We claim

1. An Electro Cardio Gram (ECG) device with impulse and channel switching Analog to Digital Converter (ADC) noise filter and an error corrector for derived leads comprising combination of ECG electrodes and lead wires (1) for measuring ECG signals and to determine the derived leads therefrom , an ECG module (2) coupled to the ECG electrodes and lead wires (1) for receiving the measured ECG signals therefrom and for digitizing the ECG signal, a user interface module (3) coupled to the ECG module (2) and a power unit (4) coupled to the ECG module (2) for providing electrical power thereto, characterized in that the said ECG module (2) is provided with a firmware wherein said firmware utilizes a burst sampling technique for filtering impulsive and channel switching ADC noise in the digitized ECG signals, followed by application of an interpolation technique for correction of errors in the derived **leads** caused by time delays due to sequential sampling of the ECG signals received from multiplexed Electronic Signal Channels (ESCs) in the ECG module, henceforth referred to as the directly measured ECG signals, and finally providing high order FIR filter utilizing convolution technique to remove noise outside ECG pass band .

2. A device as claimed in claim 1, wherein ECG module (2) comprising:
   a) an isolation buffer (2.0) to provide the isolation of the ECG signals picked up by the electrodes and leadwires (1);
   b) a multiplexer (2.1) coupled to the isolation buffer (2.0) to receive buffered ECG signal therefrom, the multiplexer adapted to switch from ECG acquisition to calibration mode during device self-calibration cycle;
   c) a signal conditioning and amplifier unit (2.2) coupled to the multiplexer (2.1) , the signal conditioning and amplifier unit comprising pre-amplification instrumentation amplifier (2.2.1), band limit filter (2.2.2), and post amplification and level shifting (2.2.3), wherein the said band limit filter is a combination of first order high pass and low pass analog filters;
   d) an averaging circuit (2.3) to calculate Einthoven's Reference Potential (ERP) in order to measure chest ECG signals with reference thereto;
   e) a calibration unit (2.4) coupled to the multiplexer (2.1), the calibration unit (2.4) comprising a voltage reference IC (2.4.1) and precision potential divider (2.4.2) to generate 1mV DC signal that is supplied to the multiplexer for subsequent

~~conversion by chopping at the multiplexer, to a 1 mV square wave calibration~~ signal with frequency within the pass band of ECG monitoring device;

f) an ADC (2.5) coupled to the signal conditioning and amplifier unit (2.2) and adapted to convert the amplified ECG signal voltages to produce digital data representative of patient's ECG waveform over a defined interval of time;

g) a control unit along with a firmware (2.6) coupled to the ADC (2.5), adapted to control and read data from the ADC (2.5), monitor and set the status indicators of the power & data indicator (2.7), control the multiplexer unit (2.1) via uni or bidirectional communication as applicable and adapted to filter the digitized directly measured ECG signals received from the ADC (2.5);

h) a power and data indicator (2.7) to visually indicate error status of the power unit (3) and the run state of the ECG module (2);

i) a communication channel (2.8) which is any one of a combination of SPI, USB, USART, RS-232, Bluetooth, zigbee, ethernet and used to communicate with the user interface module (3) ;

j) a memory unit (2.9) coupled to the communication channel ,to store and retrieve patient's digitized ECG waveform.

3. A device as claimed in claim 1, wherein the measured ECG signals received from the human body via ECG electrodes and lead wires (1) comprises left arm, right arm, left leg and chest ECG signals ; wherein these ECG signals are being input to an isolation buffer (2.0); wherein the left arm, right arm and left leg ECG signals are being input via the isolation buffer (2.0) to the averaging circuit (2.3) whose output is the ERP for measuring chest leads; wherein the said buffered ECG signals and the calibration signal from calibration Unit (2.4) are used as input to the multiplexer (2.1); wherein output of said multiplexer being used as input to the signal conditioning and amplifier unit (2.2) which provides amplified output in a required frequency range to the ADC (2.5), the output of said ADC (2.5) being used as input to the control unit (2.6) for removal of impulsive and channel switching ADC noise by using Burst sampling technique and correction for time delay due to sequential sampling of directly measured ECG signals using an interpolation method; wherein electronic signal channel (ESC) wise calibration constants are computed with the multiplexing unit (2.1) in a calibration mode and ~~wherein the digital and filtered output of said control unit (2.6) being used as input~~

~~to the User Interface Module (3) via communication channel (2.8); wherein the~~ said digitized and filtered ECG signals are being stored and retrieved from memory unit (2.9).

4. A device as claimed in claim 1 wherein the Burst Sampling technique being implemented in the control unit (2.6) for removing impulsive and channel switching ADC noise from the digitized directly measured ECG signals, comprising the steps of :

a) scanning all the multiplexed *n* ESCs for one set of readings by sending *n* ESC selection pulses to the ADC from the control unit, wherein *n* is equal to the number of multiplexed ESCs;

b)obtaining a burst of *m* digitized samples, for a given scanned ESC *i* , from the ADC where *m* denotes no. of sampling pulses and the said *m* digitized samples being numbered as $y_{i,1}$, $y_{i,2}$, .., $y_{i,m,}$ each after time interval t_s (burst sampling time)

c) sorting all the *m* digitized samples for a given ESC *i* ;

d) calculating weighted average of median and mean of *m* digitized samples to give one filtered digitized value for the scanned ESC*i* channel wherein the weight factors for the mean and median are *w* and *(1-w)* respectively, which together sum up to unity and are related as per the following:

$$\bar{y}^i = w < y^i > +(1-w)y^i_{median}$$

e) optionally in place of calculating weighted average of median and mean of *m* digitized samples , carrying out a partial median computation followed by the mean operation by discarding maximum and minimum values of *m* digitized samples and calculating mean of remaining *m-2* values, in case sorting for the median operation is time consuming in the context that the control unit (2.6) must complete scanning and processing of the signals received from *n* ESCs within the time available for one scanning cycle.

5. A device as claimed in claim 1, wherein errors in calculated derived ECG leads due to sequential sampling in time of directly measured ECG leads are corrected by ~~using values of the directly measured ECG signals interpolated to the same instant~~

~~of time; wherein the interpolated values are calculated utilizing an interpolation~~ algorithm comprising the steps of:

a) obtaining the digitized and filtered (with burst sampling technique) value y^{-i} for a given ESC i corresponding to a time (it_{ch}) relative to the time at which first ESC is measured in the current scanning cycle;

b) interpolating all the filtered digitized values y^{-i} for the n channels to a reference time ($i_0 t_{ch}$) corresponding to ESC number $i_0 = n/2$ to minimize interpolative corrections;

calculating interpolated value $y^{-i}{}_c$ ($i_0 t_{ch}$) , in terms of current filtered value y^{-i} (it_{ch}) and filtered value in the previous scanning cycle y^{-i} ($it_{ch} - \tau_s$), by using the linear interpolation formula given below:

$$\bar{y}_c^i(i_0 t_{ch}) = \bar{y}^i(it_{ch}) + (i - i_0)\left[\bar{y}^i(it_{ch}) - \bar{y}^i(it_{ch} - \tau_s)\right]\frac{t_{ch}}{\tau_s}$$

6. A device as claimed in claim 1, wherein the user interface module (3) consisting of (a) a visual graphics display, such as an LCD / Mobile phone screen/ PC monitor, to visually display the ECG signals, extracted parameters, and warning and error conditions if any (b) an input device such as keyboard, keypad, mouse, to control the ECG device, enter commands for various operations and enter patient data, etc. and (c) output devices such as a printer to provide a hardcopy of the ECG signals and extracted parameters, audio output for warnings and error conditions, wherein said user interface module (3) communicates with the memory unit and the control unit (2.6) via the communication channel (2.8) of the ECG module (2).

7. A device as claimed in claim 1, wherein the power unit (4) comprises of a power source (4.1) and an isolation chip (4.3) in case the power source is directly/indirectly connected to AC mains, or a battery (4.2), and a voltage inverter (4.4), wherein said power source provides voltage output in the range of 3V to 5V to supply electrical power to the ECG module (2).

8. A method for measuring and monitoring the electrical activity of heart using the ~~ECG monitoring device as claimed in any of the preceding claims, the method~~

comprising the steps of:

a) connecting ECG electrodes and lead wires (1) to patient ;

b) illuminating the power and data indicator (2.7) after turning on the device;

c) initializing all the hardware components of the ECG monitoring device including communication bus, timers , automatically by the control unit (2.6);

d) configuring interrupt for ECG data sampling by the control unit (2.6);

e) generating 1mV dc output as a calibration signal by the calibration unit (2.4), converting the calibration signal to a 1 mV square wave at a selected frequency in the ECG pass band by chopping by the multiplexer unit (2.1), and feeding the converted calibration signal to the circuit along the same route of amplifiers and filters etc. as the ECG signal;

f) storing digital count corresponding to 1mV calibration signal amplitude as calibration constants by the control unit (2.6);

g) passing the electrical signal measured by electrodes via isolation buffer(2.0) and also via an averaging circuit (2.3) to provide ERP for measuring chest signal with a reference point upon initiation of operation of the ECG monitoring device by a user;

h) providing the calibration signal, the ERP and the ECG signals from electrodes as input to the multiplexer(2.1) in order to arrange routing of said signals to three Electronic Signal Channels (ESCs);

i) providing output of the multiplexer(2.1) to Signal Conditioning and Amplifier unit (2.2), which outputs the signal in the required frequency range typically from 0.22Hz to 100 Hz with a typical gain of 1000;

j) applying output of Signal Conditioning and Amplifier unit (2.2) to 12 bit precision ADC (2.5);

k) receiving of Electronic Signal Channel (ESC) selection signals and receiving of ADC conversion trigger by the ADC (2.5) from the control unit (2.6) to digitize the output of Signal Conditioning and Amplifier unit (2.2)

l) applying filtering for removing impulsive and channel switching ADC noise by using 'Burst Sampling' technique from the output of ADC (2.5) by control unit (2.6);

m) checking for underflow and overflow of the ADC(2.5) for clip detection by the control unit (2.6);

n) applying linear interpolation by the control unit(2.6) for correcting errors due to non simultaneous sequential sampling of directly measured ECG signals;

o) temporarily storing digitized and filtered data into the data buffer of control unit (2.6);

p) building data frame by adding header and footer into the stored digitized and filtered ECG data after data buffer is full;

q) communicating data frame to the user interface module (3) through communication channel (2.8) by control unit (2.6) and reinitializing the data buffer of control unit(2.6);

r) parsing data frames to detect and correct transmission errors if any;

s) applying further filtering which uses real time digital FIR filters using convolution onto parsed data frames to ensure that only ECG data in the frequency band 0.3 to 32 Hz is retrieved;

t) plotting filtered data from output of FIR filters on the output device such as LCD/mobile phone/PC screen;

u) recording and storing of filtered ECG data onto the memory unit (2.9) such as MMC, hard disk, phone memory along with patient information for future reference by using platform independent graphical user interface;

v) extracting vital ECG parameters such as Heart Rate, RR Interval, PR Interval, QT Interval, QRS Width, and QRS Angle from recorded ECG data by using analysis software;

w) printing of ECG report.

9. A method as claimed in claim 8, wherein the noise in the directly measured ECG signals is removed at three stages in sequence, the stages being:

a) at the first stage, implementing a hardware based analog band limit filter (2.2.2) in the signal conditioning and amplifier unit (2.2) to filter out DC offsets and frequencies above Nyquist frequency to prevent aliasing effects, which attenuates noise, at frequencies above the Nyquist frequency in the digitized ECG signals from ADC (2.5), folding back into the ECG pass band frequencies when the FIR filters are applied later at the third stage, wherein the required pass band frequency is in the range of 0.22 Hz to 100 Hz;

b) at the second stage, implementing burst sampling filter in the control unit (2.6) to filter out noise consisting of spikes/glitches/impulses, thus removing

such noises completely or attenuating it so that the ringing or oscillations caused by application of FIR filters (at the third stage) to impulses are reduced;

c) finally at the third stage, implementing real time digital linear band pass, FIR filters, using convolution techniques in the control unit or externally on a PC/Laptop to filter base line wander, EMG noise, power line noise and other noises outside the ECG pass band of frequencies in the range of 0.3Hz to 32Hz.

10. A method as claimed in claim 8, wherein the said pass band frequencies may vary depending upon design of said analog and FIR filters.

11. A method as claimed in claim 8, wherein extraction of the vital parameters of ECG signals by analysis software comprising:

a) selecting two ECG lead signals from recorded and stored ECG Leads I, II and III with largest rms value;

b) applying high order FIR low pass filter with cut off frequency at 20Hz on selected two ECG lead signals to get smoothened ECG lead signals;

c) applying numerical differentiation on obtained smoothened ECG lead signals to get derivative ECG signal;

d) converting obtained derivative ECG signal to Multiplication of Backward Differences(MOBD) ECG signal;

e) applying adaptive threshold algorithm on obtained MOBD ECG signal to locate and identify QRS complexes;

f) computing weighted derivative of smoothened ECG lead signals;

g) locating and identifying P-wave and T- wave, using the computed weighted derivatives as is in step(f), corresponding to each identified QRS complex;

h) computing RR-interval, heart rate, PR interval, QT interval and QTc , ST segment, QRS angle and the standard deviation in each of the measured quantity by using original, that is, before appliaction of additional filtering in step (b) values of ECG lead signals in the frequency range 0.32-32 Hz.

We claim

1. An electrocardiograph (ECG) device, comprising:

a) a plurality of ECG electrodes adapted to receive respective cardiac signals from the body of a subject;

b) a plurality of electronic signal channels (ESCs) electrically connected to selected ones of the plurality of electrodes and adapted to provide ECG voltage signals corresponding to the cardiac signals;

c) an analog-to-digital converter (ADC) operatively connected to the plurality of ESCs and adapted to:

i) receive a selection of one of the ESCs;

ii) capture a plurality of time-separated samples of the ECG voltage signal from the selected ESC; and

iii) provide a plurality of digital values corresponding to the captured plurality of time-separated samples from the selected ESC;

d) a firmware storing an algorithm for a burst sampling technique;

e) a control unit responsive to the algorithm and adapted to:

i) provide successive selections of the ESCs to the ADC, so that respective pluralities of digital values are provided for each ESC;

ii) process the respective pluralities of digital values to provide a respective interpolated digital value for each ESC, wherein the respective interpolated digital value for each of the ESCs is interpolated to a common selected reference time; and

iii) process each of the respective interpolated pluralities of digital values through a high order FIR filter using convolution techniques, so that noise is reduced;

f) a power unit for providing electrical power to the control unit; and

g) a user interface module coupled to the control unit.

2. The ECG device according to claim 1, further including:

a calibration unit adapted to provide a calibration signal in a selected pass band of the ECG device; and

an isolation buffer and a multiplexer electrically connecting the ECG electrodes to the respective ESCs, wherein the isolation buffer provides respective buffered cardiac signals corresponding to the cardiac signals and the multiplexer selectively provides to each of the ESCs either a signal derived from the respective buffered cardiac signal or the calibration signal;

wherein the control unit is further adapted to:

i) cause the multiplexer to provide the calibration signal to each of the ESCs;

ii) provide successive selections of the ESCs to the ADC, so that respective pluralities of calibration digital values are provided for each ESC; and

iii) store the respective pluralities of calibration digital values.

3. The ECG device according to claim 2, wherein the calibration unit provides a 1mV AC signal at a frequency falling within the selected pass band.

4. The ECG device according to claim 2, wherein the multiplexer selectively provides to the ESCs either the respective buffered cardiac signal or the calibration signal.

5. The ECG device according to claim 1, wherein the cardiac signals include a left-arm (LA) cardiac signal, a right-arm (RA) cardiac signal, and a left-leg (LL) cardiac signal, the ECG device further including:

an isolation buffer electrically connecting the ECG electrodes to the respective ESCs, wherein the isolation buffer provides respective buffered

cardiac signals corresponding to the cardiac signals; and

an averaging circuit electrically connected to the isolation buffer to receive buffered LA, RA, and LL signals corresponding to the LA, RA, and LL cardiac signals, respectively, and adapted to produce an average of the buffered LA, RA, and LL signals as an Einthoven's Reference Potential (ERP) signal.

6. The ECG device according to claim 5, wherein the cardiac signals further include a chest signal, the plurality of ESCs includes three ESCs, and the ECG device is arranged so that the LA signal minus the RA signal is provided to a first one of the ESCs, the LL signal minus the RA signal to a second one of the ESCs, and the chest signal minus the ERP signal is provided to a third one of the ESCs.

7. The ECG device according to claim 1, wherein each of the plurality of ESCs includes a respective instrumentation amplifier, a respective band-limit filter, and a respective post-amplification and level-shifting unit electrically connected in series in that order.

8. The ECG device according to claim 1, wherein the control unit is further adapted to select each of the respective pluralities of digital values in turn, and, for each selected plurality of digital values:

compute a mean and a median of the selected plurality of digital values; and

produce a weighted average of the computed mean and the computed median as a respective filtered digitized value for the ESC corresponding to the selected plurality of digital values.

9. The ECG device according to claim 8, wherein the control unit is adapted to produce the weighted average by forming a linear combination of the mean and the median with respective weight factors that sum to unity.

10. The ECG device according to claim 8, wherein the control unit is further adapted to remove a minimum digitized value and a maximum digitized value from each selected plurality of digital values before computing the mean of the selected plurality of digital values.

11. The ECG device according to claim 8, wherein the control unit is adapted to:

repeatedly provide selections, compute means and medians, and produce weighted averages for a plurality of scanning cycles, so that a plurality of filtered digitized values are provided, one filtered digitized value for each of the ESCs in each of the scanning cycles; and

process the respective pluralities of digital values to provide the respective interpolated pluralities of digital values by:

i) selecting two consecutive ones of the scanning cycles;

ii) for each of the ESCs, determining a respective trend using the filtered digitized values corresponding to the selected scanning cycles and to that one of the ESCs; and

iii) for each of the ESCs, interpolating the respective trend to the selected reference time to provide the respective interpolated digital value for that ESC.

12. The ECG device according to claim 11, wherein the selected reference time is a midpoint of the latter of the selected scanning cycles.

13. The ECG device according to claim 1, the user interface module having a visual display, wherein the control unit provides the respective interpolated digital values to the user interface module, which displays them on the visual display.

14. The ECG device according to claim 1, further including a user input device, wherein the control unit is responsive to a start command received via the user input device to provide the successive selections.

15. The ECG device according to claim 1, further including a memory unit adapted to store the respective interpolated digital values.

16. The ECG device according to claim 1, further including a communication channel, wherein the control unit is further adapted to transmit the respective interpolated digital values via the communication channel.