

## A Chest Compression System for Cardiopulmonary Resuscitation

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### Abstract

A chest compression system for Cardiopulmonary Resuscitation (CPR) has been developed in house successfully. An electronic control unit has been developed and the details of construction and working principles are presented. Ambu manikin and the details of CPR software to analyze the data are explained. It is shown that with this indigenously developed chest compression mechatronics system it is possible to perform CPR satisfying AHA (American Heart Association) guidelines: 100 compressions per minute with a uniform compression depth of 50 mm.

**Keywords:** Micro controller, CPR, Parallel Manipulator, AHA guidelines.

### 1. Introduction

A recent U.S. National Academy of Engineering and Institute of Medicine study advocated the applications of engineering tools and information/communication technologies to improve the quality and productivity of the healthcare system [4]. Competing in a globalized market requires the adaptation of modern technology to yield flexible, multifunctional products that are better, cheaper, and more intelligent than those currently on the shelf. The importance of mechatronics is evidenced by the myriad of smart products from washing machines to multifunctional precision machines [5, 10]. In a mechatronic system, the mechanical part has to perform certain motions and the electronic part and embedded computer system add intelligence to the systems. In the mechanical part of the system, power plays a major role. In the electronic part, information processing is the main issue. The sensors convert the mechanical motions into electrical signals where only the information content is important although a proper controller enables building a cheaper physical system, a badly designed physical system will never be able to give good performance by adding a sophisticated controller. Therefore, a proper choice be made with respect to the physical system properties needed to achieve a good performance of the controlled system [3, 8]. On the other hand, knowledge about the abilities of the controller to compensate for physical system imperfections may enable that a cheaper physical system be built. It is important that the modeling of physical systems is done in a way that the dominant physical parameters are preserved in the model and that the controller design can be done simultaneously. Good mechatronic system designs are based on a real systems approach [1, 2]. The details of the development of a mechatronics chest compression system for cardiopulmonary

resuscitation are presented in this paper. It is observed from the results that the control system developed in-house works well and regulates the functioning of the system as per AHA (American Heart Association) guidelines.

## 2. Development of an Electronic Control Unit

The design of the system follows a methodical approach. The microcontroller is the center of all activity and is essentially an interpreter between the input and the hardware peripherals. All the input data is sent to the microprocessor through input panel switches. And all output peripherals are connected to microcontroller with required electronics components like LCD display units. The requirements of AHA standards like compression depth, compression rate, and pause between the chest compressions are met by the system. The LCD indicator panel for continuous display of the above and is powered by 9V AC/DC adapter. After performing 30 compressions the microcontroller stops sending signals to the relay for the pause time which is generally for providing two rescue breaths, and then starts sending signals to the solenoid for chest compressions. Fig.1 shows the flowchart in which the program is written for Atmega16 micro controller using C++ embedded programming language and built in the control system [6].

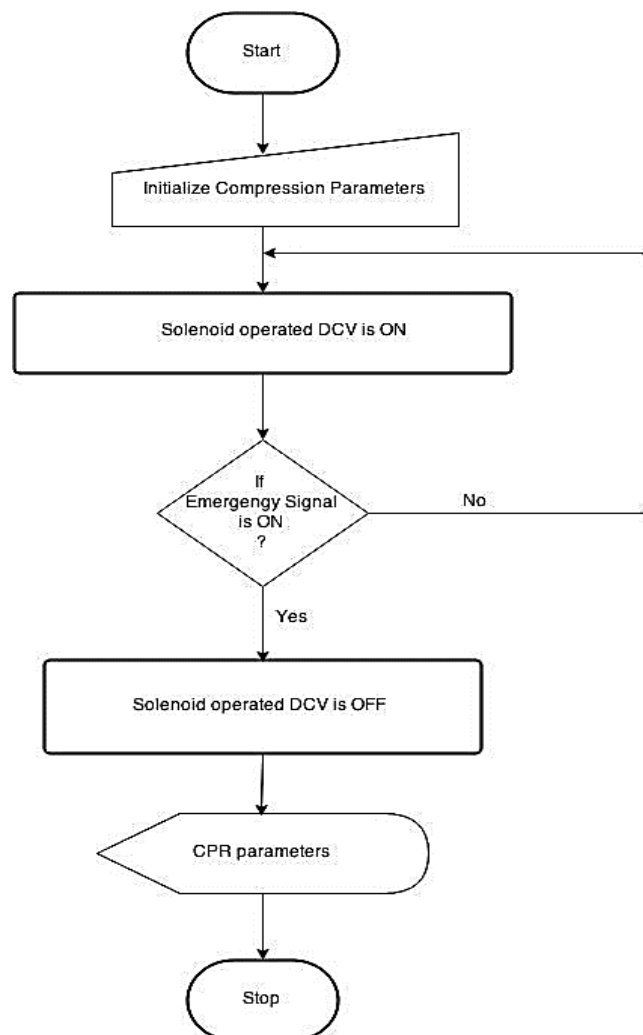


Figure 1: Flow chart

The microprocessor used for this work is the AVR ATMEGA16. It is a general purpose microcontroller with a variety of peripheral ports such as analog-to-digital converters (ADC), bidirectional TTL input/output ports, and a USART interface to allow RS232 serial communication. The original design of the embedded system hardware was to create a piece of hardware similar to a development board or kit. All of the basic oscillator, power, and programming components were implemented, and all output ports were connected to header connectors for ease of use during experiments and testing. Fig.2 shows the block diagram of the control unit and fig.3 shows the photograph of the hardware of the control unit developed.

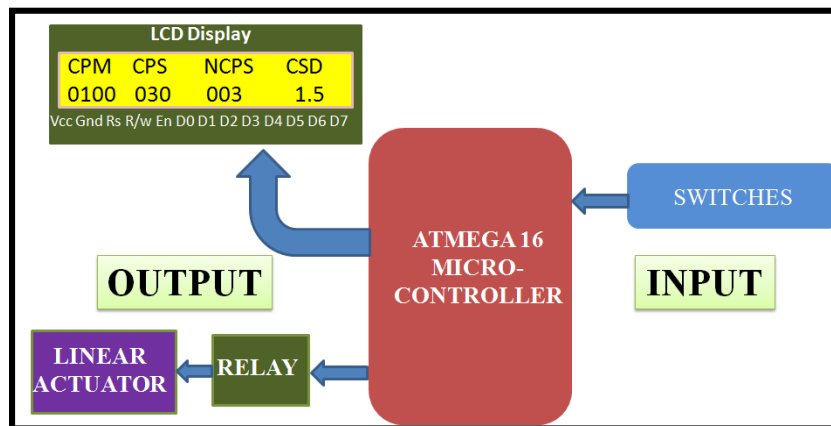


Figure 2: Block diagram of the control system

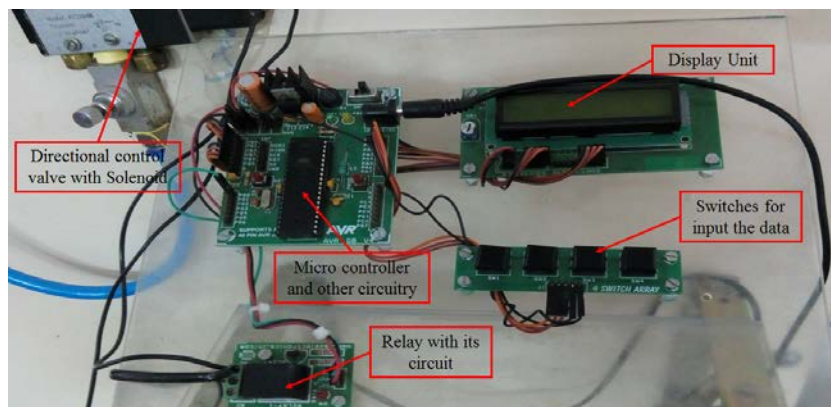


Figure 3: Photograph of a Electronic Control Unit (ECU) system

A veroboard prototype circuit was created as the final embedded software hardware. The circuit diagram in fig.4 depicts the final embedded system configuration. The microprocessor used is the AVR Atmega16 [6]. It was primarily chosen due to the following reasons:

- The development and programming interface of AVR Studio is easy to use.
- Atmega 32 is a mainstream processor and is compatible with many programmers
- Contains an adequate 16 Kbytes of flash memory

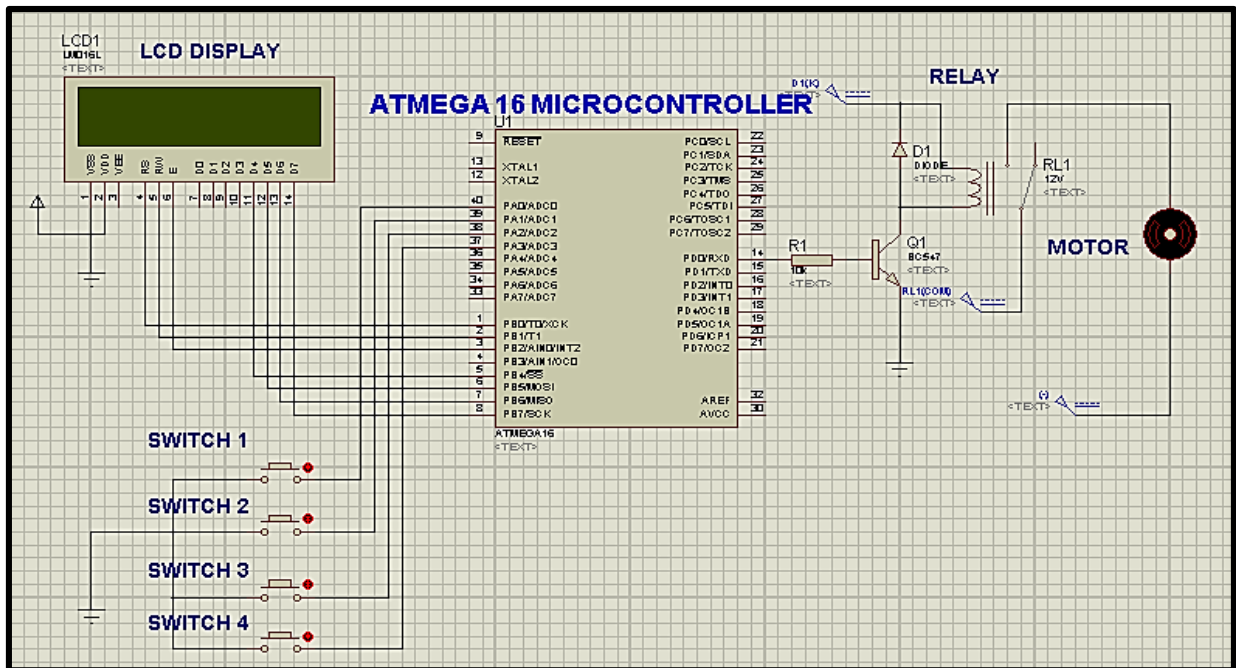


Figure 4: Circuit diagram of the control system

### 3. Ambu Manikin and CPR Software functions

#### 3.1 Configuration window

The configuration windows is separated into 4 Tabs:

- General** - In the "General" setting, a sound can be configured to indicate when the session is finished. The frequency of the metronome can be set / activated during the session to show / hide the ECG.
- Debriefing** - The tab "Debriefing" shows the settings of the ventilation parameters and all compression parameters.
- Print** - In the tab "Print" settings can be changed for the printout of the sessions
- CPR Controller** - In order to transfer the data to the CPR Controller, it must be connected to the computer.

#### 3.2 New session window

When the Ambu CPR Software is started, a routine starts to detect the manikin that is connected with the computer. The pull-down menu gives the possibility to choose a predefined scenario. It is possible to modify the chosen scenario with the Algorithm, Duration, and pull-down menus. Fig. 5 shows the details of the new session. Fig.6 gives the details of the main window.

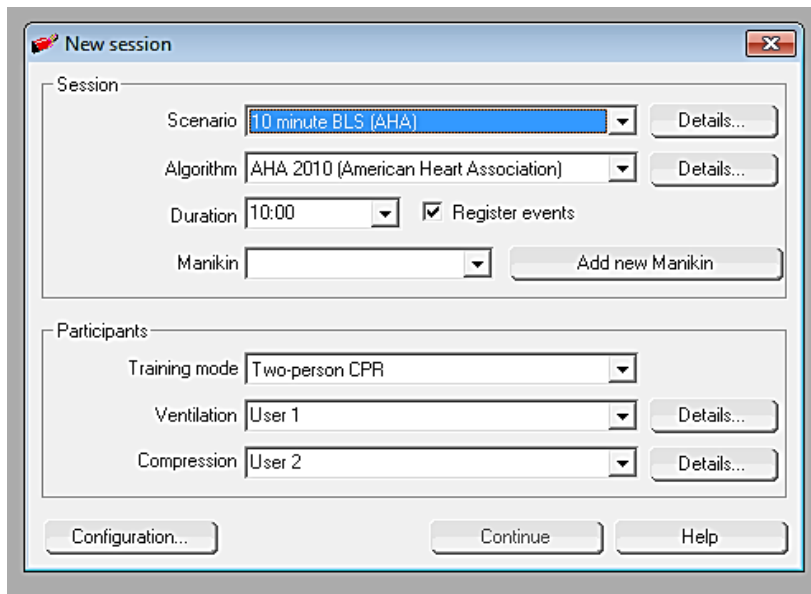


Figure 5: New session showing a particular AHA scenario.

3.3 Main window

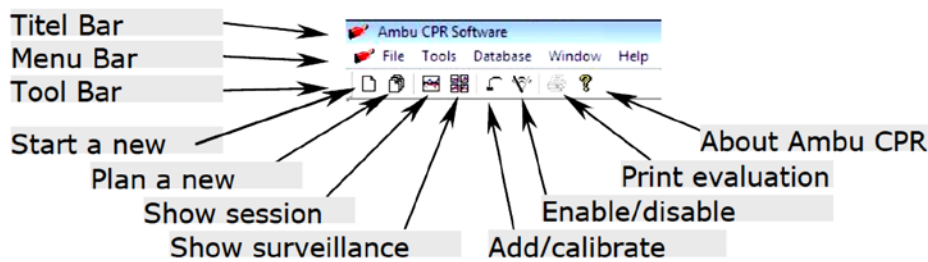


Figure 6: Main window of CPR software

3.4 Graph window

The graph window is used to visualize the different parameters (A-H). Furthermore it provides with on-screen evaluating features (I,J) and additional information (K-P). Fig. 7 gives the details of the CPR software and Table – 1 gives the terminology used in the graphics window.

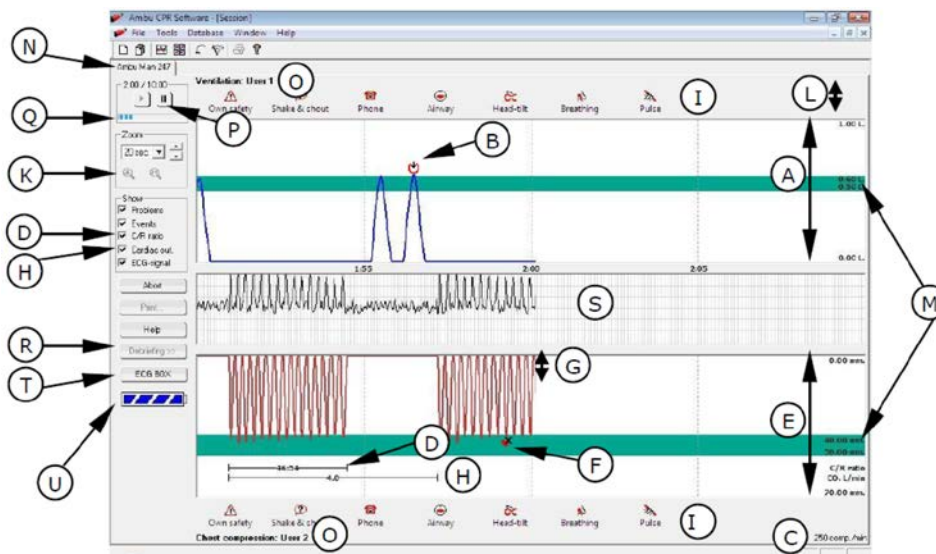


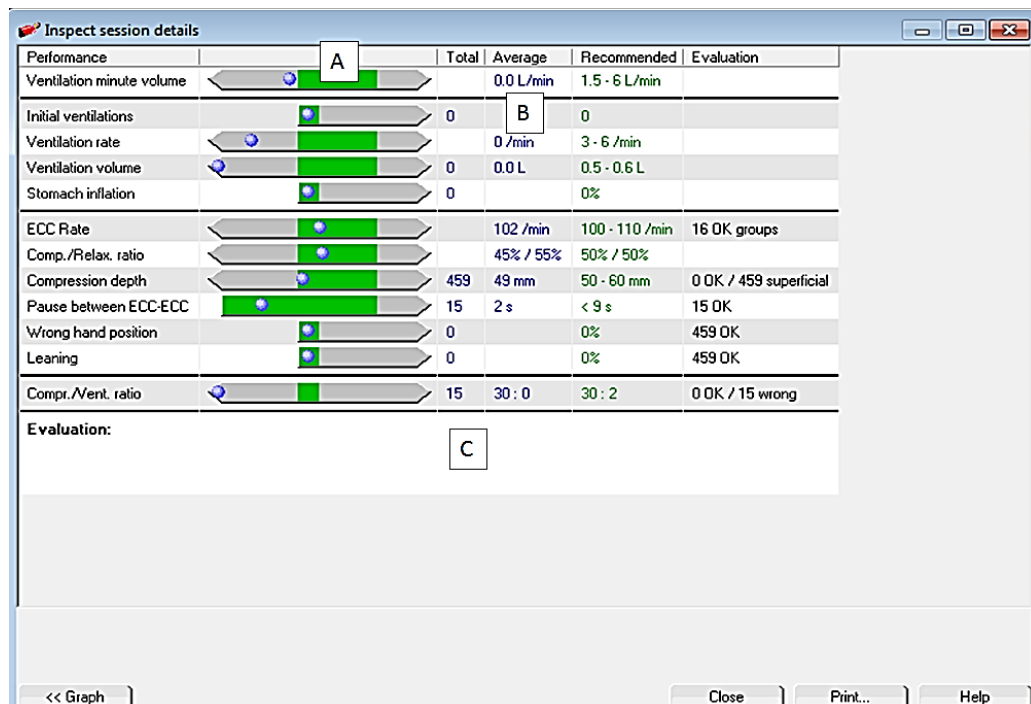
Figure 7: Details of the CPR software

**Table 1:** Terminology of the graphics window

| Ventilation      |                                 | Evaluating features / information   |  |
|------------------|---------------------------------|---|--|
| A)               | Ventilation volume              | K) Modify displayed time interval (Zoom in/out)   |  |
| B)               | Stomach inflation, indicator    |   |  |
| Compression      |                                 | L) Compression-Ventilation coordinates<br>M) Actual Recommendations<br>N) Actual manikin<br>O) Name of participants<br>P) Start / pause a session<br>Q) Actual time out of total time<br>R) Link to the result window |  |
| C)               | Actual Compression Rate (1/min) |   |  |
| D)               | Comp. / Relax. Ration           |   |  |
| E)               | Compression depth               |   |  |
| F)               | Wrong hand position             |   |  |
| G)               | Leaning                         |   |  |
| H)               | Cardiac output                  |   |  |
| Event Management |                                 | Debriefing  |  |
| I)               | Event Tool bar                  | S) ECG signal<br>T) Show / hide ECG Box<br>U) Battery Status  |  |
| J)               | Event trace (not shown)         |   |  |

### 3.5 Debriefing window

The debriefing view gives the performance of the CPR process. Figure 8 shows the details of a debriefing window. The indicator (A) must be within the green section. This indicates that the various parameters have been carried out correctly according to the recommendations in force. The indicator (B) shown in this column display the average or the percentage achieved. The personal recommendation can be added in this field(C) [7, 9].

**Figure 8:** Debriefing window



### 4. Results and discussions

The technological advances in digital engineering, simulation and modeling, electromechanical motion devices, power electronics, computers and informatics, MEMS, microprocessors, and DSPs have brought new challenges to industry and academia. Mechatronics is the synergistic combination of mechanical, electrical engineering, computer science, information technology and includes the use of control systems as well as numerical methods to design products with built-in intelligence. After developing the mechatronics system to operate the mechanism for performing the chest compressions, experiments were conducted. The mechatronics system is designed in such a way that it meets the requirements of AHA standards for frequency of chest compressions. Fig. 9 shows the complete setup of the experimental unit with power source and electronics control unit.

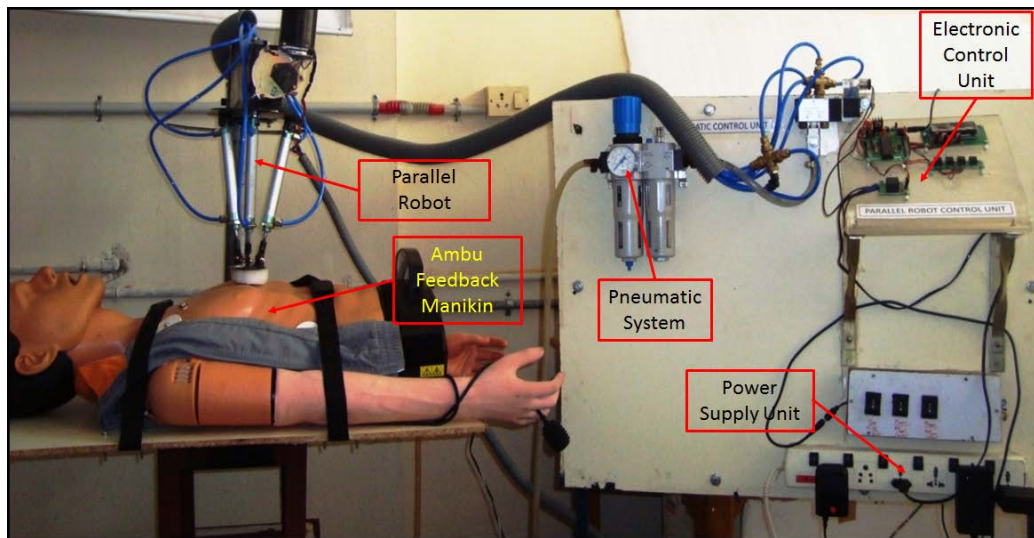


Figure 9: Experimental setup with control unit

Fig. 10 shows the output of the electronics control unit processed by the CPR software. The compressions are uniform and the depths of compressions are 50 mm as per the AHA standards.

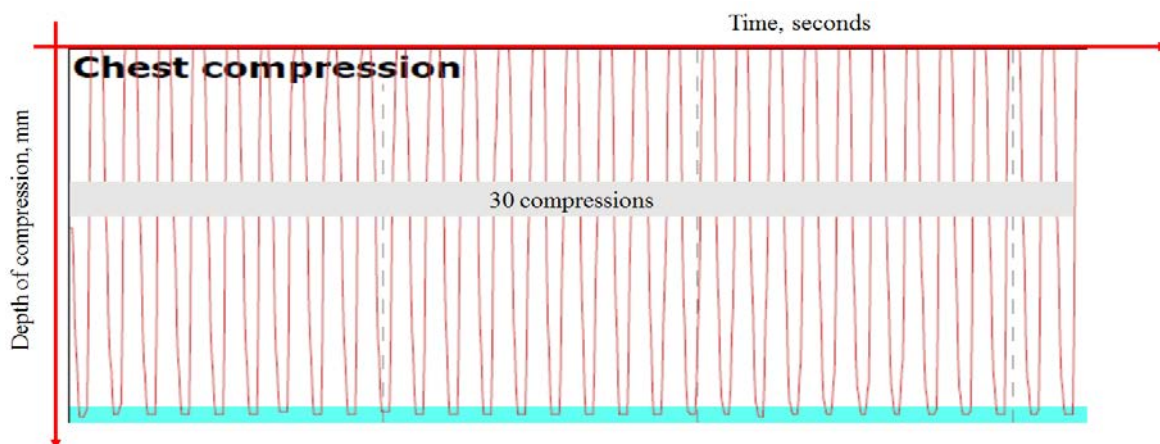
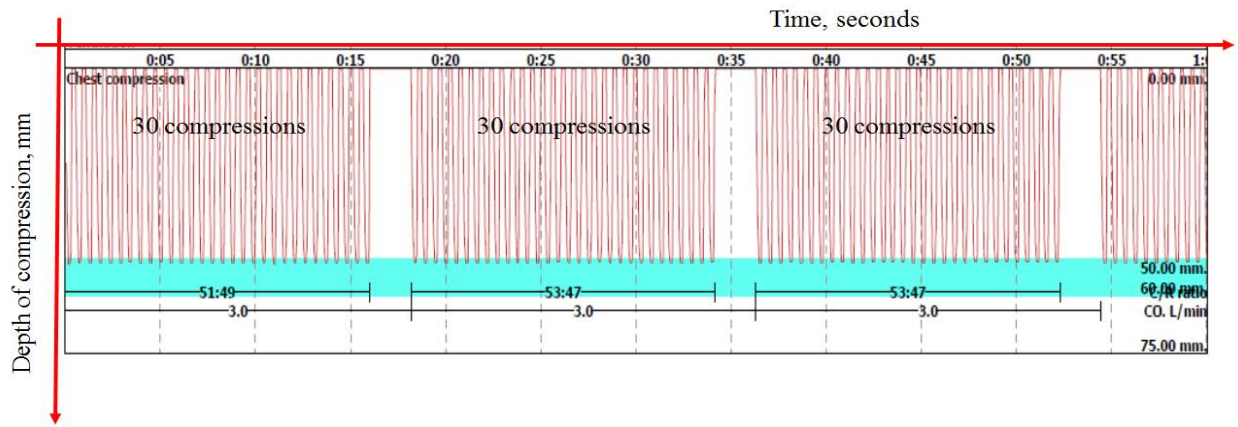


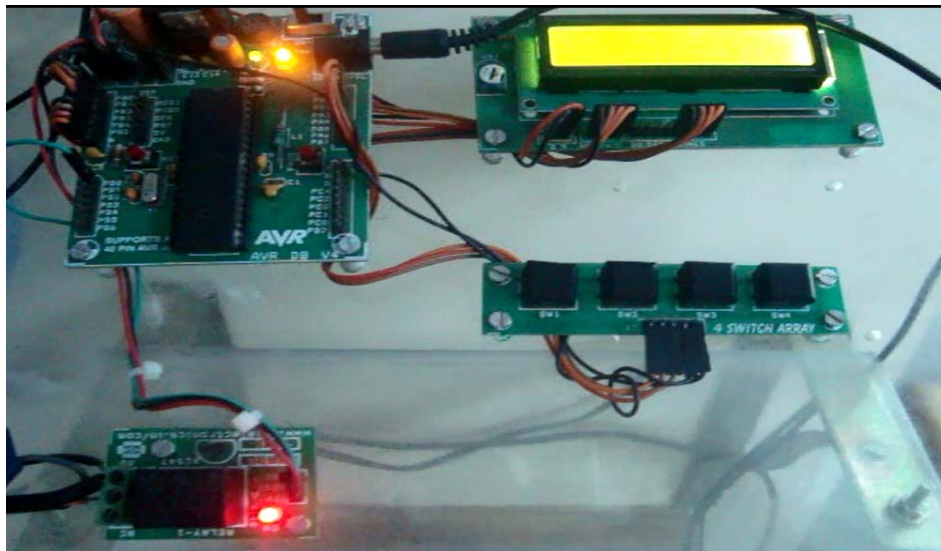
Figure 10: Output of the controller

Fig. 11 displays the chest compression rate 100 to 110 per minute as per the AHA standards for a period of 1 minute. A pause is given for 0.02 seconds for supplying oxygen.



**Figure 11:** External chest compressions rate - 100 to110 per minute

Fig. 12 shows the operation of the controller by means of LEDs which give indications to the rescue personals. LEDs indicate that the machine is ‘on’ and give information about the compression and decompression strokes. The LCD displays the running status of the machine by displaying the number of compressions (Noc) and the number of the compression set (NCS) as shown in figure 13. It is found that the system works well and the number of compressions is equal to the number of compressions set. Fig. 14 presents the compressions per minute (CPM), compressions per set (CPS), number of compression sets (NCPS) and compression set delay (CSD). It can be seen that through the set up developed indigenously, all these values are obtained accurately as per AHA standards.



**Figure 12:** LED indications during the process of chest compressions



**Figure 13:** Display of number of compressions (Noc) and number of compressions set (NCS)





**Figure 14:** Display showing compressions per minute (CPM), compressions per set (CPS), number of compression sets (NCPS) and compression set delay (CSD).

It can be seen that the control system developed indigenously works well and the experimental set up is fully ready for conducting experiments on the manikin on CPR process satisfying AHA guidelines.

## Conclusion

- The details of a control system are presented which has been developed for controlling a mechanical manipulator for performing cardiopulmonary resuscitation (CPR) as per AHA standards.
- Details related to Ambu manikin and CPR software is presented.
- It has been shown that researchers can develop low cost electronic control units to actuate mechanisms and develop in house mechatronic systems.

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## References

- [1] A. Gasparetto, R. Vidoni, V. Zanotto, "Design of a Mechatronic System for the Control of a Spatial Mechanism in a Tunnel Digging Machine," Proceedings of the 26<sup>th</sup> International Workshop in Alpe-Adria Danube Region (RAAD 2007), Ljubljana (Slovenia), June 7-9, 2007.
- [2] Annalisa Milella, Donato Di Paola and Grazia Cicirelli, "Mechatronic Systems, Applications," Published by In-Teh, Olajnica 19/2, 32000 Vukovar, Croatia, 2010.
- [3] D.A. Bradley, D. Dawson, N.C. Burd and A.J. Loader: Mechatronics - Electronics in Products and Processes, Chapman and Hall, 1991.
- [4] George T.-C. Chiu, Jaydev P. Desai, Jason Gu, and Guillaume Morel, "Guest Editorial: Introduction to the Focused Section on Healthcare Mechatronics," IEEE/ASME Transactions On Mechatronics, Vol. 15, No. 2, 165, April 2010.
- [5] G. Schweitzer, "Mechatronics - basics, objectives, examples", Journal of Systems and Control Engineering, Proc. I.Mech.E Vol 210, 1-11, 1996.
- [6] <http://www.atmel.com/images/doc2466.pdf>
- [7] <http://www.ambu-cpr-manikins.com/Basic-Life-Support.html>
- [8] Joh. Kepler University, Linz, Austria: International Mechatronics List, <http://technix.oeh.unilinz.ac.at/~strvmec/indexG.html>
- [9] Manual, Directions for Use Ambu® CPR-Software, pp. 2 to 27.
- [10] Thomos Brezina and Vlasislav Singula, "Design of Mechatronic Systems - report on Innovation of Mechanical Engineering Study Programmes", Faculty of Mechanical Engineering, BRNO University of Technology, 2006.

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