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| Sensor Electronics Specifications | | | | | | | | | | | | | | | | |
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| **Document Number** | | | | | | | | | **NANO X4 ?? 0000** | | | | | | | |
| Issue Number | | | | | | | | | A | | | | | | | |
| Issue Date | | | | | | | | | Monday 1st January 2020 | | | | | | | |
| Effective/Validity/Cir. Date | | | | | | | | | To be confirmed | | | | | | | |
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| **CIRCULATION** | | | | | | | | | | | | | | |
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| **5** | N/A | | | | | |  | | | |  | | | |

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1. executive summary / PREAMBLE / INTRODUCTION

The NanoV1 mechanical ventilator houses a host of sensors and actuators to monitor and control the relevant components. This document is a compilation of all the relevant information necessary to design the supporting electronic circuitry. Only high-level information is provided, and further research is required for more detailed information.

1. FUNCTIONAL DESCRIPTION

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Figure 1: Functional diagram of mechanical ventilator.

|  |  |
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| Table 1: LEGEND OF FUNCTIONAL DIAGRAM. | |
| **NO.** | **DESCRIPTION** |
| **1** | Oxygen blender (electronically regulated venturi). |
| **2** | Proportional solenoid controlling the supplied flow rate. |
| **3** | Proportional solenoid controlling the percentage of oxygen supplied. |
| **4** | Mass flow sensor monitoring output of oxygen blender. |
| **5** | Buffer membrane. |
| **6** | Oxygen sensor. |
| **7** | Pressure sensor. |
| **8** | Pinch solenoid valve |
| **9** | 3-way fitting with 2 directional valves. |
| **10** | Bellow drive (Bellow, stepper motor, drive system and limit switch). |
| **11** | Solenoid pinch valve. |
| **12** | Mass flow sensor monitoring supply to patient. |
| **13** | Pressure sensor. |
| **14** | Solenoid pinch valve controlling PEEP and PIP. |
| **15** | Directional valve. |
| **16** | CO2 sensor. |

The mechanical ventilator operates in either CPAP or mechanical ventilation mode. In CPAP mode the oxygen blender supplies blended oxygen at pressure directly to the patient, bypassing the bellow drive. In mechanical ventilation mode the bellow drive controls the breathing of the patient.

The oxygen blender is controlled via two proportional control valves. The one control valve manages the output flow rate whereas the other controls the percentage of oxygen. These two valves operate exclusive of each other and an increase in the valve throughput that controls the oxygen percentage will not modify the flow rate.

The bellow drive consists of a bellow that is compressed through a stepper motor driving a rack and pinon gear train. The PWM signals controlling the stepper motors are regulated via the microcontroller according to the user settings. Due to the bellow drive requiring intermittent oxygen demand and the oxygen blender operating in a mode of continuous supply, a buffer tank is required as a temporary storage location. A silicone buffer membrane is utilised for this function and an oxygen sensor is integrated in the same location to provide feedback for the proportional solenoid valve.

Solenoid pinch valves control the direction of air flow within the airways. Valves 9 and 11 are triggered based on time and are therefore syncronised with the bellow drive, whereas valve 14 is triggered to open based on time but is closed based on pressure to maintain a specified PEEP value. This valve simultaneously monitors the PIP and will open if certain limits are exceeded.

1. sensors
   1. Pressure Sensor
      1. Description

The Honeywell ABP series pressure sensor with part number ABPDANN010KG2D3 will be utilised.

* + 1. Electrical Integration

The sensor is DIP (dual inline pin) mounted directly onto the PCB and has a single axial barbed port for attaching a pressure monitoring line.

* + 1. Electrical Characteristics

The sensor requires 3.3 Vdc power supply. The output is a I2C signal with an address of 0x28.

Table 2: Operating specifications.

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Table 3: Sensor output at significant percentages.

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* + 1. Connector Description

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Figure 2: Depiction of pressure sensor.

* + 1. Conversion to physical values

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Figure 3: Conversion from digital output to pressure.

* 1. Mass Flow Sensor
     1. Description

The Sensirion SFM3000 mass flow sensor has been selected due to its sensitivity and high levels of accuracy. The sensor contains an on-board microchip housing the sensor element with further signal processing and digital calibration. The measurement results are internally linearized, and temperature compensated. The output is a I2C communication protocol. The sensor is integrated with a micro controller as follows:

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Figure 4: Sensirion connection diagram.

* + 1. Electrical integration

There is only a software requirement whereby the microcontroller needs to be setup to accept I2C from the sensor.

* + 1. Electrical Characteristics

Table 4: Electrical Characteristics.

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* + 1. Connector description

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Figure 5: Depiction of mass flow sensor.

The SFM3000 is designed for both connector attachment and through-hole technology hand soldering to a PCB. The SFM3000 sensor’s 4-pin 2 mm pitch electrical connector is compatible with Molex DuraClik™ socket (Molex product number: 502351-0400).

* + 1. Conversion to physical values



* + 1. Inlet flow conditions

In order to provide good flow conditions, the inner diameter of the connecting tube has to be approximately the same as the inner diameter of the SFM3000 main flow channel. The inlet tube has to be straight and at least 10 cm in length.

* + 1. I2C Interface and communication

Due to I2C interface restrictions, the cable length from the sensor to the microprocessor is recommended to be as short as possible and certainly not above 30 cm. For wires longer than 10 cm it is mandatory to shield the SDA and SCL. In case data is read from the sensor, the first data byte of the transaction must always be acknowledged by the master. It must be possible to reset the sensor through a hard reset, i.e. powering off and on the sensor, in case the sensor freezes. I2C Communication details are given in the application note “I2C Functional Description for SFM3000”.

* 1. Oxygen sensor
     1. Description

An oxygen sensor can be thought of as a fuel cell. When exposed to a gas a chemical reaction occurs that produces a weak electrical potential. Therefore, no external power supply is required. Additionally, this voltage is linearly proportional to the percentage of oxygen present in the gas. Thus, an oxygen sensor is an oxygen powered generator consisting of a lead anode, a gold cathode and a liquid electrolyte, typically mostly water with potassium hydroxide. The GO-12 oxygen sensor has been selected, which is equivalent and interchangeable with the MAX-12A, OOM102 and R-22MED.

The sensor output voltage in ambient conditions is susceptible to drift as the electrolyte depletes. Calibration is therefore required every time the device is switched on.

* + 1. Electrical Integration

The oxygen sensor outputs a signal with an approximate range of 5mV that needs to be sampled through an ADC on a microcontroller. This signal would need to be filtered appropriately and amplified to improve the resolution.

<https://soemarko.com/blog/diy-o2-analyzer-part-2>

* + 1. Electrical Characteristics

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* + 1. Electrical Connection

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* + 1. Mechanical Drawing

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* 1. Optical Limit Switch

switch

1. actuators
   1. Stepper Motor
      1. Description

A LAM Industries M1233070S8 (3.0Nm 4.2A; no rear end shaft) stepper motor is being utilised.

* 1. Stepper Motor Driver

TBD

* 1. Pinch Valve Solenoid

Description:

Pull action tubular solenoid with a 17.8mm stroke, 12 V dc and 7W supplied from RS-components with stock number 431-7548. The manufacturer is Saia-Burgess with manufacturing number 195224-230.

* + 1. Electrical characteristics

Table 5: Electrical characteristics

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* + 1. Performance curve

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* + 1. Electronic Requirements

Digital pin on mosfet through opto-coupler

* 1. Proportional Solenoid
     1. Description

The VSO LowPro from Parker is a proportional solenoid valve that controls the flow rate of inert gases at pressures up to 100 PSIG (6.9 bar). The 2-way valve has a “closed” default position. This ensures that an additional shut-off valve is not required.

Supply voltage: 12VDC

Electrical termination: 4.5” (114 mm) Wire leads [26 AWG] with Molex 50-57-9402 connector.

Orifice size: 0.050 in (1.27 mm).

Response time: 10 ms typical.

* + 1. Performance curve

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* + 1. Electrical Requirements

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* + 1. Electronic Requirements

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LowPro valve can be controlled by either voltage or current; however, it is highly recommended that current control be employed to ensure the most repeatable valve flow performance. For PWM control, the signal applied to the valve should have a frequency of *10 kHz or greater*. Optimum frequency will be application dependent.

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1. CONTROL SYSTEMS
   1. Digital Control System
   2. Oxygen blender: flow rate output

Bang bang control verse linear technology control

* 1. Oxygen Blender: Percentage Oxygen

1. Power Electronics
   1. Power Supply Unit
   2. Battery
   3. Battery Management System
2. HMI
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ANNEXURE A: BUDGET ALLOCATION