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Design and Development of a Suction Pump Equipped with an Error Memory

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ABSTRACT Suction pumps are essential medical devices widely used to remove fluids, secretions, and blood from patients' airways during surgical procedures and emergency care. However, their performance may be compromised by tubing occlusion or a full collection tank, potentially reducing suction efficiency and increasing patient safety risks. This study presents the design and implementation of an Arduino Uno–based suction pump integrated with an error memory system for real-time monitoring and fault recording. Negative pressure was measured using an MPX5700AP pressure sensor, while fluid level detection was performed using a water level sensor. System status, pressure values, fluid level, and recorded errors were displayed on an OLED screen, accompanied by an audible buzzer alarm to notify users of abnormal operating conditions. Experimental evaluation demonstrated that the developed system generated adjustable suction pressure ranging from –74.40 kPa to –3 kPa. The fluid level monitoring system successfully detected a full collection tank with an accuracy of ±10%, while tubing occlusion was reliably identified when the negative pressure reached –30 kPa, triggering both visual and audible alarms. Measurement uncertainty values were 10.8% at 3 kPa, 1.472% at 50 kPa, and 0.679% at 78 kPa. The integrated error memory feature effectively stored and displayed fault information, automatically stopping pump operation when critical conditions occurred. These results indicate that the proposed system can improve device reliability, facilitate biomedical maintenance, and enhance patient safety in clinical environments

.**INDEX TERMS** Alarm, error memory, sensor, suction pump.

I. INTRODUCTION

Medical professionals in hospitals require machines to remove fluids from a patient's body, especially when the patient has difficulty in breathing or in certain emergencies. One of the devices used for this is the suction pump, which can be used to suck mucus, blood or other fluids that may interfere with the patient's respiratory tract. This device is essential as it assists medical personnel in maintaining patient cleanliness and safety [1] [2] [3].

A suction pump is a tool used for clearing obstructions, as well as mucus, blood and other fluids. This device is widely used in hospitals and can be considered essential for the hygiene and safety of both patients and hospital personnel.

The suction pump's parameters are relatively simple. It features a pressure gauge that measures suction power, a motor used to draw substances from the patient into the pump, detachable and replaceable tubing, a collection tube to hold secretions, and an on/off switch. This indicates that the suction pump operates primarily on mechanical principles rather than theoretical ones. The parameters monitored by the error memory are pressure and fluid level. If the pressure is too high, the device cannot perform suction and may damage the motor; if the fluid level is too high, patients and users may face issues due to a lack of sterility, and the device may also be damaged if fluid enters the motor. Research similar to the current study has previously been conducted by Helmi Aditya and Agustina DP who also designed modules on related topics [4] [5].

In this study the author aims to present a solution to improve work efficiency of the technicians by the addition of an error memory and a self-test function. The self-test is used to detect whether there are any problems with the device, and the error memory captures data from the self-test to help electromedical technicians identify issues with the device. These features are expected to help technicians understand and identify device malfunctions more easily. Detection is performed using sensors designed to monitor leaks and the fullness of the collection tube. This development is expected to help electromedical technicians identify problems with the equipment, while also lightening and decreasing their workload.

II. METHOD

Research design is the plan and structure of an investigation organized in such a way that the researcher can obtain answers to their research questions. The plan is a comprehensive outline that encompasses the research program. This study uses the design-and-build method. Design-and-build involves translating the results of analysis into software, which is then used to create or improve an existing system.

A. RESEARCH FLOWCHART

The author created a research flowchart so that the research could proceed in an orderly manner according to the flowchart designed by the author. Research flowchart for this study is shown in Fig.1.

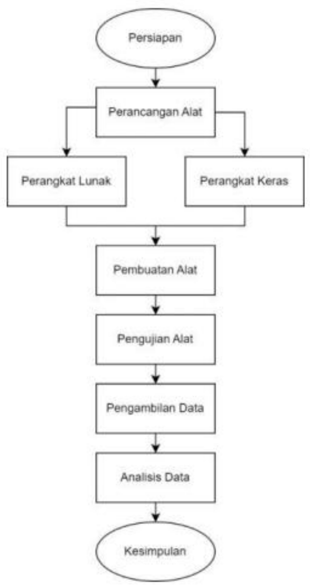

FIGURE 1. Flowchart illustrating the process taken for the study

In the research flowchart developed by the author, the first stage is the preparation stage. During this stage, the author drafts a proposal outlining the research title to be conducted. Next, the author designs the software and hardware to be used in building the device. Once the device is complete, the next stage involves testing it. The test data is then collected, and once a sufficient amount of data has been gathered, an analysis is conducted to draw conclusions. This analysis aims to assess the feasibility of the device that has been built.

B. BLOCK DIAGRAM

The hardware diagram of the proposed suction pump with error memory is designed as shown in Fig. 2.

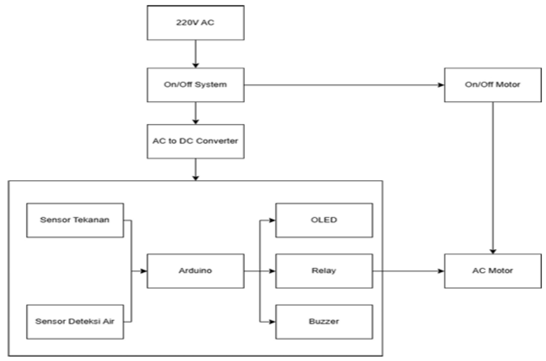

FIGURE 2. Block diagram of the suction pump complete with an error log

As shown in Fig. 2, the device is powered by a 220 V AC source that is routed through the main switch. When the switch is off, the pump will not operate. When the switch is turned on, the circuit connects to an adapter that supplies power to the microcontroller. The microcontroller then activates all supporting components, namely the OLED display, pressure sensor, water detection sensor, buzzer, and relay.

The motor will not activate until the relay's on-off switch is turned on. This mechanism is designed to enhance safety on the Arduino board while protecting the entire device. Additionally, this system serves as an extra control feature, allowing doctors to turn off the pump without having to shut down the entire device.

When the device is first turned on, the pump will operate briefly before stopping; thereafter, pump control is fully managed via the relay. At this stage, the OLED display shows the message "Suction Pump Error Memory," followed by the institution's name and the details of the last detected error.

During operation, the Arduino continuously monitors the system's status via the installed sensors. This is because the sensors monitor conditions and send data to the Arduino. With this, the device can monitor parameters such as water level and the pressure generated by the device. The data collected by the sensors is used by the Arduino for control, alarm detection, and relay control.

If excessively high pressure or a full tank is detected, the Arduino will change the relay status from HIGH to LOW, causing the pump to stop, while activating the buzzer as a warning to the user.

If the pump stops but the buzzer does not sound, the user can view the current status information on the OLED display. The buzzer uses two tone patterns to distinguish between different types of malfunctions: a single 1000 Hz tone to indicate a blockage, and a continuous 1800 Hz buzzing tone to indicate that water has reached the sensor.

C. DEVICE FLOW CHART

The flowchart in Fig. 3. illustrates the workflow of the suction pump system, which is equipped with an error memory feature. When the device is activated, the system first performs an initialization process. The screen will sequentially display: the institution's name, the device's title, and the creator's name. Once this process is complete, the pump begins operating normally, and the system performs a self-check to ensure the device's functionality.

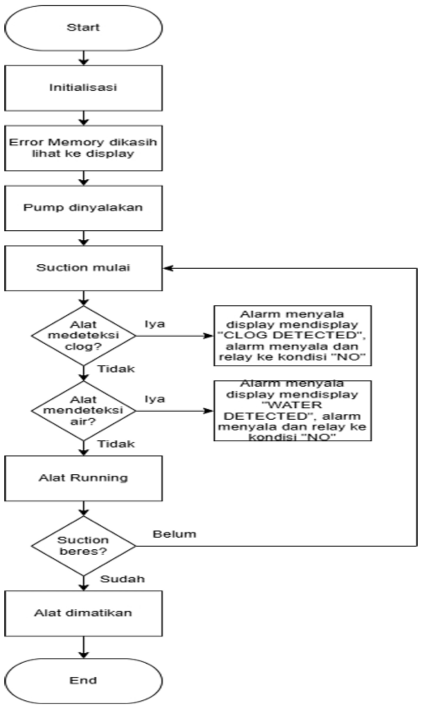

FIGURE 3. **Flowchart of how the device works**

If the sensor detects that the fluid level in the tank has reached the upper limit, the system will automatically stop the pump and sound an audible warning. In this situation, the operator can remove the tube from the tank and clean out its contents. Once the cleaning process is complete, the tank can be reattached and suction can resume as before.

Additionally, the system monitors pressure during operation. If an abnormal drop in pressure is detected, an alarm will sound and the pump will stop running. The operator must then inspect the tube, clear any potential blockages, or ensure that the airflow is not obstructed.

Once the entire process is complete and the device is no longer in use, the suction pump can be turned off by pressing the same power button used to turn it on.

D. ANALYSIS TECHNIQUE

Collecting the data is done through two measuring devices, a DPM and a measuring cup. The DPM is directly connected to the unit via a hose. This allows the device to read the pressure generated by the suction created by the module. With this setup, the measuring device will read the module's suction force in kPa. Since the kPa reading when the device is operating is 0 kPa and the threshold for detecting a blockage is approximately -30 kPa, measurements will be taken within the range between these two pressure values. This helps demonstrate the accuracy of the sensor's measurements and aids in detecting any issues with the device.

To test the device's pressure accuracy, the DPM will be connected to the module, after which the DPM will display the negative pressure generated by the device. After a beep is heard, a screenshot of the result will be taken to facilitate processing and added as a data point. The DPM will display the negative pressure it has detected, and the screen will show the current pressure. With 0 kPa as the standard pressure when the device is not suctioning and with several settings for maximum pressure at 3 kPa, 50 kPa, and 78 kPa.

As for the measuring cup, during the suction process, water will flow into the tank until it reaches the 1-liter mark in a relatively short time. When the water level reaches that point, the sensor will come into direct contact with the water. This condition triggers the sensor to output a "HIGH" status, indicating that water has been detected. This signal is then sent to the microcontroller to be processed as an indicator that the tank has been filled to the specified limit. After the water is detected by the water detection sensor, the difference in water level between the 1-liter mark and the point where the sensor becomes active is measured.

When the sensor detects water, the device automatically stops the suction process and emits a buzzing sound as a warning. When the alarm sounds and the device stops the suction process, the liquid collected in the tank is transferred to a measuring cup. The collected volume is then compared to a reference standard of 1000 ml. This procedure aims to identify any discrepancies and assess the device's relative accuracy. In the context of this test, the warning sound does not serve as a signal to permanently stop use, but rather as a cue for the operator to check the condition of the tank. This is done so that the author can measure the difference in water level and record the data needed to evaluate the system's accuracy.

For this study these are the calculation methods used:

Average Value ($\bar{x}$):

$$\bar{x} = \frac{\sum Deviation}{n} \tag{1}$$

Measurement Deviation Value

$$deviation = X\ device - Y\ DPM \tag{2}$$

Deviation% Value

$$deviation\% = \frac{deviation}{p} \tag{3}$$

The mean is the average value of a data set. To find the mean, all values must be added together and then divided by the total number of data points. The mean is used to summarize the measurement results.

III. RESULT AND DISCUSION

A. PHYSICAL APPEARANCE OF THE DEVICE

The complete device is shown in Fig. 4. it has an on off switch for power as well as one to turn on and off the suction pumps motor. There are 3 buttons used to set the different thresholds for the suction pump's maximum cut off of pressure.

FIGURE 4. The complete device

The OLED display on top will show that the suction pumps system is functioning and on startup will show the last error after a short pause as is shown in Fig. 5.

FIGURE 5. The device starting up display, the "maximum pressure" as well as if the device has an error or not currently.

The display will show the current status of the device, if an error is detected the status will change to either water detected or clog detected. The error will be logged and displayed on the next startup.

B. TEST RESULT DATA

Table I, Table II and Table III presents the pressure measurement results and the instrument's accuracy level at each pressure tested. The setting column displays the pressure value in kPa, which is used as a reference for the test. This data is used to evaluate the instrument's accuracy in reading the resulting pressure. This table also shows the pressure range the device can achieve.

TABLE I

Test	Setting	On the device (kPa)	On the DPM (kPa)	Difference (kPa)
1	3kPa	3.01	3.00	0.01
2	3kPa	3.00	3.28	0.28
3	3kPa	3.05	3.04	0.01
4	3kPa	3.07	3.20	0.13
5	3kPa	3.00	3.01	0.01
		Average difference		0.08

TABLE II

Test	Setting	On the device (kPa)	On the DPM (kPa)	Difference (kPa)
1	50kPa	49.02	50.18	1.16
2	50kPa	50.50	50.62	0.12
3	50kPa	52.55	53.98	1.43
4	50kPa	52.48	54.74	2.26
5	50kPa	52.51	49.90	3.61
		Average difference		1.72

TABLE III

Test	Setting	On the device (kPa)	On the DPM (kPa)	Difference (kPa)
1	78kPa	76.31	77.52	1.21
2	78kPa	76.00	76.59	0.59
3	78kPa	74.37	75.90	1.57
4	78kPa	78.34	77.93	0.29
5	78kPa	76.59	76.69	0.10
		Average difference		0.75

Test results show that the module functions effectively as a suction pump. Based on the data obtained, the pump is capable of reaching a maximum suction pressure of 74.40 kPa, while the minimum recorded suction pressure is approximately 3 kPa. This performance falls within an acceptable range for most categories of suction pumps, except for surgical use, which requires a pressure range of 80–40 kPa. Nevertheless, the obtained values remain adequate for use in the care of adult patients. Based on the collected data, it can be concluded that the author has successfully created a functional suction pump.

As shown in Table I, Table II and Table III, accuracy also increases as the selected pressure is raised. Accuracy appears to increase because the device has the same actual range of variation; however, since the setting is higher, the device appears to be more accurate.

TABLE IV

Test	Setting (kPa)	On the device (kPa)	DPM (kPa)	Difference (kPa)	Error Detected
1	3	3.02	3.04	0.02	Clog Detected
2	3	10.10	9.88	0.22	Clog Detected
3	3	7.00	6.08	0.98	Clog Detected
4	3	3.05	3.04	0.01	Clog Detected
5	3	3.41	3.80	0.39	Clog Detected
		Average difference		0.32	

TABLE V

Test	Setting	On the device (kPa)	DPM (kPa)	Difference (kPa)	Error Detected
1	50	51.92	50.18	1.74	Clog Detected
2	50	52.14	51.70	0.34	Clog Detected
3	50	51.68	51.70	0.02	Clog Detected
4	50	52.14	51.70	0.34	Clog Detected
5	50	52.79	51.55	1.24	Clog Detected
		Average difference		0.74	

TABLE VI

Test	Setting	On the device (kPa)	DPM (kPa)	Difference (kPa)	Error Detected
1	78	79.07	78.14	0.93	Clog Detected
2	78	77.89	78.31	0.42	Clog Detected
3	78	78.34	78.31	0.03	Clog Detected
4	78	78.12	78.31	0.19	Clog Detected
5	78	78.14	79.07	1.07	Clog Detected
		Average difference		0.53	

The above tables show the result to test if the clog sensor is functioning. Based on the data obtained, it can be seen that the measurement results are relatively consistent. However, there is an outlier in the pressure detection, where one data point shows a much larger difference compared to the other data points. This is likely caused by a problem with the DPM sealing process or because the sensor on the module operates more slowly than the DPM, so it has not yet had time to update the collected data. At the 50 kPa setting, there are two data points showing deviations (outliers), namely at points 1 and 5, with a larger margin of error compared to data points 2 through 4. This condition is likely caused by a problem with the seal, as explained previously, or by other factors affecting measurement accuracy. At this setting, there is a discrepancy of approximately 1.472%. At the 78 kPa measurement, the motor and sensor reached their capability limits. The sensor is not designed to operate at pressures above that limit, while the pump is unable to generate pressure exceeding 79 kPa. Therefore, the data obtained is relatively consistent, although there is one outlier at the 5th data point. In this data set, there is a deviation of approximately 0.679%. At the 3 kPa setting, the sensor showed fairly consistent results.

However, there were two data points (the 2nd and 3rd) that had a higher margin of error in the motor's power output. Additionally, there was a significant deviation at the 3rd data point, where the margin of error was recorded as much larger than at the other data points. This data point showed a fairly large discrepancy of 10.8%.

It can be concluded from the data obtained that the device is capable of detecting pressure with a good level of accuracy, so the module can be classified as suitable for use. The higher percentage of uncertainty in the 3 kPa measurement is not an error, but rather reflects the limitations of measurement resolution. This is to be expected because at low pressures, the resolution relative to the signal becomes larger than the signal value itself.

Accuracy testing of the water detection sensor will be conducted according to the method described in previously. In this test, the device will use a pump to draw water until the tank is full. The pump will continue to operate until the sensor detects the presence of water and automatically shuts off the pump. After the pump stops, the volume of water in the tube will be measured to assess the sensor's accuracy in detecting water. This protective layer is important because, although the motor is relatively safe from water splashes, this protection does not fully guarantee safety. If water reaches the path leading to the pressure sensor, it can cause a blockage that results in incorrect data readings by the system.

It can be seen in Table VII that there is a fairly large difference between the measured value and the tank's actual capacity. The average difference between the measured value and the actual value is approximately 102ml, indicating a fairly significant deviation. This is likely caused by the sensor being positioned too high, preventing it from detecting water early enough to produce more accurate readings.

Although the data shows a fairly large deviation, the measurement results remain consistent. The only outlier is found in the first data point, with a difference of 125 ml, while the average difference is in the range of 102 ml. Based on the data above, there is a fairly large deviation from the expected value, namely 10.2%. This deviation has the potential to cause problems when the device is in use, as the liquid stored in the tank may overflow and enter the suction pump. This condition risks causing damage to the motor, either due to corrosion caused by water or the possibility of a short circuit in the module.

TABLE VII

Experiment	Parameter	Measured (ml)	Tank Capacity (ml)	Difference (ml)	Error Description
1	Full	1125	1000 ml	125	Water Detected
2	Full of water	1100	1000 ml	100	Water Detected
3	Full of water	1095	1000 ml	95	Water Detected
4	Full of water	1110	1000 ml	110	Water Detected
5	Full of water	1080	1000 ml	80	Water Detected
	Average difference:			102 ml	

VII. CONCLUSION

Based on the series of device development and testing processes conducted by the author, it can be concluded that the design of the Suction Pump equipped with an Error Memory can be considered successful. This device is expected to assist electromedical technicians in performing their duties and carrying out medical device repairs in the field. In conclusion a suction pump has been successfully designed that provides error information when reading pressure at 3 kPa, 50 kPa, and 78 kPa, as well as error information regarding the water level when it reaches its maximum point.

The device is capable of detecting pressure with an accuracy of 2.67% at 3 kPa, 3.44% at 50 kPa, and 0.96% at 78 kPa. These results indicate that the accuracy level is not consistent across pressure changes. Additionally, the device can detect when the water tank is full with an accuracy deviation of 10.2% or an average difference of 102 mL This discrepancy is caused by residual negative pressure in the vacuum system; however, since there is still air space inside the tank, the author acknowledges that this module is not yet perfect and there are still many aspects that can be developed and improved in the future, in terms of functionality, performance, and accuracy.

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