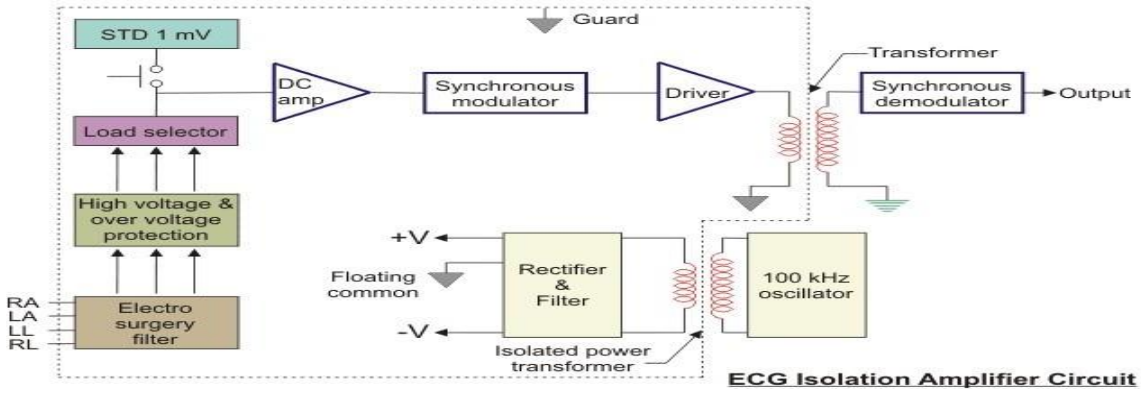
ECG Isolation Amplifier

During ECG measurement, signals generated from all leads are sent to the low pass filter. This filter is named as Electro surgery filters because it decreases the interference between electrosurgery and radio frequency. Next block is the high voltage and overvoltage protection that can withstand large voltage during defibrillation.

It goes to Lead Selector Switch block, which selects the required configuration. Lead selection output goes to the DC amplifier. We have a transformer, whose primary winding is connected to the oscillator and secondary to rectifier and filter. ECG signal is modulated with the Synchronous modulator. The second transformer delivers the output from the synchronous modulator to the synchronous demodulator. The output from the demodulator is fed as input to the power amplifier.



ECG Isolation Amplifier Circuit

ECG

- An ECG, also sometimes referred to as an EKG from the original German word 'electrocardiogram', measures the electrical activity of the heart. This electrical activity producesthe contractions and relaxations of the cardiac muscles required to pump blood around the body.
- An ECG is recorded over a series of cardiac cycles (heartbeats) and shows the different phases of the cardiac cycle.
- The ECG indirectly measures transmembrane voltages in myocardial cells that depolarize and repolarize within each cardiac cycle. These depolarizations and repolarization events produce ionic currents within the body, and these are transduced into voltages by electrodes placed on thesurface of the chest and thorax Up to twelve different lead voltages are recorded, with the magnitude of the voltages being in the low mV range, and a frequency spectrum between 0 and 30 Hz.
- The ECG signal has many distinct features, such as the P-wave, QRS-complex and T-wave. The amplitude, shape and relative timing of these features can be used to diagnose differentclinical conditions.
- An ECG is an essential part of diagnosing and treating patients with acute coronary syndromes and is the most accurate method of diagnosing ventricular conduction disturbances and cardiac arrhythmias.

- It is also used to diagnose heart conditions such as myocardial infarcts, atrial enlargements, ventricular hypertrophies and blocks of the various bundle branches. An ECG is universally used to monitor a patient's cardiac activity during surgery.
- Most ECG machines are now digital and automated, meaning that the data is analysed automatically. Software algorithms measure different aspects (such as delays, durations and slopes)of the ECG waveform and provide a set of keyword interpretations of the scan such as 'abnormal ECG' or more specific suggested diagnoses such as 'possible sinoatrial malfunction'

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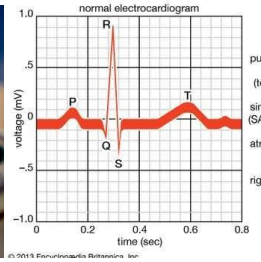
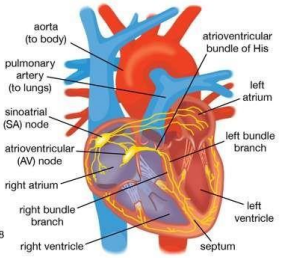




Block diagram Description of an Electrocardiograph

The potentials picked up by the patient electrodes are taken to the lead selector switch. In the lead selector, the electrodes are selected two by two according to the lead program.

By means of capacitive coupling, the signal is connected symmetrically to the long-tail pair differential preamplifier.

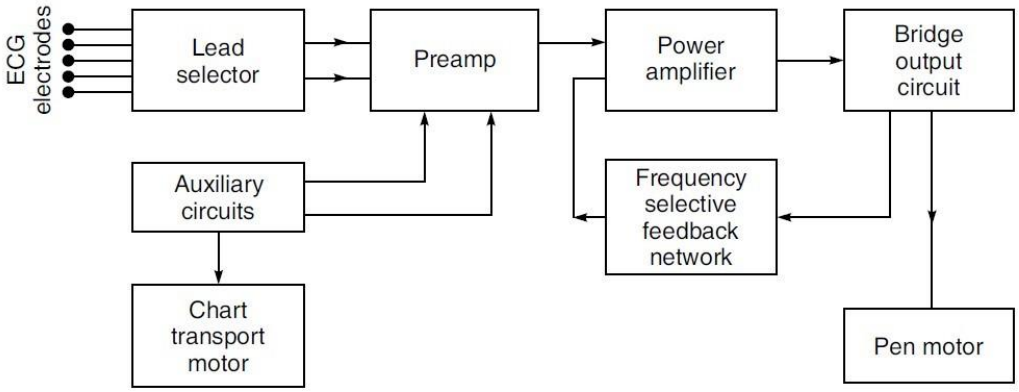
The preamplifier is usually a three or four stage differential amplifier having a sufficiently large negative current feedback, from the end stage to the first stage, which gives a stabilizing effect.

The amplified output signal is picked up single-ended and is given to the power amplifier.

The power amplifier is generally of the push-pull differential type. The base of one input transistor ofthis amplifier is driven by the preamplifier unsymmetrical signal. The base of the other transistor is driven by the feedback signal resulting from the pen position and connected via frequency selective network.

The output of the power amplifier is single-ended and is fed to the pen motor, which deflects the writing arm on the paper. A direct writing recorder is usually adequate since the ECG signal of interest has limited bandwidth. Frequency selective network is an R–C network, which provides necessary damping of the pen motor and is pre-set by the manufacturer.

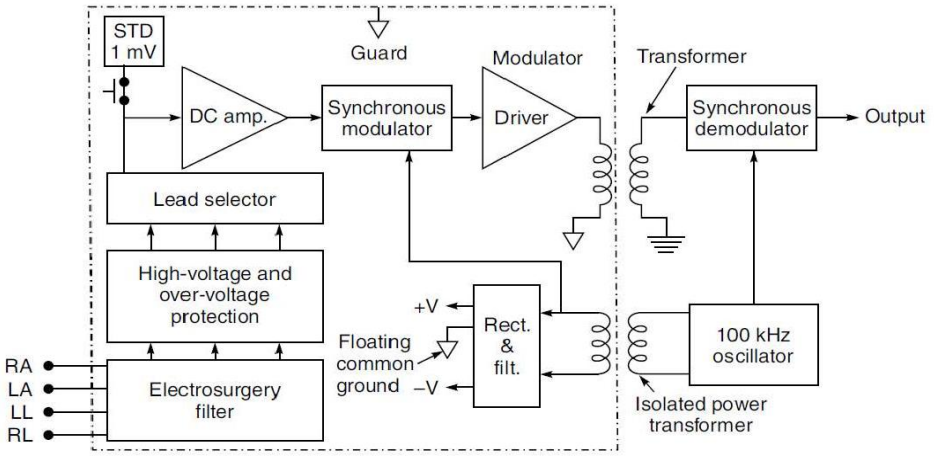
The auxiliary circuits provide a 1 mV calibration signal and automatic blocking of the amplifier during a change in the position of the lead switch. It may include a speed control circuit for the chart drive motor.



A 'standby' mode of operation is generally provided on the electrocardiograph. In this mode,the stylus moves in response to input signals, but the paper is stationary. This mode allows theoperator to adjust the gain and baseline position controls without wasting paper.

Electrocardiograms are almost invariably recorded on graph paper with horizontal andvertical lines at 1 mm intervals with a thicker line at 5 mm intervals. Time measurements andheart rate measurements are made horizontally on the electrocardiogram.

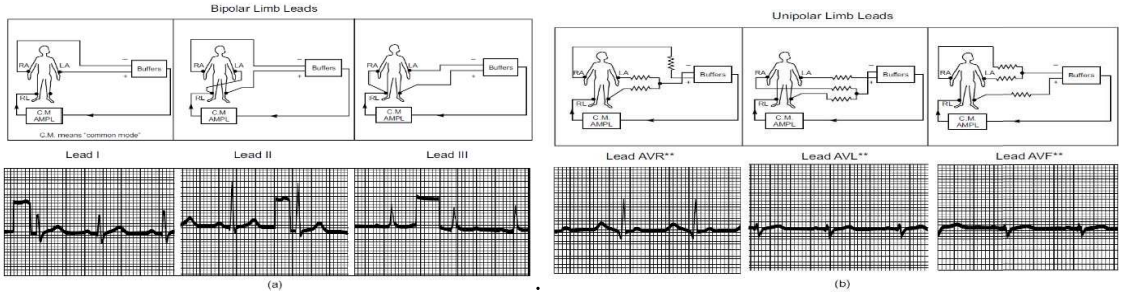
Isolated Preamplifier: It had been traditional for all electrocardiographs to have the right leg(RL) electrode connected to the chassis, and from there to the ground. This provided a ready path for any ground seeking current through the patient and presented an electrical hazard. As the micro shock hazard became better understood, particularly when intracardiac catheters are employed, the necessity of isolating the patient from the ground was stressed.
Block diagram of an isolation preamplifier used in modern electrocardiographs.



Different signals obtained from the right arm (RA), left arm (LA) and right leg (RL) are given to a low-pass filter. Filtering is required on the input leads to reduce interference caused by electro surgeryand radio frequency emissions and sometimes from the 50 kHz current used for respiration detection. The filter usually has a cut off frequency higher than 10 kHz. A multistage filter is needed to achieve a suitable reduction in high frequency signal.

Block diagram of an isolation preamplifier (transformed-coupled) commonly used in modern ECG machines

The ECG Leads
Two electrodes placed over different areas of the heart and connected to the galvanometerwill pick up the electrical currents resulting from the potential difference between them. Forexample, if under one electrode a wave of 1 mV and under the second electrode a wave of 0.2mV occurs at the same time, then the two electrodes will record the difference between them,The resulting tracing of voltage difference at any two sites due to electricalactivity of the heart is called a "LEAD"



Types of lead connections with typical ECG waveforms: (a) bipolar limb leads (b) unipolar

The electrocardiogram is of greatest use in diagnosing **cardiac arrhythmias**, **acute and prior myocardial infarctions (heart attacks)**, **pericardial disease**, and **cardiac enlargement (atrial and**

The presence of hypertension (high blood pressure), thyroid disease, and certain typesof malnutrition also may be revealed by an electrocardiogram. In addition, electrocardiography can be used to determine whether a slow heart rate is physiological or is caused by heart block.

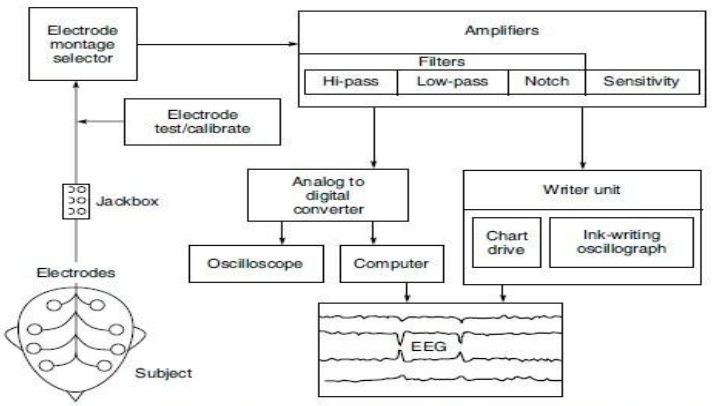
ELECTROENCEPHALOGRAPH (EEG)

- 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 thebrain 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.

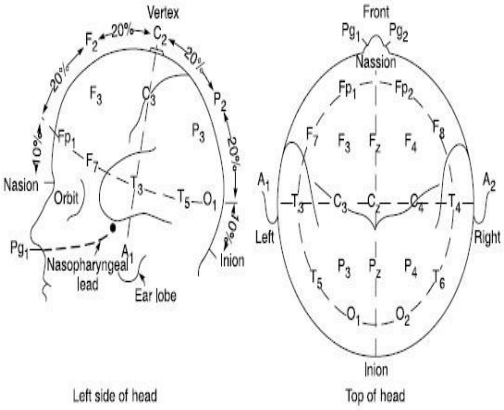
- Monitoring the electroencephalogram has proven to be an effective method of diagnosing many neurological illnesses and diseases, such as epilepsy, tumour, cerebrovascular lesions, ischemia and problems associated with trauma. It is also effectively used in the operating room to facilitate anaesthetics and to establish the integrity of the anaesthetized patient's nervous system. This has become possible with the advent of small, computer-based EEG analysers.

- 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. Thistype 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.
- 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 intervalof time in order to be able to detect any kind of abnormalities.
- Selecting the proper filter band (band width must be at least 0.5 Hz–70 Hz) is important toacquire proper signal. This is important for digitizing and data storing. Sufficient and optimumsampling rate (140 Hz) should be adopted.
- 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 impedanceas 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 themshould be less than 2 kilohms. EEG preamplifiers are generally designed to have a very highvalue of input impedance to take care of high electrode impedance.
- In today's technology, high input impedance (1 G) amplifier chips and active electrode approaches decrease dependency of the contact impedance. To acquire proper signal, electrodes should not be moved. Otherwise, it causes fluctuation of the EEG signal, and spikes on it.
- Noise reduction techniques must be considered in electronic circuitry and printed circuitboard design. Electronic cards and connection cables should be placed in a metal box to reduceelectronic noise as much as possible. Using twisted, blended, and driven signal cables gives goodresults. Because EEG signals are of low amplitude, they are very sensitive to electronic noise.
- Electronic noise should be less than 2 μV (peak-to-peak).

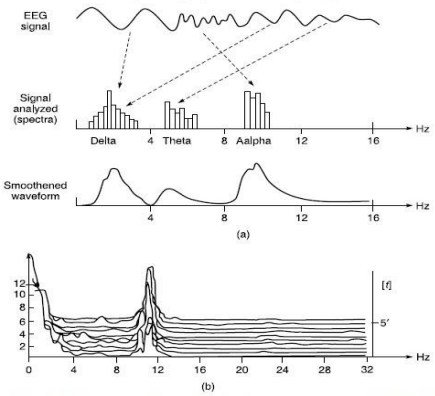
Block Diagram Description of Electroencephalograph



➤ Fig. 5.17 *Schematic diagram of EEG machine (after Isley et al., 1998)*



➤ Fig. 5.18 *10-20 System of placement of electrodes*



➤ Fig. 5.19 *(a) Typical EEG waveform broken down into frequency components (b) Mathematical and display techniques used to generate the compressed spectral array format*

EEG Uses

EEGs are used to diagnose conditions like:

- Brain tumors
- Brain damage from a head injury
- Brain dysfunction from various causes (encephalopathy)
- Inflammation of the brain (encephalitis)
- Seizure disorders including epilepsy
- Sleep disorders
- Stroke

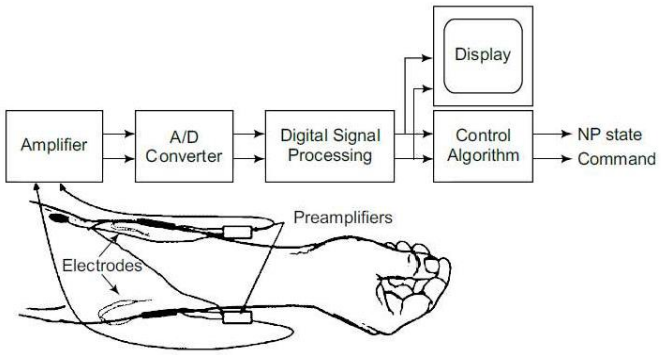
An EEG may also be used to determine if someone in a coma has died or to find the right level of anesthesia for someone in a coma.

ELECTROMYOGRAPH(EMG)

- 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 the action potentials spontaneously present in a muscle in visual and audible form or those induced by voluntary contractions as a means of detecting the nature and location of motor unit lesions; or for recordingthe 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 endingsof 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, adhesivetypes 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 loudspeaker. The stagesof data acquisition and signal processing in an electromyograph.
- The myoelectric signals are amplified with the use of preamplifiers and a differential amplifier together having an effective passband of 10 to 1,000 Hz. The signals are sampled at 5 kHz with 16-bit analog-to-digital conversion, rectified, and smoothed with a running time window average witha window length of 240 ms that is updated every 80 ms.
- The processed signals are normalized by the amplitudes of the maximum voluntary contractionsand are displayed on a computer monitor. The waveforms can be stored to facilitate playbackand study of the EMG waveforms at a later convenient time. The waveform can also be printedas a hard copy for records.



➤ Fig. 5.20 *Block diagram of a typical set-up for EMG recording*

- Modern day EMG machines invariably use digital signal processing techniques.
- Analog- to- digital converters (ADC) are used to convert the amplified differential signals into digital signals that are further processed by a microprocessor or a PC. The quality of an EMG signalis therefore largely dependent on the resolution, accuracy and sampling rate of the ADC used.

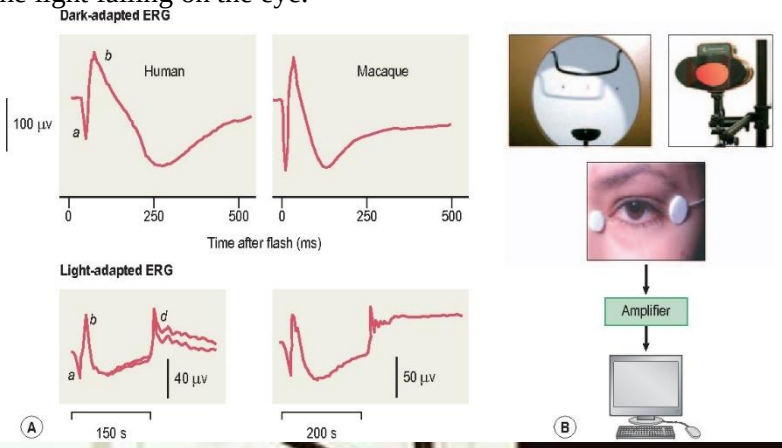
➤ Fig. 5.21 *PC based digital EMG recording system*

- Modern EMG machines are PC based available both in console as well as laptop models. They provide full colour waveform display, automatic cursors for marking and making measurements anda keyboard for access to convenient and important test controls.
- The system usually incorporates facilities for recording of the EMG and evoked potentials. The stimulators are software controlled. For report generation in the hard copy form, popular laser printers can be used.
- EMG equipment to have a range of new features and networking capabilities.
- The RS-232 serial data transfer protocol previously used in the PC-based systems is now replaced by theUniversal Serial Bus 2.0 which provides faster data exchange rates and even ameans of supplying power to the EMG ha dheld device to recharge the device.

- Increased storage capacity of data recordings on digital storage media has become a common place.
- EMG equipment to provide the user with extended mobility from the PC on PC-based systems. Acquired EMG signals can now be picked up on the body and sent wirelessly to a PC where itis recorded, processed and analysed.

Electroretinography (ERG)

- An electrical potential exists between the cornea and the back of the eye. These potential changes when the eye is illuminated. The process of recording the change in potential when light falls on the eye is called electroretinography.
- ERG potentials can be recorded with a pair of electrodes. One of theelectrodes is mounted on a contact lens and is in direct contactwith the cornea.
- The other electrode is placed on the skin adjacent to the outer corner of the eye.
- A reference electrode may be placed on the forehead. A general-purpose direct writing recordermay be used for recording electroretinograms. The magnitude of the ERG voltage dependsupon the intensity and duration of the light falling on the eye.



Types of ERG Measurement

- Focal ERG (fERG)
- Multifocal ERG (mfERG)

Testing of ERG

- ERG is one type of ophthalmic **electrophysiology test**. Depending on which eye condition is being studied, ERG may be performed in conjunction with other tests, such as electrooculography (EOG) or dark adaptometry testing.
- ERG is usually well tolerated, painless, and medical professionals can perform ERG even in cooperative children and infants. Occasionally, sedation may be necessary.
- The patient assumes a comfortable position either lying down or sitting up.
- An eye doctor dilates the patient's eyes with standard dilating eyedrops. Anesthetic drops are also given. The doctor then props the eyelids open with a speculum and gently places a contact lens electrode or an electrode resembling a fine thread on each eye. The physician placesan additional electrode on the forehead skin.
- During an ERG recording session, the patient looks into a bowl displaying different amounts of light. Retinal cells emit small electrical signals when stimulated by certain types of light. The ERG machine records the resulting electric signals' amplitude (voltage) and time course.
- The visual stimuli vary; some are done with no light in the background (dark-adapted, or scotopic readings), and some are done with light in the background (light-adapted, or photopic readings).The light stimuli include flashes of light (flash ERG) and flickering lights.

Multifocal ERG

While a standard ERG detects activity of the entire retina, the multifocal ERG tests different areas of the retina, looking for localized areas of abnormality. This test takes longer than a standard ERG.

Normal ERG Results

A normal ERG shows an a-wave (photoreceptor activity) and b-wave (Muller and bipolar cells activity) patterns in dark-adapted (scotopic) and light-adapted (photopic) settings. Wave patterns that are diminished in size or delayed or prolonged in time provide clues about the types of damaged cells.

Abnormal ERG results

Abnormal ERG results provide clues as to which specific retinal cells are affected by disease. Thereare retinal diseases in which specific cells are missing or weak at birth, while other abnormalities are acquired over time.