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TUTORIAL 4692

Introduction to Ventilators and Ventilation Rate Measurements

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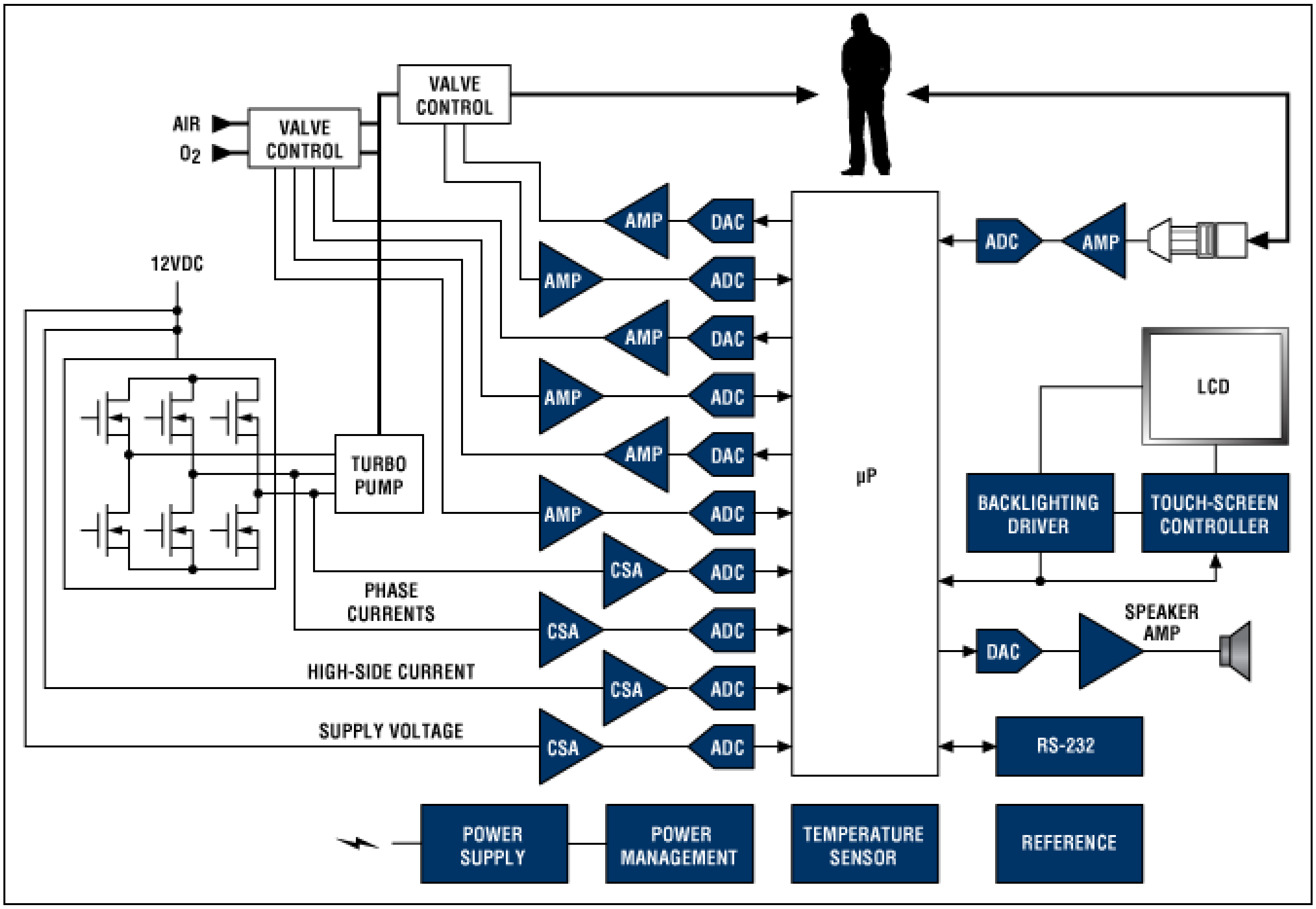
Abstract: This application note provides an introduction to ventilators and their basic functions. It discusses how ventilation rates are measured and provides the formula for determining if the tidal volume of gas exchange is sufficient for the patient. The system subfunctions addressed include air-oxygen mixture sensing, air-oxygen mixture control, inspiration control, the communication interface with the technician/doctor, and the alarm system.

Overview

A ventilator is an electromechanical (or, possibly, completely mechanical) device designed to provide all or part of the effort required to move gas into and out of a person's lungs.

Gas exchange in the lungs is required to oxygenate blood for distribution to the cells of the body and to remove carbon dioxide from the blood that the blood has collected. The exchange in the lungs occurs only in the smallest airways and the alveoli, tiny gas-exchange sacs. To determine whether enough gas is being exchanged to keep a person alive, the ventilation rate is measured. Ventilation rate is expressed as the volume of gas entering or leaving the lungs in a given amount of time. It can be calculated by multiplying the volume of gas, either inhaled or exhaled, during a breath (the tidal volume) by the breathing rate [e.g., 0.4 liter (or 0.4L) × 15 breaths/min = 6L/min].

A ventilator, therefore, needs to produce a tidal volume and a breathing rate that provide enough ventilation, but not too much ventilation, to supply the gas exchange needs of the body.



Functional block diagram of a ventilator system. For a list of Maxim's recommended solutions for ventilator designs, please go to www.maximintegrated.com/ventilator.

Operation

The process begins with creating the right air-oxygen mixture so as to deliver the desired oxygen concentration to the patient, from 21% to 100%. The inspiration period is the period that the patient is forced to breathe in, and is controlled by closing a solenoid valve. The maximum inspiration pressure is set by the relief setting of the inspiration valve. When the inspiration valve is open, the air-oxygen mixture is vented to the atmosphere, and the patient breathes out. However, if able, the patient may breathe in and out freely while the inspiration valve is open. Hence, the ventilator forces inspiration periodically, but does not limit inspiration.

A ventilator is a life-critical device. It must default to a safe condition if a single component fails, and it must monitor its own activities and deliver alarms when necessary. An alarm system, separate from the control system, monitors critical pressures and takes action should overpressure or underpressure fault conditions be detected, or if the timing of inspiration events falls outside preset limits.

The main subfunctions the system is required to monitor and control can be divided as follows:

1. **Air-oxygen mixture sensing** By monitoring the pressure of both gas flows, the controller can calculate the correct mixture.

2. **Air-oxygen mixture control** The controller can change the mixture by manipulating the state of the solenoid valves connecting the input gases.

3. **Inspiration control** An adjustable valve sets the maximum airway pressure, and a solenoid valve forces periodic inspiration at a rate determined by the therapist. The system to control this solenoid valve has multiple modes, enabling the therapist to deal with a range of patient needs from occasional assistance to complete support.

4. **Communication interface with technician/doctor** This requires the ability to display information as well as receive input from the medical team. This could include LCD drivers, touch-screen controllers, and audio alerts (beeps, tones, etc.).

5. **Alarm system** All aspects critical to safe operation must be monitored, including power-supply status, maximum and minimum inspiration pressures, and timing integrity. This alarm system must be separate from the control system, and certain components, such as pressure sensors, may be duplicated accordingly.

Given the time and expense required to achieve FDA approval, ventilator manufacturers must select a supplier with a customer-oriented discontinuance policy to ensure that system components will be available for many years.

Medical customers rely on Maxim products because, over the years, we have carefully avoided discontinuing parts. We realize how devastating product discontinuance can be to a customer, so we work diligently to transfer some products to newer production lines, create wafer buffers, allow last-time purchases, or develop upgrade devices. Very few Maxim parts have ever been discontinued while demand still existed. Maxim's Discontinuance Policy is one of the most flexible among our peer supplier companies.

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MAX4209	Ultra-Low Offset/Drift, Precision Instrumentation Amplifiers with REF Buffer	Free Samples
MAX4475	SOT23, Low-Noise, Low-Distortion, Wide-Band, Rail-to-Rail Op Amps	Free Samples
MAX4478	SOT23, Low-Noise, Low-Distortion, Wide-Band, Rail-to-Rail Op	Free Samples

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