EMBEDDED SYSTEM DESIGN

UNIT 1

2 MARKS

1. **Differentiate between time triggering and event triggered embedded systems? (may 2016)**

Event triggered:

1. Priority based communication and flexibility, average response time.
2. Complex timing analysis
3. None of properties P1 to P4.
4. Static communication scheme with interrupt based data interface and constructive integration.
5. No synchronization between the tasks within the system.

Time-Triggered:

1. Static communication scheme supported by the application
2. Easy timing analysis
3. Stability of prior services.
4. Asynchronous system properties P2,P3
5. No synchronization between the tasks within the system.

2. **Enumerate the field available in the Intel hex file format? (May 2016)**

Intel hexadecimal object file format, Intel hex format or Intellec Hex is a file format that conveys binary information in **ASCII text** form. It is commonly used for programming microcontrollers, EPROMs, and other types of programmable logic devices.

3. **What is Embedded System? (May 2018)**

An Electronic/Electro mechanical system which is designed to perform a specific function and is a combination of both hardware and firmware (Software).

An embedded system is a special-purpose computer system designed to perform one or a few dedicated functions with real-time computing constraints include hardware, software and mechanical parts.

Embedded Systems or Electronics systems that include an application Specific Integrated Circuit or a Microcontroller to perform a specific dedicated application. An Embedded System is one that has computer hardware with software embedded in it as one of its important components.

4. List the peripherals available in microcontroller? (Dec 2017)

- GPIO controllers
- Timers
- Pulse Width Modulation (PWM) controllers.
- Digital to analog converters(DAC)
- Analog to digital converters(ADC)
- Serial communication Controllers.
- Memory
- Interrupt controllers

5. List different package types available for microcontroller? (Dec2017,Sep 2020)

A microcontroller is a cheap and minimal size, easy to carry out.

- PIC Microcontroller.
- ARM Microcontroller.
- 8051 Microcontroller.
- AVR Microcontroller.
- MSP Microcontroller.

6. Write short note on roll of microcontroller in embedded system designs? (May 2017)

Microcontroller is a compressed micro computer manufactured to control the functions of embedded systems in office machines, robots, home appliances, motor vehicles, and a number of other gadgets. A microcontroller is comprises components like - memory, peripherals and most importantly a processor.

7. What is the need for having processor criteria? (May 2017)

The processor, also known as the CPU, provides the instructions and processing power the computer needs to do its work. The more powerful and updated your processor, the faster your computer can complete its tasks. By getting a more powerful processor, you can help your computer think and work faster.

8. Define embedded microcontroller? (Dec 2018)

A microcontroller is a compact integrated circuit designed to govern a specific operation in an embedded system. A typical microcontroller includes a processor, memory and input/output (I/O) peripherals on a single chip.

9. Brief about processor selection criteria? (Dec 2018)

Selecting an embedded processor used to be a pretty straightforward task. Of course, this was back in "the old days," when the focus was on a limited set of functions, user interface and connectivity didn't matter too much, and power consumption wasn't such an overarching issue. In today's realm of converged processing, where a single device can perform control, signal processing, and application-level tasks, there's a lot more to consider.

10. Compare assembly language and high level language? (May 2018 ,Sep 2020)

HLL (High Level Language) programs are machine independent. They are easy to learn, easy to use, and convenient for managing complex tasks.

Assembly language programs are machine specific. It is the language that the processor directly understands.

ASSEMBLY LEVEL LANGUAGE	HIGH LEVEL LANGUAGE
It is machine dependent	It is machine independent
In this mnemonics codes are used	In this English statement is used
It supports low **level** operation	It does not support low **level language**

11. What is the need for watch dog timer? (Nov 2016)

Watchdog timers are widely used in computers to facilitate automatic correction of temporary hardware faults, and to prevent errant or malevolent software from disrupting system operation. During normal operation, the computer regularly restarts the **watchdog timer** to prevent it from elapsing, or "timing out".

12. Explain the role of on chip debugging? (Nov 2016)

Usually the on-**chip debugger** provides the means to set simple breakpoints, query the internal state of the **chip**, and single step through code. ... The target **chip** must actually be running with a clock and a supply volt- age. Often an emulator probe can run without any external hardware.

13. What are the Major Application Areas of Embedded Systems? (Dec2017,Sep 2020)

Consumer Electronics: Camcorders, Cameras etc. Household Appliances: Television, DVD players, washing machine, Fridge, Microwave Oven etc.

Home Automation and Security Systems: Air conditioners, sprinklers, Intruder detection alarms, Closed Circuit Television Cameras, Fire alarms etc. Automotive **Industry:** Anti-lock breaking systems (ABS), Engine Control, Ignition Systems, Automatic Navigation Systems etc.

Telecom: Cellular Telephones, Telephone switches, Handset Multimedia Applications etc.

Computer Peripherals: Printers, Scanners, Fax machines etc.

Computer Networking Systems: Network Routers, Switches, Hubs, Firewalls etc.

Health Care: Different Kinds of Scanners, EEG, ECG Machines etc. **Measurement & Instrumentation:** Digital multi meters, Digital CROs, Logic Analyzers PLC systems etc.

14. What are the main components of embedded system (May 2018)

- Power supply :For the embedded system the power supply is the key component to provide the power to the embedded system circuit.
- Processor.
- Memory.
- Timers counters.
- Communication ports.
- Output and Input.
- Circuits used in application.

15. How to find the word length of the microcontroller system? (Nov /Dec 2019)

The most important part of a microcontroller is a central processing unit with a word length ranging from 4-bit to 64-bit and in some modern microcontrollers the word length goes even beyond the limit of 64-bit. A timer is one other constituent of a microcontroller.

16. Mention the packaging types of embedded system design

The types of packaging embedded system design. Availability of various packages changes from device to device.

- The most commonly used is Dual Inline Package (40 pins) known popularly as DIP.
- 8051 is also available in QFP (Quad Flat Package).
- TQFP (Thin Quad Flat Package).
- PQFP (Plastic Quad Flat Package) etc.

PART B

1. Discuss in detail about the role of microcontrollers in embedded system design and its design specifications for a suitable? (May 2016, May 2018, Dec 2019, Sep 2020)

A microcontroller (MCU for *microcontroller unit*) is a small computer on a single metal-oxide-semiconductor (MOS) integrated circuit (IC) chip. A microcontroller contains one or more CPUs (processor cores) alongwith memory and programmable input/output peripherals. Program memory in the form of ferroelectric RAM, NOR flash or OTP ROM is also often included on chip, as well as a small amount of RAM. Microcontrollers are designed for embedded applications, in contrast to the microprocessors used in personal computers or other general purpose applications consisting of various discrete chips.

Embedded system:

A microcontroller can be considered a self-contained system with a processor, memory and peripherals and can be used as an embedded system.[29] The majority of microcontrollers in use today are embedded in other machinery, such as automobiles, telephones, appliances, and peripherals for computer systems.

While some embedded systems are very sophisticated, many have minimal requirements for memory and program length, with no operating system, and low software complexity. Typical input and output devices include switches, relays, solenoids, LED's, small or custom liquid-crystal displays, radio frequency devices, and sensors for data such as temperature, humidity, light level etc. Embedded systems usually have no keyboard, screen, disks, printers, or other recognizable I/O devices of a personal computer, and may lack human interaction devices of any kind.

Interrupts

Microcontrollers must provide real-time (predictable, though not necessarily fast) response to events in the embedded system they are controlling. When certain events occur, an interrupt system can signal the processor to suspend processing the current instruction sequence and to begin an interrupt service routine (ISR, or "interrupt handler") which will perform any processing required based on the source of the interrupt, before returning to the original instruction sequence. Possible interrupt sources are device dependent, and often include events such as an internal timer overflow, completing an analog to digital conversion, a logic level change on an input such as from a button being pressed, and data received on a communication link. Where power consumption is important as in battery devices, interrupts may also wake a microcontroller from a low-power sleep state where the processor is halted until required to do something by a peripheral event.

Programs

Typically micro-controller programs must fit in the available on-chip memory, since it would be costly to provide a system with external, expandable memory. Compilers and assemblers are used to convert both high-level and assembly language codes into a compact machine code for storage in the micro-controller's memory. Depending on the device, the program memory may be permanent, read-only memory that can only be programmed at the factory, or it may be field-alterable flash or erasable read-only memory.

Manufacturers have often produced special versions of their micro-controllers in order to help the hardware and software development of the target system.

Originally these included EPROM versions that have a "window" on the top of the device through which program memory can be erased by ultraviolet light, ready for reprogramming after a programming ("burn") and test cycle. Since 1998, EPROM versions are rare and have been replaced by EEPROM and flash, which are easier to use (can be erased electronically) and cheaper to manufacture.

Other microcontroller features

Microcontrollers usually contain from several to dozens of general purpose input/output pins (GPIO). GPIO pins are software configurable to either an input or an output state. When GPIO pins are configured to an input state, they are often used to read sensors or external signals. Configured to the output state, GPIO pins can drive external devices such as LEDs or motors, often indirectly, through external power electronics.

A micro-controller is a single integrated circuit, commonly with the following features:

- central processing unit – ranging from small and simple 4-bit processors to complex 32-bit or 64-bit processors
- volatile memory (RAM) for data storage
- ROM, EPROM, EEPROM or Flash memory for program and operating parameter storage
- discrete input and output bits, allowing control or detection of the logic state of an individual package pin
- serial input/output such as serial ports (UARTs)
- other serial communications interfaces like I²C, Serial Peripheral Interface and Controller Area Network for system interconnect
- peripherals such as timers, event counters, PWM generators, and watchdog
- clock generator – often an oscillator for a quartz timing crystal, resonator or RC circuit
- many include analog-to-digital converters, some include digital-to-analog converters
- in-circuit programming and in-circuit debugging support.

2. write short note on usage of quartz crystal to create an oscillator for microcontroller ? (May 2016)

Quartz Crystal Oscillators

One of the most important features of any oscillator is its *frequency stability*, or in other words its ability to provide a constant frequency output under varying load conditions.

Some of the factors that affect the frequency stability of an oscillator generally include: variations in temperature, variations in the load, as well as changes to its DC power supply voltage to name a few.

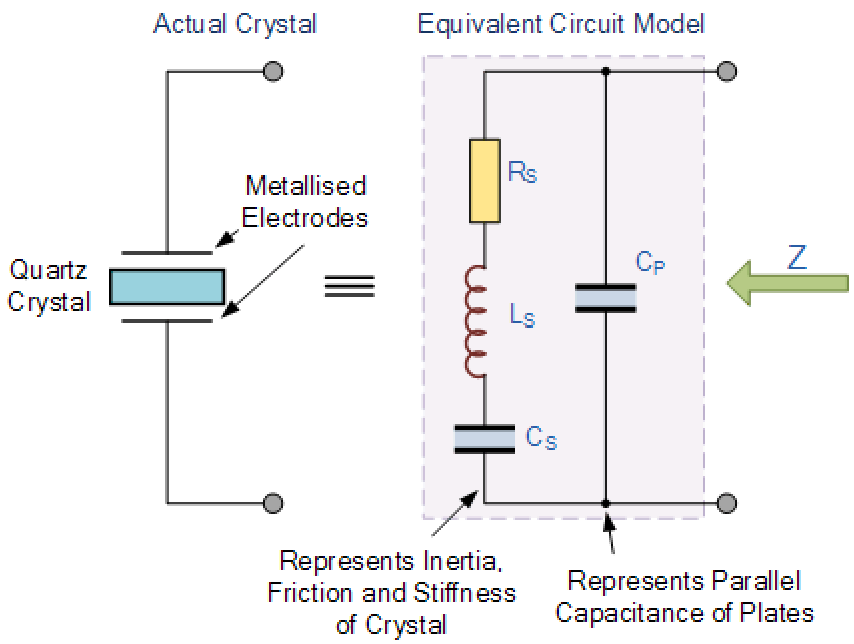
Frequency stability of the output signal can be greatly improved by the proper selection of the components used for the resonant feedback circuit, including the amplifier. But there is a limit to the stability that can be obtained from normal LC and RC tank circuits.

Quartz Crystal Oscillator

To obtain a very high level of oscillator stability a Quartz Crystal is generally used as the frequency determining device to produce another types of oscillator circuit known generally as a Quartz Crystal Oscillator, (XO).

When a voltage source is applied to a small thin piece of quartz crystal, it begins to change shape producing a characteristic known as the Piezo-electric effect. This Piezo-electric Effect is the property of a crystal by which an electrical charge produces a mechanical force by changing the shape of the crystal and vice versa, a mechanical force applied to the crystal produces an electrical charge.

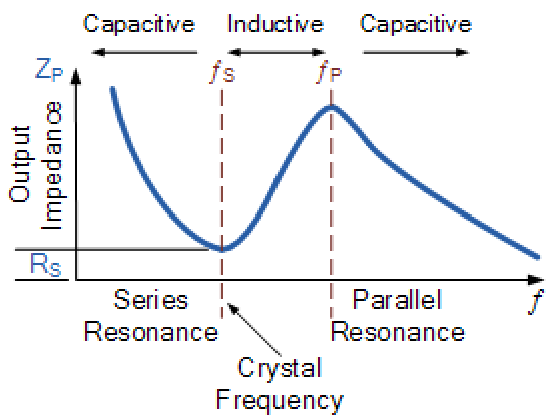
Quartz Crystal Equivalent Model



The equivalent electrical circuit for the quartz crystal shows a series RLC circuit, which represents the mechanical vibrations of the crystal, in parallel with a capacitance, Cp which represents the electrical connections to the crystal. Quartz crystal oscillators tend to operate towards their “series resonance”.

The equivalent impedance of the crystal has a series resonance where Cs resonates with inductance, Ls at the crystals operating frequency. This frequency is called the crystals series frequency, fs. As well as this series frequency, there is a second frequency point established as a result of the parallel resonance created when Ls and Cs resonates with the parallel capacitor Cp as shown.

Crystal Impedance against Frequency



$$R = R \quad \text{and} \quad X_{LS} = 2\pi f L_S$$

$$X_{CS} = \frac{1}{2\pi f C_S} \quad \text{and} \quad X_{CP} = \frac{1}{2\pi f C_P}$$

$$Z_S = \sqrt{R_S^2 + (X_{LS} - X_{CS})^2}$$

$$\therefore Z_P = \frac{Z_S \times X_{CP}}{Z_S + X_{CP}}$$

The slope of the crystals impedance above shows that as the frequency increases across its terminals. At a particular frequency, the interaction of between the series capacitor Cs and the inductor Ls creates a series resonance circuit reducing the crystals impedance to a minimum and equal to Rs. This frequency point is called the crystals series resonant frequency fs and below fs the crystal is capacitive.

As the frequency increases above this series resonance point, the crystal behaves like an inductor until the frequency reaches its parallel resonant frequency fp. At this frequency point the interaction between the series inductor, Ls and parallel capacitor, Cp creates a parallel tuned LC tank circuit and as such the impedance across the crystal reaches its maximum value.

Then we can see that a quartz crystal is a combination of a series and parallel tuned resonance circuits, oscillating at two different frequencies with the very small difference between the two depending upon the cut of the crystal.

3. Compare assembly language and high level language? (May 2016)

Definition of assembly language:

A low-level programming language which uses symbols and lack variables and functions and which work directly with CPU. Assembly language is coded differently for every type of processor. X86 and x64 processors have a different code of assembly language for performing the same tasks. Assembly language has the same commands as machine language but instead of 0 and 1, it uses names.

Definition of high-level language:

A high-level language is a human-friendly language which uses variables and functions and it is independent of computer architecture. The programmer writes code with general purpose without worrying about hardware integration part. A program written in high-level language needs to be first interpreted into machine code and then processed by a computer.

Assembly language vs high-level language

1. In assembly language programs written for one processor will not run on another type of processor. In high-level language programs run independently of processor type.
2. Performance and accuracy of assembly language code are better than a high-level.
3. High-level languages have to give extra instructions to run code on the computer.
4. Code of assembly language is difficult to understand and debug than a high-level.
5. One or two statements of high-level language expand into many assembly language codes.
6. Assembly language can communicate better than a high-level Some type of hardware actions can only be performed by assembly language.
7. In assembly language, we can directly read pointers at a physical address which is not possible in high-level
8. Working with bits is easier in assembly language.
9. Assembler is used to translate code in assembly language while the compiler is used to compile code in the high-level.
10. The executable code of high-level language is larger than assembly language code so it takes a longer time to execute.
11. Due to long executable code, high-level programs are less efficient than assembly language programs.
12. High-level language programmer does not need to know details about hardware like registers in the processor as compared to assembly programmers.
13. The most high-level language code is first automatically converted into assembly code.

Examples of assembly language:

Assembly languages are different for every processor. Some of assembly languages examples are below.

- ARM
- MIPS
- x86
- Z80
- 68000
- 6502
- 6510

Examples of high-level language:

- C
- Fortran
- Lisp
- Prolog
- Pascal
- Cobol
- Basic
- Algol
- Ada
- C++
- C#
- PHP
- Perl
- Ruby
- Common Lisp
- Python
- Golang
- Javascript
- Pharo

4. a) write short note on reset hardware ? (Dec 2017)

In a computer or data transmission system, a reset clears any pending errors or events and brings a system to normal condition or an initial state, usually in a controlled manner. It is usually done in response to an error condition when it is impossible or undesirable for a processing activity to proceed and all error recovery mechanisms fail. A computer storage program would normally perform a "reset" if a command times out and error recovery schemes like retry or abort also fail.

Most computers have a reset line that brings the device into the startup state and is active for a short time after powering on. For example, in the x86 architecture, asserting the RESET line halts the CPU; this is done after the system is switched on and before the power supply has asserted "power good" to indicate that it is ready to supply stable voltages at sufficient power levels.[1] Reset places less stress on the hardware than power cycling, as the power is not removed. Many computers, especially older models, have user accessible "reset" buttons that assert the reset line to facilitate a system reboot in a way that cannot be trapped (i.e. prevented) by the operating system. Out-of-band management also frequently provides the possibility to reset the remote system in this way.

Many memory-capable digital circuits (flip-flops, registers, counters and so on) accept the reset signal that sets them to the pre-determined state. This signal is often applied after powering on but may also be applied under other circumstances.

The ability for an electronic device to be able to reset itself in case of error or abnormal power loss is an important aspect of embedded system design and programming. This ability can be observed with everyday electronics such as a television, audio equipment or the electronics of a car, which are able to function as intended again even after having lost power suddenly

b) Processor selection criteria? (Dec 2017)

Selecting an embedded processor used to be a pretty straightforward task. Of course, this was back in "the old days," when the focus was on a limited set of functions, user interface and connectivity didn't matter too much, and power consumption wasn't such an overarching issue. In today's realm of converged processing, where a single device can perform control, signal processing, and application-level tasks, there's a lot more to consider (Figure 1). While there are too many aspects of the processor selection process to detail here, let's examine some of the more prominent areas that system designers must consider.

Processor performance:

System designers reflexively note the processing speed of a device as a major indicator of its performance. This is not a bad start, but it's an incomplete assessment. It is clearly important to evaluate the number of instructions a processor can perform each second, but also to assess the number of operations accomplished in each core clock cycle and the efficiency of the computation units. And it is no longer uncommon to employ processors with multiple cores as a way of greatly extending the computational capabilities of the device (especially in the case of homogenous cores) or clearly demarcating the control processing from the signal processing activity (often with heterogeneous cores).

Hardware acceleration

Of course, it's not just about the processor core(s). For execution of well-specified functionality, a hardware accelerator is almost always the most power-efficient method to perform the function it was designed to accelerate. One area that can make the difference in using the accelerator is how friendly it is to use in a software algorithm. For full-algorithm-type accelerators, such as an H.264 encoder, there usually is not an issue because it's substantially self-contained. However, for kernel-type accelerators like an FFT, it can be more challenging to use an accelerator within a larger algorithm. Take a look at how the hardware function performs and how it needs to be configured.

Bandwidth requirements

Bandwidth estimation is a process that's easy to oversimplify, sometimes with unfortunate results. All individual data flows in the system must be summed (with directionality and time window taken into account) to ensure that the core is capable of completing its data processing within the allotted window, and that the various processor buses are not overloaded, leading to data corruption or system failure.

After all data flows are considered, the overall system budget needs to be constructed. This budget is influenced by several factors, including DRAM access patterns (and resulting performance degradations), internal bus arbitration, memory latencies, and so on.

Power management

The ability to throttle power consumption to a level commensurate with temporal operating requirements is crucial to preserving battery life, as well as overall energy costs in mains-powered systems. Processors can offer a wide range of options for optimizing an application's power profile. One such feature is dynamic power management – the ability to adjust core frequency and operating voltage to meet a certain performance level. Another is the availability of multiple power modes that turn off various unneeded resources, including memories and peripherals, during certain time intervals.

Security needs

Over the past several years, processor security has become increasingly important. Whether or not such a scheme is a baseline requirement of a system, it is essential to view the security question from multiple vantage points before deciding on the final direction. Security needs usually take the form of platform protection, IP security, or data security – or some combination of all three.

Platform protection is needed to ensure that only authenticated code is run in the application. In other words, must "rogue code" be actively prevented from running? By "rogue code," we refer to a program that tries to access protected information on the processor, or "hijack" the processor and gain control of the larger system

5. Enumetrate in detail about the step by step procedure for oscillator. (May 2017)

(Or)

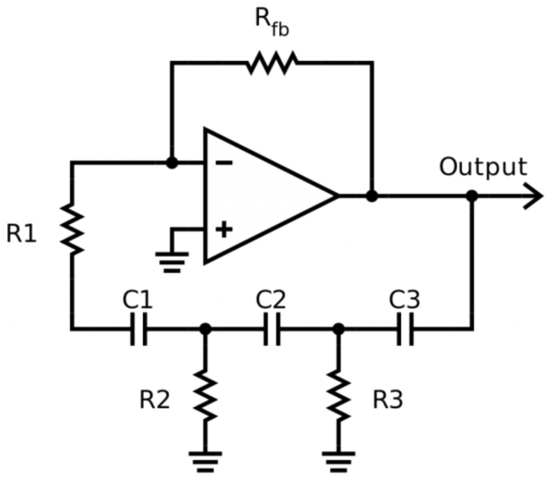
Write a short note on oscillator design? (Dec 2017)

(Or)

Explain the various aspects of oscillator for an embedded system (Apr/May2018)

An oscillator is a circuit which produces a continuous, repeated, alternating waveform without any input. Oscillators basically convert unidirectional current flow from a DC source into an alternating waveform which is of the desired frequency, as decided by its circuit components.

The basic principle behind the working of oscillators can be understood by analyzing the behavior of an LC tank circuit shown in Figure 1 below, which employs an inductor L and a completely pre-charged capacitor C as its components. Here, at first, the capacitor starts to discharge via the inductor, which results in the conversion of its electrical energy into the electromagnetic field, which can be stored in the inductor. Once the capacitor discharges completely, there will be no current flow in the circuit.



This is because, if the energy supplied is more than the energy lost, then the amplitude of the oscillations will increase (Figure 2a) leading to a distorted output; while if the energy supplied is less than the energy lost, then the amplitude of the oscillations will decrease (Figure 2b) leading to unsustainable oscillations.

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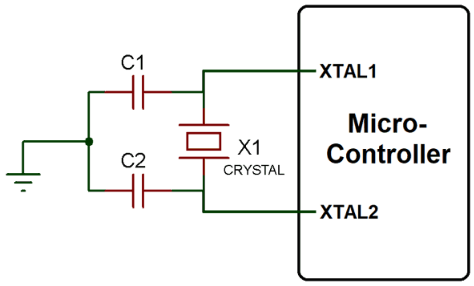


. Once the capacitor discharges completely, there will be no current flow in the circuit.
Type of Oscillator

There are many types of oscillators, but can broadly be classified into two main categories – Harmonic Oscillators (also known as Linear Oscillators) and Relaxation Oscillators.

In a harmonic oscillator, the energy flow is always from the active components to the passive components and the frequency of oscillations is decided by the feedback path.

Whereas in a relaxation oscillator, the energy is exchanged between the active and the passive components and the frequency of oscillations is determined by the charging and discharging time-constants involved in the process. Further, harmonic oscillators produce low-distorted sine-wave outputs while the relaxation oscillators generate non-sinusoidal (saw-tooth, triangular or square) wave-forms.

Oscillator Design An 8051 clock circuit is shown below. In general cases, a quartz crystal is used to make the clock circuit. The connection is shown in figure (a) and note the connections to XTAL 1 and XTAL 2. In some cases external clock sources are used and you can see the various connections above. Clock frequency limits (maximum and minimum) may change from device to device. Standard practice is to use 12MHz frequency.

If serial communications are involved then its best to use 11.0592 MHz frequency. Take a look at the above machine cycle waveform. One complete oscillation of the clock source is called a pulse. Two pulses forms a state and six states forms one machine cycle. Also note that, two pulses of ALE are available for 1 machine cycle. Development ToolsDigital transformation is touching upon various physical objects, making them smart and powerful. The engine for such devices is embedded software that is an integral part of the rapidly developing IoT ecosystem.

6. Explain in detail about the components used in embedded system?

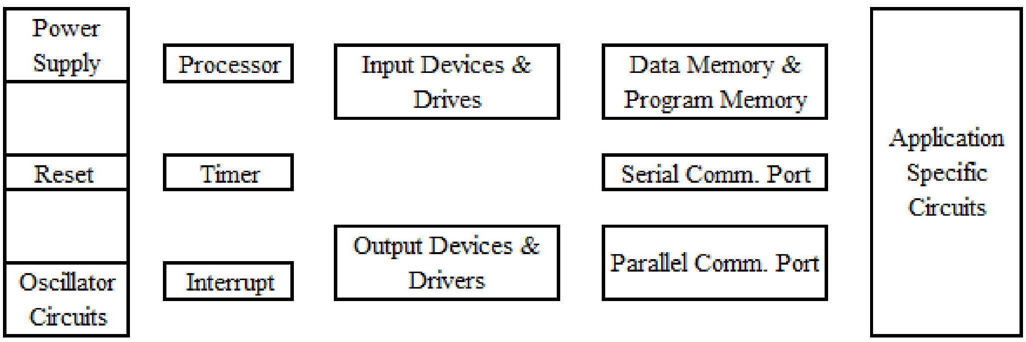
(Or)

Discuss about the components of embedded system.

(Or)

Draw and explain about the components of embedded system. (May 2017,Dec 2018, Dec 2019)

The embedded system is classified as a type of system that is made up of software and hardware components that is used for performing specific functions. The embedded systems can be used in various sectors like industries, agricultural devices, medical devices and automobiles industry, and many more sectors. The embedded system can be used to perform a single task or more than one task at the same time. There are multiple components involved in the design of an embedded system. The components used are software components and hardware components.



Components of the Embedded System

As the embedded system is made up of hardware and software components. In below section hardware components are described below:

1. Power supply

For the embedded system the power supply is the key component to provide the power to the embedded system circuit. Usually, the embedded system requires 5 V supply or can be range from 1.8 to 3.3. V. The power supply source can be battery or can be provided by a wall adaptor. The power supply is selected as per user requirements and application requirements..

2. Processor

For any embedded system the processor acts as the brain of the system. The processor is responsible for deciding the performance of the embedded system. In the market there are multiple types of processors available and can be selected as per user requirement. The embedded system can act as a microcontroller and microprocessor. The processor can be an 8-bit processor, a 16-bit processor, and a 32-bit processor

3. Memory

As there are different microcontrollers is used in the embedded system the memory is present in the microcontroller itself. There are basically two types of memory RAM(Random access memory) and ROM (Read-only memory). As the RAM is volatile type memory the data can be stored temporarily in the memory and when system is switch off the data is lost from the memory. Read-only memory is classified as code memory

4. Timers counters

In some of the applications there is always a requirement of delay that needed to provide in the application. For example, in LED display applications there is a requirement of some delay so that LED can be continuing blink. And for that timer and counter can be used in the embedded system. The programming can be done in such a way so that delay can be generating the embedded system.

5. Communication ports

The communication port is the type of interface that is used to communicate with other types of embedded systems. In the embedded system there is multiple types of communication ports like UART, USB, Ethernet, RS-485, and many more.

6. Output and Input

When the embedded system is used the input is needed to interact with the system. The input to the embedded system can be provided by the sensor or by the user itself. The processor used in the embedded system can be based on input and output. The proper configuration needs to be done for using the input and output port. In the embedded system there are fixed input and output ports so that devices can be connected to that specified ports only. For example, P0, P1, P2, and many more.

7. Circuits used in application

When the embedded system is design there are several hardware components that can be used for design purposes. The selection of the circuit is completely dependent on the application used for the embedded systems. For example, in temperature sensor applications there is a requirement of temperature sensors for measuring the temperature.

7. Explain the software tools used in designing of an embedded system? (Sep 2020)

Embedded system development tools are used in the cameras, computers, laptops, mobile phones, and tablets that we use consist of the embedded system.

Types of embedded systems development tools:

There are two types of embedded system development tools

- Embedded software development tools
- Embedded Hardware development tools

All kinds of Embedded Systems need software's to run them for performing specific functions. The microcontroller contains the software for handling all the operations. For the development of software of the embedded system, there are different tools that include a compiler, editor, debugger, and assembler. Let's discuss these embedded system software development tools in detail.

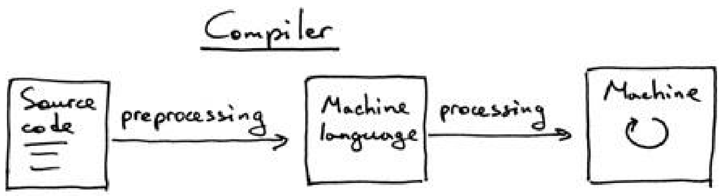
Editor

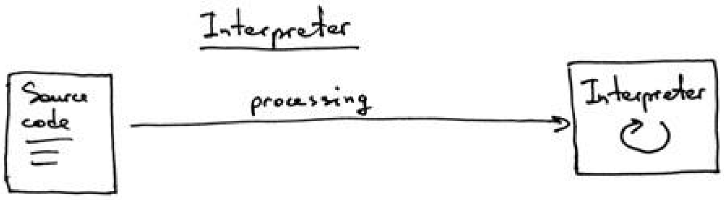
- The very first tool in the development of software for an embedded system is a text editor.
- You need to write source code. In Embedded System Development Tools, Editor is used to writing code for embedded systems applications.
- It is the editor where you write that code.
- The code is written in programming language either C++ or C.
- There is a standard ASCII text editor that is used to write source code and you save your file as ASCII text file.

Translate the code by Compiler or Assembler

- Compiler/Assembler is the second tool in your embedded system software development.
- Once you are done with your source code, you need to translate that code into the instructions on the basis of which, the microcontroller will operate.

- The set of instructions in the microcontroller is called as ‘Op Codes’.
- Now, you might be thinking what Op Codes are.These bits are decoded and then executed.
- Most of the times, the Op Codes are not written in bits but in hexadecimal numbers.





Linkers

- The codes are written into smaller parts for ease.
- The linker is a program that combines the number of codes for execution.
- Linkers are used for linking the codes that are saved in different files into one single final program.
- It also takes much care of allocation of memory of chips so that the different modules saved into a single program do not overlap.

Libraries

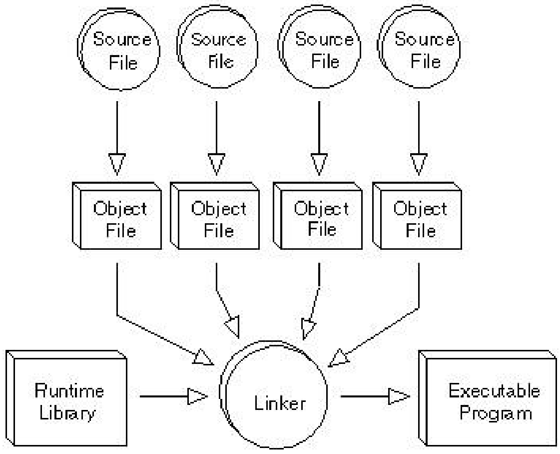
- You can say a library is an already written program that you can use instantly and some specific function is provided by that program.For the software development tools of the embedded system, the library is very significant and appropriate.
- Say for instance, you may download an Arduino microcontroller that is available with different libraries and you can use them in the development of your software for the embedded system.
- Using library you can control LED’s and or read sensors like encoders.

Debugger

- The name debugger speaks itself. This tool is used for debugging your code.

- The debugger is actually as a tester and is used to test whether your code contains error or not.
- The debugger has a complete look at the code and test if there are any errors or bugs.
- It tests different kinds of errors like any error in your syntax or if there is any runtime error and it tells where the error is actually taking place.
- The place where the error occurs is highlighted by the debugger so that you can easily remove your error by doing some changes.
- So, you get to know how important debugger in the development of software is in embedded systems.

The figure shows the cycle for the development of software.



Stimulator

- Among all other tools used for development of software for embedded system, there is another tool stimulator.
- The simulator enables you to know how the code that you created actually works in reality.
- You might be able to see the interaction of sensors by changing the input entries from sensors.
- You may analyze what type of function different components performing and what is the effect, created by changing input values.
- After knowing about some basic tools for the software development of the embedded system, you may need to know about a software that we have here in detail.
- Examples of simulators are Proteus which is used for simulation of the microcontroller based project and microprocessor based projects.

- Following video lecture will show you show to use Proteus for microcontrollers simulation to check your program output

Proteus ISIS as a simulator

Proteus is software in which we can make an easily schematic capture, PCB, and simulation of a microprocessor. It's a simple but more effective interface that simplifies the task required to be performed. It's more attracted to the user also can say that its user-friendly.It provides a powerful working environment. The user can design the different electronics circuits with all necessary components like simple resistance, power supply, and different microprocessors or microcontroller. This application mostly used in educational institutes because it easy to use and easy to understand the students.

Proteus Feature

- Easy to use.
- User-Friendly.
- Effective interface.
- Circuit designing and schematic makes easily.
- Provides working environment.

8. With suitable example ,describe the role of microcontroller in the embedded system.(Nov/ Dec 2019)

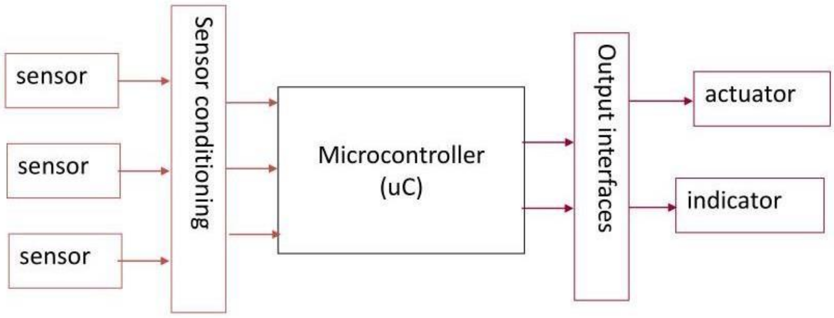
(Or)

Discuss and detail about the role of microcontroller in the embedded system. (Apr/May2018)

The Role of microcontroller in embedded system:

A microcontroller (sometimes abbreviated µC, uC or MCU) is a small computer on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals. Program memory in the form of NOR flash or OTP . Below figure shows together the microprocessor core and a rich collection of peripherals and I/O capability into a single integrated circuit.

Microcontroller is a compressed micro computer manufactured to control the functions of embedded systems in office machines, robots, home appliances, motor vehicles, and a number of other gadgets. A microcontroller is comprises components like - memory, peripherals and most importantly a processor.



ROM is also often included on chip, as well as a typically small amount of RAM. Microcontrollers are designed for embedded applications, in contrast to the microprocessors used in personal computers or other general purpose applications. Microcontrollers are used in automatically controlled products and devices, such as automobile engine control systems, implantable medical devices, remote controls, office machines, appliances, power tools, toys and other embedded systems.

By reducing the size and cost compared to a design that uses a separate microprocessor, memory, and input/output devices, microcontrollers make it economical to digitally control even more devices and processes. Mixed signal microcontrollers are common, integrating analog components needed to control non-digital electronic systems.

Microcontrollers comprise the main elements of a small computer system on a single chip. They contain the memory, and IO as well as the CPU one the same chip. This considerably reduces the size, making them ideal for small embedded systems, but means that there are compromises in terms of performance and flexibility.

Different Applications of Microcontroller

- Consumer Electronics Products: Toys, Cameras, Robots, Washing Machine, Microwave Ovens etc.
- Instrumentation and **Process Control**: Oscilloscopes, Multi-meter, Leakage Current Tester, Data Acquisition and Control etc.
- Medical Instruments
- Communication:
- Office Equipment
- Multimedia Application
- Automobile

Embedded systems are generally more basic and rudimentary than microcontrollers since they often do not have logic to run the system. Once the CPU tells the microcontroller to do something the microcontroller then directs the components of the embedded system to execute its specific tasks.

Some examples of embedded systems are MP3 players, mobile phones, video game consoles, digital cameras, DVD players, and GPS. Household appliances, such as microwave ovens, washing machines and dishwashers, include embedded systems to provide flexibility and efficiency.

An embedded system is an electronic system that has a software and is embedded in computer hardware. It is programmable or non- programmable depending on the application.

Examples of embedded systems include numerous products such as microwave ovens, washing machine, printers, automobiles, cameras, etc

The applications of embedded systems include home appliances, office automation, security, telecommunication, instrumentation, entertainment, aerospace, banking and finance, automobiles personal and in different embedded systems projects.

- They are easy for mass production.
- It is highly reliable.
- It has improved product quality.
- The embedded systems use low power operation.
- The embedded system operates very fast, and it is portable and small in size.

9. How will you select processor for an embedded system? Explain. (April/May2018)

With numerous kinds of processors with various design philosophies available at our disposal for using in our design, following considerations need to be factored during processor selection for an embedded system.

- Performance Considerations
- Power considerations
- Peripheral Set
- Operating Voltage
- Specialized Processing Units

Now let us discuss each of them in detail.

Performance considerations

The first and foremost consideration in selecting the processor is its performance. The performance speed of a processor is dependent primarily on its architecture and its silicon design. Evolution of fabrication techniques helped packing more transistors in same area there by reducing the propagation delay. Also presence of cache reduces instruction/data fetch timing. Pipelining and super-scalar architectures further improves the performance of the processor. Branch prediction, speculative execution etc are some other techniques used for improving the execution rate. Multi-cores are the new direction in improving the performance.

Rather than simply stating the clock frequency of the processor which has limited significance to its processing power, it makes more sense to describe the capability in a standard notation. MIPS (Million Instructions Per Second) or MIPS/MHz was an earlier notation followed by Dhrystones and latest EEMBC's Core Mark. Core Mark is one of the best ways to compare the performance of various processors.

Processor architectures with support for extra instruction can help improving performance for specific applications. For example, SIMD (Single Instruction/Multiple Data) set and Jazelle – Java acceleration can help in improving multimedia and JVM execution speeds.

So size of cache, processor architecture, instruction set etc has to be taken in to account when comparing the performance.

Power Considerations

Increasing the logic density and clock speed has adverse impact on power requirement of the processor. A higher clock implies faster charge and discharge cycles leading to more power consumption. More logic leads to higher power density there by making the heat dissipation difficult. Further with more emphasis on greener technologies and many systems becoming battery operated, it is important the design is for optimal power usage.

Techniques like frequency scaling – reducing the clock frequency of the processor depending on the load, voltage scaling – varying the voltage based on load can help in achieving lower power usage. Further asymmetric multiprocessors, under near idle conditions, can effectively power off the more powerful core and load the less powerful core for performing the tasks. SoC comes with advanced power gating techniques that can shut down clocks and power to unused modules.

Peripheral Set

Every system design needs, apart from the processor, many other peripherals for input and output operations. Since in an embedded system, almost all the processors used are SoCs, it is better if the necessary peripherals are available in the chip itself. This offers various benefits compared to peripherals in external IC's such as optimal power architecture, effective data communication using DMA, lower BoM etc. So it is important to have peripheral set in consideration when selecting the processor.

Operating Voltages

Each and every processor will have its own operating voltage condition. The operating voltage maximum and minimum ratings will be provided in the respective data sheet or user manual.

While higher end processors typically operate with 2 to 5 voltages including 1.8V for Cores/Analogue domains, 3.3V for IO lines, needs specialized PMIC devices, it is a deciding factor in low end micro-controllers based on the input voltage. For example it is cheaper to work with a 5V micro-controller when the input supply is 5V and a 3.3 micro-controllers when operated with Li-on batteries.

Specialized Processing

Apart from the core, presence of various co-processors and specialized processing units can help achieving necessary processing performance. Co-processors execute the instructions fetched by the primary processor thereby reducing the load on the primary. Some of the popular co-processors include

Floating Point Co-processor:

RISC cores supports primarily integer only instruction set. Hence presence of a FP co-processor can be very helpful in application involving complex mathematical operations including multimedia, imaging, codecs, signal processing etc.

Graphic Processing Unit:

GPU(Graphic Processing Unit) also called as Visual processing unit is responsible for drawing images on the frame buffer memory to be displayed. Since human visual perception needed at-least 16 Frames per second for a smooth viewing, drawing for HD displays involves a lot of data bandwidth. Also with increasing graphic requirements such as textures, lighting shaders etc, GPU's have become a mandatory requirements for mobile phones, gaming consoles etc.

Various GPU's like ARM's MALI, PowerVX, OpenGL etc are increasing available in higher end processors. Choosing the right co-processor can enable smooth design of the embedded application.

Digital Signal Processors

DSP is a processor designed specifically for signal processing applications. Its architecture supports processing of multiple data in parallel. It can manipulate real time signal and convert to other domains for processing. DSP's are either available as the part of the SoC or separate in an external package. DSP's are very helpful in multimedia applications. It is possible to use a DSP along with a processor or use the DSP as the main processor itself.

Price

Various considerations discussed above can be taken in to account when a processor is being selected for an embedded design. It is better to have some extra buffer in processing capacities to enable enhancements in functionality without going for a major change in the design. While engineers (especially software/firmware engineers) will want to have all the functionalities, price will be the determining factor when designing the system and choosing the right processor.

10. Give some example for sophisticated embedded system and illustrate them in detail. (Sep 2020)

Embedded System are classified in three types based on its microcontroller performance.

- Small Scale Embedded Systems
- Medium Scale Embedded Systems
- Sophisticated Embedded Systems

Small Scale Embedded System

Small Scale Embedded System is normally designed and created using an 8-bit microcontroller. This microcontroller can be battery activated.

Medium Scale Embedded System

Medium Scale Embedded System uses a single 16-bit or 32-bit microcontroller or multiple microcontrollers linked together. These systems have a lot of hardware as well as software complexities, hence are not preferred by many.

Sophisticated Embedded System

Sophisticated Embedded System often function on multiple algorithms that results in complexities in both hardware and software. They often need a processor that is configurable and logic array that can be programmed.

Sophisticated or Complex Embedded Systems are designed using multiple 32-bit or 64-bit micro-controllers. These systems are developed to perform large scale complex functions. These systems have high hardware and software complexities.

An embedded system can be an independent system or it can be a part of a large system. An embedded system is a microcontroller or microprocessor based system which is designed to perform a specific task. For example, a fire alarm is an embedded system; it will sense only smoke.

Examples:

Some examples of embedded systems are MP3 players, mobile phones, video game consoles, digital cameras, DVD players, and GPS. Household appliances, such as microwave ovens, washing machines and dishwashers, include embedded systems to provide flexibility and efficiency.

11. Describe the features of Microcontroller and on board peripherals available in embedded system (Sep 2020)

Features of Microcontroller :

A micro-controller is a single integrated circuit, commonly with the following features: central processing unit – ranging from small and simple 4-bit processors to complex 32-bit or 64-bit processors. volatile memory (RAM) for data storage. ROM, EPROM, EEPROM or Flash memory for program and operating parameter storage.

A peripheral is a part of a microcontroller that interfaces with the outside world. Examples of peripherals are GPIOs, I2C, SPI, UART, timers, and USB.

Peripheral Devices in Embedded System:

An embedded processor interacts with a peripheral device through a set of control and status registers. These registers are part of the peripheral hardware, and their locations, size, and individual meanings are features of the peripheral.

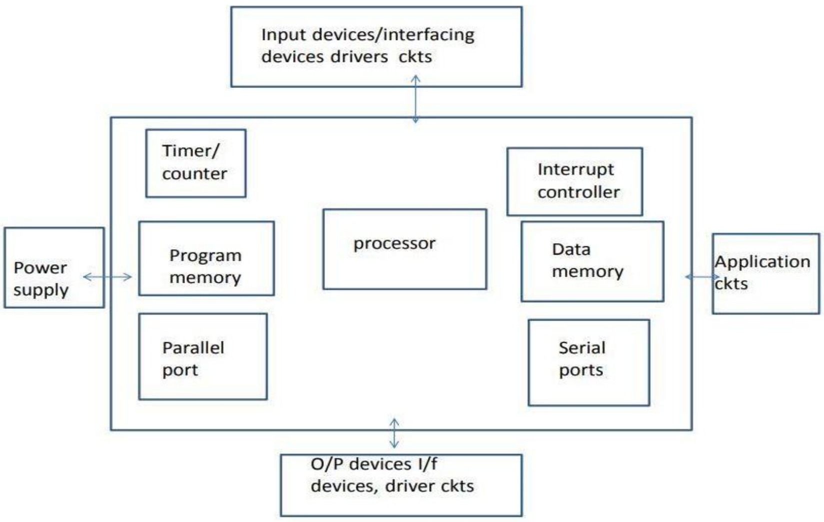
Embedded systems communicate with the outside world via their peripherals, such as following;

- Serial Communication Interfaces (SCI) like RS-232, RS-422, RS-485, etc.
- Synchronous Serial Communication Interface like I2C, SPI, SSC, and ESSI
- Universal Serial Bus (USB)
- Multi Media Cards (SD Cards, Compact Flash, etc.)
- Networks like Ethernet, Lon Works, etc.
- Field buses like CAN-Bus, LIN-Bus, PROFIBUS, etc.
- Timers like PLL(s), Capture/Compare and Time Processing Units.
- Discrete IO General Purpose Input/output (GPIO)
- Analog to Digital/Digital to Analog (ADC/DAC)
- Debugging like JTAG, ISP, ICSP, BDM Port, BITP, and DP9 ports

12. List and explain the basic hardware required to develop the embedded application. (Nov 2016)

The embedded system consist of different components embedded into it as follows:

1) Embedded Processor 2) Power supply , reset and Oscillator circuits 3) System timers 4) Serial communication port 5) Parallel ports 6) Interrupt controller 7) Output and Input Interfacing and driver circuits 8) System application specific circuits 9) Program and Data memory



Processor: The processor is the heart of embedded system. The selection of processor is based on the following consideration 1. Instruction set 2. Maximum bits of operation on single arithmetic and logical operation 3. Speed 4. Algorithms processing and capability 5. Types of processor(microprocessor, microcontroller, digital signal processor, application specific processor, general purpose processor)

Power supply, Reset, Oscillator circuit and system timers:

Power source: Internal power supply is must. Es require from power up to power down to start time task. Also it can run continuously that is stay "On' system consumes total power hence efficient real time programming by using proper 'wait' and 'stop' instruction or disable some unit which are not in use can save or limit power consumption.

Clock / oscillator Circuits The clock ckt is used for CPU, system timers, and CPU machine cycles clock controls the time for executing an instruction. Clock oscillator may be internal or external .It should be highly stable

Real time clock(RTC): It require to maintain scheduling various tasks and for real time programming RTC also use for driving timers, counters needs in the system.

Resets Ckts and power on reset: Reset process starts executing various instruction from the starting address. The address is set by the processor in the program counter. The reset step reset and runs the program in the following way 1. System program that execute from beginning 2. System boot up program 3. System initialization program

Serial and Parallel communication ports: Serial communication port and parallel communication ports are used to interface serial and parallel devices with the system and communicate between processor and devices.

Interrupt controller: It is used to receive interrupt from various sources and resolve the priority and provides the service to that interrupts.

Input and output interfacing and driver circuits: Characteristics of input or output devices may be different from the processor like voltage and current requirement to drive that specific device, hence driver circuits are needed to drive input or output devices.

Program and Data memory: The most microcontroller have inbuilt separate memory to store data and program. Following are types of memories used in embedded system.

Hardware Components of the Embedded System

When all the hardware components are selected for an embedded system the next task is to select software components for designing an embedded system.

1. Assembler

The assembler is sued when the programming language sued for designing the application is assembly language. The assembly language program is then converted into the HEX code so that it can be further processed. And after writing the code the programmer is used for writing the program in the chip.

2. Emulator

An emulator is a software tool that is used to execute the functions of the host system. All the components can be controlled by the emulator tool. The emulator is also used for finding the bugs and for debugging code. The emulator also used to transfer the code from the host system to the target system.

3. Compiler

The compiler is a type of software that is used to convert the programming language into some language that the target machine can understand and execute the functions. The basic use of the compiler is to transfer the high-level code into some low-level language. The low-level languages include machine code, object code, and assembly language.

The hardware of an embedded system has components such as:

- User interface.
- Memory.
- Display.
- Power supply.
- Memory.
- Timers.

BM T64 - EMBEDDED SYSTEM DESIGN

UNIT 2

PART-A

1. Determine the functions of TCON and TMOD. (May 2016)

TCON: TCON register specifies the type of external interrupt to the microcontroller.

TMOD: Both timers 0 and 1 use the same register, called TMOD (timer mode), to set the various timer operation modes. TMOD is an 8-bit register. The lower 4 bits are for Timer 0 and the upper 4 bits are for Timer 1. In each case, the lower 2 bits are used to set the timer mode the upper 2 bits to specify the operation.

2. Write an assembly language program to add two numbers using MCS51 microcontroller. (May 2016)

MOVR0,#20H;set source address 20H to R0
MOVR1,#30H;set destination address 30H to R1
MOVA,@R0; take the value from source to register A
MOVR5,A; Move the value from A to R5
MOVR4,#00H; Clear register R4 to store carry
INCR0; Point to the next location
MOVA,@R0; take the value from source to register A
ADDA,R5;Add R5 with A and store to register A
JNC SAVE
INCR4; Increment R4 to get carry
MOVB,R4;Get carry to register B
MOV@R1,B; Store the carry first
INCR1; Increase R1 to point to the next address
SAVE: MOV@R1,A;Store the result
HALT: SJMP HALT; Stop the program

3. What are the different types of addressing modes available for MCS51 microcontroller. (Dec. 2017, Sept. 2020)

An Addressing Mode is a way to locate a target Data, which is also called as Operand. The 8051 Family of Microcontrollers allows five types of Addressing Modes for addressing the Operands. They are:

- Immediate Addressing
- Register Addressing
- Direct Addressing
- Register – Indirect Addressing
- Indexed Addressing

4. List the ports available in MCS51 microcontroller. (Dec. 2017)

There are 4 ports available in 8051 microcontroller. They are

- Port 0 - 8 pins (P0.0-P0.7)
- Port 1 - 8 pins (P1.1-P1.7)
- Port 2 - 8-pins (P2.0-P2.7)
- Port 3 - 8 pin (P3.0-P3.7)

Each port of 8051 has bidirectional capability. Port 0 is called 'true bidirectional port' as it floats (tri-stated) when configured as input. Port-1, 2, 3 are called 'quasi bidirectional port'.

5. List out the types of instruction sets in MCS51. (May 2017, Dec. 2019)

Based on the operation they perform, all the instructions in the 8051 Microcontroller Instruction Set are divided into five groups. They are:

- Data Transfer Instructions
- Arithmetic Instructions
- Logical Instructions
- Boolean or Bit Manipulation Instructions
- Program Branching Instructions

6. What is the role of timer and counter in MCS51 microcontroller. (May 2017)

A **timer** is a specialized type of clock which is used to measure time intervals. A timer that counts from zero upwards for measuring time elapsed is often called a **stopwatch**. It is a device that counts down from a specified time interval and used to generate a time delay, for example, an hourglass is a timer.

A **counter** is a device that stores (and sometimes displays) the number of times a particular event or process occurred, with respect to a clock signal. It is used to count the events happening outside the microcontroller. In electronics, counters can be implemented quite easily using register-type circuits such as a flip-flop.

7. What is the role of processor reset and system reset? (Dec. 2018)

- The Core Reset only resets the CM4 but the System Reset resets the entire device
- In a Core Reset the peripherals will not be reset, so what would happen is that if a peripheral was already working, it will continue to work till it is reconfigured.
- On the other hand System Reset will make it work in a clean start manner. The RAM will not be affected unless the ROM execution modifies it.

8. State a cause for interrupt latency. (Dec. 2018)

Software Causes Of Interrupt Latencies Include:

- PIC (programmable interrupt controller) or APIC (advanced programmable interrupt controller)-level masking of interrupts. The Windows kernel and drivers change interrupt masking via HAL IRQL manipulation calls. Drivers routinely mask interrupts for several µs.
- Interrupt-processing overhead.

Hardware Causes Of Interrupt Latencies Include:

- Bus "hijacking" by peripheral devices. For example, a video card may stall the CPU's attempt to read the card's I/O space register.
- Burst DMA by SCSI controllers and Cache dirtying by Windows and applications.
- Most systems, particularly portables, can go to a low-power state for peripherals after a configurable time-out is set, and "wake up" with a delay that is intolerable to a real-time application.

9. What is the function of ALE signal in an 8051 microcontroller. (May 2018)

- Address Latch Enable. It is an active high input control signal.
- ALE signal is used for de-multiplexing the multiplexed Address/Data bus of Port 0 during external memory interfacing.
- In each machine cycle, there are 2 ALE pulses. ALE is also used to check whether the device is working or not.

10. How many ways an 8051 microcontroller can be interrupted. (Nov. 2016, May 2018)

8051 has 5 interrupt signals, i.e. INT0, TFO, INT1, TF1, RI/TI. Each interrupt can be enabled or disabled by setting bits of the IE register and the whole interrupt system can be disabled by clearing the EA bit of the same register.

11. Draw the special function register of 8051 and specify the functions. (Dec. 2019)

A Special Function Register (or Special Purpose Register, or simply Special Register) is a register within a microprocessor that controls or monitors the various functions of a microprocessor. The following table shows a list of SFRs and their addresses.

12. Identify the function of the given instruction (a) MOVX A, @DPTR (b) MOV A, #08. (Sept. 2020)

- It is a Data Transfer Function
- **MOV A, #08 -** Move data (08) to ACC, the Accumulator is loaded with 08.
- **MOVX A, @DPTR** – Move external RAM to ACC

13. What are the uses of software assigned priorities in an interrupt mechanism? (Nov. 2016)

- The normal interrupt mechanism of a microprocessor may be enabled and disabled by the programmer; it is said to be **maskable.** Usually a microprocessor has an interrupt mechanism that is not maskable, that is, it cannot be disabled by the programmer.
- Once a device requests an interrupt, some steps are performed by the CPU, some by the device, and others by software:
    1. *CPU*: The CPU checks for pending interrupts at the beginning of an instruction. It answers the highest-priority interrupt, which has a higher priority than that given in the interrupt priority register.
    2. *Device*: The device receives the acknowledgment and sends the CPU its interrupt vector.
    3. *Software*: The device driver may save additional CPU state. It then performs the required operations on the device. It then restores any saved state and executes the interrupt return instruction.

PART - B

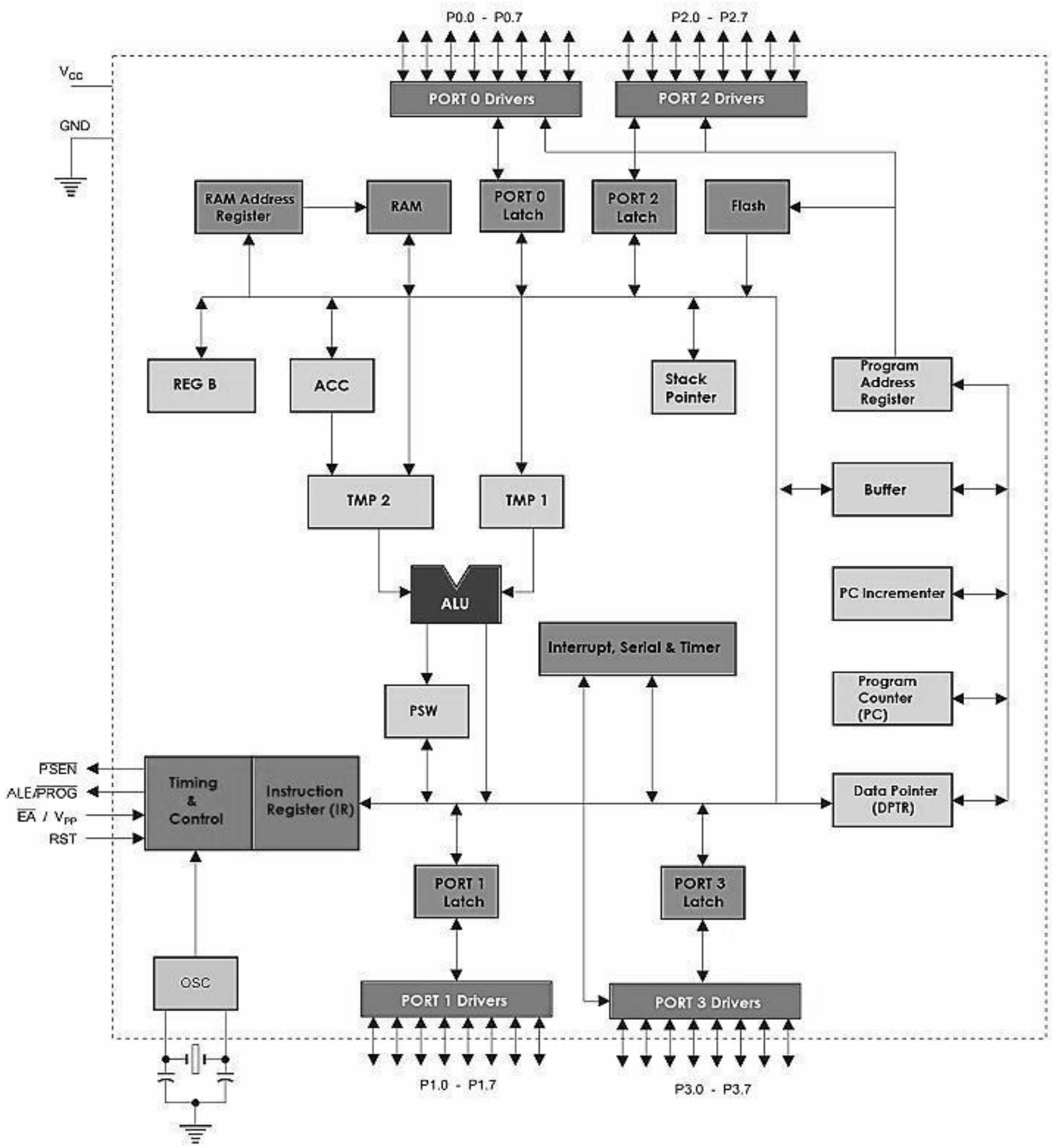
1. With neat block diagram explain the internal hardware architecture of Intel MCS51 microcontroller. (May 2016, May 2017, Dec. 2017, May 2018)

- The most popular microcontroller 8051 belongs to the MCS-51 family of microcontrollers by Intel. Following the success of 8051, many other semiconductor manufacturers released microcontrollers under their own brand name but using the MCS-51 core.
- Global companies and giants in semiconductor industry like Microchip, Zilog, Atmel, Philips, Siemens released products under their brand name. The specialty was that all these devices could be programmed using the same MCS-51 instruction sets.
- They basically differed in support device configurations like improved memory, presence of an ADC or DAC etc. Intel then released its first 16 bit microcontroller in 1982, under name MCS-96.
- In the following diagram the architecture of 8051 Microcontroller is shown, the system bus connects all the support devices to the CPU.
- The system bus consists of an 8-bit data bus, a 16-bit address bus and bus control signals. All other devices like program memory, ports, data memory, serial interface, interrupt control, timers, and the CPU are all interfaced together through the system bus.

8051 Microcontroller Architecture

The 8051 Microcontroller is an 8 – bit Microcontroller i.e. it can read, write and process 8 – bit Data. There are a bunch of manufacturers like Atmel, NXP, TI, who manufacture their own versions of 8051 Microcontroller.

Irrespective of the manufacturer, the internal hardware design i.e. the 8051 Microcontroller Architecture remains more or less the same. The following image shows the 8051 Microcontroller Architecture in a block diagram style.

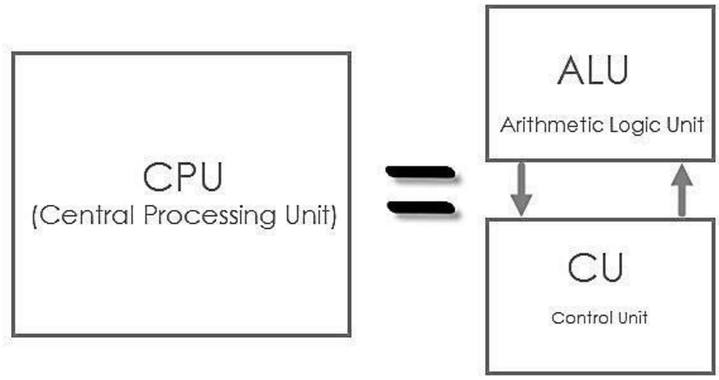


The block diagram of the 8051 Microcontroller Architecture shows that 8051 Microcontroller consists of a **CPU, RAM (SFRs and Data Memory), Flash (EEPROM), I/O Ports and control logic for communication between the peripherals.**

All these different peripherals inside the 8051 Microcontroller will communicate with each other via the 8 – bit Data Bus, also known as the internal data bus.

CPU (Central Processing Unit)

It is the heart of the Microcontroller that mainly comprises of an Arithmetic Logic Unit (ALU) and a Control Unit (CU) and other important components. The CPU is the primary device in communicating with peripheral devices like Memory, Input and Output.



ALU or Arithmetic Logic Unit, as the name suggests, performs the Arithmetical and Logical Operations. CU or Control Unit is responsible for timing of the communication process between the CPU and its peripherals.

Program Memory

The instructions of the CPU are stored in the Program Memory. It is usually implemented as Read Only Memory or ROM, where the Program written in to it will be retained even when the power is down or the system is reset.

Modern Program Memory Modules are generally made up of EEPROM (Electrically Erasable Programmable Read – only Memory), which is a type of non – volatile memory.

In this type of memory, the data can be erased and reprogrammed using special programming signals.

When the microcontroller is powered on or manually reset, the processor executes a set of instructions from a pre-defined memory location (address) in the Program Memory.

Data Memory

Data Memory in a Microcontroller is responsible for storing values of variables, temporary data, intermediate results and other data for proper operation of the program.

Data Memory is often called as RAM (Random Access Memory), which is a type of volatile memory. It is generally organized as registers and includes both Special Function Registers (SFRs) and user accessible memory locations.

Input and Output Ports

I/O Ports or Input / Output Ports provide the microcontroller, a physical connection to the outside world. Input Ports provide a gateway for passing on the data from the outside world with the help of sensors.

The data from the input ports is manipulated (depending on the application) and will determine the data on the output port.

Output Ports allow microcontroller to control external devices (like motors and LEDs). Generally, all ports in microcontrollers have dual functionality i.e. they can act as both input and output port (not at the same time though).

Clock Generator (Oscillator)

A clock signal allows the operations inside the microcontroller and other parts to be synchronous. A Clock Generator is an integral part of the Microcontroller's Architecture and the user has to provide an additional Timing Circuit in the form of a Crystal.

8051 Microcontroller Architecture Features

Some of the features like internal ROM and RAM will vary with the specific model of the 8051 Microcontroller. The features of 8051 microcontroller are as follows:

- 8 – bit CPU with two Registers A (Accumulator) and B.
- Internal ROM of 8K Bytes – It is a flash memory that supports in – system programming.
- Internal RAM of 256 Bytes – The first 128 Bytes of the RAM i.e. 00H to 7FH is again divided in to 4 banks with 8 registers (R0 – R7) in each bank, 16 bit addressable registers and 80 general purpose registers. The higher 128 Bytes of the RAM i.e. 80H to FFH consists of SFRs or Special Function Registers. Using SFRs we can control different peripherals like Timers, Serial Port, all I/O Ports, etc.
- 32 I/O Pins (Input / Output Pins) – Arranged as 4 Ports: P0, P1, P2 and P3.

- 8- bit Stack Pointer (SP) and Processor Status Word (PSW).
- 16 – bit Program Counter (PC) and Data Pointer (DPTR).
- Two 16 – bit Timers / Counters – T0 and T1.
- Control Registers – SCON, PCON, TCON, TMOD, IP and IE.
- Serial Data Transmitter and Receiver for Full – Duplex Operation – SBUF.
- Interrupts: Two External and Three Internal.
- Oscillator and Clock Circuit.

2. Explain in detail about the various addressing modes and instruction set of MCS51 microcontroller. (May 2016, May 2017, May 2018)

(OR)

Discuss in detail the different instruction set supported by 8051 microcontroller. (Sept. 2020)

ADDRESSING MODE

An Addressing Mode is a way to locate a target Data, which is also called as Operand. The 8051 Family of Microcontrollers allows five types of Addressing Modes for addressing the Operands. They are:

- Immediate Addressing
- Register Addressing
- Direct Addressing
- Register – Indirect Addressing
- Indexed Addressing

Immediate Addressing

- In Immediate Addressing mode, the operand, which follows the Opcode, is a constant data of either 8 or 16 bits. The name Immediate Addressing came from the fact that the constant data to be stored in the memory immediately follows the Opcode.
- The constant value to be stored is specified in the instruction itself rather than taking from a register. The destination register to which the constant data must be copied should be the same size as the operand mentioned in the instruction.

Example: MOV A, #030H

- Here, the Accumulator is loaded with 30 (hexadecimal). The # in the operand indicates that it is a data and not the address of a Register.
- Immediate Addressing is very fast as the data to be loaded is given in the instruction itself.

Register Addressing

- In the 8051 Microcontroller Memory Organization, we have seen in the organization of RAM as four banks of Working Registers with eight Registers in each bank. In Register Addressing mode, one of the eight registers (R0 – R7) is specified as Operand in the Instruction.
- It is important to select the appropriate Bank with the help of PSW Register. Let us see a example of Register Addressing assuming that Bank0 is selected.

Example: MOV A, R5

- Here, the 8-bit content of the Register R5 of Bank0 is moved to the Accumulator.

Direct Addressing

- In Direct Addressing Mode, the address of the data is specified as the Operand in the instruction. Using Direct Addressing Mode, we can access any register or on-chip variable. This includes general purpose RAM, SFRs, I/O Ports, Control registers.

Example: MOV A, 47H

- Here, the data in the RAM location 47H is moved to the Accumulator.

Register Indirect Addressing

- In the Indirect Addressing Mode or Register Indirect Addressing Mode, the address of the Operand is specified as the content of a Register. This will be clearer with an example.

Example: MOV A, @R1

- The @ symbol indicates that the addressing mode is indirect. If the contents of R1 is 56H, for example, then the operand is in the internal RAM location 56H. If the contents of the RAM location 56H is 24H, then 24H is moved into accumulator.
- Only R0 and R1 are allowed in Indirect Addressing Mode. These register in the indirect addressing mode are called as Pointer registers.

Indexed Addressing Mode

- With Indexed Addressing Mode, the effective address of the Operand is the sum of a base register and an offset register. The Base Register can be either Data Pointer (DPTR) or Program Counter (PC) while the Offset register is the Accumulator (A).
- In Indexed Addressing Mode, only MOVC and JMP instructions can be used. Indexed Addressing Mode is useful when retrieving data from look-up tables.

Example: MOVC A, @A+DPTR

- Here, the address for the operand is the sum of contents of DPTR and Accumulator.

INSTRUCTION SET

Types of Instructions in 8051 MCU Instruction Set are as follows:

- The structure of the 8051 Microcontroller Instruction consists of an Opcode (short of Operation – Code) followed by Operand(s) of size Zero Byte, One Byte or Two Bytes.
- The Op-Code part of the instruction contains the Mnemonic, which specifies the type of operation to be performed.
- All Mnemonics or the Opcode part of the instruction are of One Byte size.
- Coming to the Operand part of the instruction, it defines the data being processed by the instructions.
  - The operand can be any of the following:
  - No Operand
  - Data value
  - I/O Port
  - Memory Location
  - CPU register
- There can multiple operands and the format of instruction is as follows: **MNEMONIC DESTINATION OPERAND, SOURCE OPERAND.**
- A simple instruction consists of just the opcode. Other instructions may include one or more operands.
- Instruction can be one-byte instruction, which contains only opcode, or two-byte instructions, where the second byte is the operand or three byte instructions, where the operand makes up the second and third byte.
- Based on the operation they perform, all the instructions in the 8051 Microcontroller Instruction Set are divided into five groups. They are:
  - **a.** Data Transfer Instructions
  - **b.** Arithmetic Instructions
  - **c.** Logical Instructions
  - **d.** Boolean or Bit Manipulation Instructions
  - **e.** Program Branching Instructions

a. Data Transfer Instructions

The Data Transfer Instructions are associated with transfer with data between registers or external program memory or external data memory. The Mnemonics associated with Data Transfer are given below.

- MOV – Move data to ACC
- MOVC – Move code byte to ACC
- MOVX – Move external RAM to ACC
- PUSH – Push direct byte into stack

- POP – Pop direct byte from stack
- XCH – Exchange accumulator with register
- XCHD – Exchange ACC with lower order indirect RAM

b. Arithmetic Instructions

Using Arithmetic Instructions, you can perform addition, subtraction, multiplication and division.

The arithmetic instructions also include increment by one, decrement by one and a special instruction called Decimal Adjust Accumulator.

The Mnemonics associated with the Arithmetic Instructions of the 8051 Microcontroller Instruction Set are:

- ADD – Addition
- ADDC – Addition with carry
- SUBB - Subtraction
- INC - Increment
- DEC - Decrement
- MUL - Multiplication
- DIV - Division
- DA A – Decimal adjust accumulator

The arithmetic instructions have no knowledge about the data format i.e. signed, unsigned, ASCII, BCD, etc. Also, the operations performed by the arithmetic instructions affect flags like carry, overflow, zero, etc. in the PSW Register.

c. Logical Instructions

Logical Instruction are performed on Bytes of data on a bit-by-bit basis. Mnemonics associated with Logical Instructions are as follows:

- ANL – AND data
- ORL – OR data
- XRL – EX-OR data
- CLR – Clear accumulator
- CPL - Complement
- RL – Rotate accumulator left
- RLC – Rotate accumulator left through carry
- RR – Rotate accumulator right
- RRC – Rotate accumulator right through carry
- SWAP – Swap nibbles within ACC

d. Boolean or Bit Manipulation Instructions

As the name suggests, Boolean or Bit Manipulation Instructions will deal with bit variables. We know that there is a special bit-addressable area in the RAM and some of the Special Function Registers (SFRs) are also bit addressable.

The Mnemonics corresponding to the Boolean or Bit Manipulation instructions are:

- CLR – Clear carry bit
- SETB – Set bit 1
- MOV – Move accumulator
- JC – Jump if carry is set
- JNC – Jump if carry is not set
- JB – Jump if direct bit is set
- JNB – Jump if direct bit is not set
- JBC – Jump if direct bit is set and clear bit
- ANL- AND operation
- ORL – OR operation
- CPL - Complement

These instructions can perform set, clear, and, or, complement etc. at bit level.

e. Program Branching Instructions

The last group of instructions in the 8051 Microcontroller Instruction Set are the Program Branching Instructions. These instructions control the flow of program logic. The mnemonics of the Program Branching Instructions are as follows.

- LJMP – Long jump
- AJMP – Absolute jump
- SJMP - Short jump
- JZ – Jump to zero
- JNZ – Jump to Non-zero
- CJNE – Compare with a jump
- DJNZ – Decrement to jump
- NOP – No operation
- LCALL – Long subroutine call
- ACALL – Absolute subroutine call
- RET – Return from subroutine
- RETI – Return from interrupt
- JMP - Jump

All these instructions, except the NOP (No Operation) affect the Program Counter (PC) in one way or other.

3. With necessary hardware diagram, explain the concepts of Timer in MCS51 (8051) microcontroller. (Nov. 2016, Dec. 2017, Sept. 2020)

A **timer** is a specialized type of clock which is used to measure time intervals. A timer that counts from zero upwards for measuring time elapsed is often called a **stopwatch**. It is a device that counts down from a specified time interval and used to generate a time delay, for example, an hourglass is a timer.

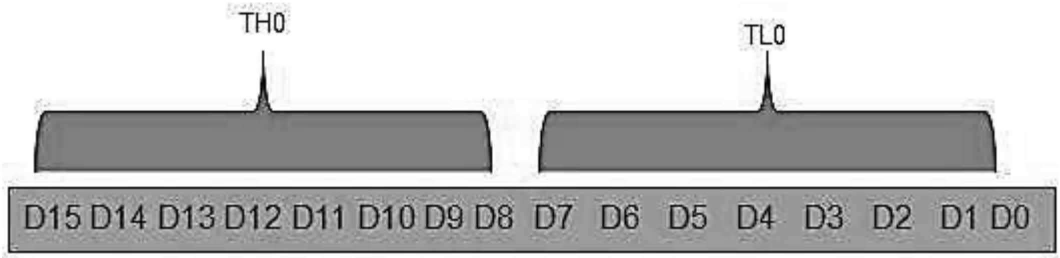
A **counter** is a device that stores (and sometimes displays) the number of times a particular event or process occurred, with respect to a clock signal. It is used to count the events happening outside the microcontroller. In electronics, counters can be implemented quite easily using register-type circuits such as a flip-flop.

Timers of 8051 and their Associated Registers

The 8051 has two timers, Timer 0 and Timer 1. They can be used as timers or as event counters. Both Timer 0 and Timer 1 are 16-bit wide. Since the 8051 follows an 8-bit architecture, each 16 bit is accessed as two separate registers of low-byte and high-byte.

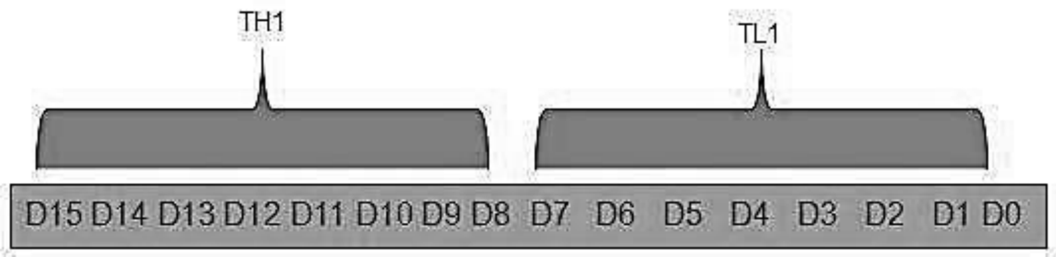
Timer 0 Register

The 16-bit register of Timer 0 is accessed as low- and high-byte. The low-byte register is called TL0 (Timer 0 low byte) and the high-byte register is called TH0 (Timer 0 high byte). These registers can be accessed like any other register. For example, the instruction **MOV TL0, #4H** moves the value into the low-byte of Timer #0.



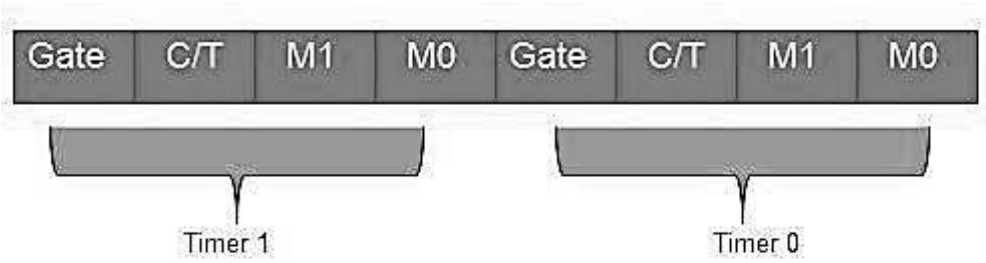
Timer 1 Register

The 16-bit register of Timer 1 is accessed as low- and high-byte. The low-byte register is called TL1 (Timer 1 low byte) and the high-byte register is called TH1 (Timer 1 high byte). These registers can be accessed like any other register. For example, the instruction **MOV TL1, #4H** moves the value into the low-byte of Timer 1.



TMOD (Timer Mode) Register

Both Timer 0 and Timer 1 use the same register to set the various timer operation modes. It is an 8-bit register in which the lower 4 bits are set aside for Timer 0 and the upper four bits for Timers. In each case, the lower 2 bits are used to set the timer mode in advance and the upper 2 bits are used to specify the location.



- **Gate** − When set, the timer only runs while INT(0,1) is high.
- **C/T** − Counter/Timer select bit.
- **M1** − Mode bit 1.
- **M0** − Mode bit 0.

GATE

Every timer has a means of starting and stopping. Some timers do this by software, some by hardware, and some have both software and hardware controls. 8051 timers have both software and hardware controls. The start and stop of a timer is controlled by software using the instruction **SETB TR1** and **CLR TR1** for timer 1, and **SETB TR0** and **CLR TR0** for timer 0.

The SETB instruction is used to start it and it is stopped by the CLR instruction. These instructions start and stop the timers as long as GATE = 0 in the TMOD register. Timers can be started and stopped by an external source by making GATE = 1 in the TMOD register.

C/T (CLOCK / TIMER)

This bit in the TMOD register is used to decide whether a timer is used as a **delay generator** or an **event manager**. If C/T = 0, it is used as a timer for timer delay generation. The clock source to create the time delay is the crystal frequency of the 8051. If C/T = 0, the crystal frequency attached to the 8051 also decides the speed at which the 8051 timer ticks at a regular interval.

Timer frequency is always 1/12th of the frequency of the crystal attached to the 8051. Although various 8051 based systems have an XTAL frequency of 10 MHz to 40 MHz, we normally work with the XTAL frequency of 11.0592 MHz. It is because the baud rate for serial communication of the 8051.XTAL = 11.0592 allows the 8051 system to communicate with the PC with no errors.

M1 / M2

M1	M2	Mode
0	0	13-bit timer mode.
0	1	16-bit timer mode.
1	0	8-bit auto reload mode.
1	1	Spilt mode.

Different Modes of Timers

Mode 0 (13-Bit Timer Mode)

Both Timer 1 and Timer 0 in Mode 0 operate as 8-bit counters (with a divide-by-32 prescaler). Timer register is configured as a 13-bit register consisting of all the 8 bits of TH1 and the lower 5 bits of TL1. The upper 3 bits of TL1 are indeterminate and should be ignored. Setting the run flag (TR1) does not clear the register. The timer interrupt flag TF1 is set when the count rolls over from all 1s to all 0s. Mode 0 operation is the same for Timer 0 as it is for Timer 1.

Mode 1 (16-Bit Timer Mode)

Timer mode "1" is a 16-bit timer and is a commonly used mode. It functions in the same way as 13-bit mode except that all 16 bits are used. TLx is incremented starting from 0 to a maximum 255. Once the value 255 is reached, TLx resets to 0 and then THx is incremented by 1. As being a full 16-bit timer, the timer may contain up to 65536 distinct values and it will overflow back to 0 after 65,536 machine cycles.

Mode 2 (8 Bit Auto Reload)

Both the timer registers are configured as 8-bit counters (TL1 and TL0) with automatic reload. Overflow from TL1 (TL0) sets TF1 (TF0) and also reloads TL1 (TL0) with the contents of Th1 (TH0), which is preset by software. The reload leaves TH1 (TH0) unchanged.

The benefit of auto-reload mode is that you can have the timer to always contain a value from 200 to 255. If you use mode 0 or 1, you would have to check in the code to see the overflow and, in that case, reset the timer to 200. In this case, precious instructions check the value and/or get reloaded. In mode 2, the microcontroller takes care of this. Once you have configured a timer in mode 2, you don't have to worry about checking to see if the timer has overflowed, nor do you have to worry about resetting the value because the microcontroller hardware will do it all for you. The auto-reload mode is used for establishing a common baud rate.

Mode 3 (Split Timer Mode)

Timer mode "3" is known as **split-timer mode**. When Timer 0 is placed in mode 3, it becomes two separate 8-bit timers. Timer 0 is TL0 and Timer 1 is TH0. Both the timers count from 0 to 255 and in case of overflow, reset back to 0. All the bits that are of Timer 1 will now be tied to TH0.

When Timer 0 is in split mode, the real Timer 1 (i.e. TH1 and TL1) can be set in modes 0, 1 or 2, but it cannot be started/stopped as the bits that do that are now linked to TH0. The real timer 1 will be incremented with every machine cycle

4. Explain about the microcontroller special function registers. (Dec. 2018)

Special function register

- A Special Function Register (or Special Purpose Register, or simply Special Register) is a register within a microprocessor that controls or monitors the various functions of a microprocessor. The following table shows a list of SFRs and their addresses.

BYTE ADDRESS	BIT ADDRESS								REGISTER NAME
FF									
F0	F7	F6	F5	F4	F3	F2	F1	F0	B
E0	E7	E6	E5	E4	E3	E2	E1	E0	ACC
D0	D7	D6	D5	D4	D3	D2	D1	D0	PSW
B8	-	-	-	BC	BB	BA	B9	B8	IP
B0	B7	B6	B5	B4	B3	B2	B1	B0	P3
A2	AF	-	-	AC	AB	AA	A9	A8	IE
A0	A7	A6	A5	A4	A3	A2	A1	A0	P2
99	NOT BIT ADDRESSABLE								SBUF
98	9F	9E	9D	9C	9B	9A	99	98	SCON
90	97	96	95	94	93	92	91	90	P1
8D	NOT BIT ADDRESSABLE								TH1
8C	NOT BIT ADDRESSABLE								TH0
8B	NOT BIT ADDRESSABLE								TL1
8A	NOT BIT ADDRESSABLE								TL0
89	NOT BIT ADDRESSABLE								TMOD
88	8F	8E	8D	8C	8B	8A	89	88	TCON
87	NOT BIT ADDRESSABLE								PCON
83	NOT BIT ADDRESSABLE								DPH
82	NOT BIT ADDRESSABLE								DPL
81	NOT BIT ADDRESSABLE								SP
80	87	86	85	84	83	82	81	80	PO

- As the special registers are closely tied to some special function or status of the processor, they might not be directly writable by normal instructions (like add, move, etc.). Instead, some special registers in some processor architectures require special instructions to modify them.
- In the 8051, register A, B, DPTR, and PSW are a part of the group of registers commonly referred to as SFR (special function registers). An SFR can be accessed by its name or by its address.

➢ Consider the following two points about the SFR addresses.

- A special function register can have an address between 80H to FFH. These addresses are above 80H, as the addresses from 00 to 7FH are the addresses of RAM memory inside the 8051.

- Not all the address space of 80 to FF are used by the SFR. Unused locations, 80H to FFH, are reserved and must not be used by the 8051 programmer.

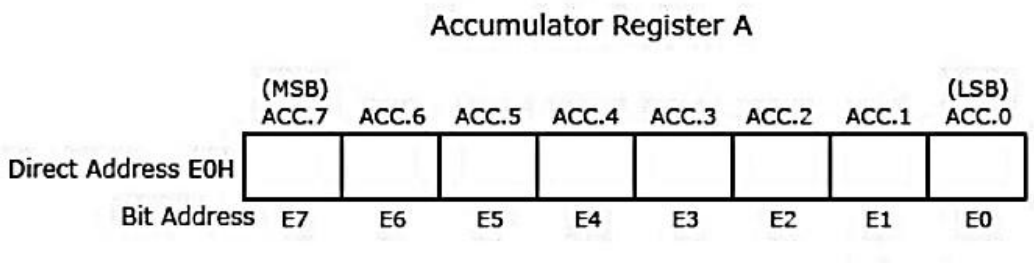
➢ There are 21 Special function registers (SFR) in 8051 micro controller and this includes Register A, Register B, Processor Status Word (PSW), PCON etc etc. There are 21 unique locations for these 21 special function registers and each of these register is of 1 byte size.

➢ Some of these special function registers are bit addressable (which means you can access 8 individual bits inside a single byte), while some others are only byte addressable.

Register A/Accumulator

➢ The most important of all special function registers, that's the first comment about Accumulator which is also known as ACC or A. The Accumulator (sometimes referred to as Register A also) holds the result of most of arithmetic and logic operations.

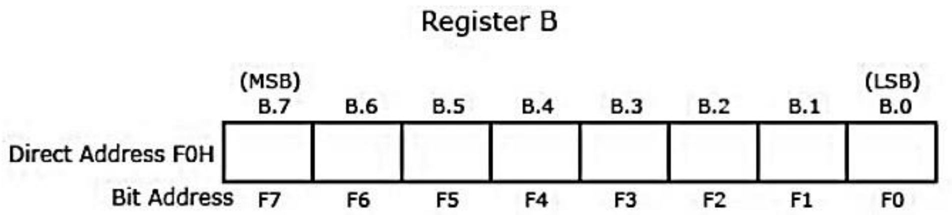
➢ ACC is usually accessed by direct addressing and its physical address is E0H. Accumulator is both byte and bit addressable. You can understand this from the figure shown below. To access the first bit (i.e bit 0) or to access accumulator as a single byte (all 8 bits at once), you may use the same physical address E0H. Now if you want to access the second bit (i.e bit 1), you may use E1H and for third bit E2H and so on.



Register B

➢ The major purpose of this register is in executing multiplication and division. The 8051 micro controller has a single instruction for multiplication (MUL) and division (DIV). If you are familiar with 8085, you may now know that multiplication is repeated addition, where as division is repeated subtraction.

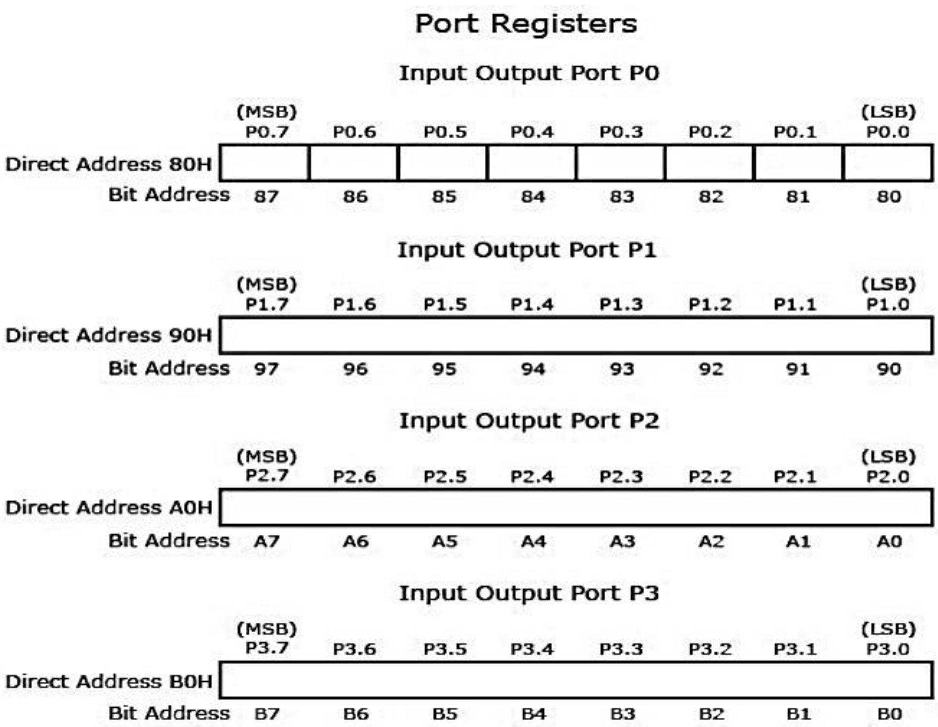
- While programming 8085, you may have written a loop to execute repeated addition/subtraction to perform multiplication and division. Now here in 8051 you can do this with a single instruction.
- Ex: MUL A,B – When this instruction is executed, data inside A and data inside B is multiplied and answer is stored in A. Note: For MUL and DIV instructions, it is necessary that the two operands must be in A and B. Register B is also byte addressable and bit addressable.



- To access bit o or to access all 8 bits (as a single byte), physical address F0 is used. To access bit 1 you may use F1 and so on. Note: Register B can also be used for other general purpose operations.

Port Registers

- The Port Register has 4 Input/Output ports named P0, P1, P2 and P3 has got four corresponding port registers with same name P0, P1, P2 and P3. Data must be written into port registers first to send it out to any other external device through ports.
- Similarly any data received through ports must be read from port registers for performing any operation. All 4 port registers are bit as well as byte addressable.



➢ From the figure:- ➢ The physical address of port 0 is 80 ➢ The physical address of port 1 is 90 ➢ And that of port 2 is A0 ➢ And that of port 3 is B0

Stack Pointer

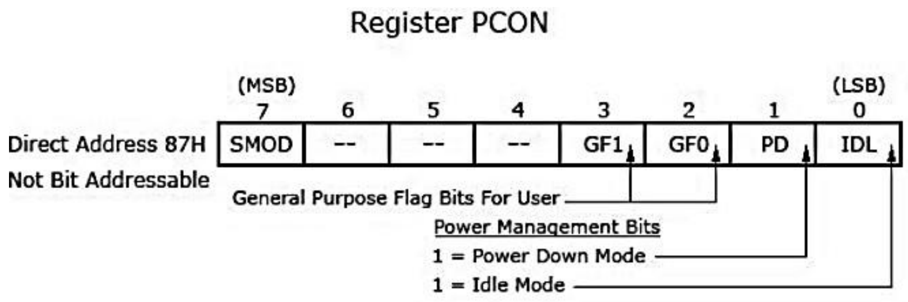
➢ Stack Pointer Known popularly with an acronym SP, stack pointer represents a pointer to the system stack. Stack pointer is an 8 bit register, the direct address of SP is 81H and it is only byte addressable, which means you can't access individual bits of stack pointer.

➢ The content of the stack pointer points to the last stored location of system stack. To store something new in system stack, the SP must be incremented by 1 first and then execute the "store" command.

➢ Usually after a system reset SP is initialized as 07H and data can be stored to stack from 08H onwards. This is usually a default case and programmer can alter values of SP to suit his needs.

Power Management Register (PCON)

➢ Power management using a microcontroller is something you see every day in mobile phones. The mobile phone automatically going into stand by mode when not used for a couple of seconds or minutes by the help of power management feature of the controller used inside that phone.



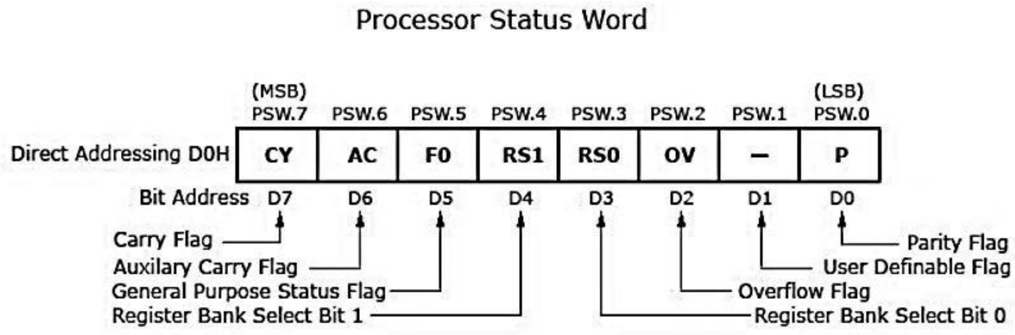
➢ As the name indicates, this register is used for efficient power management of 8051 micro controller. Commonly referred to as PCON register, this is a dedicated SFR for power management alone. From the figure below you can observe that there are 2 modes for this register :- **Idle mode and Power down mode.**

➢ Setting bit 0 will move the micro controller to Idle mode and Setting bit 1 will move the micro controller to Power down mode.

Processor Status Word (PSW)

➢ Commonly known as the PSW register, this is a vital SFR in the functioning of micro controller. This register reflects the status of the operation that is being carried out in the processor. The picture below shows PSW register and the way register banks are selected using PSW register bits – RS1 and RS0.

- PSW register is both bit and byte addressable. The physical address of PSW starts from D0H. The individual bits are then accessed using D1, D2 … D7. The various individual bits are explained below. So far we have discussed about all major SFR's in 8051.



- There many other still waiting! Please remember there are 21 SFR's and we have discussed only 9 specifically. The table below lists all other 12 SFR's.

SFR	Address	Function
DPH	83	Data pointer registers (High). Only byte addressing possible.
DPL	82	Data pointer register (Low). Only byte addressing possible.
IP	B8	Interrupt priority.Both bit addressing and byte addressing possible.
IE	A8	Interrupt enable. Both bit addressing and byte addressing possible.
SBUF	99	Serial Input/Output buffer. Only byte addressing is possible.
SCON	98	Serial communication control.Both bit addressing and byte addressing possible.
TCON	88	Timer control.Both bit addressing and byte addressing possible.
TH0	8C	Timer 0 counter (High). Only byte addressing is possible.
TL0	8A	Timer 0 counter (Low). Only byte addressing is possible.
TH1	8D	Timer 1 counter (High). Only byte addressing is possible.
TL1	8B	Timer 1 counter (Low). Only byte addressing is possible.
TMOD	89	Timer mode select. Only byte addressing is possible.

5. Describe the functions of typical parallel I/O interface with neat diagram. (Dec. 2018)

(OR)

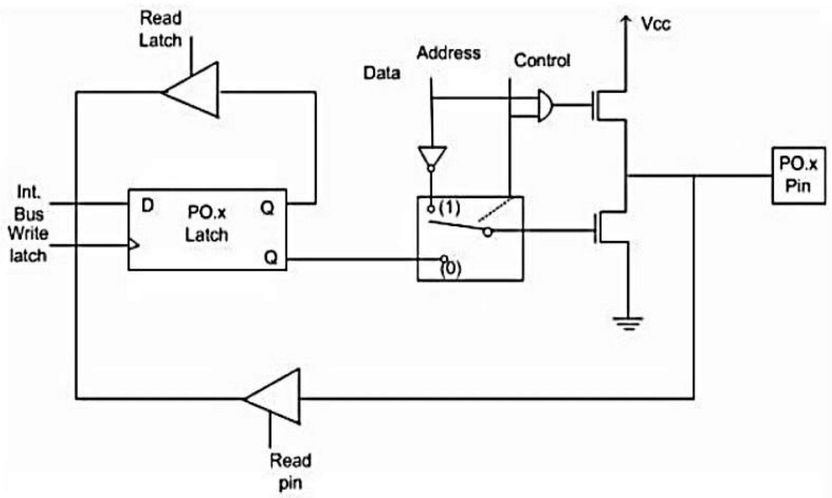
With a neat sketch, explain the I/O ports of 8051 microcontroller. (Dec. 2019)

I/O Pins Ports and Circuits of 8051 Microcontroller

Each port of 8051 has bidirectional capability. Port 0 is called 'true bidirectional port' as it floats (tristated) when configured as input. Port-1, 2, 3 are called 'quasi bidirectional port'.

Port-0 Pin Structure

- Port -0 has 8 pins (P0.0-P0.7). I/O ports and circuits Each port of 8051 has bidirectional capability. Port 0 is called 'true bidirectional port' as it floats (tristated) when configured as input. Port-1, 2, 3 are called 'quasi bidirectional port'.
- Port-0 can be configured as a normal bidirectional I/O port or it can be used for address/data interfacing for accessing external memory. When control is '1', the port is used for address/data interfacing. When the control is '0', the port can be used as a normal bidirectional I/O port.
- Let us assume that control is '0'. When the port is used as an input port, '1' is written to the latch. In this situation both the output MOSFETs are 'off'. Hence the output pin floats. This high impedance pin can be pulled up or low by an external source.

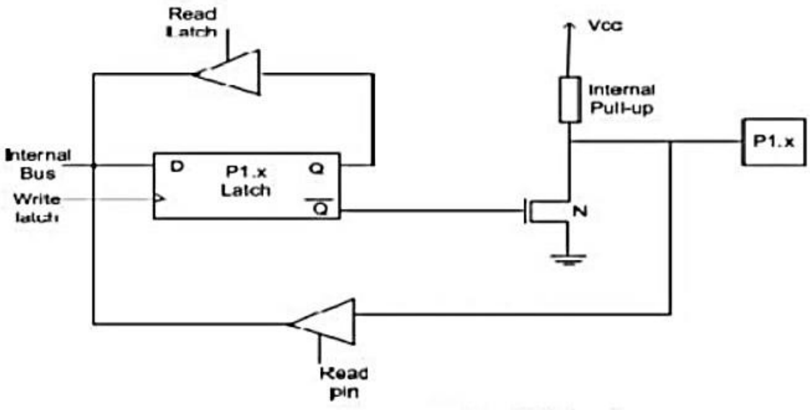


Port-0 Structure

- When the port is used as an output port, a '1' written to the latch again turns 'off' both the output MOSFETs and causes the output pin to float. An external pull-up is required to output a '1'. But when '0' is written to the latch, the pin is pulled down by the lower MOSFET. Hence the output becomes zero.
- When the control is '1', address/data bus controls the output driver MOSFETs. If the address/data bus (internal) is '0', the upper MOSFET is 'off' and the lower MOSFET is 'on'. The output becomes '0'. If the address/data bus is '1', the upper transistor is 'on' and the lower transistor is 'off'. Hence the output is '1'.
- Hence for normal address/data interfacing (for external memory access) no pull-up resistors are required.Port-0 latch is written to with 1's when used for external memory access.

Port-1 Pin Structure

- Port-1 has 8 pins (P1.1-P1.7) .The structure of a port-1 pin is shown in fig below. Port-1 does not have any alternate function i.e. it is dedicated solely for I/O interfacing. When used as output port, the pin is pulled up or down through internal pull-up. To use port1 as input port, '1' has to be written to the latch.

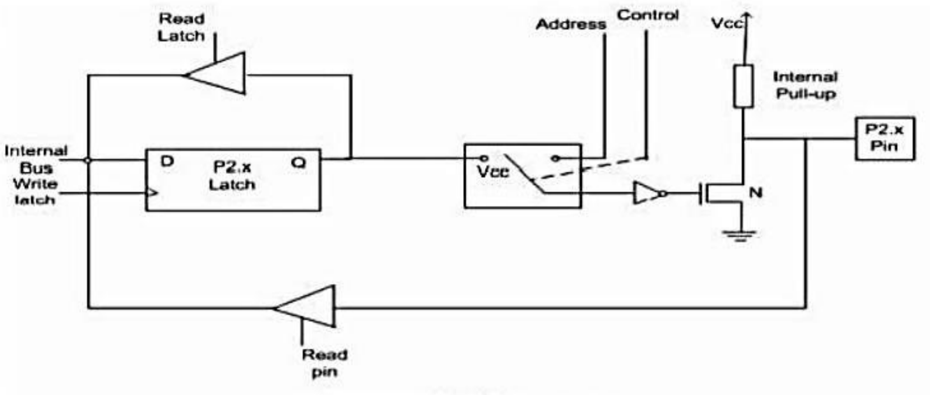


Port 1 Structure

- In this input mode when '1' is written to the pin by the external device then it read fine. But when '0' is written to the pin by the external device then the external source must sink current due to internal pull-up. If the external device is not able to sink the current the pin voltage may rise, leading to a possible wrong reading.

Port-2 Pin Structure

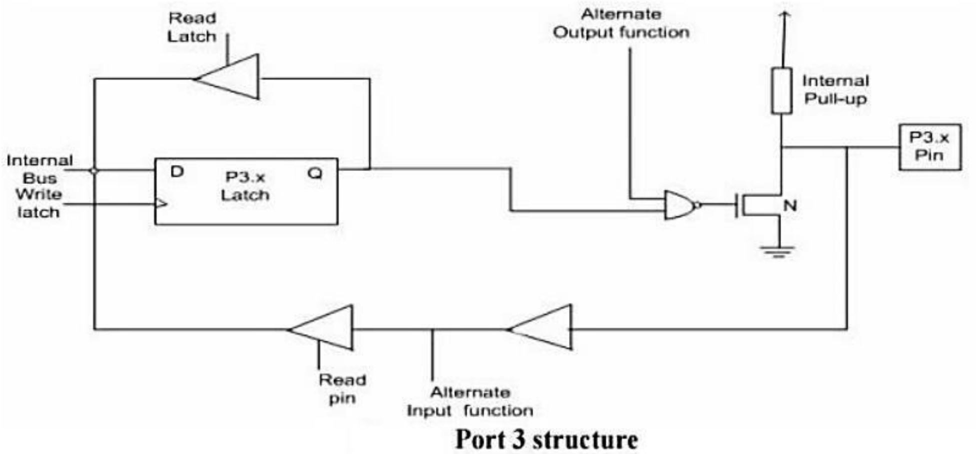
- Port-2 has 8-pins (P2.0-P2.7). The structure of a port-2 pin is shown in figure below: Port-2 is used for higher external address byte or a normal input/output port. The I/O operation is similar to Port-1. Port-2 latch remains stable when Port-2 pin are used for external memory access. Here again due to internal pull-up there is limited current driving capability.



Port 2 structure

Port-3 Pin Structure

- Port-3 has 8 pin (P3.0-P3.7). Port-3 pins have alternate functions. The structure of a port-3 pin is shown in figure. Each pin of Port-3 can be individually programmed for I/O operation or for alternate function.
- The alternate function can be activated only if the corresponding latch has been written to '1'. To use the port as input port, '1' should be written to the latch. This port also has internal pullup and limited current driving capability.



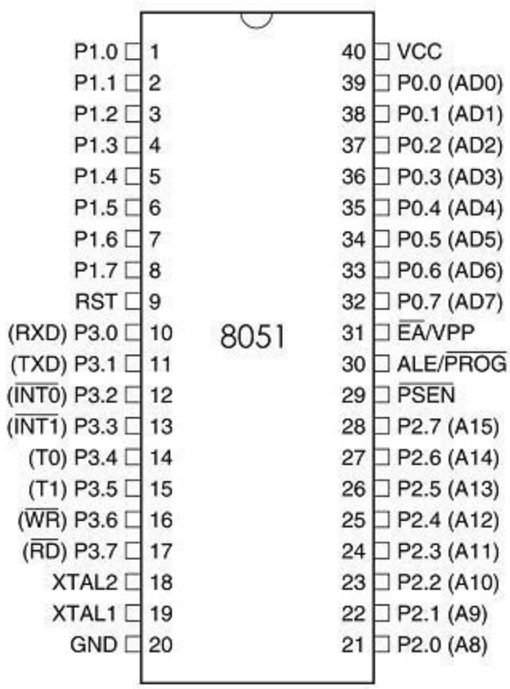
Port 3 structure

6. Draw the pin diagram of 8051 microcontroller and explain them in detail. (Dec. 2019)

8051 Microcontroller Pin Diagram

The 8051 Microcontroller is available in a variety of packages like 40 – pin DIP or 44 – lead PLCC and TQFP. The pin orientation of an 8051 Microcontroller may change with the package but the Pin Configuration is same.

The following image shows the 8051 Microcontroller Pin Diagram with respect to a 40 – pin Dual In-line Package (DIP). Since it is a 40 – pin DIP IC, each side contains 20 Pins. The other packages of 8051 are the 44 – Lead PLCC and the 44 – Lead TQFP.



40 - PIN DIP

8051 Microcontroller Pin Description

The Pin Description or Pin Configuration of the 8051 Microcontroller will describe the functions of each pins of the 8051 Microcontroller. Let us now see the pin description.

Pins 1 – 8 (PORT 1): Pins 1 to 8 are the PORT 1 Pins of 8051. PORT 1 Pins consists of 8 – bit bidirectional Input / Output Port with internal pull – up resistors. In older 8051 Microcontrollers, PORT 1 doesn't serve any additional purpose but just 8 – bit I/O PORT.

In some of the newer 8051 Microcontrollers, few PORT 1 Pins have dual functions. P1.0 and P1.1 act as Timer 2 and Timer 2 Trigger Input respectively. P1.5, P1.6 and P1.7 act as In-System Programming Pins i.e. MOSI, MISO and SCK respectively.

Pin 9 (RST): Pin 9 is the Reset Input Pin. It is an active HIGH Pin i.e. if the RST Pin is HIGH for a minimum of two machine cycles, the microcontroller will be reset. During this time, the oscillator must be running.

Pins 10 – 17 (PORT 3): Pins 10 to 17 form the PORT 3 pins of the 8051 Microcontroller. PORT 3 also acts as a bidirectional Input / Output PORT with internal pull-ups. Additionally, all the PORT 3 Pins have special functions. The following table gives the details of the additional functions of PORT 3 Pins.

PORT 3 Pin	***Function***	***Description***
P3.0	RXD	Serial Input
P3.1	TXD	Serial Output
P3.2	INT0	External Interrupt 0
P3.3	INT1	External Interrupt 1
P3.4	T0	Timer 0
P3.5	T1	Timer 1
P3.6	WR	External Memory Write
P3.7	RD	External Memory Read

Pins 18 & 19: Pins 18 and 19 i.e. XTAL 2 and XTAL 1 are the pins for connecting external oscillator. Generally, a Quartz Crystal Oscillator is connected here.

Pin 20 (GND):Pin 20 is the Ground Pin of the 8051 Microcontroller. It represents 0V and is connected to the negative terminal (0V) of the Power Supply.

Pins 21 – 28 (PORT 2): These are the PORT 2 Pins of the 8051 Microcontroller. PORT 2 is also a Bidirectional Port i.e. all the PORT 2 pins act as Input or Output. Additionally, when external memory is interfaced, PORT 2 pins act as the higher order address byte. PORT 2 Pins have internal pull-ups.

Pin 29 (PSEN): Pin 29 is the Program Store Enable Pin (PSEN). Using this pins, external Program Memory can be read.

Pin 30 (ALE/PROG): Pin 30 is the Address Latch Enable Pin. Using this Pins, external address can be separated from data (as they are multiplexed by 8051). During Flash Programming, this pin acts as program pulse input (PROG).

Pin 31 (EA/VPP): Pin 31 is the External Access Enable Pin i.e. allows external Program Memory. Code from external program memory can be fetched only if this pin is LOW. For normal operations, this pins is pulled HIGH. During Flash Programming, this Pin receives 12V Programming Enable Voltage (VPP).

Pins 32 – 39 (PORT 0): Pins 32 to 39 are PORT 0 Pins. They are also bidirectional Input / Output Pins but without any internal pull-ups. Hence, we need external pull-ups in order to use PORT 0 pins as I/O PORT. In addition to acting as I/O PORT, *PORT* 0 also acts as lower order address/data bus when external memory is accessed.

Pin 40 (VCC): Pin 40 is the power supply pin to which the supply voltage is given (+5V).

7. Describe serial interface and interrupts in 8051. (Nov. 2016)

Serial Communication

- The fastest way of transmitting data, within a microcomputer is parallel data transfer. For transferring data over long distances, however, parallel data transmission requires too many wires.
- For long distance transmission, data is usually converted from parallel form to serial form so that it can be sent on a single wire or pair of wires. Serial data received from a distant source is converted to parallel form and it can be easily transferred on the microcomputer buses. The types of communication systems are,

    1. Simplex

    2. Half-duplex

    3. Full-duplex

- **In simplex communication**, data can be transmitted only in one direction, ie. Data from sensors to processor. Eg : commercial radio stations.
- **In half-duplex transmission**, data can be transmitted in either direction between two systems, but can occur only in one direction at a time. Eg : two-way radio system,

where one user always listens while the other talks because the receiver circuitry is turned off during transmit.

- **In full duplex**, the data can be send and received at the same time. Eg : A normal phone conversation.

Serial data can be sent by two ways. They are,

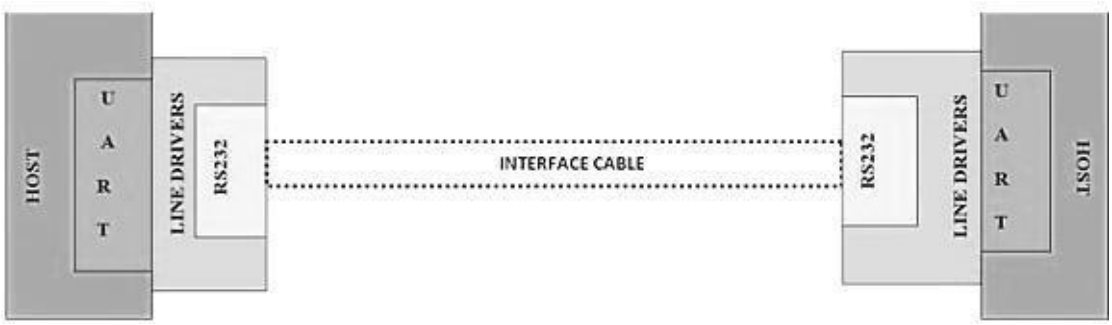
1. Synchronous communication

2. Asynchronous communication

- Microcontrollers need to communicate with external devices such as sensors, computers and so on to collect data for further processing. Data communication generally done by means of two methods: **Parallel and Serial mode.**
- In the **parallel mode** data bits are transferred in a fast manner using more number of lines. But when comes to a Microcontroller system, we cannot afford to dedicate many lines for data transfer. **So UART or Serial communication** in 8051 microcontroller will allow the controller to send and receive data's just by using two pins.
- Serial Communication uses only two data lines to establish communication between Microcontroller and external devices. In this communication data bits are transferred one bit at a time, so the process will be slow.

RS-232 and MAX-232

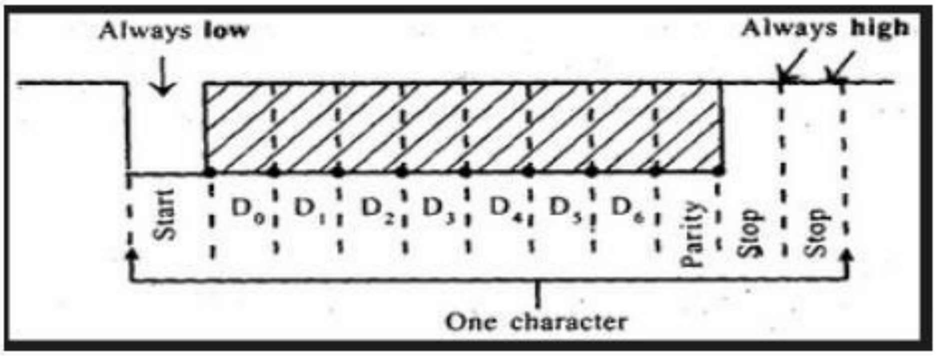
- To establish communication between a controller and PC, we must use a serial I/O standard RS-232 which was widely used in PC and several devices. PC works on the RS-232 standards which operates at a logic level of -25V to +25V.



- But Microcontrollers use TTL logic which works on 0-5V which is not compatible with the RS-232 standards. MAX232 is a specialized IC which offers intermediate link between the Microcontroller and PC.
- The transmitters of this IC will convert the TTL input level to the RS-232 Voltage standards. Meanwhile the receivers of this IC will convert RS-232 input to 5V TTL logic levels.

Working of MAX232 IC

- The RS-232 interface works in combination with UART universal asynchronous receiver/transmitter. It is a piece of integrated circuit integrated inside the processor or controller. It takes bytes and transmits the individual bits in a sequential fashion in a frame.



- A frame is defined structure, carrying meaningful sequence of bit or bytes of data. It has a start bit followed by 8 data bits, a parity bit and a stop bit. Once data is changed into bits separate line drivers are used to convert the logic level of UART to RS-232 logic.
- Finally the signals are transferred along the interface cable at the specified voltage level of RS-232. The data is sent serially on RS232.
- Each bit is sent one after the other. This mode of transmission requires that receiver is aware when the actual data bits are arriving to synchronize itself with coming data. So logic 0 is sent as a start bit.
- The start bit in the frame signals the receiver that a new character is coming. Once the receiver acknowledges the next five to eight bits are sent which represents the character.
- This is followed by parity bit used for error detection. Parity bit is used to specify even or odd number of one's in the set of bits. For error detection we add an extra bit to the data word.
- The transmitter calculates the value of the bit depending on the information sent and receiver also performs the same calculation. It checks the parity value to the calculated value. The stop bit helps the receiver to identify the end of message.
- The start bit always has space value and stop bit has mark value. Now, if a receiver detects a value other than mark when stop bit should be present, it knows that's there is synchronization error. This causes a framing error condition in the receiving UART.
- The device then tries to resynchronize on new incoming bits. At the other end again the line driver interface converts it into UART compatible logic levels. At the destination, a second UART re-assembles the bits into bytes.

Interrupts programming

Interrupts are the events that temporarily suspend the main program, pass the control to the external sources and execute their task. It then passes the control to the main program where it had left off.

8051 has 5 interrupt signals, i.e. **INT0, TFO, INT1, TF1, RI/TI**. Each interrupt can be enabled or disabled by setting bits of the IE register and the whole interrupt system can be disabled by clearing the EA bit of the same register.

IE (Interrupt Enable) Register

This register is responsible for enabling and disabling the interrupt. EA register is set to one for enabling interrupts and set to 0 for disabling the interrupts. Its bit sequence and their meanings are shown in the following figure.

EA	-	-	ES	ET1	EX1	ET0	EX0

EA	IE.7	It disables all interrupts. When EA = 0 no interrupt will be acknowledged and EA = 1 enables the interrupt individually.
-	IE.6	Reserved for future use.
-	IE.5	Reserved for future use.
ES	IE.4	Enables/disables serial port interrupt.
ET1	IE.3	Enables/disables timer1 overflow interrupt.
EX1	IE.2	Enables/disables external interrupt1.
ET0	IE.1	Enables/disables timer0 overflow interrupt.
EX0	IE.0	Enables/disables external interrupt0.

IP (Interrupt Priority) Register

The priority levels of the interrupts can be changed by changing the corresponding bit in the Interrupt Priority (IP) register as shown in the following figure.

A low priority interrupt can only be interrupted by the high priority interrupt, but not interrupted by another low priority interrupt.

If two interrupts of different priority levels are received simultaneously, the request of higher priority level is served. If the requests of the same priority levels are received simultaneously, then the internal polling sequence determines which request is to be serviced.

-	-	PT2	PS	PT1	PX1	PT0	PX0

bit7 bit6 bit5 bit4 bit3 bit2 bit1

-	IP.6	Reserved for future use.
-	IP.5	Reserved for future use.
PS	IP.4	It defines the serial port interrupt priority level.
PT1	IP.3	It defines the timer interrupt of 1 priority.
PX1	IP.2	It defines the external interrupt priority level.
PT0	IP.1	It defines the timer0 interrupt priority level.
PX0	IP.0	It defines the external interrupt of 0 priority level.

TCON Register

TCON register specifies the type of external interrupt to the microcontroller.

8. Explain the RAM memory space allocation in 8051. (Nov. 2016)

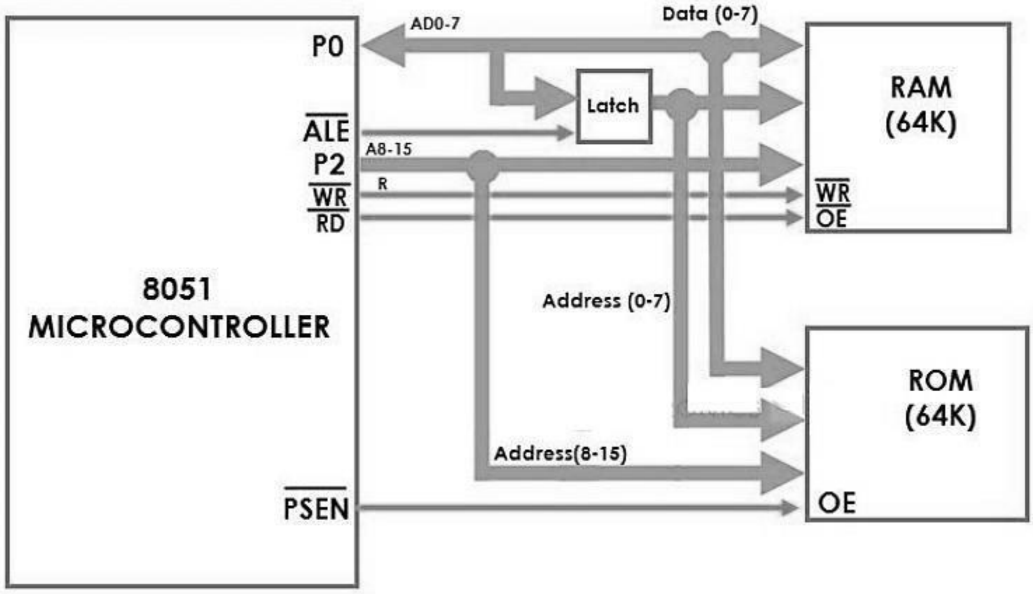
Interfacing External Memory with 8051 Microcontroller

A typical 8051 Microcontroller has 4KB of ROM and 128B of RAM (most modern 8051 Microcontroller variants have 8K ROM and 256B of RAM). The designer of an 8051 Microcontroller based system is not limited to the internal RAM and ROM present in the 8051 Microcontroller.

There is a provision of connecting both external RAM and ROM i.e. Data Memory and Program. EX0 IE.0 Enables/disables external interrupt0. The reason for interfacing external Program Memory or ROM is that complex programs written in high – level languages often tend to be larger and occupy more memory.

Another important reason is that chips like 8031 or 8032, which doesn't have any internal ROM, have to be interfaced with external ROM. A maximum of 64B of Program Memory (ROM) and Data Memory (RAM) each can be interface with the 8051 Microcontroller.

The following image shows the block diagram of interfacing 64KB of External RAM and 64KB of External ROM with the 8051 Microcontroller.



BM T61 – DIAGNOSTIC AND THERAPEUTIC EQUIPMENTS

UNIT-3

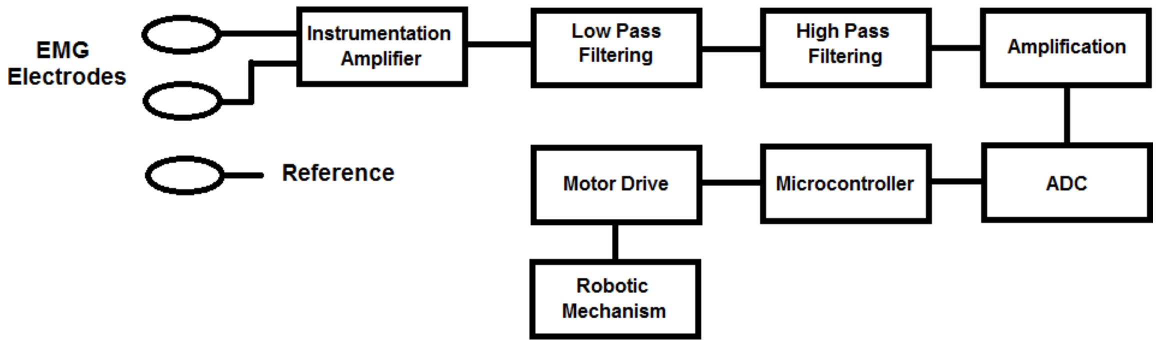
2 MARKS:

1. Write down the characteristics muscle fatigue.(April/May2018)

Muscle fatigue can present as a:

- Loss of force or power output
- Slowing of relaxation
- Changes in contractile characteristics and
- Alterations in electrical properties.

2. Draw the block diagram for EMG signal acquisition.(April/May2018)



3. Differentiate the A mode and M-mode display of ultrasound.(April/May2018)

A-MODE	M-MODE
• One dimensional ultrasound image	• Both one and two dimensional.(two dimensional is an advancement)
• Amplitude modulation	• Time Motion mode or TM mode
• It is the display of amplitude spikes of different height	• It is the display of an image that is used for analysing moving body parts
• Not applicable to a regional anaesthesia	• Use in regional anaesthesia is negligible

4. Write the principle of dialysis.(April/May2018)

Dialysis works on the principles of the diffusion of solutes and ultrafiltration of fluid across a semi-permeable membrane. Diffusion is a property of substances in water; substances in water tend to move from an area of high concentration to an area of low concentration.

5. Define latency.(May2017)

Latency is the delay between a user's action and a web application's response to that action, often referred to in networking terms as the total round trip time it takes for a data packet to travel.

While according to science, The time between onset of a stimulus and peak of the ensuing action potential.

6. What is nerve stimulators used for?(May2017)

It is a battery-operated device that some people **use** to treat pain.

- Endometriosis.
- Arthritis.
- Sports injuries.
- Multiple sclerosis.
- Fibromyalgia.
- Painful diabetic neuropathy.
- Spinal cord injury.

7. What is fatigue?(April/May2016)

Fatigue is a term used to describe an overall feeling of tiredness or lack of energy. It isn't the same as simply feeling drowsy or sleepy. When you're **fatigued**, you have no motivation and no energy. Being sleepy may be a symptom of **fatigue**, but it's not the same thing.

8. Write a short note on muscle stimulators.(April/May2016)

Muscle stimulators employ the sinusoidal output. The sensory nerves are stimulated in a fashion that disrupts pain perception through gate control or opiate system mechanisms. The **stimulation** of the motor nerves elicits **muscular** contractions.

9. a) Enlist the type of electrodes used for electro diagnostic application.(November 2016)

b) Mention the types of electrodes used for EMG.(September 2020)

There are two main **types** of **EMG electrodes**: surface (or skin **electrodes**) and inserted **electrodes**. Inserted **electrodes** have further two **types**: needle and fine wire **electrodes**. The three **electrodes** (needle, fine wire and surface)

10. Write a note on nerve stimulators.(November 2016)

A **nerve stimulator works** by masking pain signals before they reach the brain. A **stimulator** device delivers electric pulses to electrodes placed over the spinal cord. Modified by the pulses, the pain signals are either not perceived or are replaced by a tingling feeling.

11. a)What is muscle fatigue?(May 2019)

b) What is meant by muscle fatigue? List the causes for fatigue. (November/December2018)

Muscle fatigue is the decline in ability of **muscles** to generate force. It can be a result of vigorous exercise but abnormal **fatigue** may be caused by barriers to or interference with the different stages of **muscle** contraction.

Fatigue can result from:

- Physical exertion.
- Lack of physical activity.
- Lack of sleep.
- Being overweight or obese.
- Periods of emotional stress.
- Boredom.
- Grief.
- Taking certain medications, such as antidepressants or sedatives.

12. Define nerve conduction velocity and also mention the value for normal person. (May2019)

A **nerve conduction velocity** (NCV) test — also called a **nerve conduction** study (NCS) — measures how fast an electrical impulse moves through your **nerve**. NCV can identify **nerve** damage. During the test, your **nerve** is stimulated, usually with electrode patches attached to your skin. **Normal** impulses in peripheral **nerves** of the legs travel at 40–45 m/s, and 50–65 m/s in peripheral **nerves** of the arms. Largely generalized, **normal conduction velocities** for any given **nerve** will be in the **range of** 50–60 m/s.

- **Median Sensory:** 45–70 m/s
- **Ulnar Sensory:** 48–74 m/s
- **Sural Sensory:** 46–64 m/s
- **Ulnar Motor:** 49+ m/s

13. What is muscle twitching?(November/December2018)

Muscle twitches can happen for lots of reasons, like stress, too much caffeine, a poor diet, exercise, or as a side effect of some medicines. Lots of people get **twitches** in the eyelid, thumb, or calf **muscles**. These types of **twitches** usually go away after a few days. They're often related to stress or anxiety.

14. What is nerve conduction velocity? (November/December2017)

A **nerve conduction velocity** (NCV) test — also called a **nerve conduction** study (NCS) — measures how fast an electrical impulse moves through your **nerve**. NCV can identify **nerve** damage. During the test, your **nerve** is stimulated, usually with electrode patches attached to your skin.

15. Differentiate muscular stimulator & nerve stimulator(November/December2017)

TENS	EMS
Uses steady current to stimulate nerves	Uses a cycle of impulses to cause muscle contractions
Primary use is to relieve pain	Primary use is for physical therapy of muscle tissue
Blocks pain signals from reaching the brain	Prevents wastage or damaging of muscles due to injuries
Temporary pain reduction	Reduces muscle atrophy
Low penetration value and temporary benefits	Deep penetration value and permanent results
Helps body produce more natural pain-relieving substances	Helps increase blood flow, range of motion, and increases muscle
Relieves both chronic and acute pain	Relieves muscle pain from spastic muscles, tight or sore muscles
Used for: • Arthritis • Back pain • Carpal tunnel syndrome • Foot pain • Labor pain • Multiple sclerosis • Sciatica	Used for: • Muscle strengthening • Rehabilitation purposes • Prevent disuse muscle atrophy • Increase blood circulation • Relaxation of muscles • Cosmetic muscle toning

16. Write down the principle used for the measurement of nerve conduction velocity and define latency.(September 2020)

The **nerve conduction velocity** (**speed**) is then calculated by **measuring** the distance between electrodes and the time it takes for electrical impulses to travel between electrodes. A related procedure that may be performed is electromyography (EMG).

Latency is the delay between a user's action and a web application's response to that action, often referred to in networking terms as the total round trip time it takes for a data packet to travel.While according to science, The time between onset of a stimulus and peak of the ensuing action potential.

11 MARKS:

1. Draw the EMG waveform and differentiate between muscle stimulator and nerve stimulation.(April/May2018)

TENS	EMS
• TENS stimulates the nerves – the logic is that these stimulatory actions prevents pain signals from	• EMS accelerates contraction of muscles – by mimicking the action potential that comes from the

reaching the brain.	central nervous system
• TENS devices offer a wider range of signals with respect to frequency, pulses and intensities.	• EMS devices offer limited signals and thus narrower functions in this regard
• TENS therapy, offers short-term pain relief. TENS is not painful and is an efficient and effective therapy to mask pain like diabetic neuropathy. TENS therapy also encourages the production of endorphins, which act as body's natural painkillers.Electrical stimulation from TENS also improves circulation locally. It can also either minimize or completely put an end to muscle spasms.	• In medicine, Electrical muscle stimulation is used for rehabilitation purposes. It should never be utilized as a replacement for training.
It is also used for; • Arthritis relief • Relieves acute, chronic, and psychogenic pain • Bursitis • Tendonitis • Osteoarthritis • Nerve pain • Shoulder pain • Migraines and Headaches • Sciatic pain relief •	Some of the uses of EMS are: • It aids in muscle strengthening when in pain or injured • Electrical muscle stimulation can help activate fatigued muscles, with no risk to the athlete. • Electrical muscle stimulation is an extremely useful tool to assist a healthy or injured athlete, in conjunction with tactical and proven concords. • EMS also offers the added benefit of pain reduction for patients who are not willing or are not able to

	take oral pain reduction medications or any anti-inflammatory tablets or liquid drugs. • EMS benefits also include Muscle Atrophy, Osteoarthritis, Pressure Sore Prevention, muscle re-education, massaging of sore muscles.
• TENS generates stimulatory actions in nerves to block pain and relax muscles consequence. TENS provides immediate painrelief.	• EMS stimulates muscles cells. An EMS unit is usually appropriate before and after physical exercise or any workout sessions or can also be used on the advice of a physiotherapist in case you are rebuilding your muscles that have suffered atrophy. EMS offers long range treatment for muscle development.
• Low penetration value and temporary benefits	• Deep penetration value and permanent results

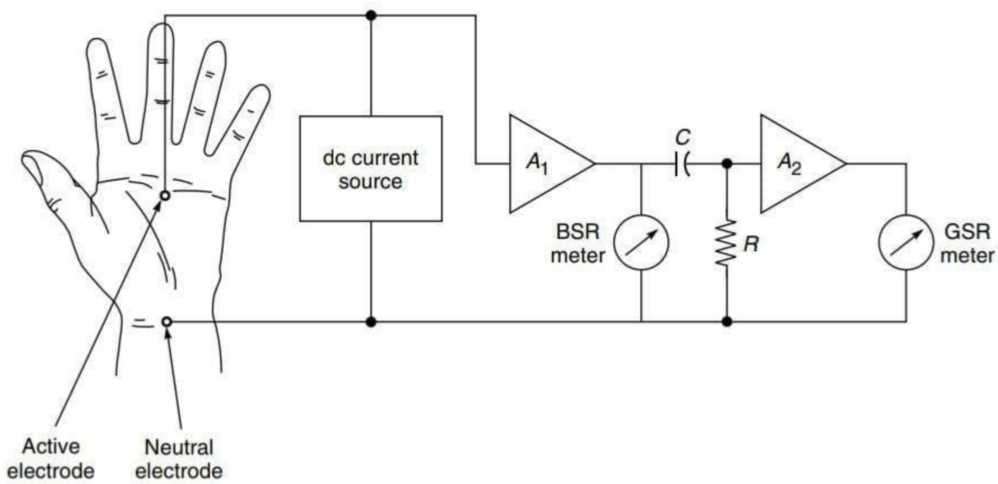
2. a) Explain in detail about EMG bio feedback instrumentation.(April/May2018)

b) List out the function of muscle stimulator and explain the EMG biofeedback system(May 2019)

- Feedback is a common engineering term and refers to its function to control a process. When this concept is applied to biological processes within the body, it is known as biofeedback.
- Here again, biofeedback is a means for gaining control of the body processes to create a specially required psychological state so as to increase relaxation, relieve pain and develop healthier and more comfortable life patterns.

- The technique involves the measurement of a variable produced by the body process and compares it with a reference value.
- Based on the difference between the measured and reference value, action is taken to bring the variable to the reference value.
- Many different physiological processes have been evaluated for possible control by biofeedback methods. However, the following four neural functions are commonly employed:
    - Emotions or Electrodermal Activity (Galvanic skin response measurements)
    - Muscle tension or EMG (Electromyograph measurements)
    - Temperature/sympathetic pattern (Thermistor readings)
    - Pulse (Heart rate monitoring)

Electrodermal activity is measured in two ways: BSR (basal skin response) and GSR (galvanic skin response) is a measure of the average activity of the sweat glands and is a measure of the phasic activity (the high and low points) of these glands. BSR gives the baseline value of the skin resistance where as GSR is due to the activity of the sweat glands.



3. Describe in detail about the echoencephalogram with a neat diagram.(April/May2018)

- Electroencephalograph is an instrument for recording the electrical activity of the brain, by suitably placing surface electrodes on the scalp.
- EEG, describing the general function of the brain activity, is the superimposed wave of neuron potentials operating in a non-synchronized manner in the physical sense.

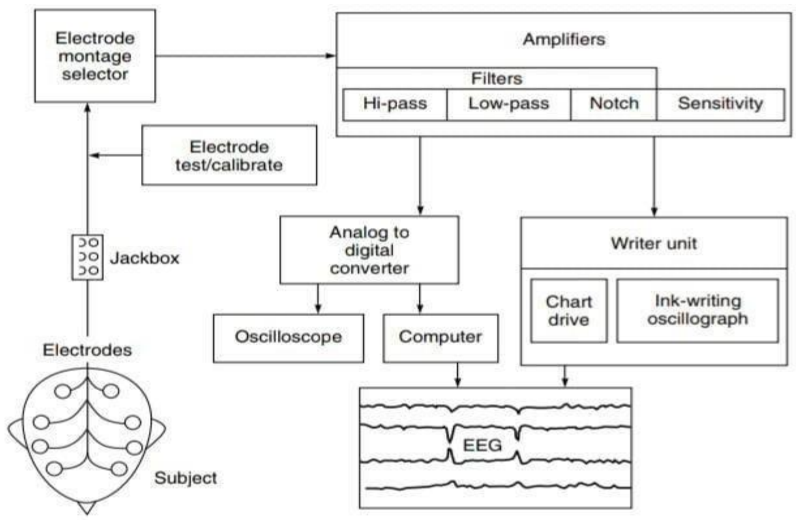
Its stochastic nature originates just from this, and the prominent signal groups can be empirically connected to diagnostic conclusions.

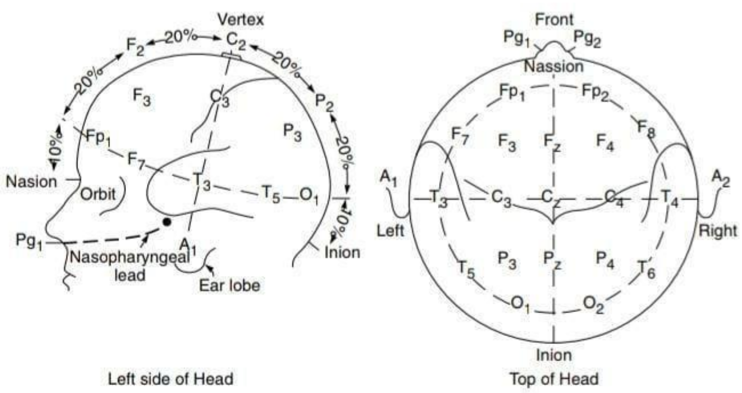
- Monitoring the electroencephalogram has proven to be an effective method of diagnosing many neurological illnesses and diseases, such as epilepsy, tumour, cerebrovascular lesions, ischemia and problems associated with trauma.
- It is also effectively used in the operating room to facilitate anaesthetics and to establish the integrity of the anaesthetized patient’s nervous system.
- This has become possible with the advent of small, computer-based EEG analyzers. Consequently, routine EEG monitoring in the operating room and intensive care units is becoming popular.
- Several types of electrodes may be used to record EEG. These include: Peel and Stick electrodes, Silver plated cup electrodes and Needle electrodes.
- EEG signals picked up by the surface electrodes are usually small as compared with the ECG signals. They may be several hundred microvolts, but 50 microvolts peak-to-peak is the most typical.
- The brain waves, unlike the electrical activity of the heart, do not represent the same pattern over and over again. Therefore, brain recordings are made over a much longer interval of time in order to be able to detect any kind of abnormalities.
- Several types of electrodes may be used to record EEG. These include: Peel and Stick electrodes, Silver plated cup electrodes and Needle electrodes.
- EEG electrodes are smaller in size than ECG electrodes. They may be applied separately to the scalp or may be mounted in special bands, which can be placed on the patient’s head. In either case, electrode jelly or paste is used to improve the electrical contact.
- If the electrodes are intended to be used under the skin of the scalp, needle electrodes are used. They offer the advantage of reducing movement artefacts. EEG electrodes give high skin contact impedance as compared to ECG electrodes.
- Good electrode impedance should be generally below 5 kilohms. Impedance between a pair of electrodes must also be balanced or the difference between them should be less than 2 kilohms. EEG preamplifiers are generally designed to have a very high value of input impedance to take care of high electrode impedance.

- EEG may be recorded by picking up the voltage difference between an active electrode on the scalp with respect to a reference electrode on the ear lobe or any other part of the body. This type of recording is called 'monopolar' recording.
- However, 'bipolar' recording is more popular wherein the voltage difference between two scalp electrodes is recorded. Such recordings are done with multi-channel electroencephalographs.

BLOCK DIAGRAM:

- Montages: A pattern of electrodes on the head and the channels they are connected to is called a montage. Montages are always symmetrical. The reference electrode is generally placed on a non- active site such as the forehead or earlobe. EEG electrodes are arranged on the scalp according to a standard known as the 10/20 system.





: *10-20 system of placement of electrodes*

- Electrode Montage Selector: EEG signals are transmitted from the electrodes to the head box, which is labelled according to the 10–20 system, and then to the montage selector.
- Preamplifier: Every channel has an individual, multistage, ac coupled, very sensitive amplifier with differential input and adjustable gain in a wide range. Its frequency response can be selected by single-stage passive filters.
- Sensitivity Control: The overall sensitivity of an EEG machine is the gain of the amplifier multiplied by the sensitivity of the writer.
- Filters: Just like in an ECG when recorded by surface electrodes, an EEG may also contain muscle artefacts due to contraction of the scalp and neck muscles, which overlie the brain and skull. The artefacts are large and sharp, in contrast to the ECG, causing great difficulty in both clinical and automated EEG interpretation.
- Noise: EEG amplifiers are selected for minimum noise level, which is expressed in terms of an equivalent input voltage. Two microvolts is often stated as the acceptable figure for EEG recording.
- Writing Part: The writing part of an EEG machine is usually of the ink type direct writing recorder.
- Paper Drive: This is provided by a synchronous motor. An accurate and stable paper drive mechanism is necessary and it is normal practice to have several paper speeds available for selection.
- Channels:An electroencephalogram is recorded simultaneously from an array of many electrodes. The record can be made from bipolar or monopolar leads.

4. Discuss in detail about the application of ultrasound in obsterics and gynecology.(April/May2018)

- The introduction of ultrasound to obstetrics and gynecology has made tremendous impact to patient care as it allowed imaging of the fetus and placenta in obstetrics and maternal internal organs in gynecology with such clarity to allow advanced diagnosis and also to guide various life saving interventions.
- Understanding the physical principles of ultrasound is essential for a basic knowledge of instrument control and also for understanding safety and bioeffects of this technology. In this chapter, we present the basic concepts of the physical

principles of ultrasound, define important terminology, review the safety and bioeffects and report on ultrasound statements of national and international organizations.

- Sound is a mechanical wave that travels in a medium in a longitudinal and straight-line fashion. When a sound travels through a medium, the molecules of that medium are alternately compressed (squeezed) and rarefied (stretched).
- Sound cannot travel in a vacuum; it requires a medium for transmission, as the sound wave is a mechanical energy that is transmitted from one molecule to another. It is important to note that the molecules do not move as the sound wave passes through them, they oscillate back and forth, forming zones of compression and rarefaction in the medium. Seven acoustic parameters describe the characteristics of a sound wave.
- Ultrasound waves are generated from tiny piezoelectric crystals packed within the ultrasound transducers. When an alternate current is applied to these crystals, they contract and expand at the same frequency at which the current changes polarity and generate an ultrasound beam.
- The ultrasound beam traverses into the body at the same frequency generated. Conversely, when the ultrasound beam returns to the transducer, these crystals change in shape and this minor change in shape generate a tiny electric current that is amplified by the ultrasound machine to generate an ultrasound image on the monitor.
- The piezoelectric crystals within the transducer therefore transform electric energy into mechanical energy (ultrasound) and vice-versa. One crystal is not sufficient to produce an ultrasound beam for clinical imaging and modern transducers have large number of crystals arranged into parallel rows .
- Each crystal can nevertheless be stimulated individually. The crystals are protected by a rubber covering that helps decrease the resistance to sound transmission (impedance) from the crystals to the body.
- The high frequency sound generated by a transducer do not travel well through air, so in order to facilitate their transfer from the transducer to the skin of the patient, a watery gel is applied that couples the transducer to the skin and permits the sound to go back and forth.
- Ultrasound is therefore generated inside transducers by tiny crystals that convert electric current to ultrasound and convert returning ultrasound beams from the body

into electric currents. Modern transducers have crystals made of synthetic plumbium zirconium titanate (PZT).

5. a) What is EMG?Briefly explain about the recording set up of the same.(May2017)

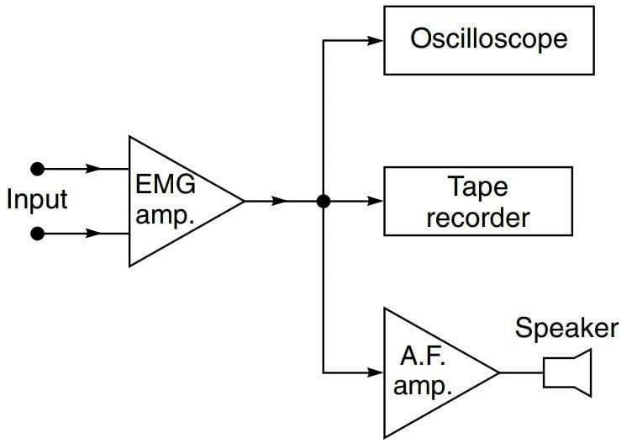
b) Discuss EMG recording system in detail.(November 2016)

c)Analyse the EMG waves taken from a normal person and also explain the generation of those waves.(May 2019)

d)Describe the recording set up used in EMG.(November/December2018, November/December2017)

- Electromyograph is an instrument used for recording the electrical activity of the muscles to determine whether the muscle is contracting or not; or for displaying on the CRO and loudspeaker the action potentials spontaneously present in a muscle or those induced by voluntary contrac- tions as a means of detecting the nature and location of motor unit lesions; or for recording the electrical activity evoked in a muscle by the stimulation of its nerve.
- The instrument is useful for making a study of several aspects of neuromuscular function, neuromuscular condition, extent of nerve lesion, reflex responses, etc.
- EMG measurements are also important for the myoelectric control of prosthetic devices (artificial limbs).
- This use involves picking up EMG signals from the muscles at the terminated nerve endings of the remaining limb and using the signals to activate a mechanical arm. This is the most demanding requirement from an EMG since on it depends the working of the prosthetic device.
- EMG is usually recorded by using surface electrodes or more often by using needle electrodes, which are inserted directly into the muscle. The surface electrodes may be disposable, adhesive types or the ones which can be used repeatedly.
- A ground electrode is necessary for providing a common reference for measurement. These electrodes pick up the potentials produced by the contracting muscle fibres. The signal can then be amplified and displayed on the screen of a cathode ray tube.

- It is also applied to an audio- amplifier connected to a loudspeaker. A trained EMG interpreter can diagnose various muscular disorders by listening to the sounds produced when the muscle potentials are fed to the loud- speaker.
- The block diagram shows a typical set-up for EMG recordings. The oscillo- scope displays EMG waveforms. The tape recorder is included in the system to facilitate playback and study of the EMG sound waveforms at a later convenient time. The waveform can also be photographed from the CRT screen by using a synchronized camera.



- The amplitude of the EMG signals depends upon various factors, e.g. the type and placement of electrodes used and the degree of muscular exertions. The needle electrode in contact with a single muscle fibre will pick up spike type voltages whereas a surface electrode picks up many overlapping spikes and therefore produces an average voltage effect.
- A typical EMG signal ranges from 0.1 to 0.5 mV. They may contain frequency components extending up to 10 kHz. Such high frequency signals cannot be recorded on the conventional pen recorders and therefore, they are usually displayed on the CRT screen.

6. With neat diagram, describe the method of measuring the nerve conducting velocity.(May2017)

Also called an **electroneurography**, **EneG**, or **nerve conduction study**, a **nerve conduction velocity (NCV) test** is a measurement of the speed of conduction of an electrical impulse through a nerve. NCV can determine nerve damage and destruction.

A nerve conduction study (NCS) is a test commonly used to evaluate the function, especially the ability of electrical conduction, of the motor and sensory nerves of the human body. Nerve conduction velocity (NCV) is a common measurement made during this test.

During the test, flat electrodes are placed on the skin at intervals over the nerve that is being examined. A low intensity electric current is introduced to stimulate the nerves thus generating nerve impulses.

The Nerve Impulse

The nerve impulse is a wave of cell depolarisation immediately followed by a wave of repolarisation, collectively called an action potential, occurring on the plasma membrane of a

What abnormal results mean is that most often, abnormal results are caused by some sort of neuropathy (nerve damage or destruction) including:

- Demyelination (destruction of the myelin sheath)
- Conduction block (the impulse is blocked somewhere along the nerve pathway)
- Axonopathy (damage to the nerve axon)

Some of the associated diseases or conditions include:

- Alcoholic neuropathy
- Diabetic neuropathy
- Nerve effects of uremia (from kidney failure)
- Traumatic injury to a nerve
- Guillain-Barre syndrome

Some of the common disorders which can be diagnosed by nerve conduction studies include:

- Peripheral neuropathy
- Carpal tunnel syndrome
- Ulnar neuropathy
- Guillain-Barré syndrome etc,…

The nerve conduction study consists of the following components:

- Motor NCS
- Sensory NCS
- F-wave study
- H-reflex study

Patient risk

Nerve conduction studies are very helpful to diagnose certain diseases of the nerves of the body. The test is not invasive, but can be a little painful due to the electrical shocks. However, the shocks are associated with such a low amount of electrical current that they are not dangerous to anyone. Patients with a permanent pacemaker or other such implanted stimulators such as deep brain stimulators or Spinal Cord Stimulators must tell the examiner prior to the study. This does not prevent the study, but special precautions are taken.

7. Explain in detail about the peripheral nerve stimulator and its application in pain relief. (April/May2016)

- Electrical nerve stimulation is a procedure that uses an electrical current to treat chronic pain. Peripheral nerve stimulation (PNS) and spinal cord stimulation (SCS) are two types of electrical nerve stimulation.
- In either, a small pulse generator sends electrical pulses to the nerves (in peripheral nerve stimulation) or to the spinal cord (in spinal cord stimulation). These pulses interfere with the nerve impulses that make you feel pain.

Post treatment care:

You will have a small incision that you should keep clean and dry until it heals.

This treatment may be done for people with severe, chronic pain who have:

- Failed back surgery syndrome.
- Severe nerve-related pain or numbness.
- Chronic pain syndromes, such as complex regional pain syndrome.

Electrical nerve stimulation is typically considered investigational for various other conditions, includingmultiple sclerosis, paraplegia, and intractable angina.

- Nerve stimulation is done in two steps. To see if it will help your pain, your doctor will first insert a temporary electrode through the skin (percutaneously) to give the treatment a trial run. The electrode is connected to a stimulator that the patient can control.
- If the trial is successful, your doctor can implant a permanent stimulator under your skin. This is typically done using a local anesthetic and a sedative.
- The stimulator itself is implanted under the skin and the small coated wires (leads) are inserted under the skin to the point where they are either connected to nerves or inserted into the spinal canal.
- After this outpatient procedure is complete, you and your doctor determine the best pulse strength. You are then told how to use the stimulator at home.
- A typical schedule for spinal cord stimulation is to use it for 1 or 2 hours, 3 or 4 times a day.
- When in use, electrical nerve stimulation creates a tingling feeling.

Working :

- There isn't a lot of evidence to show how well spinal cord stimulation works. It seems to help certain types of chronic pain, such as failed back surgery syndrome and complex regional pain syndrome.
- Spinal cord stimulation may also help chronic low back pain.
- Some researchers have reported that more than half of people receiving spinal cord stimulation for chronic low back and leg pain, ischemic leg pain (for example, from peripheral arterial disease), or complex regional pain syndrome have pain reduction or relief.
- There is some evidence that peripheral nerve stimulation helps certain types of chronic pain, such as peripheral nerve pain and pain after surgery.
- Studies so far have been small.
- Initial pain relief is often followed by a gradual decline in effectiveness. Apparently, this is caused by the body's increasing tolerance to the treatment.

Risks

Possible risks related to electrical nerve stimulation include:

- Scar tissue (fibrosis) developing around the electrode.
- Pain gradually moving beyond the reach of the nerve stimulator.

- Breakage of an electrode or hardware failure.
- Infection.
- Leakage of spinal fluid during spinal cord stimulation.
- Headache from spinal cord stimulation.
- Bladder problems in spinal cord stimulation.
- Getting used to the stimulation, making it less effective.

- Some people who have an implanted stimulator may not be able to have a magnetic resonance imaging (MRI)test. If you have an appointment for an MRI, be sure to take the device card that was given to you when you got your implanted stimulator.
- The imaging staff will know if it is safe for you to have an MRI.
- There is still not strong proof that electrical nerve stimulation works. Better research is needed. Treatment success varies widely and is influenced by the cause of pain.
- Electrical nerve stimulation may be recommended for some people who have certain types of chronic pain.

8. Describe in detail about the various types of aneasthetic machines.(April/May2016)

The types of **Modern Anesthesia Machine** are as follows:

(1) Air anesthesia machine

- The air anesthesia machine is a semi-open anesthesia device. It mainly consists of a liquid medicine tank, an ether regulating switch, folding bellows, and a suction and exhalation one-way valve and a bellows.
- The device is lightly applicable and can directly use air and oxygen as a carrier gas to assist in breathing and control breathing to meet various surgical requirements.
- The working principle is that the patient connects the air anesthesia machine to the closed mask or the tracheal tube after completing the anesthesia induction.
- When inhaling, the anesthetic mixture enters the patient through the open inspiratory flap; when exhaled, the expiratory flap opens, and the inspiratory flap closes, expelling the exhaled gas. Folding bellows can be used when assisting or controlling breathing.

- Press down during inhalation and pull up when exhaling to ensure adequate ventilation. At the same time, according to actual needs, adjust the ether switch to maintain a stable anesthesia level.
- The shortcoming of this device is that the concentration of ether is low, and it can only be used as anesthetic maintenance, and the consumption of ether is large, which is likely to cause environmental pollution.

(2) DC anesthesia machine

- The direct current anesthesia machine consists of high-pressure oxygen, pressure reducer, flow meter, and anesthetic liquid evaporator. The device can only provide oxygen and adjust the concentration of anesthetic gas to be inhaled.
- There must be other devices in series with the output site for anesthesia.The exhaled gas is re-used through the exhalation flap into the CO2 absorber.

(3) Closed Anesthesia Machine

- The device supplies the patient with a low-flow anesthetic mixture and a one-way activity through the outgassing flap (door).
- The exhaled gas is re-used through the exhalation flap into the CO2 absorber. Its structure is mainly composed of oxygen supply and nitrous oxide device, gas flow meter, evaporator, CO2 absorber; one-way valve, breathing tube, outgassing valve, storage airbag and so on.
- Modern anesthesia machines are also equipped with ventilator airway pressure, expiratory flow, end-tidal CO2 concentration, inhalation anesthetic concentration, oxygen concentration monitor, hypoxic alarm and hypoxic-nitrous oxide automatic protection device.

9.Define latency. How will you measure the conduction velocity in peripheral nerves?(November 2016)

- Latency is the delay between a user's action and a web application's response to that action, often referred to in networking terms as the total round trip time it takes for a data packet to travel.While according to science, The time between onset of a stimulus and peak of the ensuing action potential.

- Electrical nerve stimulation is a procedure that uses an electrical current to treat chronic pain. Peripheral nerve stimulation (PNS) and spinal cord stimulation (SCS) are two types of
- electrical nerve stimulation. In either, a small pulse generator sends electrical pulses to the nerves (in peripheral nerve stimulation) or to the spinal cord (in spinal cord stimulation). These pulses interfere with the nerve impulses that make you feel pain.

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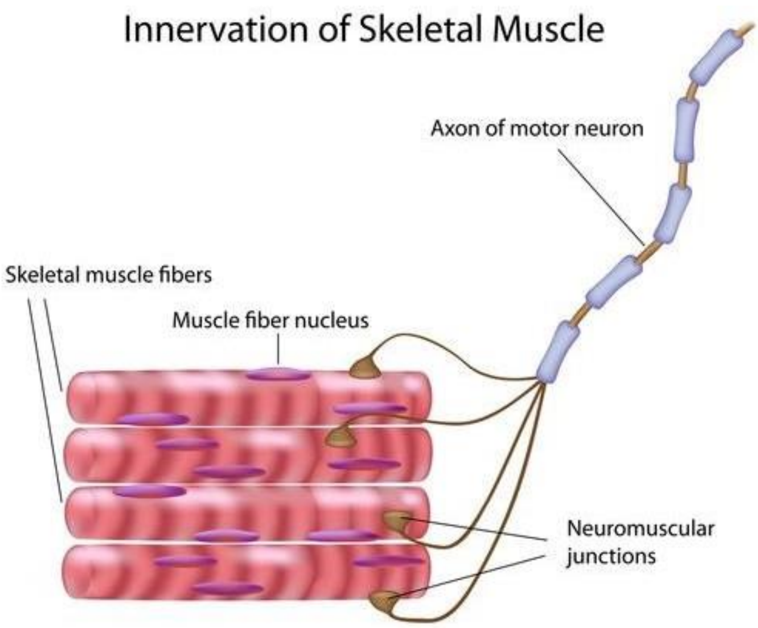
10. Describe the sliding theory of contraction of skeletal muscle.(November/December2018)

- It starts with a signal from the nervous system. So it starts with a signal from your brain. The signal goes through your nervous system to your muscle. Your muscle contracts, and your bones move. And all this happens incredibly fast.



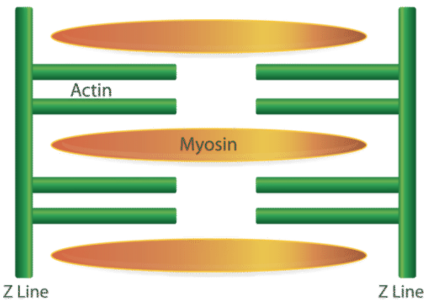
Muscle Contraction

- Muscle contraction occurs when muscle fibers get shorter. Literally, the muscle fibers get smaller in size. To understand how this happens, you need to know more about the structure of muscle fibers.

Structure of Muscle Fibers

- Each muscle fiber contains hundreds of organelles called **myofibrils**. Each myofibril is made up of two types of protein filaments: **actin** filaments, which are thinner, and **myosin** filaments, which are thicker.
- Actin filaments are anchored to structures called **Z lines** (Figure 13.13.2). The region between two Z lines is called a **sarcomere**. Within a sarcomere, myosin filaments overlap the actin filaments. The myosin filaments have tiny structures called **cross bridges** that can attach to actin filaments.

Parts of a Sarcomere



Sliding Filament Theory

- The most widely accepted theory explaining how muscle fibers contract is called the **sliding filament theory**. According to this theory, myosin filaments use energy from ATP to “walk” along the actin filaments with their cross bridges.
- This pulls the actin filaments closer together. The movement of the actin filaments also pulls the Z lines closer together, thus shortening the sarcomere.
- When all of the sarcomeres in a muscle fiber shorten, the fiber contracts. A muscle fiber either contracts fully or it doesn’t contract at all. The number of fibers that contract determines the strength of the muscular force. When more fibers contract at the same time, the force is greater.

Muscles and Nerves

- Muscles cannot contract on their own. They need a stimulus from a nerve cell to "tell" them to contract. Let's say you decide to raise your hand in class.
- Your brain sends electrical messages to nerve cells, called **motor neurons**, in your arm and shoulder.
- The motor neurons, in turn, stimulate muscle fibers in your arm and shoulder to contract, causing your arm to rise. Involuntary contractions of cardiac and smooth muscles are also controlled by nerves.

11.Discuss the different types of current waveforms used in muscle stimulator with its clinical application. (November/December2017)

Muscle Stimulator:

- **Electronic muscle stimulation (EMS)** may help you to strengthen weak muscles. There are several theories on how EMS may assist muscle strengthening.
- There are three basic **waveforms used** in commercial therapeutic electrical **stimulation** units: direct **current**, alternating **current**, **and** pulsed **current**.
- One potential reason is that when you maximally contract a muscle, at best, only 30% of all your muscle fibres are in a state of contraction.
- The remaining 70% are dormant and awaiting recruitment when the contracting fibres fatigue. With EMS you can potentially electrically stimulate these resting muscle fibres to improve their strength.
- Clinically, EMS appears to be more effective when the muscles are very weak and you have difficulty performing normal anti-gravity exercises.

Benefits of Electric Muscle Stimulation

Electric muscle stimulation (EMS) can help treat musculoskeletal injuries or ailments.

EMS is a common and effective way to:

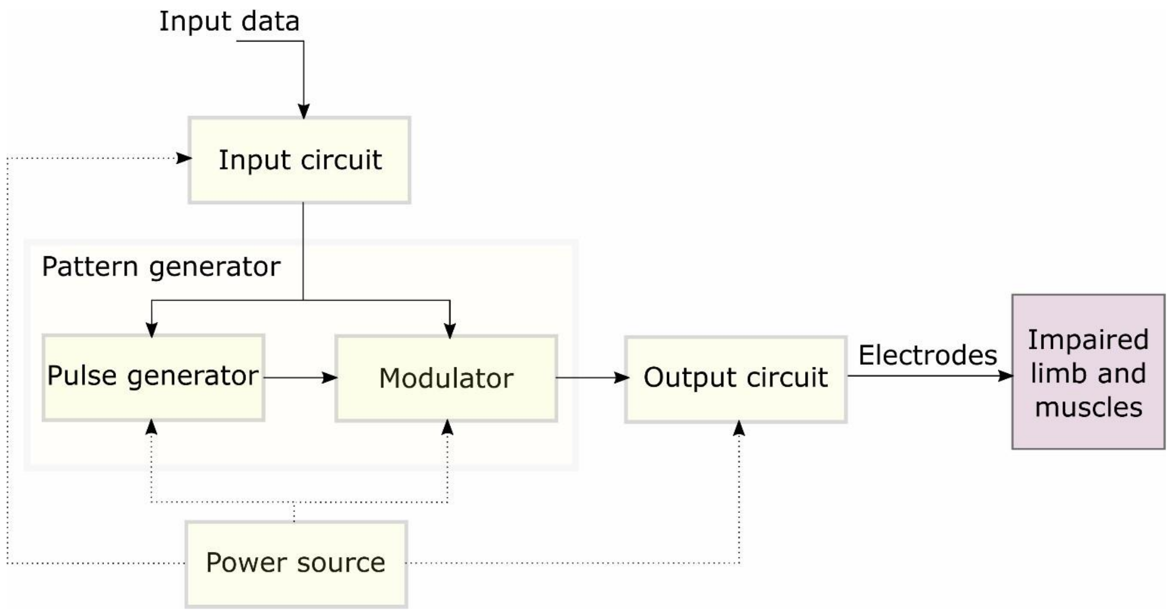
- Relieve discomfort and pain
- Reduce muscle spasms
- Restore muscle tone
- Rehabilitate parts of the body

How Electric Stimulation Works

- Electric stimulation works by attaching stick-on pieces of equipment to the skin and using the control unit to transmit currents to targeted muscle groups. The control unit is where the timer, sensory knobs and other devices are located to produce the electric current.
- Two lead wires and two to four neurostimulation electrodes are the tools that are attached to the skin to transmit the current. The machine may cause a number of unique sensations when turned on and applied to a specific muscle group.

How Electric Stimulation Feels

- Some patients report feeling pins and needles, muscle twitching and/or a dull tingling. These sensations usually only last during the treatment, but there are times patients will feel them up to 30 minutes after the therapy session.



Added Benefits of EMS

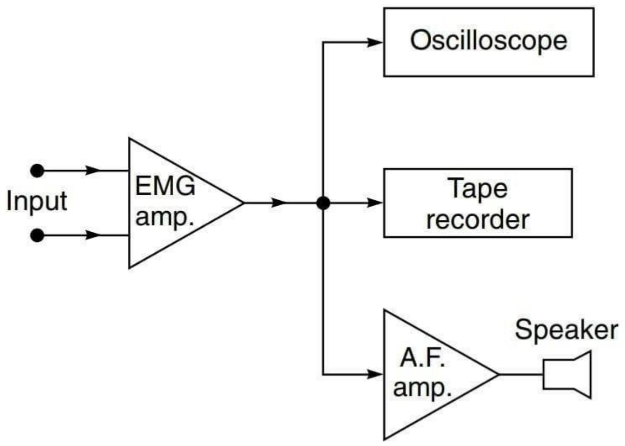
- There are many benefits to this kind of therapy. To start, it can help reduce edema (swelling) and expedite the healing process of injured or damaged tissue. Electric muscle stimulation can also help reduce chronic pain. Other benefits include:
  - May improve joint pain and swelling
  - Prevents and reveres muscle atrophy (loss of muscle mass/tissue)
  - Enhances rehabilitation of muscles
  - Increases range of motion for tense muscles or tendons
  - Reduces stress and discomfort
  - Improves blood flow and circulation

12. Explain the EMG biofeedback instrumentation using measurement and record of basal skin resistance(BSR) and Galvanic skin response(GSR)(September 2020)

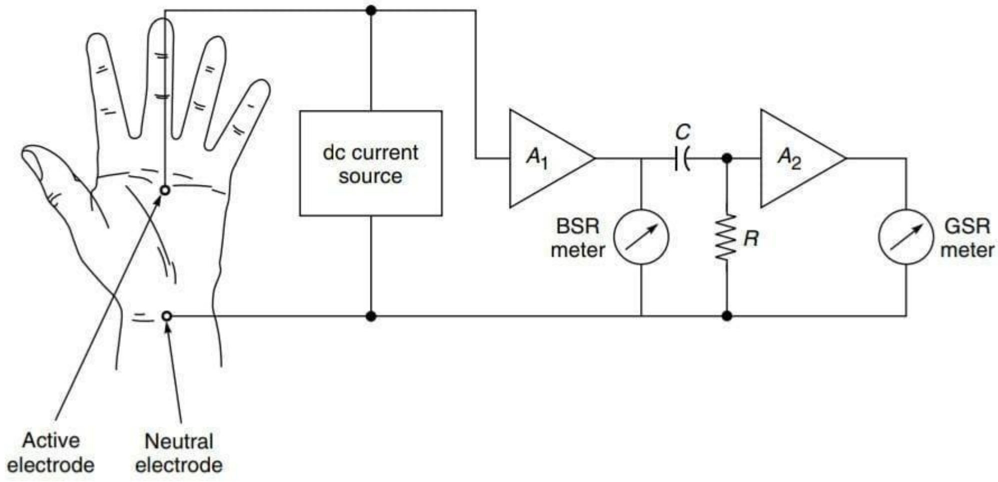
- Electromyograph is an instrument used for recording the electrical activity of the muscles to determine whether the muscle is contracting or not; or for displaying on the CRO and loudspeaker the action potentials spontaneously present in a muscle or those induced by voluntary contrac- tions as a means of detecting the nature and location of motor unit lesions; or for recording the electrical activity evoked in a muscle by the stimulation of its nerve.
- The instrument is useful for making a study of several aspects of neuromuscular function, neuromuscular condition, extent of nerve lesion, reflex responses, etc.
- EMG measurements are also important for the myoelectric control of prosthetic devices (artificial limbs).
- This use involves picking up EMG signals from the muscles at the terminated nerve endings of the remaining limb and using the signals to activate a mechanical arm.
- This is the most demanding requirement from an EMG since on it depends the working of the prosthetic device.
- EMG is usually recorded by using surface electrodes or more often by using needle electrodes, which are inserted directly into the muscle.
- The surface electrodes may be disposable, adhesive types or the ones which can be used repeatedly. A ground electrode is necessary for providing a common reference for measurement. These electrodes pick up the potentials produced by the contracting

muscle fibres. The signal can then be amplified and displayed on the screen of a cathode ray tube. It is also applied to an audio- amplifier connected to a loudspeaker.

- A trained EMG interpreter can diagnose various muscular disorders by listening to the sounds produced when the muscle potentials are fed to the loud- speaker. The block diagram shows a typical set-up for EMG recordings.
- The oscillo- scope displays EMG waveforms. The tape recorder is included in the system to facilitate playback and study of the EMG sound waveforms at a later convenient time. The waveform can also be photographed from the CRT screen by using a synchronized camera.



- Electrodermal activity is measured in two ways: BSR (basal skin response) and GSR (galvanic skin response) is a measure of the average activity of the sweat glands and is a measure of the phasic activity (the high and low points) of these glands.
- BSR gives the baseline value of the skin resistance where as GSR is due to the activity of the sweat glands. The GSR is measured most conveniently at the palms of the hand, where the body has the highest concentration of sweat glands. The measurement is made using a dc current source.
- Silver-silver electrodes are used to measure and record the BSR and GSR. The figure shows the arrangement for measuring these parameters. The BSR output is connected to an RC network with a time constant of 3 to 5 seconds which enables the measurement of GSR as a change of the skin resistance.

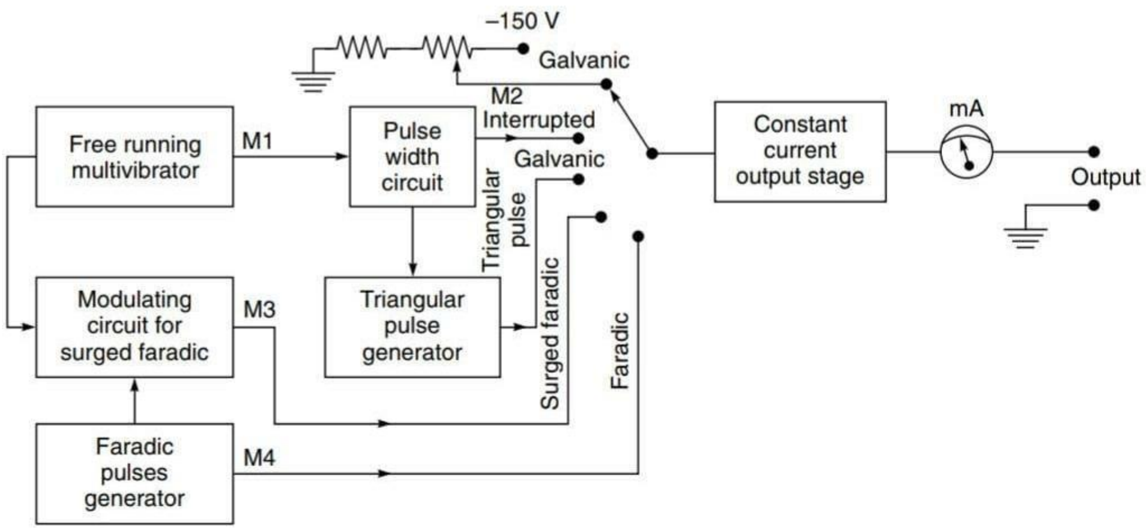


- Biofeedback instrumentation for the measurement of EMG, temperature and pulse/heart rate is not different from other instruments used for the measurement of physiological variables. Transducers and amplifiers are employed to measure the variable that is to be controlled by the feedback process.
- The magnitude of the measured variable or changes in the magnitude are converted into a suitable visual or auditory stimulus that is presented to the subject. Based on the stimulus, the subject learns to control the abnormal conditions.
- Reports have appeared in literature regarding applications of biofeedback to control migraine headaches, to slow down heart rate, etc. Biofeedback techniques have been greatly refined and computerized biofeedback training and psychological computer-assisted guidance programs in the privacy of one's home are now a reality.

13. Draw the functional block diagram of a diagnostic/therapeutic stimulating unit and explain the functioning.(September2020)

- A versatile electro-diagnostic therapeutic stimulator. It makes use of a variable rate multi-vibrator (M1) to set the basic stimulus frequency. The output from the free running multi-vibrator triggers a monostable multi-vibrator (M2) circuit which sets the pulse width.
- The output pulse from the monostable provides an interrupted galvanic output whose rate as well as duration can be independently controlled. Another astable multi-vibrator produces short duration pulses called faradic currents.

- Faradic currents are usually modulated at the frequency set by the multi-vibrator Ml, in a mixer circuit (M4). Since the modulation of Faradic pulses takes place with a slow rate of increase and decrease, the output of M4 is surged Faradic currents. By integrating the output of M2, the interrupted galvanic pulses can be modified to have an exponential rise and fall.
- The shape of these pulses is similar to a triangular waveform. Galvanic current is also made available by suitably tapping the DC supply.
- Finally, any one of the waveforms can be selected through a selector switch and fed either to an emitter-follower stage in order to provide a low output impedance constant voltage output or to a high output impedance constant current stage.
- Usually the output impedance of a constant voltage stimulator is of the order of 100 W and that of a constant current type is greater than 100 kW.



- The two methods have been widely used for providing isolation of the stimulator output, but they have some drawbacks.
- The simple transformer cannot transmit square waves without distorting the waveform and the method of radio-frequency is rather complex.
- Isolation can also be provided through the opto-isolation technique.

BM T61 – DIAGNOSTIC AND THERAPEUTIC EQUIPMENTS

UNIT-1V

2 MARKS

1. What is nebulizer? (May 2017, May 2018)

- Nebulizers are used to supply moisture in the form of droplets. A jet of air or gases may be used to entrain water drawn from a reservoir. Nebulizers based on this principle are also used in some ventilators.

- In ultrasonic nebulizers, water is broken into droplets by continuous bombardment of ultrasound energy which vigorously vibrates the water.

2. What is meant by inhalator? (May 2018)

- An apparatus used to help inhale air, anesthetics, medicinal vapors, etc is called as inhalator.

- An apparatus designed to mix carbon dioxide and oxygen, especially for use in artificial respiration.

3. Define tidal and residual volume. (May 2017)

Tidal Volume (TV): The volume of gas inspired or expired (exchanged with each breath) during normal quiet breathing, is known as tidal volume.

Residual Volume (RV): The volume of gas remaining in the lungs after a forced expiration.

3. Define tidal and inspiratory reserve volume. (Nov 2017)

Tidal Volume (TV): The volume of gas inspired or expired (exchanged with each breath) during normal quiet breathing, is known as tidal volume.

Inspiratory Reserve Volume (IRV): The volume of gas, which can be inspired from a normal end- tidal volume. IRV = VC – (TV + FRC)

4. What is the function of Nebulizers? (Nov 2017)

- Nebulizers are used to supply moisture in the form of droplets.

- A jet of air or gases may be used to entrain water drawn from a reservoir.

5. What is a spirometer? (May 2016)

- The instrument used to measure lung capacity and volume is called a spirometer.
- Spirometers are calibrated containers that collect gas and make measurements of lung volume or capacity that can be expired.

6. Write a note on tidal volume. (May 2016, Nov 2018)

Tidal Volume (TV):

- The volume of gas inspired or expired (exchanged with each breath) during normal quiet breathing, is known as tidal volume.
- Tidal volume is the depth of breathing or the volume of gas inspired or expired during each respiratory cycle. It can be calculated by multiplying the flow rate setting by the set inspiratory time(seconds).

7. Define Plethysmography. (Nov 2016)

- Plethysmography measures changes in volume in different areas of your body. It measures these changes with blood pressure cuffs or other sensors.
- These are attached to a machine called a plethysmograph.It can help your doctor determine if you have a blood clot in your arm or leg.

8. Write the working principe of ventilators? (Nov 2016)

- A ventilator is a machine that provides mechanical ventilation by moving breathable air into and out of the lungs, to deliver breaths to a patient who is physically unable to breathe, or breathing insufficiently.
- Ventilators are computerized microprocessor-controlled machines, but patients can also be ventilated with a simple, hand-operated bag valve mask. Ventilators are sometimes called "respirators".

9. What is so called cessation of breathing? (May 2019)

- Apnea is called the cessation of breathing.

- During apnea, there is no movement of the muscles of inhalation, and the volume of the lungs initially remains unchanged.

10. Differentiate nebulizer and ventilator. (May 2019)

Nebulizer	Ventilator
Nebulizers are used to supply moisture in the form of droplets.	A ventilator is a machine that provides mechanical ventilation by moving breathable air into and out of the lungs, to deliver breaths to a patient who is physically unable to breathe, or breathing insufficiently.
A nebulizer is a device used to administer nebulized medications to a patient.	It is used to breathe for a patient who cannot breathe. It is sometimes referred to as life support.

11. What is lung compliance? (Nov 2018)

- Lung compliance is the ability of the alveoli and lung tissue to expand on inspiration. The lungs are passive, but they should stretch easily to ensure the sufficient intake of the air.
- In clinical practice it is separated into two different measurements, static compliance and dynamic compliance.
- Static lung compliance is the change in volume for any given applied pressure. Dynamic lung compliance is the compliance of the lung at any given time during actual movement of air.

12. What is the role of aspirator in respiration therapy? (Sept 2020)

Aspirators are often included as part of a ventilator to remove mucus and other fluids from the airways. Alternatively, a separate suction device may be utilized to achieve the same purpose.

13. Write down the working principle of Fleisch Pneumotachometer. (Sept 2020)

- Flow transducers generally used in respiratory studies are the Fleisch-type pneumotachometer. Airflow can be measured directly with a pneumotachometer and a transducer.

- A pneumotachometer converts the flow of gases through it into a proportional signal of pressure difference on either side of a central mesh whose design ensures a signal linearity over a range of flow rates with a minimum dead space.

11 MARKS

1.Explain the need of whole body plethysmograph with neat block diagram. (Nov 2017, May 2018)

- Plethysmography can measure volumes not available through spirometry, although it is not appropriate in all circumstances.Spirometry is the standard method for measuring many lung volumes; however, it is not capable of providing information about absolute volumes of air in the lung.

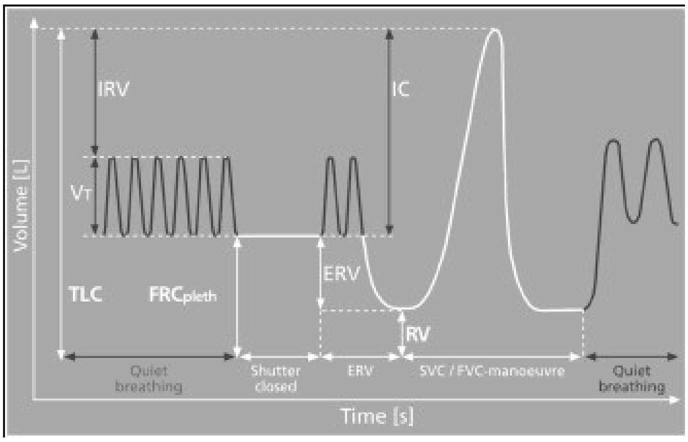
- A different approach is required to measure residual volume (RV), functional residual capacity (FRC), and total lung capacity (TLC). Two of the most common methods of obtaining information about these volumes are gas dilution tests and body plethysmography.

- Because they cannot be measured with simple spirometry, RV, FRC, and TLC, as well as airway resistance and airway conductance, are considered elusive lung volumes. TLC is the total volume of air in the chest after a maximal inspiration.

- FRC is the volume of air in the lungs at the end of a normal expiration, when the respiratory muscles are relaxed. Physiologically, it is an important lung volume because it approximates the normal tidal breathing range.

- Outward elastic-recoil forces of the chest wall tend to increase lung volume, but they are balanced by the inward elastic recoil of the lungs, which tends to reduce lung volume. These forces are normally equal and opposite at about 40% of TLC.

- Loss of lung elastic recoil in chronic obstructive pulmonary disease (COPD), for example, increases FRC. Conversely, the increased lung stiffness seen in pulmonary edema, interstitial fibrosis, and other restrictive lung disorders decreases FRC. The difference between total TLC and FRC is called inspiratory capacity.



- FRC has two components: residual volume (the volume of air remaining in the lungs at the end of a maximal expiration) and expiratory reserve volume. The RV normally accounts for about 25% of TLC. Normally, changes in the RV parallel those in the FRC.

- In restrictive lung disease and chest-wall disorders, however, RV decreases less than the FRC and TLC. In disease of the small airways, premature closure during expiration leads to air trapping, so the RV is elevated while the FRC and forced expiratory volume in 1 second remain close to normal.

- **The Plethysmography Procedure**
  During whole-body plethysmography, the subject is enclosed in a chamber equipped to measure pressure, flow, and volume changes.

- Secondary tests that can be performed during whole-body plethysmography include spirometry, bronchial challenge, diffusing capacity for carbon monoxide, single-breath nitrogen, multiple-breath nitrogen washout, pulmonary compliance, and occlusion pressure. Whole-body plethysmographs are usually found in pulmonary function laboratories, but they may also be used in cardiopulmonary laboratories, clinics, and pulmonology offices.

- During whole-body plethysmography, the patient sits or stands inside an airtight chamber and inhales or exhales to a particular volume (usually FRC); a shutter then drops across the breathing tube. The patient makes respiratory efforts against the closed shutter, causing chest volume to expand and decompressing the air in the lungs. The increase in chest volume slightly reduces the box's volume, thus slightly increasing the pressure in the box.

- **Selection Criteria**

  Indications for whole-body plethysmography include the diagnosis of restrictive lung disease, evaluation of obstructive lung disease, and measurement of lung volumes to distinguish between restrictive and obstructive processes.

- Patients should not be subjected to whole-body plethysmography if they are mentally confused, experience muscular incoordination, have conditions that prevent them from entering the plethysmograph cabinet or adequately performing the required maneuvers, are claustrophobic, or require continuous oxygen therapy that should not be discontinued, even temporarily.

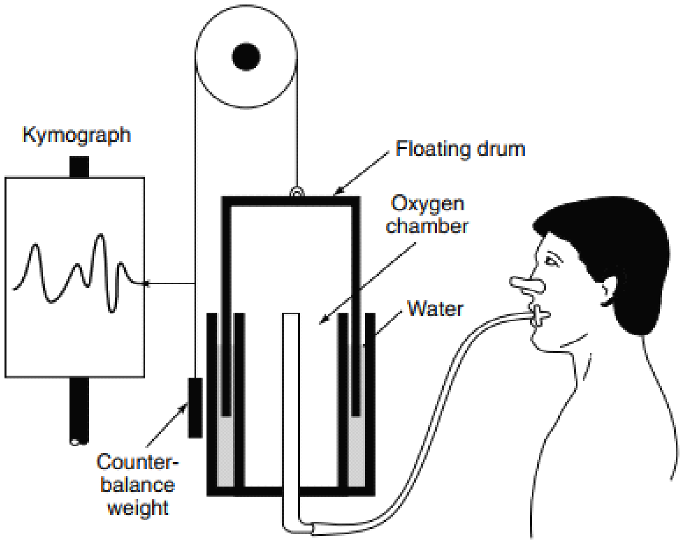
  In most cases, whole-body plethysmography is performed by the respiratory care technician. Providing attention to detail during the testing process and following the recommendations of the American Association for Respiratory Care (sidebar) will help to ensure the quality and validity of results.

2.Describe in detail about spirometer and describe the lung volume, tidal volume and residual volume of lung. (May 2017, May 2018, May 2019, Sept 2020)

- The instrument used to measure lung capacity and volume is called a spirometer. Basically, the record obtained from this device is called a spirogram. Spirometers are calibrated containers that collect gas and make measurements of lung volume or capacity that can be expired. By adding a time base, flow–dependent quantities can be measured. The addition of gas analyzers makes the spirometer a complete pulmonary function testing laboratory.

- Most of the respiratory measurements can be adequately carried out by the classic water-sealed spirometer. This consists of an upright, water filled cylinder containing an inverted counter weighted bell. Breathing into the bell changes the volume of gases trapped inside, and the change in volume is translated into vertical motion, which is recorded on the moving drum of a Kymograph. The excursion of the bell will be proportional to the tidal volume. For most purposes, the bell has a capacity of the order of 6–8.

- Also, the frequency response of a spirometer must be adequate for the measurement of the forced expiratory volume. The instrument should have no hysteresis, i.e. the same volume should be reached whether the spirometer is being filled or being emptied to that volume.

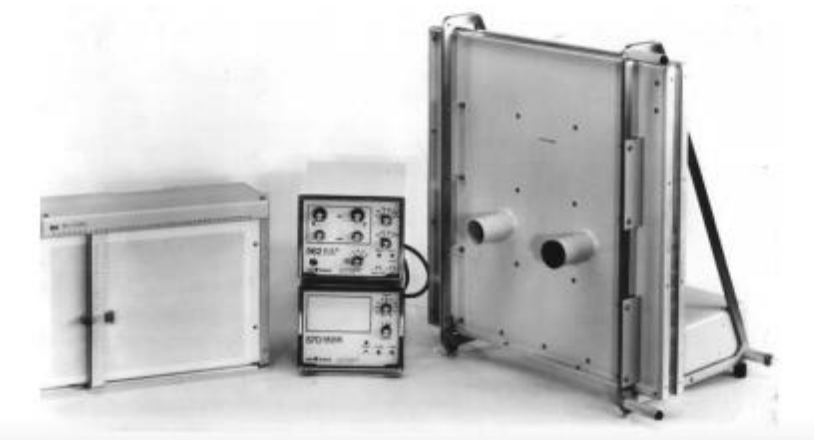


Basic water sealed spirometer

- As the water-sealed spirometer includes moving masses in the form of the bell and counter- weights, this leads to the usual problems of inertia and possible oscillation of the bell. This can lead to an over-estimation of the expiratory volume. This requirement applies not only to the spirometer, but also to the recorder used in conjunction with the recording device.

- The spirometer is a mechanical integrator, since the input is air flow and the output is volume displacement. An electrical signal proportional to volume displacement can be obtained by using a linear potentiometer connected to the pulley portion of the spirometer.

- The spirometer is a heavily damped device so that small changes in inspired and expired air volumes are not recorded. The spirometers can be fitted with a linear motion potentiometer, which directly converts spirometer volume changes into an electrical signal. A wedge spirometer consists of two square pans, parallel to each other and hinged along one edge. The first pan is permanently attached to the wedge casting stand and contains a pair of 5 cm inlet tubes.



Wedge spirometer

- As gas enters or leaves the wedge, the moving pan will change position in compensation for this change in volume. The construction of the wedge is such that the moving pan will respond to very slight changes in volume. Under normal conditions, the pressure gradient that exists between the wedge and the atmosphere amounts to only a fraction of a millimetre of water.

- Volume and flow signals for the wedge are obtained independently from two linear transducers. The transducers are attached to the fixed frame and are coupled to the edge of the moving pan. One transducer produces a dc signal proportional to displacement (volume), while the other has a dc output proportional to velocity (flow).

- The transducer outputs are connected to an electronics unit, which contains the power supply, an amplifier, and the built-in calibration networks.

- A pointer attached to the moving pan and a scale affixed to the frame, combine to provide a mechanical read out for determining the approximate volume position of the spirometer. When open to the atmosphere and standing upright, the wedge will empty itself due to the force of gravity acting on the moving member.

- Ultrasonic spirometers depend, for their action on transmitting ultrasound between a pair of transducers and measuring changes in transit time caused by the velocity of the intervening fluid medium. They employ piezo-electric transducers and are operated at their characteristic resonant frequency for their highest efficiency.

3.Write notes on a) Humidifiers b)Apnea Monitors.(May 2017)

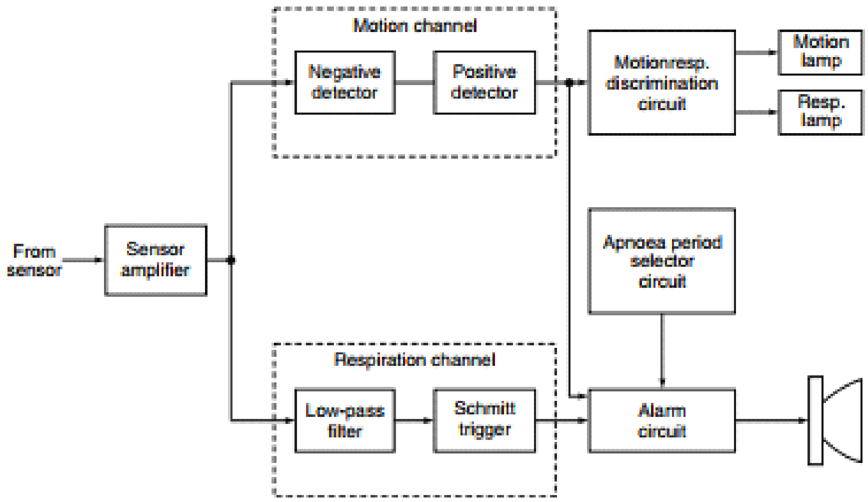
HUMIDIFIERS:

- The main task of a humidifier is to replace humidity in the upper air passages which has been lost by intubation. The humidity should be as close to 100% as possible, or speaking in terms of water, the absolute content per litre breathing gas should be more than 30 mg, regardless of environmental conditions. Therefore, in order to prevent damage to the patient’s lungs, the air or oxygen applied during respiratory therapy must be humidified.
- Thus, all ventilators include arrangements to humidify the air, either by heat vapourization (stream) or by bubbling an air stream through a jar of water.Dry gases supplied by the anaesthesia machine may cause clinically significant desiccation of mucus. This may contribute to retention of secretion and the mucus flow may cease. Lung compliance will consequently fall.
- Therefore, air or anaesthetic gases need to be humidified. Absolute Humidity: This is the maximum mass of water vapour which can be carried by a given volume of air (mg/L). This quantity is pre-dominantly determined by temperature. Warm air can carry much more moisture.
- Relative Humidity (RH): This is the percentage of the amount of humidity present in a sample, as compared to the absolute humidity possible at the sample temperature.

- It is ideal to provide gases at body temperature and 100% RH to the patient's airway. The humidification measures that are commonly employed include heated airway humidifiers, nebulizers and heat and moisture exchangers.
- In the heated humidifiers, the air passes over the surface of the heated water and vapourization takes place. The temperature of the water is thermostatically controlled.Handbook of Biomedical Instrumentation.

APNEA MONITOR :

- Apnea monitors detect the cessation of breathing (apnea) in infants and adults who are at risk of respiratory failure and alert the parent or attendant to the condition.



- The Greek word "apnea" literally means "without breath." There are three types of sleep apnea: obstructive, central, and mixed. Of the three, obstructive sleep apnea, often called OSA for short, is the most common.
- Apnea is the cessation of breathing which may precede the arrest of the heart and circulation in several clinical situations such as head injury, drug overdose, anaesthetic complications and obstructive respiratory diseases. Apnea may also occur in premature babies during the first weeks of life because of their immature nervous system. Apnea monitors are particularly useful for monitoring the respiratory activity of premature infants.

- Apnea monitors detect the cessation of breathing (apnea) in infants and adults who are at risk of respiratory failure and alert the parent or attendant to the condition.This information is passed to a micro computer system.A home apnea monitor is a machine used to monitor a baby's heart rate and breathing after coming home from the hospital. Apnea is breathing that slows down or stops from any cause.

4.What is pneumotachometer? Explain how it is used for measuring the lung volumes.(Nov 2017)

- Pneumotachometers are devices that measure the instantaneous rate of volume flow of respired gases. Basically, there are two types of pneumotachometers, which are:

(i) Differential manometer—It has a small resistance, which allows flow but causes a pressure drop. This change is measured by a differential pressure transducer, which outputs a signal proportional to the flow according to the Poiseuille law, assuming that the flow is laminar. The unit is heated to maintain it at 37°C to prevent condensation of water vapour from the expired breath.

(ii) Hot–wire anemometer—It uses a small heated element in the pathway of the gas flow. The current needed to maintain the element at a constant temperature is measured and it increases proportionally to the gas flow that cools the element.

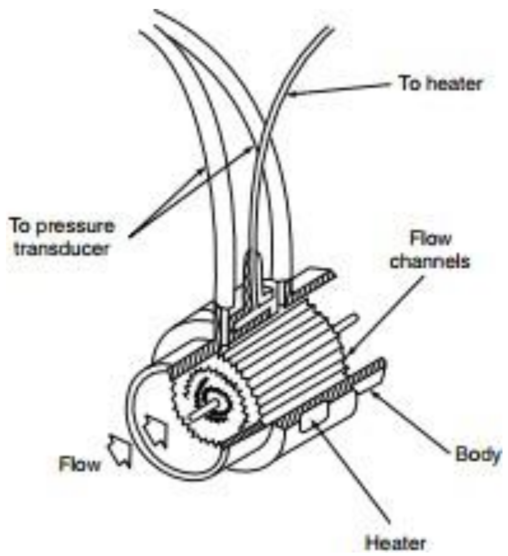
- Pneumotachometer is commonly used to measure parameters pertaining to pulmonary function such as forced expiratory volume (FEV), maximum mid-expiratory volume, peak flow and to generate flow-volume loops. Although these devices directly measure only volume flow, they can be employed to derive absolute volume changes of the lung (spirometry) by electronically integrating the flow signal.

Fleisch pneumotachometer:

- Flow transducers generally used in respiratory studies are the Fleisch-type pneumotachometers. These transducers are made by rolling a sheet of thin, corrugated metal with a plain strip of metal and inserting this core within a metal cover. Thus, these transducers are resistance elements consisting of small, parallel metal channels.

- This construction helps to maintain a laminar flow at much higher flow rates than would be possible for a gauze of similar area. In case of laminar flow, the pressure drop across the element is directly proportional to the flow rate of a gas passing through it.

- The output of the flow transducer appears as a differential pressure. To convert this pressure into an electrical signal, a second transducer is required. A capacitance type pressure transducer is used in such applications. They are more stable and less vibration-sensitive than resistive or inductive type transducers.



Venturi-type pneumatochometer:

- This type works similarly to the Fleisch pneumotachometer, but have a venturi-throat for the linear resistance element. The resulting pressure drop is proportional to the square of volume flow. They have open geometry and therefore are less prone to problems of liquid collection. Their main disadvantages are the non-linearity of calibration and the requirement for laminar flow.

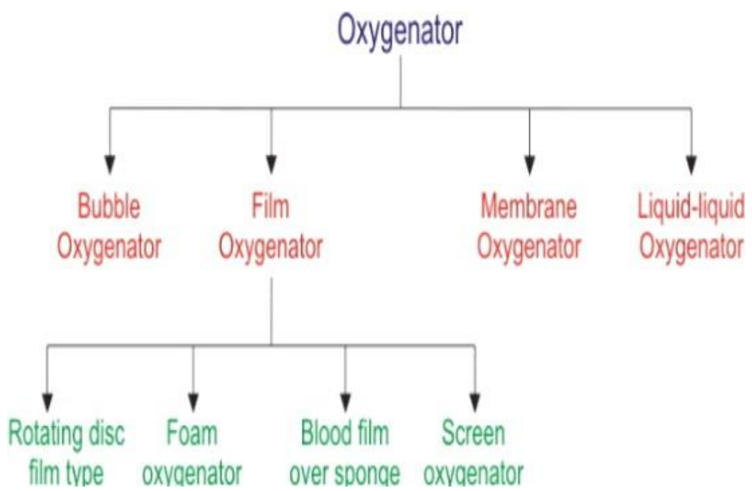
Turbine-type pneumatochometer:

- In this design, air flowing through the transducer rotates a very low mass (0.02 g) turbine blade mounted on jewel bearings. Rotation of the turbine blade interrupts the light beam of a light- emitting diode (LED). The interrupted light beam falls on a phototransistor, which produces a train of pulses, which are processed and accumulated to correspond to an accumulated volume in litres.

- A special feature of this transducer is a bias air flow, applied to the turbine blades from a pump. This flow keeps the blades in constant motion even without the sample flow through it.

5.Describe in detail about working principles of various types of oxygenators.(May 2016)

- An oxygenator is a medical device that is capable of exchanging oxygen and carbon dioxide in the blood of human patient during surgical procedures that may necessitate the interruption or cessation of blood flow in the body, a critical organ or great blood vessel.
- A heart-lung machine is connected to the heart by drainage tubes that divert blood from the venous system, directing it to an oxygenator. The oxygenator removes carbon dioxide and adds oxygen to the blood, which is then returned to the arterial system of the body.
- Oxygenators not only supply vital oxygen for the blood, but also transport carbon dioxide,anaesthetics and other gases into and out of the circulation.There are four types of oxygenators as shown below.

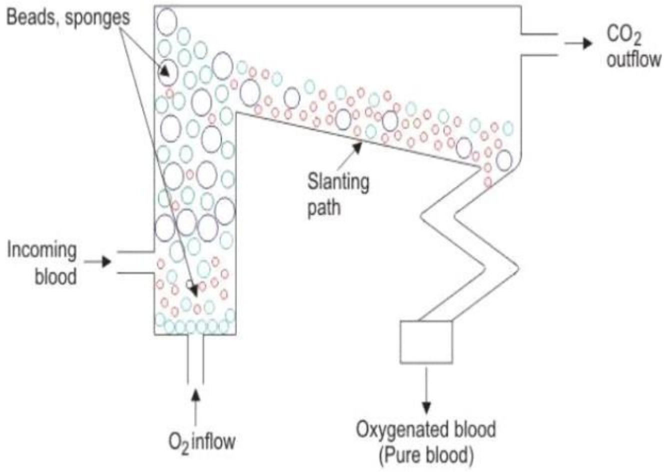


Types of oxygenators

BUBBLE OXYGENATORS: The venous blood is passed up a vertical column through which bubbles of oxygen are rising.Oxygen enters the blood and carbon dioxide is released.The gas exchange by directly infusing the gas into a column of systemic venous blood.

Oxygenating chambers: Bubbles produced by ventilating gas through diffusion plate into venous blood column.

Larger the number of bubbles; greater the efficiency of the oxygenators.Larger bubbles improve removal of CO_2,diffuses 25 times more rapidly in plasma than O_2.

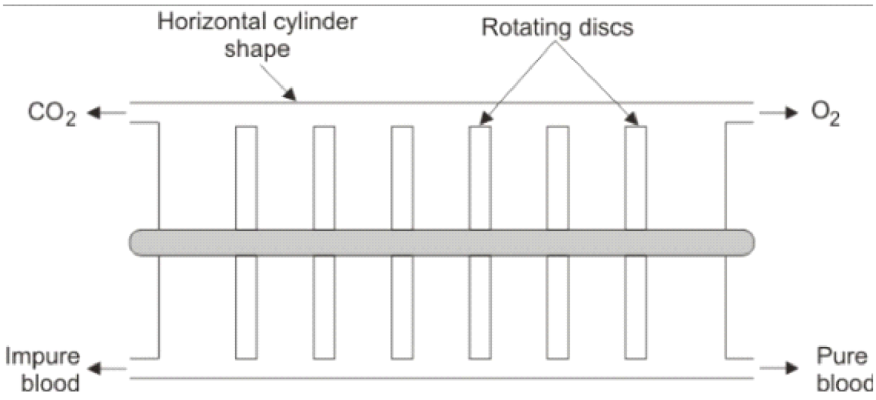


Bubble oxygenator

FILM OXYGENATOR:

Here the film of blood is spread on a rotating disc or metal screen and an oxygen mixture flows over this thin layer of blood.There are several types in this oxygenator.They are

- Foam oxygenator
- Screen oxygenator
- Blood film over sponge
- Rotating disc film oxygenator



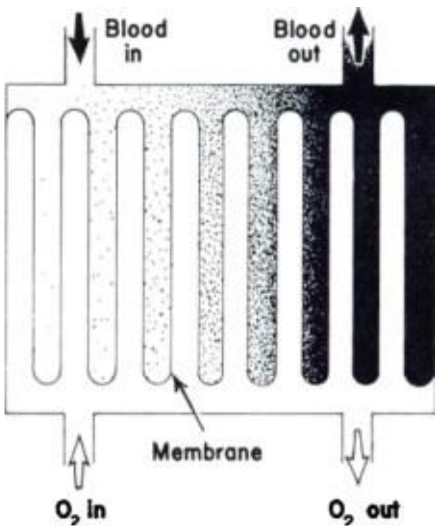
Film oxygenator

MEMBRANE OXYGENATOR:

- A membrane oxygenator is a device used to add oxygen to, and remove carbon dioxide from the blood. It can be used in two principal modes: to imitate the function of the lungs in cardiopulmonary bypass (CPB), and to oxygenate blood in longer term life support, termed extracorporeal membrane oxygenation (ECMO).

- A membrane oxygenator consists of a thin gas-permeable membrane separating the blood and gas flows in the CPB circuit; oxygen diffuses from the gas side into the blood, and carbon dioxide diffuses from the blood into the gas for disposal.

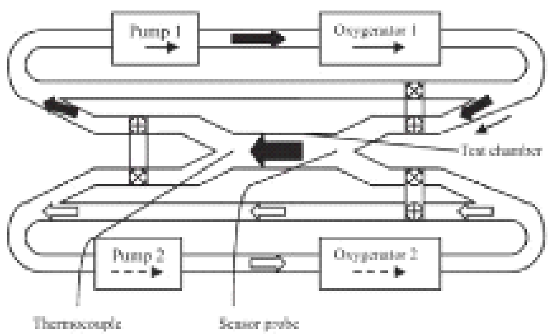
- Effective oxygenation is obtained when oxygen and blood are running in opposite directions through a thin porous membrane.The blood flows on one side of a membrane permeable to gas and oxygen flows on other side.The membrane is made of microporous polyethylene which has highest permeability for oxygen.



Membrane oxygenator

LIQUID-LIQUID OXYGENATOR:

The oxygen dissolved fluoridised organic fluid and blood flow are flowing in the opposite directions and oxygenation of blood takes place.



Liquid - Liquid Oxygenator

Fluoridised organic liquid is the working liquid which readily dissolves oxygen and carbon dioxide which then diffuse.Even though the blood is in direct contact with the working liquid, it is entirely different chemical compound.

6.Explain in detail about the pulse oximetry and any one method to measure respiratory volume. (May 2016)

- **Pulse oximetry** is a non invasive method for monitoring a person's oxygen saturation. Peripheral oxygen saturation (SpO_2) readings are typically within 2% accuracy (within 4% accuracy in the worst 5% of cases) of the more desirable (and invasive) reading of arterial oxygen saturation (SaO_2) from arterial blood gas analysis.[1] But the two are correlated well enough that the safe, convenient, noninvasive, inexpensive pulse oximetry method is valuable for measuring oxygen saturation in clinical use.
- In its most common (transmissive) application mode, a sensor device is placed on a thin part of the patient's body, usually a fingertip or earlobe, or in the case of an infant, across a foot. Fingertips and earlobes have higher blood flow rates than other tissues, which facilitates heat transfer.
- A pulse oximeter is a medical device that indirectly monitors the oxygen saturation of a patient's blood (as opposed to measuring oxygen saturation directly through a blood sample) and changes in blood volume in the skin, producing a photoplethysmogram that may be further processed into other measurements

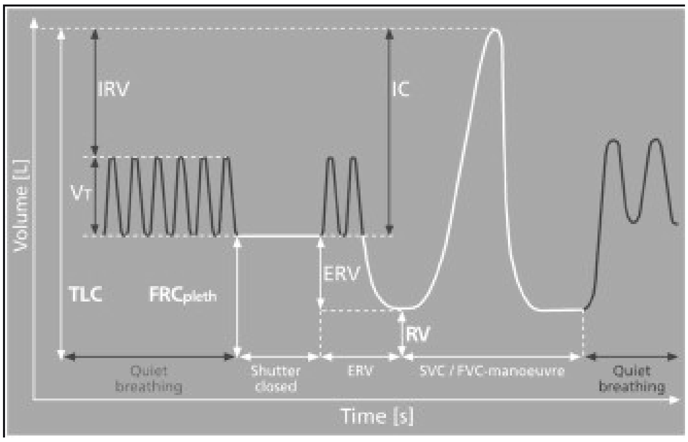
- . The pulse oximeter may be incorporated into a multiparameter patient monitor. Most monitors also display the pulse rate. Portable, battery-operated pulse oximeters are also available for transport or home blood-oxygen monitoring.

Method to measure respiratory volume:

- Plethysmography can measure volumes not available through spirometry, although it is not appropriate in all circumstances.Spirometry is the standard method for measuring many lung volumes; however, it is not capable of providing information about absolute volumes of air in the lung.

- A different approach is required to measure residual volume (RV), functional residual capacity (FRC), and total lung capacity (TLC). Two of the most common methods of obtaining information about these volumes are gas dilution tests and body plethysmography.

- Because they cannot be measured with simple spirometry, RV, FRC, and TLC, as well as airway resistance and airway conductance, are considered elusive lung volumes. TLC is the total volume of air in the chest after a maximal inspiration. FRC is the volume of air in the lungs at the end of a normal expiration, when the respiratory muscles are relaxed. Physiologically, it is an important lung volume because it approximates the normal tidal breathing range.



- Airway resistance can be measured directly using whole-body plethysmography, but is more commonly inferred from dynamic lung volumes and expiratory flow rates, which can be obtained more easily.

- **The Plethysmography Procedure**

  During whole-body plethysmography, the subject is enclosed in a chamber equipped to measure pressure, flow, and volume changes. Secondary tests that can be performed during whole-body plethysmography include spirometry, bronchial challenge, diffusing capacity for carbon monoxide, single-breath nitrogen, multiple-breath nitrogen washout, pulmonary compliance, and occlusion pressure. Whole-body plethysmographs are usually found in pulmonary function laboratories, but they may also be used in cardiopulmonary laboratories, clinics, and pulmonology offices.

- During whole-body plethysmography, the patient sits or stands inside an airtight chamber and inhales or exhales to a particular volume (usually FRC); a shutter then drops across the breathing tube. The patient makes respiratory efforts against the closed shutter, causing chest volume to expand and decompressing the air in the lungs. The increase in chest volume slightly reduces the box's volume, thus slightly increasing the pressure in the box.

- **Selection Criteria**

  Indications for whole-body plethysmography include the diagnosis of restrictive lung disease, evaluation of obstructive lung disease, and measurement of lung volumes to distinguish between restrictive and obstructive processes.

- Patients should not be subjected to whole-body plethysmography if they are mentally confused, experience muscular incoordination, have conditions that prevent them from entering the plethysmograph cabinet or adequately performing the required maneuvers, are claustrophobic, or require continuous oxygen therapy that should not be discontinued, even temporarily.

  In most cases, whole-body plethysmography is performed by the respiratory care technician. Providing attention to detail during the testing process and following the recommendations of the American Association for Respiratory Care (sidebar) will help to ensure the quality and validity of results.

7.Explain detail about intra-alveolar and thoracic pressure measurements.(May 2019)

Respiration is the process of gas exchange and occurs on two levels:

Internal Respiration: The use of oxygen by the mitochondria to produce ATP by oxidative phosphorylation with production of carbon dioxide as a waste product.

External Respiration : Exchange of oxygen and carbon dioxide between the atmosphere and body tissues.

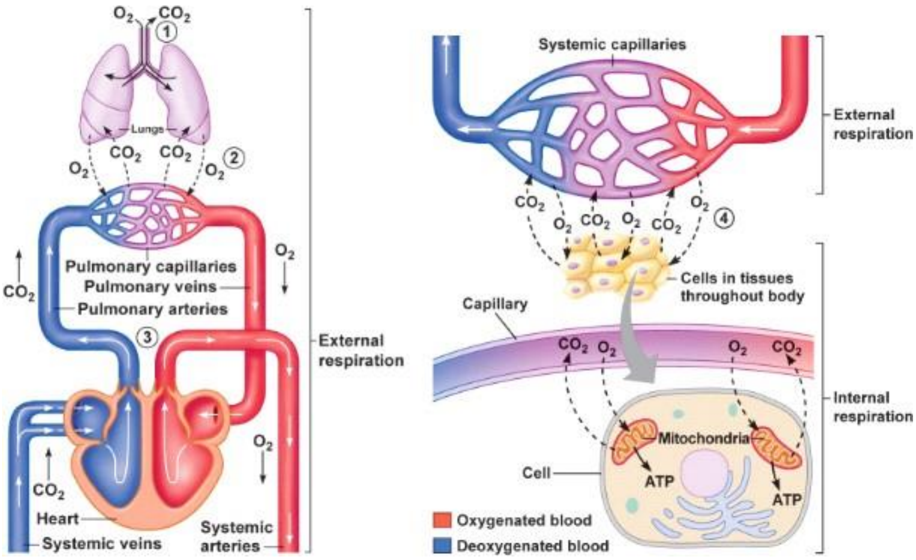
External Respiration Involves:

1. Pulmonary ventilation - movement of air in and out of the lungs.

2. Exchange of gases by diffusion between air and blood.

3. Transportation of gases by blood.

4. Exchange of gases by diffusion between blood and tissues.



Forces for Pulmonary Ventilation

Ventilation results from bulk flow of air as the result of pressure gradients created between alveoli and atmospheric pressure.

Pulmonary Pressures

There are four primary pressures associated with ventilation:

Atmospheric Pressure

The pressure of the outside air at sea level is 760 mm Hg. The remaining lung pressures are expressed relative to this pressure.

Intra-Alveolar Pressure

Varies with ventilation. During inspiration it is less than atmospheric pressure. During expiration it is greater than atmospheric pressure. At rest it is equal to atmospheric pressure. When it is equal to atmospheric pressure it is considered to be at 0 mm Hg.

Intrapleural Pressure

At rest it is - 4 mm Hg. It varies during ventilation but it is always less than intra-alveolar pressure and is always negative (that is, less than atmospheric pressure) during normal breathing. This negative pressure results from the elastic forces exerted on the intrapleural space by the chest wall and the lungs. Both the chest wall and lungs are elastic. The chest wall is compressed and the elastic forces are pulling it outward. The lung walls are stretched and the elastic forces are pulling them inward. Hence, the elastic forces are trying to open the intrapleural space. The tension resisting these elastic forces is the surface tension of the pleural fluid.

Transpulmonary Pressure

Transpulmonary pressure is the difference between the intrapleural pressure and the intra-alveolar pressure. This force operates across the walls of the lungs and causes the lungs to expand.

Mechanics of Breathing

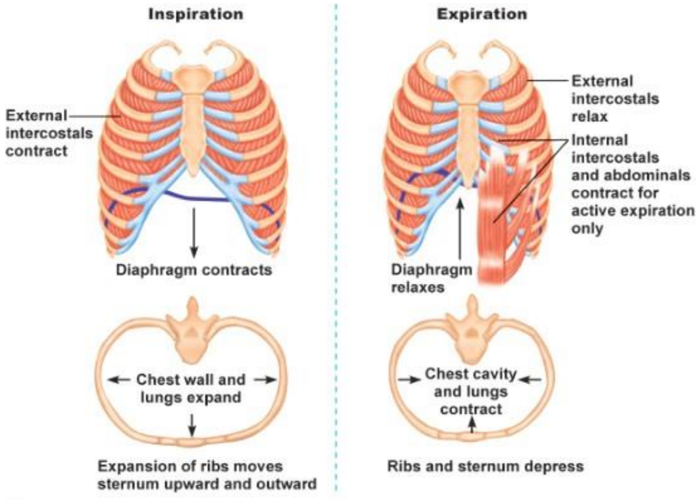
- Between breaths, when the lungs are at rest, the volume of air in the lungs is called the functional residual capacity (FRC). No air is moving into or out of the lungs during this time. Air flow results from the muscles of respiration creating pressure gradients by changing the volume of the lungs.
- The relationship between pressure and volume is expressed by Boyle's law. This law states that the pressure of gas in any container is inversely related to the volume of the container. In other words, when volume increases, pressure decreases and when volume decreases, pressure increases.
- Air flows into the lungs by bulk flow.

Determinants of Intra-alveolar Pressure

The changes in intra-alveolar pressure creates the pressure gradient that causes air to flow into and out of the lungs. Two factors determine intra-alveolar pressure:

1. the quantity (moles) of air molecules in the alveoli;

2. the volume of the alveoli



Inspiration

- The expansion of the thoracic cavity during respiration causes intrapleural pressure to decrease. This increases the transpulmonary pressure that is due to the difference between the intra-alveolar pressure and the intrapleural pressure.
- This increase in transpulmonary pressure causes the lungs to expand. The increase in the volume of the alveoli that accompanies this expansion decreases intra-alveolar pressure.

Expiration

- During normal breathing expiration is a passive process in which the muscles of inspiration relax and the elastic properties of the chest wall and lungs cause lung volume to decrease. This decrease in lung volume causes an increase in intra-alveolar pressure and creates the pressure gradient that causes an outflow of air.
- A more forceful expiration results from contraction of the muscles of expiration in a process called active expiration.

8.How is respiration rate measured? Explain. (Nov 2016)

- The primary functions of the respiratory system are to supply oxygen and remove carbon dioxide from the tissues. The action of breathing is controlled by a muscular action causing the volume of the lung to increase and decrease to effect a precise and sensitive control of the tension of carbon dioxide in the arterial blood.

- Under normal circumstances, this is rhythmic action with the result that the respiration rate provides a fairly good idea about the relative respiratory activity. Several techniques have been developed for the measurement of the respiration rate. The choice of a particular method depends mostly upon the ease of application of the transducer and their acceptance by the subject under test. Some of the commonly used methods for the measurement of respiration rate are explained below.

- The respiratory cycle is accompanied by changes in the thoracic volume. These changes can be sensed by means of a displacement transducer incorporating a strain gauge or a variable resistance element.

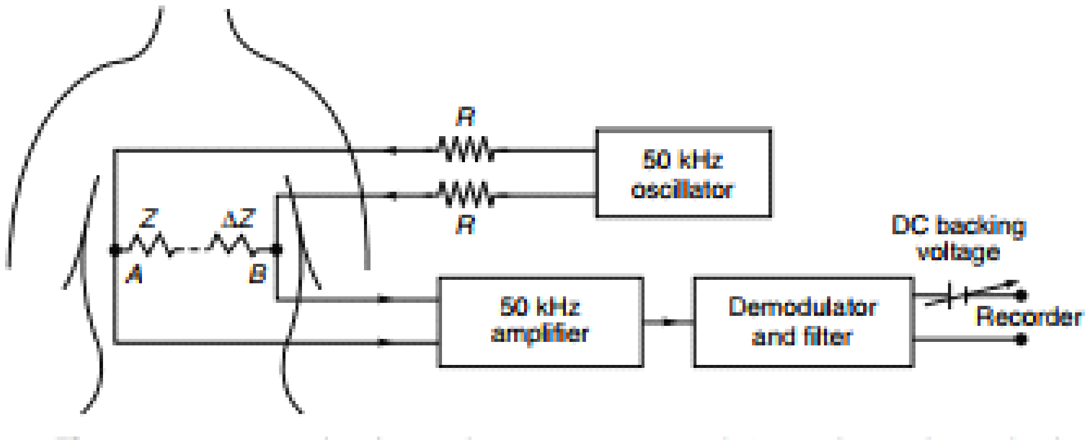
- The transducer is held by an elastic band, which goes around the chest. The respiratory movements result in resistance changes of the strain gauge element connected as one arm of a Wheatstone bridge circuit. Bridge output varies with chest expansion and yields signals corresponding to respiratory activity.

- Since air is warmed during its passage through the lungs and the respiratory tract, there is a detectable difference of temperature between inspired and expired air. This difference of temperature can be best sensed by using a thermistor placed in front of the nostrils by means of a suitable holding device.

- In case the difference in temperature of the outside air and that of the expired air is small, the thermistor can even be initially heated to an appropriate temperature and the variation of its resistance in synchronism with the respiration rate, as a result of the cooling effect of the air stream, can be detected. This can be achieved with thermistor dissipations of about 5 to 25 mW.

- Excessive thermistor heating may cause discomfort to the subject. The thermistor is placed as part of a voltage dividing circuit or in a bridge circuit whose unbalance signal can be amplified to obtain the respiratory activity. The method is simple and works well except in the case of some patients who object to having anything attached to their nose or face. This method is found to satisfy the majority of clinical needs including for operative and post-operative subjects.

- This is an indirect technique for the measurement of respiration rate. Using externally applied electrodes on the thorax, the impedance pneumograph measures rate through the relationship between respiratory depth and thoracic impedance change.



- To avoid the stimulation of sensory receptors, nerves and muscle, currents higher in frequency than 5 kHz must be used for the measurement of physiological events by impedance. Frequencies lower than 5 kHz are particularly hazardous since ventricular fibrillation may be produced with substantial current flow.

- The use of higher frequencies not only provides the protection sought in the avoidance of tissue stimulation, but also provides the safe use of currents of magnitude, which could be lethal if the frequencies were lower.

- Electrical impedance changes associated with physiological activity have been studied exten- sively. Some of the physiological quantities which have been measured and recorded by the impedance method include respiration, blood flow, stroke volume, autonomic nervous system activity, muscle contraction, eye movement, endocrine activity and activity of the brain cells.

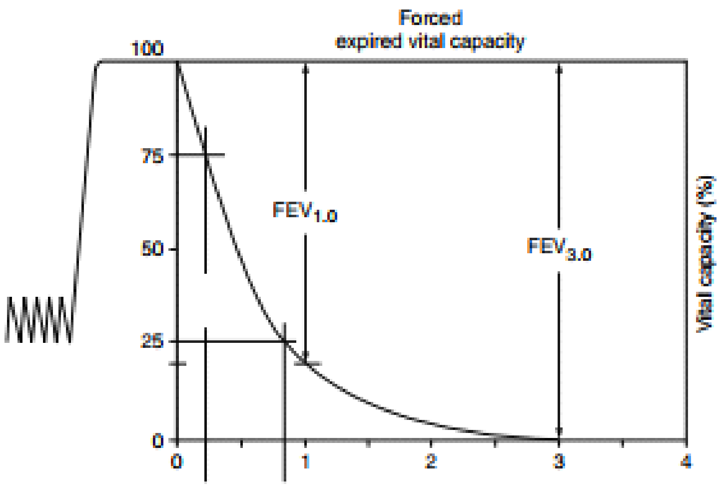
- Respiration rate can also be derived by continuously monitoring the CO2 contained in the subject's alveolar air. Measurement of CO2 in expired air is otherwise useful in several ways; for example, for originally setting up the respirator and in making adjustments to it afterwards, supervising patients suffering from respiratory paralysis, and other cases where there is respiratory involve- ment.

- The measurement is based on the absorption property of infrared rays by certain gases. Suitable filters are required to determine the concentration of specific gases (like CO2, CO, and NO2) constituting the expired air. Rare gases and diatomic gases do not absorb infrared rays.

9.Explain the dynamic mechanics during small volume changes and flow in lungs.

(Nov 2016)

- A number of forced breathing tests are carried out to assess the muscle power associated with breathing and the resistance of the airway. Among these are:
- Forced Vital Capacity (FVC): This is the total amount of air that can be forcibly expired as quickly as possible after taking the deepest possible breath.
- Forced Expiratory Volume (FEV): The percentage of the VC that can be forced out of the lungs in a given period with 'maximal exertion'. This is written as FEVT where T is usually in seconds. Maximum Mid-Expiratory Flow (MMEF or MMF) or Maximum Mid-Flow Rate (MMFR): The maximum rate of flow of air during the middle half of the FEV spirogram. One half VC is obtained from the volume indicated by the curve between 25 and 75% VC. Mid-Expiratory Time (MET): It is the time in seconds over which this volume is forcibly exhaled. The MMEF is calculated from MMEF.



- Normal values for each of these volumes and capacities have been calculated. They have been found to vary with sex, height and age. All pulmonary volumes and capacities are about 20 to 25 % less in females than in males.

- A particular pattern of abnormal lung volume may occur in a particular form of lung disease and such a pattern is useful confirmatory evidence of a diagnosis made on clinical grounds. Further, serial lung function testing is of use in demonstrating progressive deterioration in function or in confirming a satisfactory response to therapy. If the FEV1/FVC is greater than 85%, a so called 'restrictive' defect may be present. This is seen in cases of diffuse pulmonary fibrosis.
- Pulmonary function tests are performed for the assessment of the lung's ability to act as a mechanical pump for air and the ability of the air to flow with minimum impedance through the conducting airways. These tests are classified into two groups: single-breath tests and multiple- breath tests.

There are three types of tests under the single-breathcategory. These are

- Tests that measure expired volume only.
- Tests that measure expired volume in a unit time.
- Tests that measure expired volume/time.

A resting person inspires about 0.5 litre of air with each breath, with the normal breathing rate of 12 to 20 breaths per minute. With exercise, the volume may increase 8 to 10 times and the breathing rate may reach 40 to 45 breaths per minute. A respiratory disease may be suspected if these volumes, capacities or rates are not in the normal range.

10. What are the various lung volumes and capacities that aids in the analysis of pulmonary function of an individual. Discuss about it.(Nov 2018)

Tidal Volume (TV): The volume of gas inspired or expired (exchanged with each breath) during normal quiet breathing, is known as tidal volume.

Minute Volume (MV): The volume of gas exchanged per minute during quiet breathing. It is equal to the tidal volume multiplied by the breathing rate.

Alveolar Ventilation (AV): The volume of fresh air entering the alveoli with each breath.

Alveolar Ventilation = (Breathing rate) * (Tidal volume – Dead space).

Inspiratory Reserve Volume (IRV): The volume of gas, which can be inspired from a normal end- tidal volume.

$$\mathbf{IRV = VC - (TV + FRC)}$$

Expiratory Reserve Volume (ERV): The volume of gas remaining after a normal expiration less the volume remaining after a forced expiration.

$$\mathbf{ERV = FRC - RV}$$

Residual Volume (RV): The volume of gas remaining in the lungs after a forced expiration.

Functional Residual Capacity (FRC): The volume of gas remaining in the lungs after normal expiration.

Total Lung Capacity (TLC): The volume of gas in the lungs at the point of maximal inspiration.

$$\mathbf{TLC = VC + RV}$$

Vital Capacity (VC): The greatest volume of gas that can be inspired by voluntary effort after maximum expiration, irrespective of time.

Inspiratory Capacity (IC): The maximum volume that can be inspired from the resting end expiratory position.

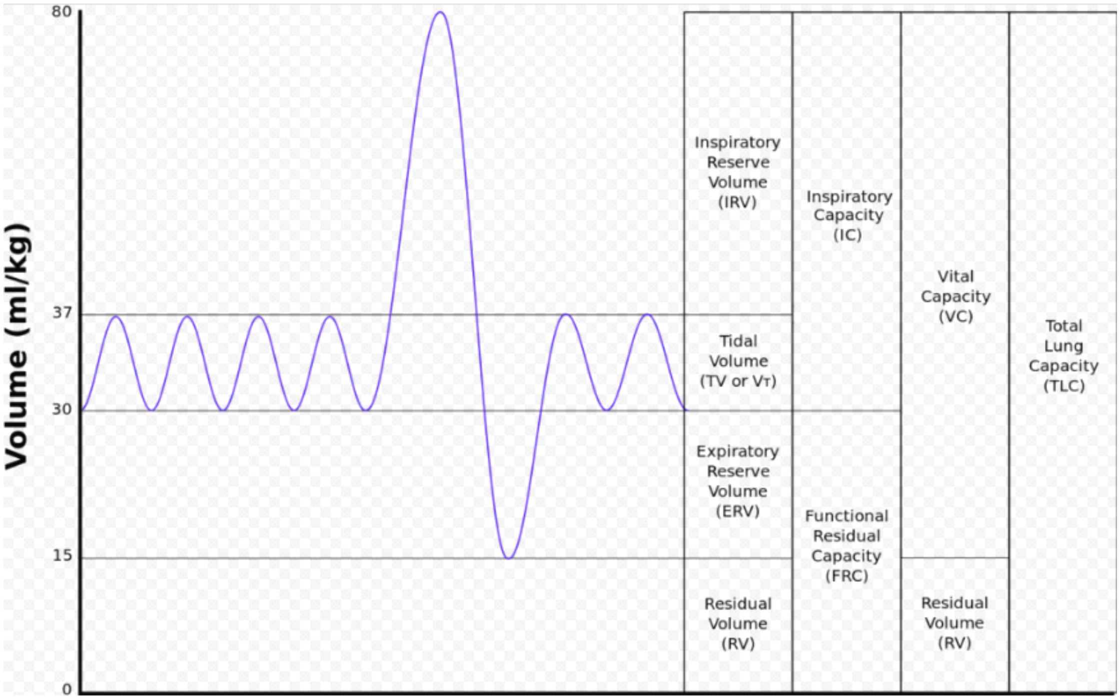
Dead Space: Dead Space is the functional volume of the lung that does not participate in gas exchange.**Compliance (C):** Change in volume resulting from unit change in pressure.

Lung Compliance : Change in lung volume resulting from unit change in transpulmonary pressure (PL)

Chest-Wall Compliance : Change in volume across the chest wall resulting from unit change in transchest-wall pressure.

Static Compliance : Compliance measured at point-of-zero airflow by interruption or breach- hold technique.

Elastance (E): Reciprocal of compliance. Units are cmH2O/litre.



Transpulonary Pressure: Pressure gradient developed across mouth (Pao) and pleural surface at lung (PPL).

Transalveolar Pressure: Pressure gradient developed between alveolar wall (PALV – PAL).
Transairway Pressure : Pressure gradient developed between alveoli and mouth.

Static Elastic Recoil Pressure : Pressure developed in elastic fibers of the lung by expansion.

A number of forced breathing tests are carried out to assess the muscle power associated with breathing and the resistance of the airway. Among these are:

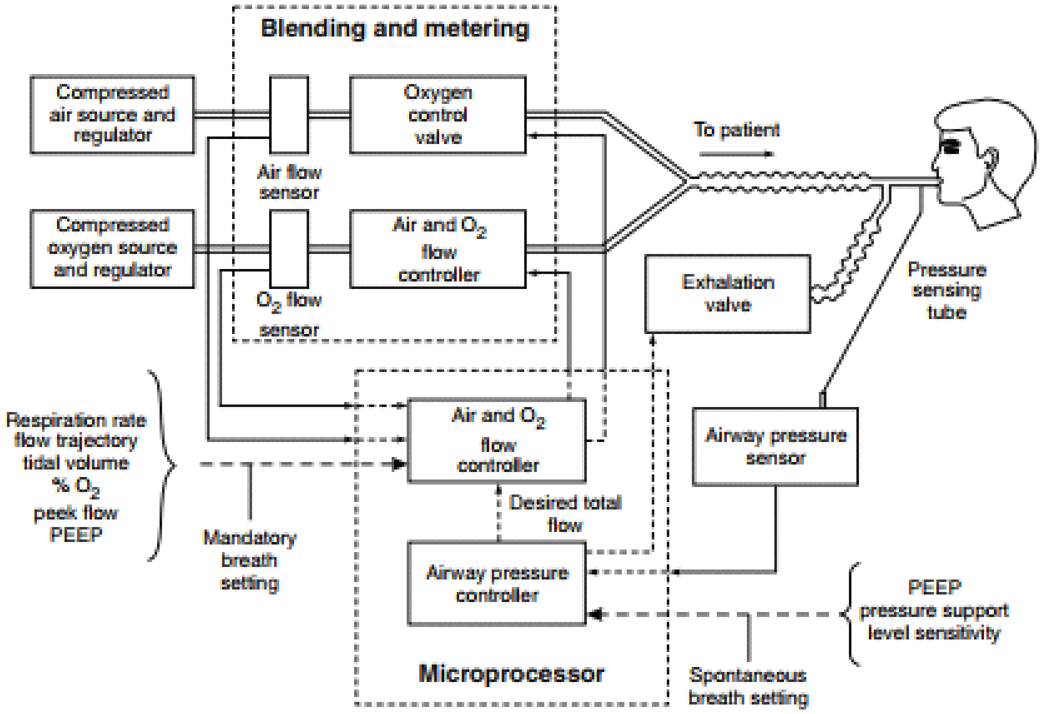
Forced Vital Capacity (FVC): This is the total amount of air that can be forcibly expired as quickly as possible after taking the deepest possible breath.

Forced Expiratory Volume (FEV): The percentage of the VC that can be forced out of the lungs in a given period with 'maximal exertion'. This is written as FEVT where T is usually in seconds. Maximum Mid-Expiratory Flow (MMEF or MMF) or Maximum Mid-Flow Rate (MMFR): The maximum rate of flow of air during the middle half of the FEV spirogram. One half VC is obtained from the volume indicated by the curve between 25 and 75% VC.

Mid-Expiratory Time (MET): It is the time in seconds over which this volume is forcibly exhaled. The MMEF is calculated from MMEF.

11. Explain the working of microprocessor controlled ventilator with block diagram. (Nov 2018, Sept 2020)

- The current and future trends in critical care ventilatory management demand precise flow, pressure and oxygen control for application to both adult and paediatric patients. In addition, patient monitoring and rapid, understandable alarms are extremely important for timely care of the patient. This has become possible by making use of computer technology in the ventilators to achieve a wide range of functions and controls.
- Modern ventilator machines consist of two separate but inter-connected systems: the pneumatic flow system and an electronic control system.
- These gases enter the air/oxygen mixer where they combine at the required percentage and reduced in pressure to 350 cm H2O. An electronically controlled flow valve proportions the gas flow from the reservoir tank to the patient breathing circuit. In some ventilators, an air compressor is used in place of a compressed air tank. The primary objective of the device is to ensure proper level of oxygen in the inspiratory air and deliver a tidal volume according to the clinical requirements.
- As the gasses leave the ventilator, they pass by an oxygen analyser, a safety ambient air inlet valve and a back-up mechanical over pressure valve. In the patient breathing circuit is a bi-directional flow sensor to measure the gas flows. The exhaled gasses exit through an electronically controlled exhalation valve located at pressure valve is used to provide safety in case the pressure in the patient circuit exceeds 110 cm of H2O.
- The electronic control system may use one or more microprocessors and software to perform monitoring and control functions in a ventilator. These parameters include setting of the respiration rate, flow waveform, tidal volume, oxygen concentration of the delivered breath, peak flow and PEEP.



Block diagram of microprocessor controlled ventilator

- The system consists of monitors for pressure flow and oxygen fraction. The sensors are connected to electronic processing circuits which makes them available for digital readouts. The signals are also compared with pre-set alarm levels so that if they fall outside a pre-determined normal range, alarms are sounded.

- The pressure sensors are normally of semiconductor strain gauge type placed in a bridge configuration. For measurement of fraction of oxygen in the inspired air, a fuel cell type oxygen sensor is used. This sensor generates a current proportional to pO2.As this sensor is temperature- sensitive, compensation for its operating temperature is included in the circuit. Usually, a thermistor is used to carry out this function.

- The flow sensor usually consists of a variable orifice and by measuring the pressure drop across the variable orifice, the patient flows can be calculated.Ventilators are life saving equipment and therefore need regular maintenance and calibration which should be carried out as per the instructions of the manufacturers.

BM T61 – DIAGNOSTIC AND THERAPEUTIC EQUIPMENTS

UNIT-5

2 MARKS

1) What is lithotripsy? (April/ May 2016)

- Lithotripsy is a medical procedure involving the physical destruction of hardened masses like kidney stones, bezoars or gallstones. The term is derived from the Greek words meaning "breaking stones".
- The two types of lithotripsy are extracorporeal shock wave lithotripsy (ESWL) and Laser Lithotripsy.

2) List out the applications of Laproscopy. (April/ May 2016)

- The diagnosis and treatment of endometriosis, chronic pelvic pain, pelvic inflammatory diseases, and causes of infertility
- The removal of fibroids, uterus, ovarian systs, lymph nodes, or an ectopic pregnancy
- The treatment of a range of disorders, including urinary incontinence, pelvic organ prolapse, and certain forms of cancer.
- Evaluating certain cancers, including those of the ovary, uterus and cervix.

3) State the principle of bubble oxygenator. (Nov 2016)

- By bubbling the oxygen through a large column of blood and then making the flow of blood through a slanting path, the carbon di oxide is removed from the blood.

4) (a) List few ICU/ CCU equipments. (May 2017)

(b) List out the equipments inside the ICU and CCU. (April/ May 2018)

(c) What are the various equipments used in ICU? (May 2019)

(d) Name the equipment mainly used in post-operative ICU. (Nov 2016)

- Ventilator
- CPAP System
- BPAP System
- Patient System
- Infusion Pump
- Syringe Pump
- Blood Warmer
- Defibrillator
- Multi para monitor

5) What is thermography? (May 2017, Nov/ Dec 2018)

- Thermography is the process of recording true thermal images of the surfaces of objects under study. In medicine, thermography displays images representing the thermal radiation of skin areas.
- Taking into account possible local changes in skin emissivity, these images may generally be considered as maps of temperature.
- Such thermograms contain both qualitative and quantitative information relevant to the images itself and to temperatures.
- Thermography is an important diagnostic aid in many diseases especially in Breast Cancers and in rhematic diseases (or) joint diseases.

6) What is the need for heart-lung machine? (Nov/ Dec 2017)

- During open heart surgery for installation of a valve prosthesis or correction of a congenital mal formation, the heart cannot maintain the circulation.
- It is necessary to provide extra-corporeal circulation with a special machine called **heart lung machine.** Further this is also used to provide circulatory assistance to support a faulty heart.
- While doing open heart surgery, it is necessary to bypass the heart to enable the surgeon to work in a bloodless field under direct vision.
- The heart-lung machine replaces the functions of heart and lung thereby providing the rest of the body with a continuous supply of oxygenated blood while the heart is stopped.

7) Give the principle of cryogenic techniques. (Nov/ Dec 2017)

- **Cryogenics –** also known as low temperature technology – is becoming increasingly important in industrial applications.
- Fields of application include storing liquid hydrogen as fuel for fuel cell vehicles.
- High-field superconducting magnets are another application area. In this case, liquid helium cools magnetic coils.

8) List out the different types of oxygenators used in heart-lung machines. (Sep 2020)

- Bubble Oxygenators
- Film Oxygenators

  Divided into following 4 types

  - Rotating disc film type
  - Foam oxygenator
  - Blood film over sponge

- Screen oxygenator

- Liquid-Liquid Oxygenators
- Membrane Oxygenator

9) Difference between finger pump and roller pump. (April/ May 2018)

FINGER PUMP	ROLLER PUMP
Finger Pump push a series of rods against a flexible tubing in sequence, forcing fluid along the tube.	A Peristaltic pump, also commonly known as a **roller pump,** is a type of positive displacement pump used for pumping a variety of fluids.
Finger pump is often found in medical applications, pumping blood or other fluids.	The degree of trauma is considerably increased when high flow are needed – hence the **roller pump** is most often used in applications where flow rates are low, such as dialysis and apheresis.

10) Write the function of infusion pump. (Nov/ Dec 2018)

- In many medical applications, intra-venous (IV) fluids and drugs need to be infused over a period of time, which could be several minutes, hours and days.
- The most common method of doing this is by manual injection of bolus doses using syringes by manually setting the drip rate of gravity feed intra-venous infusion sets.
- The application of infusion delivery devices continues to grow, extending to patient–controlled analgesia, home therapy, chemotherapy, implantable drug pumps (such as insulin delivery pumps) etc.
- For meeting the exacting requirements of these applications in terms of flow rate of the fluids in a safe and effective manner, the pumps are becoming smaller and smarter.

11) Mention the types of detectors used in thermography. (Sep 2020)

- Infrared detectors are used to convert infrared energy into electrical signals.
- Basically, there are two types of detectors: thermal detectors and photo-detectors.
- Thermal detectors include thermocouples and thermistor bolometers.
- They feature constant sensitivity over a long wavelength region.

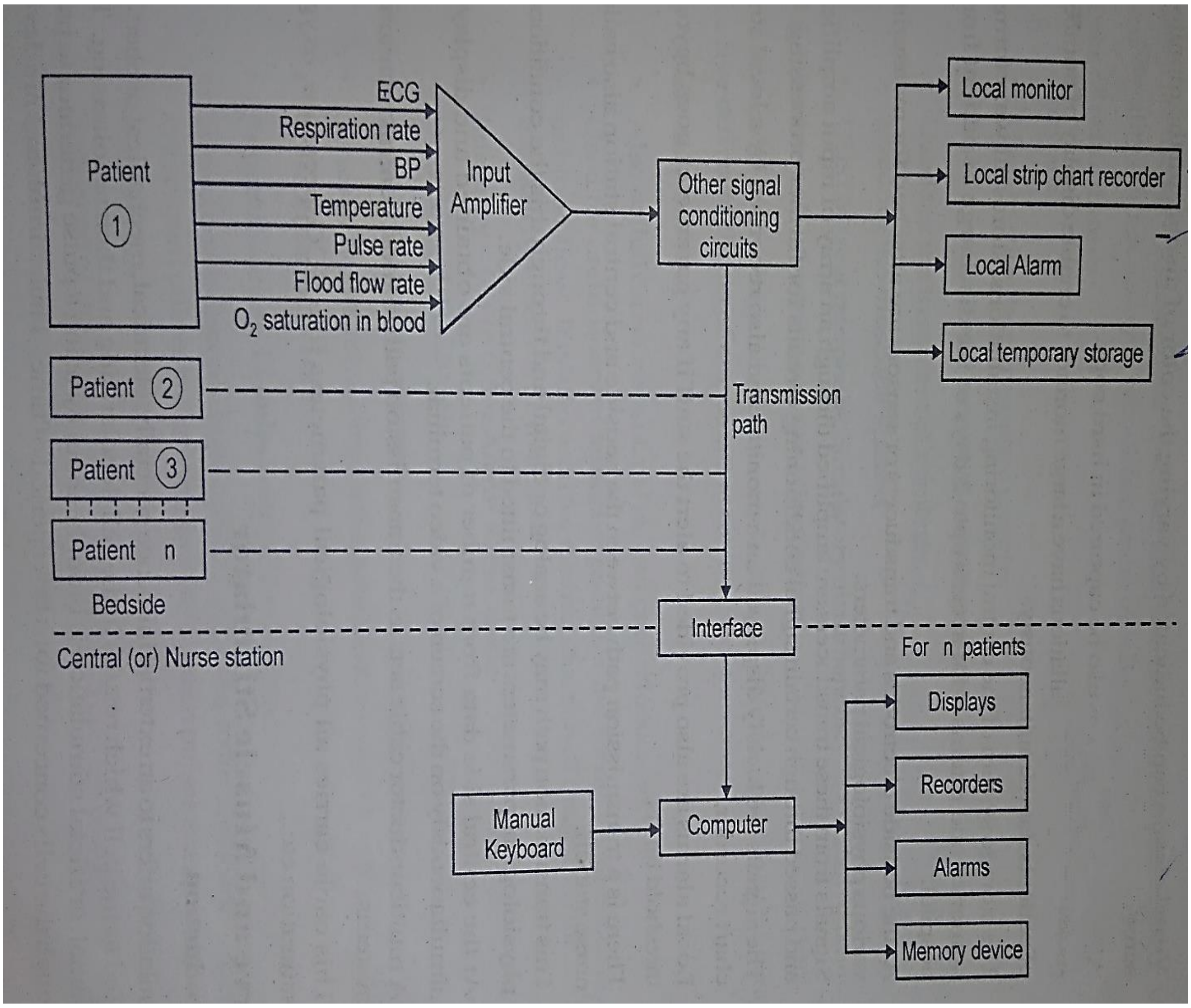
12) Why we go for lithotripsy and also mention the frequency of the wave used? (May 2019)

- Lithotripsy is a medical procedure involving the physical destruction of hardened masses like kidney stones, bezoars or gallstones.
- For optimal Shockwave Lithotripsy frequency range for treating urinary stones i.e., high frequency (100-120 waves/ minute), intermediate-frequency (80-90 waves/ minute), and low-frequency (60-70 waves/ minute) lithotripsy.
- In Laser Lithotripsy, in order to dust a stone it is indicated to use low energy (~5 Hz), high frequency (15-20 Hz), and long pulse (800 microseconds), with a total power of 7.5-10 W. Conversely, high energy (1.5-2 Hz), Low frequency (5 Hz), and short pulse (200 microseconds) are required for fragmentation.

11 MARKS

1) Write in detail about the working of digital central patient monitoring system. (April/ May 2016)

- The central monitoring system, the physiological values of patients are measured at bed side and these are displayed and recorded at a central station.
- The physiological parameters measured at the bedside include,
  - ECG
  - Respiration rate
  - Blood pressure
  - Temperature
  - Pulse rate
  - Oxygen saturation in blood, etc.,
- The electronics which aid for measurement and the signal condition are located at the bedside whereas the display, recorders, alarms, etc., are located at the central station.
- The central monitoring system is build up with many microprocessors which enable the smooth display of waveforms, alphanumerics and graphics on a single CRT.
- The central monitoring system provides all measured information at a glance. It generates audible and visual alarms if the value measured exceed their preset limit. It displays the patient’s vital sign data.



Block diagram of typical central monitoring system

- Trend plots of patient’s vital sign are also available which will guide for patients therapy. Trend plots may be long trend (9 hour to 24 hours) or short tuned 90 minutes.
- The information (physiological parameters) from patient’s bed side like blood pressures ECG, heart rate, respiration, entidal Carbon dioxide, and temperatures are transmitted as analog signals through cables.
- Status signals like alarm signals are also carried by the same cable. The incoming physiological values are sampled and digitized by 10-bit analog to digital converter.
- ECG waveforms are sampled every two milliseconds to maintain the 0-100 Hz. Temperature is sampled every four seconds
- The display has 2 sections,
    - Raster type display – for wave forms

- 300 x 260 picture element bit map – for alphanumerics

- The hard copy of the waveforms can also be obtained. Waveforms can also be temporarily stored for 24 hours. CMOS RAM is used.
- Alarms can be both audible and visual. Audible alarms can be distinguished by varying the pitch, volume, duration and sequencing of tones.
- Visual alarms can be indicated by varying the color of display on the monitor screen. Alarm condition can also be captured in hard copy.
- Central monitoring installations have a large monitor to enable display of number of patient's data simultaneously.
- The storage system of the central monitoring installations, stores all waveforms, numerics and retains it for access upto 3 days of the discharge of patient from hospital.
- All bedside electrodes and transducers or sensors are attached for measuring various physiological parameters.
- Signals from these transducers are amplified through an array of input amplifiers and passed through certain signal conducted circuits for further processing.
- Signals are locally displayed on the monitor and also recorded by a local strip chart recorder.
- Local alarms are also provided to alert the staff if any parameter goes beyond the threshold limits.
- There is a transmission path between the bedside and the central station also called nurse stations.
- This transmission path may be analog or digital and through this the conditioned physiological parameters are transmitted through the central side.
- At the central side the data from number of patients are obtained and displayed simultaneously on the screen of a video terminal.
- A multiconductor cable acts as a transmission path in most central monitoring systems. This cable carries all physiological parameters like ECG, pressure, oxygen saturation, etc.,

2) (a) Explain in detail about principles of cryogenic technique and add their applications. (April/ May 2016)

(b) Explain the principle of cryogenic and its application. (May 2019)

CRYOGENIC TECHNIQUES

Definition

- Cryogenics is the study of the production of very low temperature (below 123 K) and the behaviour of materials at those temperatures. Cryogenics uses the Kelvin scale of temperature.
- Liquefied gases such as liquid nitrogen and liquid helium are used in many cryogenic applications. Liquid nitrogen is the most commonly used element in cryogenic.
- Liquid helium is also commonly used and allows for the lowest attainable temperature to be reached.
- These liquids are held in special containers called Dewar flasks, which are generally about six feet in height and three feet in diameter.
- Scientists found that metals frozen to low temperature showed more resistance to wear and tear. This is known as cryogenic hardening.
- Cryogens like liquid nitrogen are further used especially for chilling and freezing applications.

Cryobiology

- The branch of biology involving the study of the effects of low temperatures on organisms (most often for the purpose of achieving cryopreservation).

Cryo-conservation of animal genetic resources

- The conservation of genetic material with the intention of conserving a breed.

Cryosurgery

- The branch of surgery applying cryogenic temperatures to destroy and kill tissue, e.g. cancer cells.

Production

- Cryogenic cooling of devices and material is usually achieved via the use of liquid nitrogen, liquid helium, or a mechanical cryocooler (which uses high-pressure helium lines).
- Gifford-McMahon cryocoolers, pulse tube cryocoolers and Stirling cryocoolers are in wide use with selection based on required base temperature and cooling capacity.
- The most recent development in cryogenics is the use of magnets as regenerators as well as refrigerators.
- These devices work on the principle known as the magnetocaloric effect.

Detectors

- There are various cryogenic detectors which are used to detect cryogenic particles.
- For cryogenic temperature measurement down to 30K, Pt100 sensors, a resistance temperature detector (RTD), are used. For temperatures lower than 30K it is necessary to use a silicon diode for accuracy.

Cryogenic fluids

Cryogenic fluids with their boiling point in kelvins

Fluid	Boiling point (K)
Helium-3	3.19
Helium-4	4.214
Hydrogen	20.27
Neon	27.09
Nitrogen	77.09
Air	78.8
Fluorine	85.24
Argon	87.24
Oxygen	90.18
Methane	111.7

MEDICAL APPLICATIONS

(i) Magnetic Resonance Imaging (MRI)

- MRI is used to scan the inner organs of human body by penetrating very intense magnetic field.
- The magnetic field is generated by super conducting coils with the help of liquid helium.
- It can reduce the temperature of the coil to around 4K. At this low temperature, very high resolution images can be obtained.
- Magnetic resonance imaging (MRI) is a complex application of NMR where the geometry of the resonances is deconvoluted and used to image objects by detecting the relaxation of protons that have been perturbed by a radio-frequency pulse in the strong magnetic field.
- This is mostly commonly used in health applications.

(ii) Nuclear magnetic resonance (NMR)

- It is one of the most common methods to determine the physical and chemical properties of atoms by detecting the radio frequency absorbed and subsequent relaxation of nuclei in a magnetic field.
- This is one of the most commonly used characterization techniques and has applications in numerous fields.
- Primarily, the strong magnetic fields are generated by supercooling electromagnets, although there are spectrometers that do not require cryogens.
- In traditional superconducting solenoids, liquid helium is used to cool the inner coils because it has a boiling point of around 4 K at ambient pressure.
- Cheap metallic superconductors can be used for the coil wiring.
- So-called high-temperature superconducting compounds can be made to super conduct with the use of liquid nitrogen, which boils at around 77 K.

(iii) Blood storage

- Certain rare blood groups are stored at low temperatures, such as −165 °C, at blood banks

3) (a) Reason out the need for a heart lung machine during open heart surgery and explain the principle of working? (Nov 2016)

(b) Explain the working of a heart lung machine. (May 2017)

(c) Describe in detail about need for heart lung machine. (April/ May 2018)

(d) What is the need for heart lung machine and also explain its function? (May 2019)

(e) Describe with the schematic diagram the working of heart lung machine used in cardiopulmonary bypass. (Nov/ Dec 2018)

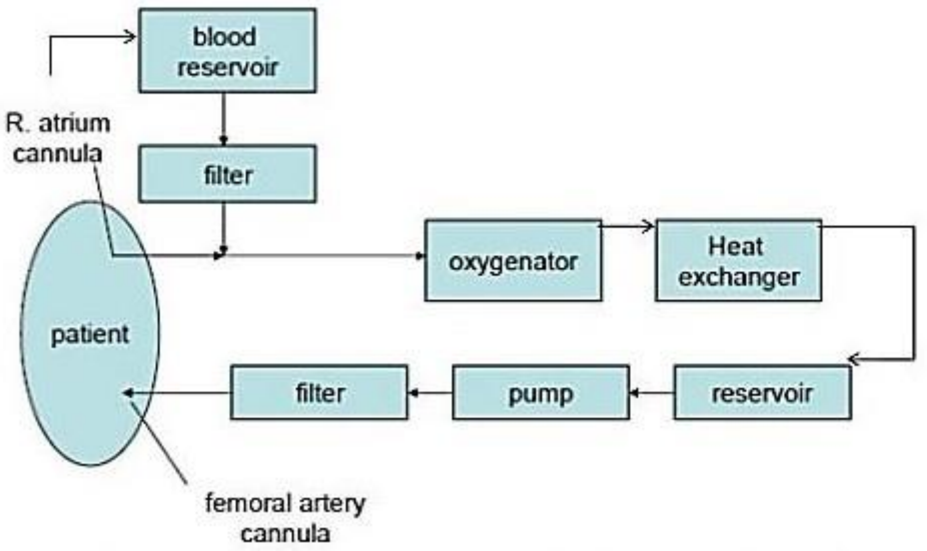
HEART-LUNG MACHINE

- During open heart surgery for installation of a valve prosthesis or correction of a congenital mal formation, the heart cannot maintain the circulation.
- It is necessary to provide extra-corporeal circulation with a special machine called **heart lung machine.** Further this is also used to provide circulatory assistance to support a faulty heart.
- While doing open heart surgery, it is necessary to bypass the heart to enable the surgeon to work in a bloodless field under direct vision.
- The heart-lung machine replaces the functions of heart and lung thereby providing the rest of the body with a continuous supply of oxygenated blood while the heart is stopped.
- In other words, the machine circulates the essential oxygen-rich blood to the brain and other vital organs during open-heart surgery, allowing the cardiac surgery team to operate on a heart that is blood-free and still.
- When the surgery is complete, the heart is restarted and the heart-lung machine is disconnected.

Function of heart-lung machine

- The heart-lung machine carries blood from the upper-right chamber of the heart (the right atrium) to a special reservoir called an oxygenator.
- Inside the oxygenator, oxygen bubbles up through the blood and enters the red blood cells.
- This causes the blood to turn from dark (oxygen-poor) to bright red (oxygen-rich)

Block Diagram of heart-lung machine



Block Diagram of Heart-Lung Machine

The main components of a heart-lung machine and their functions are briefly described below:

Roller-Pump

- The pump comfort frequently consists of numerous revolving motor pumps that peristaltically ‘massage’ tubing.
- Pumping action occurs because the rollers on the rotating arm comprises the tubings carrying the blood and forces the blood ahead of the compressed section.
- This action is called peristaltic action and this leads to a pulsatile flow of blood through the tubings. The heart-lung machine uses five pump heads normally.
- In some cases we use centrifugal pumps for the safeguarding and control of blood flow during the surgical procedure.
- By changing the RPM of pump head, blood flow is maintained. This kind of pumping action is measured to be better to the action of roller pumps because it produces less damage to the blood.

Oxygenator

- The oxygenator is planned to move oxygen to the infused blood and take away carbon dioxide from venous blood.

- So simply the oxygenator assembly allows to oxygenate the blood.
- Bubble oxygenators, membrane oxygenators and heparin coated blood oxygenators are the different types of oxygenators. Of them, heparin coated blood oxygenators are the commonly used one as they prevent blood coating.

Heat Exchanger

- Heat exchangers permit body and organ temperatures to be attuned. The uncomplicated heat exchange design is a container of water.
- As the blood transfers through the tubing positioned in the bath, the blood temperature will alter.
- A more complex system separated the blood and water interface with a metallic barrier. As the water temperature is changed, the blood temperature also changes, which in turn changes the tissue temperature.
- Once the tissue temperature reaches the desired level, the water temperature is maintained.
- Heat exchangers can be of two types namely plate type and coil type. In plate type of heat exchangers, two sheets of metals are used and they are coated with a non – thrombogenic substance.
- This configuration offers good efficient transfer of heat. Coil configuration consists of a hollow coil through which water circulates. The disadvantage of this type is it is a non-disposable unit and is very difficult to clean.

Temperature Controller

- During the time the patient uses a heart-lung machine, body temperature is to be maintained at a normal range.
- This unit allows the pump operator to keep the blood at a proper temperature.

Blood and Oxygen Dispersion Plates

- In a heart – lung machine, the gas bubbles are dispersed into the venous blood in the bubble column and acts as vehicles for both oxygen and carbon dioxide.
- Here oxygen diffuses from the bubble into the blood film surrounding the bubble. Various types of dispersion plates are used.

Reservoir

- A reservoir gather blood drained from the venous flow. Reservoir arranges include open or closed systems.
- The open system displays demarcations corresponding to blood volume in the container. The design is open to environment permitting blood to cross with environmental gases.
- The closed system contains a bag and it eliminates the air-blood interface. Volume is measured by weight or change in radius of the container.

Nylon Mesh Filters

- The nylon mesh filters used in heart-lung machines are attuned with a broad choice of solvents.
- They are particularly used for gathering of algae and cells, atom analysis, big particulate filtration, prefiltration of solvents and so on.

Cannulae

- Numerous cannulae are sewn into the suffering patient's body in a diversity of position depending on the kind of surgery.
- A venous cannula takes away the oxygen destitute blood from the patient's body and an arterial cannula is sewn into the suffering patient's body to impart oxygen rich blood.
- The cannula utilized to return oxygenated blood is frequently inserted in the rising aorta.

4) Why is Patient monitoring system necessary? (Nov 2016)

- The objective of patient monitoring is to have a quantitative assessment of the important physiological variables of the patients during critical periods of their biological functions.
- For diagnostic and research purposes, it is necessary to know their actual value or trend of change.
- Patient monitoring systems are used for measuring continuously or at regular intervals, automatically, the values of the patient's important physiological parameters.
- There are several categories of patients who may need continuous monitoring or intensive care.
- Critically ill patients recovering from surgery, heart attack or serious illness, are often placed in special units, generally known as intensive care units, where their vital signs can be watched constantly by the use of electronic instruments.

- The long-term objective of patient monitoring is generally to decrease mortality and morbidity by:
  a) Organizing and displaying information in a form meaningful for improved patient care,
  b) Correlating multiple parameters for clear demonstration of clinical problems,
  c) Processing the data to set alarms on the development of abnormal conditions,
  d) Providing information, based on automated data, regarding therapy
  e) Ensuring better care with fewer staff members.
- During a surgical operation, the patient is deprived of several natural reaction mechanisms, which normally restore abnormalities in his physical condition or alert other people.
- Indications or alarms that cannot be given by the patient himself can be presented by patient monitoring equipment.
- Besides this, in special cases, it is not uncommon for surgical procedures to last for several hours.
- During these lengthy operative procedures, it is difficult for the anaesthesiologist and the surgeon to maintain intimate contact with the patient’s vital signs and at the same time attend to anaesthesia, surgery, fluid therapy and many other details that are required under such circumstances.
- Also, when a patient is connected to a life-support apparatus, e.g. heart-lung machine or ventilator, correct functioning of these has to be monitored as well.
- A patient monitoring system thus better informs the surgeon and the anaesthesiologist of the patient’s condition.
- With patient monitoring systems, the risk that surgery involves has been considerably reduced since it is possible to detect the complications before they prove dangerous as suitable remedial measures can be taken well in time.
- The choice of proper parameters, which have a high information content, is an important issue in patient monitoring. It is, however, generally agreed that monitoring of the following biological functions is often needed.
- Electrocardiogram (ECG), heart rate (instantaneous or average), pulse rate, blood pressure (indirect arterial blood pressure, direct arterial blood pressure or venous blood pressure), body temperature and respiratory rate.

- In addition to these primary parameters, electroencephalogram (EEG), oxygen tension (pO2) and respiratory volume also become part of monitoring in special cases.
- In addition to these, equipment such as defibrillators and cardiac pacemakers are routinely needed in the intensive care wards.
- The general requirements for patient monitoring equipment have not changed much over the past few decades.
- However, today's equipment monitors more parameters and processes more information.
- Trends in monitoring include software control, arrhythmia monitoring, haemodynamics monitoring, monitoring during transportation of the patient and increased user friendliness.
- With more than 10 parameters to be monitored and scores of calculations to be made, the requirement for an easy-to-use user interface has assumed great significance.
- Monitoring is generally carried out at the bedside, central station and bedside with a central display.
- The choice amongst these is dependent upon medical requirements, available space and cost considerations.

4) How does a hemodialyser unit help in purification of blood? Explain with a block diagram. (May 2017)

Hemodialysis

- Hemodialysis, also spelled haemodialysis, or simply dialysis, is a process of purifying the blood of a person whose kidneys are not working normally.
- This type of dialysis achieves the extracorporeal removal of waste products such as creatinine and urea and free water from the blood when the kidneys are in a state of kidney failure.
- Hemodialysis is one of three renal replacement therapies (the other two being kidney transplant and peritoneal dialysis).
- An alternative method for extracorporeal separation of blood components such as plasma or cells is apheresis.

Medical uses

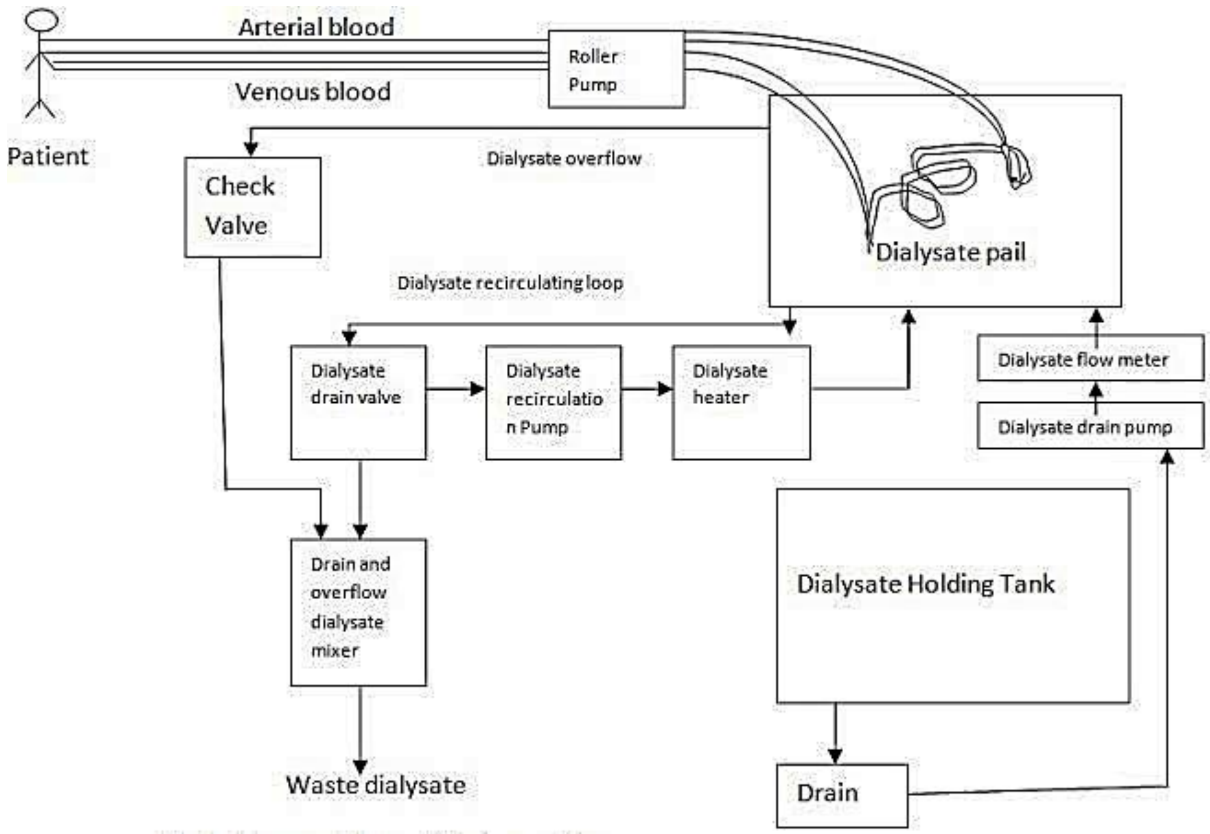
- Hemodialysis is the choice of renal replacement therapy for patients who need dialysis acutely, and for many patients as maintenance therapy. It provides excellent, rapid clearance of solutes.

Hemodialysis Machine Working

- The aim of hemodialysis machine is to replace the vital kidney functions. But in most cases this 'artificial kidney' cannot replace the vital kidney functions. But in most cases this 'artificial kidney' cannot replace the total kidney operation.
- The hemodialysis machine propels the patient's blood and dialysate through a dialyzer.
- The newest dialysis machines on the marketplace are extremely automated and constantly check different parameters including blood flow rate, dialysate flow rate, dialysis solution conductivity, blood pH, temperature etc.
- Any evaluation that is out of usual range, triggers an easy to hear alarm to aware the patient care technician. An extensive water filtration system is totally fundamental for hemodialysis machine.
- If the water utilized amid dialysis method not carefully filtered, mineral contaminations or bacterial endotoxins can go into the patient's body to cause numerous health problems.
- Hence water utilized as a part of hemodialysis machine is precisely purified before utilize. At first it is filtered and temperature balanced and its pH is rectified by including an acid or base.
- Primary purification is finished by forcing water through a penetrable with very little pores. This membrane is called reverse osmosis membrane. This gives the water pass through and holds back even very small solutes. Once filtered water is blended with dialysate concentrate, its conductivity would increases.
- Amid dialysis the conductivity of dialysate solution is consistently checked to clear that the water and the dialysate concentrate are blended in proper proportions. The block diagram representation of a hemodialysis machine is shown in figure.

Hemodialysis Machine Block Diagram

- The blood is occupied from the artery of the patient and mixed with an anticoagulant such as heparin and forced into the equipment called artificial kidney or hemodialysis machine.



Block Diagram of Hemodialysis machine

Dialysate Pail

- Dialysate pail is the storage place of the dialysate.
- It is through the dialysate that the blood from the patient is directed to flow through channels or tubes bounded by cellophane membrane.
- This membrane is permeable to small solutes and impermeable to macromolecules.

Dialyzer

- Dialyzer is the major part of equipment that actually filters the blood. Dialyzer membranes have dissimilar pore sizes.
- Those with lesser pore size are called low flux membrane and those with bigger pore size are called high flux membranes.
- Dialyzer membranes used in made of cellulose. Another group of membrane is made from synthetic objects using polymers.

- Nanotechnology is used in some high flux membranes to produce uniform pore size. Dialyzers come in numerous dissimilar sizes.
- A bigger dialyzer with a bigger membrane can remove more solutes.

Dialysate Heater

- The dialysate should be kept at a proper temperature.
- The temperature is controlled by the dialysate heater.

Check Valve

- The function of dialysate check valve is to control the flow of dialysate to the dialysate pail.
- If the overflow condition of dialysate occurs, it will be directed by the check valve to the dialysate overflow and drain mixer where the dialysate will be mixed with the drained dialysate.
- The mixed component is thrown out as exhaust.

Dialysate Recirculating Loop

- This loop acts in such a way that the drained dialysate is reconverted into fresh dialysate and properly heated and redirected to the dialysate pail itself.
- The dialysate may moreover be discarded after each action or be used again. Reused dialyzers are not shared between patients.
- If the reuse of dialyzers is finished cautiously and properly it will produce similar outcomes to a single use of dialyzers.

Dialysate Holding Tank

- The dialysate holding tank holds the fresh dialysate and whenever the dialysate of the pail has to be changed, the fresh dialysate from the holding tank is taken to the pail.

Flow Meter

- In order to regulate the flow of fresh dialysate from the dialysate holding tank to the dialysate pail, we normally use a flow meter in the machine set up.

Disadvantages

- Restricts independence, as people undergoing this procedure cannot travel around because of supplies' availability
- Requires more supplies such as high water quality and electricity
- Requires reliable technology like dialysis machines
- The procedure is complicated and requires that care givers have more knowledge
- Requires time to set up and clean dialysis machines, and expense with machines and associated staff.

Complications

- First-use syndrome
- Fluid shift
- Access related
- Venous needle dislodgement
- Anticoagulation related
- Cardiovascular
- Vitamin deficiency
- Electrolyte imbalances

5) (a) Explain the working of any two types of oxygenators. (Nov/ Dec 2017)
(b) Describe the types of oxygenators. (April/ May 2018)

OXYGENATORS

- An oxygenator is a medical device that is capable of exchanging oxygen and carbon dioxide in the blood of human patient during surgical procedures that may necessitate the interruption or cessation of blood flow in the body, a critical organ or great blood vessel.
- A heart-lung machine is connected to the heart by drainage tubes that divert blood from the venous system, directing it to an oxygenator. The oxygenator removes carbon dioxide and adds oxygen to the blood, which is then returned to the arterial system of the body.
- Oxygenators not only supply vital oxygen for the blood, but also transport carbon dioxide, anaesthetics and other gases into and out of the circulation. In ideal oxygenators the following conditions are required:
    a. Lower priming volume
    b. Minimum trauma to blood
    c. Simple, safe and reliable operation
    d. Ensured sterilization
    e. No microembolus formation and

f. Short preparation time

- There are four types of oxygenators. They are:
    - Bubble Oxygenators
    - Film Oxygenators

      Divided into following 4 types
        - Rotating disc film type
        - Foam oxygenator
        - Blood film over sponge
        - Screen oxygenator
    - Liquid-Liquid Oxygenators
    - Membrane Oxygenator

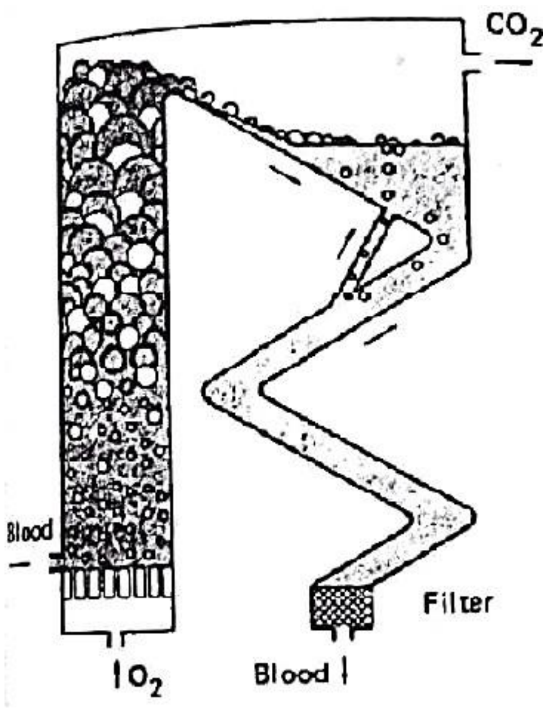
(A) <u>BUBBLE OXYGENATOR</u>

Principle

- By bubbling the oxygen through a large column of blood and the making the flow of blood through a slanting path, the carbon di oxide is removed from the blood.

Working

- There are two major components. In one component, oxygen is bubbled through the blood in a finely dispersed form.
- In the other component called gas separating component, gaseous exchange is taking place. Meanwhile the bubbles and foam are removed.
- The existence of bubbles in blood causes air emboli. To remove bubbles, beads, sponges, meshes and fabrics coated with defoaming agent like silicon is used.
- The surface tension of bubbles is reduced by the silicon and hence it causes the bubbles to break. There are also permanent and disposable oxygenators.



Bubble Oxygenator

Features

1. The oxygenators is effective because of the large surface area. But large surface area leads to pronounced foaming and damage to the red cells. Therefore these are suitable only for short operations.
2. It is the simplest among the different oxygenators.
3. Due to the mechanical strees introduced by the bubbles, trauma produced in it is the highest.
4. In the case of disposable unit, except the long preparation time and expensive material cost, we can get cleaniness, sterility, simplicity and inexpensive manpower cost. But in the case of permanent unit, except the difficulty in cleaning and expensive manpower cost, we can get shorter preparation time and inexpensive material cost.

(B) FILM OXYGENATOR

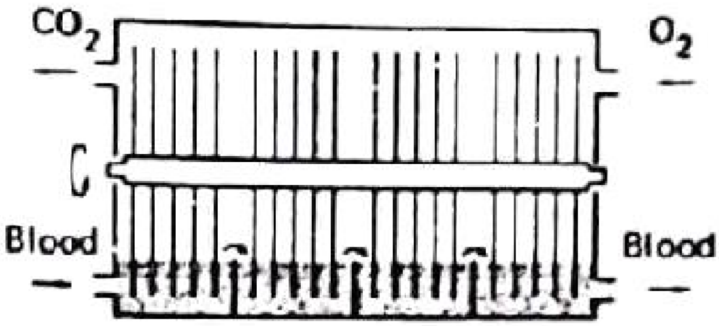
Principle

- Here the thin film of blood is spread on a rotating disc or metal screen and an oxygen mixture flows over this thin layer of blood.

Working

There are several types in this oxygenator.

(i) <u>Rotating disc film type oxygenator</u>



<u>Film Oxygenator (Disc Type Oxygenator)</u>

- A horizontal cylinder in which a number of discs are mounted on a central axis. In the above figure rotating discs are shown as vertical line.
- A blood level is maintained at the hollow of the cylinder so that only the outer edge of the disc is immersed in the blood.
- Rotation of the central axis of the cylinder causes a thin blood film to form on the periphery of the discs.
- After a short exposure to oxygen which is filled in the oxygenator housing, the blood is washed off from the discs.
- At the same time a new blood film is formed on the same disc. This new film is also washed off at the next revolution.
- Since the cylinder is rotated at 120 RPM the exposure time of the blood film with the oxygen atmosphere is only 0.5 seconds.

Features

1. These are difficult to clean
2. Trauma produced in these are very small.
3. Effective oxygenation can be done.

(ii) <u>Foam oxygenator</u>

- Blood is poured over the top of the blood foam.

- The oxygen mixture is bubbled through the blood in the opposite direction.
- The blood is spreading over the surface of the bubble in a thin film form and effectively it is exposed to oxygen.
- The filmed blood is oxygenated while falling down. Defoaming is done afterwards.

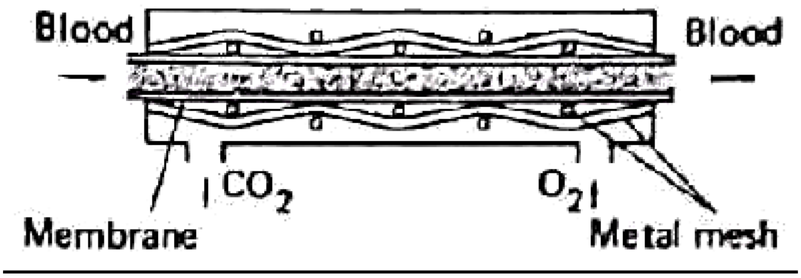
(iii) <u>Blood film over sponge</u>

- A small volume of sponges saturated with blood provides a large surface area for blood oxygenators if oxygen is simultaneously distributed in the sponge.
- It is called artificial alveoli.

(iv) <u>Screen oxygenator</u>

- A thin film of blood is over a screen (stationary or rotating) is exposed to oxygen for oxygenation.
- This causes less trauma to blood.
- Disposable units are also available in this type.

(C) <u>MEMBRANE OXYGENATOR</u>



<u>Membrane oxygenator</u>

Principle

- Effective oxygenation is obtained when oxygen and blood are running in opposite direction through a thin porous membrane.

Working

- The blood flows on one side of a membrane permeable to gas and oxygen flows on the other side of it.

- The membrane is made of microporous polyethylene which has higher permeability for oxygen. Silicone rubber is also rarely used.
- Here the carbon di oxide transport is limited by the permeability of the membrane. Further the oxygen transport is also limited by the thickness of the blood layer.

Features

1. These are so expensive and hence these are not commonly used.
2. Trauma produced in these oxygenators is very small which we compare it with others. This is due to the advantage that the blood does not come into direct contact with the oxygen mixture. Therefore bubbles and form do not form.
3. These are very difficult to clean.

(D) <u>LIQUID-LIQUID OXYGENATOR</u>

<u>Liquid-Liquid Oxygenator</u>

Principle

- The oxygen dissolved fluoridised organic fluid and blood are flowing in the opposite directions and oxygenation of the blood takes place.

Working

- Fluoridizes organic liquid is the working liquid which readily dissolves oxygen and carbondioxide which then diffuse to and from the blood respectively.
- Eventhough the blood is in direct contact with the working liquid, it is entirely a different chemical compound with respect to the blood constituents and so there is no chemical reaction between them.
- During their opposite flow through a small tube, gaseous exchange takes place.

Features

1. No trauma is produced.
2. Effective oxygenation can be required.

6) Explain the principle, recording and clinical application of thermography. (Nov/ Dec 2017)

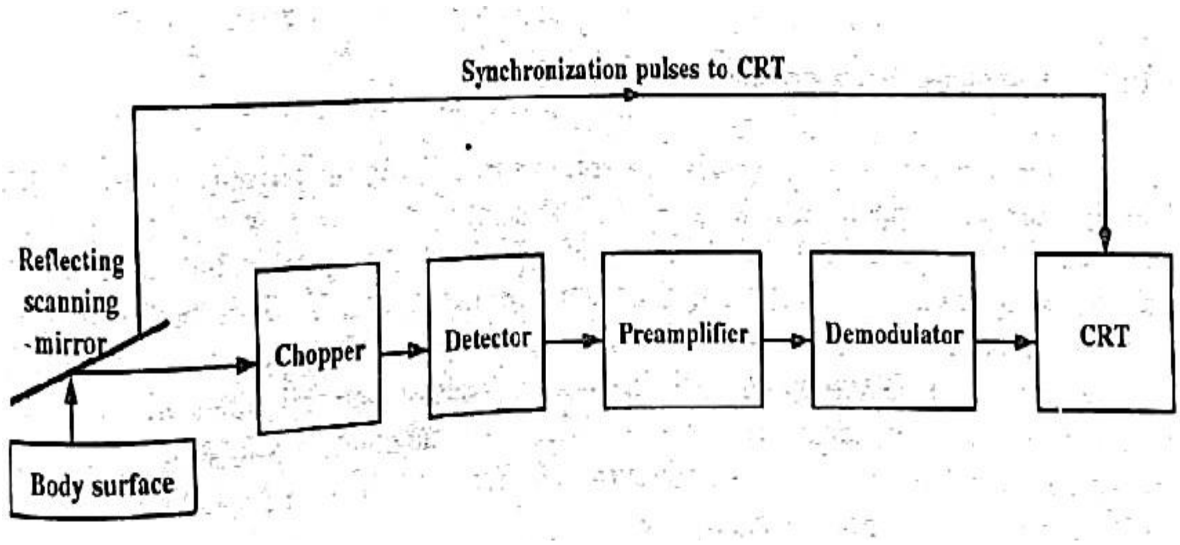
THERMOGRAPHY=PRINCIPLE

- Medical Thermography (digital infrared thermal imaging – DITI) is used as a method of research for early pre-clinical diagnosis and control during treatment of homeostatic imbalances.
- There are few devices, which operate in a passive method like infrared Thermography medicine; amongst these are the ECG and EEG.
- The intrinsic safety of this method makes infrared Thermography free from any limitations or contra- indications.
- Thermography is a non-invasive, non-contact tool that uses the heat from your body to aid in making diagnosis of a host of health care conditions. Thermography is completely safe and uses no radiation.
- Medical Thermography equipment usually has two parts, the IR camera and a standard PC or laptop computer. These systems have only a few controls and relatively easy to use.
- Monitors are high-resolution full colour, isotherm or grey scale, and usually include image manipulation, isothermal temperature mapping, and point-by-point temperature measurement with a cursor or statistical region of interest.
- The systems measure temperatures ranging from 10° C – 55° C to an accuracy of 0.1° C. Focus adjustment should cover small areas down to 75 x 75mm.
- These systems are PC based and therefore able to store tens of thousands of images (and these images may be retrieved for later analysis).
- The ability to statistically analyse the thermograms at a later date is very important in clinical work.
- Copies of images can easily be sent (via e-mail, floppy disk, etc.) to referring doctors or other healthcare professionals.
- The medical applications of DITI are extensive, particularly in the fields of Rheumatology, Neurology, Oncology, Physiotherapy and sports medicine.

- Thermal imaging systems are an economical easy-to-use tool for examining and monitoring patients quickly and accurately.
- Utilising high-speed computers and very accurate thermal imaging cameras, the heat from your body is processed and recorded in the computer into an image map which can then be analyzed on screen, printed or sent via email.
- A doctor can then use the image map to determine if abnormal hot or cold areas are present. These hot and cold areas, can relate to a number of conditions for which the Food and Drug Administration, Bureau of Medical Devices has approved the thermography procedure.
- These include, the screening for breast cancer, extra-cranial vessel disease (head and neck vessels), neuro-musculo-skeletal disorders and vascular disease of the lower extremities.
- There have been a number of advancements in the past decade, which has brought thermal imaging in medicine back to the forefront of diagnosis. As technology has advanced, so has our "medical" concept of thermal imaging.

RECORDING OF THERMOGRAPHY

- The following figure shows the simplified block diagram of thermographic equipment. Every thermographic equipment is provided with a special infrared camera that scans the object and a display unit for displaying the thermal picture on the screen.
- The camera contains an optical system in the form of an oscillating flat plane mirror which scan the field of view at a very high speed horizontally and vertically and focuses the collected infrared radiation onto the chopper.
- The chopper disc interrupts the infrared beam so that a.c signals are produced and amplified and demodulated further.



Block diagram description of thermography equipment

- The demodulated signals are given to the cathode ray tube in synchronization with scanning mechanism.
- The signals are displayed on the screen by intensity modulation which controls brightness and contrast with the strength of the signal.

CLINICAL APPLICATIONS OF THERMOGRAPHY

Breasts pathologies

- Probably the most applied area of Medical Thermography – breast cancer, benign tumours, mastitis, and fibrocystic breast disease.
- The utilization of thermography as a screening tool in the detection of breast cancer has been for the past decade a very controversial topic within the health care community.
- However, the technology has gained in scientific acceptance, has been approved for screening purposes and is clearly a powerful tool in the war on breast cancer.
- The concept is quite simple. Thermography measures the heat coming from your body. Metastatic cancers create heat which can be imaged by digital infrared imaging. This is due to two separate yet connected factors.
- The first is the metabolic activity of the tumour tissue as compared with the temperature of tissue adjacent to the tumour, and in the opposite breast.
- By comparing the breast in question with the normal breast which acts as the patient's own control, abnormal heat signatures associated with the metabolism of the tumour can be detected easily. These differences in temperature are referred to as a Delta T.

- The second method of detection is due to the angiogenesis of the tumour. I.e. Cancerous tumours produce a chemical which actually promotes the development of blood vessels supplying the area where the tumour resides.
- Also, normal blood vessels which are under the control of the sympathetic nervous system are essentially paralyzed, causing vaso-dilation, or an increase in size of the blood vessel.
- The increase in blood in the region due to angiogenesis and combined with the vaso-dilation simply means more heat, recordable with thermal imaging procedures.

Extra-Cranial Vessel Disease

- In a similar way, a variety of conditions which relate to flow of blood through the vessels of the neck and head are readily accessed with thermal imaging.
- As the blood vessels in the face and skull are coursing through very thin tissue between the bones of the skull and the skin covering the skull, they are readily and easily visualized with thermal imaging.
- As the vessels of the neck are very large calibre vessels, they too are very easily visualized with thermography and clues to the potential of developing vascular disease which might lead to stroke are a consideration when performing thermography.
- The use of thermography in differentiation of various types of headache (migraine, cluster, cervical spine related), facial nerve injury as in the case of a blow to the face or a car accident where the face contacts a windshield or the steering wheel, the visualization of TMJ disorders (tempero-mandibular joint) are commonly used aspects of thermographic diagnosis and analysis of the head and neck.
- The ability of thermal imaging to safely indicate the heat from sources in the jaw and teeth is providing a very exciting opportunity to screen individuals for dental decay and cavitations without routine screening x-rays.
- Also, a number of patients have been seen with heat signatures in the jaw related to amalgam fillings which might be toxic for that particular patient. This area of thermal imaging is very promising.

Neuro-Musculo-Skeletal

- This is one of the clearest examples of thermography's ability to accurately diagnose patients with a host of back, neck and extremity disorders.

- When muscle tissue is strained or torn, it releases chemicals which cause increased heat. This can be seen as intense patterns of hyperthermia in the region of the muscle, or trigger point, as in the case of fibromyalgia.
- Heat patterns can also be seen in the legs and soles of the feet which indicate altered gait or weight bearing mechanics, which might relate to a low back or foot condition.
- Further, back strain produces very consistent heat patterns which not only tell us about the source of probable spinal injuries, but can also tell us about areas of spinal compensation,
- In effect, a low back might be being treated by a chiropractor, when the mid back or neck is actually the source of the problem.
- Nerve damage, as occurs in disc herniation and spinal nerve root compression displays on the thermographic map in exactly the opposite direction as muscle injury by revealing cool areas of hypothermia in the nerve tracts coming from the spine. In this way, thermography can demonstrate and document permanency of spinal injuries which are causing a person disability.

Other areas where medical Thermography is successfully applied:

- Respiratory dysfunctions
- Digestive disorders
- Urinary diseases
- Nervous dysfunctions
- Endocrine Disorders
- Surgical Assistance
- Skin Problems
- Ear, Nose, and Throat dysfunction
- Dentistry

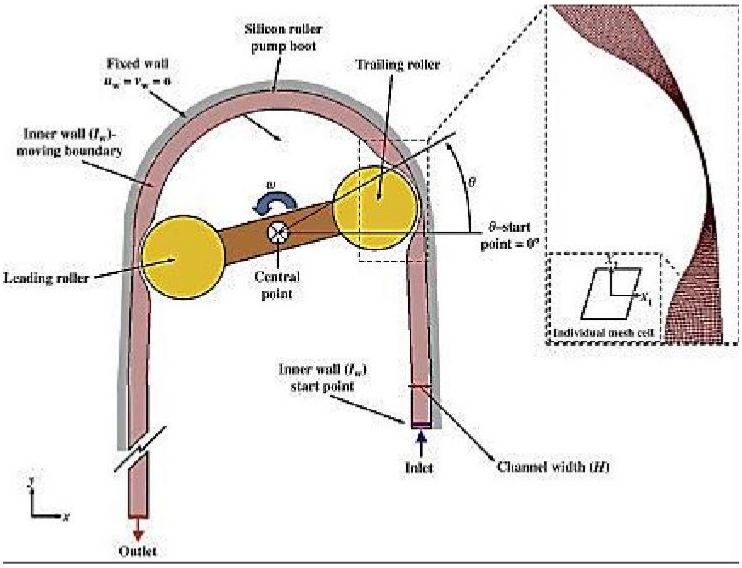
7) Write note on finger pump and roller pump. (May 2019)

<u>FINGER PUMP</u>

- Finger pumps push a series of rods against a flexible tubing in sequence, forcing fluid along the tube. In this pump the fluid moves from left to right.
- Since nothing but the tube actually touches the fluid, the fluid can be kept clean so this pump is often found in medical applications, pumping blood or other fluids.
- The individual fingers can be operated by a rotating camshaft above them, by individual solenoids electronically actuated in sequence, or by other methods.

ROLLER PUMP

- The roller pump comes under the category of positive displacement pumps and has been the most commonly used pump for CPB for the past 50 years.
- The golden era of this pump is passing due to developments in systems using radial (centrifugal) pumps. The roller pump contains a tubing placed inside a curved wall. This wall is located at the travel perimeter of rollers installed on the ends of rotating arms.
- One of these arms always compresses the tubing at all times. The blood is pushed ahead by this compression and the moving roller, which produces continuous blood flow.
- The output of the rotary pump is determined by the frequency of rotation or revolutions per minute (RPM) of the pump.
- The volume of pumped blood depends on the size of the tubing, the length of the track and the RPM of motor.
- The roller pumps are categorized as single, double and multiple roller pumps. The single roller pumps were used for CPB in the middle of the 20th century.
- The flow in this type was more pulsatile. The most commonly used pump for CPB is the double-roller pump. This pump consists of a 210° semicircular support plate and two rollers with the rotating arms set 180° apart.
- When one roller ends its operational phase, the second roller has already begun its phase. Due to hemolysis issues, the third type (multiple roller pump) is not clinically available. The following figure shows a schematic of a roller pump (pumping chamber).
- As the figure shows, there are two rollers (leading and trailing). The central point of rotation is connected to an electric motor which controls the speed of rotation and the blood flow rate of the blood pump.
- Compressing of the tube by the rollers leads to an increasing hemolysis (blood cell damage) which is an important issue for patients (see Fig. below).



Schematic of a roller pump operation

- There are three materials currently used for tubing in the medical device industry: silicone; latex and polyvinyl chloride (PVC).
- Regarding microparticle releasing, the PVC is the best material for tubing because the latex generates more hemolysis and the silicon tube releases more microparticles than the PVC. One of the common problems in blood pumps is the tube occlusion.
- Occlusion can be controlled by either increasing or decreasing the compression of the tube by the rollers and the optimization between increasing and decreasing the compression is very vital in pumping the blood, because more compression increases hemolysis and less generates occlusion, although the priority is with forward output of the blood.
- Selection of these pumps depends on several factors such as flow rate, pressure, rate of hemolysis, operation time, etc. The blood flow rate and pressure (pump head) are the most important aspects among pump features.

Advantages

- No contamination. Because the only part of the pump in contact with the fluid being pumped is the interior of the tube, it is easy to sterilize and clean the inside surfaces of the pump.
- Low maintenance needs and easy to clean; their lack of valves, seals and glands makes them comparatively inexpensive to maintain.
- They are able to handle slurries, viscous, shear-sensitive and aggressive fluids.

- Pump design prevents backflow and siphoning without valves.
- A fixed amount of fluid is pumped per rotation, so it can be used to roughly measure the amount of pumped fluid.

Disadvantages

- The flexible tubing will tend to degrade with time and require periodic replacement.
- The flow is pulsed, particularly at low rotational speeds. Therefore, these pumps are less suitable where a smooth consistent flow is required. An alternative type of positive displacement pump should then be considered.
- Effectiveness is limited by liquid viscosity

Applications

- Peristaltic pumps are typically used to pump clean/sterile or highly reactive fluids without exposing those fluids to contamination from exposed pump components.
- Some common applications include pumping IV fluids through an infusion device, apheresis, highly reactive chemicals, high solids slurries, and other materials where isolation of the product from the environment are critical.
- They are also used in heart-lung machines to circulate blood during a bypass surgery, and in hemodialysis systems, since the pump does not cause significant hemolysis, or rupture of the blood cells

Typical application

- Peristaltic pump used in chemical treatment process of a water purification plant
- Medicine
- Dialysis machines
- Open-heart bypass pump machines
- Medical infusion pumps
- Testing and research
- AutoAnalyzer
- Analytical chemistry experiments
- Carbon monoxide monitors
- Media dispensers

8) Discuss the principle of oximetry. With suitable diagrams explain transmission and reflection type pulse-oximetry. (Nov/ Dec 2018)

OXIMETRY

- Oximetry refers to the determination of the percentage of oxygen saturation of the circulating arterial blood.
- By definition:

$$\boxed{\text{Oxygen saturation} = \frac{[HbO_2]}{[HbO_2]+[Hb]}}$$

- Where [HbO2] is the concentration of oxygenated haemoglobin [Hb] is the concentration of deoxygenated haemoglobin.
- In clinical practice, percentage of oxygen saturation in the blood is of great importance. This saturation being a bio-constant, is an indications of the performance of the most important cardio-respiratory functions.
- It is maintained at a fairly constant value to within a few percent in an healthy organism.
- The main application areas of oximetry are the diagnosis of cardiac and vascular anomalies; the treatment of post-operative anoxia and the treatment of anoxia resulting from pulmonary affections.
- Also, a major concern during anaesthesia is the prevention of tissue hypoxia, necessitating immediate and direct information about the level of tissue oxygenation.
- Oximetry is now considered a standard of care in anaesthesiology and has significantly reduced anaesthesia-related cardiac deaths.

PULSE OXIMETRY

- Pulse oximetry is based on the concept that arterial oxygen saturation determinations can be made using two wavelengths, provided the measurements are made on the pulsatile part of the waveform.
- The two wavelengths assume that only two absorbers are present; namely oxyhaemoglobin (HbO2) and reduced haemoglobin (Hb). These observations, proven by clinical experience, are based on the following:

(i) Light passing through the ear or finger will be absorbed by skin pigments, tissue, cartilage, bone, arterial blood, venous blood.

(ii) The absorbances are additive and obey the Beer-Lambert law:

$$\boxed{A = -\log T = \log I_0 / I = \varepsilon D C}$$

Where

Io and I are incident and transmitted light intensities,

e is the extinction coefficient,

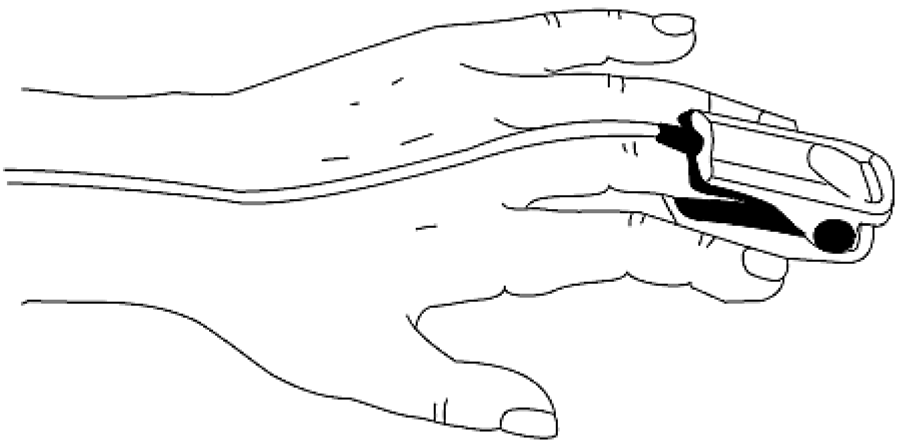
D is the depth of the absorbing layer

C is concentration.

(iii) Most of the absorbances are fixed and do not change with time. Even blood in the capillaries and veins under steady state metabolic circumstances is constant in composition and flow, at least over short periods of time.

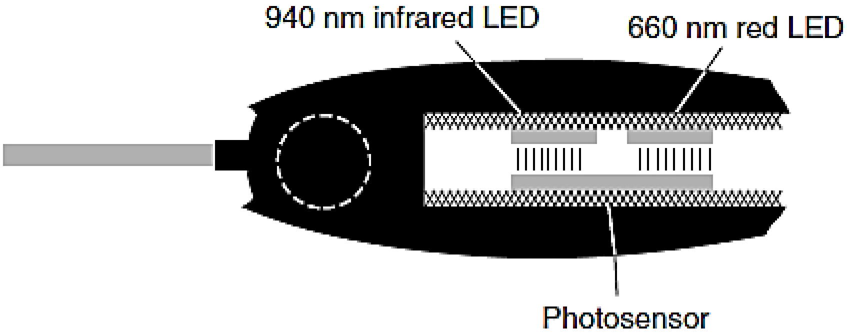
(iv) Only the blood flow in the arteries and arterioles is pulsatile.

- Therefore, only measuring the changing signal, measures only the absorbance due to arterial blood and makes possible the determination of arterial oxygen saturation (SaO2).
- This is uninfluenced by all the other absorbers which are simply part of the constant background signal.
- Figure below shows a typical finger-tip oximeter probe in use.



A typical finger-tip pulse oximeter probe in use

- Figure below shows the construction of a typical pulse oximeter probe.



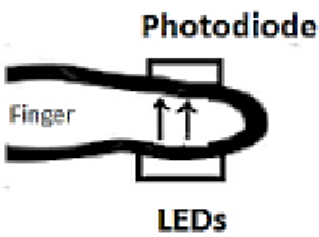
Components of a pulse oximeter probe

- This has two LEDs (light emitting diodes), one that transmits infrared light at a wavelength of approximately 940 nm and the other transmitting light at approximately 660 nm.
- The absorption of these select wavelengths of light through living tissues is significantly different for oxygenated haemoglobin (HbO2) and reduced haemoglobin (Hb).
- The absorption of these selected wavelengths of light passing through living tissue is measured with a photosensor.
- The red and infrared LEDs within the probe are driven in different ways, depending on the manufacturer. Most probes have a single photodetector (PIN-diode), so the light sources are generally sequenced on and off.

TYPES OF PULSE OXIMETER PROBES

- Currently, the 2 basic types of pulse oximeter probes are transmission probes and reflectance probes.

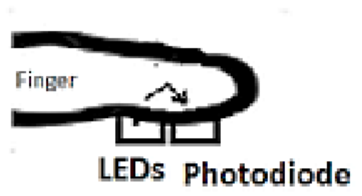
TRANSMISSION MODE



Transmission mode

- With transmission probes, the light emitter and sensor are placed opposite each other on pulsatile tissue such as a digit or ear.
- The lights used to measure tissue oxygenation are typically placed across from a detector surrounding approximately 5-10 mm of tissue that contains pulsatile blood flow, such as a fingertip or ear lobe.

REFLECTANCE MODE



Reflectance mode

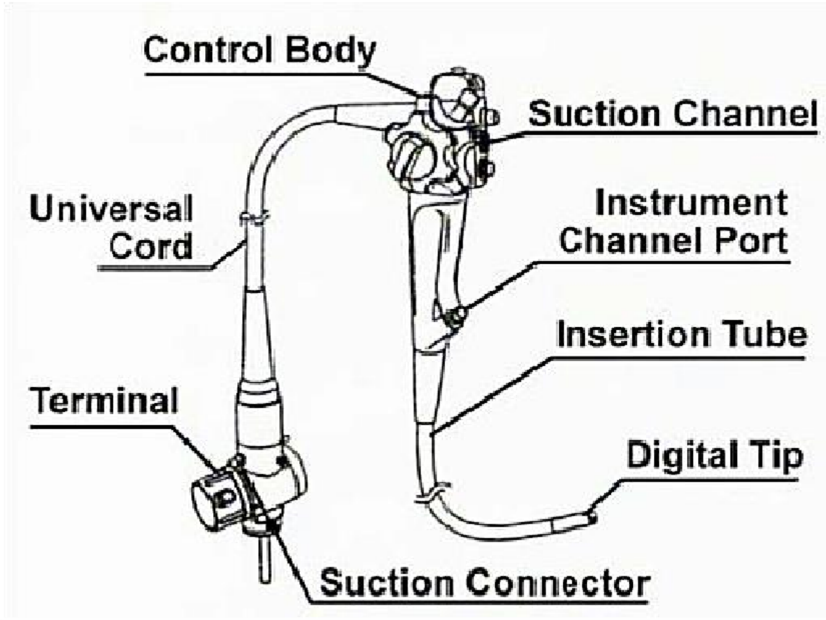
- With reflectance probes, the light emitter and sensor are placed side by side on a flat body surface.
- The detector lies adjacent to the light source on a flat surface such as the forehead. This information can be used noninvasively to help evaluate the hemodynamic status of a patient and to detect hypoxemia in various clinical settings.

9) With neat diagram explain the components of an endoscopy. (Sep 2020)

ENDOSCOPES

- Essentially, an endoscope may be described as a long, thin illuminated flexible tube that has a camera on one end.
- Today, the endoscope has become of the most important devices in medicine serving to view the inside of body cavities.
- Although endoscopes are usually inserted through such openings as the mouth and the rectum, they are also inserted into the body through small incisions on the skin particularly during keyhole surgery (minimal invasive surgery).

PARTS OF ENDOSCOPE



General Flexible Endoscopes

- A standard endoscope in composed of the following parts:
  - A thin, long flexible tube
  - A lens or lens system
  - A light transmitting system
  - The eyepiece
  - Control system

WORKING OF ENDOSCOPE

- Basically, a typical endoscope uses fiber optics, which allow for effective transmitting of light. In this technique (fiber optics) light is transmitted through a flexible fiber of glass (transparent) known as optical fiber(s).
- The optical fiber allows for light to travel through curved paths, which makes one of the best systems to view spaces that would normally be difficult to reach.
- Here, total internal reflection makes it possible for light to travel along the fibers with the light rays hitting the fiber walls at an angle (minimum angle of 82 degree).
- Given that individual fibers can be thinner than human hair, fiber optics is one of the best techniques to enter and view different areas of the body. There are typically two sets of the fibers.

- These include the outer fiber that functions to supply light and an inner coherent ring that serves to transmit the image.

The outer fiber

- This fiber contains a number of fibers that have been bundled together in no particular order. It is for this reason that the outer fiber is commonly referred to as the incoherent bundle.
- The fiber is entirely enclosed with a sleeve to protect it. Typically, it is coated with either plastic or steel which protects it from water or moisture (making it waterproof).

Inner fiber

- Like the outer fiber, the inner bundle is also composed of a bundle of fibers. However, unlike the outer bundle, the inner fiber is in perfect order, which is why it is referred to as the coherent bundle.
- The tiny lens connected to the end of this bundle allows for light to be effectively focused so that reflected light from the object of interest can be collected and transmitted for viewing.

OTHER IMPORTANT PARTS

- **Water pipes** - The pipes serve to carry water which is used to wash the lens thereby maintaining a clear view.
- **The operational channel** - This is an opening on the device that is used to move various accessories to the distil end (of the endoscope) for surgery purposes.
- **Control cables** - This is used to control the direction that the distil end will bend as it moves through body cavities.

NEW ENDOSCOPE TECHNOLOGIES

(a) Wireless Capsule Endoscopy

- Capsule endoscopy is one of the new procedures that involve the use of a very small wireless camera to take pictures in the digestive system.
- For this procedure, one swallows a capsule the size of vitamin-sided capsule or a large pill. The technology involves the use of a wireless miniature encapsulated camera that takes pictures as the capsule travels through the digestive system.

- As it travels down the digestive system, the capsule wirelessly transmit the images it captures which can then be used to detect any issues in the digestive tract.
- The images (it can take thousands of images) are then transmitted to a recorder from which they can be retrieved. Like ingested food, the capsule travels through the digestive system and ultimately leaves the body when the individual passes stool.

The main components of capsule endoscopy include:

- **Sensor array (electrodes)** - The patient wears this around the abdomen area like a sensor belt
- **Data recorder** worn by the patient and connected to the electrodes
- **The capsule** that is 26mm by 11mm in size - Some of the components of the capsule include; a lens, diodes (that emit light) a semi-conductor, an antenna as well as a transmitter.
- Since its approval by the FDA in 2001, capsule endoscopy has been shown to be an effective procedure with a number of advantages that include:
    - painless
    - disposable
    - non-invasive

(b) Confocal Laser Endomicroscopy and Endocytoscopy

- These are some of the new procedures aimed at enhanced high resolution in the assessment of gastrointestinal mucosal histology at both the cellular and sub- Basically, the technique is based on the principle of illuminating the tissue of interest with low power laser which in turn allows for the detection of fluorescent light that is reflected from the tissue.
- With this procedure, it becomes possible to carry out in vivo examinations with images being displayed in real-time.
- It has been shown to be particularly beneficial in the detection of abnormal growth of tissue in conditions like ulcerative colitis.

USES OF ENDOSCOPES

Although endoscopy is largely used for the purposes of examining a patient's digestive tract, endoscopes are also used for:

- Arthroscopy
- Bronchoscopy
- Endoscope Biopsy
- Laparoscopy

10) Explain the functioning of lithotripter system with neat diagram. (Sep 2020)

Lithotripsy

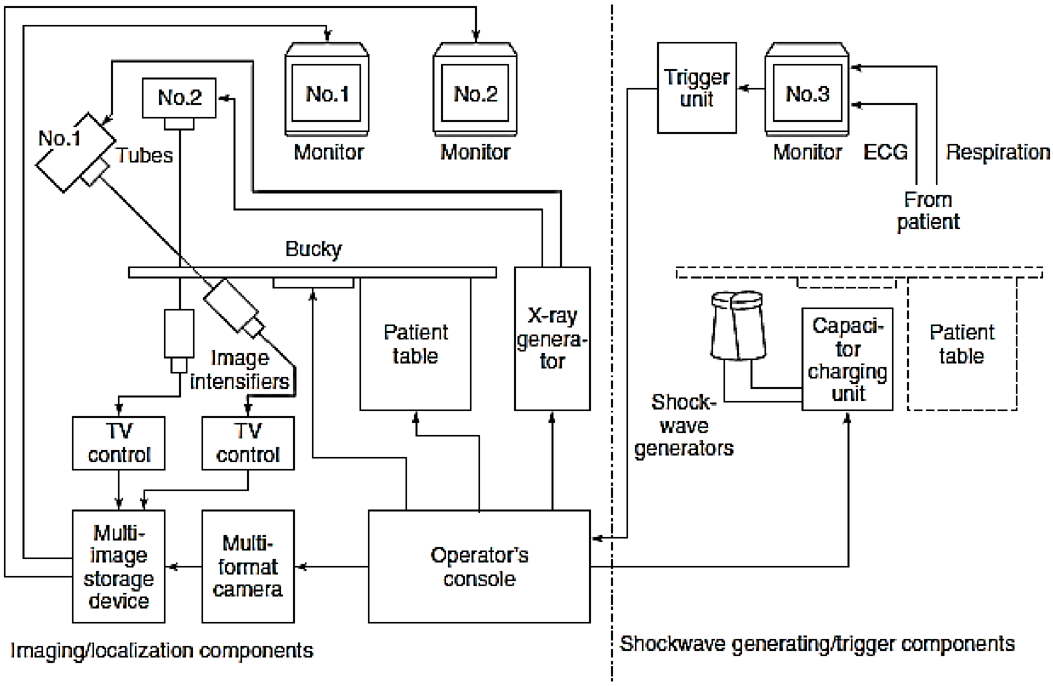
- Lithotripsy is a procedure that uses shock waves to break up stones in the kidney and parts of the ureter (tube that carries urine from your kidneys to your bladder). After the procedure, the tiny pieces of stones pass out of your body in your urine.

Modern Lithotriptor system

- First generation electro-hydraulic lithotriptors had several major disadvantages. The early machines were relatively expensive to install and operate, and required dedicated facilities and treatment.
- Besides, using the systems was painful and required general anaesthesia, which resulted inprolonged in-patient stays and higher overall costs. Modern machines incorporate clinical advantages over their predecessors.
- The integration of a variety of reflector sizes and control over voltage and power output allows for greater ease of use as well as customization of treatment parameters for increased treatment efficiency and decreased discomfort for the patient.
- Shock-wave lithotripsy machines currently in the market vary in terms of several operational factors such as the energy source, the focusing system and stone localization system.
- In general, the main components of a lithotriptor system are:
    - Focused shock-wave source;
    - Means for acoustic coupling of the shock-wave to the body;
    - Imaging modalities for stone localization and therapy control;
    - A patient table with either the table or the shock-wave source movable in three dimensions;
    - System for the measurement of physiological variables and their monitoring; and

- Trigger generation and control system.

➢ Figure below shows the schematic diagram of a lithotriptor system:



Schematic diagram of a lithotriptor system with biplane X-ray imaging

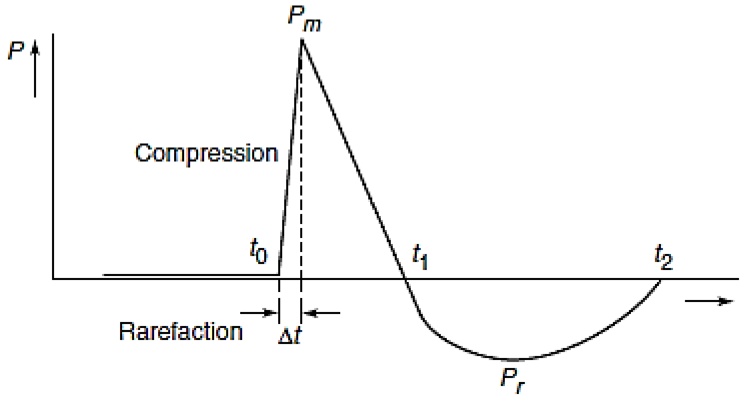
Focused shock-wave source

➢ Focused acoustic shock-waves are necessary for extra-corporeal lithotripsy for which focal pressures of 10 to 100 Megapascal (100-1000 bars) acting in a cigar-shaped focal volume with a across-sectional diameter of approximately 2 to 8 mm and a length of about 25 to 50 mm, are required depending on the design of the particular device.

➢ These shock-waves are generated by an emitter outside the body and transmitted as pulsed longitudinal waves through a fluid coupling medium and the body tissue to the target, the concrement to be destroyed.

➢ Shock-waves are unharmonic and non-linear acoustic phenomena, characterized by an extremely steep change in pressure amplitude, the shock front.

➢ It is generally accepted that an ideal shock-wave for extracorporeal lithotripsy shows a shock front only in the compressional part of the pulse up to a peak pressure, followed by decay (Fig. below).



Schematic of an acoustic shock-wave pulse

- Due to general physical principles, this compression is accompanied by a rarefaction. The characteristic parameters of the shock-wave are the peak value of the pressure and duration of compression and rarefaction, and the rise time of pressure Delta t.
- In order to achieve the best results, the shock-wave must be developed with a sufficiently high positive pressure amplitude and a low negative-pressure amplitude.
- Shock-waves in lithotripsy need to be strongly focused in order to keep the area of interaction with tissue or concrements restricted to the pre-determined region of interest. Any tissue in front of, behind or adjacent the target area should be left unaffected.
- The technical answer to this medical requirement is to use large aperture systems which spread the shock-wave energy over a wide skin entrance area.
- Simultaneously, the system concentrates the acoustic energy precisely to a small focal volume with a cross-sectional diameter of a few millimeters.
- Modern systems use aperture angles of 80 to 90 degrees to provide these favourable field parameters. Depending on the type of indication, focal distances up to 16.5 cm are available for the treatment of deeply lying structures like the kidney and ureteral stones.
- To-date there is no standard to define the ‘strength’ of shock-waves. However, for comparison and dosage purposes, the ‘energy flux density’ measured by milli joule per mm2 (mJ/mm2) turns out to match fairly well with clinical efficiency.
- Of clinical importance is the ability of shock-wave devices to precisely adjust the delivered shock-wave energy.
- Electro-hydraulic or spark gap technology cannot provide shock-wave pulses of precisely defined energy due to the statistical nature of spark gap formation.

- Peak focal pressures of spark gap systems may show a pulse to pulse variability exceeding 50% whereas a state-of-the-art electromagnetic system provides a repetition accuracy better than 3%.
- The three basic types of shock-wave sources for lithotripsy are:

1. Plasma explosion method;
2. Electromagnetic system;
3. Piezo-ceramic system.

- These excitation sources are coupled with the following focusing methods:

(a) Ellipsoidal reflector;

(b) Focusing with an acoustic lens; and

(c) Self-focusing source.