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Design of Intermediate Control and Communication Unit for Health Kiosk

Sanjana S[1] and Mr.Rathnakara S[2]
[1]M.Tech Student
Email: sanjanadarshan@gmail.com
[2]Dept. of Instrumentation Technology,
Sri Jayachamarajendra College of Engineering, Mysore, India
Email: rathnakara_s@sjce.ac.in

***Abstract*— This paper describes the design of interface board that integrates all the medical COTS (Commercial Off the Shelf) OEM (Original Equipment Manufaturer) modules into a single device that will be able to control and communicate with the OEM modules and transfers the read data to the cloud software via the kiosk application. This device shall have a custom protocol designed that will enable secure communication with the kiosk. The OEM Module connected to this device shall be able to measure the primary vital signs such as pulse rate, blood pressure, Oxygen saturation level(SpO2), temperature, Blood Glucose, Total Hemoglobin Content along with other parameters such as height and body weight.**

***Index Terms*— Embedded System, Microcontroller, Vital Signs, Interface device, COTS OEM modules.**

I. INTRODUCTION

According to World Health Organization (WHO) norm of 1:1000 doctor-patient ratios, the doctor to patient ratio in India is around 1 doctor for every 1700 patients and India is short of 500,000 doctors. Therefore in modern India to increase the patient care efficiency and also to have easy access to doctors for consultation, there is a need to screen the vital signs in every public health centers and Private health centers[16][17][18][19].

The major cause for poor health services is India is that the rural populations are neglected. Although, there are large number of Public Health Centers and rural hospitals yet the urban bias is visible. The health system in India has completely neglected preventive, pro-motive, rehabilitative and public health measures.

Primary health care is a cause of concern across most developing nations. Given the massive population in India, there is always a dearth of medical practitioners, which makes it highly challenging to offer primary health care to people in both urban and rural areas. Hence in an attempt to bridge the gap between doctors and people in need of medical attention, health kiosks appear to serve as a solution. Therefore, a health kiosk connects the doctor to the patient, wherever the patient is nearly ready to consult a true doctor and use the facilities within the boothto ownthe first diagnoses disbursed[3][8][11][12].

Health Kiosk are standalone stations with a set of medical devices for gathering the vital signs, video conferencing equipment, etc intended to be used by a larger group of patients in “public” areas such as corporation offices or hard to reach rural areas[1][4][9][11]. Since the diagnostic kiosks are shared between

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patients the following criteria become more critical:

- Full automation of the processes
- Data security
- Ease of sterilization
- High reliability (including mechanical reliability)

When thinking of designing such a system, it is important to have a vision of the future trends in the health care industry. Some of the key things that need to be considered are:

- Flexibility and scalability to address in terms of performance, costs optimizations, availability of interfaces.
- Fast prototyping to validate the key assumptions and resolve the usability problems by providing pre-integrated hardware / software solutions.
- Reduction of the development costs and shortening the time-to-market.
- Reduction of the BOM costs of final customized solutions.

In this paper we explain about the design that meets the above mentioned features and also Increase the reliability and the quality of health products by using tested and pre-certified “building blocks”. The main aim is to design such a device that integrates different tested and pre-certified Commercial-Off-the-shelf modules such as SpO2 module, Blood Pressure module, Thermometer module, Blood Glucose module, Total hemoglobin content module, ultrasonic sensor which measures the distance and the Load cell module for weight measurement and shall combine the results obtained from all the modules and transfers the read data to the cloud software via the kiosk application.

The Interface board provides very basic health services and monitoring of basic health data and also to act as a bridge and the intermediate source between the COTS OEM Modules and the PC end. With invent of internet of things and more, a two way video conferencing can also be employed in the Health Kiosk. It enables the Kiosk to measure the vital signs and provide reliable data for diagnosis [6][7]. This Interface Board is named as the Intermediate Control and Communication Unit.

By choosing the “off-the-shelf” platform based approach, the OEMs and medical device vendors can reduce their efforts on the custom hardware development and fully focus on value add areas of the business such as applications development.

II. DEVICE DESIGN AND IMPLEMENTATION

Defining an embedded system is not so easy but simply put, all computing systems other than general purpose computer are embedded systems. Embedded system is a system that has software(firmware) embedded into hardware, which makes a system dedicated for an application (s) or specific part of an application or product or part of a larger system[13][14][15][16]. The current interface board that is being designed is a part of a larger system that shall be used in Health Kiosk. This device shall act as an interface between the Health Kiosk and the Medical OEM Devices. The medical OEM device will have been designed with a custom proprietary protocol from the equipment manufacturer. Keeping in mind all the above points, an Interface board named as Intermediate Control and Communication Unit is designed to integrate all these devices to extract data and convert it to a common known format that the Health kiosk will be able to understand[2][13][14].

The Intermediate Control and Communication Unit is capable of integrating seven medical OEM devices that measures eight parameters of the patient such as Height, Weight, Non-Invasive Blood Pressure, Oxygen Saturation Level, Total Hemoglobin Count, Pulse rate/Heart rate, Blood glucose, and Body temperature.

The design of the Intermediate Control and Communication Unitinvolves the following stages in the design workflow.

- Hardware Design;
- Firmware Design;
- Custom Protocol Designs

III. HARDWARE DESIGN AND IMPLEMENTATION

The hardware design begins with the selection of the major component/s in this case that is the microcontroller. NXP/Freescale's Kinetis K60 series MCU has been selected to form the core of the ICCU. The finalization of this microcontroller is arrived after compiling and comparing with a set of other equivalent controllers that meet the initial basic requirement of the device. This process is called Decision Analysis and Resolution (DAR).

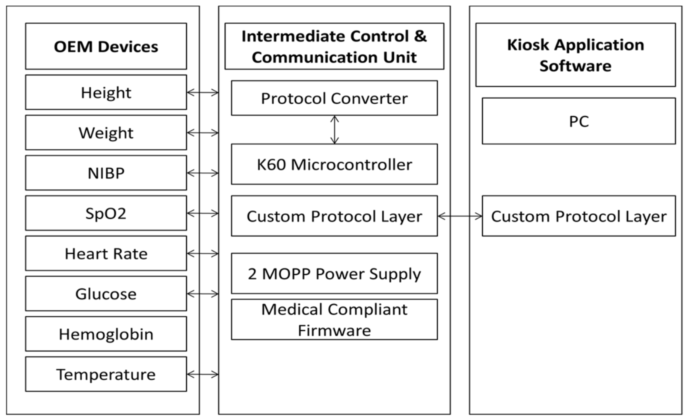

Figure1. Block Diagram Of The System Level Design

The selected microcontroller is an ARM Cortex-M4 core 120MHz 32-bit MCU. The front end Medical OEM devices have UART or RS-232 as the default hardware communication layer, therefore the interface device should be designed to accept this input. Each OEM device is connected to a dedicated port for communication. An RS-232 to UART level converter circuit that form the protocol converter circuit of the device is designed to connect it to K60 MCU. In order to send the data response from Intermediate Control and Communication Unit to Kiosk Application Software USB or RS232 port is used. Hardware design along with Firmware constitutes the whole system design.Fig.1.shows different blocks implemented in hardware as well as firmware design**.**

IV. FIRMWARE DESIGN AND IMPLEMENTATION

Firmware is a type of software that provides control, monitoring and data manipulation in embedded systems. The firmware consists of low-level control program for the device. In this project we have considered a low level programming method known as bare metal coding/programming that is specific to the hardware used. This is often used in small devices that require optimized coding. The below image is a typical baremetal firmware stack-up.

The application layer, API defines the high level interface of the behavior and capabilities of the component and its inputs and outputs. The HAL is a hardware abstraction layer that defines a set of routines, protocols and tools for interacting with the hardware driver. The driver and board support interface with the hardware and is the lowest layer of the firmware.Fig. 2 shows the Firmware Stack-Up.

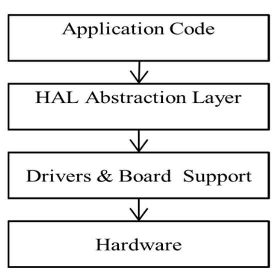

Figure2. Firmware Stack-Up

In order to establish communication it is necessary to implement drivers like UART Driver and USB Driver.

A. UART Driver

The data sensing module is interfaced to the Kinetis K60 microcontroller on UART lines. The UART line carries the command from microcontroller and response and data to and from it. In order to bring up the UART peripheral in the microcontroller, corresponding driver needs to be integrated in the baremetal program. The UART driver has the following functionalities.

- UART channel to initialize
- UART module Clock configuration
- UART baud rate, parity, Bit settings
- UART hardware interrupt configuration

B. USB HOST Driver

The USB Host low lever driver contains the low level driver code, commonly used class drivers, and some basic applications. The initialization flow starts when the application initializes the class driver that in turn initializes the low level driver and the controller. The class driver also registers the callbacks it requires for events occurring in the USB bus.

Sometime after this, the host starts the enumeration process by sending the setup packet to get descriptors for device, configuration, and string. These requests are handled by the class driver that uses the descriptors defined by the application.Fig. 3 shows in the next page shows USB HOST Driver Architecture Layers. The enumeration finally ends when the host sets the device configuration. At this point, the class driver notifies the application that the connection has been established.

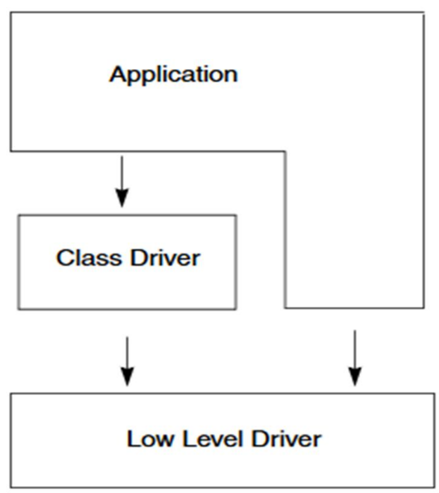

Figure3.USB HOST Driver Architecture Layers

C. Firmware Layer and Code Flow

Fig. 4 briefs the Code Flow Algorithm employed in the design of Intermediate Control and Communication Unit. The algorithm is divided into two parts, the K60 Algorithm and the Protocol Algorithm. Firstly all the UART peripherals in the K60 microcontroller are initialized by setting the clock source and the baud rate of the device connected to the corresponding UARTs. After initialization of the UARTs, the vector number and IRQ number are assigned in order to enable the interrupts.

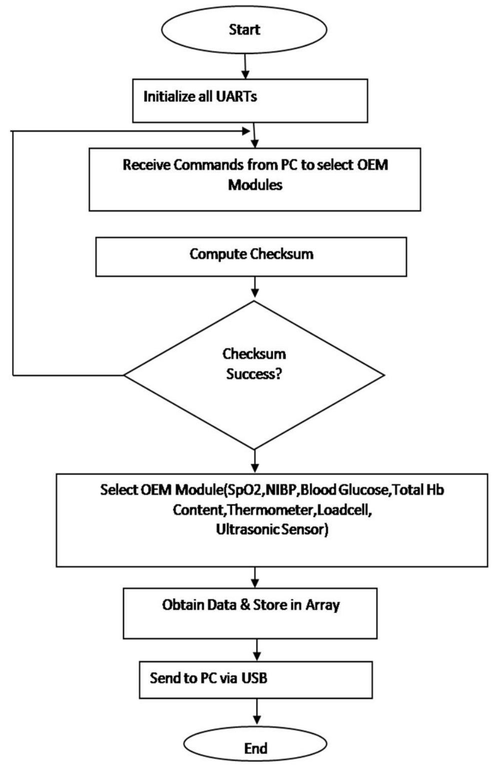

Figure4. Stage Wise Implementation Of Code Flow Algorithm

The program waits to receive the commands from the PC which are sent according to the custom proprietary protocol. Then the checksum is computed and verified with the checksum in the command. Once the checksum is verified, the specified OEM module is selected based on the Data ID in the command from PC and the data is read and the same data is simply pushed to the PC application side as defined in the custom proprietary protocol. In case of errors while reading the data from modules, error handling will be done.

V. CUSTOM PROPRIETARY PROTOCOL

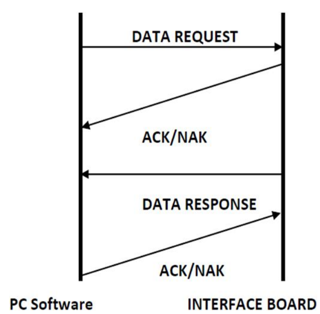

Figure5.Protocol Data Flow Diagram

As given in Fig.5, the PC Software sends the command in the specific defined format to the interface board. Upon receiving the data request packets, the Interface Board sends Acknowledgement (ACK) response after verifying the checksum of the data request command else if the checksum does not match then a Negative Acknowledgement (NAK) is sent to the PC Software. After sending the ACK or NAK, the interface board sends the Data response to PC software. After verifying the checksum of the data response command, the PC software sends ACK or NAK command to Interface board. Once the command is sent from PC Software to

interface board .The PC Software wait for a timeout of 5 seconds for the ACK. If timeout occurred without ACK the PC will send the command again and this process is iterated twice.
The command sent to Interface Board from PC is in the defined data format given below. TABLE 1 also shows the number of bytes. The frame size is 7 bytes.

TABLE 1.DATA FORMAT FROM PC TO INTERFACE BOARD

START BYTE	DATA ID	FLAGS	ERROR CODE	CSUM	STOP BYTE
STX	1 Byte	1 Byte	2 Byte	1 Byte	ETX

The data response data format sent from Interface Board to PC is given below. The frame size is 11 bytes. The 3rd Field in the data format indicated the data obtained from the module and will be 4 bytes in size.

TABLE 2.DATA FORMAT INTERFACE BOARD TO PC

START BYTE	DATA ID	DATA	FLAGS	ERROR CODE	CSUM	STOP BYTE
STX	1 Byte	4 Bytes	1 Byte	2 Byte	1 Byte	ETX

VI. RESULTS AND DISCUSSION

After integrating all the COTS OEM modules with the intermediate control and communication unit, each of the parameter is measured according to the sequence given in the TABLE 3.The process of measurement starts with measuring height of the patient. The program is executed in "IAR Embedded Workbench" which is written in C Programming Language. Data from each module is read and stored in the array in the hexadecimal format as given in TABLE 2. The obtained results are displayed in the hyper terminal as given in Custom Proprietary Protocol. The hyper terminal used is "Real Term: Serial Capture Program 2.0.0.70". Thus all the parameters are measured and results are obtained as per the sequence after integration.

TABLE3. OBTAINED RESULTS

Sequence No.	**Description**	**Measured Parameters with Units**	**Data Response (in Hex)**
1	Height of the user is measured.	Height –cm	02,10,C5,00,00,00,00,00,00,35,03 • C5 h=197 cm
2	Weight of the user is measured.	Weight-Kg	02,11,32,00,00,00,00,00,00,63,03 • 32 h =50 Kg
3	The normal blood oxygen saturation levels (SpO2) & Pulse rate are measured.	SPO2 (SpO2-1%-100%) (Pulse Rate-beats per minute)	02,12,62,55,00,00,00, 00,00,29,03 • SpO2 (62 h=98 %) • Pulse Rate(55h=85 bpm)
4	The blood pressure of the user is measured non-invasively. Also the Heart rate and Mean Arterial Pressure is measured.	NIBP (Systolic,Diastolic ,Heart Rate,Mean Arterial Pressure) (mmHg)	02,13,76,00,50,5A,60, 00,00,33,03 • Systolic (76h – 118 mmHg) • Diastolic(50h -80 mmHg) • Heart Rate(5Ah-90 bpm) • Mean Arterial Pressure (60h-96 mmHg)
5	Blood Sugar levels of the user are measured.	Blood glucose -mg/dL	02,15,59,00,00,00,00,00,2E,03 • 59h-89 mg/dL
6	Total Hb count of the user is measured.	Total Hemoglobin Content-g/L	02,16,0F,00,00,00, 00,00,45,03 • 0Fh-15g/L
7	Body Temperature of the user is measured.	Thermometer -˚C	02,17,25,00,00,00, 00,00,5C,03 • 25h-37˚C

VII. CONCLUSION

The work presented reveals that, a system based on the "Off-the–shelf" approach of integrating various different modules is achievable. Also, the Intermediate Control and communication Unit can be used in high level designs like Health Kiosk and Patient Monitoring Systems. This system provides effective solution to upgrade the existing health system. The system which consist the powerful K60 Arm Microcontroller can communicate with6 modules when compared to other microcontrollers. One of the drawbacks of the Intermediate control and Communication Unit is that only 6 modules can be integrated. This unit can be upgraded by interfacing more number COTS OEM Modules provided there is availability of a microcontroller with more than 6 UART ports. The unique combination of COTS OEM Modules and microcontroller will provide efficient design for system integration and this in conjunction with Health kiosk and Patient Monitoring Systems eliminate the barrier in patient health monitoring to enhance practical health delivery.

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