Strumentazione Biomedica - ECG

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Secretary General, *IUPESM* (2018-2022)
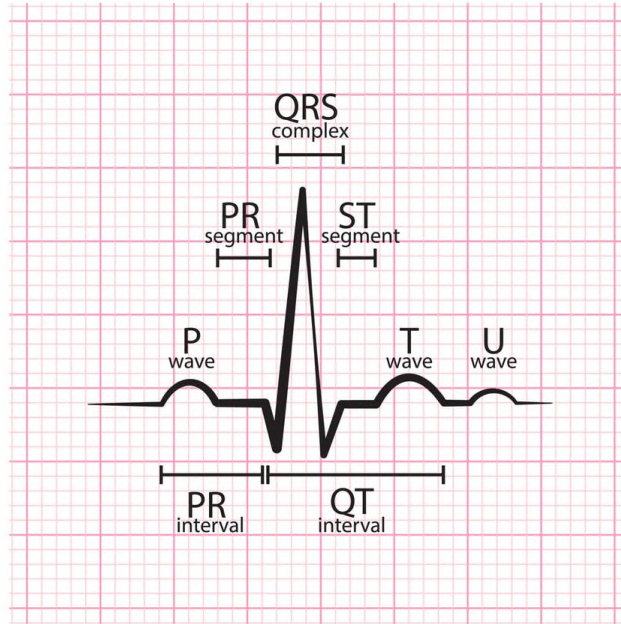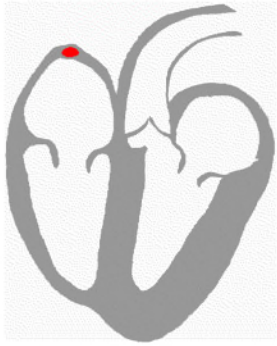Treasurer, *IFMBE CED* (2018-21)

Electrocardiograph

The electrocardiograph is a device that is able to graphically represent the time evolution of the cardiac potentials, through the use of a writing system dependent on the cardiac signal, sensed through electrodes placed according to certain derivations and consequently amplified and conditioned.

ECG

- RR interval: 0.6-1.2 seconds
- P wave: 80 milliseconds
- PR interval: 120-200 milliseconds
- PR segment: 50-120 milliseconds
- QRS complex: 80-100 milliseconds
- ST segment: 80-120 milliseconds
- T wave: 160 milliseconds
- ST interval: 320 milliseconds
- QT interval: 420 milliseconds or less if heart rate is 60 beats per minute (bpm)

A small box is **1 mm × 1 mm** and represents **0.1 mV × 0.04 seconds**. A large box is **5 mm × 5 mm** and represents **0.5 mV × 0.20 seconds**.
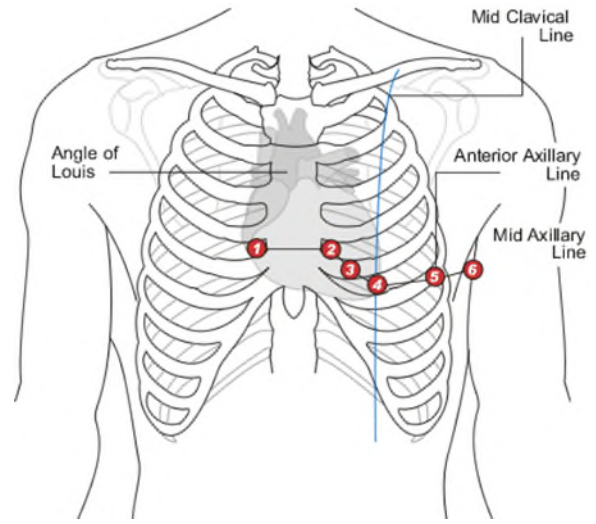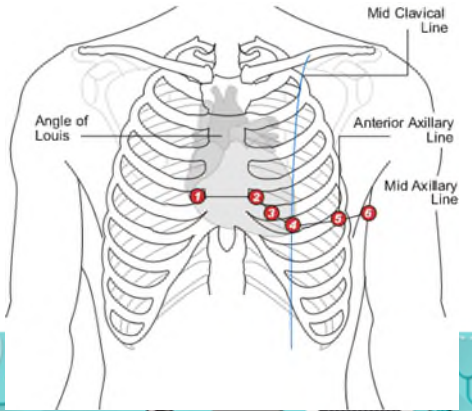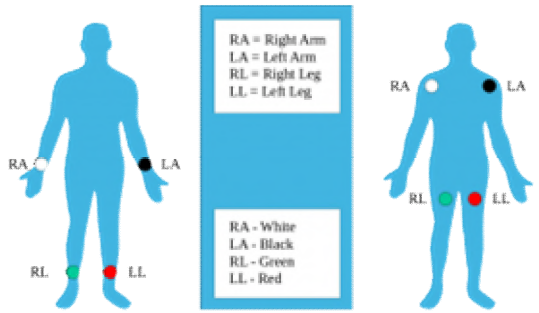
Lead placement
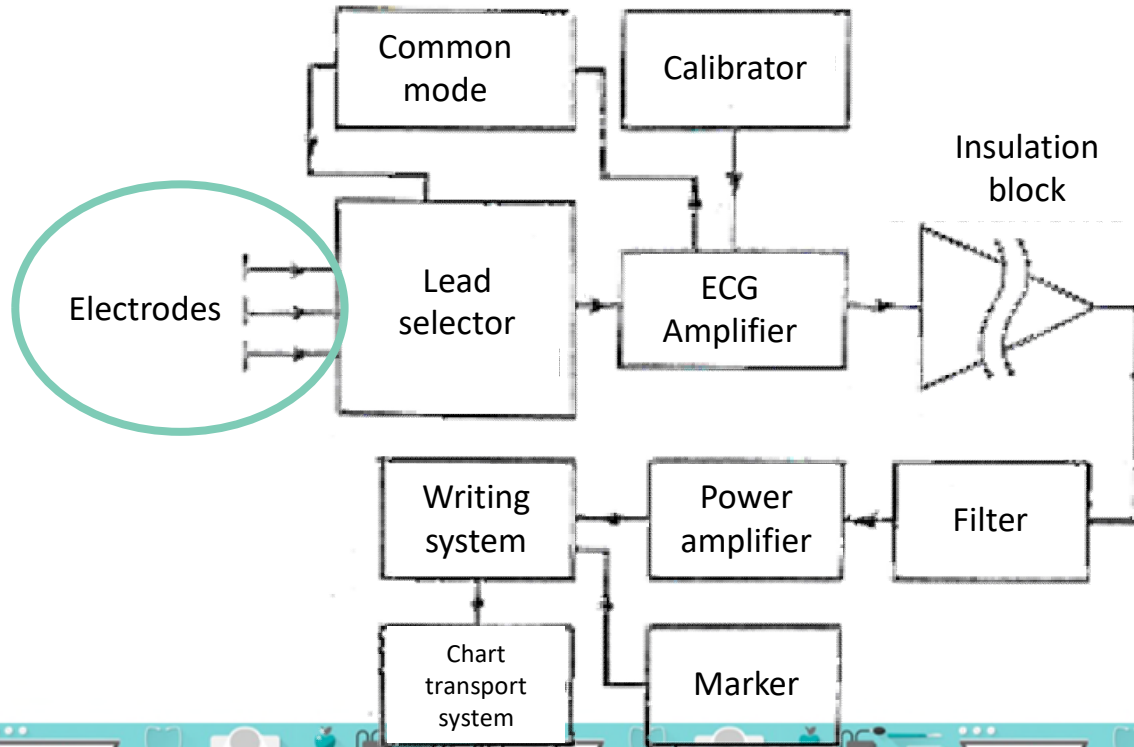
Einthoven's triangle
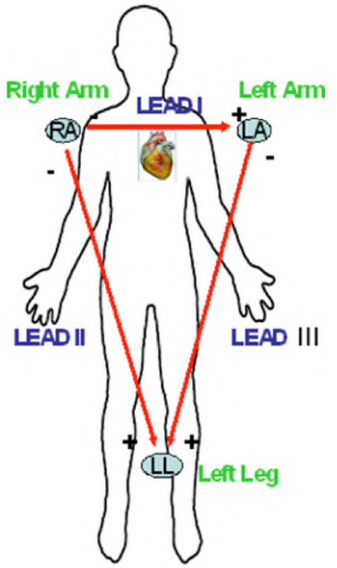
6-lead placement

12-lead placement

ECG – Block diagram

Electrodes
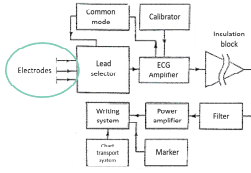
- **Disposable electrodes:** they contain a circular electrode (stainless steel or silver/silver chloride), positioned in a self-adhesive support, which is used to stick the electrode to the patient's skin, once it's shaved and degreased. They do not require the use of electrode gel.

- **Reusable electrodes:** they are made of stainless steel or silver/silver chloride. They require conductive gel, must be cleaned with water or ethyl alcohol after each use to remove the gel. If the electrodes are made of silver/silver chloride, the use of abrasive substances should be avoided to avoid damages to the AgCl layer.

ECG – Block diagram
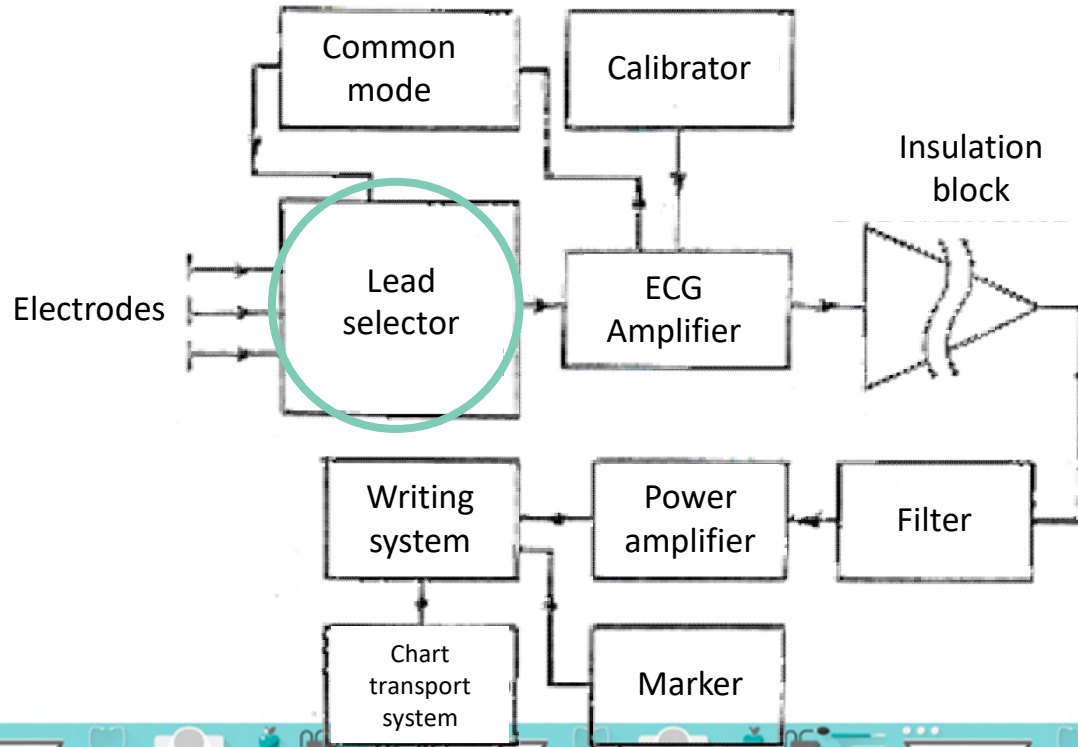
ECG – Lead Selector

This circuit combines the signals coming from the set of electrodes linked to the patient so that the operator can select the different derivations without changing the position of the electrodes on the patient.

ECG – Block diagram
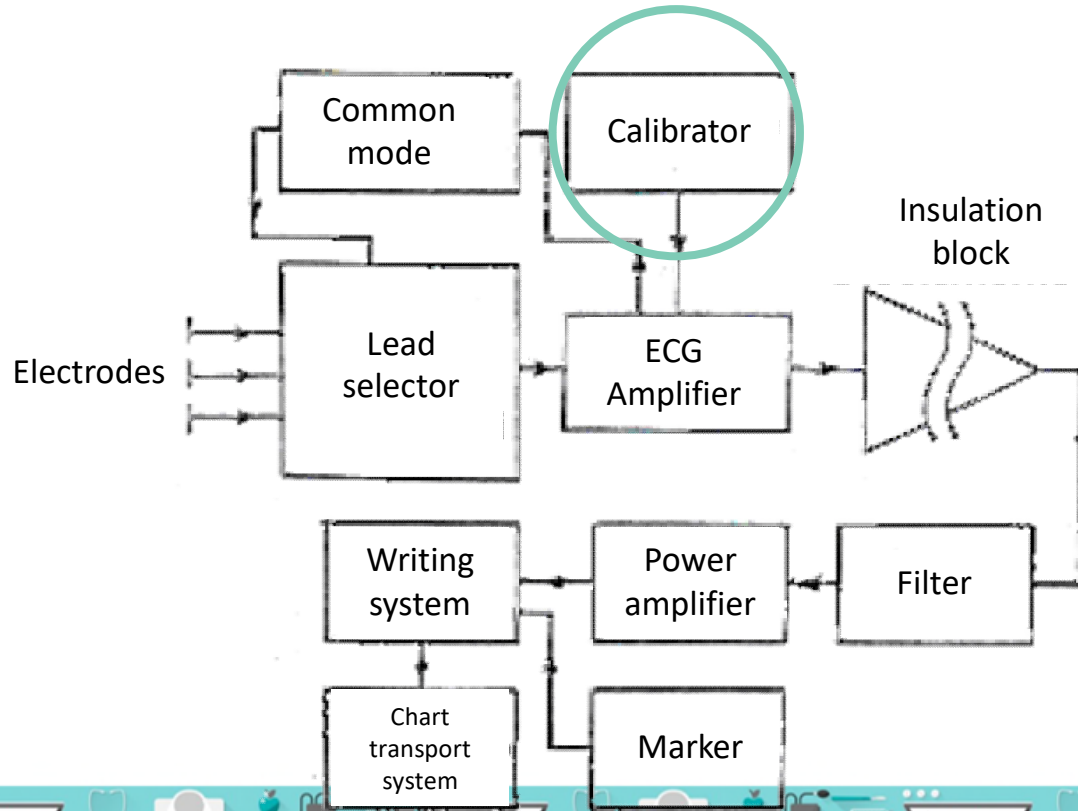
ECG – Calibrator

It allows the operator to manually input a signal with a certain amplitude (ideally constant in time) as an input to the amplifier, in order to calibrate the device

ECG – Block diagram
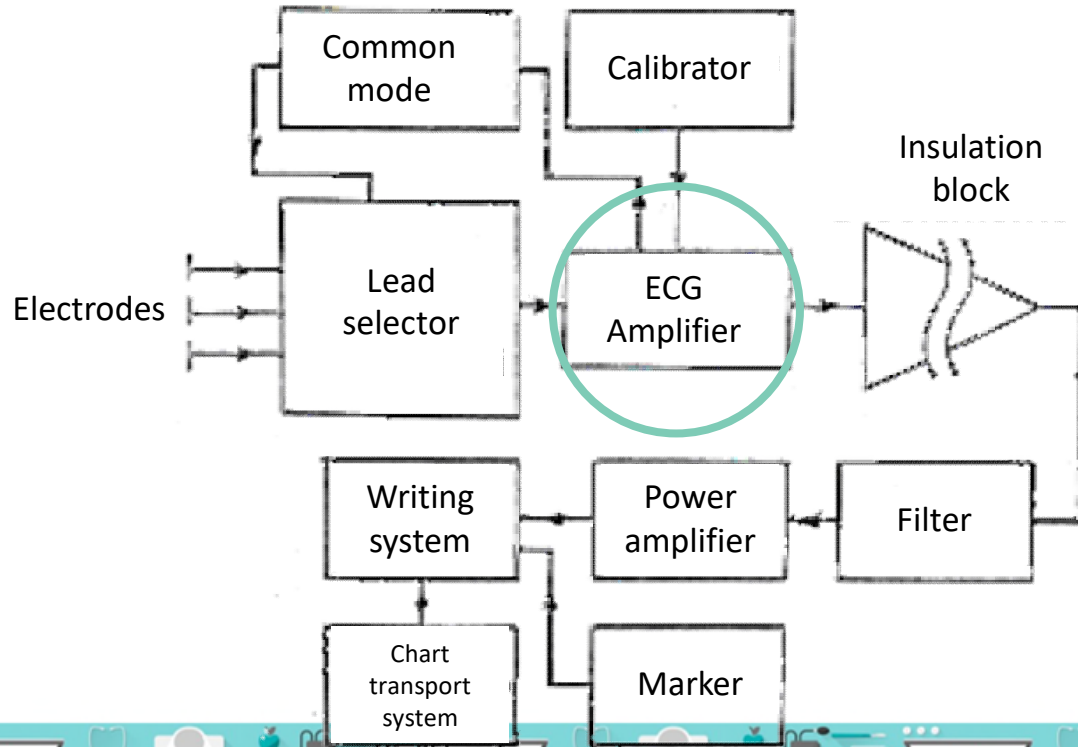
ECG – Preamplifier

It is used to amplify the ECG. Typical features of this stage are:
1) Differential input;
2) High input impedance (1-10 Mohm) to optimise the signal transfer to the following stages;
3) High CMMRR (common mode rejection ratio), about 60-80 dB to minimise the effect of the noise due to the common mode signals that are fed as an input.

In some models the preamplifier has the common mode signals as one of the outputs, which can be conditioned and fed back to the patient to diminish its effect on the ECG.

ECG – Block diagram
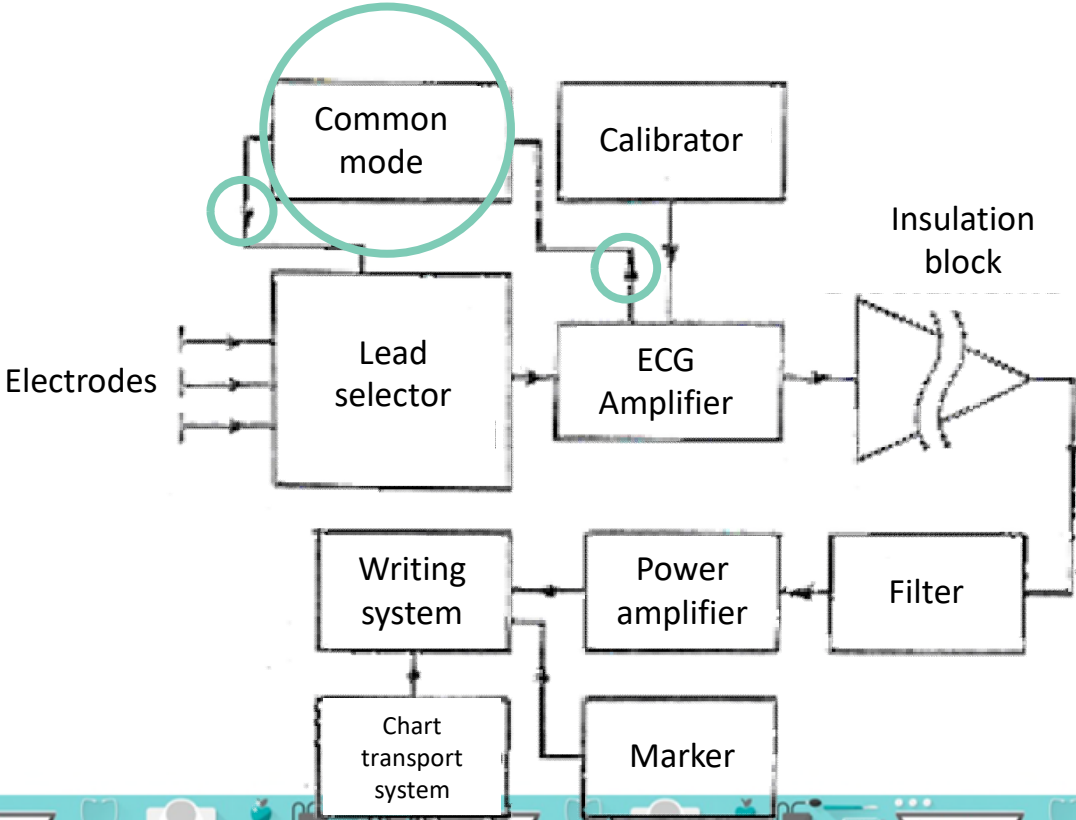
ECG – Common mode

This block allows to feed the common mode signal (one of the outputs of the preamplifier) back to the patient. This signal will need to be in phase opposition with the original common mode signal, to diminish its effects.
A high resistor (5-10 Mohm) is placed in series with this output of the preamplifier to avoid that a high current flows in the patient.
Not all the ECGs have this block.

ECG – Block diagram
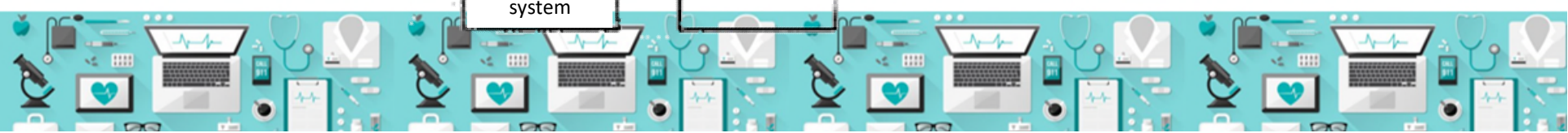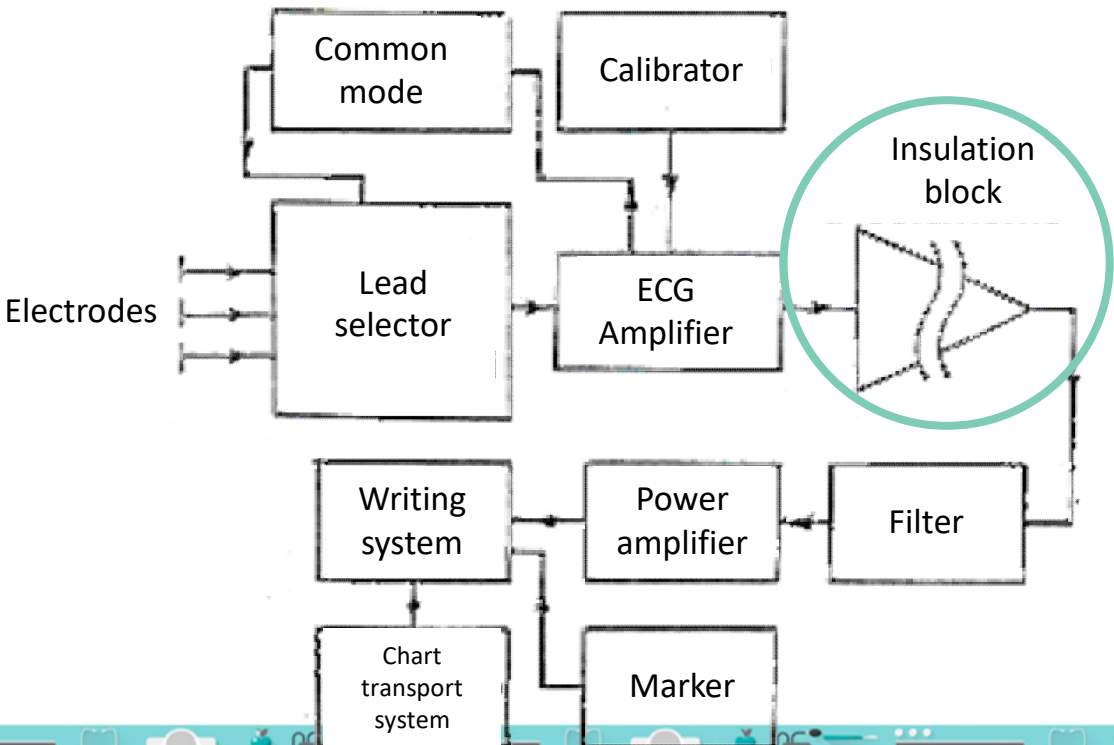
ECG – Insulation block

Not all the ECGs have this block.

The ones that have it belong to class CF and got this symbol

This block:

1) Electrically insulates the patient from the electrical grid, to avoid that the patient is exposed to high currents in case of malfunctioning;

2) Avoid that some leakage currents coming from other devices linked to the patients flow to the ground through the ECG.

The insulation can be optic or electromagnetic (usually used together).

A malfunctioning of this block compromises the measures and exposes the operators and the patients to the risk of accidental electrocution.
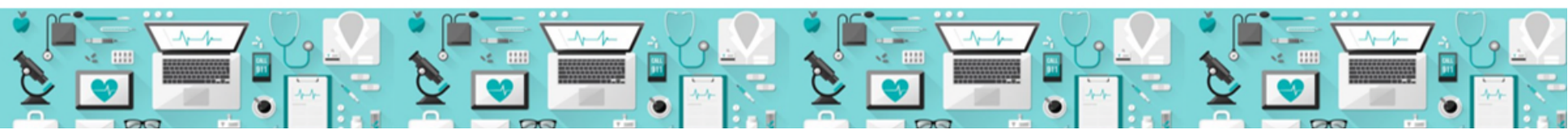
ECG – Block diagram
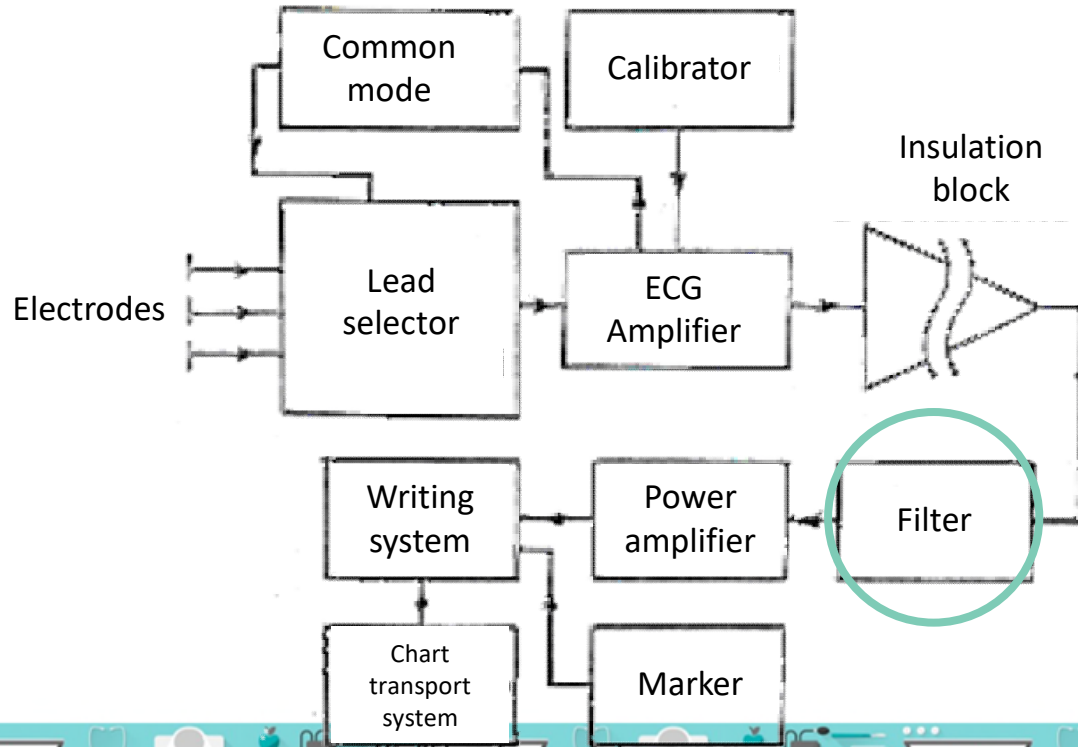
ECG – Insulation block

They let to attenuate some frequency bands in order to improve the readability of the signal. All the available ECGs today allow to apply a band-stop filter to attenuate the noises that have the same frequency as of the electrical grid.
It is possible to add other filters in more advanced devices. The most frequent filter is the one used to reduce the artefacts due to breathing and muscle tremors.

ECG – Block diagram
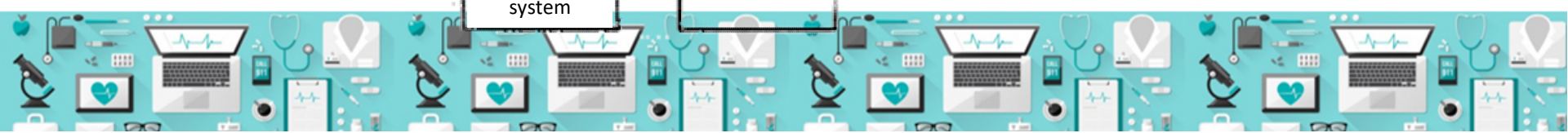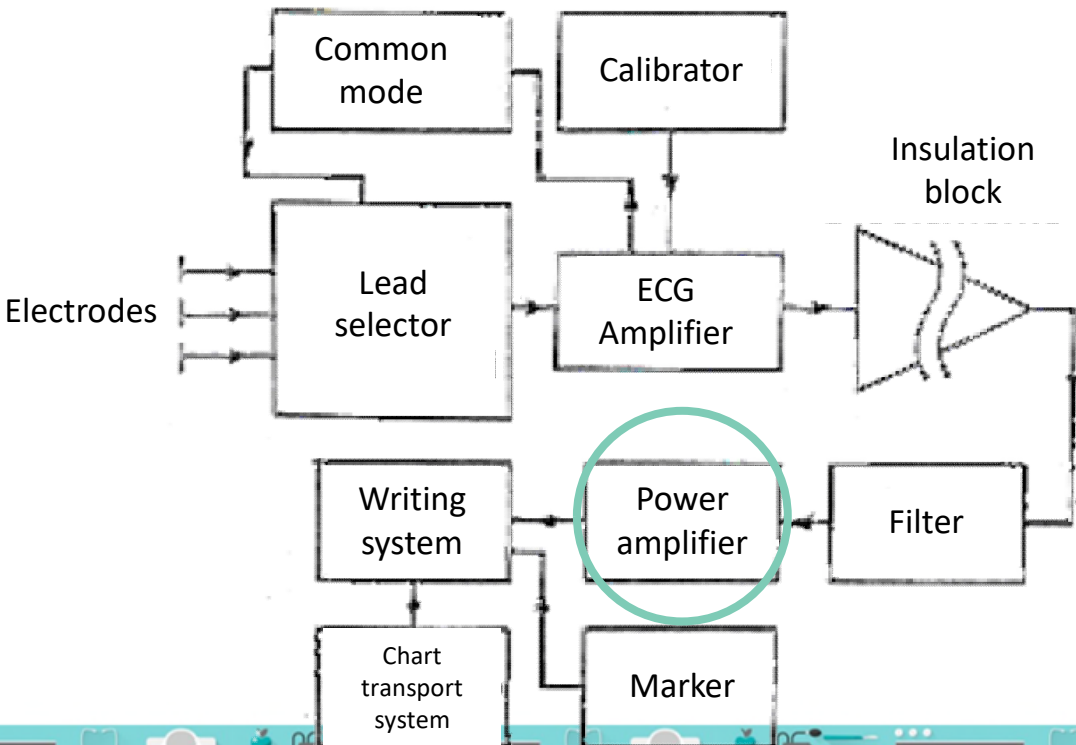
ECG – Power amplifier

This block amplifies the ECG signal that has been conditioned by the previous stages. This block allows to superimpose a continuous component, variable thanks to a potentiometer, to let the operator to position the pen on the desired line.

ECG – Block diagram
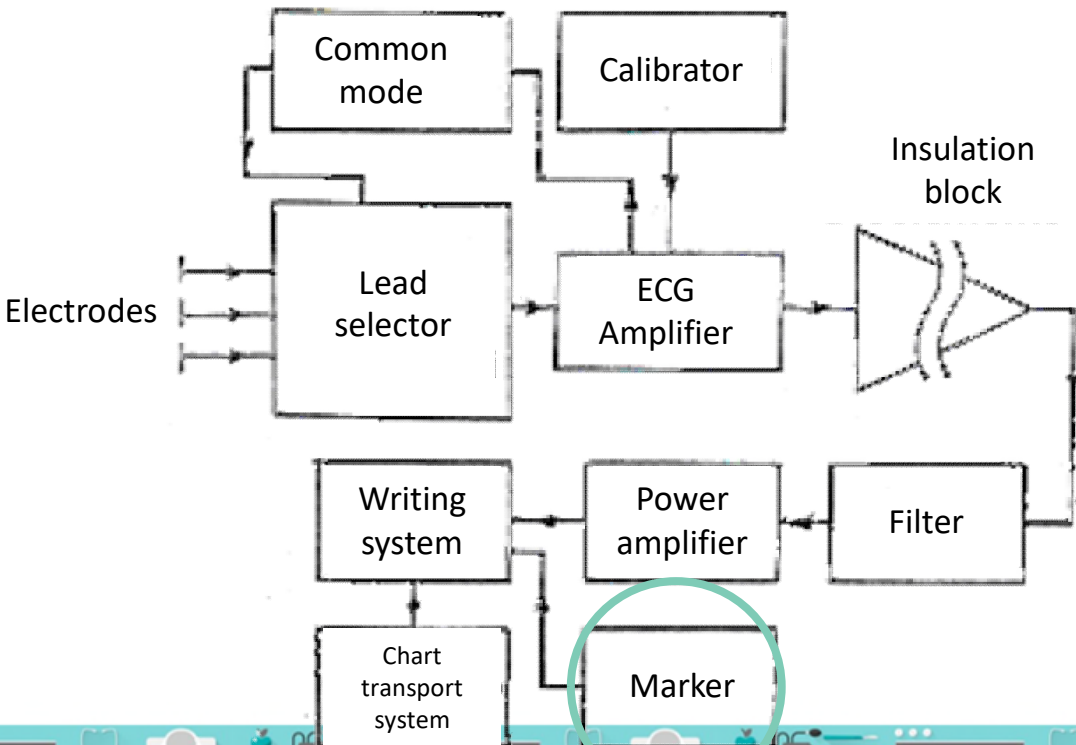
ECG – Marker

It allows the operator to mark particularly interesting sections of the signal in order to make them easy to find while reading the ECG.

Defibrillator protection
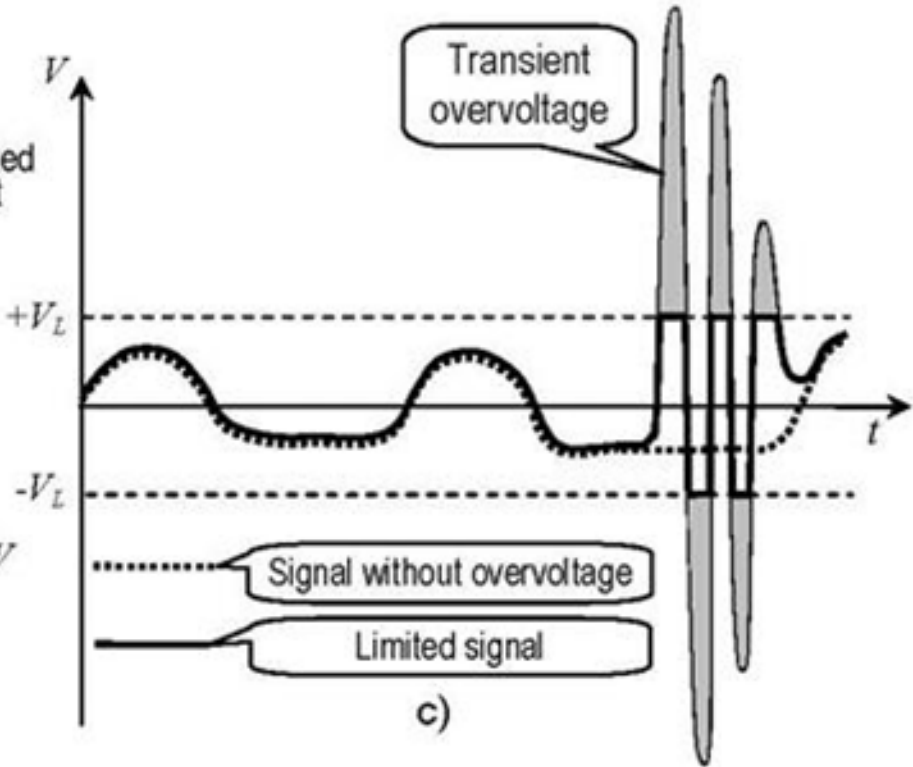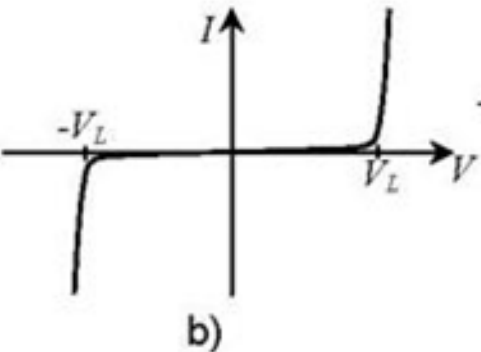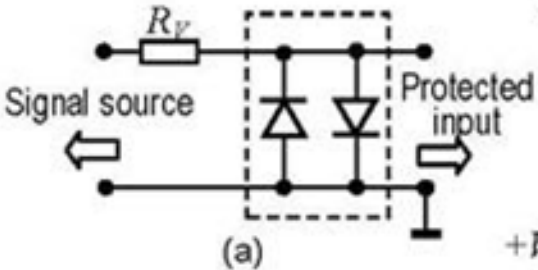
Safety

The patient linked to a ECG can be exposed to the risk of electrocution in 2 ways:
1) When leakage currents, coming from the electrodes on the patient or from the chassis of the device towards the ground, flow through him;
2) When the patient is linked to other devices or when the patient comes into contact with a metallic mass with a potential different from the ground potential.

In order to keep the patient safe the leakage currents should be less than 100 microampere if the link patient-device is done through external electrodes. If the link patient-device is done through electrodes directly positioned on the heart, the leakage current should be less than 10 microampere.

In order to avoid accidental electrocution with other devices, the patient should be isolated from the ground:
- Use beds made of insulating materials;
- Avoid linking the patient to other devices that can be a low-impedance path towards the ground;
- Avoid that the patient comes into contact with metallic masses such as radiators, metallic bedside tables etc.

Holter: a portable device for cardiac monitoring
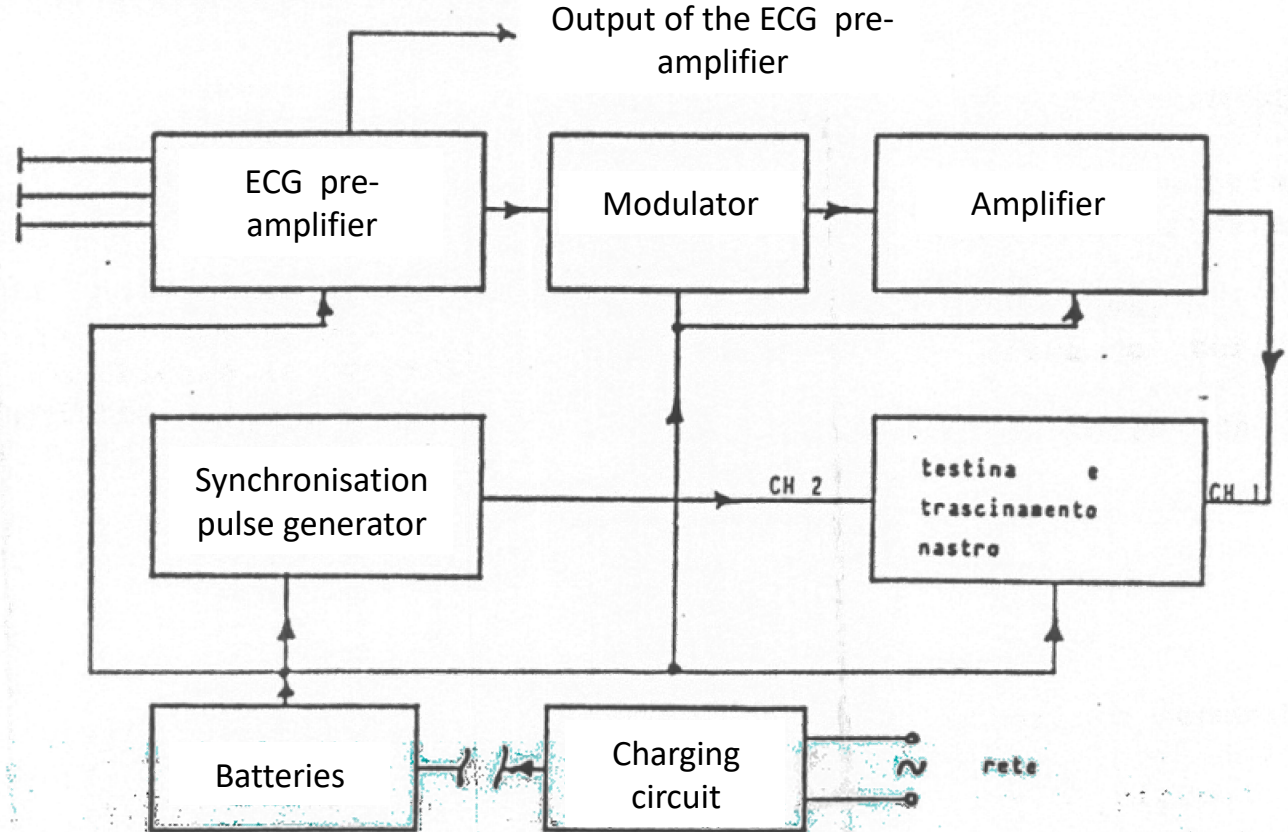
Periodic Maintenance

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ECG Monitors
Procedure/Checklist 409-0595


Equipment Needed: Electrical Safety Analyzer, Patient Simulator and
associated cables
1. Qualitative Tests
     1.1  Chassis - verify physical integrity, cleanliness
     1.4  AC Plug - verify integrity
     1.5  Line Cord - verify proper insulation and integrity
     1.6  Strain Reliefs - verify physical integrity at both ends of line
cord
     1.9  Inspect patient cable and leads
     1.10 Fittings/Connectors examine all cable connectors
     1.13 Controls/Switches - verify proper operation
     1.18 Indicators/Displays - verify proper illumination and operation
          - verify trace quality and linearity
          - verify QRS waveform on display
     1.19 1mV Step Response - verify proper operation of TEST/CAL button
     1.22 Labeling - verify presence and placement of all labels, placards,
                      instruction cards, etc.        2. Quantitative Tests
                                                          2.1  Grounding Resistance [< 0.5 ohm]
                                                          2.2  Chassis Leakage [< 300 microamps]
                                                               Lead Leakage [< 10 microamps (G), <50 microamps (NG)]
                                                               Inter-lead Leakage  [< 10 microamps (G), <50 microamps (NG)]
                                                               Input Isolation [< 50 microamps]
                                                          2.10 Rate Calibration
                                                               - verify rate accuracy at 60 BPM and 120 BPM
                                                                 [+/-  5% or 5 BPM, whichever is greater]
                                                          2.11 Rate Alarm
                                                               - verify visual and audible alarms at 60 BPM 120 BPM
                                                                 [+/-  5% or 5 BPM, whichever is greater]
                                                          2.12 Alarm Delay
                                                               - verify high and low alarm delay
                                                                 [< 10 sec]
                                                          2.13 Asystole Alarm Delay
                                                               - verify asystole alarm delay
                                                                 [< 5 sec]
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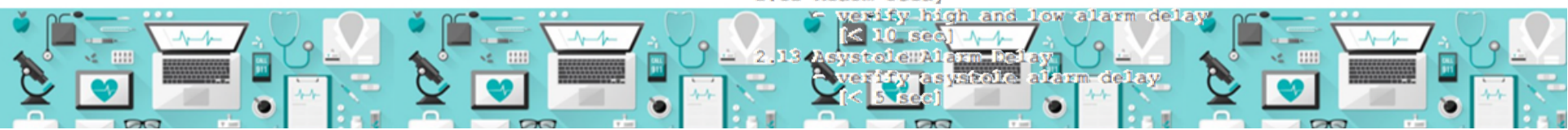
6.5 Troubleshooting

The following table summarises certain problems that may occur and the relative causes.

Problem	Cause
Isoelectric line drift	- Use of electrodes other than originals Use of electrodes in saturation - Insufficient electrode/skin contact - Electrode surface dirty - Patient moving
Interference from a.c. mains supply	- Voltage generator too close; presence of other clinical instruments (e.g. X-rays, etc.) - Patient in contact with metallic parts or with other persons
Muscle tremors	- Patient not relaxed - Peripheral electrodes adhering too tightly
Irregular paper transport	- End of paper roll - Paper roll incorrectly positioned - Use of non-original paper
Analysis impossible	Signal too unstable or noisy
No copy of trace	Recording interrupted before 10 seconds have elapsed
Abnormal signal	- Defective patient cable - Defective electrodes

8 Technical specifications

A.c. mains power supply	Device specified class I 230 V ± 10% 50/60Hz 115 V ± 10% 50/60 Hz
Maximum current absorbed	0.5 mA at 115 V ~ ±10% 0.25 mA at 230 V ~ ±10%
Mains protection	Fuse: T 0.5 A
Internal power source	12 V - 2Ah rechargeable lead battery
Internal power supply protection	Pico fuse SHF SLO-BLO T 5 A Littelfuse
Applied part	CF type
Defibrillation protection	Internal
Input dynamic	± 300 mV @ 0 Hz.± 10 mV in pass band
Input impedance	> 100 MΩ on each electrode
Common mode rejection	> 100 dB balanced electrode impedence
Frequency response	0.05 - 150 Hz (-3dB)
Time constant	3.3 s
Acquisition	12 bit 1000 samples/s/channel printing and filters 500 samples/s/channel in calculation and filters Resolution 5 µV/bit
Leads	12 leads in Standard, Cabrera
Signal memory	10 seconds for each lead in auto isochronous
Recording sensitivity	*Manual:* 5 – 10 – 20 mm/mV *Automatic:* dependent on number of channels printed
Writing system	Thermal printer, 8 dot/mm Usable print height 210 mm
Print channels	12
Print format	Automatic mode: 3, 6×1, 6×2, "Full Page"(3×4+R)×1 e (3×4+3R)×1, 12×1 Manual mode: 3, 6, 12
Paper transport speed	5 mm/s ± 10% 25 – 50 mm/s ± 5%
Screen scrolling speed	12.5 – 25 – 50 mm/s
Thermal paper	*in rolls:* height 210x280 mm, length 17 m, gridded. *Z-fold pack:* length 30 m, page 210x150 mm, gridded. *Z-fold pack:* length 60 m, page 210x300 mm, gridded
Pacemaker recognition	Recognises pulse in accordance with current IEC standards
Filters	*Mains interference:* Modified digital notch filter 50 - 60 Hz linear phase - may be switched on/off. *Anti-drift:* Digital high-pass 0.5 Hz, linear phase, always enabled
Serial interface	Infrared
Keyboard	Membrane, with functional and alphanumeric keyboard extended
Display	Black and white type graphic LCD, 320x240 pixels (5.7 inch). Actual display area120x89 mm.
	Backlit with cold cathode fluorescent light.
Interpretation program	Parameter calculation (optional) *ECG interpretation* (optional): Arrhythmia Program (optional) HRV: RR variability (optional)
Type of use	Continuous
Operating modes	*Manual:* acquisition and printing in real time *Automatic* : simultaneous acquisition *Timed:* acquisition at user-defined intervals *Arrhythmia:* arrhythmic event recognition (optional) *PC-ECG:* real time acquisition with display at PC *HRV:* heart rate variability analysis *Emergency:* acquisition in emergency *Paper saving:* acquisition without printing
Options	- Memories option - ECG measurements option - ECG interpretation option - Arrhythmia option - HRV option - PC archive option - PC ECG option
Battery capacity	*Internal battery:* 1 hour in continuous recording and printing
Recharging time	*Internal battery:* 24 hours 100%
Housing protection category	IP 20
Ambient conditions:	
- operation	*Ambient temperature:* from +10°C to +40°C *Relative humidity:* from 25% to 95% (without condensation) *Atmospheric pressure:* from 700hPa to 1060 hPa
- transport and storage	*Ambient temperature:* from –10°C to +40°C *Relative humidity:* from 10% to 95% (without condensation) *Atmospheric pressure:* from 500 to 1060 hPa
Dimensions	325 x 80 x 345 mm (length x height x depth)
Weight	5000 grams without paper
Conformity to standards	EN 60601-1: 1990 EN 60601-1/A1: 1992 EN 60601-1/A2: 1995 EN 60601-1/A13: 1995 *General standards for safety of electromedical equipment* EN 60601-1-2: 1993 *Standards on electromagnetic compatibility of electromedical equipment* EN 60601-2-25: 1995 EN 60601-2-25/A1: 1999 *Particular safety standards for electrocardiographs* IEC/60601-2-51/Ed.1: 2001 *Particular standards on essential recording and analysis performance safety of single and multichannel electrocardiographs.*