DEVELOPMENT OF CONFIGURABLE PATIENT MONITORING SYSTEM WITH SMS ALERTS

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ABSTRACT

It is necessary to constantly monitor the vital physiological parameters of aged people and patients in intensive care units and keep their records appropriately. In a large clinical set-up where few medical practitioners (doctors and nurses) attend to many patients, it becomes very difficult to keep informed about the conditions of each of the patients; and there is also possibility of human errors in measuring or recording process. Also, Telemedicine which is a rapidly developing area of health care where medical information is transferred through the phone or internet for the purpose of consulting and performing remote medical procedures is becoming popular. All these reasons demand a versatile automated patient monitoring system. The availability of low-cost biomedical sensors and the increasing computing power of embedded systems make it possible now. This work is aimed at developing a low-cost system for monitoring vital physiological signs such as blood pressure, heart rate and body temperature. The measured physiological parameters are displayed on a Liquid Crystal Display, time-stamped and stored in SD card memory. The system can be configured to perform the monitoring continuously or at a predefined time. Any of the stored parameters can be queried remotely through Short Message Service (SMS). The system can also be configured to notify medical personnel or care giver via SMS in the situations where any of the physiological signs are above or below predefined thresholds.

Keywords: *Blood Pressure, Heart Rate, Body Temperature, Embedded systems, Short Message Service.*

1.0 Introduction

Life becomes meaningless when one falls sick or dies due to improper medical care, and health nursing at home is not probable without a visit to a medical practitioner. For the medical profession, it becomes important to continue to monitor the vital physiological parameters such as; heartbeat, body temperature and blood pressure of aged people and patients in intensive care units which is usually done by doctors or other paramedical staff. They measure these physiological parameters of patients continuously and maintain a record of it, as these are the chief indicators of normal functioning of the body (Maruf *et al.*, 2014).

Meanwhile, the nature of the human body is to keep these vital physiological signs within a narrow, safe range in spite of large variations outside the body (Sim et al., 2012). If there is any abnormality in any of these vital parameters, then the patient is in distress and if the early actions are taken the health condition can be managed effectively and many patients can be cured and saved.

In a large clinical set-up where few doctors and nurses attend to many patients, it becomes difficult to keep informed about critical conditions of their patients. Therefore, for a sick person that is in critical condition and needs to be constantly monitored by physician or nurse, there must be some kind of health status monitoring device which would help to keep tracking the vital parameters for a patient and do data logging continuously, so that in case of any abnormality in the health status to raise an alarm and sends result as an SMS to concerned medical practitioner to quickly diagnose the patient's condition and take early precaution to save the patient's life.

Presently, mobile communication has become a widespread part and parcel of everyday life even in the rural areas of developing countries (Maruf *et al.*, 2014); so that at any given instant, a precise person can be contacted with by making voice call or sending a text message. Instant text messaging allows quick transmission of SMS, and this allows individual to share relevant information. Nonetheless, the applications of mobile phone cannot be restricted to sending text message or making conversations. New innovation can still be derived which can further expand its scope of applications. This sole reason is why this paper proposed a Patient Monitoring System (PMS) with SMS support for monitoring vital signs of patient health and in case of a critical condition, sends result as SMS to concerned physician or nurse to quickly examine the patient's condition. Henceforth, it helps to give patients a timely and proper health care. Therefore, for a good guarantee of the patient's daily life, a monitor designed for this purpose is needed.

2.0 Review of Related Works

The first monitoring system with heartbeat rate (without a body temperature and blood pressure detector) was invented in 1975 by writer, lecturer and inventor Gregory Lekhtman (Brown, 2011). Lekhtman continues to design fitness electronic devices for his international award winning company, Biosig Instruments Incorporated. He has also collaborated with fitness equipment manufacturers such as Sony, Polar and Nordic Track. By 1977, improvements were made on the original heart rate monitor, and the Polar Electro Company produced the first wireless heart rate monitor. It was specifically used in training the Finnish National Cross Country Ski team. By the late 1970s and early 1980s, heart rate monitors were available in stores abroad for consumers. There are some PMS available in the market but all are having some defect. What makes this project different from the existing products is that, it can be used for monitoring multiple critical physiological signs (heartbeat, body temperature and blood pressure) of patient and transmit the vital information to concerned medical practitioner. This PMS can monitor the patient and utilize an SMS support for a communication of signal collected by the sensor placed on the patient's body. The SMS support makes this device unique and extraordinary. It alerts the doctor when the patient's heartbeat, body temperature or blood pressure is abnormal. The system is very simple and can be used by medical professionals and non-professionals.

3.0 Methodology

The developed Patient Monitoring System (PMS) is made from inter-connection of different modules and sub-systems. The sub-systems are controlled and monitored by a Digital Signal Processor (DSP) - dsPIC30F4011. Figure 3.1 shows the block diagram of the developed PMS system, showing the different sub-systems: Blood Pressure/Heart Rate Measuring Unit, Temperature Measuring Unit, Remote Interface (GSM Modem), SD Card Memory, Real-Time Clock, Liquid Crystal Display and Push Buttons. The DSP firmware was developed in Microchip's MPLAB IDE.

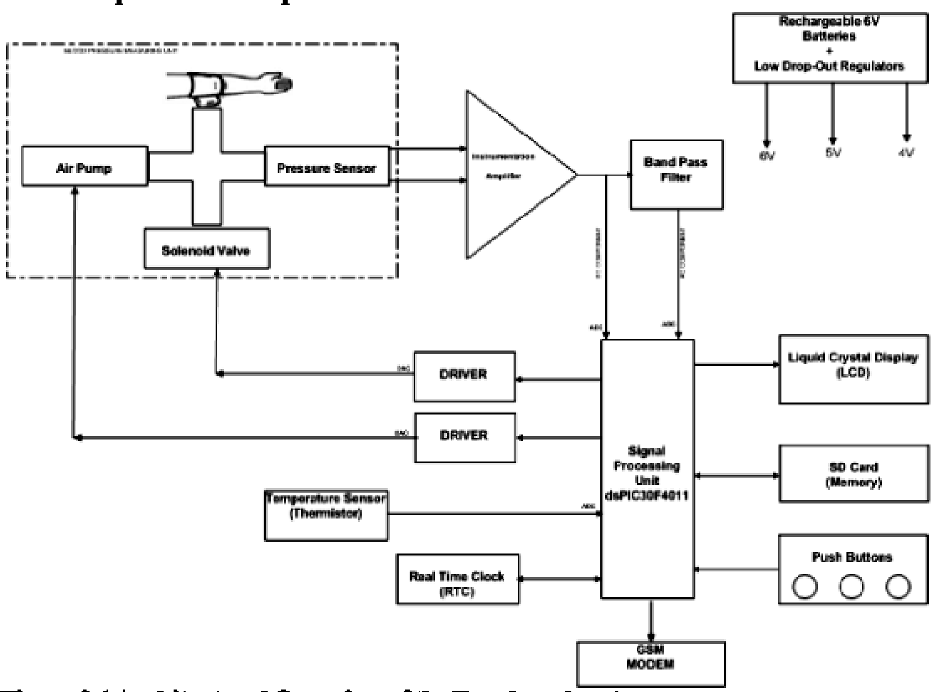

Figure 3.1 Architectural Overview of the Developed system

3.1 Principle of Operation

Measurement of vital signs (Blood Pressure, Pulse Rate and Body Temperature) is commenced by pressing the START button on the system. Body temperature is sampled, averaged and recorded. Blood pressure and pulse rates are equally measured and analyzed. If any of the values is above or below a pre-configured threshold, a notification SMS will be sent to a pre-programmed mobile number (possibly a doctor or care giver number). Also, the system can be configured to operate in AUTO mode. In this mode, the body vital signs are measured and analyzed at a preconfigured interval of time. The values obtained in MANUAL or AUTO mode are time-stamped, stored in SD Card, and displayed on a Liquid

Crystal Display (LCD). The stored values can be viewed locally at any point in time. In addition, an enquiry SMS can be sent to the system to get the values obtained at a specified date and time.

3.2 Blood Pressure Measuring Unit

This unit is a non-invasive pressure measuring unit that is used to measure blood pressure and pulse rate. It comprises blood pressure cuff, air pump, solenoid valve, piezo-resistive pressure sensor (MPS-3110-Wheatstone bridge type), instrumentation amplifier (INA128) and band-pass filter. As shown in Figure 3.2, the air pump inflates the blood pressure cuff and solenoid valve deflates it. Instrumentation amplifier (INA) is used to condition the analog signal acquired from the air pressure sensor. The output signal of the INA is split into two paths. One path, representing the cuff pressure, is connected to the ADC1 channel of the microcontroller. Another path is passed through a 2- pole active high-pass filter with cut-off frequencies of 0.4Hz and 5.0Hz, and a gain of 100. The output of the high-pass filter, representing the oscillation signal, is sent to the ADC2 channel of the DSP.

The unit measures systolic and diastolic pressures by oscillometric method. It measures blood pressure and pulse rate during inflation. The Measuring-while-Inflating approach helps in reducing overall measuring time, which in turn reduces discomfort caused by the pressure in the cuff. The motor is changed to slow mode gradually and linearly inflating the cuff after the motor pumps the pressure up to 30 mmHg in fast mode. When the pressure in the cuff gets high enough to just begin constricting the flow of blood, the arterial pulse becomes detectable by the pressure sensor. At this point, the waveform captured from the output of the analog high pass filter starts to show the onset of the blood pressure oscillation. The oscillation signal is then filtered by a digital low-pass filter. The Mean Arterial Pressure (MAP) is the cuff pressure which corresponds to the maximum oscillation signal. Based on the algorithm for blood pressure calculation, the Systolic Pressure (SYS) and the Diastolic Pressure (DIA) can be determined using the MAP value and a lookup table of empirical formulas (see Table 1). The inflation process is automatically stopped when the pressure reaches a specified value. To obtain the oscillation wave and its envelop, systolic and diastolic parameters are required. The method used in getting these parameters from the oscillation curve is the proportionality coefficient method, where a proportional relationship exists between average pressures, systolic and diastolic (the coefficients are called Ks and Kd, respectively).

SP/MP = Ks (value range: 0.3 to 0.75), DP/MP = Kd (value range: 0.45 to 0.90).These two coefficients are obtained from a large number of statistical data. The proportionality coefficients (Ks, Kd) are listed in Table 3.1.

Table 3.1: The average systolic and diastolic pressure proportionality coefficients - (Texas Instruments)

AVERAGE PRESSURE RANGE (mmHg)	Ks	AVERAGE PRESSURE RANGE (mmHg)	Kd
MAP > 200	0.5	MAP > 180	0.75
200 ≥ MAP > 150	0.29	180 ≥ MAP > 140	0.82
150 ≥ MAP > 135	0.45	140 ≥ MAP > 120	0.85
135 ≥ MAP > 120	0.52	120 ≥ MAP > 60	0.78
120 ≥ MAP > 110	0.57	60 ≥ MAP > 50	0.6
110 ≥ MAP > 70	0.58	50 ≥ MAP	0.5
70 ≥ MAP	0.64	50 ≥ MAP	0.5

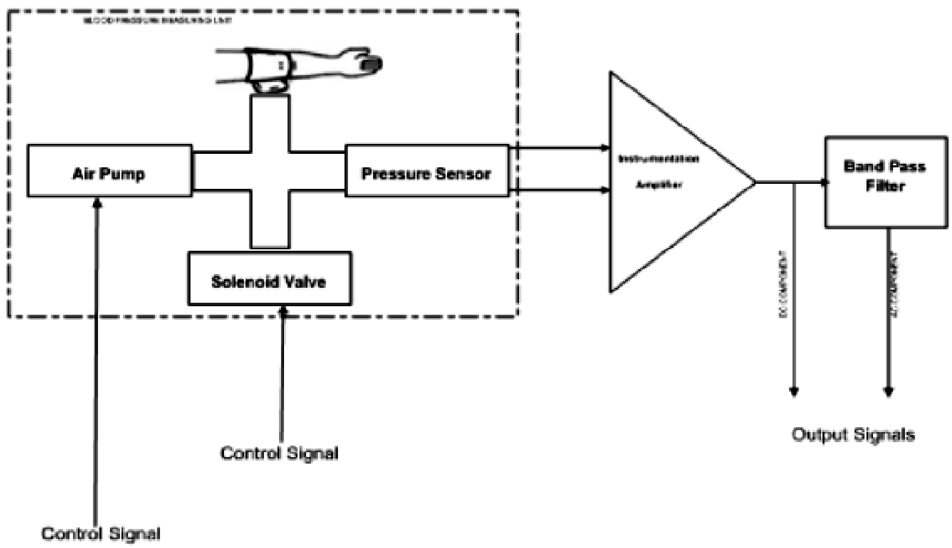

Figure 3.2 **Blood Pressure Measuring Unit**

3.3 Heart Rate Measurement

The Pulse Rate is calculated in the digital domain from the signal sample rate and sample numbers obtained in multiple consecutive pulses. As the cuff is deflated during blood pressure measurement, when systolic pressure value is approached, pulsations start to appear. These pulsations represent the pressure changes due to heart ventricle contraction and can be used to estimate the heartbeat rate. Pulsations grow in amplitude until mean arterial pressure (MAP) is reached, then decrease until they disappear. To measure the amplitude of the pulsations, the threshold level of a valid pulse is set to be 1.60 V to eliminate noise. As soon as the amplitude of a pulse is identified, the DSP will ignore the signal for 400 ms to prevent any false peak due to oscillation. Thus, this algorithm can only detect pulse rate which is less than 150 beats per minute. Next, the amplitudes of all the pulses detected are stored in the DSP RAM for further filtering and analysis.

3.4 Body Temperature Measurement

One of the vital signs that indicate human beings' overall physiological state is Body Temperature. Human body temperature varies within a narrow range of values. Variation of body temperature depends on many factors such as level of activity, time of day, and psychological states. Due to its ruggedness, a thermistor is used for measuring body temperature. A non-linear thermistor with tolerance of ±0.2°C can measure temperatures ranging from 0°C to 50°C and has a fast response time and low power dissipation, which makes it suitable for medical applications. The schematic diagram for the Temperature measurement is shown in Figure 3.3.The thermistor is connected to a 10k fixed resistor to form a Voltage Divider. This configuration minimizes self-heating of the thermistor. The output voltage can range from 0 V to +2.5 V. Change in temperature causes the thermistor's resistance to change accordingly. The relationship between this thermistor's resistance and temperature is non-linear. When the thermistor's resistance changes due to change in temperature, the output voltage will change. A buffer is connected to the divider's output to ensure low impedance into the ADC input. This voltage output is sent to the integrated ADC of the DSP. Body Temperature is computed by the DSP using equation 1-3:

$$V_{out} = V_{dd} \frac{R_n}{R_n + R_L} \qquad 1$$

$$R_n = R_0 e^{B\left(\frac{1}{T} - \frac{1}{T_0}\right)} \qquad 2$$

$$T = \frac{B}{\frac{B}{T_0} + \ln \frac{R_L V_{out}}{R_0 (V_{dd} - V_{out})}} \qquad 3$$

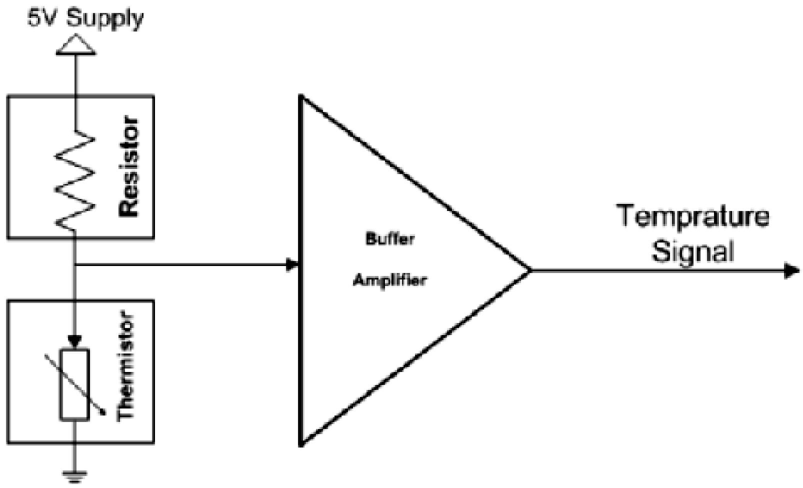

Figure 3.3: **Body Temperature Measuring Unit**

3.5 GSM Interface

A GSM modem is a specialized type of modem, which accepts a SIM card, and operates like a mobile phone. This modem supports the "extended AT command set" for sending/receiving SMS messages which is supported by the SMS/MMS Gateway. The developed system uses SIMCOM SIM800 GSM module. SIM800 Modem is built with tri Band GSM/GPRS engine, and works on 900/ 1800/ 1900 MHz. The modem has internal TCP/IP stack suitable for SMS, Voice as well as data transfer application in M2M interface. The Modem has RS232-TTL interface which allows direct connection with DSP. AT commands are used to send the sensed/measured parameters from patient to the modem, which then transmits all the parameters to the configured mobile phone via SMS.

3.6 Firmware Development

The firmware for this system was developed using high level language, C30 which is integrated with microchip's Integrated Development Environment, MPLAB IDE. The algorithm flowchart for the firmware is shown in Figure 3.4.

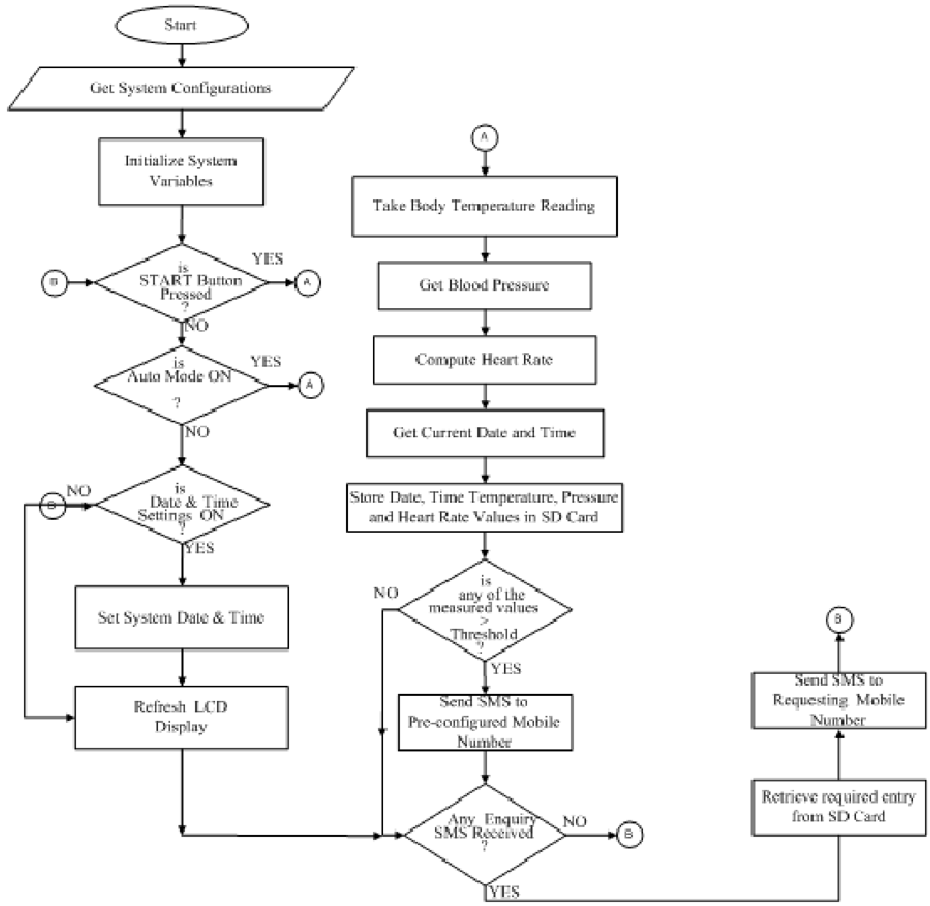

Figure 3.4 Flowchart of the System Firmware

The picture of the developed PMS is shown in Figure 3.5

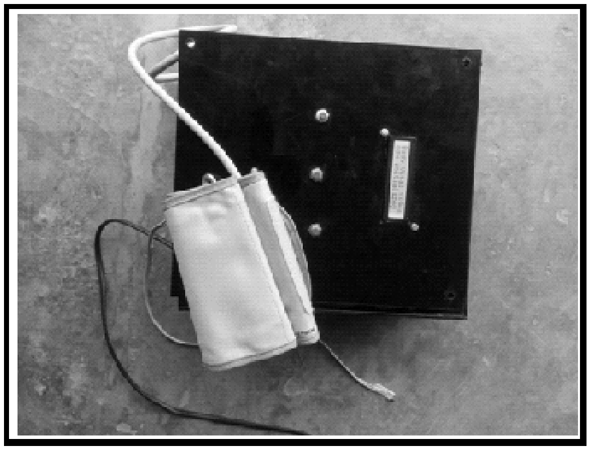

Figure 3.5 Picture of the developed PMS

4.0 Results and Discussion

In order to test for durability, efficiency, and effectiveness of the system; and to ascertain if there is need to modify the design, the system was first assembled using a breadboard. The system was switched ON and the device sensor was placed on a hot plate. As the temperature of the plate increased above 37 °c, a message alert tone was sounded at the concerned mobile phone, indicating that if a patient's body temperature increases beyond the threshold, the sensor can detect it and trigger an alarm at the receiver end. Furthermore, the sensor was connected to the hypertensive patient wrist; a message alert tone was sounded at the same mobile phone. Therefore, the system is in good working condition. Some of the results obtained for various tests carried out on patients are shown in fig. 3.6 and Tab. 4.1.

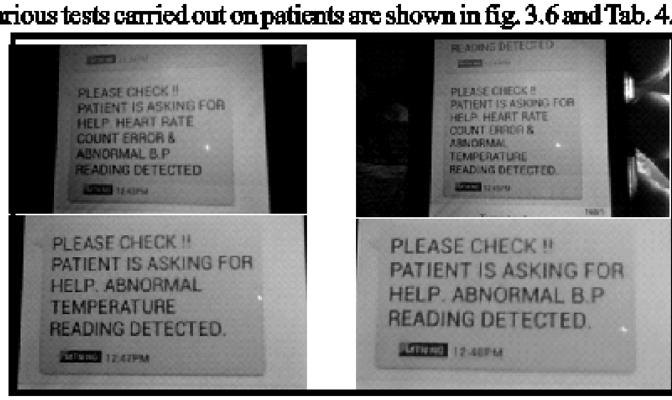

Fig. 3.6 Some screenshots of the implementation

Table 4.1: Test results obtained

Local Crystal Display Readings					Message sent
Date	Time	Temp	Heart rate	Blood Pressure	
03-04-2015	08:10:12	32	175	92/175	Please check!! Patient is asking for help. Heart rate count error & abnormal B.P reading detected.
03-04-2015	08:11:14	40	176	72/126	Please check!! Patient is asking for help. Heart rate count error & abnormal Temperature reading detected.
03-04-2015	09:10:11	42	78	68/128	Please check!! Patient is asking for help. Abnormal Temperature reading detected.
03-04-2015	09:55:15	36	87	90/160	Please check!! Patient is asking for help. Abnormal B.P reading detected.

5.0 Conclusion

Using this system, we can combat untimely death caused by cardio-vascular arrest, excessive body temperature and hypertension. In addition, implementation of these devices will be a great advantage for both medical professionals and non-professionals and can provide healthcare facilities for the deprived majority of less privileged people.

In the system we are making use of an embedded technology and SMS support for helping out the doctors to take care of multiple patients' health status by monitoring them remotely. Thus, the application of these devices will reduce the duration of hospital stays.

It is recommended that there could be improvement in the integration of more bio-signal sensors in order to capture additional physiological parameters from the subject. Provision could be made for sending SMS to more than two personnel for swift response to achieve the set objectives. Also, the profile of SMS received could be used hourly, daily or weekly for effective routine check.

References

Brown .W.C. (2011). "The History of Transmission by Radio Waves," Artech. House press.

Maruf H. S., Krishna C. R. & Rokibul H. R. (2014). "Development of a Portable GSM SMS-Based Patient Monitoring System for Healthcare Applications", Global Journal of Computer Science and Technology: G Interdisciplinary, vol. 14 Issue 2 Version 1.0.

Ramamurthy B., Bhargavi S., R. ShashiKumar R., (2010). "Development of a Low-Cost GSM SMS-Based Humidity Remote Monitoring and Control system for Industrial Applications," (IJACSA) International Journal of Advanced Computer Science and Applications, vol. 1, no. 4.

Sim S.Y., Lee W.K., Baek H.J., Par K.S., (2012). "A non-intrusive temperature measuring system for estimating deep body temperature in bed," Proceedings of 34th Annual International Conference of the IEEE EMBS.