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Human body Air bubble Detection using I2C Multiplexer Protocol

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Abstract— **There are 2 types of dialysis that is Hemodialysis & Peritoneal dialysis. Peritoneal dialysis is a process where human peritoneum membrane properties are used for filtration. During this process due to leakage of pipe or due to some manual error there may be chances of flowing air bubbles along with the fluid, which will be harmful to the patient. To overcome this problem, we use light-to-digital sensor in order to monitor constantly the changes in the fluid when air bubble is passed through the fluid, by using the principle of scattering of light. And also, by using the same principle we can detect whether the patient's peritoneum is infected or not by the drain fluid collected at the end of the therapy. This is planned to be done on 32-bit Controller, I2C Mux & Embedded c language.**

Keywords—32-bit controller, light-to-digital sensor, I2C Multiplexer.

1.INTRODUCTION

Dialysis is a treatment for kidney failure sufferers. Kidney failure is a stage five type of chronic kidney disease (CKD). Typically, the kidney removes extra fluid from the body and cleans out waste particles from the blood. The need for this dialysis treatment arises from the fact that the patient's kidneys can no longer adequately filter blood wastes and eliminate excess fluid.

During hemodialysis, the patient's blood passes through a machine with a filter to purify the blood. A dialyzer, often known as an artificial kidney, is the device. The specialist must gain access to your veins in order to get your blood into the dialyzer. Peritoneal dialysis is a type of dialysis that uses that peritoneum, a membrane in the middle of the abdomen, to exchange fluid and dissolved chemicals with the blood. Since a few years ago, peritoneal dialysis has produced results that are superior to hemodialysis. During this dialysis due to leakage of pipes / due to some manual error there may be chances of flowing air bubble through the fluid which is harmful to patient it may lead to death. Other thing is based on the turbidity of the drain which comes out of the patient's body at the end of the therapy we detect whether patient's peritoneum is infected or not. Both of these conditions can be achieved under the principle of scattering of light by using various components.

A 32-bit, 200Mhz Arm-based controller is used. It has the capacity to perceive a great number of other peripherals. Additionally, the term "32-bit microcontroller" denotes that the microcontroller is able to perform arithmetic operations on values with a 32-bit value. The 32-bit microcontroller executes a function in less instruction cycle than an 8-bit microcontroller because of its bigger data bus, however the program's code size is too vast for an 8-bit microcontroller. 32-bit microcontroller are also developed with more flash memory.

2.SYSTEM MODEL

2.1 IMPLEMENTATION OF DETECTING AIR BUBBLES AND TURBIDITY ON HUMAN BODY.

During therapy, the fluid starts flowing from the therapy bag. Here, pump (diaphragm pump) is used for pumping the fluid from the bag through the pipe in which the fluid is contained in a flexible tube.

The main aim of the work is to detect the volume of air bubble passing through the pipe and also detect whether the patient's peritoneum is infected or not. This can be achieved by using Light-to-digital sensor. There are 2 main processes as shown below:

A. Bubble detection:

During this process there are the chances of entering air bubble (due to the damage of tube/ due to some manual error) into the human body, this may lead to patient's death. When the liquid starts flowing through the pipe, light (IR LED) is transmitted. If no bubble is detected then the refracted light travels in a straight line and doesn't scatter, due to this theirs no variation in light intensity. If the air bubble is detected in the liquid flow, then the transmitted light hits the bubble because of this the light scatters and will be reflected at the sensors placed. Due to this the light intensity at sensor varies, this sensor consists of integrated ADC converters which converts the light intensity to digital output and is given to the controller.

B. Detection of Turbidity:

At the end of the therapy based on the turbidity of the drain fluid collected, we can detect whether the patient's peritoneum is being infected or not. This can be achieved using 2 light sensors placing it as top and side sensor. Here LED is placed opposite to the top sensor. So that when LED is transmitted, if the fluid collected is not turbid then the light intensity at the top sensor receives maximum intensity because light travels in a straight line

due to the absence of particle and the side sensor receives less intensity. Therefore, the light doesn't scatter this indicates that the patient's peritoneum is not infected. If the fluid collected is more turbid then the light intensity at the top sensor decreases and the light intensity at side sensor increases due to the presence of particles in the fluid, the light gets scattered. This indicates that the peritoneum is infected. All these data will be sent to controller through I2C which acts as an intermediate between sensors and the controller for communicating. In detail about I2C can be seen in further section.

The hardware components required for the implementation of detection of volume of air bubble and turbidity detection are 32-bit controller, ALS light-to-digital sensors which has integrated ADC converter it is a I^2C based sensor which has SCL and SDA lines to communicate with controller, as we use 2 I^2C's of same address I^2C multiplexer is used to communicate with both $I^2C's$ which has common host to control multiple $I^2C's$. IR LED used for refraction of light it is chosen because of its high wavelength and finally, Diaphragm pump which is used to pump the fluid from the therapy bag during PD.

I. Hardware components:

The hardware setup for human body air bubbles detection using I2C multiplexer protocol is shown below.

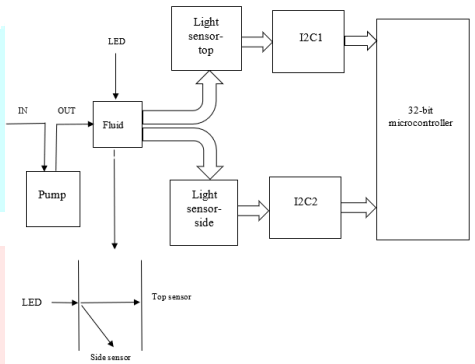

Fig:2.1. Block diagram of air bubble detection

(a)32-bit controller:32-bit microcontrollers offer many serial and parallel peripherals that can be connected to a wide range of electronic components.

Static random-access memory of 128byte is utilized in these modules. To provide support to the flash memory static RAM adaptable static memory controller is utilized. Its working voltage is from 1.8 volts to 3.6 volts. The crystal oscillator of 4 to 26Mhz is utilized in this module. It has an internal 16Mhz industrial facility managed RC. It involves a 32khz oscillator for RTC (real-time-Clock). This module comprises of 3 I2C interfacings. It has 4 USART and 2 UART and 3 SPI. Industrial control, low power consumption, home appliances, computer network, and communications have all benefited from the widespread use of 32-bit controller. Up to 5 serial ports, free peripheral communications are available.

(b)ALS, light-to-digital sensor:

The sensor used in this model is light-to- digital sensor. This device is equipped with ambient light detection (ALS). In addition, when using the low gain mode, the operating range is expanded to 60,000 lux in sunlight. But is especially useful for controlling displays that provide optimal viewing in different lighting settings while saving battery life. Integrated photodiodes, integrated amplifier, ADC, battery, clock, buffer, comparator, state machine, and I2C interface are all features of the light-to-digital converter. Channel 0 (CH0) photodiodes sensitive to both visible and infrared light are coupled to a single infrared sensitive channel 1 (CH1) photodiode in each device. The amplified photodiode currents are simultaneously converted to digital values with up to 16-bit resolution using two built-in ADCs. At the end of the conversion cycle, the result of the conversion is moved into the data register. The calculator can calculate illuminance (ambient light intensity) in lux by reading this numerical result and using empirical formulas to estimate the response of the human eye. A dedicated pin beyond the breaker's support. When an interrupt is set and exceeds the set value, the interrupt pin turns on and remains on until cleared by the controller firmware. The mute feature simplifies the system and improves performance by eliminating the need to probe the sensor for brightness readings. An interrupt is generated when the value of the ALS switch exceeds a high or low threshold. Additionally, a programmable interrupt latch feature allows the user to specify the number of consecutive threshold crossings that must occur before the interrupt is triggered. The below figure shows the pin diagram of Light-to-digital sensor:

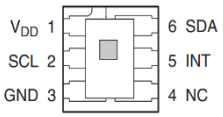

Fig:3.1. Pin assignment of light-to-digital sensor

(i)Ambient light sensing (ALS):

Simulates the reaction of the human eye to light. The analog gain and integration time are programmable. Dynamic range 45,000,000: 1. It operates at 60,000 lux in direct sunlight and is extremely sensitive. A UV filter for packaging, ideal for use behind dark glass.

(ii)Maskable interrupts:

Persistence filters with programmable upper and lower thresholds.

The light sensor is ideal for use with portable music players, TVs, tablets, monitors, mobile phones and TVs where the display backlight can consume up to 70% of the system's capacity.

(c)Communication protocol used I2C multiplexer TCA9548A:

The I2C bus can be used to control eight bidirectional translating switches on the TCA9548A device. Eight downstream pairs or channels are created by the SCL/SDA upstream pair. Depending on the information in the programmable control register, any particular SCL/SDA channel, or set of channels, can be selected. Conflicts between I2C slave addresses can be resolved via these downstream channels. For instance, if the application requires eight identical digital temperature sensors, one sensor can be linked to each of the channels 0–7. The system master can reset the TCA9548 in the event of a time-out or another improper action by asserting a low in the RESET input. The I2C bus state machine is initialized together with deselecting all channels, much as the power on the reset. Reset triggers the same reset and start up without powering down the component. This permits recovery in the event that one of the downstream I2C buses is stuck in a low condition. The switches pass gates are built in such a way that the maximum high voltage that the TCA9548A can pass can be controlled using the VCC pin.

It is possible to use different bus voltages on each pair by restricting the maximum high voltage, allowing 5-V components to communicate with 1.8-V, 2.5-V, or 3.3-V components without the need for additional safety. External pullup resistors elevate the bus to the desired voltage level for each channel. All I/O pins can withstand 5 volts. This is accomplished by pulling the bus with external pull-up resistors. The TCA9548A can be reset by asserting a low to

the RESET pin if the microcontroller detects a bus conflict or another inappropriate operation. By allocating a distinct channel to each sensor slave sub-bus, the TCA9548 enables a single microcontroller to connect with up to "64 sensors" using either the same or alternative I2C addresses.

(d) IR LED:

It is comparable to a standard LED. The term "Infrared Light Emitting Diode" (IR LED) refers to a device that can emit light with wavelengths up to 940 nm, which is in the infrared region of the electromagnetic spectrum. From 760 nm to 1 mm, the wavelength range varies. It is a unique kind of LED that beams infrared energy. Because it falls outside of the range of the electromagnetic radiation that is observable to humans, this light is invisible to human sight.

(e) PUMP:

The pump used for the proposed system is Diaphragm pump. A diaphragm pump is a positive displacement, hydraulically or mechanically operated pump that moves liquids using a combination of reciprocating action and either a flapper valve or a ball valve to transfer liquids.

II. Software tools:

(a)A free version tool on 32-bit microcontroller:

A free version tool to configuring 32-bit microcontrollers at startup. Additionally, a code generator is included, which self-generates the required code for system initialization. This makes it the perfect solution for developers to concentrate on creating sincere apps rather than working on the challenging microcontroller clock configuration process.

(b)Embedded C using Keil µvision:

For writing code for 32-Bit microelectronics, there are many software development tools available. Integrated development environments (IDEs), which bring all necessary tools together into one workspace, are available as software tools. Keil MDK ARM (µvision IDE) is one of them, a fairly reliable development environment is the MDK ARM IDE, which is available for the free download. This permits the creation of the code with a maximum application size of 32 KB. Keil µvision is having debugger tool which helps us in using the peripherals and GPIO pin access in the main function as soon as the code has been generated. The while loop must be expanded to include the code that executes in a loop. Once functional coding is complete, we must debug that is: test and execute the code on the controller board. Click on debug (or press ctrl+ F5) to begin debugging.

4.Results and Conclusion

The results are obtained as per the experimental setup and executed using 32-bit microcontroller and I2C multiplexer using Keil software. The data readings and obtained graph for different trials for detecting air volume(bubbles).

Table:4.1. Average of Trails at 10µL

Trial 1	Trial 2
1285	1380
1381	1431
1477	1371
1510	1319
1237	1463
1446	1435
1357	1498
1465	1421
1407	1394
1484	1299
1431	1487
Total:1407	**1409**

Table:4.2. Average of Trails at 20µL

Trial 1	Trial2
1254	1294
1322	1271
1437	1070
1335	1285
1377	1309
1346	1279
1414	1255
1313	1348
1368	1300
1389	1292
1332	1208
Total:1353	**1264.63**

Table:4.3. Average of Trails at 30µL

Trial 1	Trial 2
1229	1257
1151	1150
1060	1283
1310	1287
1246	1248
1036	1271
1318	893
1362	1289
1218	1243
1410	1272
1239	1252
Total:1234.4	**1222.2**

Table:4.3. Avg. value obtained at different µl's

Air volume	ADC Value
10µL	1408.1
20µL	1308.5
30µL	1228.9

After obtaining the average of ADC values at top and side sensor the ratio of the top by side sensor should be done for 1NTU and 10NTU and must be differentiated then the difference value obtained must be 2 or less than 2. If the value obtained is more than 2 then it indicates that the patient's peritoneum is being infected.

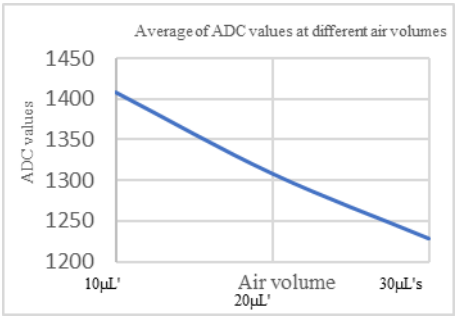

Fig:4.4. Graph of ADC value at Different µL's

Detecting the accurate volume of air bubble passed and indicating to the patient/ to the care taker to stop the therapy. As we conducted multiple trials by injecting 10,20 and 30µL's volume of air bubble we took an average of an ADC value of all four different microliters of air bubble. The difference obtained by the average of ADC values at 10 µL's is 1375 and 1318. By differentiating it we get 57.i.e., for every 1µL's of air volume theirs decrease in 11.3 of ADC

value. Hence, it gives very accurate results in air volume detection. And for turbidity, the trials are done at 1NTU and 10NTU. Based on the ratio obtained by the top and side sensor of both 1& 10 NTU we can consider that if the result of the ratio is less than 1 then it is considered as therapy fluid, if the ratio obtained is below 2 then it indicates that the turbidity is below 10NTU and both these condition shows that patients peritoneum is not infected. If the ratio obtained is beyond 2, this means the turbidity is more than 10 NTU and it indicates that patient's peritoneum is infected.

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