Bedside Patient Monitoring Systems

Bedside monitors are available in a variety of configurations from different manufacturers. They are designed to monitor different parameters but the common feature amongst all is the facility to continuously monitor and provide non-fade display of ECG waveform and heart rate. Some instruments also include pulse, pressure, temperature and respiration rate monitoring facilities.

The advent of microcomputers has marked the beginning of a fundamentally new direction in patient monitoring systems. Such systems are intended to replace the traditional monitoring devices with a single general purpose unit capable of recognizing the nature of the signal source and processing them appropriately. The hardware responsible for physiological signal analysis, information display and user interaction is actually a set of firmware modules implemented in terms of a microcomputer program. The firmware gives the system its functional personality and the usual switches, knobs, dials and meters can be replaced by a touch-sensitive character display. A typical example of a microprocessor-based bedside patient monitoring instrument is shown in Fig.1.

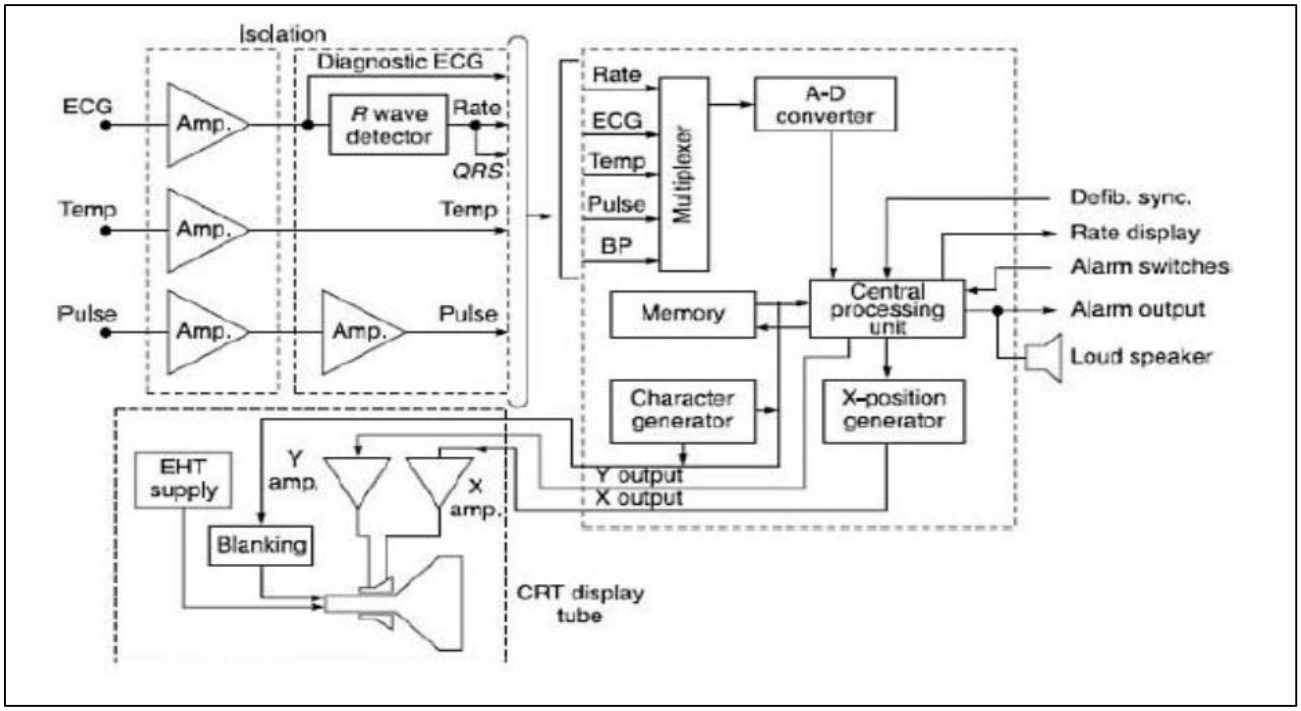

Figure1: Block diagram of the bedside patient monitor (Courtesy: Albury Instruments, U.K.)

The system is designed to display an electrocardiogram, heart rate with high and low alarms, pulse rate, dynamic pressure or other waveforms received from external preamplifiers. It also gives immediate and historical data on the patient for trend information on heart rate, temperature, and systolic and diastolic blood pressures for periods up to eight hours. The system basically consists of three circuit blocks: Preamplifier section, Logic boards and Display part. The preamplifiers incorporate patient isolation circuits based on optical couplers. The ECG waveform has facilities for lead-off detection, 'pacer' detection and quick recovery circuit for overload signals. Various amplified signals are carried to a multiplexer and then to an analog-to-digital converter, included in the logic board.

The central processing unit along with memory gives X and Y output for the CRT display. The character generator output is mixed with the Y output for numeric display on the CRT. The alarm settings, selection switches for different parameters and the defibrillator synchronization system communicate with the CPU. The alarm signals are also initiated under its control. The memory comprises 5 K bytes ROM and 3.25 K bytes RAM with 256 samples of ECG. Eight seconds delayed ECG is available for recording purposes.

Several important trends in the design and function of bedside monitors have emerged in the past few years. More bedside units are now software based, a feature that facilitates changes and updates in function by the simple replacement of computer memory chips. Wider use of on board microprocessors also permits bedside monitors to perform increasingly sophisticated signal- processing tasks. Advances in monitoring the haemodynamic parameters are particularly noteworthy. New smart algorithms help to carry out automatic calculations of indices of cardiovascular functions and artefact removal tasks. The trend in ECG monitoring is towards display and analysis of data from multiple leads.

Several manufacturers now include arrhythmia monitoring, including the monitoring of the ST segment of the ECG, as a standard feature in bedside monitors. While increasingly sophisticated monitoring capabilities have been added to bedside monitors, many monitors today are much easier to use than their predecessors were. Improvements in software and features such as touch screen make today's bedside monitors a user-friendly equipment.

Patient monitors are also known as vital sign monitors as they are primarily designed to measure and display vital physiological parameters. These monitors consist of the modular parts for measurement of the following:

- ECG and respiration
- Blood pressure (non-invasive) measuring electronics, pump and tubing
- Blood pressure (invasive)
- Temperature measurement
- Pulse probe and SpO2 (pulse oximetry)
- Microprocessor board including analog signal multiplexer, A-D
- converter and real time clock
- Video control board to convert the CPU commands into video signal
- Video display module
- Transformer and power supply board to generate necessary voltages
- Mother board including signal buses and analog input signal buffers
- Keyboard

Figure 2: Vital signs monitor (Courtesy: M/s Welch Allyn)

The whole system works under the control of multiple processors. Fig.2 shows a typical vital signs monitor. Today, patient monitors are portable, flexible devices capable of being adapted to a variety of clinical applications, supporting various wired and wireless interfaces. Fig. 3 shows block diagram of a multi-parameter patient monitoring system. Whether the monitor is a single or multi-parameter device; targeted capability, power consumption and system versatility are often key requirements. Nowadays, a monitor can move with the patient from the operating room to an intensive care unit, to the hospital room, and even into their home. This is paramount in today's world of health care.

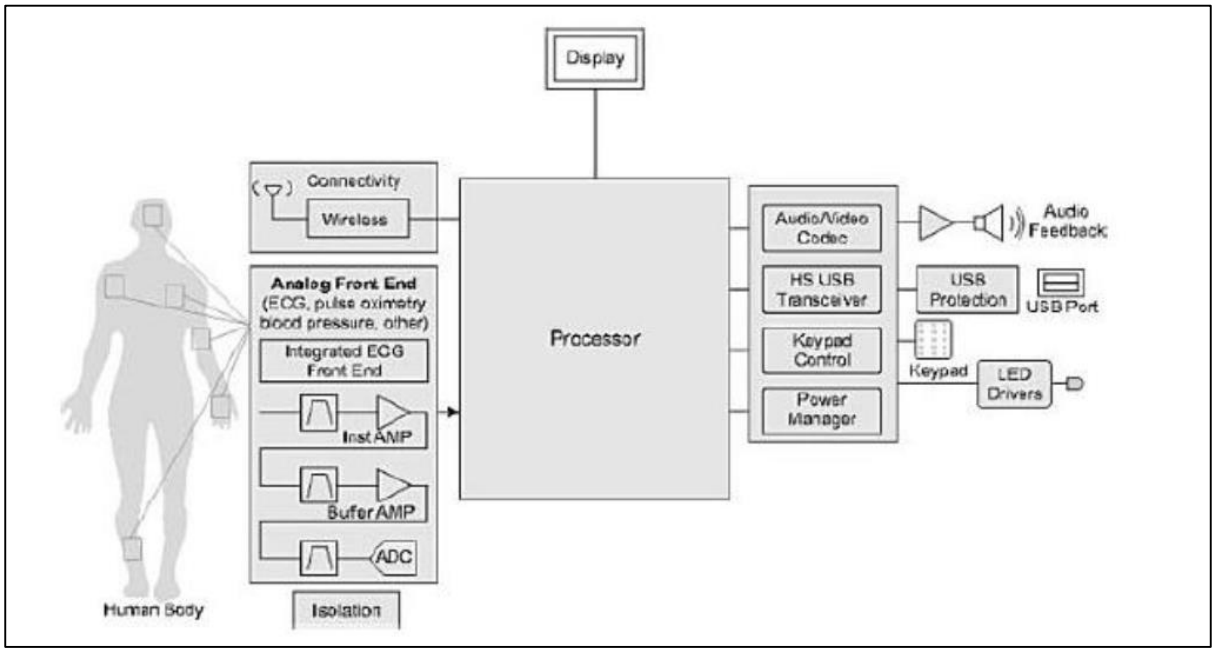

Figure 3: Block diagram of a multi parameter patient monitoring system with wireless connectivity (Adapted from M/s Texas Instruments)

Thus, the important features in today's patient monitors are mobility, ease of use, and effortless patient data transfer. Mobility includes portability as well as the ability to interface with other medical devices such as anaesthesia machines or defibrillators. Ease of use can be achieved with touch screen displays and multilevel menu driven profiles that can be configured for the environment as well as the patient's vital statistics. Data transfer across everything from wireless to RS232 needs to be possible. Hospitals may support a specific infrastructure throughout all areas; however, ambulance, home and other environments may need support for different protocols. The ever-increasing need to minimize healthcare costs is driving the healthcare providers to move the patient treatment and monitoring outside the hospital. The challenges in implementing such patient treatment and monitoring equipment’s are strikingly similar to cellular phone systems.

Central Monitoring

With central monitoring, the measured values are displayed and recorded at a central station. Usually, the information from the bedside monitors is also displayed with alarms etc. in a central station.

The central station monitoring equipment may incorporate a multi-microprocessor architecture to display a flexible mixture of smooth waveforms, alphanumerics and graphics on a single display. This presents all the information at a glance and thus assists the hospital staff in several ways. First, it generates audible and visual alarms if preset vital sign limits are exceeded. It is important that the central station announces these emergencies without generating too many false alarms, arising due to patient movements, etc. Secondly, it displays the patient's vital sign data. By watching this data, the attending staff can detect problems before they reach the alarm stage. Trend plots of vital signs aid in guiding the patient's therapy. Thirdly, it provides a recording of the ECG and sometimes of other parameters, especially of the few seconds just before an alarm, which shows what kind of irregularity led to the alarm.

Central stations are primarily designed for coronary care patients to display ECG waveforms and heartrate information, say for eight patients. A long trend (for either 9 or 24 h) or short trends (90 min) may be selected for display for observation and/or documentation. The information for the central monitor is collected from the bedside. Each bedside cable contains as many as fifteen analog signals representing physiological parameters, which may include several blood pressures, ECG, heart rate, respiration, end-tidal CO2 and temperature. Status information such as alarm signals is also carried by the same cable. The 80 or so incoming physiological values are then sampled and digitized at appropriate rates by an analog-to-digital converter. ECG waveforms are sampled every two milliseconds to maintain the 0-100 Hz bandwidth. Slowly varying variables such as temperature are sampled every four seconds.

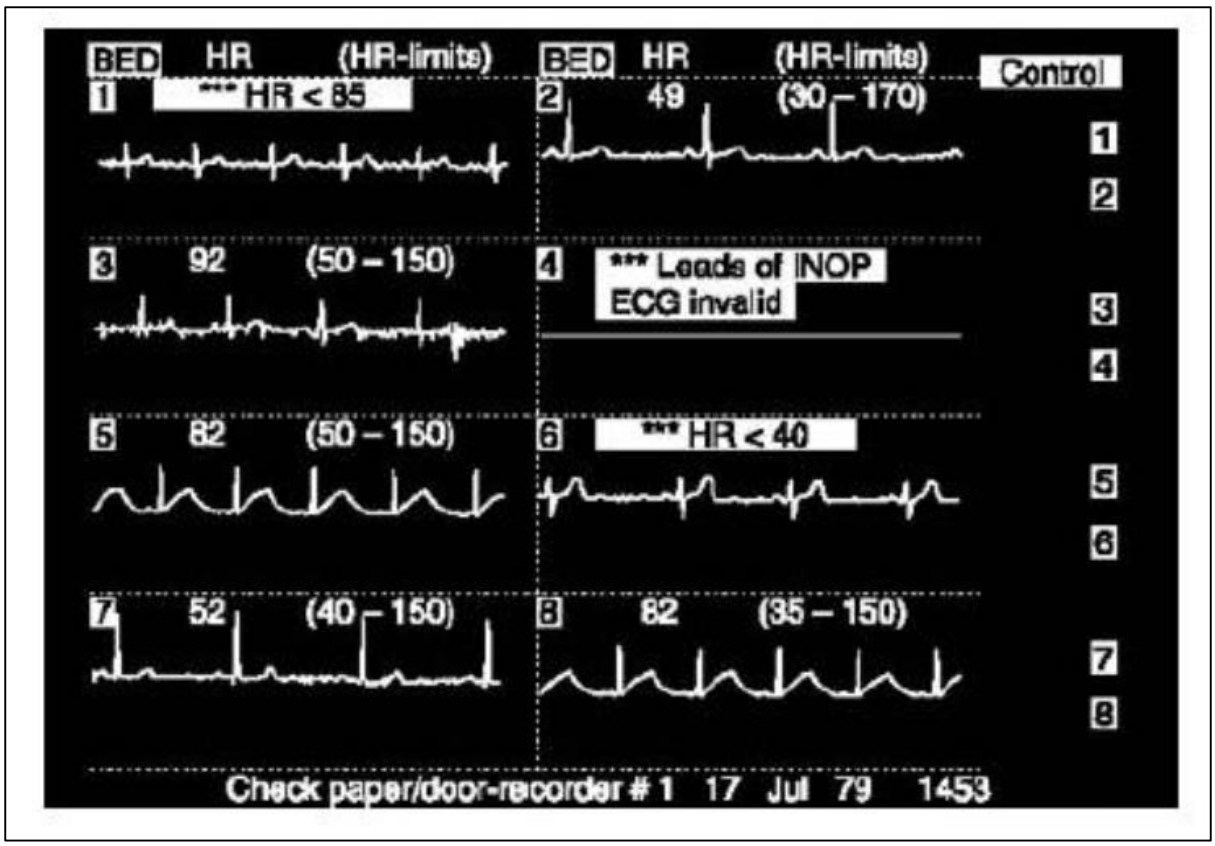

Figure 4: Typical displays on the patient information centre. The display depicts information on the heart rate, alarm limits, display of ECG waveforms from four to eight patients (Courtesy: Hewlett Packard, U.S.A.)