

Research Article

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Low Cost Continuous Positive Airway Pressure with Humidifier Parameter Temperature and Humidity

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Abstract

Continuous Positive Airway Pressure (CPAP) is a treatment used to alleviate obstructive sleep apnea (OSA). It works by providing a continuous stream of air through the nose or mouth, keeping the upper airway open. While CPAP therapy is highly effective, it often leads to side effects such as dryness in the nose, mouth, and throat. To mitigate these side effects, it is recommended to use a humidifier integrated with the CPAP device. Given that CPAP devices are typically expensive, there is a need for a more affordable option that includes a humidifier. This project aims to design a low-cost CPAP device with an integrated humidifier. The device features a heater for generating heat, an SHT30 sensor for measuring temperature and humidity, an Arduino Uno microcontroller, an HME filter for bacterial filtration, a heater driver to control the heater, and a 20 x 4 LCD display. The device does not require additional oxygen. The results indicated that, under condition 1, the highest measurement error for the temperature parameter was 3.8% at a 40°C setting, and the lowest was 2.1% at a 32°C setting. Under condition 2, the highest error was also 3.8% at a 40°C setting, with the lowest being 2.1% at 32°C.

Keywords

Low Cost Continuous Positive Airway Pressure (CPAP), Humidifier, dryness, SHT30, Arduino Uno.

Specifications table

Hardware name	<i>Low Cost Continuous Positive Airway Pressure With Humidifier</i>
Subject area	• Biomedical Engineering • Medical Device Engineering • Respiratory Therapy
Hardware type	• Medical Devices • Field measurements and sensors • Electrical engineering and computer science • Mechanical engineering and materials science • Mechatronic engineering
Closest commercial analog	<i>This hardware provides multiple pressure selection and multiple temperature selection</i>
Open source license	https://creativecommons.org/licenses/by-sa/4.0/
Cost of hardware	194.39 US\$
Source file repository	DOI 10.17605/OSF.IO/VMGXD
OSHWA certification UID	

1. Hardware in context

Obstructive sleep apnea (OSA) is a type of sleep disease that affects breathing during sleep by restricting the upper airway, either completely or partially. A meta-analysis of 17 research across 16 nations revealed that 936 million persons between the ages of 30 and 69 have symptoms of OSA, with 10% having moderate OSA, 38% having mild OSA, and 52% having severe OSA [1]. A therapy called continuous positive airway pressure (CPAP) is used to treat obstructive sleep apnea (OSA). This CPAP machine works by forcing air through the mouth or nose to maintain an open upper airway at all times. [2]. CPAP has been demonstrated in numerous studies to be beneficial in mitigating symptoms (e.g., daytime sleepiness), enhancing long-term survival, and averting symptoms including cardiovascular problems resulting from OSA. The side effects of CPAP therapy, which include dryness of the nose, mouth, and throat, sneezing, runny nose, nasal congestion, sinusitis, nosebleeds, nasal mask side effects, conjunctival inflammation from mask air leakage, and others, are associated with the therapy, despite the fact that it is very effective in treating OSA disorders. Dryness of the mouth, nose, and throat, which affects 30% to 66% of CPAP users, is one of the most often reported adverse effect [3]. To overcome dryness of the nose, mouth and throat due to side effects of using CPAP, it is recommended to use an integrated humidifier in the chamber connected to the CPAP device and CPAP mask which has proven to be very effective [3]. Typically, humidifiers are made up of a heater that increases the temperature of the water in the humidification chamber in order to produce more water vapor. After that, the pressured room air is released, allowing the water vapor to enter the airway and travel via the nose, throat, and lungs. This humidified air helps ease dryness brought on by using a CPAP and lessen discomfort along the respiratory tract[4]. CPAP devices are not cheap medical devices. As researched according to Adi Suhendra and Dyah Kusuma Wardani, states that currently Ulin Hospital has limited CPAP tools due to the high cost. The CPAP unit price is around Rp 92 million per unit [5]. Then humidifier devices that can heat and humidify the air before it goes into the nose are expensive. For example, in Australian dollars, a disposable unit that humidifies inhaled gases costs about \$120 and also a reusable humidifier costs about \$3600. So to overcome this problem, a CPAP device equipped with a humidifier is needed at a cheaper price [6]. Based on previous research, in 2018 Desmond J Bennett, et al conducted a study entitled "Evaluation of a Low-Cost Bubble CPAP System Designed for Resource-Limited Settings". This study aimed to compare low-cost bubble CPAP devices with existing commercial bubble CPAPs. This tool works using an ambient air compressor, adjustable flow meter, pressure regulator and also a plastic container filled with water used for humidification. This tool uses a temperature probe placed on a plastic container for humidification which is used as monitoring the increase in system temperature. However, there is still no temperature setting for humidification [7]. In 2021, Athra'a sabeeh Mikha and Hadeel K. Aljobouri conducted a research entitled "A Simplified Design of CPAP Device Construction by Using Arduino NANO for OSA Patients". This research aims to make CPAP design using Arduino nano and by using fewer materials available on the market. This tool works using a MPS20N0040D pressure sensor, Brushless 12/24V DC silent-Centrifugal Blower, M274 rotary encoder, Arduino nano microcontroller, and 16x2 Lcd. However, in this study, the air that entered the nose and mouth did not have a humidification system [8]. In 2021 Lyneham A., et al conducted a study entitled "Low Cost CPAP for the Developing World". In this study, the CPAP machine uses a small pump that can circulate air at room temperature and humidity or can immerse a hose into a chamber that has been given warmed water. The disadvantage of this study is the use of a chamber that is not equipped with a heater as a heater and there is also no temperature setting [6]. In 2022 Jeyalakshmi M.S., et al conducted a research entitled "Design and Development Of CPAP (Continuous Positive Airway Pressure) Using Internet of Things". This study aims to discuss the design and construction of CPAP devices as proof of concept to be used as Portable Devices. It is designed using Arduino, snoring detection sensors, MCU nodes, MAX30100, air flow motor compressors, LCDs and relay circuits. As well as heart rate parameters and also SPO2 can be viewed on the LCD, ThingSpeak web page, and App. However, in this tool there is no humidification system, so the air entering the facility has not been humidified [9].

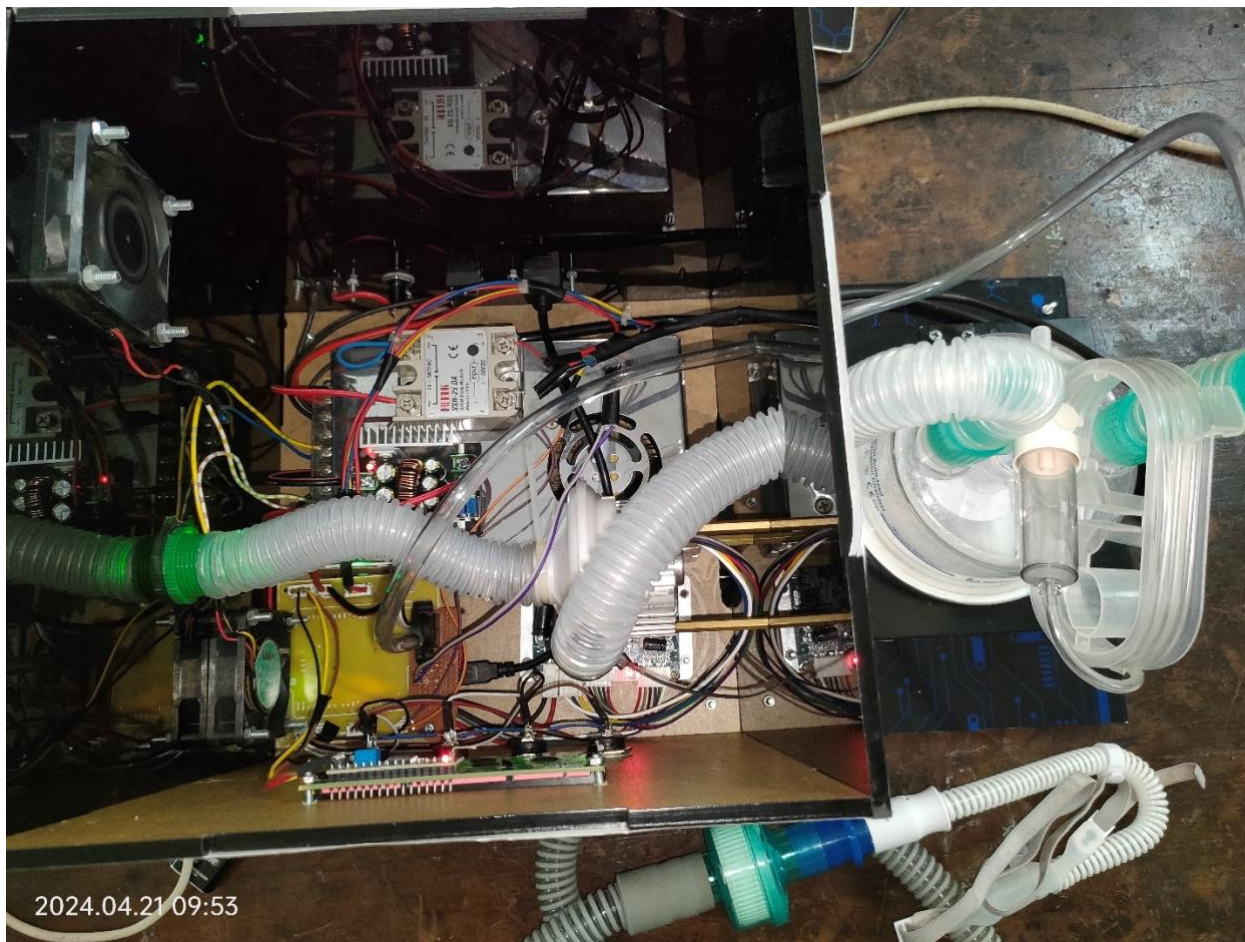


Fig.1. The proposed hardware of the Low Cost Continuous Positive Airway Pressure With Humidifier

Based on the results of previous research described above, it can be concluded that development can still be carried out in the form of a CPAP device equipped with a humidifier that can be set the temperature to be used and can be monitored humidity at a low cost. Based on the background explanation above, the author intends to conduct a study entitled "Low Cost Continuous Positive Airway Pressure With Humidifier" (Temperature and humidity parameters). The tool (**Fig. 1**) that will be made in this study is used to warm and monitor the humidity from the air passed through the heated chamber which will then be flowed into the airway with low cost design. Low cost design aims to design CPAP equipped with a humidifier as an alternative solution that can be used by patients with OSA at a much cheaper price and easy to use. Thus, it can be useful as a form of resilience of the Indonesian state in developing technology in the health sector. The manufacture of this tool is expected to be an alternative solution for OSA healing therapy at a lower cost than existing healing methods. This humidifier works using a heater as a heat generator, SHT30 sensor as a temperature and humidity sensor, Arduino Uno as a microcontroller, HME filter as a bacteria filter, driver heater as a heater regulator, and a 20 x 4 LCD display. And this tool does not use additional oxygen.

2. Hardware description

In **Fig. 2**, The power supply will transform the AC voltage from the PLN mesh into DC voltage when the on switch is turned on. The microcontroller receives voltage from the DC voltage. Centrifugal blowers use free air or water as an input. As a signal that the appliance is turned on, the LCD will be active. Additionally, the pressure and desired temperature can be selected using the push button for temperature selection and pressure. Press the push start button to initiate the process after choosing the pressure and temperature. Using the provided commands, the microcontroller will control how the tool is operated. To power the centrifugal motor, the voltage must first reach the blower driver.

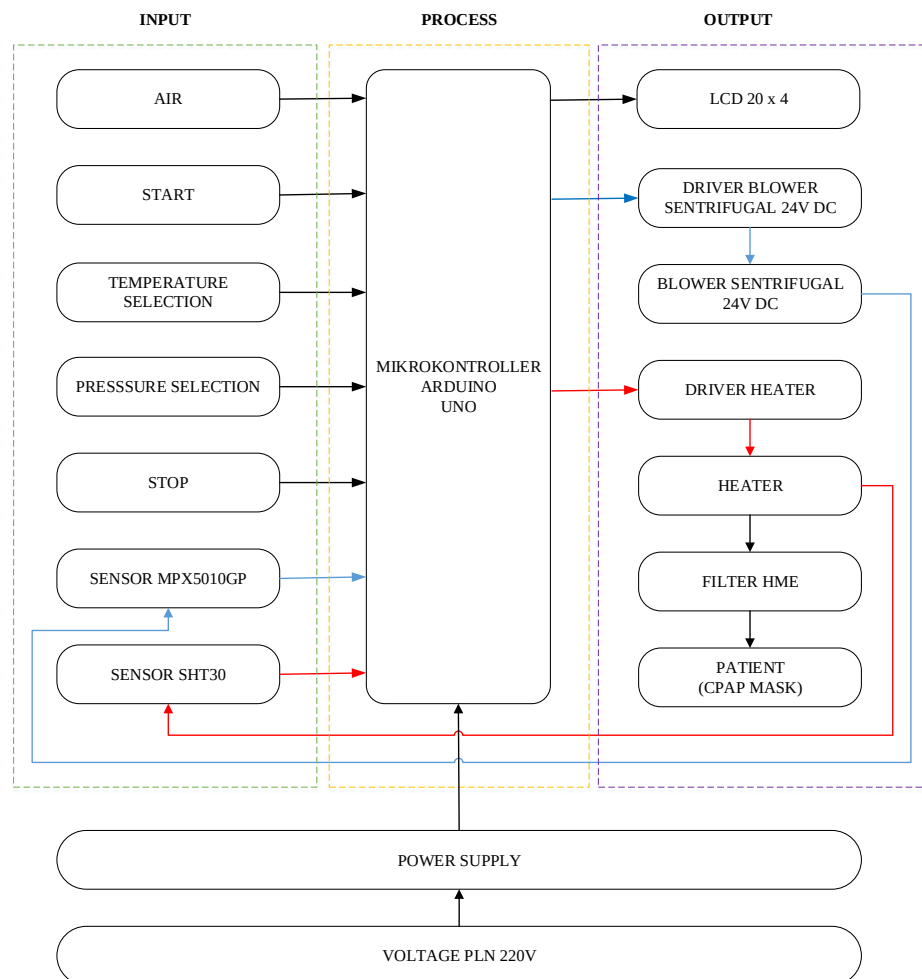


Fig. 2. The diagram block of the Low Cost Continuous Positive Airway Pressure With Humidifier

When the centrifugal motor exhales positive pressure air, the sensor MPX5010GP acts as an air pressure reader. The humidifier chamber will then receive the humidified air output from the centrifugal motor after it has gone through the breathing circuit. In addition, the heater driver that is, the solid state relay will receive commands from the microcontroller to switch on and off the heater chamber. Using the temperature choice that has been chosen, the heater chamber will heat the water. In the event that the temperature measurement on the breathing circuit has been reached, the heater will switch off; otherwise, it will continue to operate using the SHT30 sensor. Additionally, the SHT30 sensor will be used to measure the humidity in the humidified air. After that, it is sent to the HME filter, where it will go via the CPAP mask and into the patient's airways. After the Arduino Uno has processed the data from the MPX5010GP and SHT30 sensors, it is transmitted and shown on a 20 x 4 LCD. To reset the pressure and temperature to be utilized, hit the stop push button. If you don't, the therapy will terminate and the gadget will stop functioning. Press the switch off to stop the tool.

2.1. Low Cost CPAP With Humidifier hardware

This study generated a Low Cost CPAP design with a humidifier that may be used for humidity monitoring, temperature modulation, and positive pressure control. Sensors, blowers, heaters, drivers, and displays are all integrated into this system. This layout is displayed in **Fig. 3**.



Fig. 3. The Hardware of the Low Cost Continuous Positive Airway Pressure With Humidifier

2.2. Hardware Circuit

The hardware circuit is shown in (**Fig. 4**). In this research, the microcontroller we use is Arduino Uno R3, SHT30 series humidity and temperature sensor, heater, solid state relay, 20x4 LCD with I2C, and 4 push buttons.

Table 1
Summary of Arduino Uno R3 Specification

Microcontroller	ATmega 328
Operating Voltage	5V
Recommended input voltage	7-12 V
Input Voltage Limit	6 – 20 V
Number of digital I/O pins	14 digital pins (6 of which provide PWM output)
Number of Analog input pins	6 pin
DC current per I/O pin	40 mA
DC current for the pin is 3.3 V	50 mA
Flash Memory	32 KB (ATmega 328) about 0,5
SRAM	2 KB (ATmega 328)
EPROM	1 KB (ATmega 328)
Clock Speed	16 MHz
Microcontroller	ATmega 328
Operating Voltage	5V
Recommended input voltage	7-12 V

The device design (**Fig. 4**) process will start from the SHT30 sensor which takes readings of temperature and humidity values from the CPAP humidifier output. The SHT30 Sensor has 4 pins that are connected to the pin pins on the arduino UNO microcontroller. The four pins are red as VCC pins, blue as GND pins, yellow as SCL pins connected to A5 microcontroller pins, and green as SDA pins supported by A4 microcontroller pins. In the design of this device, there is

also a series of temperature controllers consisting of SHT30, Solid State Relay (SSR), and also heaters. Where the heater will work when the measurement results of the SHT30 sensor have not reached the set temperature so that SSR will command the heater to work. The heater has 2 positive and negative wires. And SSR has 4 foot pins. The positive wire on the heater is connected to pin 1 of SSR and pin 2 of SSR is connected to AC 220V, while the negative wire on the heater is connected to AC neutral 220V. Then for pin 3 SSR is connected with PWM pin D10 on arduino while pin 4 SSR is connected with GND Arduino. This tool also uses a step down module which is used to reduce voltage as an Arduino supply. The step down module has 4 pin pins, namely the IN- and IN+ pin is connected to the output – and + power supply, the OUT- and Out+ pin is connected to the GND and VIN pins on the Arduino. The design of this tool is equipped with 4 push buttons, including pressure selection push button, temperature selection push button, start push button, stop push button. The pin on the pressure selection push button is connected to the D2 pin of the arduino, the pin on the push button of the temperature selection is connected to the D3 pin of the arduino, the pin on the push button start is connected to the D4 pin of the arduino, the pin on the push button stop is connected to the D5 pin of the arduino. The four push button pin pins are also connected to the Arduino GND pin. A 20x4 LCD screen with I2C was then used to display the design of this tool. The pins used in 20x4 LCDs with I2C consist of GND, VCC, SDA, and SCL. The GND and VCC pins are connected to the 5V and GND pins of the Arduino. While the SDA pin is connected to the A4 pin of the Arduino and the SCL is connected to the A5 pin.

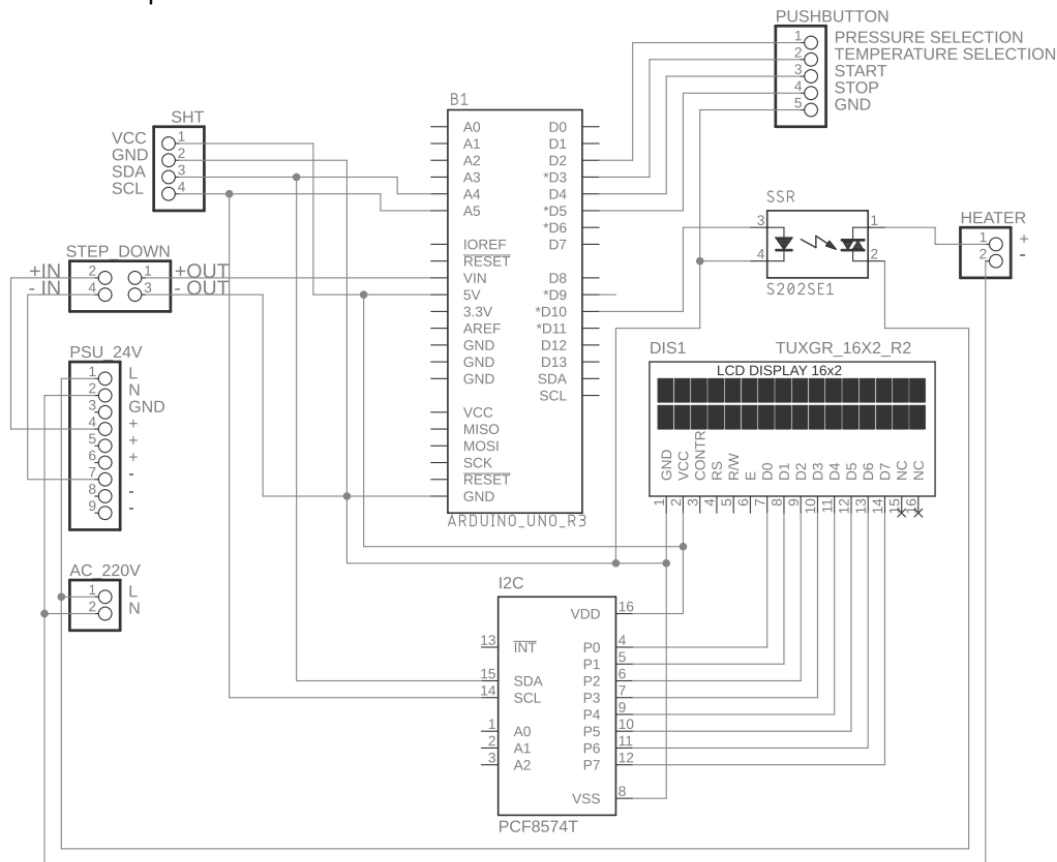


Fig. 4. System hardware circuit

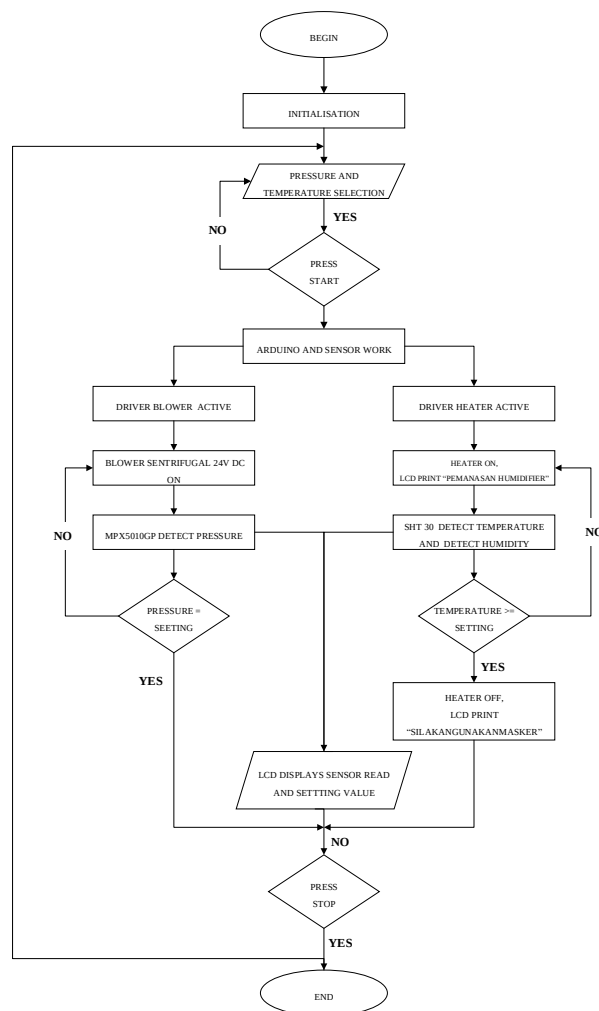


Fig. 5. Firmware flowchart

2.3. Low Cost CPAP With Humidifier Firmware

In **Fig. 5** It is evident that when the appliance is turned on, the procedure will begin with the initialization of all variables and sensors on the system. Then, using the pressure selection push button and the temperature selection push button, the temperature selection and pressure selection processes are carried out. Following your selection of the desired pressure and temperature, activate the CPAP therapy process by pressing the push button start. This will activate the microcontroller and sensor. The centrifugal blower will be turned on by the blower driver with instructions from the microcontroller, and the MPX5010GP sensor will then read the pressure measurement. The centrifugal blower will keep running if the pressure sensor readout is less than the chosen pressure setting. The centrifugal blower will keep running to supply positive pressurized air to the circuit breathing and maintain the pressure value in accordance with the selection when the value read by the pressure sensor matches the selected pressure value and enters the humidifier chamber to be humidified. Moreover, the SHT30 sensor will detect the temperature and softness of the positive pressured air that has traveled through the chamber before it is transferred to the brewing circuit. When the temperature in the grilling circuit drops below the temperature setting, the microcontroller will then tell the heater driver to switch on the heater and the words "Humidifier Heating" will appear on the LCD display. When the temperature on the grilling circuit reaches or equals the temperature setting and the LCD shows the message "Please Use the Mask," the heater driver will then turn off the heater. After that, the patient will receive the humidified air that has passed through the HME filter. The 20 x 4 LCD will show the pressure, temperature, and humidity sensors' measurements. Pressing the stop button will cause the device to stop operating and return to the pressure selection menu once the CPAP therapy has finished.

2.4. Easy to control the Low Cost CPAP

Low Cost Cpap With Humidifier is used for patients suffering from sleep apnea as therapy to keep the upper airway open. This Low Cost Cpap With Humidifier system is designed using an Arduino Uno Microcontroller, MPX5010GP Sensor, SHT30 Sensor, Blower Driver, 24 VDC centrifugal blower, SSR, heater, 20x4 LCD, and 4 push buttons. The advantages of this tool are that the cost to produce the tool is cheap, the smallest error value is 0% and the highest error value is 4.8% in pressure parameter, the highest measurement error for the temperature parameter was 3.8% and the lowest was 2.1%, setting this tool is easy to operate, just select the pressure and temperature using a push button and displayed using a 20x4 LCD with I2C, and this tool does not use oxygen. addition but only uses ambient air. This makes it an attractive option for use in hospitals or healthcare facilities with limited resources, especially in low-income areas.

2.5. Cost

The high price of commercial CPAP products on the market (>1574.02 USD) is an obstacle in carrying out sleep apnea therapy, especially for people with middle to low incomes. (**Fig. 6**). However, this design has a low cost, namely 251.40 USD for one Low Cost CPAP With Humidifier product. Apart from that, this design is open source so that other researchers can develop it with other features and improvements.



Fig. 6. (a) Airsence 10 Autoset CPAP - RESMED, (b) ResMed AirCurve 10 VAuto BiLevel (BiPAP)

2.6. Summary

Continuous Positive Airway Pressure (CPAP) is a therapy to help heal OSA disorders. The contribution of this research is explained as follows:

1. The design hardware is simple by not adding oxygen and is designed in an easy way of operation by simply pressing the pushbutton to select the parameters to be used.
2. This LowCost CPAP device is equipped with a pressure selection from 4 – 20 cmH2O and a temperature selection of 32 °C, 36 °C, and 40 °C.
3. This device can also monitor the humidity results produced by the chamber humidifier.
4. Any pressure and temperature results produced by this tool will be displayed on an easy-to-read 20 x 4 LCD.
5. In this tool, all systems have been controlled by an arduino uno microcontroller so that the device can run according to the system that has been made.

3. Design files summary

3.1. Design file

This section explains the resulting design files, both hardware designs (schematics and printed circuit boards (PCB)) and firmware for low cost CPAP operation, as shown in Table 2. Furthermore, the low cost CPAP mechanical design using Corel Draw is also attached to this study.

Table 2**Design file summary of exoskeleton for hand rehabilitation**

Design file name	File type	Open source license	Location of the file
Schematic.sch	schematic, eagle file	CC BY-SA 4.0	DOI 10.17605/OSF.IO/VMGXD
Board.brd	board, eagle file	CC BY-SA 4.0	DOI 10.17605/OSF.IO/VMGXD
Low Cost CPAP.ino	Firmware, Arduino	CC BY-SA 4.0	DOI 10.17605/OSF.IO/VMGXD
Design Box.cdr	Coreldraw file	CC BY-SA 4.0	DOI 10.17605/OSF.IO/VMGXD

3.2. Schematic and Board

Low Cost CPAP With Humidifier was designed using the Eagle application program (6.3.0, free version for Windows, CadSoft Computer GmbH, Germany). The schematic circuit consists of SSR component pins, Blower Driver, 4 Push Buttons, MPX5010GP Sensor, SHT30 Sensor, Vin, and 20x4 LCD with I2C.

3.3. Firmware

The low cost CPAP with humidifier firmware was developed using the Arduino application program (Version 1.8.4, visit website: [URL](https://www.arduino.cc/)). Table 2 shows the firmware namely Low Cost CPAP.ino. All programming is contained in that file. Starting from MPX5010GP and SHT30 sensor readings, PWM blower programs, selection programs using push buttons, and display programs on 20 x 4 LCD with I2C.

3.4. Design Box

The low-cost CPAP box design with humidifier was designed using the Corel Draw x7 application (available in a free trial: <https://www.coreldraw.com/en/pages/coreldraw-x7/>). Design Box.cdr file in Table 2 consists of several pairs of puzzle-like boxes which will later form a cube box.

4. Bill of materials summary

Table 4**Bill of materials of a Low Cost Continuous Positive Airway Pressure With Humidifier**

Designator	Component	Number	Cost per unit (USD)	Total cost (USD)	Source of materials	Material type
BLOWER	24V tiga fase tanpa sikat perangkat medis/kipas Blower Cpap	1	64.9	64.9	https://www.alibaba.com/product-detail/24V-Three-Phase-Brubootss-DC-Medical_1600536184423.html	Plastic, magnetic
DRIVER_BLOWER	24volt motor 30000 rpm Motor driver	1	18.3	18.3	https://www.alibaba.com/product-detail/24volt-motor-30000-rpm-Motor-driver_60599718501.html?spm=a2700.detail.0.0.55c35eefWbvKSF	Plastic
B1	Arduino Uno R3	1	6.50	6.50	https://indonesian.alibaba.com/p-detail/UNO-1601140797453.html?spm=a2700.galleryoff	Semi-conductor

					erlist.p_offer.4.72ee2802zdyNTG&s=p	
MPX	MPX5010	1	7.80	7.80	https://indonesian.alibaba.com/p-detail/Mpx5010-60747030007.html?spm=a2700.galleryofferlist.p_offer.4.7e2911457oil0c&s=p	Plastic
SHT	SHT30	1	7.59	7.59	https://indonesian.alibaba.com/p-detail/JYX-1600516655739.html?spm=a2700.galleryofferlist.p_offer.4.63b134dduW86Jt&s=p	Plastic, silicon
SSR	Solid State Relay	1	6.00	6.00	https://indonesian.alibaba.com/p-detail/24V-380V-1600053542028.html?spm=a2700.galleryofferlist.p_offer.d_price.131f7376ZHKeSH&s=p	Plastic, semi-conductor
HEATER	Heater	1	20.00	20.00	https://indonesian.alibaba.com/p-detail/High-62576160201.html?spm=a2700.galleryofferlist.normal_offer.d_price.5bc85872jRYk1i	Aluminium
DIS1	LCD 20 x 4	1	2.44	2.44	https://id.shp.ee/dKpo djx	Plastic
IC1	I2C	1	0.43	0.43	https://id.shp.ee/8Z3ehiP	Semi-conductor
-	Chamber Humidifier	1	10.92	10.92	https://tokopedia.link/GboC3gVFtKb	Plastic, metal
PSU 24V	Power Supply	1	6.67	6.67	https://id.shp.ee/ACQ QwQa	Semi-conductor
-	Nasal mask	1	11.28	11.28	https://tokopedia.link/jRHHHB8GtKb	Plastic
-	HME Filter	1	2.16	2.16	https://tokopedia.link/sBMNJgXOtKb	Plastic
-	Connector Circuit	2	1.83	3.66	https://id.shp.ee/fhx3xsv	Plastic
-	Breathing Circuit	1	5.98	5.98	https://id.shp.ee/wmNjSWx	Plastic
-	Connector USB	1	1.40	1.48	https://id.shp.ee/5fbitVz	Plastic, metal
PUSHBUTTON	Push Button	4	0.11	0.44	https://id.shp.ee/scSRscP	Plastic, metal
-	Fuse Holder	1	0.12	0.12	https://id.shp.ee/NSfg7CW	Plastic, metal
-	Main Switch	1	0.04	0.04	https://id.shp.ee/LnE3QAP	Plastic, metal
Acrylic Cutting	Acrylic	1	17.68	17.68	https://id.shp.ee/X6j7sjZ	Acrylic

5. Build instructions

5.1. Design Box

The Low Cost CPAP with humidifier box design in **Fig. 7** uses black acrylic material with a thickness of 5 mm. This box was designed using the CorelDraw application and made like a puzzle consisting of several boxes measuring 4500 mm x 450 mm, so that they can be arranged into a cube shape.

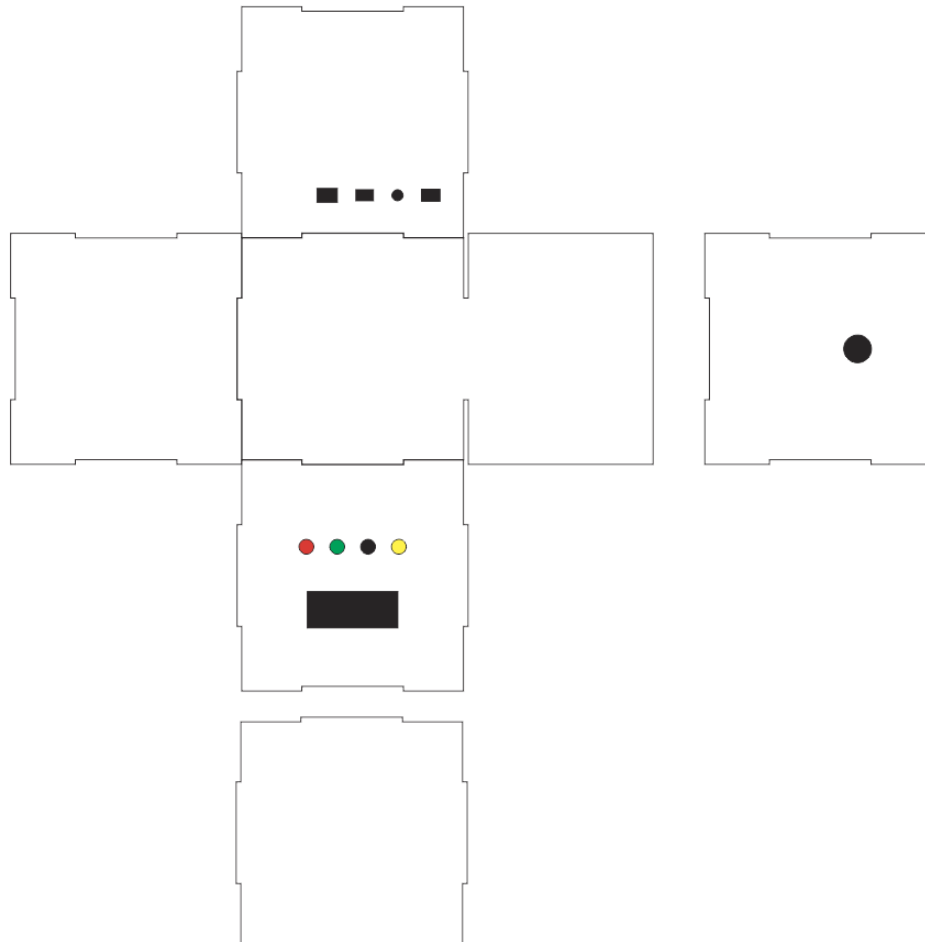


Fig. 7. Design Box Low Cost CPAP

5.2. Firmware Design

The firmware **Fig. 8** is designed using Arduino software (Version: 1.8.4). In this case, the entire program is designed and compiled here. After the entire program has been created, we upload it to the Arduino microcontroller via the Arduino Ide application. After the program has been uploaded, the process will run according to the program that was created previously. all sensors will work, the blower will be active, and the display will be displayed on the 20 x 4 LCD with I2C.

```

File Edit Sketch Tools Help
Tekanan_Tertutup
#include <Wire.h>
#include <LiquidCrystal_I2C.h>
#include <Adafruit_SHT31.h>

const int blowerPin = 9; // Pin Arduino yang terhubung ke blower (PWM untuk blower)
const int SSRPin = 10; // Pin Arduino yang terhubung ke SSR (PWM untuk SSR)
int tekananIndex = 0; // Indeks tekanan yang dipilih
int suhuIndex = 0; // Indeks suhu yang dipilih
int nilaiPWM[] = {70.50, 73.50, 75.50, 78.50, 80.50, 82.50, 84.50, 86.50, 89.50, 92.00, 93.50, 94.50, 96.90, 98.00, 100.00, 102.00}; // PWM untuk blower sesuai tekanan
int nilaiPWMSuhu[] = {150, 200, 250}; // PWM untuk SSR sesuai suhu
bool prosesBerjalan = false; // Status apakah proses sedang berjalan

// Inisialisasi LCD
LiquidCrystal_I2C lcd(0x27, 20, 4);

// Pin untuk push button
const int pilihButtonPin = 2;
const int pilihSuhuButtonPin = 3;
const int startButtonPin = 4;
const int stopButtonPin = 5;

int lastPilihButtonState = HIGH;
int lastStartButtonState = HIGH;
int lastStopButtonState = HIGH;
int lastPilihSuhuButtonState = HIGH;

bool SSRState = false; // Menyimpan status SSR

const float ADC_mV = 4.0920125; // konversi dari nilai Arduino ADC ke tegangan dalam mV
const float SensorOffset = 265.0; // dalam mV diambil dari datasheet
const float sensitivity = 4.413; // dalam mV/mmHg diambil dari datasheet
const float mmHg2_cmHg2 = 10; // bagi dengan angka ini untuk mengubah mmHg2 menjadi cmHg2
const float mmHg2_kPa = 0.00981; // konversi dari mmHg2 ke kPa

float suhu;
float kelembapan;

// Inisialisasi sensor SHT31
Adafruit_SHT31 sht31 = Adafruit_SHT31();

```

Fig. 8 Low Cost CPAP Arduino code in Arduino IDE

5.3. Hardware Circuit

Once the firmware is programmed, the hardware is ready to operate. The schematic that has been made will become a PCB as an Arduino shield. Install the header connector pin on the Arduino PCB shield, then attach it to the Arduino. Next, install the sensor connections, blower driver, push button, SSR, LCD, and power supply for Arduino. After everything is installed in **Fig. 9**, the tool can be turned on and operated.

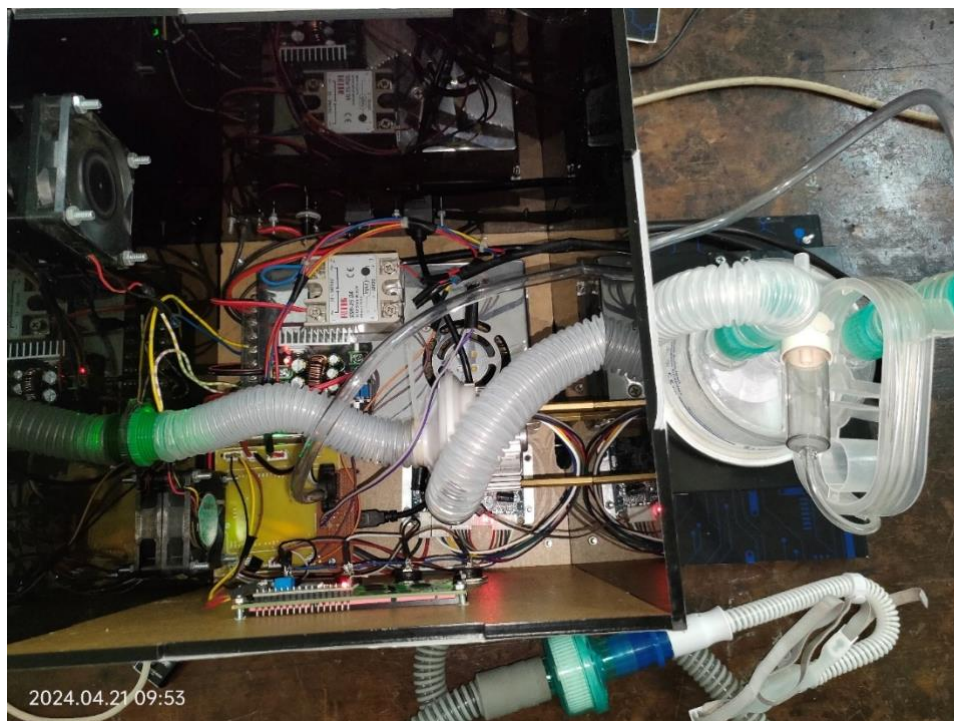


Fig. 9. Circuit hardware build instruction

6. Operation instructions

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The module operates according to the program set on the microcontroller. When the main switch is pressed, the entire circuit inside the module is energized by the power supply. When the module is on, data initialization will occur first. Next, select the temperature using the push button for temperature selection. When the pressure has been selected, then press the push button start to start. When the process starts, the microcontroller and sensors will work. The microcontroller will give commands to the heater driver, namely the solidstate relay, to turn on/off the heater if the temperature read by the SHT30 sensor has not reached the temperature setting. The temperature and humidity values generated the CPAP humidifier output will be displayed on the 20 x 4 With I2C LCD. When you want to end the process, press the push button stop, then all processes will stop. Press the main switch to turn off the module.

7. Validation and characterization

The data collection technique carried out in the research was to measure the temperature and humidity on the output of the CPAP humidifier on a module that had been made with the SHT30 sensor. Then the measurement results will be compared with the Thermohygrometer comparator. Temperature parameter data collection is carried out by measuring the temperature setting of the CPAP humidifier when the pressure is closed and when the pressure is given a little leakage. Meanwhile, in the humidity parameter, the humidity percentage reading follows the humidity found in the CPAP humidifier (there is no humidity setting on the CPAP humidifier). Measurements are carried out 3 times and each measurement is carried out for 10 minutes.

The LCD's humidity value validation was cross-checked with the thermohygrometer in Table 4.

Table 4 Humidity Measurement Results

Setting (°C)	Average Modul (%RH)			Average Standart (%RH)		
	1	2	3	1	2	3
32	98.7	96	94	99	97.9	97.7
36	97.7	97.2	98.2	98	98.1	98.5
40	98	96.3	94.6	98.3	96.2	96.8

The thermohygrometer was used to validate the temperature reading in condition 1 as displayed on the LCD. The mistake was displayed in the Table 5.

Table 5 Temperature Measurement Result in Condition 1

Setting (°C)	Average Modul (°C)	Average Standart (°C)	Error (%)	SD (°C)	Time
32	32.1	32.1	0.3	0.05	9 minute
36	36.3	35.9	1.0	0.29	9 minute
40	40.1	40.8	1.7	0.31	9 minute

Table 5 The temperature parameter measurements were conducted under condition 1, with three measurements taken, each lasting 10 minutes. Data was collected at 1-minute intervals to assess the temperature stability of the module. The highest error rate recorded was 1.7% at the 40 °C setting, while the lowest error rate was 0.3% at the 32 °C setting. The 32 °C setting also had the lowest standard deviation, indicating that the measurements were closer to the average value, showing less variation. The results showed that for temperature settings of 32 °C, 36 °C, and 40 °C, the heater took 9 minutes to reach the set point.

The thermohygrometer was used to validate the temperature reading in condition 2 as displayed on the LCD. The mistake was displayed in the **Table 6**.

Table 6 Temperature Measurement Result in Condition 2

Setting (°C)	Average Modul (°C)	Average Standart (°C)	Error (%)	SD (°C)	Time
32	32.0	31.3	2.1	0.01	10 minute
36	36.2	35.2	2.9	0.10	15 minute
40	40.1	38.6	3.8	0.28	20 minute

Table 6 The temperature parameter measurements under condition 2 were conducted three times, with each measurement lasting 10 minutes. Data was collected at 1-minute intervals to assess the stability of the temperature produced by the module. The highest error rate recorded was 3.8% at the 40 °C setting, while the lowest error rate was 2.1% at the 32 °C setting. The 32 °C setting also had the lowest standard deviation, indicating that the measurements were closer to the average value and showed less variation. According to the results, the heater took 10 minutes to reach the 32 °C setting, 15 minutes to reach the 36 °C setting, and 20 minutes to reach the 40 °C setting.

8. Conclusion

Based on the results of planning, discussion, purpose of making modules and analysis of measurement data, it can be concluded that:

1. It can be made with the title "*Low Cost Continuous Positive Airway Pressure*" with temperature and humidity parameters.
2. Arduino Uno R3 microcontroller can run a *heater driver* system to generate temperatures at 32 °C, 36 °C, and 40 °C settings. The time it takes for the heater to reach the temperature set temperature at closed pressure is faster than at the pressure given leakage.
3. SHT30 sensor can be used to read temperature and humidity measurement results through a customized program.
4. 20 x 4 LCD can display the temperature selection results and readings of temperature and humidity measurement results well according to the program made.
5. After testing the operation of the device by measuring and collecting data on temperature conditions with 1 *thermohygrometer reference device*, the highest module and comparator measurement error value was obtained which was 3.8% at a setting of 40 °C. Then for the lowest error value of 2.1% at the setting of 32 °C. Then at temperature condition 2 has the highest module error value against the comparator which is 3.8% at a setting of 40 °C. Then for the lowest error value of 2.1% at the setting of 32 °C.

Ethics statements

The author confirmed that informed consent was obtained from the subjects. This research has passed the ethical examination conducted by Health Research Ethics Committee Poltekkes Kemenkes Surabaya, Indonesia, No.EA/1245/KEPK-Poltekkes_Sby/V/2022

Credit author statement

Fadhila Rahmadia Nandra : Conceptualization, Methodology, Software, Data Collection and Measurement, Box Design, Electronics. **I Dewa Gede Hari Wisana**: main mentor. **Levana Forra Wakidi** : second mentor.

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Declaration of interests

The authors declare that there is no conflict of interest.

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