloscope

Open Windows oscilloscopes from the 5000, 6000, 7000, and 8000 series are Windows-based and contain scope-specific software for acquisition, connectivity, and control. By default, the scope user interface runs Windows-based application software that performs the following scope-specific tasks:

- Presents the scope user interface
- Configures scope hardware based on commands from the user and signal content
- Displays acquired signals and derivations of acquired signals

It can use LabVIEW to extend the feature list of your scope to include the following tasks:

- Custom analysis and signal processing of acquired signals
- Automation of scope-related tasks and sequences of tasks
- A unique and customizable user interface
- Custom reports, including reports that you can publish live over the Internet
- Remote, Internet-based control and monitoring

Example:

Connect the function generator to the scope and put up the sample waveform. Increase the amplitude to 2v and pull down the VISA box and click on GPIB for the oscilloscope. The display of the wave is shown in the fig 7.

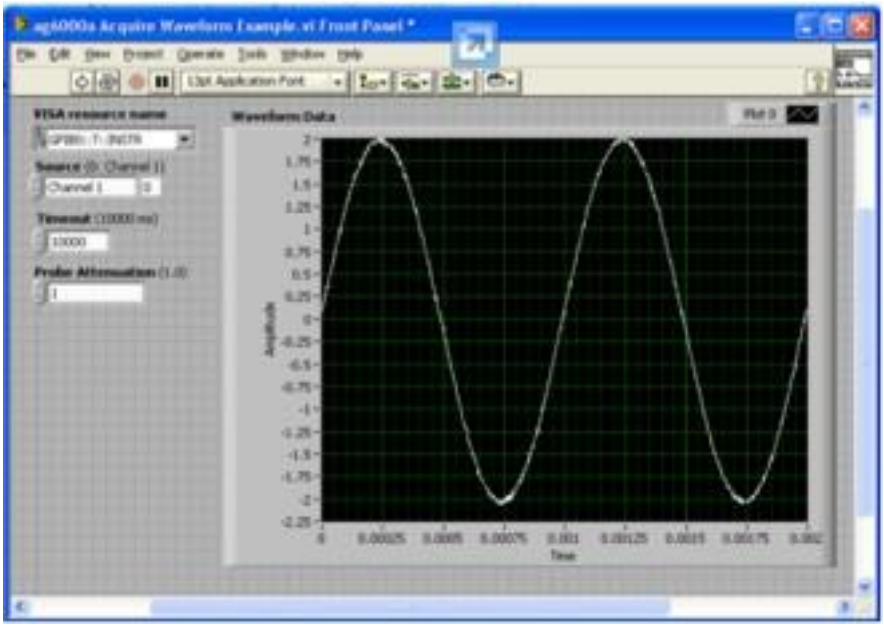


Fig 7: waveform acquired by oscilloscope

Digital Multimeter

Digital Multimeters (DMMs) are specialized in taking flexible, high resolution measurements
• Low to medium acquisition speeds
• High resolution
• Measures current or resistance in addition to voltage.
• Different form factors: PXI, PCIe, PCI, USB Software Support in NI LabVIEW and Signal Express The NI 407x series of DMMs offer unique capabilities
− Isolated Digitizer Mode at up to 1.8 MS/s
− Industry Leading Accuracy
− 2-year Calibration Cycle
• USB-4065 & PCMCIA-4050 for portable measurements

Example:

Design a digital multimeter along with its front panel and block diagram

Fig 8 : Front Panel

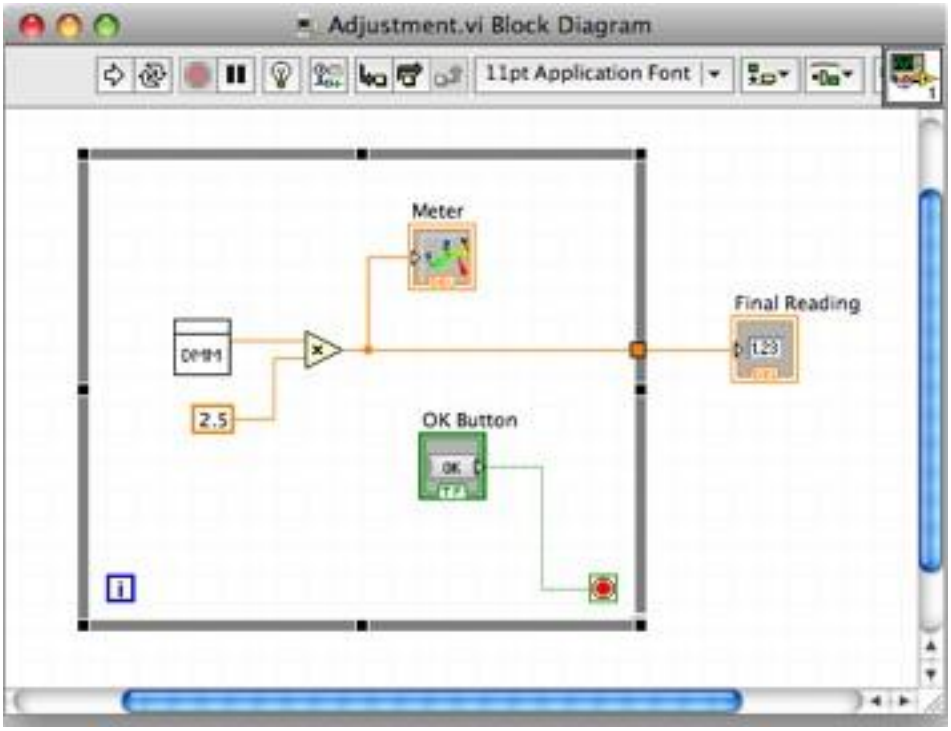


Fig 9: Block diagram of multimeter

Motion control employing stepper motor

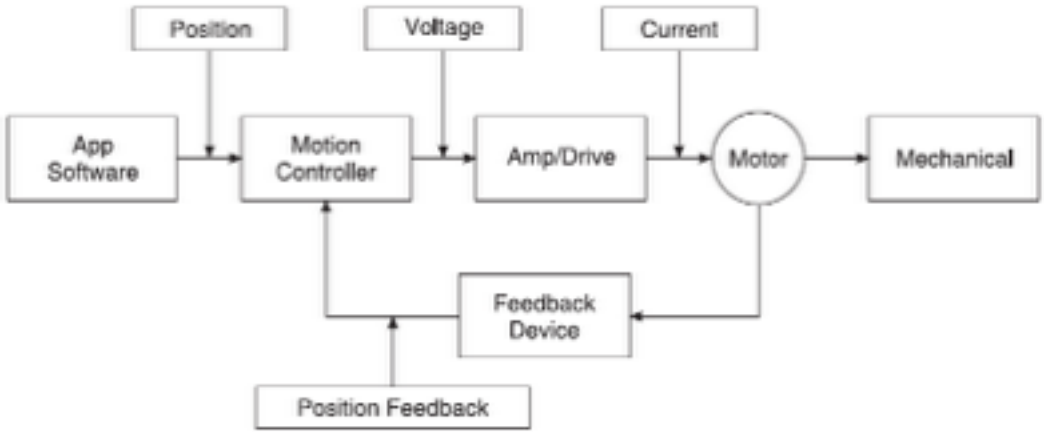


Fig 10: Components of motion control

Motion controller: The motion controller acts as brain of the system by taking the desired target positions and motion profiles and creating the trajectories for the motors to follow, but outputting a ±10 V signal for servomotors, or a step and direction pulses for stepper motors.

Amplifier or drive: Amplifiers (also called drives) take the commands from the controller and generate the current required to drive or turn the motor.

Motor: Motors turn electrical energy into mechanical energy and produce the torque required to move to the desired target position.

Mechanical elements: Motors are designed to provide torque to some mechanics. These include linear slides, robotic arms and special actuators.

Feedback device or position sensor: A position feedback device is not required for some motion control applications (such as controlling stepper motors), but is vital for servomotors. The feedback device, usually a quadrature encoder, senses the motor position and reports the result to the controller.

5.6 Image Acquisition and Processing

Image analysis combines techniques that compute statistics and measurements based on the gray level intensities of the image pixels. Image processing contains information about lookup tables, convolution kernels, spatial filters and grayscale morphology. The lookup table (LUT) transformations are basic image-processing functions that highlight details in areas containing significant information at the expense of other areas. These functions include histogram equalization, gamma corrections logarithmic corrections, and exponential corrections. NI-IMAQ is a complete and robust API for image acquisition. Whether you are using LabVIEW,
Measurement Studio, Visual Basic, or Visual C++, NI-IMAQ gives you high-level control of National Instruments image acquisition devices. NI-IMAQ performs all of the computer- and board-specific tasks, allowing straightforward image acquisition without register-level programming. NI-IMAQ is compatible with NI-DAQ and all other National Instruments driver software for easily integrating an imaging application into any National Instruments solution. NI-IMAQ is included

with your hardware at no charge that you can call from your application programming environment. These functions include routines for video configuration, image acquisition (continuous and single-shot), and memory buffer allocation, trigger control and board configuration. NI-IMAQ performs all functionality required to acquire and save images. For image analysis functionality, refer to the IMAQ Vision software analysis libraries which are discussed later in this course. NI-IMAQ resolves many of the complex issues between the computer and IMAQ hardware internally, such as programming interrupts and DMA controllers.

Fig 11: NI IMAQ functions

NI-IMAQ and IMAQ Vision use five categories of functions to acquire and display images:

● **Utility functions**—Allocate and free memory used for storing images; begin and end image acquisition sessions

● **Single buffer acquisition functions**—Acquire images into a single buffer using the snap and grab functions

● **Multiple buffer acquisition functions**—Acquire continuous images into multiple buffers using the ring and sequence functions

● **Display controls**—Display images for processing

● **Trigger functions**—Link a vision function to an event external to the computer, such as receiving a pulse to indicate the position of an item on an assembly line

Snaps and grabs are the most basic types of acquisitions. A snap is simply a snapshot, in which you acquire a single image from the camera. A grab is more like a video, in which acquire every image that comes from the camera. The images in a grab are displayed successively, producing a full-motion video, consisting of around 25 to 30 frames per second. IMAQ Snap, IMAQ Grab Setup and IMAQ Grab Acquire are used to snap and grab images.

IMAGE PROCESSING TOOLS AND FUNCTIONS IN IMAQ VISION

Utility functions include VIs for image management and manipulation, file management, calibration and region of interest processing. Image processing functions include VIs for analysis, color processing, frequency processing, filtering, morphology, operations, and processing, including IMAQ Histogram, IMAQ Threshold and IMAQ Morphology. Machine vision VIs are used for common inspection tasks such as checking for the presence or absence of parts in an image or measuring dimensions in comparison to specifications. Some examples of the machine vision VIs are the caliper and coordinate system VIs.

Image processing is a time-consuming process, both in computer processor time and development time. National Instruments has developed an application to accelerate the design time of a machine vision application.. IMAQ Vision Assistant allows even the first-time vision developer to learn image processing techniques and test inspection strategies. In addition, more experienced developers can develop and explore vision algorithms faster with less programming.

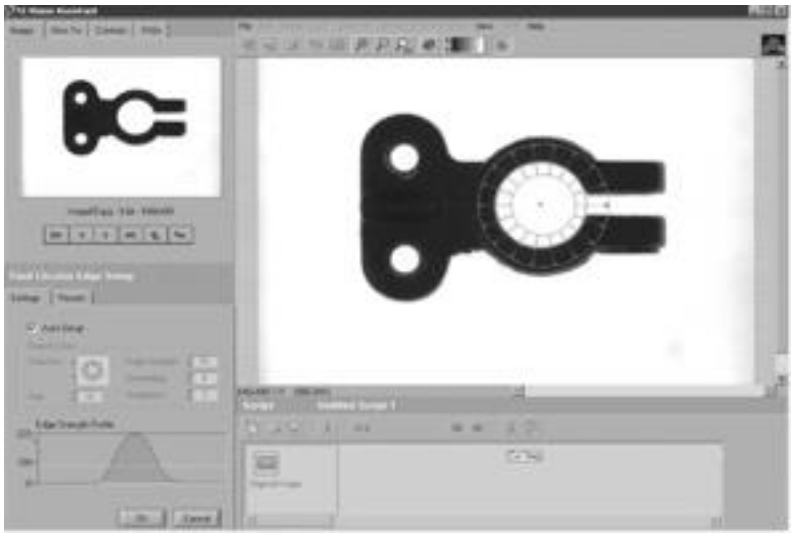


Fig 12: IMAQ Assistant

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2. Lisa K. Wells and Jeffrey Travis, LABVIEW for Everyone, PHI, 1997.
3. Skolkoff, Basic concepts of LABVIEW 4, PHI, 1998