



كلية الهندسة - برنامج الهندسة الطبية والحيوية

# معمل الهندسة الطبية

الدور الثالث مبني المعامل البحرية

كلية الهندسة

وملحق به غرفة الطباعة ثلاثية

الابعاد وقاعة عرض مشاريع

التخرج

مبنى البرامج النوعية الدور الرابع



## Contents:

- الرؤية والرسالة والاهداف ..... (٢)
- المعلومات الاساسية ..... (٣)
- الخدمات المجتمعية التي يقدمها المعمل ..... (٥)
- قائمة باجهزة المعمل ..... (٦)
- قائمة بتجارب المعمل ..... (٨)
- صور من المعمل ..... (٩)
- صور حجرة الطباعة ثلاثية الابعاد ..... (٢٣)
- تجارب المعمل
- تركيب وتشغيل وصيانة جهاز الموجات الفوق صوتية (السونار)
- How to Use Ultrasound Machine: What Does It Consist Of & How Does It Work?..... (26)
- تركيب وتشغيل وصيانة جهاز رسم العضلات
- How to Use EMG Machine: What Does It Consist Of & How Does It Work?.....(35)
- تركيب وتشغيل وصيانة جهاز رسم القلب
- How to Use ECG Machine: What Does It Consist Of & How Does It Work?.....(40)
- تركيب وتشغيل وصيانة جهاز رسم المخ
- How to Use EEG Machine: What Does It Consist Of & How Does It Work?.....(48)
- تركيب وتشغيل وصيانة جهاز التنفس الصناعي
- What is a breathing machine (mechanical ventilator) and what does it do? .....(53)
- تركيب وتشغيل وصيانة شاشة عرض المؤشرات الحيوية للمريض
- How to use a Vital Signs Monitor .....(60)
- الطباعة ثلاثية الابعاد
- 3D PRINTING .....(64)



### رؤية المعمل

يأمل المعمل أن يكون مركزا متفردا في مجال اصلاح وصيانة وتطوير الأجهزة الطبية، مع طموح الكلية والجامعة في دقة الأداء وجودة المخرجات والتطوير المستمر نحو الأفضل.

### رسالة المعمل:

- يهدف معمل الهندسة الطبية إلى إعداد اجيال من الباحثين المتميزين وتسليحهم بالمعارف والمهارات بحيث يكونوا قادرين على العطاء والإبداع والمنافسة
- المشاركة الفعالة في حل مشكلات المجتمع وتلبية متطلبات سوق العمل

### أهداف المعمل:

- خدمة المجتمع وإيجاد السبل المناسبة لحل مشكلاته المتعلقة بالأجهزة الطبية وكذلك تقديم الاستشارات الفنية في مجال تخصص المعمل
- تحسين جودة الأداء فيما يتعلق بالبرامج التعليمية من خلال تدريب الطلاب داخل المعمل
- دعم الدراسات العليا والبحوث عبر فتح آفاق جديدة للبحث العلمي والإرتقاء بمستوى الرسائل العلمية
- رفع كفاءة الكوادر البشرية المشاركة من مختلف كليات الجامعة سواء من أعضاء هيئة التدريس أو الهيئة المعاونة أو الفنيين



معلومات اساسية:

اسم المعمل	معمل الهندسة الطبية
القسم العلمي	برنامج الهندسة الطبية والحيوية وقسم هندسة الالكترونيات والاتصالات
المشرف	ا.م.د. حسام الدين صلاح مصطفى
مهندس المعمل	م/ امل السيد حسين
امين المعمل	ا. احمد جمال
التليفون	ت. داخلي ١٢٧٨
الموقع	الدور الثالث مبني المعامل البحرية كلية الهندسة
المساحة	م <sup>٢</sup> ١٢٦.٧٥
السعة الطلابية	طالب ٣٥
الطلاب الذين يخدمهم المعمل	<ul style="list-style-type: none"><li>• طلاب برنامج الهندسة الطبية</li><li>• طلاب قسم هندسة الاتصالات</li><li>• طلاب ماجستير هندسة الاتصالات</li><li>• طلاب دبلومة الهندسة الطبية</li><li>• بعض طلاب الاقسام والبرامج الاخرى وبعض الباحثين</li></ul>
الدورات التي يمكن أن يقدمها المعمل	دورة صيانة وتشغيل الاجهزة الطبية



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**بيانات الملحق الاساسية (غرفة الطباعة ثلاثية الابعاد):**

اسم المعمل	ملحق معمل الهندسة الطبية (معمل الهندسة الطبية ٢)
القسم العلمي	برنامج الهندسة الطبية والحيوية
المشرف	ا.م.د. حسام الدين صلاح مصطفى
مهندس الملحق	م/ امل السيد حسين
امين الملحق	ا. احمد منصور
الموقع	الدور الرابع مبني البرامج النوعية - كلية الهندسة
المساحة	٢٨.٧٥ م <sup>٢</sup>
السعة الطلابية	١٥ طالب
الطلاب الذين يخدمهم الملحق	<ul style="list-style-type: none"><li>• طلاب برنامج الهندسة الطبية</li><li>• طلاب دبلومة الهندسة الطبية</li></ul>
الاجهزة المتواجدة بالمعمل	طابعة ثلاثية الابعاد



### الخدمات المجتمعية التي يقدمها المعمل:

يعتبر معمل الهندسة الطبية هو حلقة الوصل بين عالم الطب وامكانيات الهندسة. حيث تتجلى فيه العلوم الطبية بشكل هندسي متطور لدراسة وتشخيص وتعريف اعظم الة موجودة على وجه الارض وهي الجسم البشري.

يستخدم المعمل في اقامة ورش عمل في مجال الهندسة الطبية، باشراف من اساتذة متخصصين من كلية الطب ومهندسين متميزين من الشركات العاملة في مجال الاجهزة الطبية. لرفع كفاءة طلاب وخريجي برنامج الهندسة الطبية، ووفنيي الاجهزة الطبية بمستشفيات جامعة المنصورة للوصول لخدمات طبية متميزة تليق بالمنصورة عاصمة الطب في مصر.

ويقوم مشرفي وفنيي المعمل بموجب البروتوكول الموقع بين كلية الهندسة وبرنامج الهندسة الطبية وكلية الطب بفحص الاجهزة التي ترغب مستشفيات جامعة المنصورة بتغييرها او تطويرها او تكييفها وذلك لتحقيق اقصى استفادة من موارد الجامعة.

كما أن الطباعة ثلاثية الأبعاد متاحة لكل اقسام الكلية.

ويمكن استغلال اجهزة المعمل في الكشف الطبي علي الطلاب وأعضاء هيئة التدريس والعاملين.



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**أجهزة المعمل:**

الملاحظات	تكهين	لا يعمل وقابل للصيانة	يعمل	العدد	الجهاز
			١٠	١٠	Matrix multimeter
			١	١	جهاز رسم المخ EEG
			١	١	جهاز رسم العضلات EMG
			١	١	شاشته مريض patient
			١	١	جهاز الموجات فوق الصوتية
			١	١	جهاز بصمه الاصبع
			١	١	جهاز نسبة السكر
			١	١	جهاز قياس الوزن اللاسلكي
			٢	٢	جهاز رسم القلب EGG
			٢	٢	جهاز قياس ضغط الدم
			٤	٤	أدوات إصلاح أجهزة طبية
			١	١	سرير مستشفى
			١	١	كمبروسور خاص لجهاز تنفس
			١	١	بالونه اختبار



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			١	١	وصله مريض هاميلتون
			١	١	بورده ج.م.ب وبورده الباور
			١	١	فلوسنور هاميلتون

- يوجد بالمعمل أجهزه طبية مكهنة من المستشفيات كوسائل إيضاح للطلبة



**قائمة بالتجارب التي يتم تدريسها بالمعمل:**

- تركيب وتشغيل وصيانة جهاز رسم القلب
- تركيب وتشغيل وصيانة جهاز رسم العضلات
- تركيب وتشغيل وصيانة جهاز رسم المخ
- تركيب وتشغيل وصيانة جهاز الموجات فوق صوتية (السونار)
- تركيب وتشغيل وصيانة جهاز التنفس الصناعي
- تركيب وتشغيل وصيانة شاشة عرض المؤشرات الحيوية للمريض
- الطباعة ثلاثية الابعاد
- تجارب متنوعة على الاجهزة الطبية

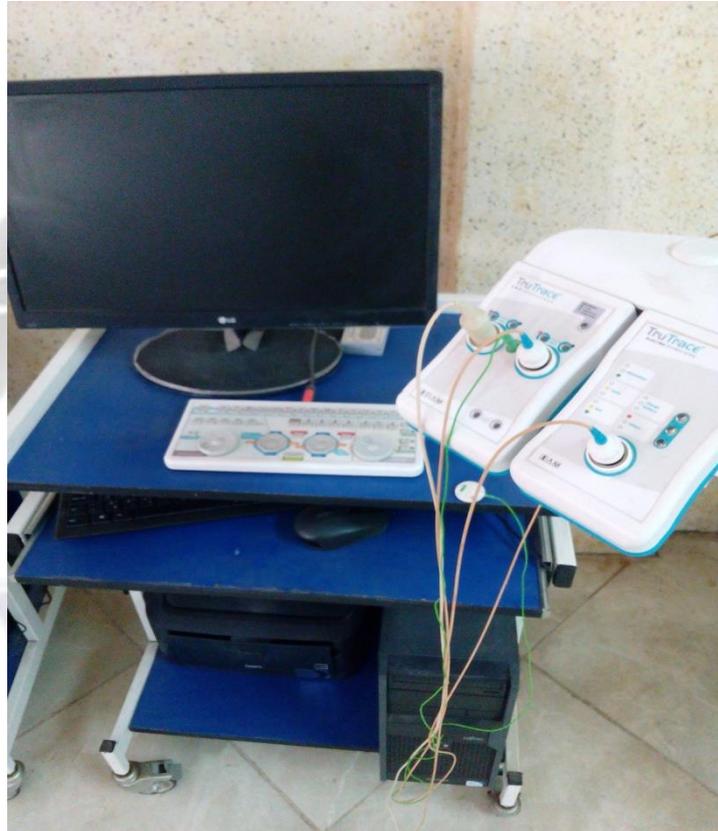
## غرف وأجهزة المعمل:





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## صور من غرفة الطباعة ثلاثية الابعاد ومعرض مشاريع التخرج





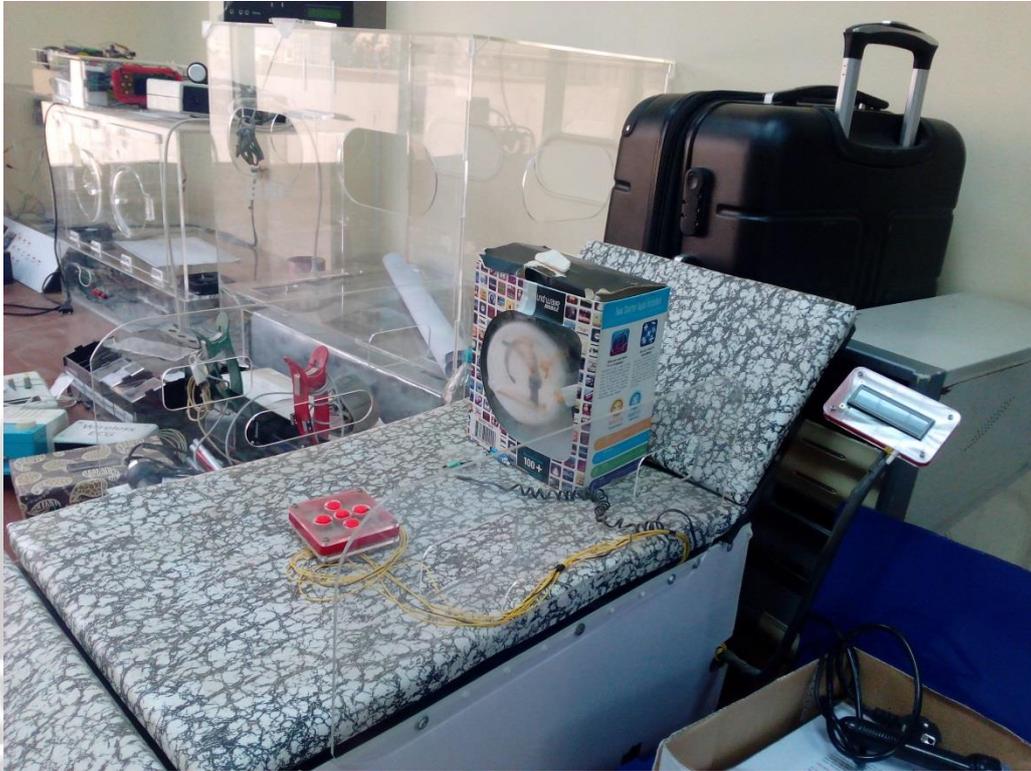


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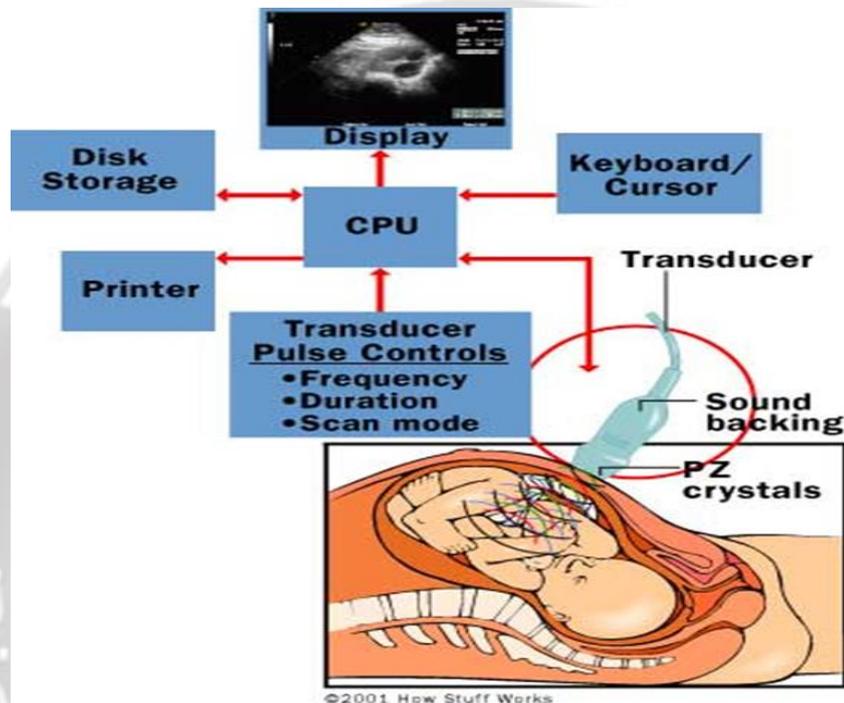
# Experiment (1): How to Use Ultrasound Machine: What Does It Consist Of & How Does It Work?

Ultrasound machine is a special medical device used in ultrasonography for diagnostic and therapeutic purposes. Ultrasonography, commonly known as ultrasound, is a popular medical imaging technique used in physical therapy and diagnostics, and which uses high-frequency sound pulses and their echoes to specific body regions. Ultrasonic waves are specifically helpful in visualizing or imaging subcutaneous or internal body structures including muscles, tendons, vessels, joints or internal organs for any pathology or lesions.

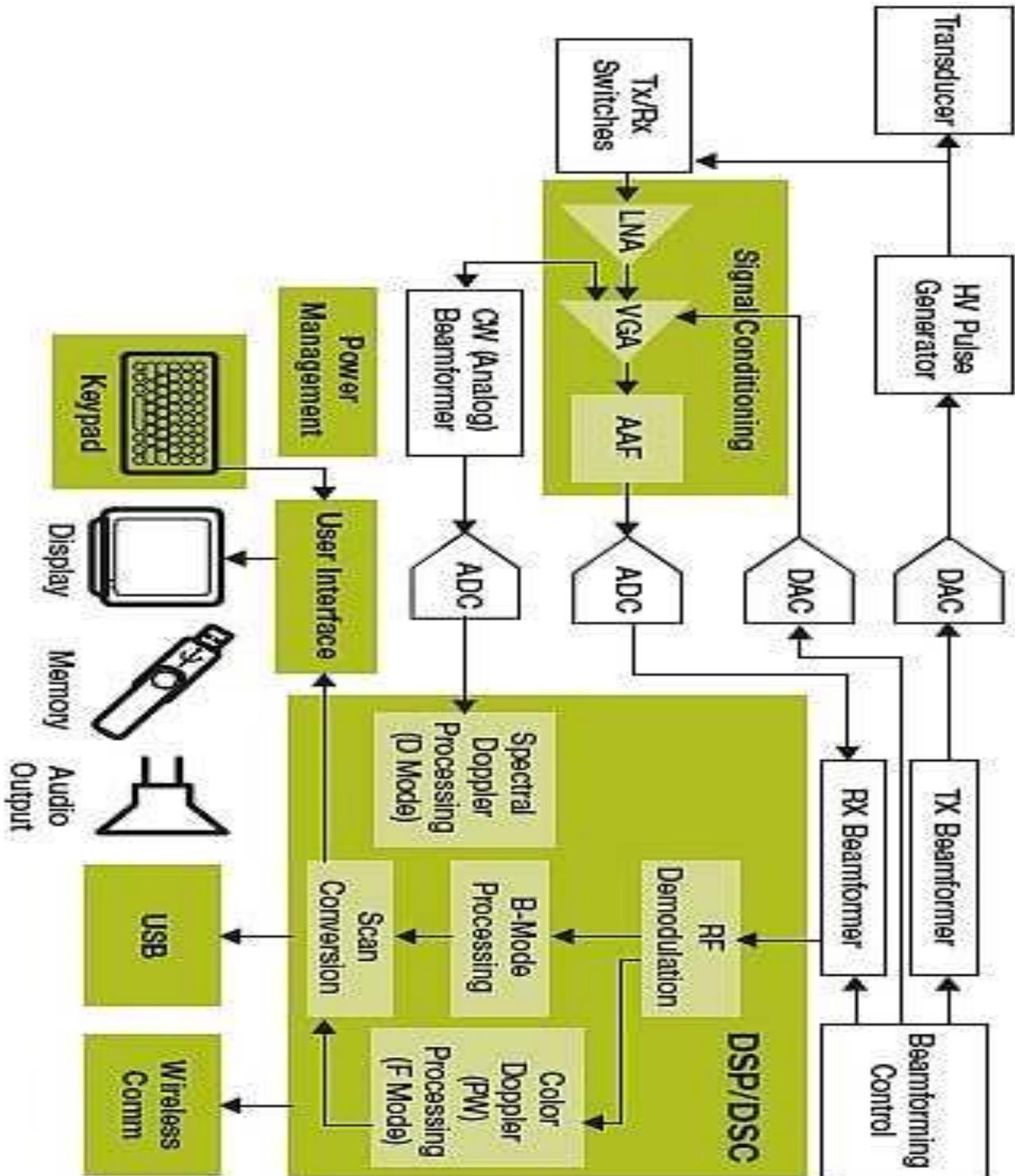


Ultrasound machine is constantly becoming very popular for its diagnostic and therapeutic qualities. It doesn't matter whether you're pregnant and your obstetrician would like to monitor a developing fetus or determine the due date, or you're experiencing blood circulation problems in your limb or heart and your physician needs to check your blood flow, ultrasound is always at your service. Ultrasound machines are successfully helping patients in reducing pain and improving the healing process, such as generating heat deep into muscles or breaking up minor calcifications and bruises by creating localized vibrations, increasing nutrients & oxygen and reducing swelling.

**A basic ultrasound machine consists of the following parts:**



- **transducer probe** - probe that sends and receives the sound waves
- **central processing unit (CPU)** - computer that does all of the calculations and contains the electrical power supplies for itself and the transducer probe
- **transducer pulse controls** - changes the amplitude, frequency and duration of the pulses emitted from the transducer probe
- **display** - displays the image from the ultrasound data processed by the CPU
- **keyboard/cursor** - inputs data and takes measurements from the display
- **disk storage device (hard, floppy, CD)** - stores the acquired images
- **printer** - prints the image from the displayed data



## Transducer Probe

The transducer probe is the main part of the ultrasound machine. The transducer probe makes the sound waves and receives the echoes. It is, so to speak, the mouth and ears of the ultrasound machine. The transducer probe generates and receives sound waves using a principle called the piezoelectric (pressure electricity) effect, which was discovered by Pierre and Jacques Curie in 1880. In the probe, there are one or more



quartz crystals called piezoelectric crystals. When an electric current is applied to these crystals, they change shape rapidly. The rapid shape changes, or vibrations, of the crystals produce sound waves that travel outward. Conversely, when sound or pressure waves hit the crystals, they emit electrical currents. Therefore, the same crystals can be used to send and receive sound waves. The probe also has a sound absorbing substance to eliminate back reflections from the probe itself, and an acoustic lens to help focus the emitted sound waves.

Transducer probes come in many shapes and sizes, as shown in the photo above. The shape of the probe determines its field of view, and the frequency of emitted sound waves determines how deep the sound waves penetrate and the resolution of the image. Transducer probes may contain one or more crystal elements; in multiple-element probes, each crystal has its own circuit. Multiple-element probes have the advantage that the ultrasound beam can be "steered" by changing the timing in which each element gets pulsed; steering the beam is especially important for cardiac ultrasound (see Basic Principles of Ultrasound for details on transducers). In addition to probes that can be moved across the surface of the body, some probes are designed to be inserted through various openings of the



body (vagina, rectum, esophagus) so that they can get closer to the organ being examined (uterus, prostate gland, stomach); getting closer to the organ can allow for more detailed views.

## **Central Processing Unit (CPU)**

The CPU is the brain of the ultrasound machine. The CPU is basically a computer that contains the microprocessor, memory, amplifiers and power supplies for the microprocessor and transducer probe. The CPU sends electrical currents to the transducer probe to emit sound waves, and also receives the electrical pulses from the probes that were created from the returning echoes. The CPU does all of the calculations involved in processing the data. Once the raw data are processed, the CPU forms the image on the monitor. The CPU can also store the processed data and/or image on disk.

## **Transducer Pulse Controls**

The transducer pulse controls allow the operator, called the ultrasonographer, to set and change the frequency and duration of the ultrasound pulses, as well as the scan mode of the machine. The commands from the operator are translated into changing electric currents that are applied to the piezoelectric crystals in the transducer probe.

## **Display**

The display is a computer monitor that shows the processed data from the CPU. Displays can be black-and-white or color, depending upon the model of the ultrasound machine.

## **Keyboard/Cursor**

Ultrasound machines have a keyboard and a cursor, such as a trackball, built in. These devices allow the operator to add notes to and take measurements from the data.

## Disk Storage

The processed data and/ or images can be stored on disk. The disks can be hard disks, floppy disks, compact discs (CDs) or digital video discs (DVDs). Typically, a patient's ultrasound scans are stored on a floppy disk and archived with the patient's medical records.

## Printers

Many ultrasound machines have thermal printers that can be used to capture a hard copy of the image from the display.

**If you're about to use an ultrasound machine, remember the following steps and procedures to be followed:**

- remove clothes or bandages that may impede ultrasonic waves from penetrating into the afflicted tissue or organ;
- apply hypo-allergic gel & anti-inflammatory cream to the area to be treated;
- turn on the ultrasound unit (place the transducer probe on the gel and work it in circular motion for 5-10 minutes):
  1. the machine uses a transducer probe for transmitting high-frequency sound waves into the patient's body;

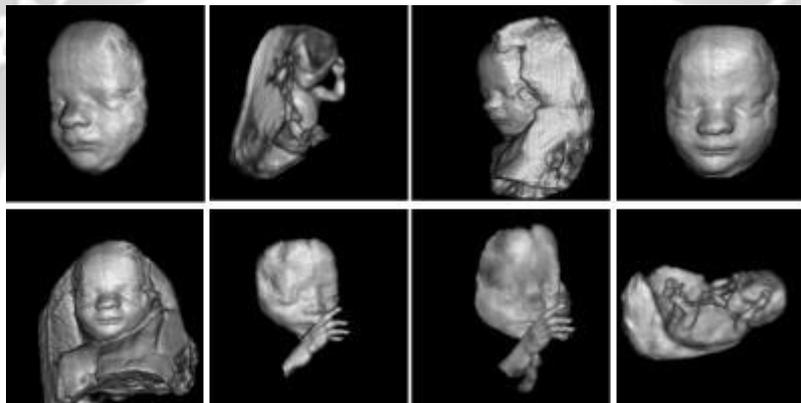


2. sound pulses travel into the patient's body and hit a boundary between tissues;
  3. some sound waves will get reflected from the boundary back to the probe, while others continue to travel until another boundary is reached and then they get reflected as well;
  4. the transducer picks up the reflected sound pulses and relays them to the machine;
  5. the ultrasound machine uses the sound speed in tissue and each echo's return time to calculate the distance from the probe to the organ or tissue;
  6. the ultrasound unit forms a two-dimensional image, which is a display of the distances and intensities of the echoes;
- turn the ultrasound off & wipe the hypo-allergenic gel away.



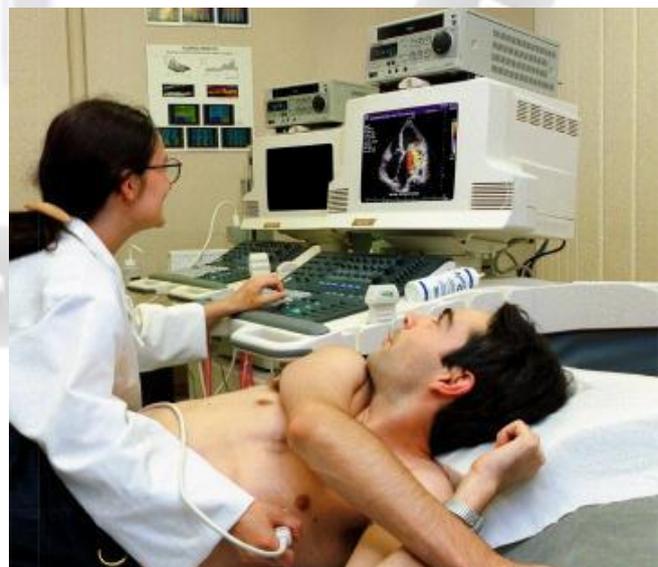
### 3D Ultrasound Imaging

In the past two years, ultrasound machines capable of three-dimensional imaging have been developed. In these machines, several two-dimensional images are acquired by moving the probes across the body surface or rotating inserted probes. The two-dimensional scans are then combined by specialized computer software to form 3D images.



### Doppler Ultrasound

Doppler ultrasound is based upon the **Doppler Effect**. When the object reflecting the ultrasound waves is moving, it changes the frequency of the echoes, creating a higher frequency if it is moving toward the probe and a lower frequency if it is moving away from the probe. How much the frequency is changed depends upon how fast the object is moving. Doppler ultrasound measures the change in frequency of the echoes to calculate how fast an object is moving. Doppler ultrasound has been used mostly to measure the rate of blood flow through the heart and major arteries.





## Major Uses of Ultrasound

Ultrasound has been used in a variety of clinical settings, including obstetrics and gynecology, cardiology and cancer detection. The main advantage of ultrasound is that certain structures can be observed without using radiation. Ultrasound can also be done much faster than X-rays or other radiographic techniques. Here is a short list of some uses for ultrasound:

- **Obstetrics and Gynecology**
  - measuring the size of the fetus to determine the due date
  - determining the position of the fetus to see if it is in the normal head down position or breech
  - checking the position of the placenta to see if it is improperly developing over the opening to the uterus (cervix)
  - seeing the number of fetuses in the uterus
  - checking the sex of the baby (if the genital area can be clearly seen)
  - checking the fetus's growth rate by making many measurements over time
  - detecting ectopic pregnancy, the life-threatening situation in which the baby is implanted in the mother's Fallopian tubes instead of in the uterus
  - determining whether there is an appropriate amount of amniotic fluid cushioning the baby
  - monitoring the baby during specialized procedures - ultrasound has been helpful in seeing and avoiding the baby during amniocentesis (sampling of the amniotic fluid with a needle for genetic testing). Years ago, doctors use to perform this procedure blindly; however, with accompanying use of ultrasound, the risks of this procedure have dropped dramatically.
  - seeing tumors of the ovary and breast
- **Cardiology**
  - seeing the inside of the heart to identify abnormal structures or functions
  - measuring blood flow through the heart and major blood vessels
- **Urology**
  - measuring blood flow through the kidney
    - seeing kidney stones
    - detecting prostate cancer early.

## Experiment (2):

# How to Use EMG Machine: What Does It Consist Of & How Does It Work?

EMG (electromyography) records the movement of our muscles. It is based on the simple fact that whenever a muscle contracts, a burst of electric activity is generated which propagates through adjacent tissue and bone and can be recorded from neighboring skin areas.

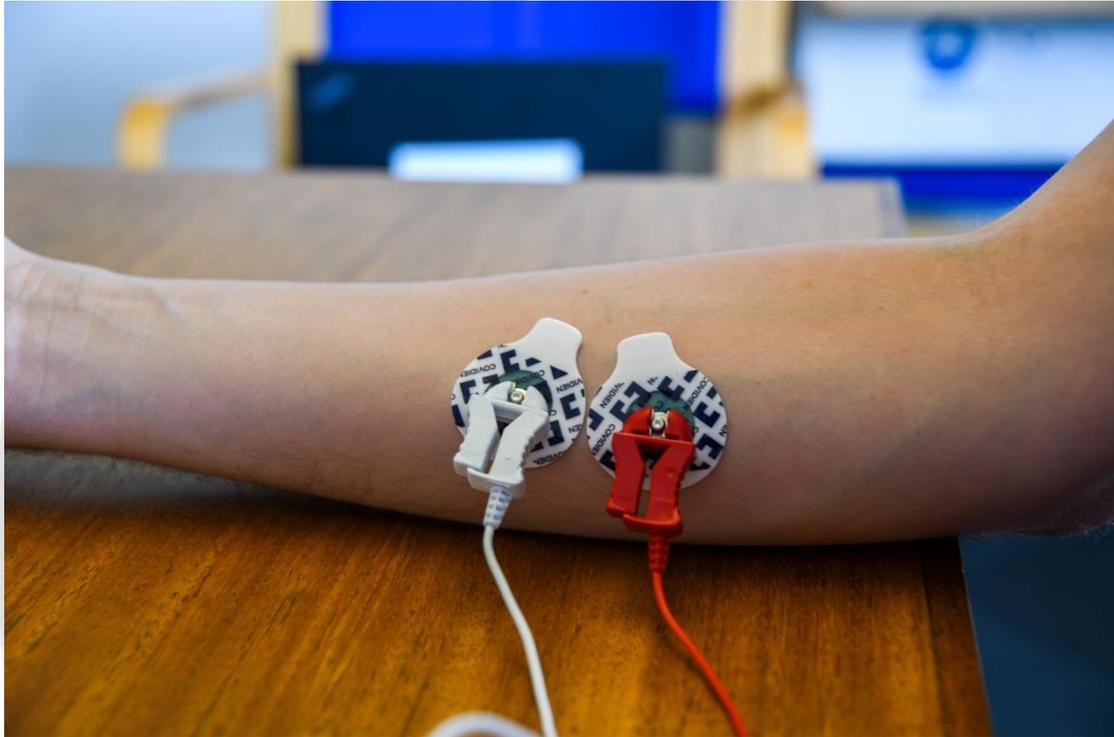


### How do muscles move?

The process of course begins in the brain. Triggering muscle movements begins in the motor cortex, where neural activity (a series of action potentials) signals to the spinal cord, and the information about the movement is conveyed to the relevant muscle via motor neurons. This begins with upper motor neurons, that carry the signal to lower motor neurons.

The lower motor neurons are the actual instigators of muscle movement, as they innervate the muscle directly at the neuromuscular junction. This innervation causes the release of Calcium ions within the muscle, ultimately creating a mechanical change in the tension of the muscle [1,2]. As this process involves depolarization (a change in the

electrochemical gradient), the difference in current can be detected by EMG.



### **What information does EMG provide?**

As EMG activity (measured in microvolts) is linearly related to the amount of muscle contraction as well as the number of contracted muscles – or in other words, the stronger the muscle contraction and the higher the number of activated muscles, the higher the recorded voltage amplitude will be.

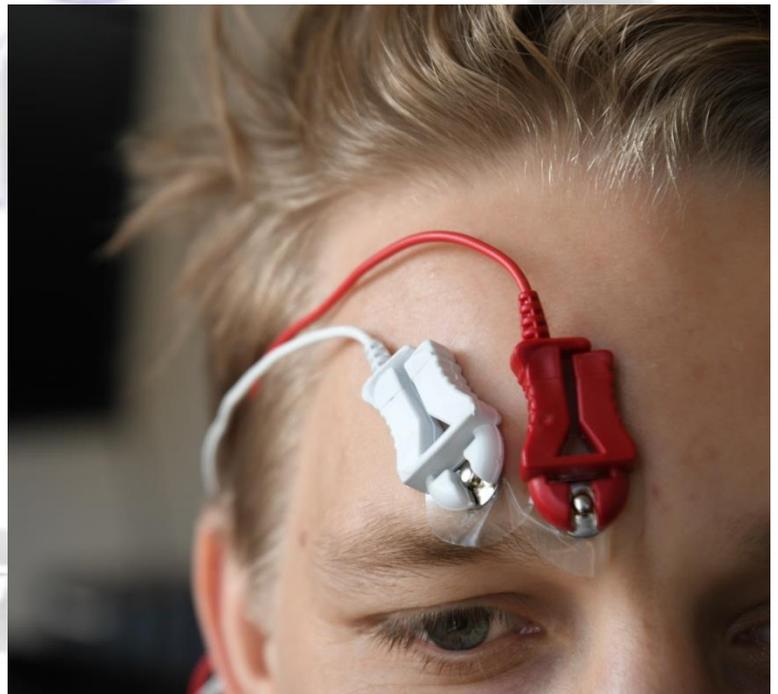
As EMG activity is even measurable when we do not display obvious actions or even inhibit certain behaviors, EMG recordings represent an additional source of information into cognitive-behavioral processing which would be hidden based on pure observation.

Previous research indicates a close coupling between muscular EMG and motor cortex EEG as reflected by significant correlations in signal features such as frequency power and phase in the (12 – 25 Hz) beta band . This emphasizes the power of EMG recordings for monitoring the interaction of cortical and motor systems.

While EMG is clearly helpful in understanding how people move, the use of fEMG (facial electromyography, in which EMG signals are recorded from the muscles of the face), can also provide information about facial expressions.

## Facial electromyography

The particular strength of fEMG as compared to automated or manual facial expression analysis (that is based on the analysis of video recordings), is the sensitivity it has in detecting signals. While more difficult to set up than video recordings, the data it provides is more robust. It can even detect the non-visible muscular activity of the face, providing information about suppressed expressions, or those that otherwise do not pass the threshold for visible activity.

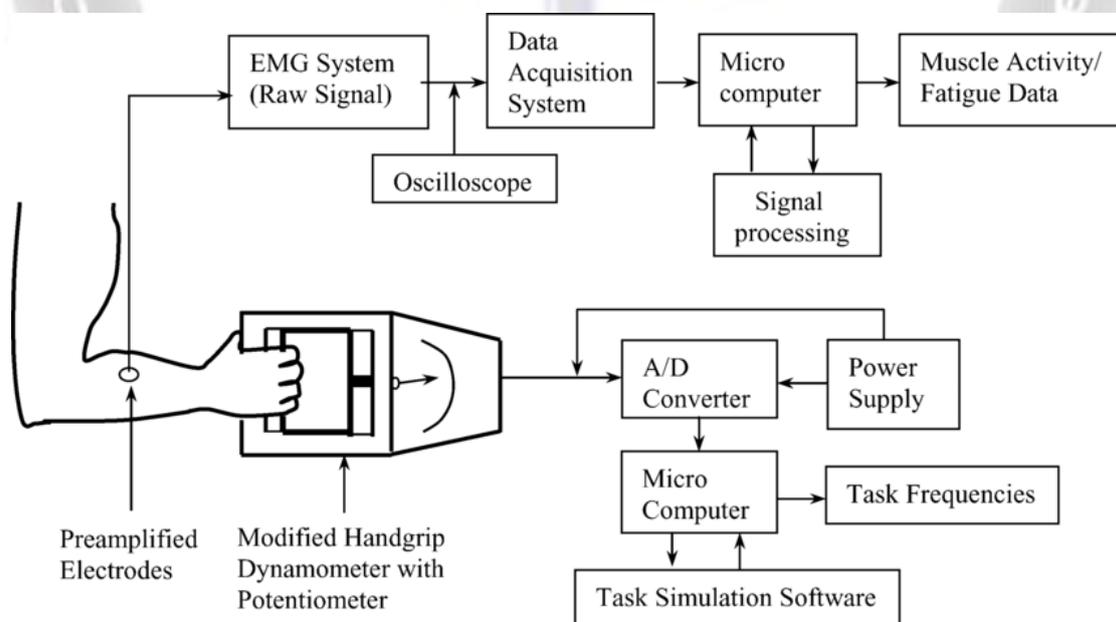
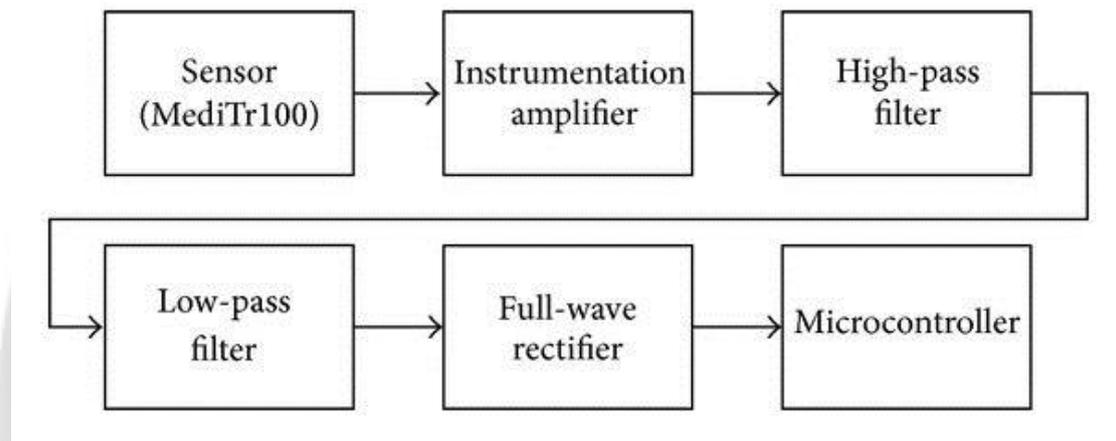


This sensitivity is instrumental in understanding the hidden (intentionally or not) facial expressions that can be linked to an internal emotional state , allowing a window to see how someone is implicitly feeling.

This process can be made even more powerful if complemented with other measures of human behavior, such as eye tracking or GSR (galvanic

skin response), allowing you to see where someone looks, and their level of emotional arousal, as well as the direction of those emotions.

**A basic EMG machine consists of the following parts:**





## How to get started with EMG

- Use surface electrodes
  - Surface EMG is a completely non-invasive technology that allows you to easily place EMG electrodes with stickers to the skin.
  - As these electrodes are non-invasive, EMG is an ideal method for monitoring physiological processes without interfering established routines and movement patterns.
  - In order to obtain high-quality data, keep in mind to always clean the recording sites and remove makeup using alcohol rubs.
- Place EMG electrodes over muscle groups of interest
  - Admittedly, this requires a certain level of anatomic knowledge. Only if you know the muscle regimes involved in a specific action you will be able to get valid and reliable signals.
  - Facial EMG recordings, for example, are complicated by the fact that there are 43 muscles in the face. Most of these are controlled by the seventh cranial nerve (the “facial nerve”), which routes from the cerebral cortex to five primary branches (temporal, zygomatic, buccal, mandibular and cervical).
  - Each branch innervates muscles in different face areas, allowing for intricate facial twists and contortions.
- Select an appropriate reference site
  - EMG data is collected as the voltage difference between recording site and reference site, therefore selecting an appropriate reference site is as important as the actual recording site.
  - We recommend placing EMG reference channels at bony body parts such as an elbow, hip or collar bones.
- Use short electrode cables/leads
  - In order to minimize the amount of electrical noise picked up from surrounding power sources, keep the length of the cables that connect the recording electrodes with the amplifier/recording device as short as possible.

## Experiment (3):

# How to Use ECG Machine: What Does It Consist Of & How Does It Work?

ECG (electrocardiography) is a method of collecting electrical signals generated by the heart. This allows us to understand the level of physiological arousal that someone is experiencing, but it can also be used to better understand someone's psychological state.



Below we'll go through the importance of physiological arousal in emotions, the physiology of the heart, how the activity can be measured, and what parameters are of interest.

### **Emotional Arousal**

When people are asked to identify the cause of an increase in physiological arousal, they often misattribute the source. We might think we understand everything that's going on with our body, but studies show that this is often not the case.

An influential study by Schacter and Singer in 1962 showed how this occurs. Participants were told that their vision would be tested after they were given vitamins. They were instead either given epinephrine (also known as adrenaline), or a placebo drug.



They were then told that the the effects of the drug were the same as epinephrine, or that they might feel some discomfort, or they were told nothing at all.

Epinephrine is known to activate the central nervous system, bringing about such changes as increased heart rate and pupil dilation. The participants were then placed in a waiting room with a confederate (an actor employed by the researchers) of the study who either pretended to be angry, or happy.

The angry or happy conditions were a series of standardized steps (step fifteen of the happy condition: “Stooge replaces the hula hoop and sits down with his feet on the table. Shortly thereafter the experimenter returns to the room.”) that were intended to influence the emotional state of the participant.

The participant then had to complete a questionnaire about how they were feeling. They found that not only was the emotional state of the participant influenced by the apparent emotion of the confederate (and more so in the epinephrine condition), but that the participants also attributed that emotion to events entirely unrelated to the situation they were currently in.

This suggested that participants (and people more generally) are less aware of the malleability of their emotional states, misattributing how they are influenced.

Why do we bring that up? Let’s explain: physiological arousal is related to emotional arousal, yet the reasons for our emotional state can be difficult to know.

With this in mind, monitoring arousal using biosensors presents an objective alternative to the otherwise subjective inferences that participants inevitably make. Heart activity is closely linked to physiological and psychological arousal, making it ideal for understanding our mental states in greater detail.

How can the beat of your heart be recorded and made available for analysis and interpretation? What is ECG exactly? Let's figure this out.

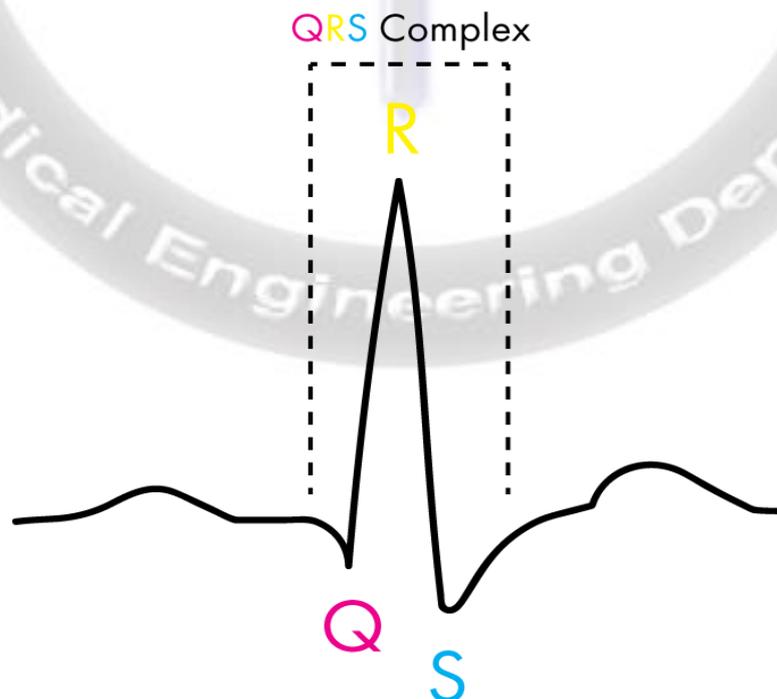
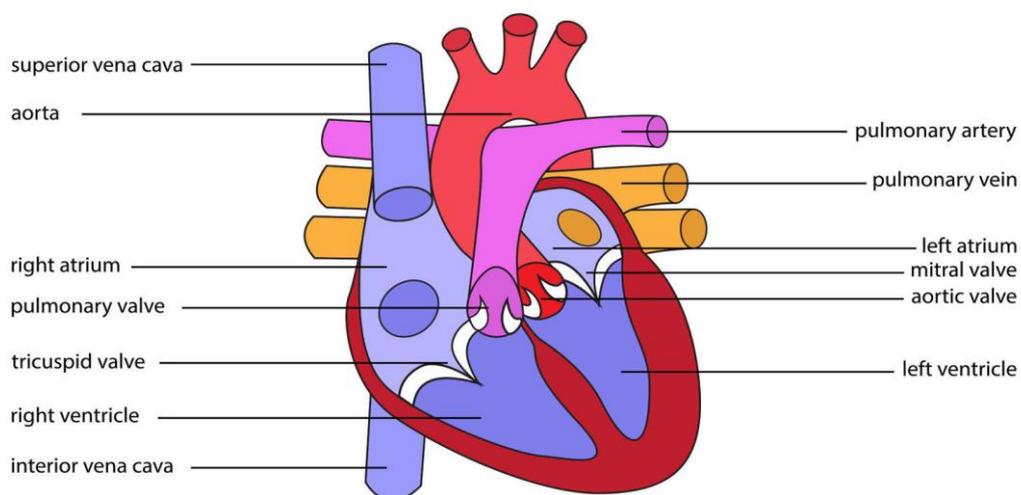


## Physiology and function of the heart

Before we dig deeper into the fundamentals of ECG, let's go through the basics of heart physiology and function:

- The heart has four chambers. The upper two chambers (left/right atria) are entry-points into the heart, while the lower two chambers (left/right ventricles) are contraction chambers that send blood out to the body. The circulation is split into a "loop" through the lungs (pulmonary) and another "loop" through the body (systemic).
- The cardiac cycle refers to a complete heartbeat from its generation to the beginning of the next beat, comprising several stages of filling and emptying of the chambers. The frequency of the cardiac cycle is reflected as heart rate (beats per minute, or bpm).

- The heart operates automatically – it is self-exciting (this is a unique feature compared to other muscles in the body that require nervous stimuli for excitation). The rhythmic contractions of the heart occur spontaneously, but are sensitive to nervous or hormonal influences, particularly to sympathetic (arousing) and parasympathetic (decelerating) activity.



## How to measure heart activity?

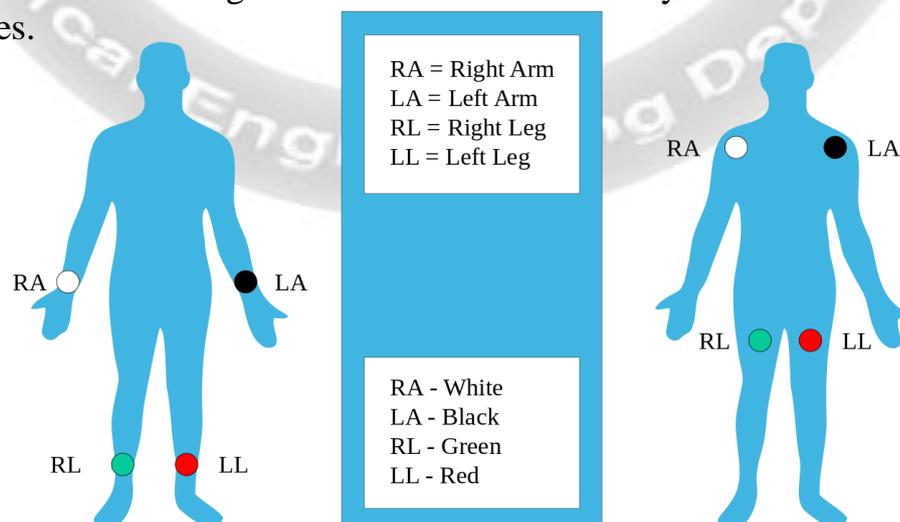
Heart activity can be recorded in two ways:

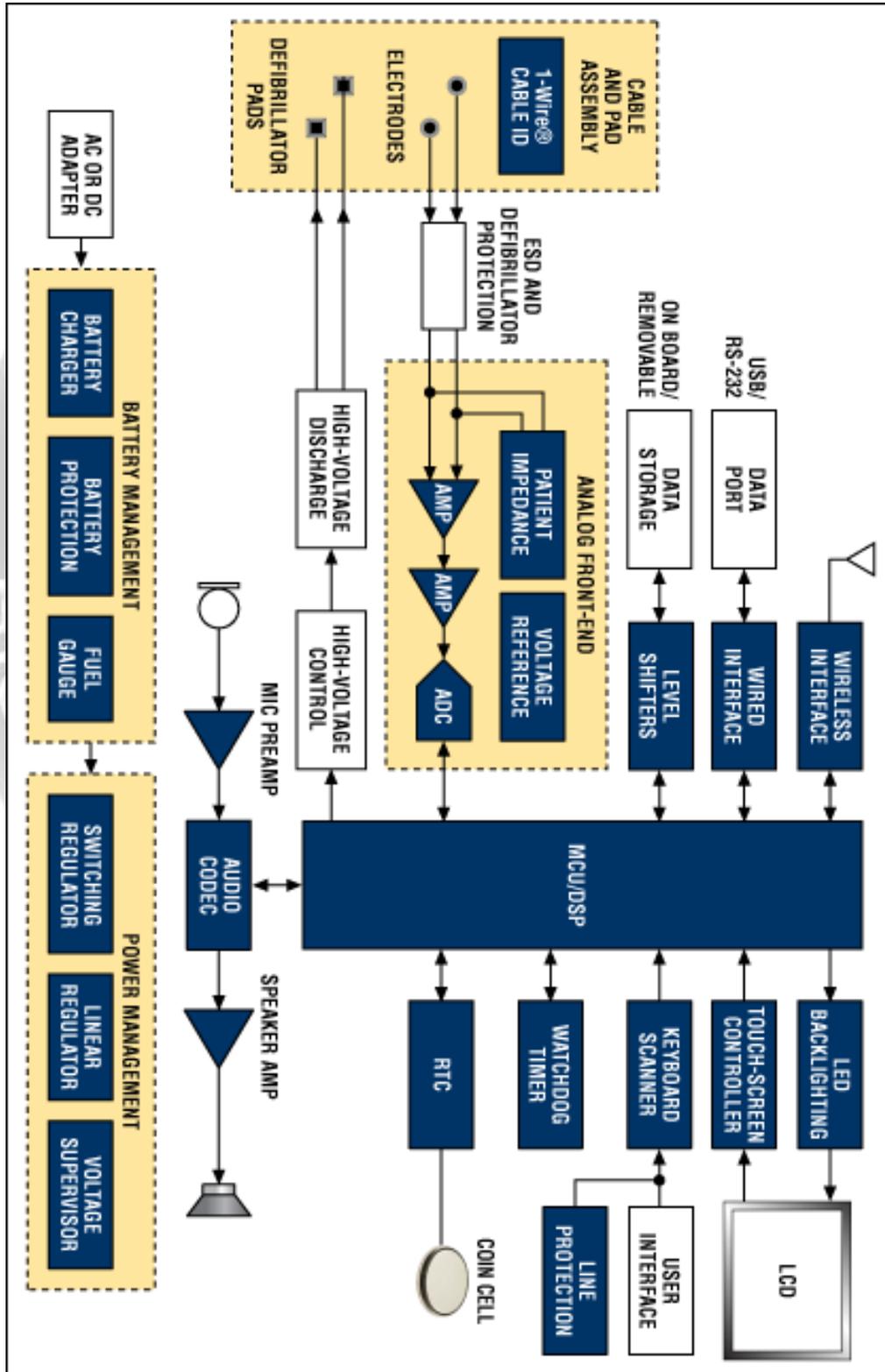
### 1. Electrocardiography (ECG, EKG)

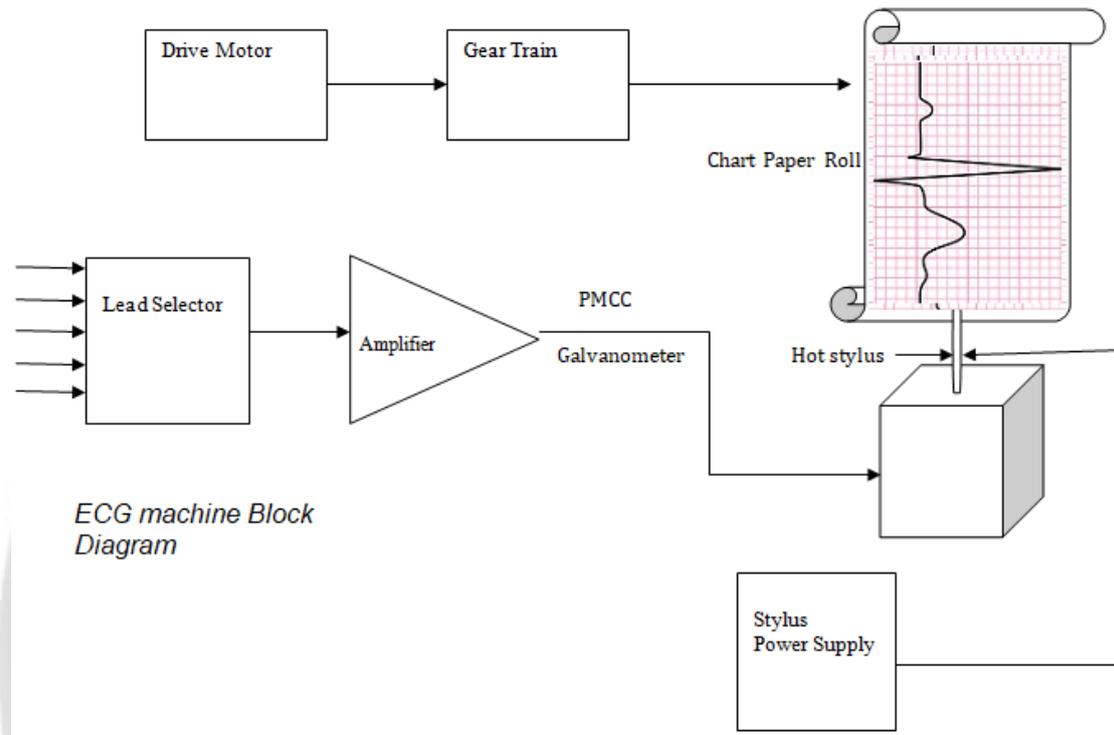
ECG records the electrical activity generated by heart muscle depolarizations, which propagate in pulsating electrical waves towards the skin. Although the electricity amount is in fact very small, it can be picked up reliably with ECG electrodes attached to the skin (in microvolts, or  $\mu\text{V}$ ).



The full ECG setup comprises at least four electrodes which are placed on the chest or at the four extremities according to standard nomenclature (RA = right arm; LA = left arm; RL = right leg; LL = left leg). Of course, variations of this setup exist in order to allow more flexible and less intrusive recordings, for example, by attaching the electrodes to the forearms and legs. ECG electrodes are typically wet sensors, requiring the use of a conductive gel to increase conductivity between skin and electrodes.







## 2. Photo-Plethysmography (PPG).

Throughout the cardiac cycle, blood pressure throughout the body increases and decreases – even in the outer layers and small vessels of the skin. Peripheral blood flow can be measured using optical sensors attached to the fingertip, the ear lobe or other capillary tissue.

The device has an LED that sends light into the tissue and records how much light is either absorbed or reflected to the photodiode (a light-sensitive sensor). PPG clips use dry sensors and can be attached much quicker compared to ECG setups, making the device relatively easy to use, and less bothersome for participants.



## Cardiac parameters of interest

Recording heart rate data gives you access to the following parameters that can be interpreted with respect to a participant's arousal:

**Heart Rate (HR).** HR reflects the frequency of a complete heartbeat from its generation to the beginning of the next beat within a specific time window. It is typically expressed as bpm. HR can be extracted using ECG and PPG sensors.

**Inter-Beat Interval (IBI).** The IBI is the time interval between individual beats of the heart, generally measured in units of milliseconds (ms). Typically, the RR-interval is used for the analysis.

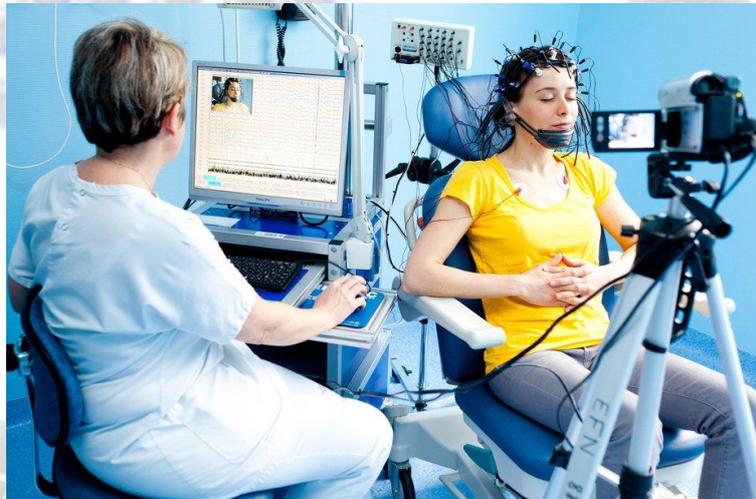
**Heart Rate Variability (HRV).** HRV expresses the natural variation of IBI values from beat to beat. HRV is closely related to emotional arousal: HRV has been found to decrease under conditions of acute time pressure and emotional stress (meaning that the heartbeat is more consistent).

HRV has also been found to be significantly reduced in individuals reporting a greater frequency and duration of daily worry , as well as in patients suffering from post-traumatic stress disorder (PTSD) . For IBI and HRV analysis, ECG sensors are recommended as they are more sensitive to certain signal characteristics which PPG sensors cannot pick up.

## Experiment (4): How to Use EEG Machine: What Does It Consist Of & How Does It Work?

**Electroencephalography**, or EEG, is the physiological method of choice to record the electrical activity generated by the brain via electrodes placed on the scalp surface. For faster application, electrodes are mounted in elastic caps similar to bathing caps, ensuring that the data can be collected from identical scalp positions across all respondents.

Your brain runs the show. Think of the last time you tried to solve a crossword puzzle or started to learn a new language. Recall the last time you woke up in the middle of a weird dream or needed to find your way in a city you have never been before.



As you think, dream, see, and sense, your brain is constantly active, absorbing all information, compacting and re-connecting existing data, and integrating everything into a consistent experience. For you, that experience constitutes your reality.

Your brain is alive. Your brain shapes how you see your environment, filters or highlights objects and information most relevant to you. It creates its own stories based on your thoughts, emotions, desires and experiences, ultimately driving your behavior.

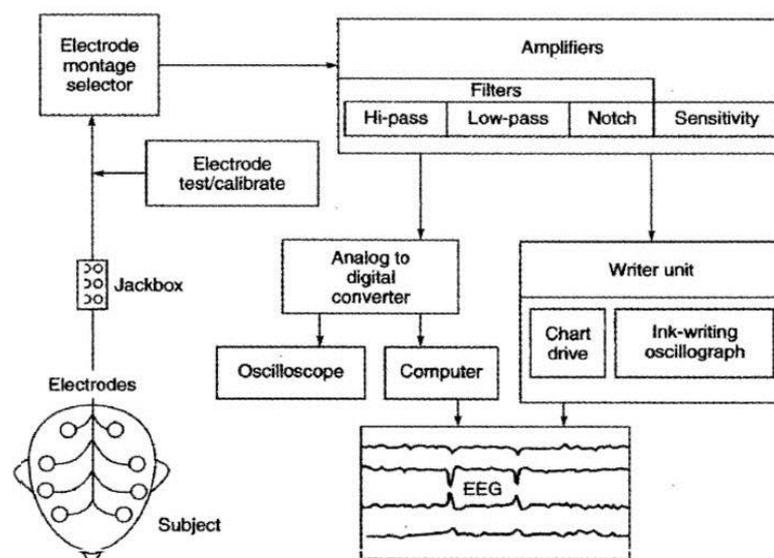
## Electrical activity of the brain

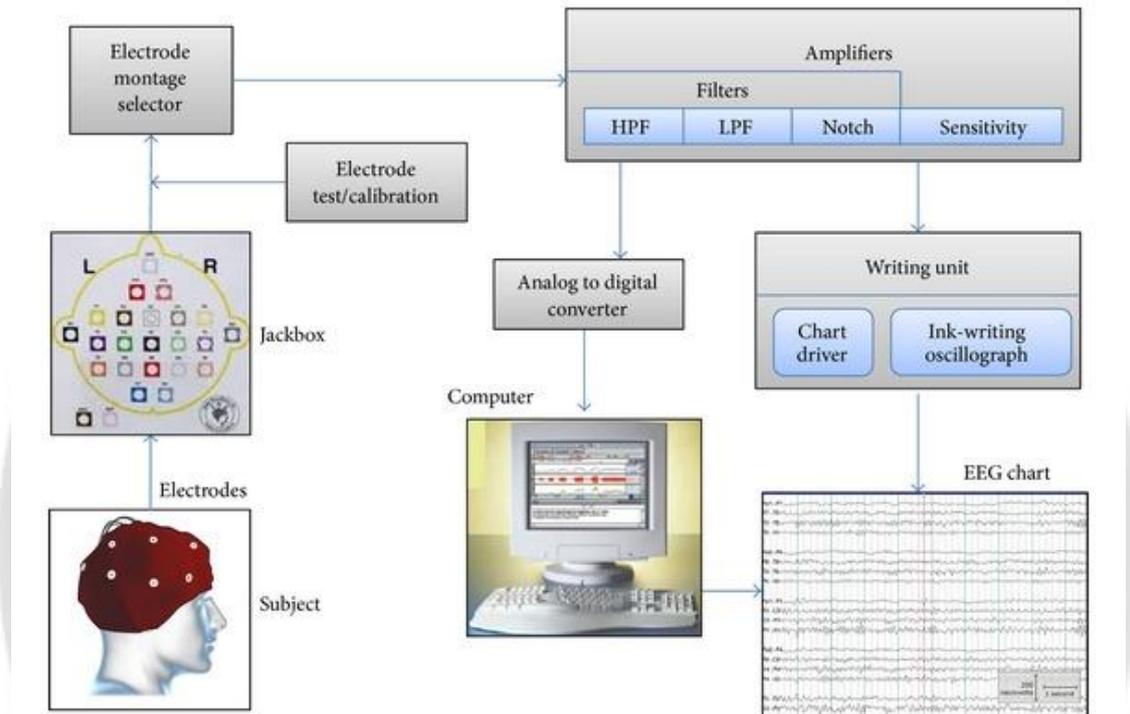
The brain consists of billions of cells, half of which are neurons, half of which help and facilitate the activity of neurons. These neurons are densely interconnected via synapses, which act as gateways of inhibitory or excitatory activity.

Any synaptic activity generates a subtle electrical impulse referred to as a *postsynaptic potential*. Of course, the burst of a single neuron is difficult to reliably detect without direct contact with it. However, whenever thousands of neurons fire in sync, they generate an electrical field which is strong enough to spread through tissue, bone, and skull. Eventually, it can be measured on the head surface.

Think of this as a constant rumble of subtle earthquakes. Taken by itself, each burst might be too small to notice, but if several of them occur at the same time, in the same location, and in the same rhythm, they all add up to a mega-quake that will be noticeable even hundreds

Despite its somewhat daunting name (and pronunciation), grasping the essentials of electroencephalography is surprisingly simple:





### EEG:

- measures electrical activity generated by the synchronized activity of thousands of neurons (in volts)
- provides excellent time resolution, allowing you to detect activity within cortical areas -even at sub-second timescales

As the voltage fluctuations measured at the electrodes are very small, the recorded data is digitized and sent to an amplifier. The amplified data can then be displayed as a sequence of voltage values.

Price differences in EEG systems are typically due to the number of electrodes, the quality of the digitization, the quality of the amplifier, and the number of snapshots the device can take per second (this is the sampling rate in Hz).

EEG is one of the fastest imaging techniques available as it often has a high sampling rate. One hundred years ago the time course of an EEG was plotted on paper. Current systems digitally display the data as a continuous flow of voltages on a screen.

## How can EEG data be interpreted?

As EEG monitors the time course of electrical activity generated by the brain, you can interpret which areas of the cortex are responsible for processing information at a given time:

### 1. Occipital cortex

This part of the brain is primarily responsible for processing visual information. EEG experiments with visual stimuli (videos, images) often focus on effects in occipital regions.

### 2. Parietal cortex

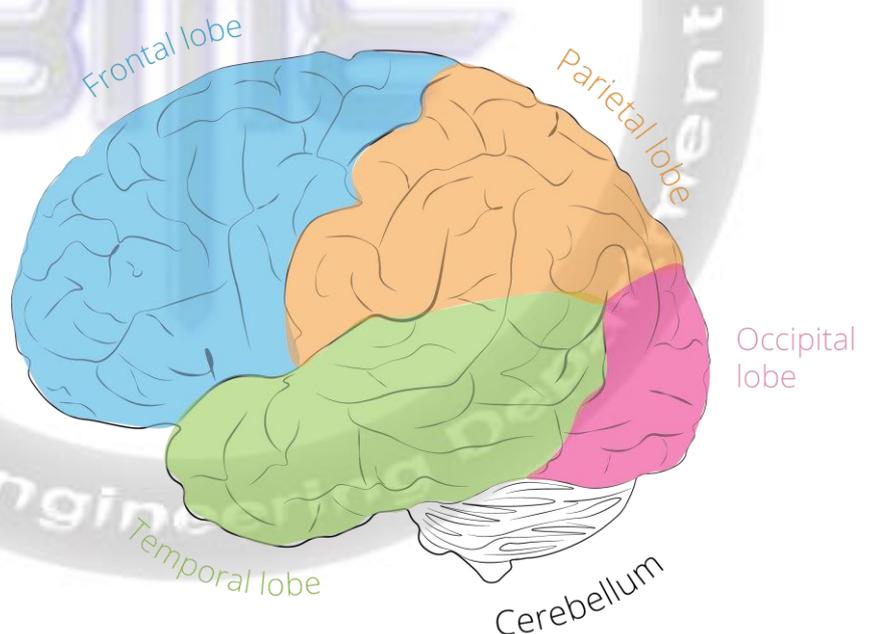
Parietal cortex is primarily responsible for motor functions and is active during self-referential tasks – when we are encountering objects or information that is important to us, for example.

### 3. Temporal cortex

Temporal cortex has lateral aspects which are responsible for language processing and speech production. Medial (inner) regions are more active during spatial navigation.

### 4. Frontal cortex

The frontal part of the human brain is enlarged compared to most other mammals. Basically, the frontal cortex is all about executive function: it helps us maintain control, plan for the future, and monitor our behavior. Apart from the regional characteristics of where certain electrical activity originates, you can also analyze which frequencies primarily drive the ongoing activity.





Whenever your brain is in a certain state, the frequency patterns change, giving insight into cognitive processes.

- **Delta (1 – 4 Hz)** – in sleep labs, delta waves are examined to assess the depth of sleep. The stronger the delta rhythm, the deeper the sleep
- **Theta (4 – 7 Hz)** – theta is associated with a wide range of cognitive processing such as memory encoding and retrieval as well as cognitive workload
- **Alpha (7 – 12 Hz)** – whenever we close our eyes and bring ourselves into a calm state, alpha waves take over. Alpha levels are increased when in a state of relaxed wakefulness.
- **Beta (12 – 30 Hz)**- over motor regions, beta frequencies become stronger as we plan or execute movements of any body part
- **Gamma (>30 Hz, typically 40 Hz)** – Some researchers argue that gamma reflects attentive focusing and serves as carrier frequency to facilitate data exchange between brain regions

Analyzing EEG data can get quite challenging. Signal processing, artifact detection and attenuation, feature extraction, and computation of mental metrics such as workload, engagement, drowsiness, or alertness all require a certain level of expertise and experience to properly identify and extract valuable information from the collected data.



## **Types of EEG**

### **Routine EEG**

A routine EEG recording lasts for about 20 to 40 minutes.

During the test, you'll be asked to rest quietly and open or close your eyes from time to time. In most cases, you'll also be asked to breathe in and out deeply (called hyperventilation) for a few minutes.

At the end of the procedure, a flashing light may be placed nearby to see if this affects your brain activity.

### **Sleep EEG or sleep-deprived EEG**

A sleep EEG is carried out while you're asleep. It may be used if a routine EEG does not give enough information, or to test for sleep disorders.

In some cases, you may be asked to stay awake the night before the test to help ensure you can sleep while it's carried out. This is called a sleep-deprived EEG.

### **Ambulatory EEG**

An ambulatory EEG is where brain activity is recorded throughout the day and night over a period of one or more days. The electrodes will be attached to a small portable EEG recorder that can be clipped onto your clothing.

You can continue with most of your normal daily activities while the recording is being taken, although you'll need to avoid getting the equipment wet.

### **Video telemetry**

Video telemetry, also called video EEG, is a special type of EEG where you're filmed while an EEG recording is taken. This can help provide more information about your brain activity.

The test is usually carried out over a few days while staying in a purpose-built hospital suite.

The EEG signals are transmitted wirelessly to a computer. The video is also recorded by the computer and kept under regular surveillance by trained

## Experiment (5): What is a breathing machine (mechanical ventilator) and what does it do?

Some patients need help to breath. In this situation a “breathing machine” – also known as a mechanical ventilator – is used to assist the function of the lungs.

The ventilator blows air into the lungs, helping to maintain proper levels of oxygen in the blood.

To use a mechanical ventilator, the medical team needs some form of access to the patient’s lungs.

A tube can be inserted into the mouth or nose to reach the lungs. This is called intubation.

Or, a tube can be inserted into the windpipe, medically known as the trachea. The procedure to create an opening in the windpipe is called a tracheostomy.

Mechanical ventilators are complex machines that can be adjusted to meet the needs of each patient.

The most common adjustments will affect how much effort the patient needs to make, and how much oxygen is delivered.

Adjustments are made fairly frequently throughout the day to improve the patient’s comfort level and ensure proper oxygen levels in the blood.

Respiratory therapists and physicians use protocols, or guidelines, to adjust the controls, and they discuss changes and improvements with the team on a daily basis.



A ventilator (VEN-til-a-tor) is a machine that supports breathing. These machines mainly are used in hospitals. Ventilators:

Get oxygen into the lungs. Remove carbon dioxide from the body. (Carbon dioxide is a waste gas that can be toxic.) Help people breathe easier.

Breathe for people who have lost all ability to breathe on their own.

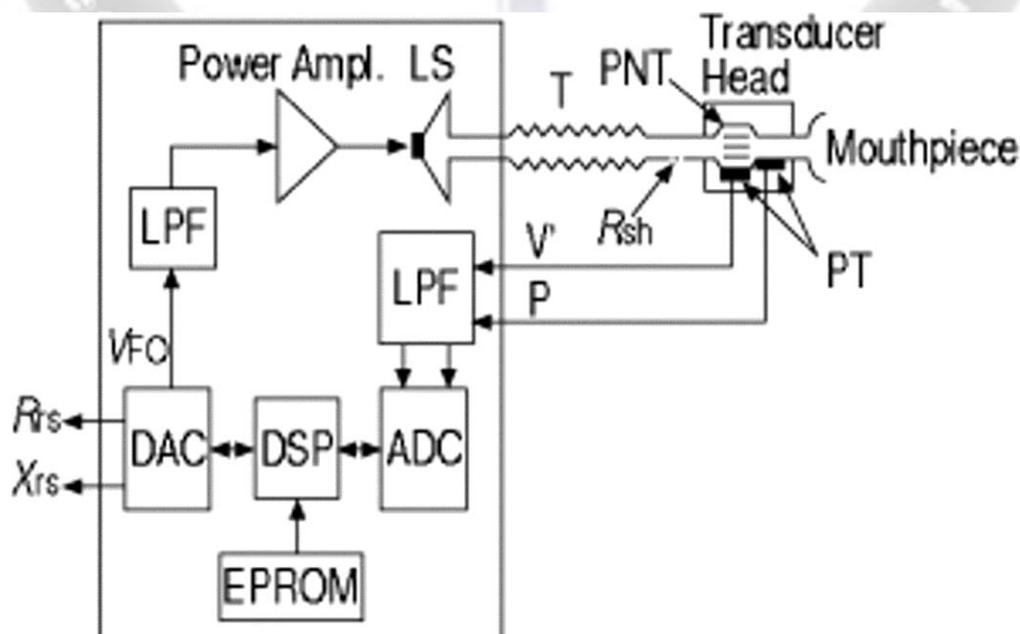
A ventilator often is used for short periods, such as during surgery when you're under general anesthesia (AN-es-THE-ze-ah). The term "anesthesia" refers to a loss of feeling and awareness. General anesthesia temporarily puts you to sleep.

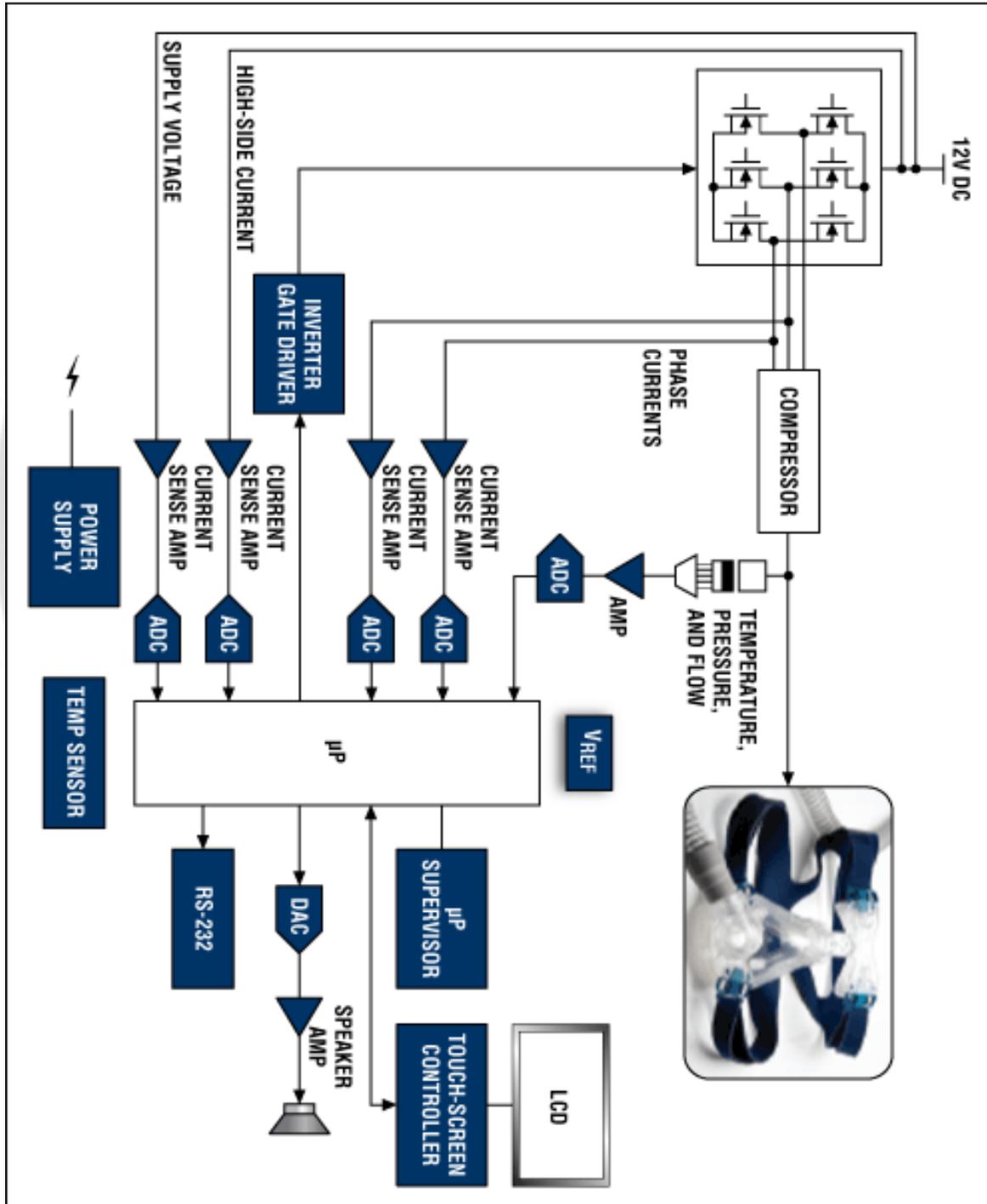
The medicines used to induce anesthesia can disrupt normal breathing. A ventilator helps make sure that you continue breathing during surgery.

A ventilator also may be used during treatment for a serious lung disease or other condition that affects normal breathing.

Some people may need to use ventilators long term or for the rest of their lives. In these cases, the machines can be used outside of the hospital—in long-term care facilities or at home.

A ventilator doesn't treat a disease or condition. It's used only for life support.







## **Other Names- Ventilator/Ventilator Support**

Mechanical ventilator

Respirator

Breathing machine

## **Who Needs a Ventilator?- Ventilator/Ventilator Support**

Ventilators most often are used:

During surgery if you're under anesthesia (that is, if you're given medicine that makes you sleep and/or causes a loss of feeling)

If a disease or condition impairs your lung function

The Ventilator

A ventilator uses pressure to blow air or a mixture of gases (like oxygen and air) into the lungs. This pressure is known as positive pressure. You usually exhale (breathe out) the air on your own, but sometimes the ventilator does this for you too.

A ventilator can be set to "breathe" a set number of times a minute. Sometimes it's set so that you can trigger the machine to blow air into your lungs. But, if you fail to trigger it within a certain amount of time, the machine automatically blows air to keep you breathing.

Rarely, doctors recommend a ventilator called a chest shell. This type of ventilator works like an iron lung—an early ventilator used by many polio patients in the last century. However, the chest shell isn't as bulky and confining as the iron lung.

The chest shell fits snugly to the outside of your chest. A machine creates a vacuum between the shell and the chest wall. This causes your chest to expand, and air is sucked into your lungs. No breathing tube is used with a chest shell.

When the vacuum is released, your chest falls back into place and the air in your lungs comes out. This cycle of vacuum and release is set at a normal breathing rate.



## **What To Expect While on a Ventilator- Ventilator/Ventilator Support**

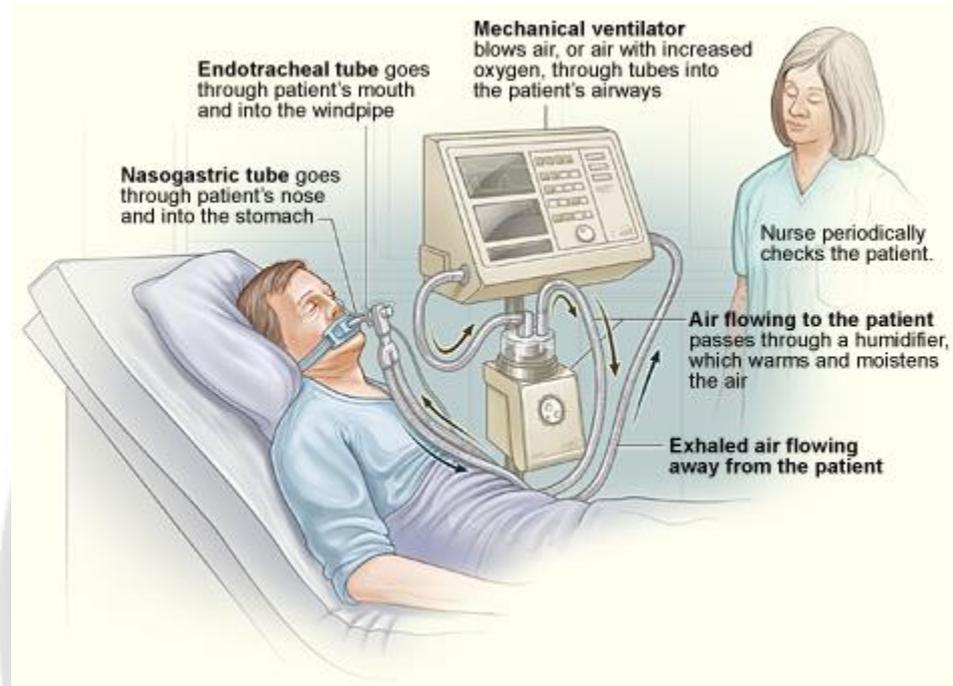
Ventilators normally don't cause pain. The breathing tube in your airway may cause some discomfort. It also affects your ability to talk and eat.

If your breathing tube is a trach tube, you may be able to talk. (A trach tube is put directly into your windpipe through a hole in the front of your neck.)

Instead of food, your health care team may give you nutrients through a tube inserted into a vein. If you're on a ventilator for a long time, you'll likely get food through a nasogastric, or feeding, tube. The tube goes through your nose or mouth or directly into your stomach or small intestine through a surgically made hole.

A ventilator greatly restricts your activity and also limits your movement. You may be able to sit up in bed or in a chair, but you usually can't move around much.

## Patient on a Ventilator



The illustration shows a standard setup for a ventilator in a hospital room. The ventilator pushes warm, moist air (or air with increased oxygen) to the patient. Exhaled air flows away from the patient.

If you need to use a ventilator long term, you may be given a portable machine. This machine allows you to move around and even go outside, although you need to bring your ventilator with you.

Sometimes the ventilator is set so that you can trigger the machine to blow air into your lungs. But, if you fail to trigger it within a certain amount of time, the machine automatically blows air to keep you breathing.

## Experiment (6):

### Patient Monitor

Patient monitors measure, record, distribute and display combinations of biometric values such as heart rate, SPO2, blood pressure, temperature and more. High-capability, multi-function monitors are typically used in hospitals and clinics to ensure a high-level of quality patient care. Portable patient monitors are designed to be compact and power-efficient. This allows them to be used in remote areas or by paramedics to aid diagnosis in the field, enable monitoring and transmitting data to health care providers in other locations.



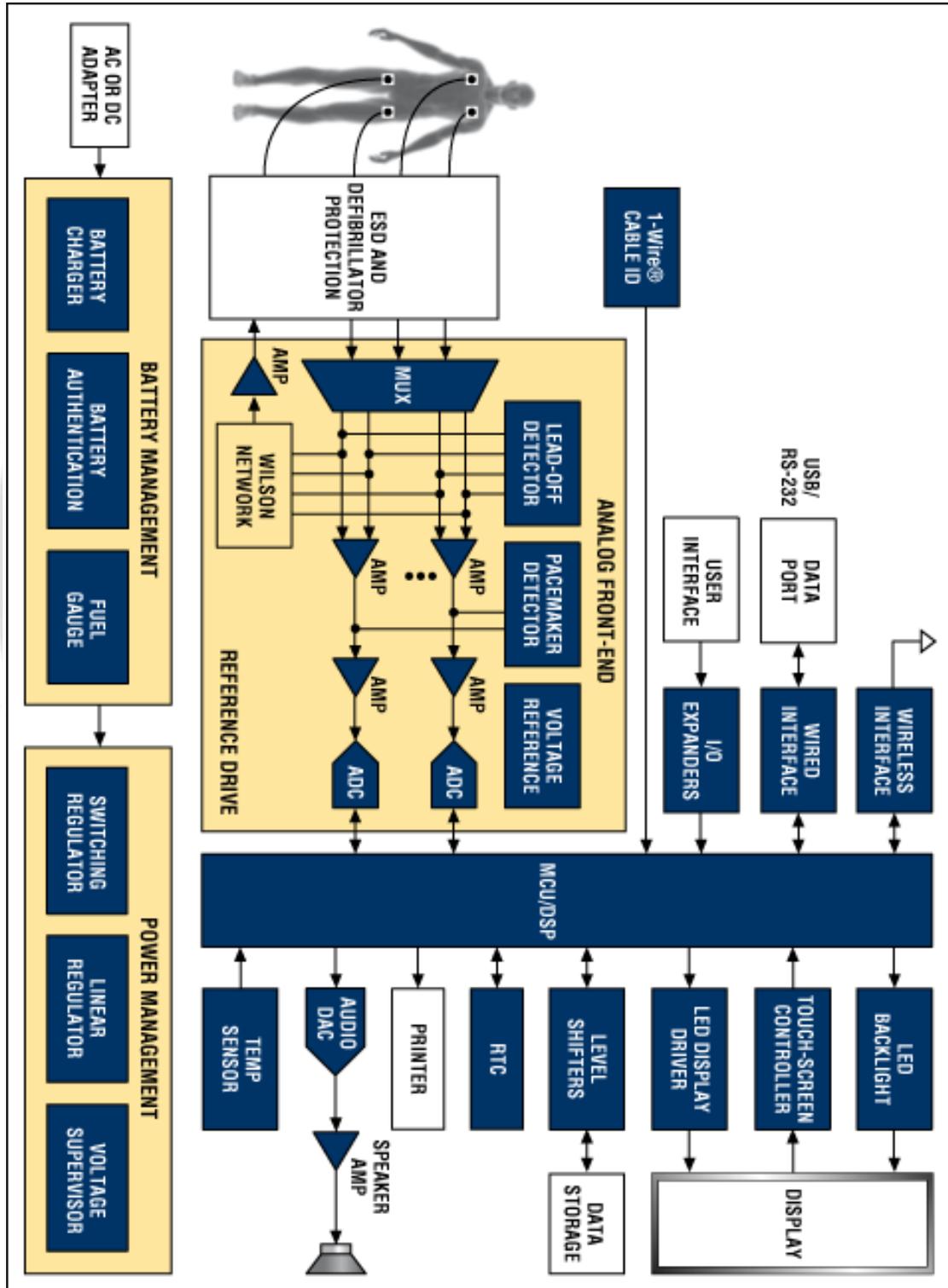
#### How to Read a Vital Signs Monitor

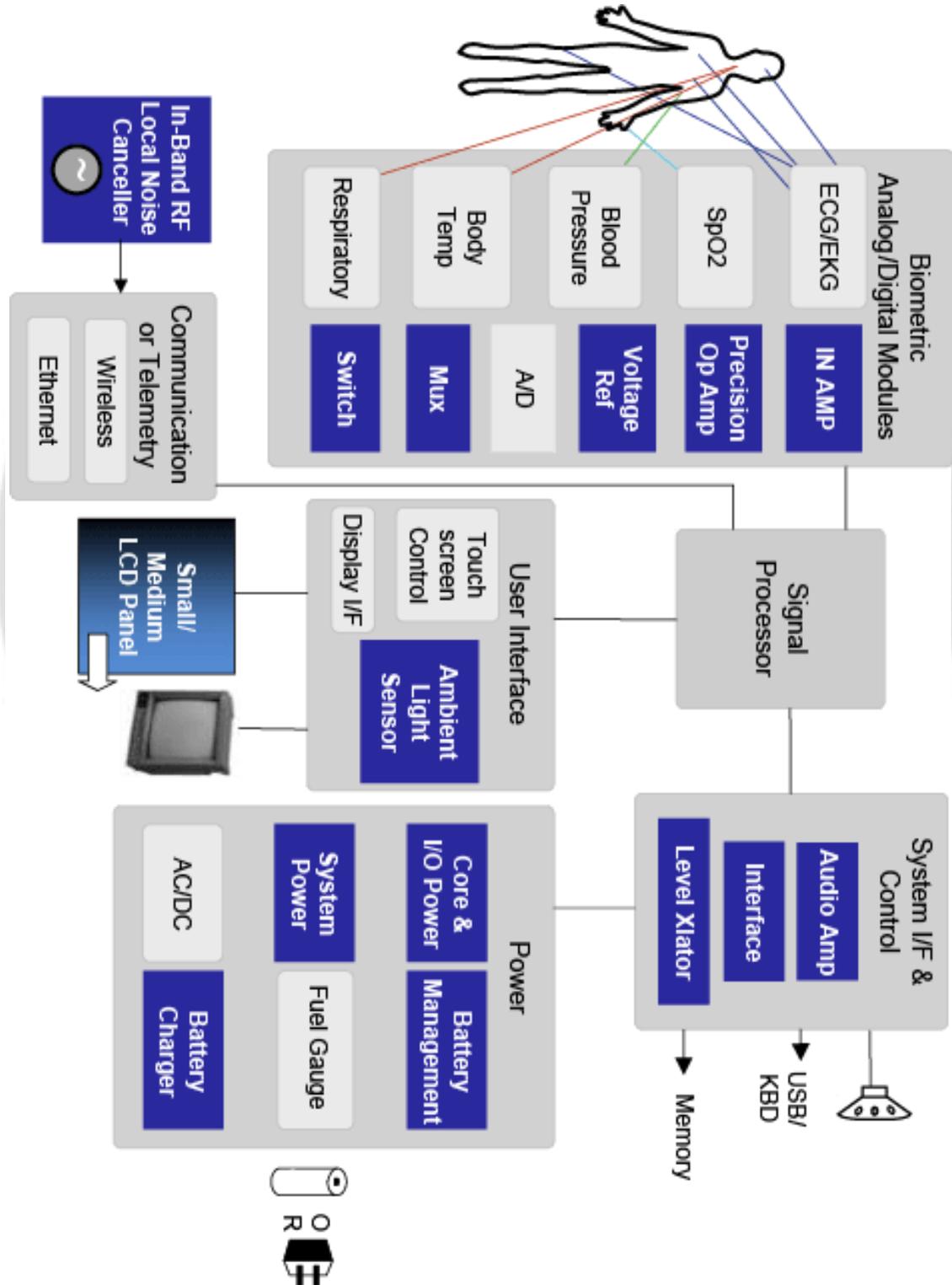
Electronic vital sign monitors have been common in hospitals for more than 40 years. On TV or in movies, they start making noises, and doctors and nurses come running, yelling things like “stat!”

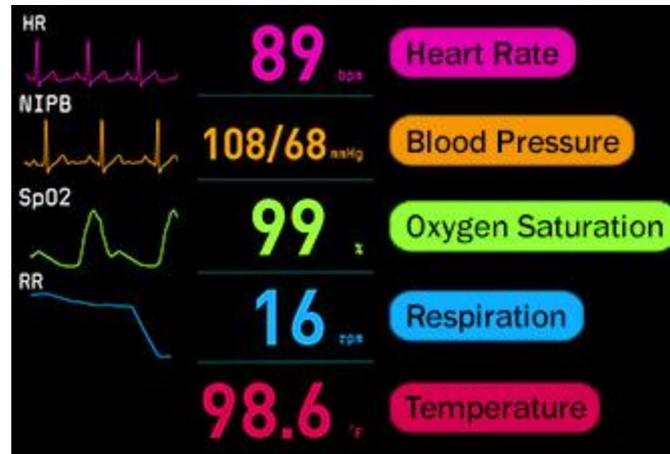
If you or a loved one is in the hospital, you might find yourself paying closer attention to it, wondering what the numbers and beeps mean. Though there are many different makes and models of vital sign monitors, most generally work the same way.

#### How They Work

Small sensors attached to your body carry information to the monitor. Some sensors are patches that stick to your skin, while others may be clipped on one of your fingers. The devices have changed a lot since the first electronic heart monitor was invented in 1949. Many today have touch-screen technology and get information wirelessly.







The most basic monitors show your heart rate, blood pressure, and body temperature. More advanced models also show how much oxygen your blood is carrying or how fast you're breathing. Some can even show how much pressure is on your brain or how much carbon dioxide you're breathing out. The monitor will make certain sounds if any of your vital signs fall below safe levels.

## What the Numbers Mean

**Heart rate:** The hearts of healthy adults typically beat 60 to 100 times a minute. People who are more active can have slower heartrates.

**Blood pressure:** This is a measure of the force on your arteries when your heart is beating (known as systolic pressure) and when it's at rest (diastolic pressure). The first number (systolic) should be between 100 and 130, and the second number (diastolic) should be between 60 and 80.

**Temperature:** Normal body temperature is usually thought to be 98.6 F, but it actually can be anywhere from just under 98 degrees F to a little over 99 without concern.

**Respiration:** A resting adult typically breathes 12 to 16 times a minute.

**Oxygen saturation:** This number measures how much oxygen is in your blood, on a scale up to 100. The number is normally 95 or higher, and anything below 90 means your body may not be getting enough oxygen.

## Experiment (7):

### 3D Printing Basics

A 3D Printer is a manufacturing tool used to create three-dimensional artifacts that have been designed on a computer. 3D printers have a wide range of shapes, sizes, and types, but in essence they are all computer controlled additive manufacturing machines. Similar to how paper printers lay down ink in one layer to create an image, 3D printers lay down or cure material layer by layer to create a three-dimensional object.



3D printers have a huge range of applications; designers use them to test out product ideas, manufacturing companies use them to make complicated parts for assemblies, and makers use them for DIY fabrication for anything they can imagine. Although the different types and uses of 3D printers vary widely, all 3D printers can be simply described as tools; they allow people to make things that they weren't able to make before.



## Step 1: What Is 3D Printing?



3D printers as machines fall under a couple different categories. They are controlled by a computer, making them CNC, or Computer Numerical Controlled, machines. Because of the way that 3D printers work, they are referred to as additive manufacturing machines. Instead of the machine cutting or drilling parts out of a block of raw material to form a certain shape (subtractive manufacturing), 3D printers add material bit by bit to form their work, making them additive manufacturing machines. To sum everything up, this means that 3D printers are machines controlled by computers that add material to create a shape that you tell it to create.



Compared to other CNC industrial machines, 3D printers are inefficient because they take on the scale of hours to make parts, while other machines, like injection molding machines, can produce stronger, more durable parts in minutes. Different 3D printers have different drawbacks and benefits, but most 3D printers produce relatively weak, small parts because of the way the parts are created. So why use 3D printing?

3D printers can be very inexpensive, so they allow anyone who has one to make anything very easily. They let designers go straight from ideas to reality, they allow for rapid iteration on designs, and they can create complicated geometries without much difficulty. In short, with just the push of a button, you can create whatever you imagine.

## Step 2: Rapid Prototyping



Unlike most other CNC machines, 3D printers have very minimal associated setup costs or procedures. 3D printers can be used to produce custom designed parts relatively quickly and cheaply, making 3D printers one of the best rapid prototyping tools. Larger scale manufacturing machines may require precisely machined molds or fixtures for each new part, which means that they have more setup costs and steps required to produce content; they are set up to make hundreds or thousands of specific parts over and over again. Using a 3D printer, a part can be cheaply designed and made, and then its design can be modified, printed, and tested multiple times in rapid succession before the part reaches full scale production.

### Step 3: Intricate Geometries



3D printing is a hands-off manufacturing process; just by pressing a button, whatever you design will be made. Other manufacturing methods, like the drill press, lathe, or milling machine, need to be operated by the maker. The workpiece needs to be aligned, measured, and machined by the user, which introduces human error into the making of the part. 3D printers, because of the way that they create parts, can make many parts with intricate geometries, including natural shapes like prosthetic limbs or animal models, or more complicated shapes like polyhedra or scale building replicas. 3D printers open up a lot of opportunity to makers just because they allow people to make things they feasibly couldn't before.

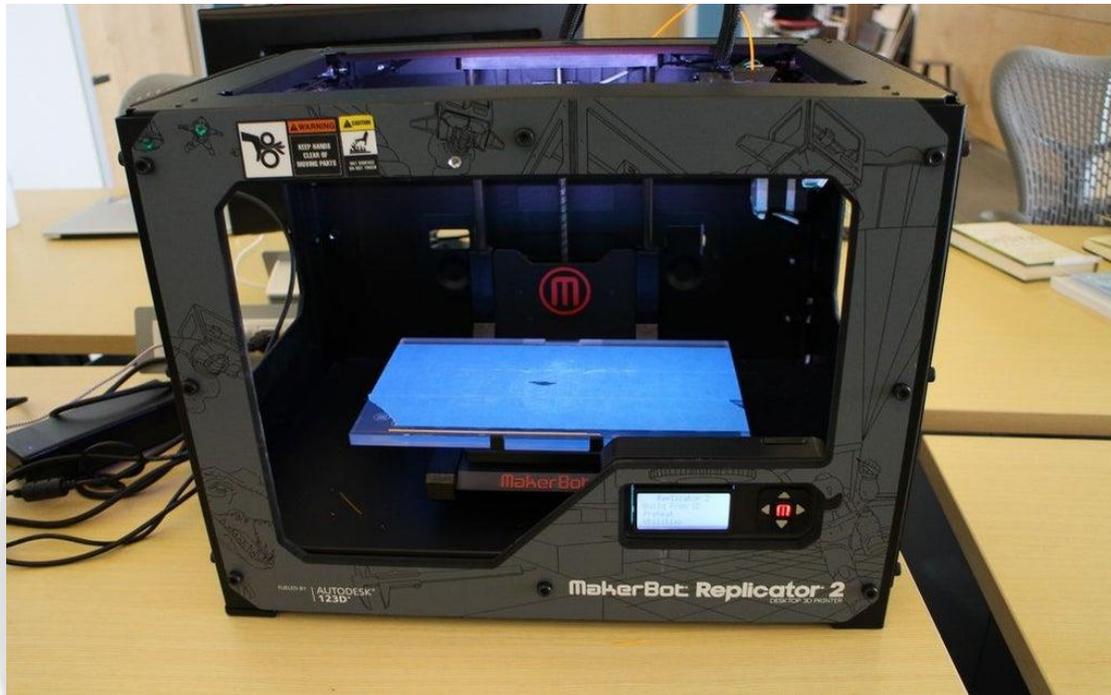
## Step 4: Customized Content

As explained previously, 3D designs can be easily changed on the computer and then re-printed. This means that files can be customized for certain people or things, and printed easily, with no change to the setup of the machine. Being able to create personalized content is valuable for both small-scale manufacturing and for makers, because it allows them to create designs for specific people, or even



produce designs that others give them. Personalized jewelry, custom fit prosthetics, and even 3D scans of people can be printed and modified to suit the end recipient.

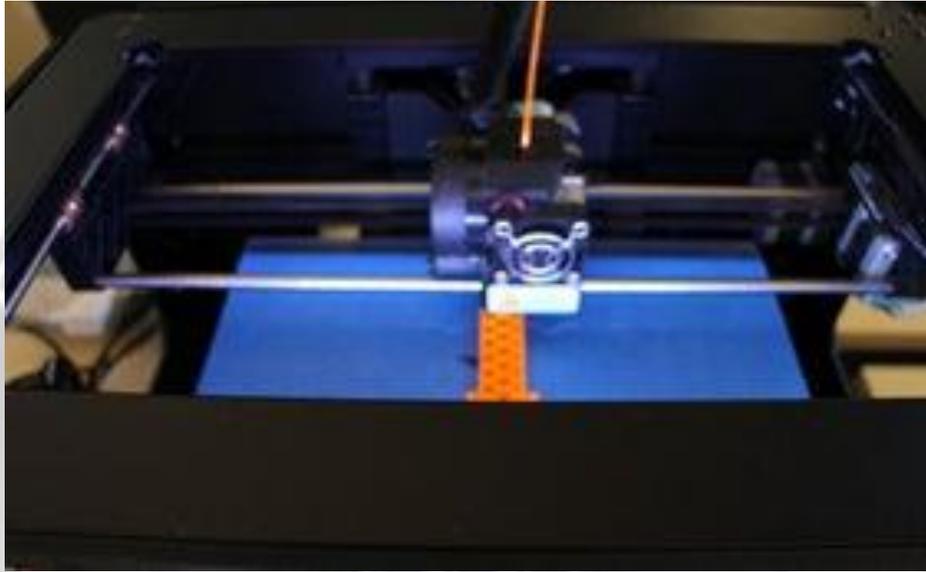
## Step 5: How Does 3D Printing Work?



To understand more specifically how 3D printers work and how to design for them, you'll need to understand the different types of 3D printers on the market. Although the materials and methods with which parts are created varies widely, all 3D printers construct parts by adding material layer by layer, fusing each layer together to make a solid object.

There are a couple different types of 3D printing processes: some are more well suited for larger scale manufacturing, others allow for multiple materials or colors during prints, and some types of printers can even be built fairly easily because of the way that they work. I've included the most common types of 3D printers in this guide, there are a few other types of printers out there, but for the most part they stem from the following four.

## Step 6: Fused Deposition Modeling (FDM)



Fused Deposition Modeling is probably one of the most common types of 3D printing, and it is the easiest to understand. In this type of 3D printing, the material, usually ABS or PLA plastic, is melted down by the printer head and extruded onto the printer bed, similar to how ink is deposited onto a page on a paper printer. The extruder head of the printer lays down material layer by layer to build up a 3D model, and each layer fuses to the previous one as it cools.

FDM printers are very common desktop printers because they are inexpensive and easy to build. Their precision depends upon the quality of the motors that control the position of the extruder head relative to the build platform, and the fineness of the extruder head as it extrudes material. Because the material is built up layer by layer, printed parts tend to be weak along their horizontal cross sections. Additionally, any

overhanging sections of 3D printed parts on FDM printers require support material to hold up the overhang. FDM printers with multiple extruder heads can print in a soluble support material that dissolves when immersed in certain chemicals, while those with single extruders print in a less dense material that can be broken off after the print is complete. Multiple extruder heads also allow FDM printers to print in multiple colors or materials, expanding their capabilities.

### Step 7: Stereolithography (SLA)





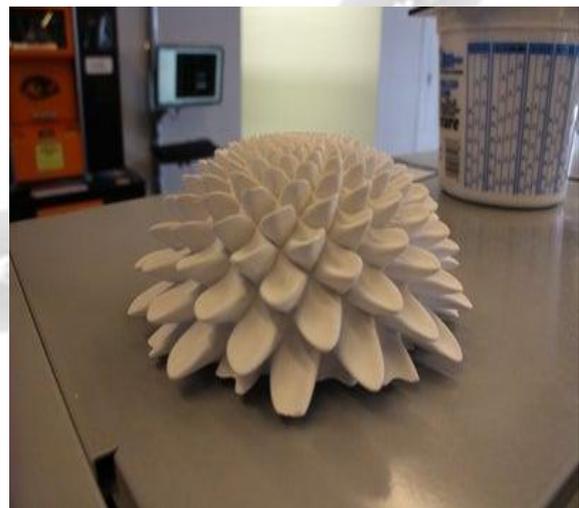
Stereolithography is the oldest 3D printing method, in which a laser is used to solidify liquid resin with ultraviolet light. While FDM printers draw out the layers of filament to form the 3D model, the laser beam on an SLA printer draws out a slice of the part to cure the liquid resin layer by layer, generating the 3D part. While most other 3D printers print from the bottom of the part and work their way up, SLA printers can print from the top down. The laser and resin bath sit at the base of the printer, and the part is fixed to the bottom build platform and is drawn up as it prints.

SLA printers can be very fast and precise because of their nature. However, the resin itself is expensive, and because it is photocurable, needs to be stored in specialized containers. Most resins, when they cure, are usually very brittle, and cannot withstand much force, so SLA printing is usually useful when it comes to prototyping, but not production. Like FDM printers, SLA printers require support structures for printed parts, but their materials are limited because they can only print in cured resin, and cannot print multiple material types at once. However, the precision of SLA printers allows them to print very intricate, delicate structures.

## Step 8: Selective Laser Sintering (SLS)



Selective Laser Sintering is very similar to stereolithography in that a laser is used to solidify material and form a solid shape. The biggest difference between the two technologies is that while SLA printing uses liquid resin, laser sintering cures powdered material. Layers of powder are laid down onto a



print bed, and the particles of each layer are cured by a laser. Selective Laser Sintering is advantageous in that it can support a wide range of materials, including plastics, glass, and some metals.

No support material is needed to print parts on an SLS machine because the parts are immersed in power, so they can be used to create more complicated and precise parts than most other printers. However, they are usually only found in industry as they require high power lasers and can be very expensive.

### Step 9: Laminated Object Manufacturing (LOM)

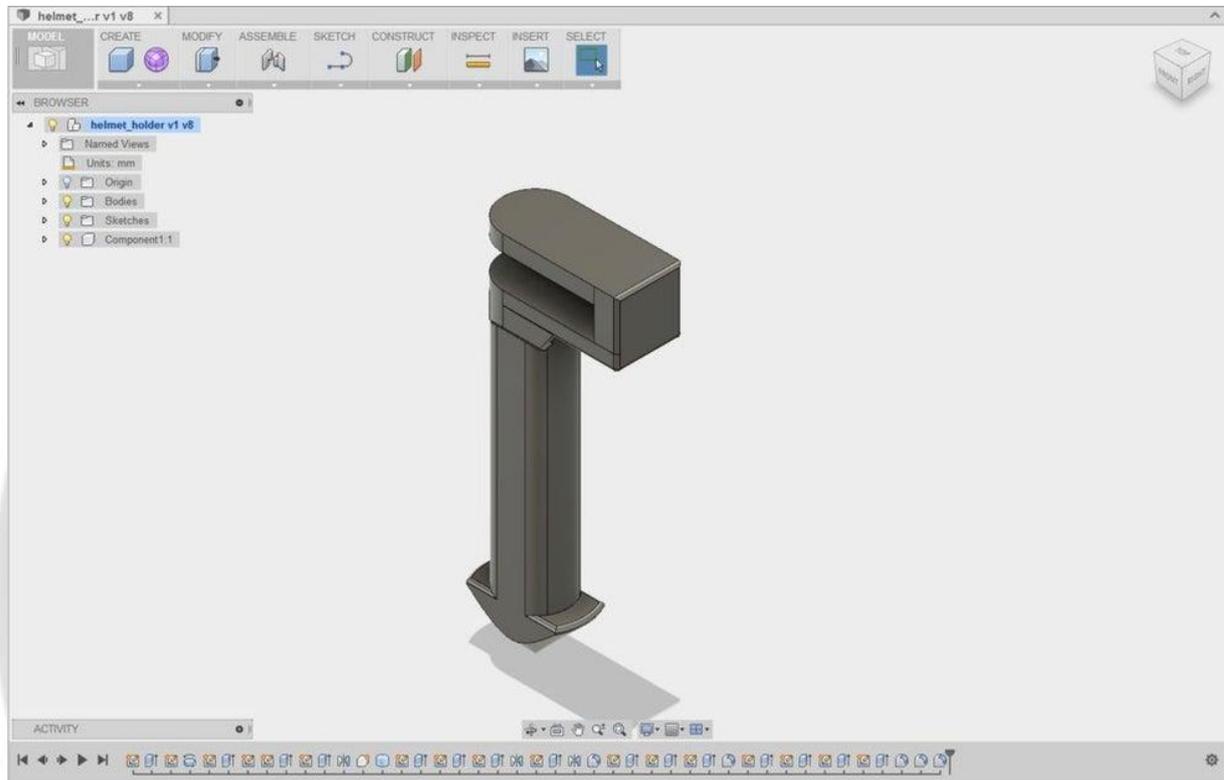


In the Laminated Object Manufacturing process, a laser or knife is used to cut slices of the 3D model out of sheets of material. Each sheet of material is pulled over the previous sheet and cut out by the cutting tool, and then glue is laid down so that the next sheet will adhere to it. The printer thus generates stacks of sheet material cut out and fused together. Because LOM printers consist of stacks of paper, the paper can be printed on (in 2D) before used on the machine, meaning that these printers can actually be used to create colored 3D printed artifacts.



These printers have very low production costs because the raw materials are just reams of paper or plastic. They have the benefit of printing flexible, strong parts because of the material properties of the sheets. While the parts are strong, they are just stacks of paper, so they tend to wear easily and small part features can easily be peeled open. LOM machines are best at creating large parts with minimal small details. Each print requires a lot of post-processing to remove the part from the rest of the material. These printers usually generate a lot of waste because each part needs to be dug out of stacks of paper and the geometries of the parts created are restricted due to the way parts are manufactured.

## Step 10: 3D Design for 3D Printing

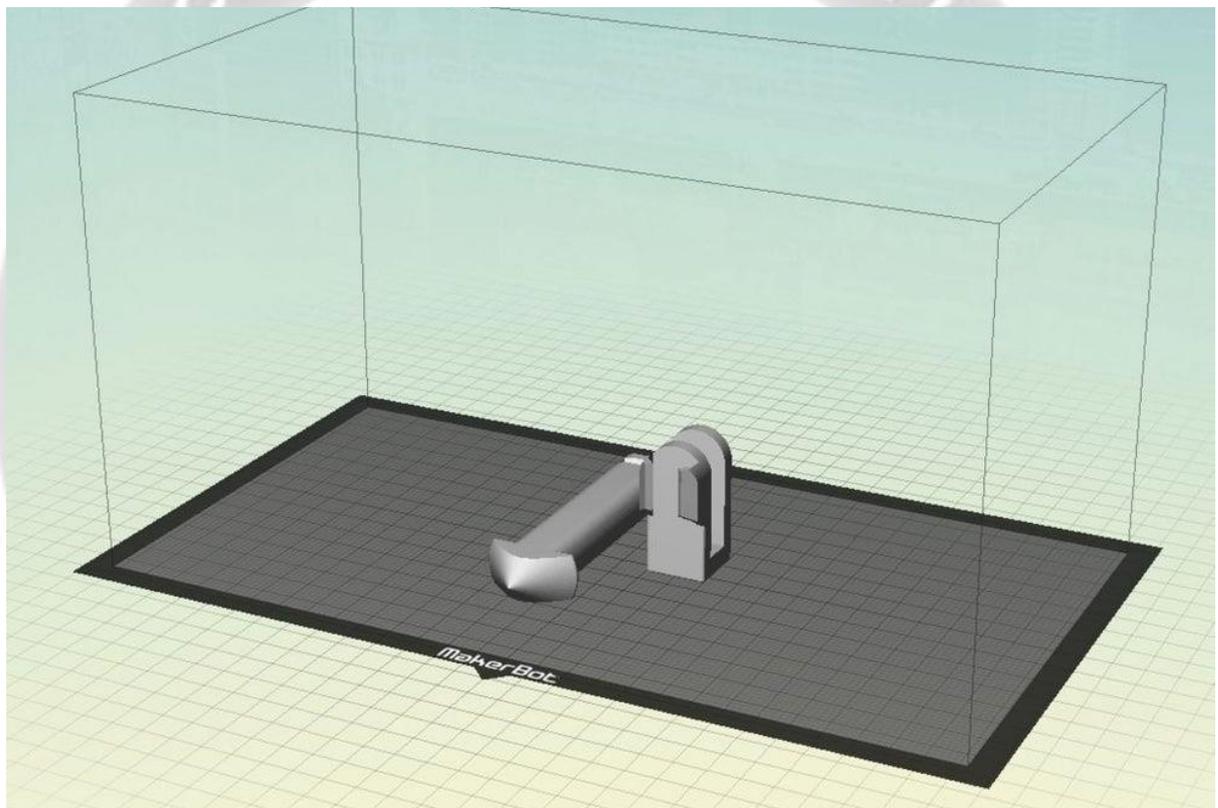


3D printers allow designers to go straight from concept ideas and designs to physical models. In order to do so, the object needs to be designed on a computer using some sort of 3D design software. Once a part is designed, it can be imported into software specific to the 3D printer in use, which will slice the part and send the printer a list of paths and directions used to create the part.

There are many different CAD (Computer Aided Design) programs out there to design 3D models for a variety of purposes. Design programs like Tinkercad or Autodesk 123D are free and great for beginners interested in 3D design and 3D printing, while programs like SolidWorks and Autodesk Inventor are used by professional engineers to design parts and

assemblies for production. I'll cover some of the considerations necessary when designing a part to be 3D printed.

### Step 11: Part Orientation



When designing for 3D printing, there are a few design guidelines and constraints that should be followed, as there are for any manufacturing process. One of the most important considerations during the design process involves designing with a build face in mind. All printers start building the part from the print bed, so remembering what face the part is being printed from is important. While determining optimal part orientation is slightly different on all printers, designing to optimize that



orientation will minimize material usage, print time, and risk of print failure.

### **Reducing Print Time and Support Material**

By orienting your part well, you can reduce the amount of support material needed, which can minimize material and print time. Support material can be hard to remove and creates a rough surface finish, which isn't the best if you want your part to look like a finished product. In order to remove the effects of the support material, parts need to be polished and sanded down, which may affect the tolerances of your part if it is interfacing with something else.

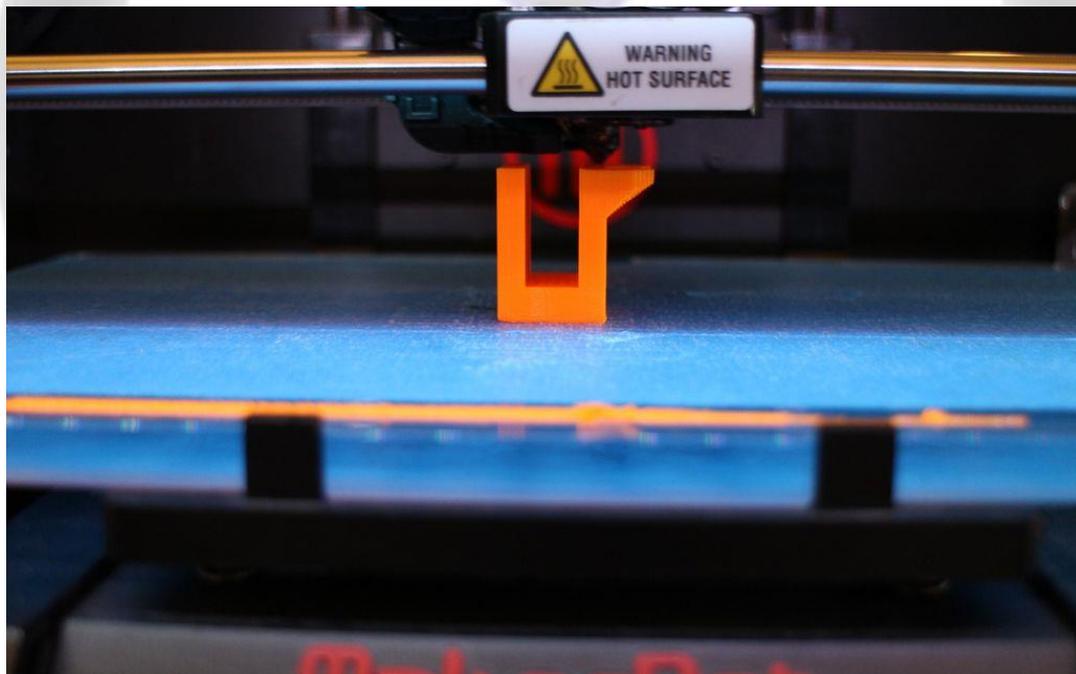
### **Part Strength**

On most desktop printers, parts usually tend to break along cross-sections of the part that are parallel to the build plate. Material is laid down or cured layer by layer, and the layers don't fuse as well as they do in higher end printers, creating seams along the cross-sections of the part. This means that parts can shear easily along those planes if force is applied. If you know how and where force will be applied to your part, orient your part such that the direction of force is not along those cross-sectional planes.

### **Build Adhesion**

On most printers, primarily FDM machines, the 3D printed parts stick to the build plate as they are printing, and a very small contact area may result in the part falling off the build plate. The side of your part has the most surface area on the same plane is usually the side you'll want to print on, although this can change depending on the features of a given printer.

### Step 12: Overhangs and Arches



As I mentioned previously, most printers require printed support structures to hold up flat overhanging features of their parts. Because material is laid down layer by layer, most printers (primarily FDM and SLA printers) can handle up to about 45 degrees of overhang from the horizontal without requiring supports, and can also create features like

vertical holes or round arches with minimal drooping. To avoid support material, note where the flat or low-angle overhangs are and either re-orient the part or make sure that they are supported by other part features, like angled overhangs or arches.

### Step 13: Interfacing With Other Parts





Most 3D printers involve the heating and melting of plastic or resin, so parts tend to shrink slightly when they cool down. This means that printing parts like gears, sliders, or holders that will interface with other objects can be tricky.

### **Tolerances**

If you are designing a part that will fit into or around something else, make sure you leave some clearance tolerance between the two parts. This tolerance will depend upon the printer you are using, so you may want to print out a few test pieces to try out the fit.



## Holes

On many 3D printers, holes are never going to be as precise as they would be if you drilled or reamed them out. This is because the shrinking of the parts alters the size of the part slightly, and also because usually a cartesian-based printer is being used to make a circular hole. To ensure precise holes on your parts, design the hole to be slightly undersized (by a few thousandths of an inch) and then use a reamer to drill out the hole to the right size.

## Threads

When designing parts that screws or nuts will screw onto, don't print the threads, because the tolerances may not be able to make them as precise as the threads on the components. To fix a screw to a 3D printed part, make the hole slightly smaller than the thread diameter of the component and tap the hole after the print is finished.

## Part Corrosion

Most 3D printers use plastic that have relatively low melting points because the plastic needs to be feasibly heated and safe when hot. This is why ABS and PLA are commonly used for FDM machines. However, a low melting point means that they corrode very easily with applied friction. SLA printers usually produce very brittle parts because of the type of resin they require. 3D printed parts are usually not well suited for high speed or high force situations because features tend to rub off after a while, or parts break. Sliding, spinning, or moving parts will work when 3D printed, but will wear down.

## Step 14: Related Technologies



### CNC Machines

3D printers fall under a category of machines called "Computer Numerical Control" (CNC) Machines. CNC machines are machines whose operations are controlled by a computer. The machine controller gives the machine a CAD file, and the machine goes through a series of operations to create that object. CNC machines are usually much more precise and reliable than human-operated machines. 3D printers are additive manufacturing CNC machines because they are computer controlled and they add material to create a part. Other machines, like mills and lathes, are subtractive manufacturing machines because they



remove material to make parts, just how you would cut up a piece of paper to make a shape.

### **Laser Cutters**

Laser Cutters, like 3D printers, are another type of rapid prototyping CNC technology. Laser Cutters are very quick, efficient tools that use lasers to cut or etch flat material based on two dimensional CAD drawings. They can be used to make functional prototypes out of wood, plastic, and sometimes metal, among other materials, and can also be used to make works of art because of their rastering capabilities.

### **3D Scanners**

A 3D scanner is another piece of technology that usually goes hand in hand with 3D printing. 3D scanners generate 3D CAD models of real world objects. To scan objects, 3D scanners map points on the object to distances from the scanner, and can thus generate a 3D representation of the object, which can be 3D printed or used for more design work.



## Step 15: Resources

### Desktop Printers

- **MakerBot**: A great FDM desktop 3D printer
- **FormLabs**: High resolution desktop SLA printer
- **RepRap**: A build-your-own FDM 3D printer kit
- **Ember**: An open source, efficient SLA printer

### 3D Model Sites

- **Thingiverse**: A great site to share and find 3D printable designs
- **Pinshape**: Another 3D printable content sharing site
- **MyMiniFactory**: A site where you can buy and sell 3D printable designs
- **Shapeways**: Purchase parts that others have made via Shapeways

### Free 3D Design Software

- **Autodesk 123D**: A group of free apps and programs designed to make 3D design easy
- **Tinkercad**: A very simple, free CAD program designed to create and print 3D content.
- **SketchUp**: Another simple, easy to learn CAD program
- **OpenSCAD**: A 3D design tool for programmers used to make easily modifiable designs
- **Blender**: A 3D design tool used to design biological and natural shapes.