MODULE IV

SYLLABUS

- **Micro Electromechanical system (MEMS) --**Advantages and applications, MEMS micro sensors and actuators, manufacturing process: bulk micro machining and surface micromachining, MEMS accelerometers
- **Virtual instrumentation system**: Architecture of virtual instruments – virtual instruments and traditional instruments – concepts of graphical programming

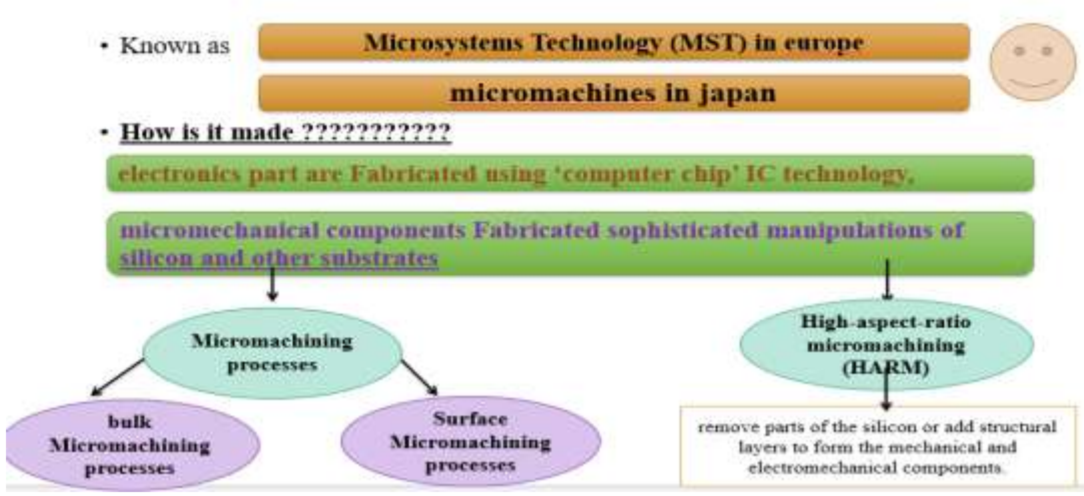
QUESTION BANK

1. What you mean by MEMS and where we used? Explain with help of block diagram. Also mention advantages and disadvantages of MEMS
2. Discuss the applications of MEMS. Explain any three applications in detail
3. What is micro actuator? Explain in detail with help of block diagram
4. What are the applications of micro actuator
5. What is micro sensor? Explain in detail. Also mention the applications.
6. Which MEMS sensors used in a typical car
7. Compare the Integrated Circuits and MEMS
8. What is micro machining? Why micro machining? Explain briefly about bulk micromachining and surface micromachining
9. What are the steps for surface micro machining. Explain it
10. Discuss the difference between bulk micromachining and surface micromachining
11. Explain micro accelerator with help of diagram and write the applications
12. Define Virtual Instrumentation
13. Draw the architecture of virtual instruments. Explain it
14. Compare traditional instruments and virtual instruments
15. Write a short note on
    a. Graphical programming in Lab View
    b. Front panel and block diagram
    c. Data flow

MEMS(MICRO-ELECTRO-MECHANICAL SYSTEMS

MEMS has been identified as one of the most promising technologies for The 21St Century and has the potential to revolutionize both industrial and Consumer products by combining silicon-based microelectronics with Micromachining technology. Its techniques and microsystem-based Devices have the potential to dramatically affect of all of our lives and the Way we live. Micro-electro-mechanical systems, or MEMS, is A technology that in its most general form can be defined as miniaturized mechanical and electro-mechanical elements (I.E., Devices and structures) that are made using the techniques of micro fabrication.It is used to create tiny Integrated devices or systems that combine mechanical and electrical components. They are Fabricated using integrated circuit (IC) batch processing techniques .Size range few micrometers to millimetres.

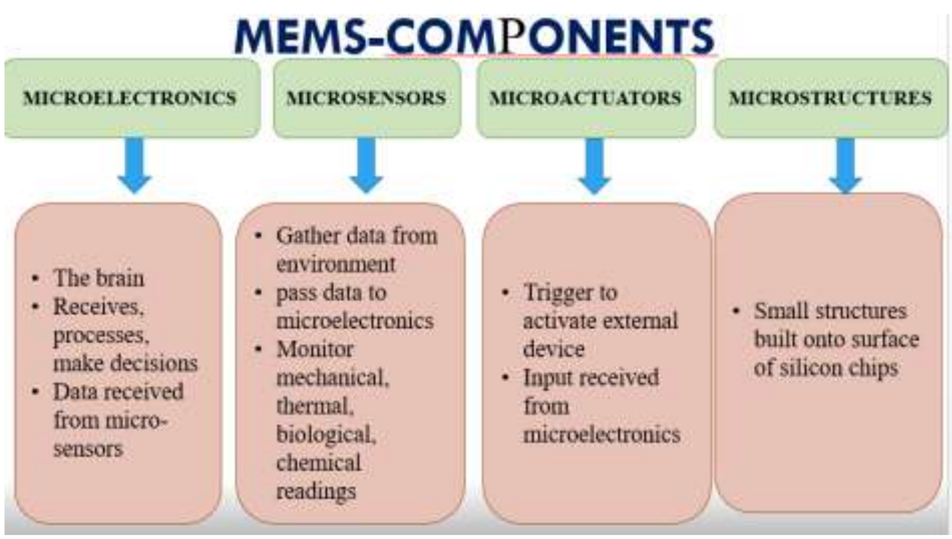
It has the ability to sense, Control and actuate on the micro scale, and generate effects on the macro scale.



- The technology of microscopic devices, particularly those with moving parts.
- It merges at the nano-scale into nano-electromechanical systems (nems) and nanotechnology
- Integration of mechanical elements, sensors, actuators and electronics on a common silicon substrate through fabrication technology
- made up of components between 1 and 100 micrometers in size (i.E., 0.001 to 0.1 mm),
- MEMS devices generally range in size from 20 micrometers to a millimeter (i.e., 0.02 to 1.0 mm)
- although components arranged in arrays

SCALE OF INTEGRATION

- **SSI-→**Small Scale Integration
- **Msi-→**Medium Scale Integration
- **Lsi-→**Large Scale Integration
- **Vlsi-→**Very Large Scale Integration
- **Vvlsi** or **ulsi ---→** Very VLSI Or Ultra LSI



MEMS MATERIALS

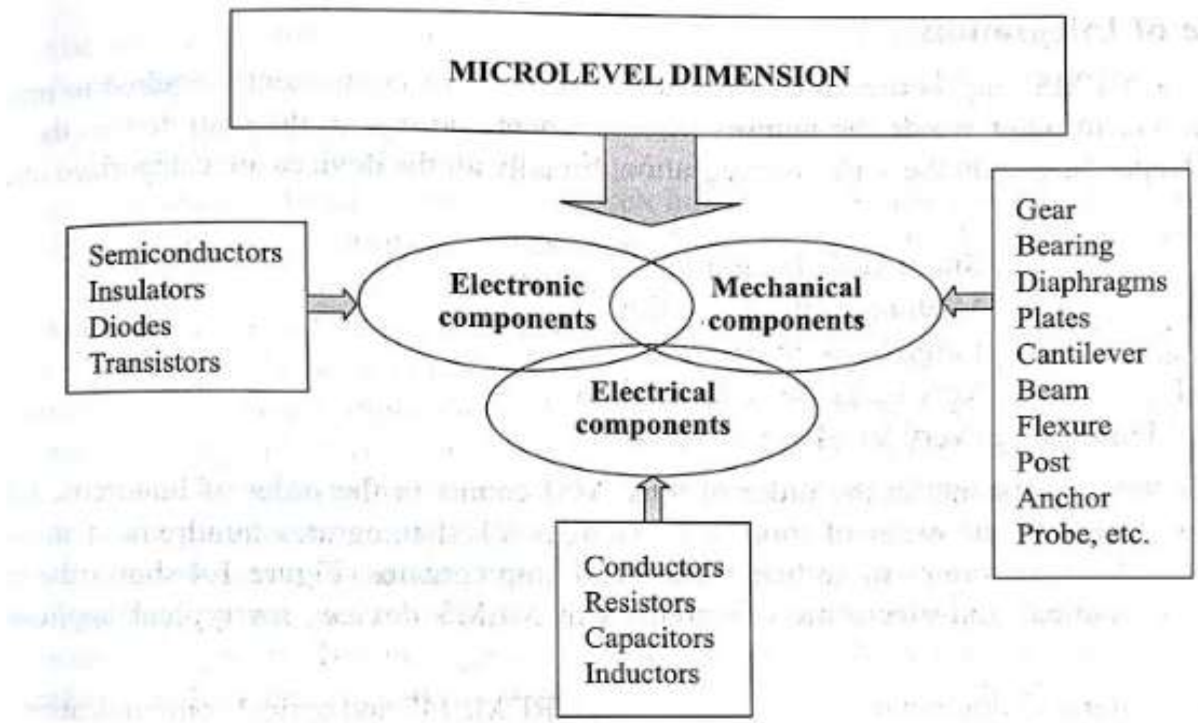
- Micro-electronics heritage

Si is a good semiconductor, properties can be tuned
Si oxide is very robust
Si nitride is a good electrical insulator

Substrate	Cost	Metallization	Machinability
Silicon	High	Good	Very good
Plastic	Low	Poor	Fair
Ceramic	Medium	Fair	Poor
Glass	Low	Good	Poor

ADVANTAGES	DISADVANTAGES
1)Minimize energy and material used in manufacturing	1)Farm establishment require huge investment
2)Improved reproducibility	2)Very complex design procedure
3)Cost and performance advantages	3)Prior knowledge is needed for integration of MEMS devices
4)Higher accuracy, sensitivity, selectivity	4)Market value of component are high

MEMS Device comprises electronics, electrical and mechanical elements



APPLICATIONS OF MEMS

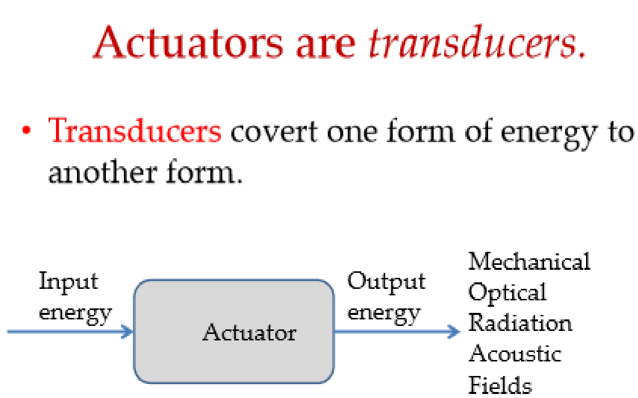
Automotive	Electronics	Medical	Communications	Defence
Internal navigation sensors	Disk drive heads	Blood pressure sensor	Fibre-optic network components	Munitions guidance
Air conditioning compressor sensor	Inkjet printer heads	Muscle stimulators & drug delivery systems	RF Relays, switches and filters	Surveillance
Brake force sensors & suspension control accelerometers	Projection screen televisions	Implanted pressure sensors	Projection displays in portable communications devices and instrumentation	Arming systems
Fuel level and vapour pressure sensors	Earthquake sensors	Prosthetics	Voltage controlled oscillators (VCOs)	Embedded sensors
Airbag sensors	Avionics pressure sensors	Miniature analytical instruments	Splitters and couplers	Data storage
"Intelligent" tyres	Mass data storage systems	Pacemakers	Tuneable lasers	Aircraft control

MICRO ACTUATORS

- An actuator is a control device that makes something move.
- Actuators use input energy and release output energy in a controlled manner.
- Mechanical actuators act upon something and move it with force or torque.
- The process of micro movement is called micro actuation
- MICRO ACTUATORS are light in weight , conformable and precision devices
- Produce motions over small distances. –Of the order of microns to mm.
- Produce small forces. –Of the order of pN to mN.
- Produce motion and force in entities of small sizes.
- **<u>Mechanical micro-actuators with different input energies and how they are used.</u>**

    •Electrostatic
    •Electro-magnet based
    •Thermal
    •Chemical
    •Piezo-electric
    •Shape memory alloy (SMA)
    •Smart material-based
    •Light-induced
    •Biological

- There are many types of actuators.
    –Based on the type of output energy released
    - –Based on the way output energy is released
    - –Based on the input energy used



<u>APPLICATIONS OF MICROACTUATORS</u>

- Actuation of micro mirrors to scan laser beams
- Printing applications
- Driving of cutting tools for microsurgical applications
- Driving micro pumps and and valves for fluid and gas transportation
- Data reading and recording tool
- RF signal tuning
- Optical signal switching

MEMS AS A MICROSENSOR

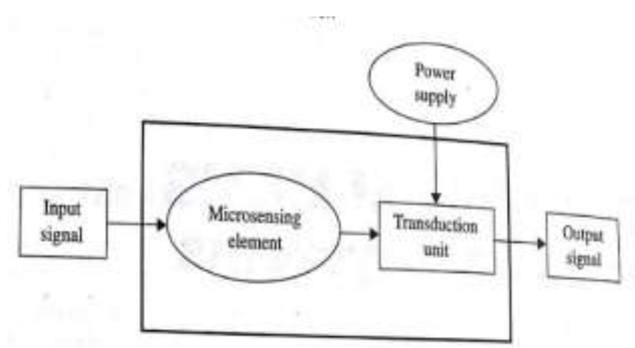
A sensor is a device that measures information from a surrounding environment and provides An electrical output signal in response to the parameter it measured. Sensors Measure something, which we call a measurand.

sensors BASED ON

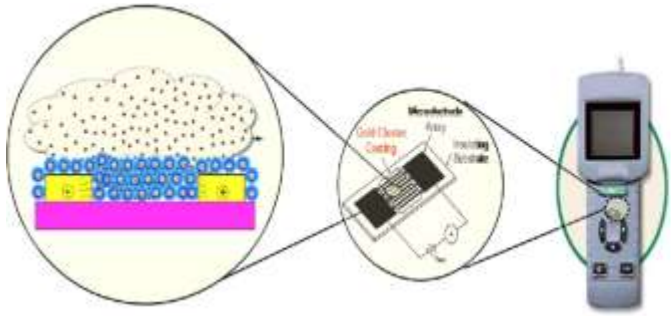
- **–Based on the measurands**
- **–based on the way they measure**

SENSOR MEASURES

- mechanical - force, pressure, velocity, acceleration, position
- thermal - temperature, entropy, heat, heat flow
- chemical - concentration, composition, reaction rate
- radiant - electromagnetic wave intensity, phase, wavelength, polarization
- Reflectance, refractive index, transmittance
- magnetic - field intensity, flux density, magnetic moment, permeability
- electrical - voltage, current, charge, resistance, capacitance, polarization



Micro sensors have the advantages of being sensitive and accurate with minimal amount of required sample substance.They are primarily employed to observe the temporal effects of the environment and subsequently to calibrate the observed values in order to produce meaningful information.Sensors vary from simple to highly complex

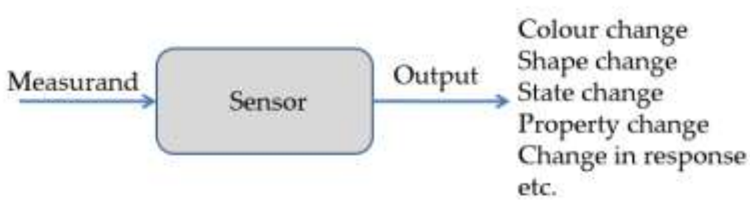


<u>MEMS BASED SENSORS USED IN TYPICAL CAR</u>

1. Air conditioning and compression sensor
2. Force sensor
3. Pressure and inerstial sensor for braking control
4. Inertial navigation sensor for sensing acceleration
5. Tire pressure sensor
6. Crash sensor
7. Mass air flow sensor
8. Exhaust gas sensor
9. Microphone for noise cancellation
10. Air bag side impact sensor
11. Fuel sensor
12. Nozzle sensor for checking fuel injection

Sensors are transducers

Transducers convert one form of energy to another form



MICROSENSORS

- Capacitive accelerometer
- Piezo-resistive pressure sensor
- Conductometric gas sensor
- Virus-detecting micro cantilever
- Fibre-optic crack sensor
- Portable blood analyser

COMPARISON: IC'S VS. MEMS

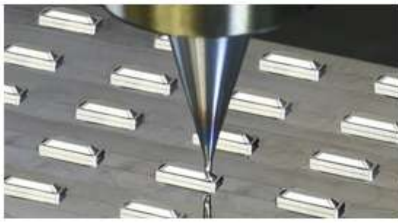
MEMS	IC
3D complex structures	2D structures
Doesn't have any basic building block	Transistor is basic building block
May have moving parts	No moving parts
May have interface with external media	Totally isolated with media
Functions include Biological,Chemical,Optical	Only Electrical
Packaging is very complex	Packaging Techniques are well developed

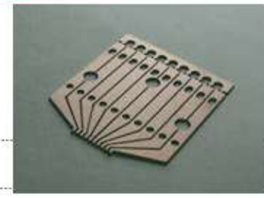
MICROMACHINING

MICRO + MACHINING

REMOVAL OF MATERIAL AT MICROLEVEL

MACRO COMpONENTS , MATERIAL REMOVAL AT MACRO/NANO LEVEL





FOR SHApING AND SIZING AND SURFACE FINISH

MEMS FABRICATION METHODS - MICROMACHINING

Fabrication of micromechanical structures with the aid of etching techniques to remove part of substrate or a thin film

1.bulk micromachining

3. high-aspect-ratio micromachining (HARM),

2.surface micromachinin g

pRinting from a plane surface- lithography

LIGA technology (a German acronym from lithographie, galvanoformung, abformung translated as lithography, Electroforming and moulding).

Why Micro Machining?

- *Final finishing operations in manufacturing of precise parts are always of concern owing to their most critical, labour intensive and least controllable nature.*
- *In the era of nanotechnology, deterministic high precision finishing methods are of utmost importance and are the need of present manufacturing scenario.*
- *The need for high precision in manufacturing was felt by manufacturers worldwide to improve interchangeability of components, improve quality control and longer wear/fatigue life.*

MEMS fabrication, uses High volume IC style <u>batch processing</u> - addition or subtraction of two Dimensional layers on a substrate (usually silicon) based on

Photolithography

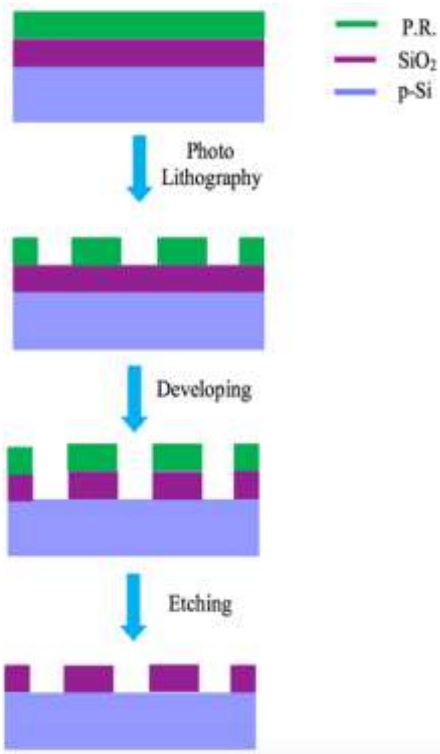
Photolithography, also called optical lithography or UV lithography, is a process used in microfabrication to pattern parts of a thin film or the bulk of a substrate. It uses light to transfer a geometric pattern from a photomask to a photosensitive chemical photoresist on the substrate

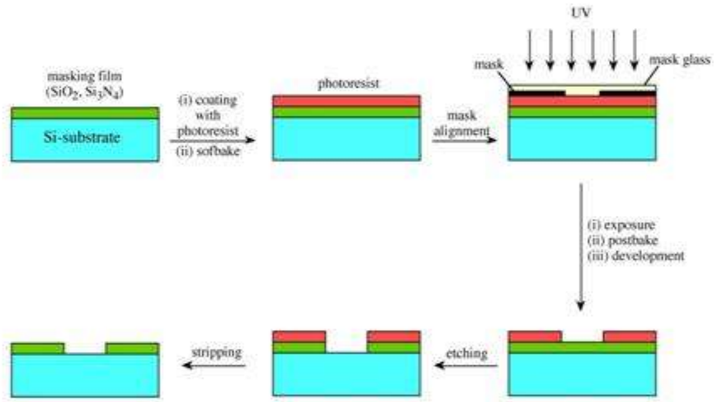
<u>patterns the structural material</u>

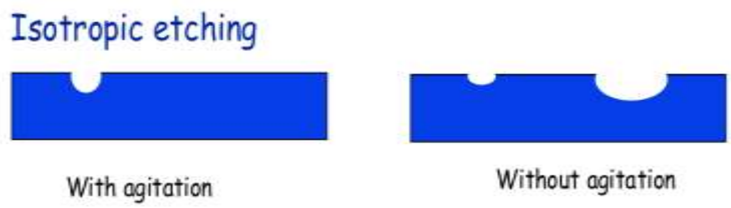
chemical Etching

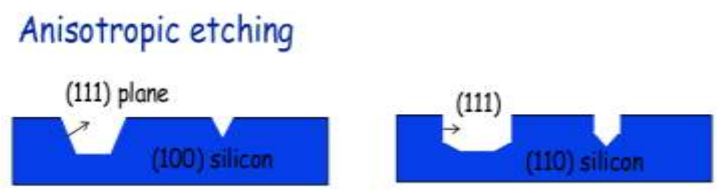
is the subtractive manufacturing process of using baths of temperature-regulated etching chemicals to remove material to create an object with the desired shape. It is mostly used on metals

<u>removal of material</u>







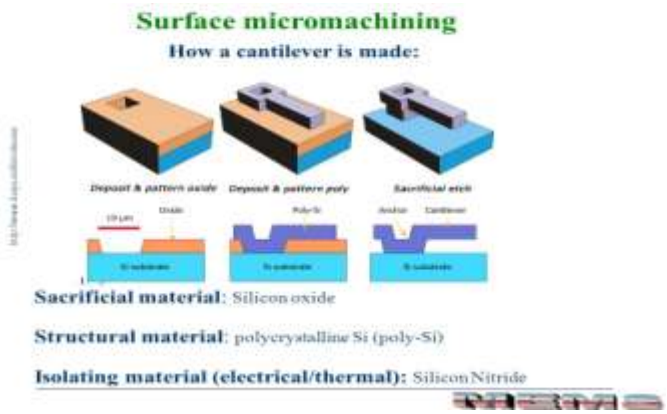


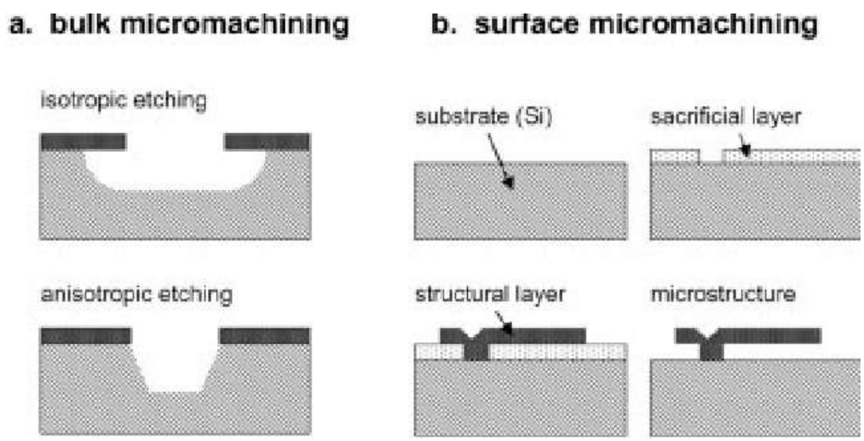
BULK MICROMACHINING

Bulk micromachining is a process used to produce micro machinery or micro electromechanical systems (MEMS). Bulk micromachining refers to etching through both sides(front and back) of a bulk material to form the desired structures.The structures are formed by wet chemical etching or by reactive ion etching(RIE).The advantage of bulk micromachining is that substrate materials such as quartz or single crystal silicon are readily available and reasonably high aspect ratio structures can be fabricated

SURFACE MICROMACHINING

Processing above the substrate - Foundation layer on which to build.Material is added to the substrate- form of layers of thin films (silicon wafer). structural Layers ,later to be removed, free standing structure - polycrystalline silicon or polysilicon, Silicon nitride and aluminium) and a sacrificial material, deposited wherever either an open.





DIFFERENCE BETWEEN BULK AND SURFACE MACHINING

BULK MACHINING

- Bulk micromachining means that 3D features are etched into the bulk of personal crystalline and non-crystalline materials
- Bulk micromachining is useful for forming microstructures, like trenches and, holes.
- Bulk micromachining wet etching techniques can be used quickly and uniformly over a large wafer surface area.
- Bulk micromachining techniques are not time-consuming
- Bulk micromachining is that it is not easily integrated with microelectronics. This flaw is due to the isotropic nature of wet etching, which limits line width resolution

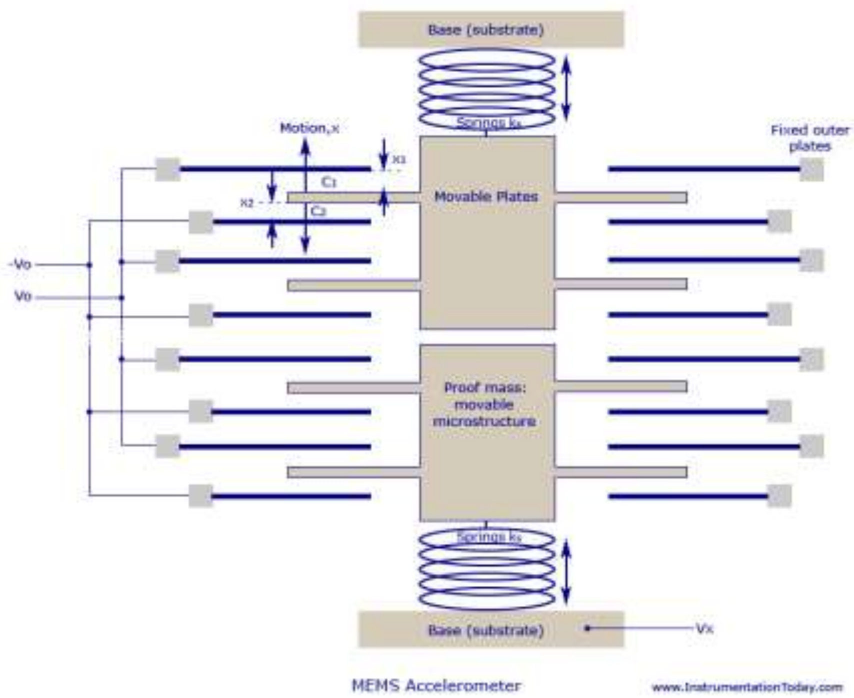
SURFACE MACHINING

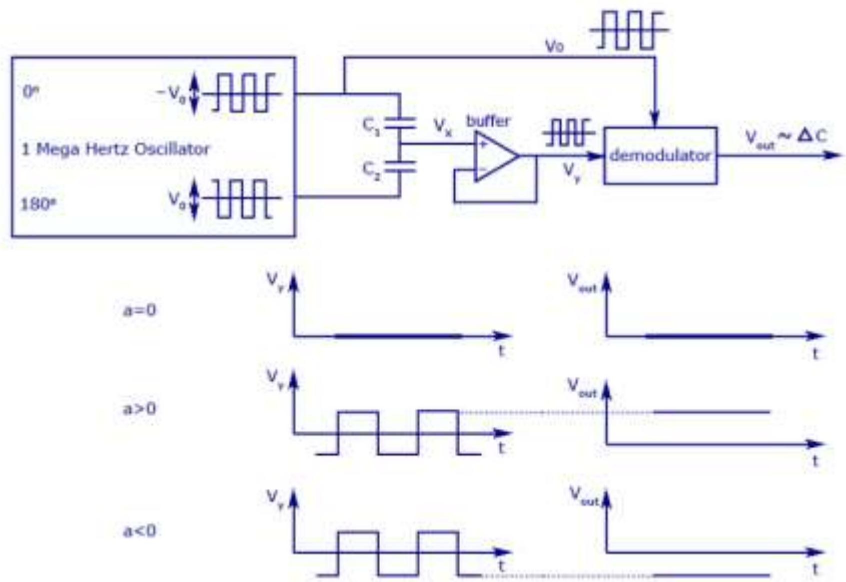
- Surface micromachining is the process of forming movable structures by placing the structures on initially rigid platforms, then removing the platforms, usually by etching the material away.
- Surface micromachining is useful for forming free moving microstructures, including basic rotating structures.

- Surface micromachining is highly anisotropic, but since it relies on high speed, high energy ion collisions, there is a high potential for radiation damage to the surface of the wafer, and sometimes results in poor selectivity.
- Surface micromachining techniques are often much more time-consuming
- Surface micromachining is that it is easily integrated with microelectronics.

MEMS ACCELEROMETER

An accelerometer is an electromechanical device that measures both static (gravity) and dynamic (motion or vibration) accelerations. The development of MEMS technology has revolutionized the original accelerometer applications, making them smaller, lower power and more accurate.





WORKING

One of the most commonly used MEMS accelerometer is the capacitive type.

- high sensitivity and its accuracy at high temperatures. T
- does not change values depending on the base materials used
- depends only on the capacitive value that occurs due to the change in distance between the plates.
- If two plates are kept parallel to each other and are separated by a distance' **d**', and if '**E**' is the permitivity of the separating material, then capacitance produced can be written as

$$C_0 = E_0.E\ A/d = E_A/d$$

$$E_A = E_0 EA$$

A – Area of the electrodes

•

Change in the values of E, A or d will help in finding the change in capacitance and thus helps in the working of the MEMS transducer. Accelerometer values mainly depend on the change of values of d or A.Called a simple one-axis accelerometer. If more sets of capacitors are kept in 90 degrees to each other you can design 2 or 3-axis accelerometer. A simple MEMS transducer mainly consists of a movable microstructure or a proof mass that is connected to a mechanical suspension system and thus on to a reference frame.The movable plates and the fixed outer plates act as the capacitor plates. When acceleration is applied, the proof mass moves accordingly. This produces a capacitance between the movable and the fixed outer plates.When acceleration is applied, the distance between the two plates displace as x1 and x2, and they turn out to be a function of the capacitance produced.From the image above it is clear that all sensors have multiple capacitor sets. All upper capacitors are wired parallel to produce an overall capacitance C1 and the lower ones produce an overall capacitance of C2.

If vx is the output voltage of the proof mass, and V0 is the output voltage produced between the plates, then

$$(V_x + V_0)\, C1 + (V_x - V_0)\, C2 = 0$$

$$V_x = V_0\, [(C2-C1)/(C2+C1)] = (x/d)\, V_0$$

When no acceleration is given (a=0), the output voltage will also be zero.

When acceleration is given, such as (a>0), the value of value of vx changes in proportion to the value of v0.

When a deceleration is given, such as (a<0), the signals vx and vy become negative. He demodulator produces an output equal to the sign of the acceleration, as it multiplies both the values of vy and V0 to produce VOUT, which has the correct acceleration sign and correct amplitude.

Applications

1. MEMS sensors are being used in latest mobile phones and gaming joysticks as step counters, user interface control, and also for switching between different modes.
2. Used in mobile cameras as a tilt sensor so as to tag the orientation of photos taken.
3. To provide stability of images in camcorders and also to rotate the image to and fro when you turn the mobile.
4. A 3d accelerometer is used in nokia 5500 so as to provide easier tap and change feature by which you can change mp3's by tapping on the phone when it is lying inside the pocket.
5. Used to protect hard disk drives in laptops from getting damaged when the pc falls to the ground. The device senses the free fall and automatically switches off the hard disk.
6. Used in car crash airbag sensors, where it senses the sudden negative acceleration and determines the correct time to open the airbag.
7. Used in real-time applications like military monitoring, missile launching, projectiles

VIRTUAL INSTRUMENTATION

It is the use of customizable software and modular measurement hardware to create user-defined measurement systems.

- Virtual instrumentation is an inter disciplinary field that merges sensing, hardware and software technologies in order to create flexible and sophisticated instruments for control and monitoring applications
- Virtual Instrumentation is the use of customizable software and modular measurement hardware to create user defined measurement systems called virtual instruments.
- Virtual instrument provides all the software and hardware needed to accomplish the measurement or control task

Definition for VI:

"Virtual instrumentation combines mainstream commercial technologies, such as the PC, with flexible software and a wide variety of measurement and control hardware."

➢ Engineers use virtual instrumentation to bring the power of flexible software and PC technology to test, control and design applications making accurate analog and digital measurements.

➢ . Industries with automated processes, such as chemical or manufacturing plants use virtual instrumentation with the goal of improving system productivity, reliability, safety, optimization and stability.

➢ Virtual instrumentation is computer software that a user would employ to develop a computerized test and measurement system for controlling from a computer desktop, an external measurement hardware device, and for displaying, test or measurement data collected by the external device on instrument-like panels on a computer screen.

➢ It extends to computerized systems for controlling processes based on data collected and processed by a computerized instrumentation system.

National Instruments LabVIEW, a premier virtual instrumentation graphical development environment, uses symbolic or graphical representations to speed up development. The software symbolically represents functions. Consolidating functions within rapidly deployed graphical blocks further speeds up development.

Figure 1.10 uses highly productive software, modular I/O and commercial platforms. The modular I/O, designed to be rapidly combined in any order or quantity to ensure that virtual instrumentation can both monitor and control any development aspect. Using well-designed software drivers for modular I/O, engineers and scientists quickly can access functions during concurrent operation.

Commercial platforms, often enhanced with accurate synchronization, ensures that virtual instrumentation takes advantage of the very latest computer capabilities and data transfer technologies. This element delivers virtual instrumentation on a long-term technology base that scales with the high investments made in processors, buses and more.
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Virtual Instrument Architecture

- A virtual instrument is composed of the following blocks:
  - ➢ Sensor Module,
  - ➢ Sensor Interface,
  - ➢ Medical Information Systems Interface,
  - ➢ Processing Module,
  - ➢ Database Interface, and
  - ➢ User Interface.

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. Biomedical virtual instruments are often integrated with some other medical information systems such as hospital information systems. In this way the configuration settings and the data measured may be stored and associated with patient records.

a) <u>Sensor module</u>

- 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.

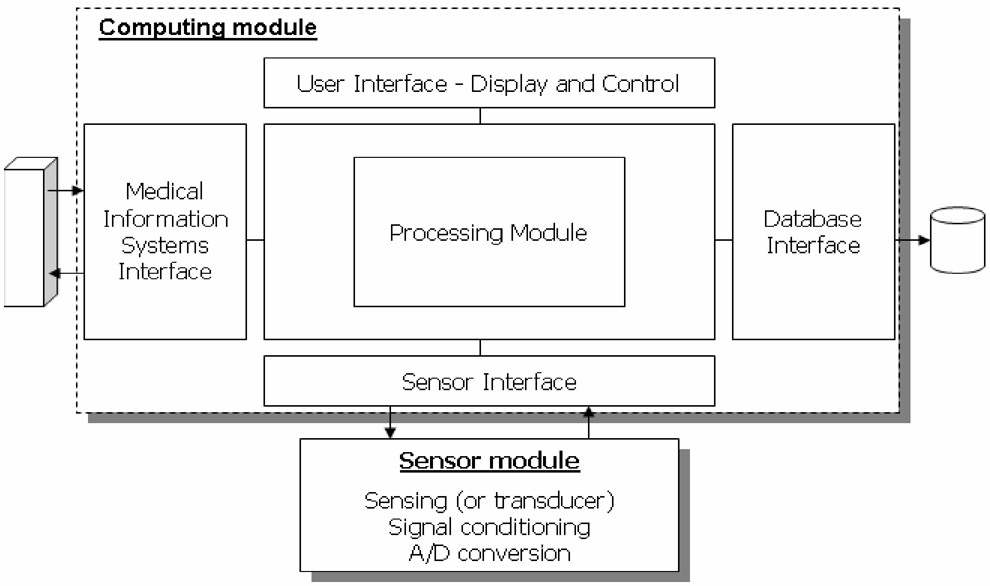

Table #: *Human physiological signals.*

Group	Physiological signals
Electrical signals (require only amplification)	Electromyograph (EMG)
	Electrocardiograph (ECG)
	Electroencephalograph (EEG)
	Electrooculograph (EOG).
Non-electrical signals (require a transducer to change the information to an electrical signal)	Skin conductivity (Galvanic Skin Response - GSR)
	Respiratory rate
	Blood pressure
	Peripheral body temperature

A sensor module principally consists of three main parts:
· **the sensor,**
· **the signal conditioning part, and**
· **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.

According to their position, biomedical sensors can be classified as:

· ***Implanted sensors,*** where the sensor is located inside the user's body, for example, intracranial stimulation.
· ***On-the-body sensors*** are the most commonly used biomedical sensors. Some of those sensors, such as EEG or ECG electrodes, require additional gel to decrease contact resistance.
· ***Noncontact sensors***, such as optical sensors and cameras that do not require any physical contact with an object.

The signal-conditioning module performs (usually analog) signal conditioning prior to AD conversion, such as . 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

b) 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 General Purpose Interface Bus (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 . Wireless communication is especially important for implanted sensors where cable connection is impractical or not possible

c) 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***.

i) . Analytic processing

- 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

ii) Artificial intelligence techniques

- 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, were 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

d) Database interface

- Computerized instrumentation allows measured data to be stored for off-line processing, or to keep record as a part of the patient record There are several currently available database technologies that can be used for this purpose

Table #. *The most frequently used contemporary databases interfaces.*

Database interface	Description
File System	Random writing and reading of files.
eXtensible Markup Language (XML)	Standardized markup files.
Open Database Connectivity (ODBC)	SQL based interface for relation databases.
Java Database Connectivity (JDBC)	Java programs' SQL based object-oriented interface for relation databases.
ActiveX Data Objects (ADO)	Windows programs' object-based interface for various data sources including relational databases and XML files.
Data Access Objects (DAO)	Windows programs' object-based interface for relation databases.

e) Medical 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, realtime alerts and predictive warnings .

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Biomedical Applications of Virtual Instrumentation

Virtual instrumentation is being increasingly accepted in biomedical field. In relation to the role of a virtual instrument, we may broadly classify biomedical applications of virtual instrumentation in four categories

- *Examination*, where a physician does online or off-line examination of patient measurements,
- *Monitoring*, which can be used as a basis for real-time alerts and interactive alarms,
- *Biofeedback*, where measured signals are presented back to a patient in real-time, and
- *Training and education*, where a virtual instrument may simulate or playback earlier measured signals.

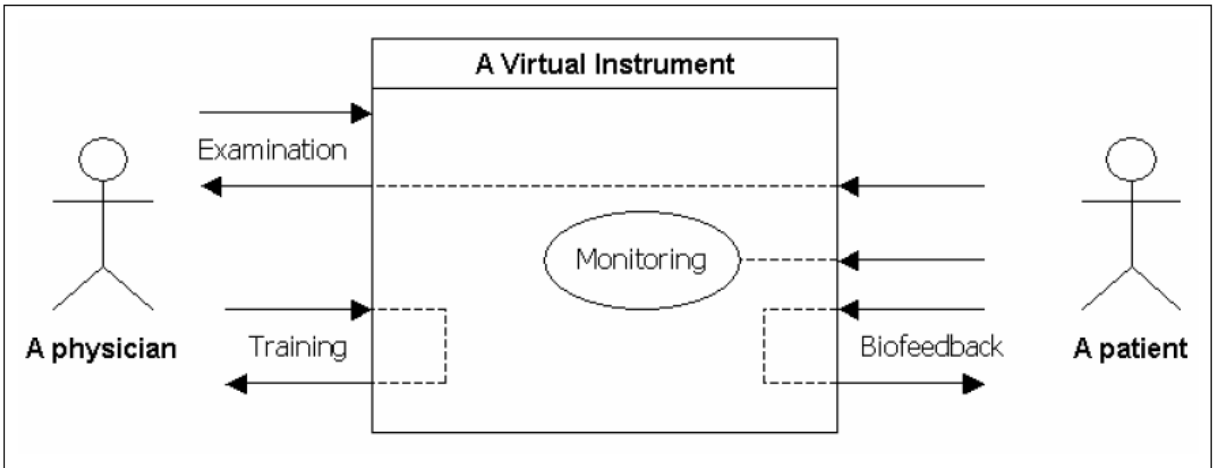

Figure #. *Types of biomedical applications of virtual instrumentation.*

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VIRTUAL INSTRUMENT AND TRADITIONAL INSTRUMENT

Traditional Instrument:

- A traditional instrument is 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 cover a physical or software device that performs an analysis on data acquired from another instrument and then outputs the processed data to display or recording means.
- This second category of instruments includes 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, light and sound frequencies and amplitudes, and also electrical parameters including voltage, current and frequency.

Virtual Instruments:

- A virtual instrument (VI) is defined as an industry-standard computer equipped with user friendly application software, cost-effective hardware and driver software that together perform the functions of traditional instruments.
- Simulated physical instruments are called virtual instruments (VIs). Virtual instrumentation software based on user requirements defines general-purpose measurement and control hardware functionality.
- With virtual instrumentation, engineers and scientists reduce development time, design higher quality products, and lower their design costs.
- Virtual instrumentation is necessary because it is flexible.
- It delivers instrumentation with the rapid adaptability required for today's concept, product and process design, development and delivery.
- Consider modern cell phones. Most of them contain the latest features of the last generation, including audio, a phone book and text messaging capabilities. New versions include a camera, MP3 player, and Bluetooth networking and Internet browsing.
- Virtual instruments are defined by the user while traditional instruments have fixed vendor-defined functionality
- Every virtual instrument consists of two parts—**software and hardware**.
- A virtual instrument provides all the software and hardware needed to accomplish the measurement or control task.
- In addition, with a virtual instrument, engineers and scientists can customize the acquisition, analysis, storage, sharing and presentation functionality using productive, powerful software.

Comparison:

- ➢ Without the displays, knobs and switches of a conventional, external box-based instrumentation products, a virtual instrument uses a personal computer for all user interaction and control.
- ➢ In many common measurement applications, a data acquisition board or card, with a personal computer and software, can be used to create an instrument.
- ➢ In fact, a multiple-purpose virtual instrument can be made by using a single data acquisition board or card.
- ➢ The primary benefits of apply data acquisition technology to configure virtual instrumentation include costs, size, and flexibility and ease of programming.
- ➢ Traditional instruments and software-based virtual instruments largely share the same architectural components,
- ➢ Most conventional instruments do not have any computational power as compared to a virtual instrument.

➢ Since the virtual instrument is part of a person computer configuration, the personal computer’s computational as well as controlling capability can be applied into a test configuration.

➢ Virtual instruments are compatible with traditional instruments almost without exception. Virtual instrumentation software typically provides libraries for interfacing with common ordinary instrument buses such as GPIB, serial or Ethernet.

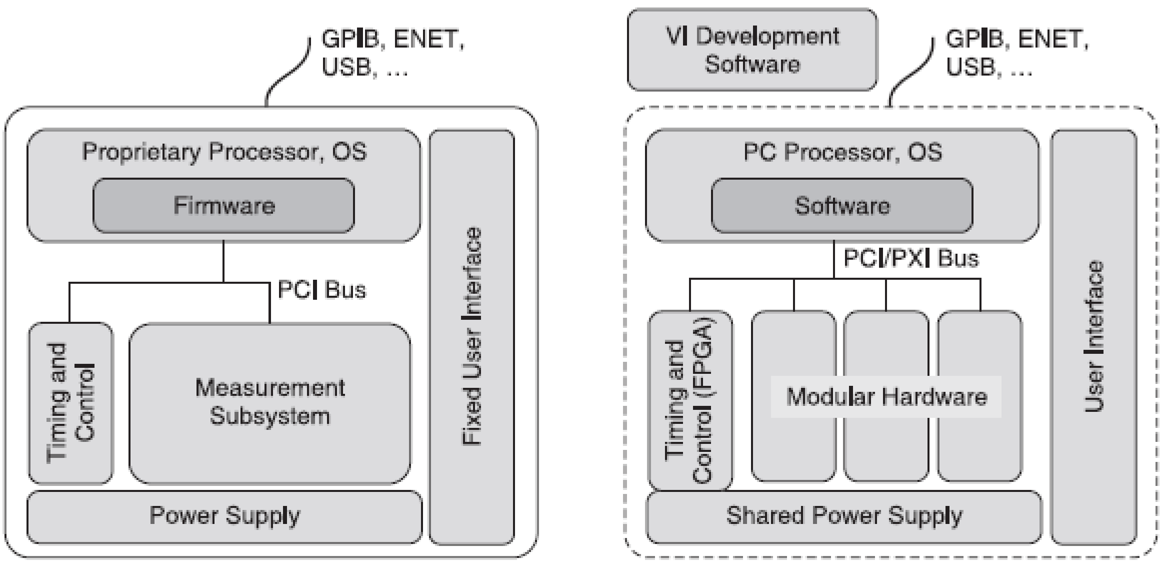

Figure 1.11 Traditional instruments (left) and software based virtual instruments (right).

- 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.
- A traditional instrument might contain an integrated circuit to perform a particular set of data processing functions; in a virtual instrument, these functions would be performed by software running on the PC processor.
- By employing virtual instrumentation solutions, we can lower capital costs, system development costs, and system maintenance costs, while improving time to market and the quality of our own products.
- . With these advances in technology, comes an increase in data acquisition rates, measurement accuracy, precision and better signal isolation building measurement and automation systems.
- Virtual instruments take advantage of PC performance increase by analyzing measurements and solving new application challenges with each new-generation PC processor, hard drive, display and I/O bus.

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GRAPHICAL PROGRAMMING AND TEXTUAL PROGRAMMING

- Graphical programming is a visually-oriented approach to programming.
- Graphical programming is easier and more intuitive to use than traditional textual programming.
- Textual programming requires the programmers to be reasonably proficient in the programming language.
- Non-programmers can easily learn the graphical approach faster at less amount of time.
- The main advantage of textual languages like C is that they tend to have faster graphical approach execution time and better performance than graphical programs.
- Textual programming environments are typically used in determining high throughput virtual instrumentation systems, such as manufacturing test systems.
- Textual programming environments are popular and many engineers are trained to use these standardized tools.
- Graphical environments are better for nonprogrammers and useful for developing virtual instruments quickly and need to be reconfigured rapidly.

Virtual instrumentation is not limited to graphical programming but can be implemented using a conventional programming language.

The most important task is to understand how to use standard analysis packages that can directly input data from the instruments and can be used to analyze, store and present the information in a useful format. Irrespective of whether it is classical or graphical environment any system with a graphical system design can be looked at as being composed of two parts—the user interface and the underlying code. The code in a conventional language like C comprises a number of routines while in the graphical language G it is a collection of icons interconnected by multi-colored lines.

TABLE 1.1 Comparison of text-based and graphical programming

Text-based programming	Graphical programming
• *Syntax* must be known to do programming.	• *Syntax* is knowledge but is not required for programming.
• The execution of the program is from *top to bottom*.	• The execution of program is from *left to right*.
• To check for the *error* the program has to be compiled or executed.	• *Errors* are indicated as we wire the blocks.
• *Front panel* design needs extra coding or needs extra work.	• *Front panel* design is a part of programming.
• Text-based programming is *non interactive*.	• Graphical programming is highly *interactive*.
• This is text-based programming where the programming is a *conventional method*.	• The programming is *Data Flow Programming*.
• *Logical Error* finding is easy in large programs.	• *Logical Error* finding in large programs is quiet complicated.
• Program flow is *not visible*.	• Data flow is *visible*.
• It is *test-based* programming.	• It is *icon-based* programming and wiring.
• Passing parameters to *sub routine* is difficult.	• Passing parameters to *sub VI* is easy.

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INTRODUCTION TO LabVIEW

- ❖ LabVIEW (Laboratory Virtual Instrument Engineering Workbench) is a graphical programming environment which has become prevalent throughout research labs, academia and industry.
- ❖ It is a powerful and versatile analysis and instrumentation software system for measurement and automation. Its graphical programming language called *G programming* is performed using a graphical block diagram that compiles into machine code and eliminates a lot of the syntactical details.
- ❖ LabVIEW offers more flexibility than standard laboratory instruments because it is software based.
- ❖ Using LabVIEW, the user can originate exactly the type of virtual instrument needed and programmers can easily view and modify data or control inputs.
- ❖ **LabVIEW programs are called virtual instruments (VIs), because their appearance and operation imitate physical instruments like oscilloscopes**.
- ❖ LabVIEW is designed to facilitate data collection and analysis, as well as offers numerous display options.
- ❖ With data collection, analysis and display combined in a flexible programming environment, the desktop computer functions as a dedicated measurement device.
- ❖ LabVIEW contains a comprehensive set of VIs and functions for acquiring, analyzing, displaying, and storing data, as well as tools to help you troubleshoot your code.

LabVIEW can communicate with hardware such as data acquisition, vision, and motion control devices, and GPIB, PXI, VXI, RS-232, and RS-485 devices.
LabVIEW also has built-in features for connecting your application to the Web using the LabVIEW Web Server and software standards such as TCP/IP networking and ActiveX.
Using LabVIEW, you can create test and measurement, data acquisitions, instrument control, datalogging, measurement analysis, and report generation applications.

ADVANTAGES OF LabVIEW

The following are the advantages of LabVIEW:

● Graphical user interface: Design professionals use the drag-and-drop user interface library by interactively customizing the hundreds of built-in user objects on the controls palette.

● Drag-and-drop built-in functions: Thousands of built-in functions and IP including analysis and I/O, from the functions palette to create applications easily.

● Modular design and hierarchical design: Run modular LabVIEW VIs by themselves or as subVIs and easily scale and modularize programs depending on the application.

● Multiple high level development tools: Develop faster with application specific development tools, including the LabVIEW Statechart Module, LabVIEW Control Design and Simulation Module and LabVIEW FPGA Module.

● Professional Development Tools: Manage large, professional applications and tightly integrated project management tools; integrated graphical debugging tools; and standardized source code control integration.

● Multi platforms: The majority of computer systems use the Microsoft Windows operating system. LabVIEW works on other platforms like Mac OS, Sun Solaris and Linux. LabVIEW applications are portable across platforms.

● Reduces cost and preserves investment: A single computer equipped with LabVIEW is used for countless applications and purposes—it is a versatile product. Complete instrumentation libraries can be created for less than the cost of a single traditional, commercial instrument.

● Flexibility and scalability: Engineers and scientists have needs and requirements that can change rapidly. They also need to have maintainable, extensible solutions that can be used for along time

● Connectivity and instrument control: LabVIEW has ready-to-use libraries for integrating stand-alone instruments, data acquisition devices, motion control and vision products,

● Open environment: LabVIEW provides the tools required for most applications and is also an open development environment.

● Visualization capabilities: LabVIEW includes a wide array of built-in visualization tools to present data on the user interface of the virtual instrument as chart, graphs, 2D and 3D visualization.

● Compiled language for fast execution: LabVIEW is a compiled language that generates optimized code with execution speeds comparable to compiled C and develops high performance code.

● Object– oriented design: Use object-oriented programming structures to take advantage of encapsulation and inheritance to create modular and extensible code.

● Algorithm design: Develop algorithms using math-oriented textual programming and interactively debug .m file script syntax with LabVIEW MathScript.

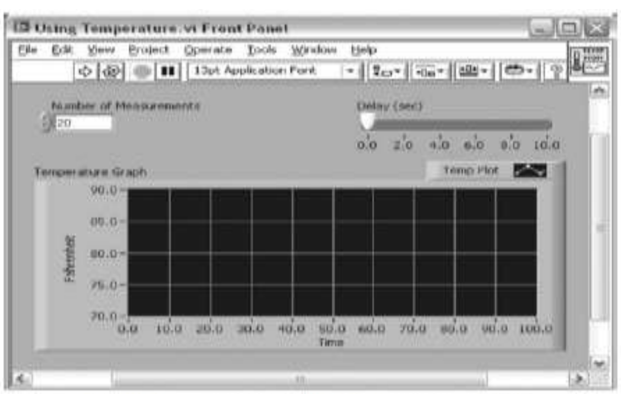

Figure 2.1 LabVIEW virtual instrument front panel.

The front panel can include knobs, push buttons, graphs and various other controls (which are user inputs) and indicators (which are program outputs).

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