January 16, 2019

Easy-to-build CPAP device prototype

Technical Information

corresponding to the device described and tested at:
Farré R, Montserrat JM, Solana, G, Gozal D, Navajas D. Easy-to-build and affordable CPAP device for adult patients in low-income countries. Eur Repir J, 2019, in press.

This document is released under free terms following an **open-source hardware** approach and presents the technical information required to build a CPAP device prototype.

DISCLAIMER

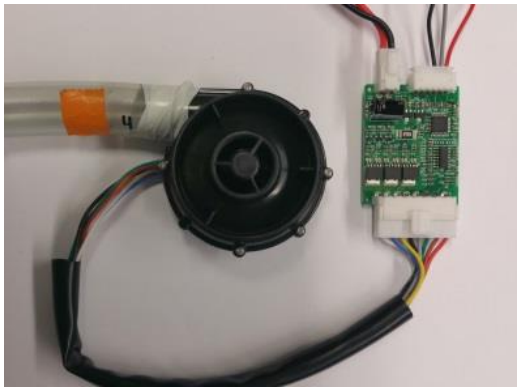
This document provides technical information on the specific device prototype described in the publication indicated above.

Using components different from (although similar to) the ones described here may require technical adjustments or adaptations and therefore the final performance of the resulting device must be specifically assessed.

The authors of this document are not responsible for the use of the information contained herein nor for any device built using such information.

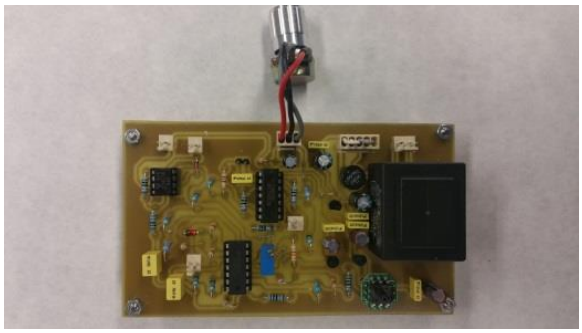
The system has the following components:

Blower and controller

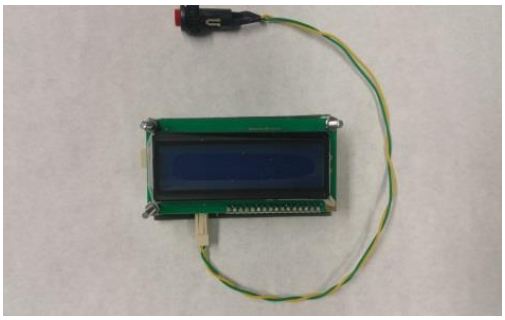


Power source

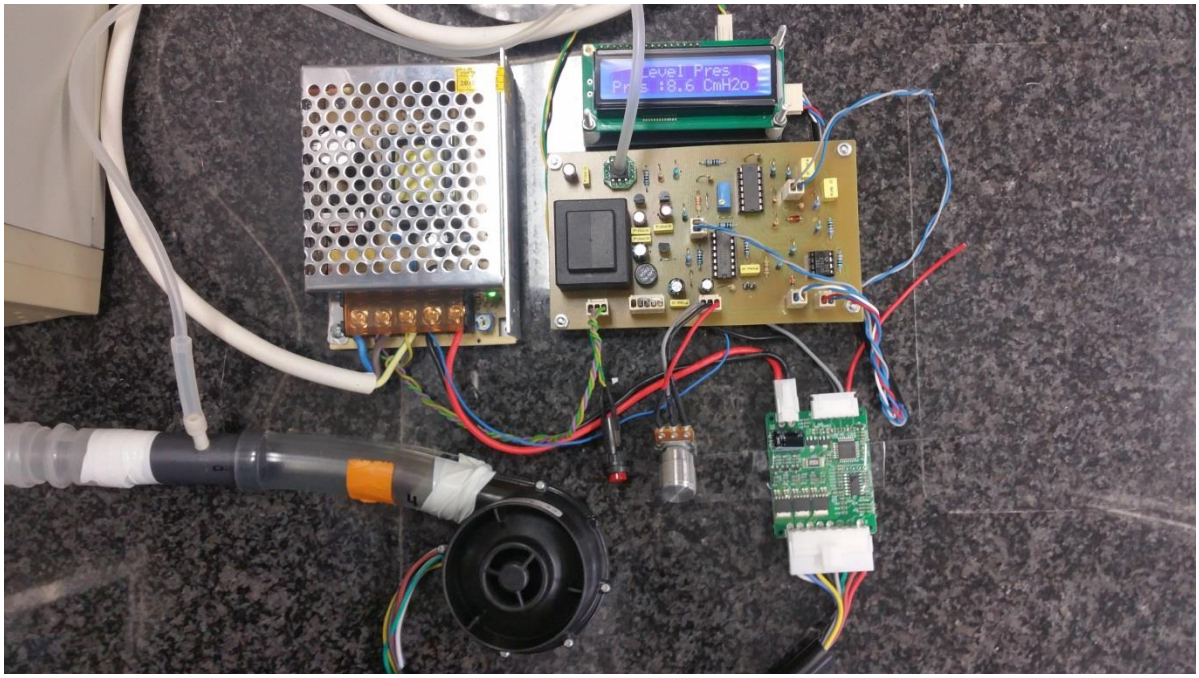
PI Controller circuit



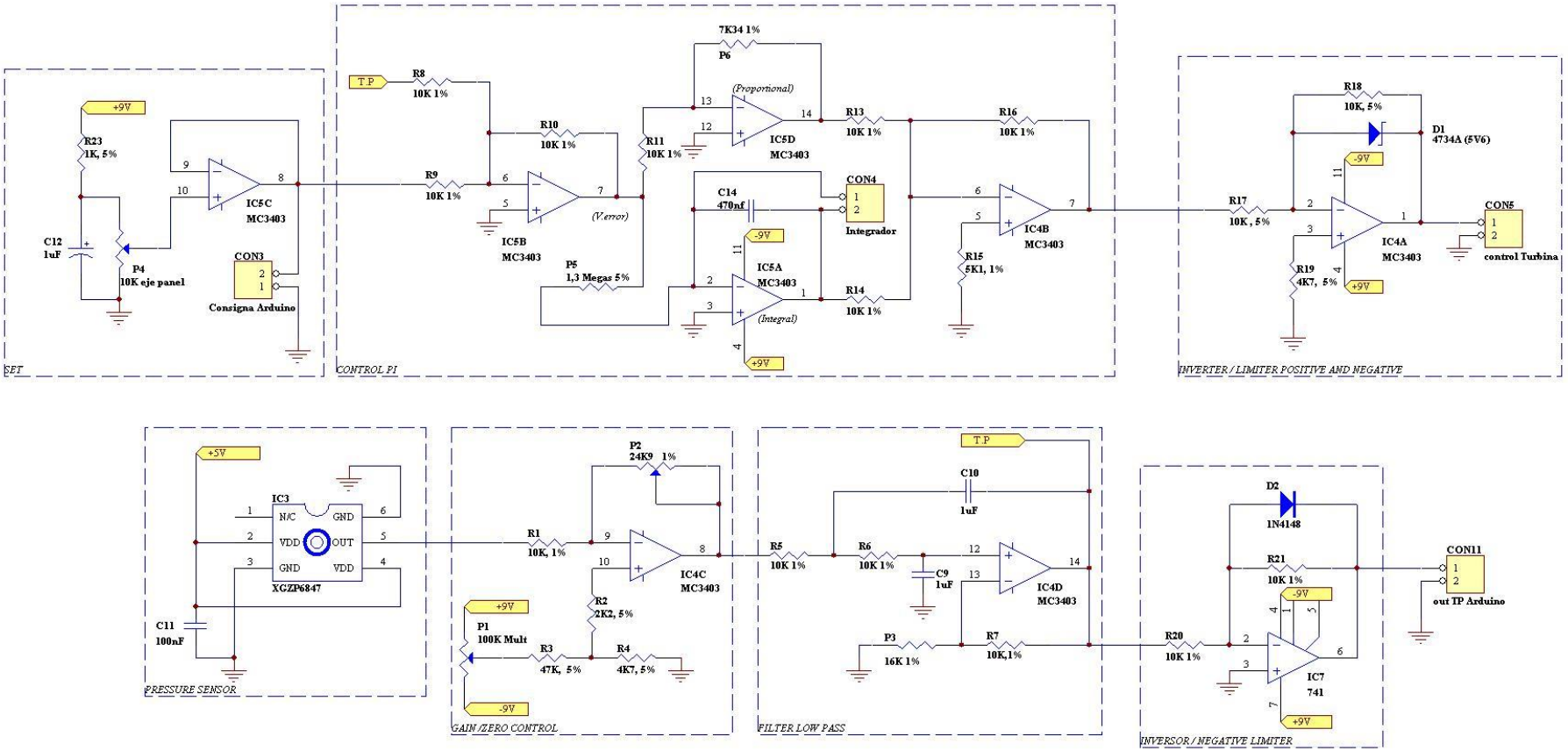
LDC display

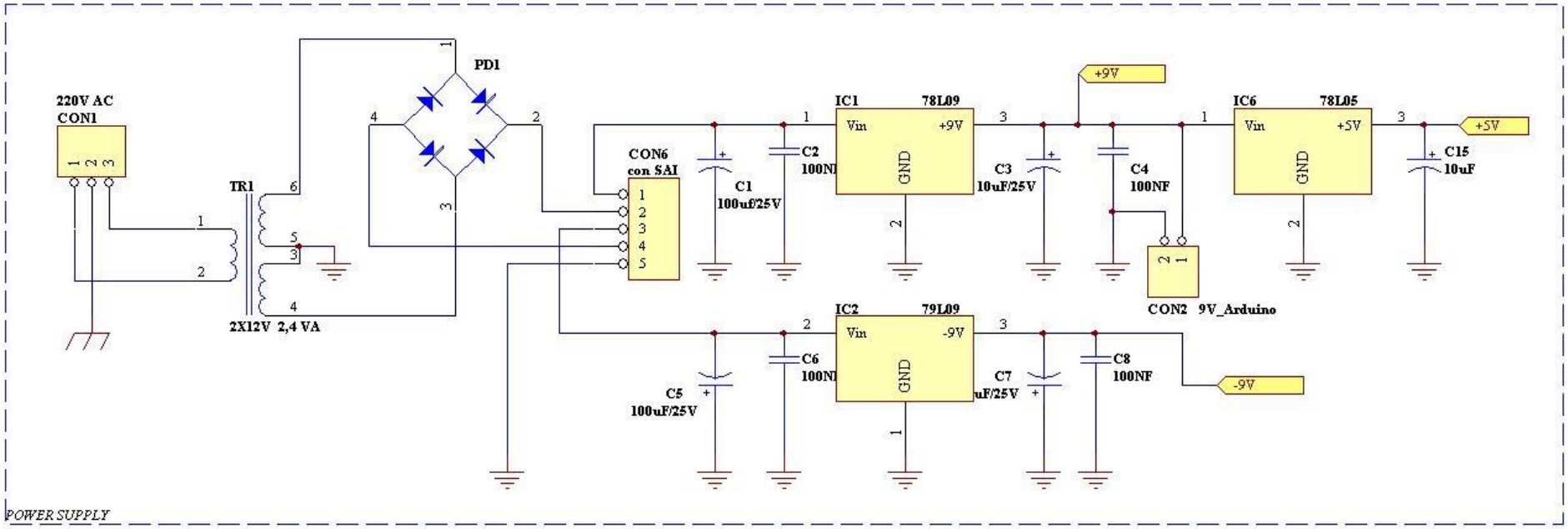


Whole assembled system

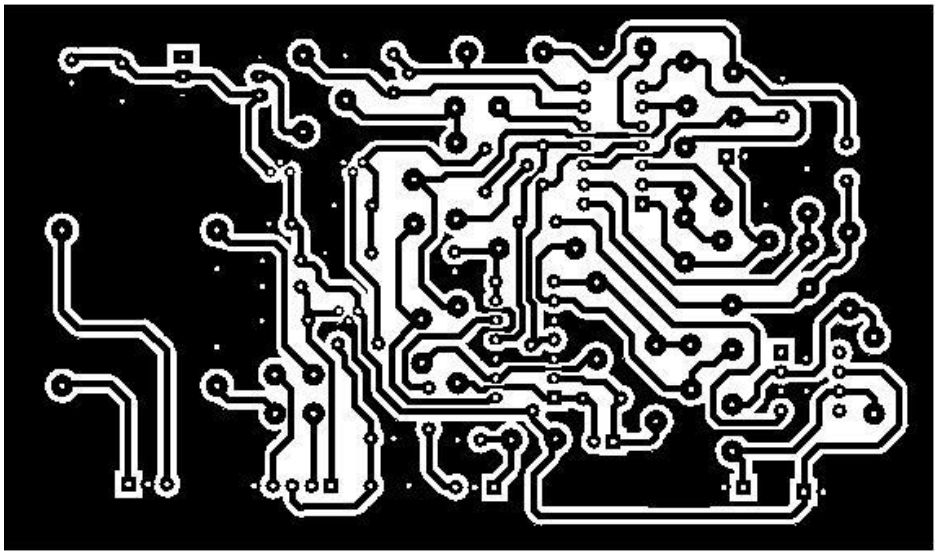


Circuit of the Proportional-Integral (PI) controller

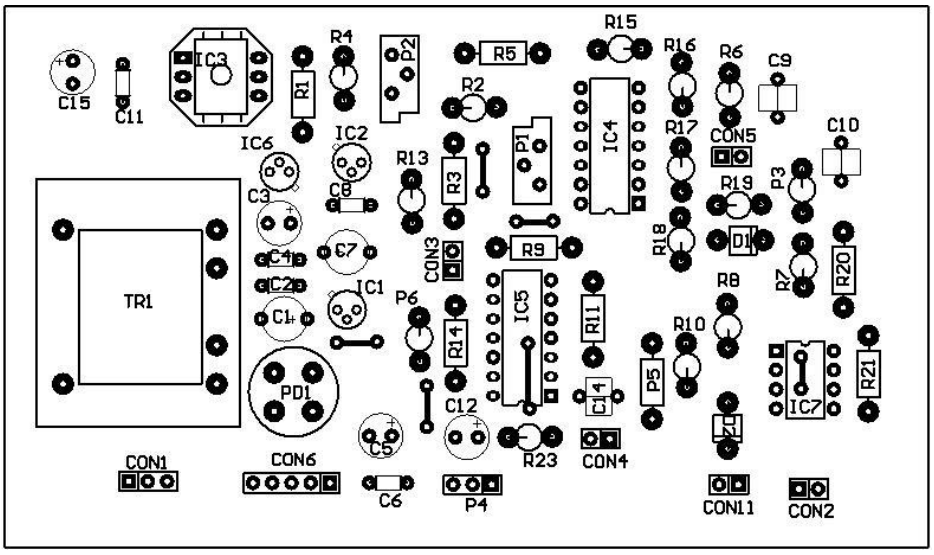


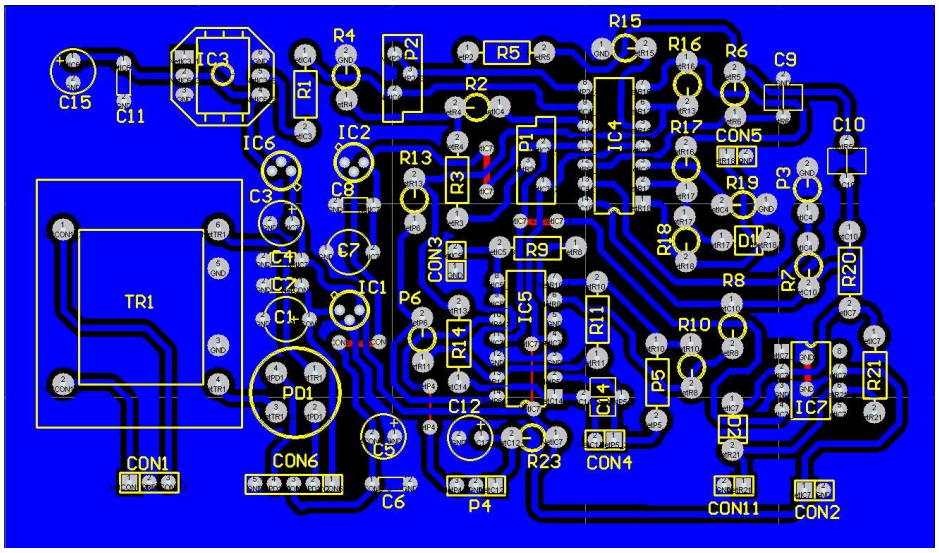

220V AC
CON1
TR1
2X12V 2,4 VA
PD1
CON6
con SAI
C1
100uf/25V
C2
100NF
IC1
78L09
Vin
+9V
GND
C3
10uF/25V
C4
100NF
+9V
CON2 9V_Arduino
IC6
78L05
Vin
+5V
GND
C15
10uF
+5V
IC2
79L09
Vin
-9V
GND
C5
100uF/25V
C6
100NF
C7
uF/25V
C8
100NF
-9V
POWER SUPPLY

Photomask of Circuit of the Proportional-Integral (PI) controller



Actual size: 122mm x 71mm



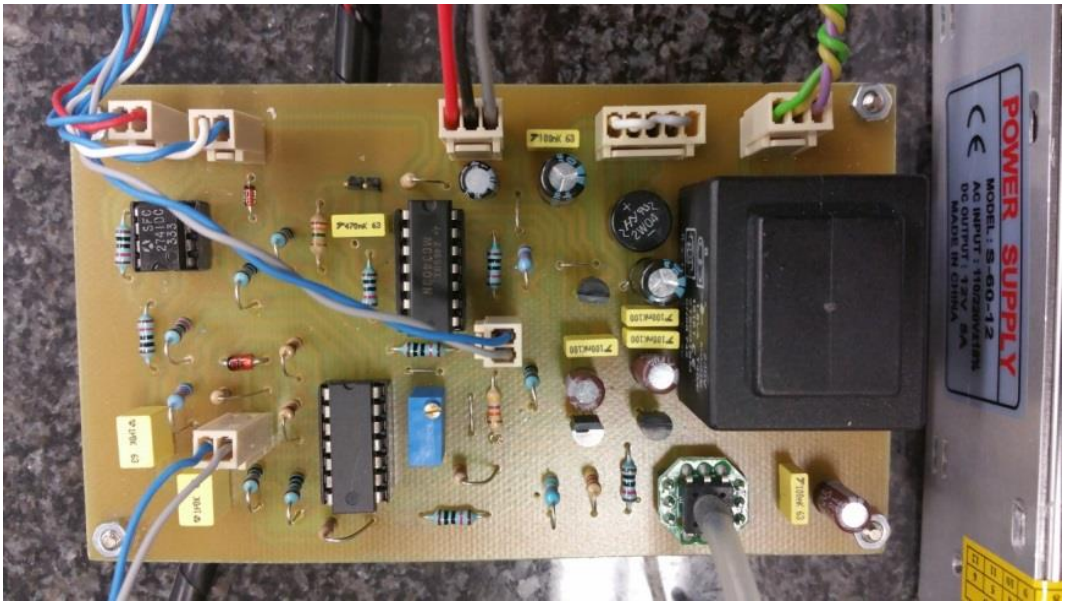


Components:

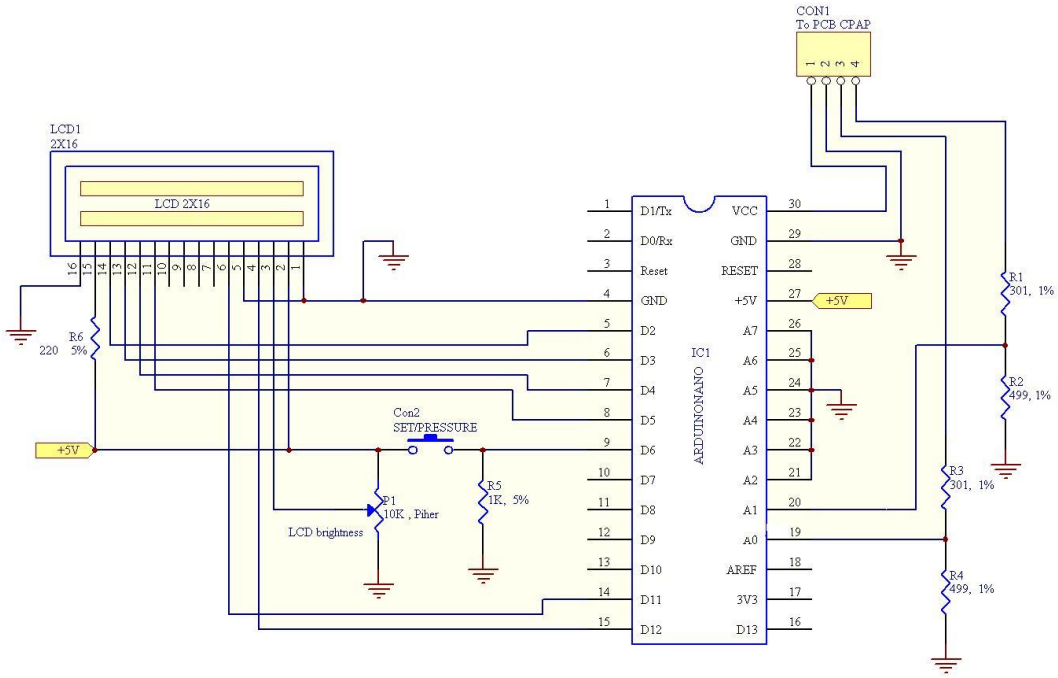
Designator	Value	Description
R1	10K	Resistor 1/4W 1%
R2	2K2	Resistor 1/4W 5%
R3	47K	Resistor 1/4W 5%
R4	4K7	Resistor 1/4W 5%
R5	10K	Resistor 1/4W 1%
R6	10K	Resistor 1/4W 1%
R7	10K	Resistor 1/4W 1%
R8	10K	Resistor 1/4W 1%
R9	10K	Resistor 1/4W 1%
R10	10K	Resistor 1/4W 1%
R11	10K	Resistor 1/4W 1%
R13	10K	Resistor 1/4W 1%
R14	10K	Resistor 1/4W 1%
R15	5K1	Resistor 1/4W 1%
R16	10K	Resistor 1/4W 1%
R17	10K	Resistor 1/4W 5%
R18	10K	Resistor 1/4W 5%
R19	4K7	Resistor 1/4W 5%
R20	10K	Resistor 1/4W 1%
R21	10K	Resistor 1/4W 1%
R23	1K	Resistor 1/4W 5%
P1	100K (potentiometer)	potentiometer multiturn
P2	24K9 (Resistor)	Resistor 1/4W 1%
P3	16K2 (Resistor)	Resistor 1/4W 1%
P4	10K (External potentiometer)	3 pin connector 2,54
P5	1M3 (Resistor)	Resistor 1/4W 5%
P6	7K34 (Resistor)	Resistor 1/4W 1%
C1	100uf/25V	Radial Electrolytic Capacitor
C2	100NF	Polyester Capacitor
C3	10uF/25V	Radial Electrolytic Capacitor

C4	100NF	Polyester Capacitor
C5	100uF/25V	Radial Electrolytic Capacitor
C6	100NF	Polyester Capacitor
C7	10uF/25V	Radial Electrolytic Capacitor
C8	100NF	Polyester Capacitor
C9	1uF	Polyester Capacitor
C10	1uF	Polyester Capacitor
C11	100nF	Polyester Capacitor
C12	1uF	Radial Electrolytic Capacitor
C14	470nf	Polyester Capacitor
C15	10uF	Radial Electrolytic Capacitor
D1	4734A (5V6)	Zener Diode
D2	1N4148	Diode
IC1	78L09	Regulador +9V (100ma)
IC2	79L09	Regulador -9V (100ma)
IC3	XGZP6847	Sensor de Presion
IC4	MC3403	4xAO (DIP14)
IC5	MC3403	4xAO (DIP14)
IC6	78L05	Regulador +5V (100ma)
IC7	LM 741	1 AO (DIP8)
CON1	220V AC	3 pin connector 2,54
CON2	9V_Arduino	2 pin connector 2,54
CON3	Consigna Arduino	2 pin connector 2,54
CON4	Integrador	2 pin connector 2,54
CON5	control Turbina	2 pin connector 2,54
CON6	con SAI	5 pin connector 2,54
CON11	out TP Arduino	2 pin connector 2,54
TR1	2X12V	encapsulated transformer 2,4VA

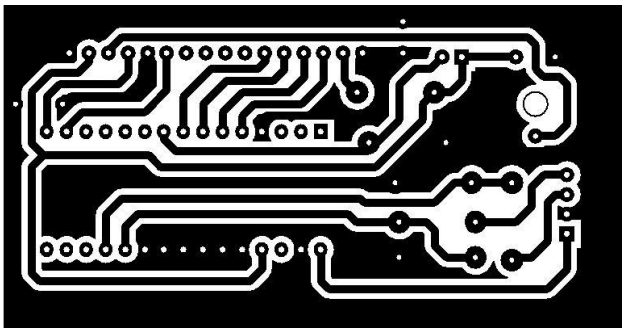
PCB Circuit of the Proportional-Integral (PI) controller

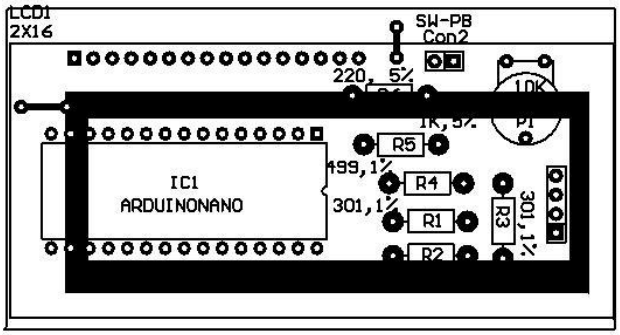


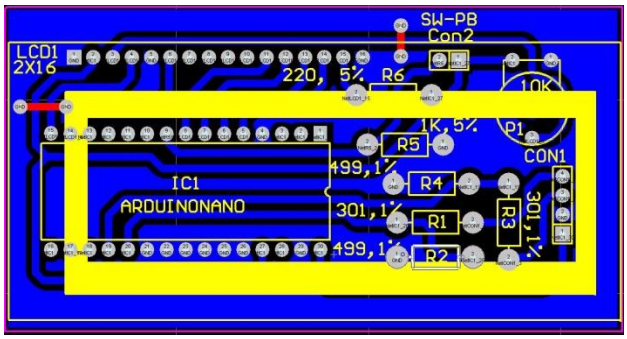
Circuit of te LCD display



Photomask of Circuit of te LCD display Actual size: 80.5mm x 41.9 mm



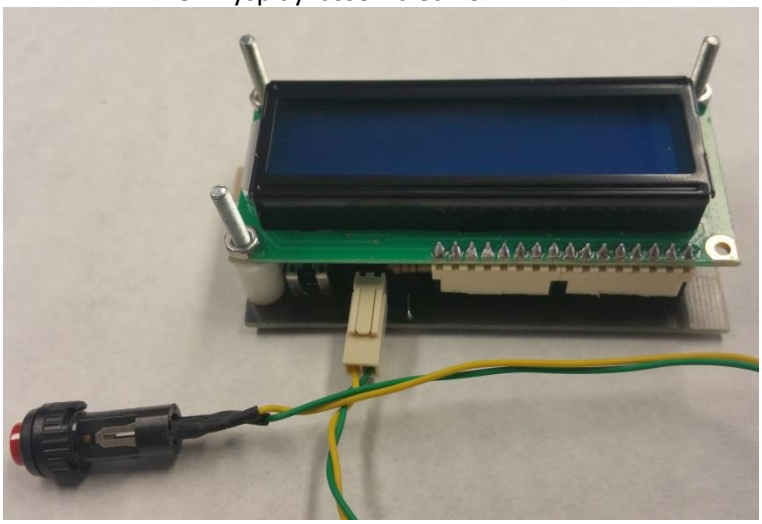


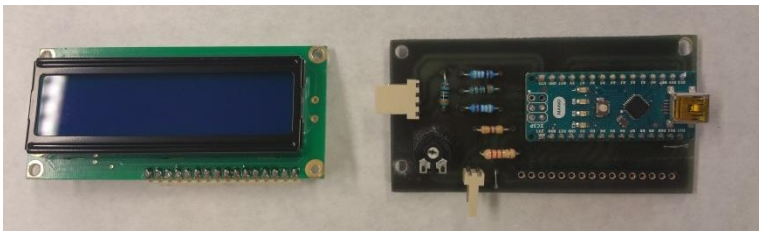


Components:

Designator	Value	Description
R1	301Ω	Resistor 1/4W 1%
R2	499Ω	Resistor 1/4W 1%
R3	301Ω	Resistor 1/4W 1%
R4	499Ω	Resistor 1/4W 1%
R5	1KΩ	Resistor 1/4W 5%
R6	220Ω	Resistor 1/4W 5%
P1	10KΩ	Potentiometer Vertical Adjustment, PIHER PT-10LV
IC1	ARDUINO NANO	µControlador
CON1	To PCB CPAP	4 pin connector 2,54
CON2	SET/PRESSURE	2 pin connector 2,54 (external red push button)
LCD1	16X2	16×2 LIQUID CRYSTAL DISPLAY
1x16 Female Pin Header Strip 16 Pin for conector LCD to PCB		

PCB Dysplay assembled LCD





Code to be uploaded to Arduino Nano (Cpapdisplay_filtrado.ino):

```
#include <LiquidCrystal.h>
LiquidCrystal lcd(12,11,5,4,3,2);
const int switchPin = 6;
int switchState = 0;
int prevSwitchState = 0;
int i =0;
int n =100; //muestras a  promediar
int samplepressure[100];
float totalpress = 0.00, promediopress = 0.00;
int samplecons[100];
float totalcons = 0.00, promediocons = 0.00;
const int sensorpress=A0;
const int consigna=A1;

void setup()      {

                  for(i=0; i< n; i++) //Inicialización de la array a 0.
                        {
                        samplepressure[i] = 0;
                        samplecons[i] = 0;
                        }
                  i=0;
                  lcd.begin(16,2);
                  pinMode(switchPin,INPUT);
                  }

void loop() {

samplepressure[i] = analogRead(sensorpress); //Agrega lecturas a diferentes posiciones dentro de la array
totalpress = totalpress + samplepressure[i];  //suma las lecturas realizadas
samplecons[i] = analogRead(consigna); //Agrega lecturas a diferentes posiciones dentro de la array
totalcons = totalcons + samplecons[i];  //suma las lecturas realizadas
i = i + 1;
```

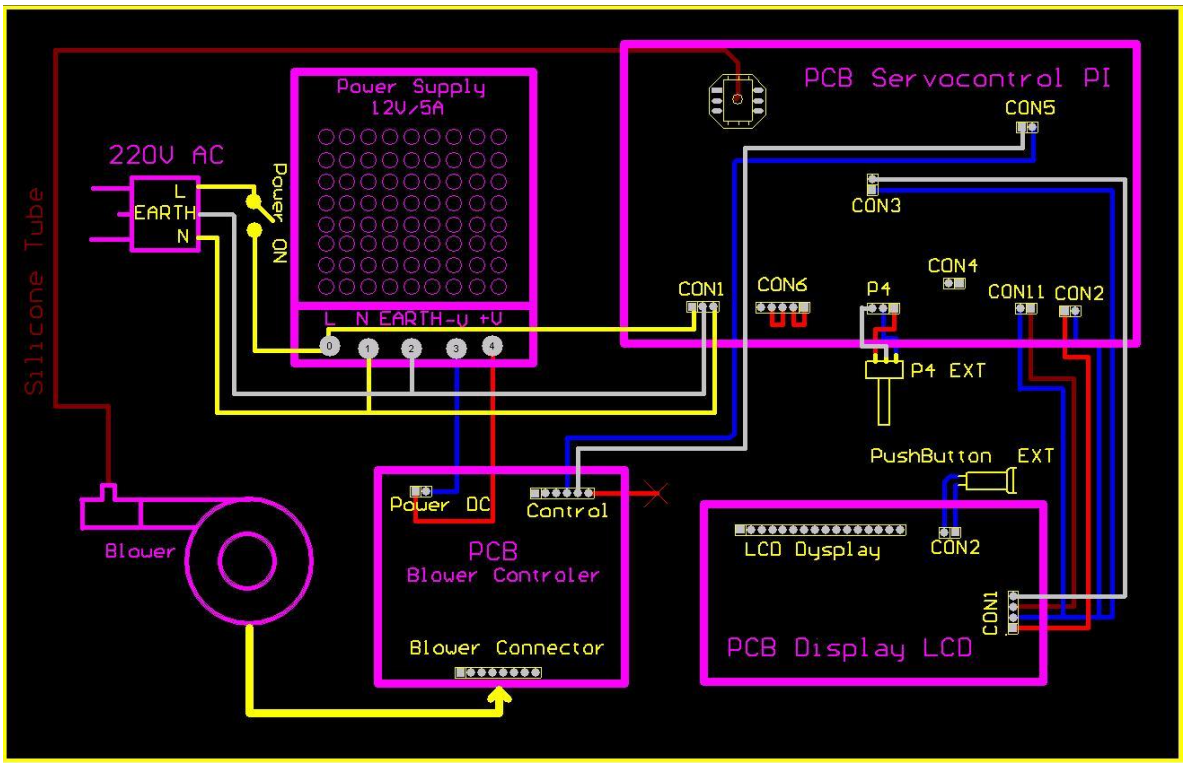
```
if (i >= n)          {
                              i = 0;
float promediopress = (totalpress /( n+1));  // calcula el promedio de las n medidas almacenadas en la variable Total
float promediocons = (totalcons / (n+1));
float P_sensor=(promediopress/1024)*5.0*5.1058;       //(*)
float Padj=(promediocons/1024)*5.0*5.1058;            //(*)
switchState = digitalRead(switchPin);

          if (switchState == LOW)          {
                                                lcd.setCursor(0,0);
                                                lcd.print("   Level Pres   " );
                                                lcd.setCursor(0,1);
                                                lcd.print("Pres :");
                                                lcd.print(P_sensor,1);
                                                lcd.print(" CmH2o");
                                                promediopress = 0.00;
                                                totalpress=0;
                                          }

          Else                                  {
                                                lcd.setCursor(0,0);
                                                lcd.print(" Adj Pres Level " );
                                                lcd.setCursor(0,1);
                                                lcd.print("Pres :");
                                                lcd.print(Padj,1);
                                                lcd.print(" CmH2o");
                                                promediocons=0.00;
                                                totalcons=0;
                                          }



                    }
          }
```

The software required to upload the code can be uploaded from:
https://www.arduino.cc/en/Main/Software

The file “Cpapdisplay_filtrado.ino” with the code to upload to Arduino can be downloaded from:

http://www.ub.edu/biofisica/dwn/Cpapdisplay_filtrado.zip

Conection between the different components:



Adjustments:
The only required adjustment is the offset of the pressure transducer. To this end, the PI controller and the LCD display should be connected and the blower power source should be disconnected so that actual pressure is zero. Then potentiometer P1 (blue color in the PI board) should be adjusted until the LCD display indicates “0.0 cmH2O”.

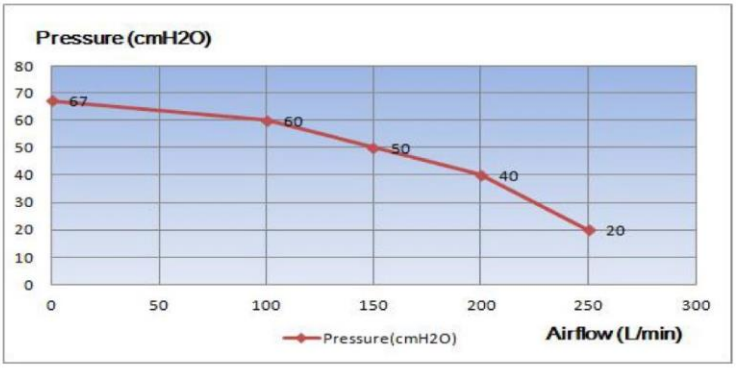
External potentiometer P4 (in the PI board) is used to set the pressure level.

Blower and blower-controller:

These figures/tables were obtained from the provider website (December 12, 2018):

Brushless 12/24V dc silent blower for auto CPAP to cure Sleep Apnea			
Voltage and Current		12V (4.5A±0.1A) , 24V (2.7A±0.1A)	
Max Air Flow (Air pressure=0)	240L/min, 14m³/h, 8.5 CFM	Max Pressure （Air flow=0)	7.5 Kpa, 75 cm H2O
Size	70mm*40mm	Noise	45dB(1Kpa-1M) 73dB(7Kpa-1M)
Power	65 W	Warranty	12 months
Speed	35000±5% rpm	MOQ	100 pcs
Material	PA66+GF	Price	$17.39-$35
Certification	CE	Port	Ningbo/Shanghai

WM7040-24V 风量风压变化关系图：

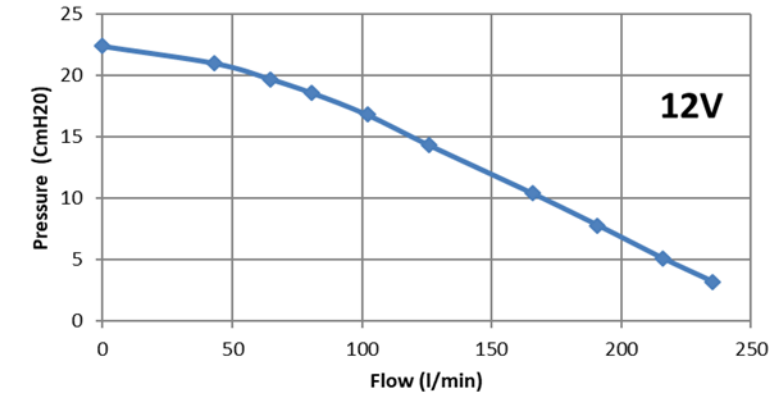


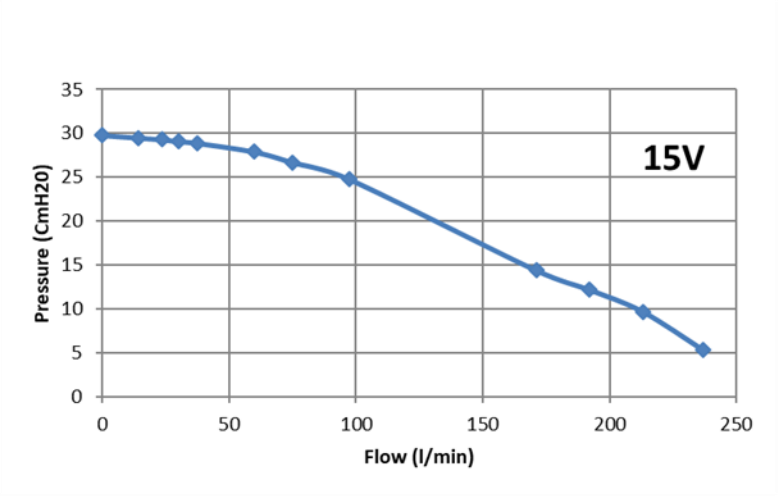
Technical parameters:

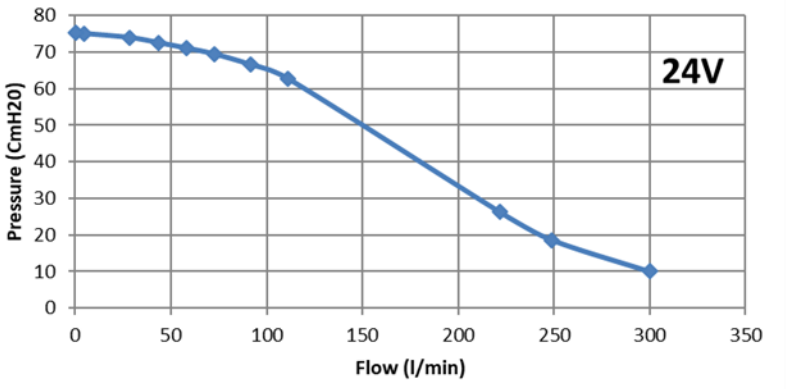
+5V	Voltage supply to Hall		+5V	5V voltage supply
HU	Hall U		VSR	0-5 voltage or PWM to adjust speed
HV	Hall V		GND	GND
HW	Hall W		EN	Running Or Stop
GND	GND		FR	CCW or CW
U	Phase U		FG	Speed Pulse Output
V	Phase V		GND	24V Power -
W	Phase W		+	24VPower +

Product model	Unit	Driver Of 7040-24V
Rated voltage	V	24
Allowable operating voltage	V	7-26
Maximum continuous current	A	3
Holzer electrical angle	Degree	60
Weight	Gram	18

The following figures correspond to the pressure-flow (P-V) relationship measured in the specific blower unit used in this setting for different power supply: 12 V, 15 V and 24 V.







For 24 V, the P-V relationship closely match the one shown by the provider (page 13). Blower performance exceeded by far the requirements for CPAP application: it can provide more than 50 cmH_2O for flow up to 150 l/min. Reducing power supply to 15 V, the pressure generated by the blower was higher than 25 cmH_2O for air flow up to 100 l/min.

With a power supply of 12 V, the blower can provide up to 16 cmH_2O with a flow of 110 l/min which should be enough for most clinical applications of CPAP, considering that the air flows corresponding to patient's inspiration peak, intended air leak through the 5-mm diameter exhalation port and unintended air leak are 36 l/min (0.6 l/s), 39 l/min (for CPAP=16 cmH_2O) and 35 l/min, respectively. Accordingly, this 12 V power supply option was the one selected for implementing our CPAP device.

However, in case that higher pressure or flows are required, blower power supply can be increased.

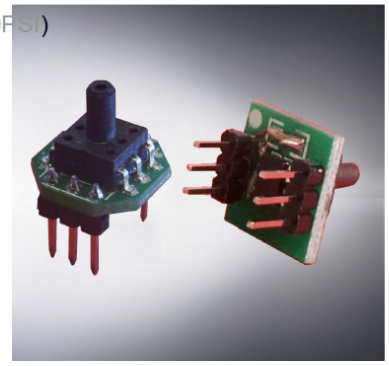
Pressure transducer:

These figures/tables were obtained from the provider website (December 12, 2018):

XGZP6847 Pressure Sensor Module

Features

- Ranges: -100kPa～0kPa…1000kPa(-15PSI～0PSI…150PSI)
- Perfect Accuracy(±1.0%) of full scale
- Gage,Vacuum Type
- For Non-corrosive gas or dry air
- Calibrated,Amplified analog output
- Temp. Compensated:0℃～+85℃(32℉～+185℉)
- Direct application,Low Cost.



Performance Parameter

Unless otherwise specified, measurements were taken with a supply voltage of 5 Vdc at a temperature of 25±1℃ and humidity ranging from 25%～85

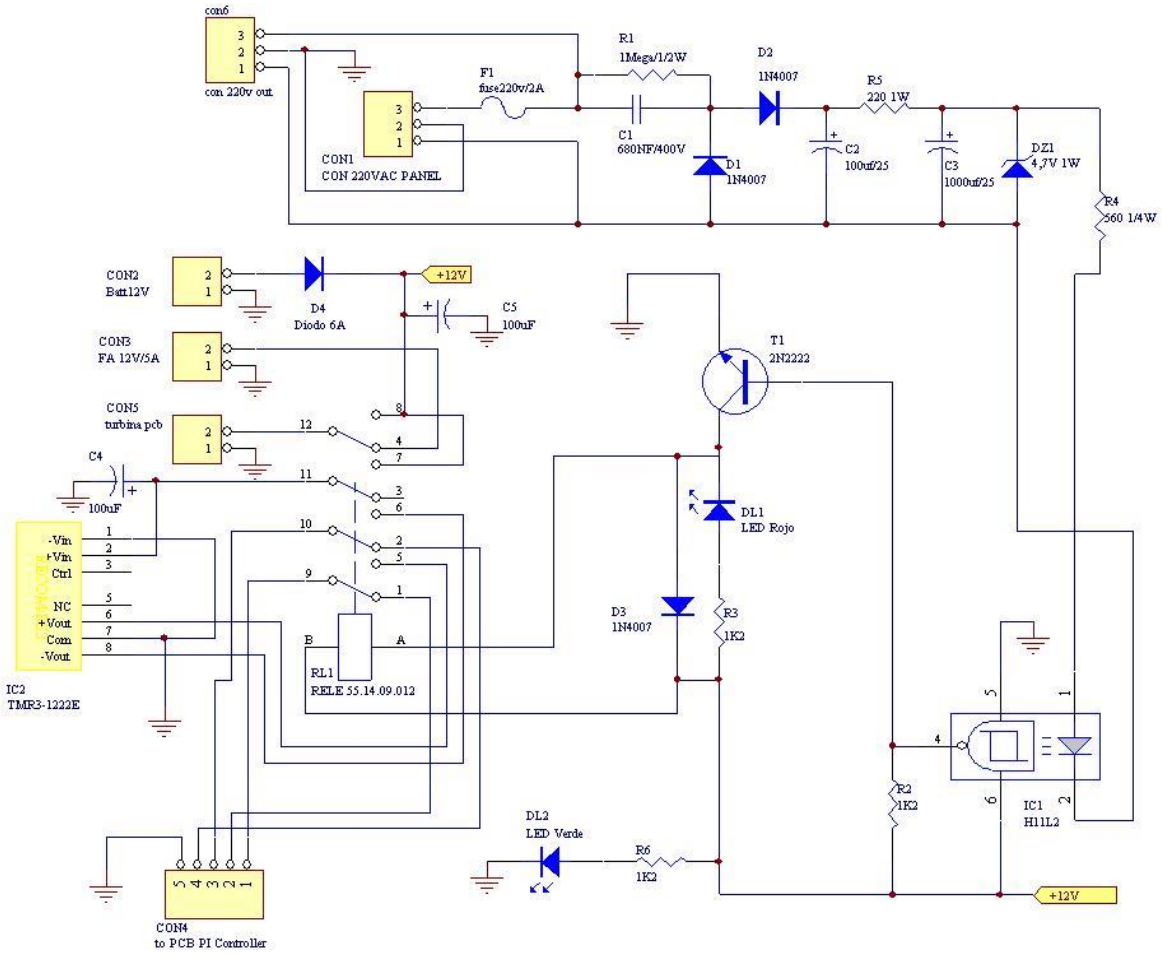
Item	Data	Unit
Power Supply	5(or 3.3v by custom)	V
Output Signal	0.5-4.5(or by custom)	V
Accuracy	±1.0	%Span
TSO(Temp. Coefficient of Offset)	±0.03	%FS/℃
TCS(Temp. Coefficient of Span)	±0.03	%FS/℃
Long Term Stability(1year)	±2	%Span
Over Pressure	2X (≤500kPa)	Rated
	1.5X(≥500kPa)	
Compensation Temp.	0 ～ 85/32 ～ 176	℃/℉
Ambient Temp.	-20 ～ 100/-4 ～ 212	℃/℉
Storage Temp.	-40 ～ 125/-40 ～ 257	℃/℉

www.CFSensor.com
High-Tech Bldg ,High-Tech Area,Wuhu, Anhui,P.R.C.241081
Tel/Fax:+86 553 4018202 Email:Sales@CFSensor.com

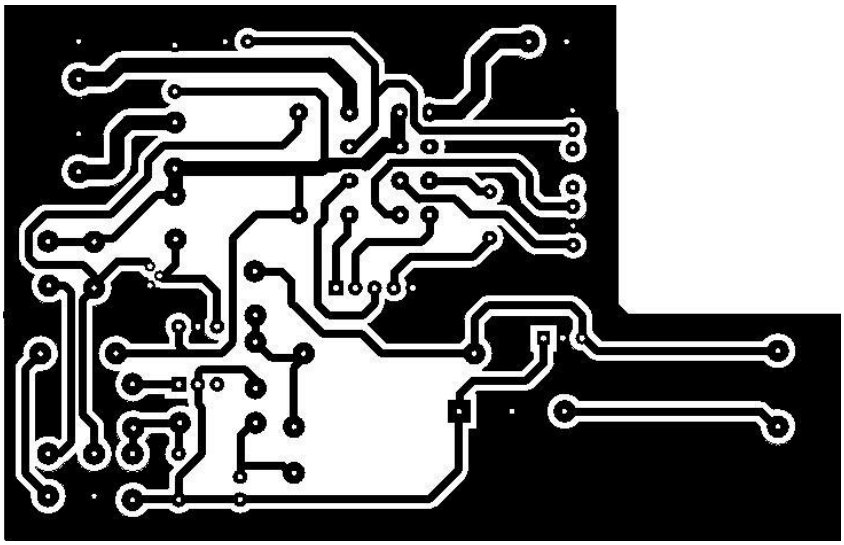
Annex 1. Uninterruptible power supply (UPS) (update Feb 11, 2019).

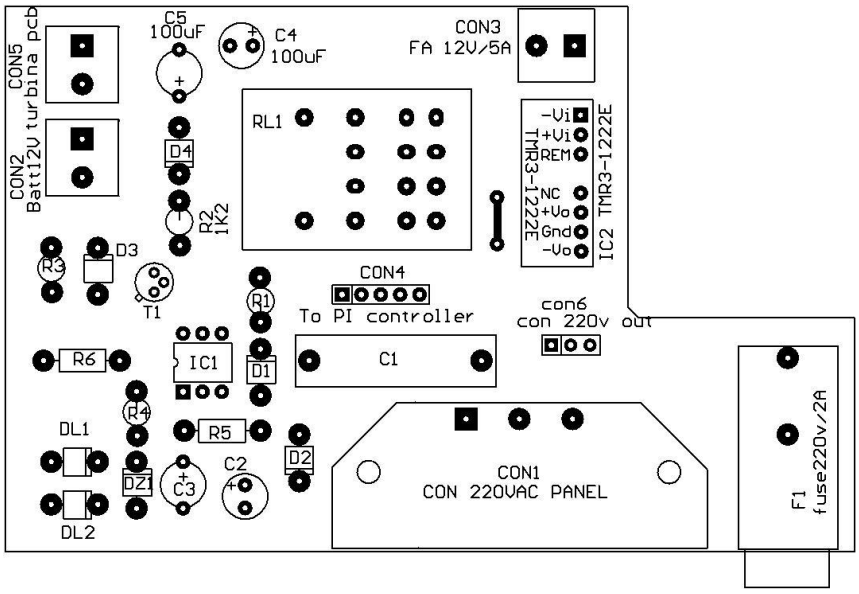
This is an optional part to allow automatic connection to a 12 V battery in case of 220 V power supply interruption.

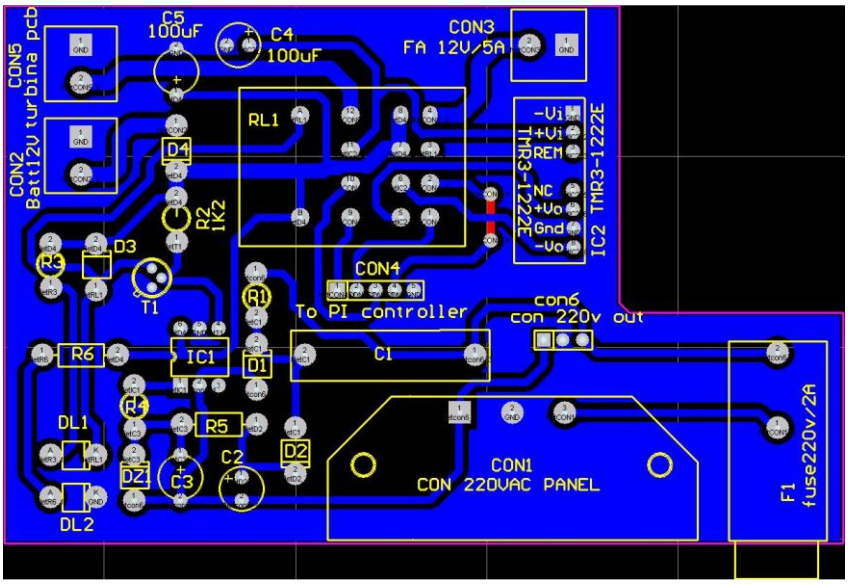
UPS circuit:



Photomask of the UPS circuit. Actual size: 110.7mm x 70.7 mm





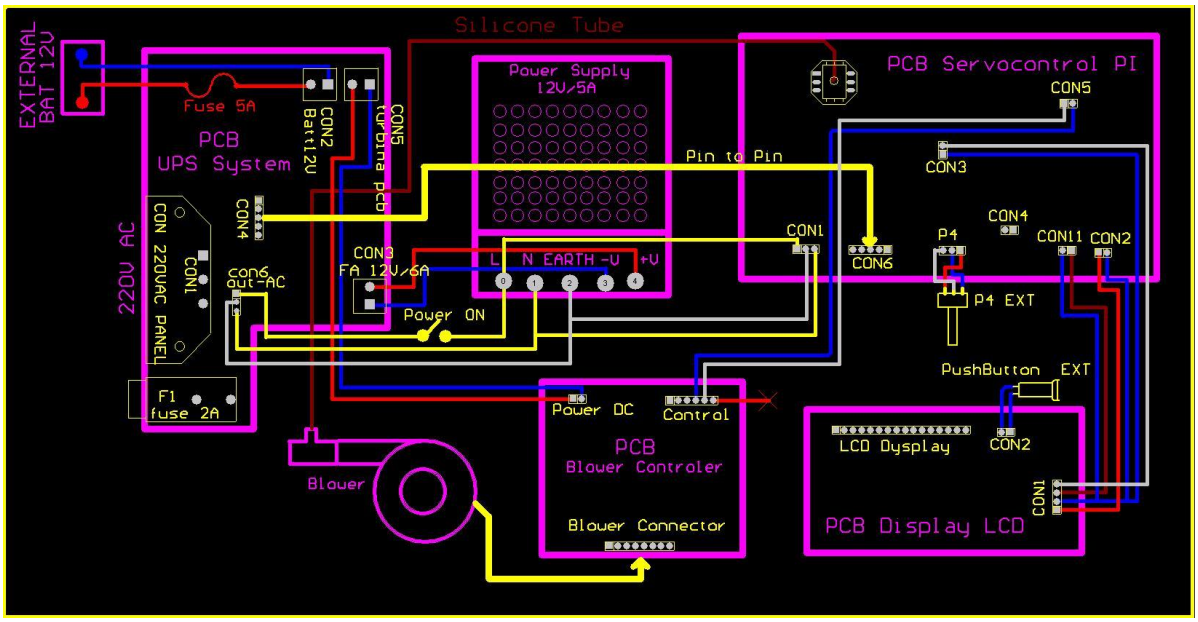


Components:

Designator	Value	Description
R6	1K2	Resistor 1/4W 1%
R3	1K2	Resistor 1/4W 1%
R2	1K2	Resistor 1/4W 1%
R1	1Mega	Resistor 1/2W 1%
D1	1N4007	Rectifier diode 1ª
D2	1N4007	Rectifier diode 1ª
D3	1N4007	Rectifier diode 1ª
T1	2N2222	NPN Transistor
DZ1	4,7V/1W	Zener Diode
C4	100uF/25V	Radial electrolytic capacitor
C5	100uF/25V	Radial electrolytic capacitor
C2	100uf/25	Radial electrolytic capacitor
C1	680NF/400V	Axial polypropylene capacitor
C3	1000uf/25	radial electrolytic capacitor
R5	220 Ohm	Resistor 1W 1%
R4	560 Ohm	Resistor 1/2W 1%
CON2	Batt12V	2 Pin PCB Terminal Block
CON1	CON 220VAC PANEL	Connector 220V pcb panel
D4	Diodo 5A	Rectifier diode 5ª
CON3	FA 12V/5A	2 Pin PCB Terminal Block
IC1	H11L2	Optocopler
DL1	LED Rojo	LED 5mm
DL2	LED Verde	LED 5mm
RL1	RELAY 55.14.09.012	Relay Finder
IC2	TMR3-1222E	DC/DC converter

con6	con 220v out	3-pin connector 2,54
F1	fuse220v/2A	5x20 fuse holder PCB bayonet closure
CON4	To PCB PI controller	5-pin connector 2,54
CON5	To Power blower PCB	2 Pin PCB Terminal Block

Connection between the different components: when including the UPS:



Annex 2. 3D-Printed box (update Feb 11, 2019)

A customized box can be obtained by using a conventional 3D printer. The cost of the ink to build the box is ≈15 €.

The standard files to command the 3D printer can be downloaded at: http://www.ub.edu/biofisica/dwn/box_printer3D.zip.