I) Block Diagram:

Figure 17 illustrates the block diagram of the data signal transport in the Dräger Cato ventilator.

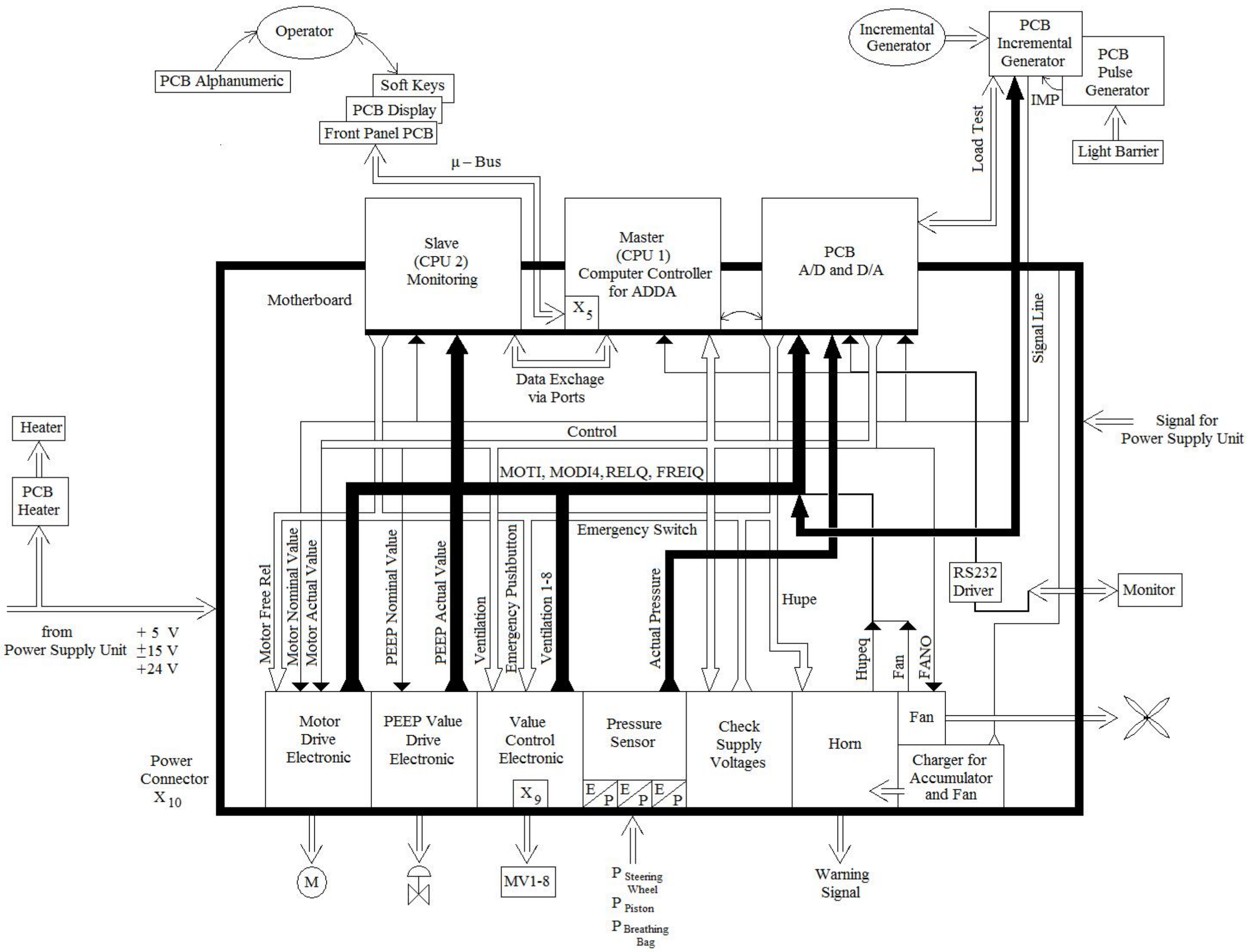


**Figure 1 -** *Block Diagram of Data Transfer for Dräger Cato*

II) Anesthesia Ventilator:

- The ventilator in the Cato System is an electronically controlled piston cylinder system which is driven by an electric motor. The ventilator has a compact breathing system which can be removed separately.

- The operator can adjust all the parameters on the front panel of the unit via a membrane keypad and a rotary knob (incremental encoder). The rotary knob is used to select and confirm the selected parameters. The settings can be checked on the display.
- The fresh gas from the fresh-gas source in the flow-meter block flows through a tubing into the compact breathing system. The piston cylinder unit generates a specific gas volume. This gas is supplied to the patient via the breathing system. The pneumatic control consists of several pressure regulators and safety valves which produce a control pressure of approximately 87 mbar. The control pressure is supplied to the control valves in the breathing system via an electro-pneumatic control unit (solenoid valves).
- The electronic control occurs via 2 independent, mutually monitoring microprocessor systems. The electronics converts the valves set by the operator into control signals for the drive motor and the control solenoid valves. The control valve exerts a pressure (control pressure) on the pneumatic diaphragm valves in the compact breathing system in order to generate the desired ventilation mode. The respective position of the piston in the cylinder is determined by an incremental encoder, and the value is channeled back to the control unit.

Figure 18 shows the ventilator control mode.

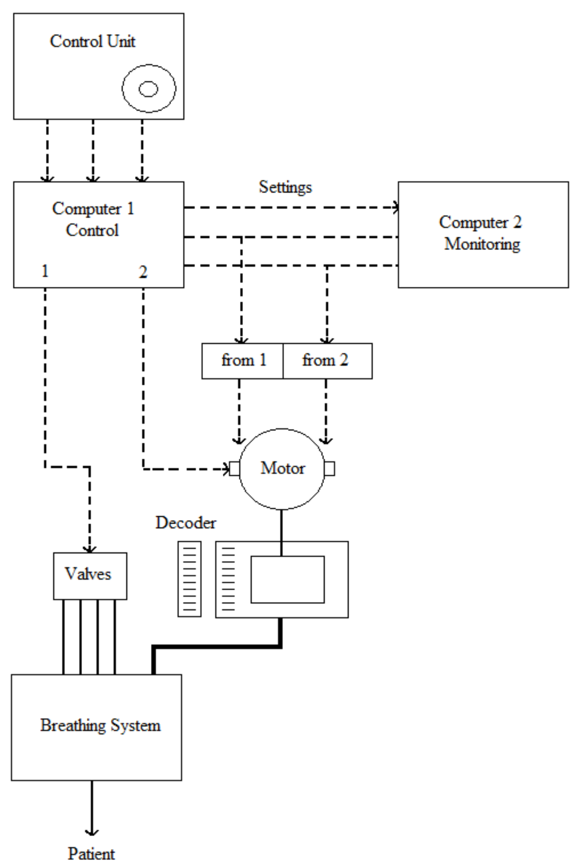


**Figure 2 -** *Ventilator Control Mode on Dräger Cato*

- The concept of mutual monitoring makes sure that the unit is switched off in a defined condition should a failure occur. The following conditions are especially monitored: piston stroke, cylinder pressure, respiratory gas pressure, and valve control.

  Figure 19 illustrates the ventilation monitoring mode.

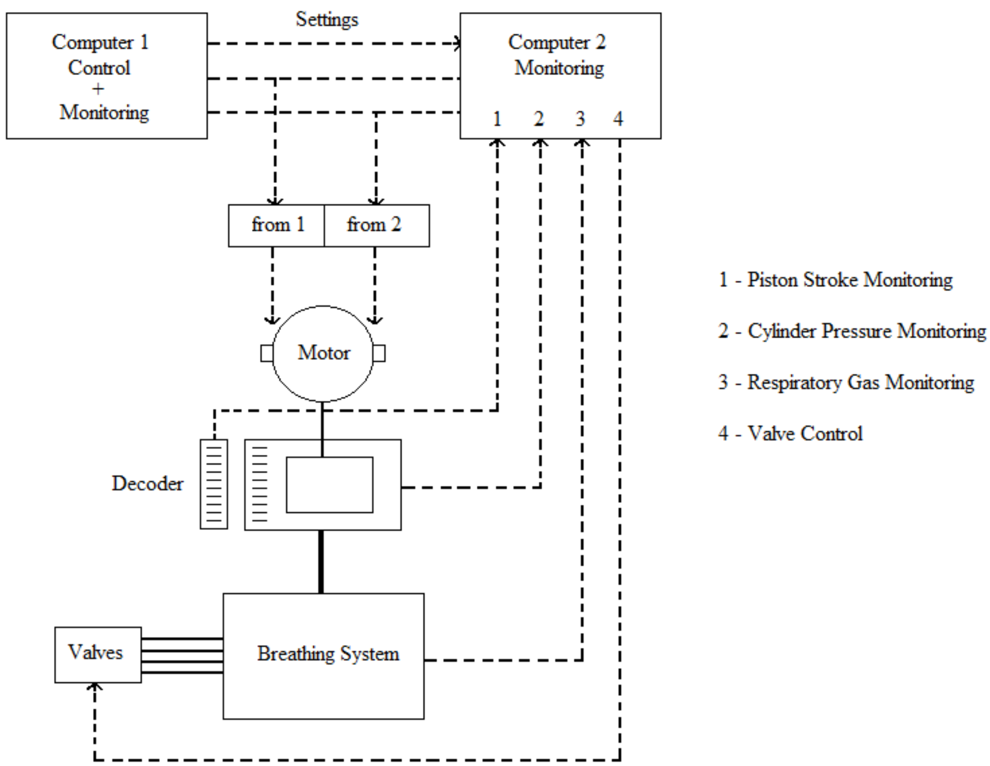


**Figure 3 -** *Ventilator Monitoring Mode on Dräger Cato*

A) Piston Cylinder Unit:

The function of the piston cylinder unit is to deliver the fresh gas supplied from the flow-meter block and stored in the breathing bag to the patient at a defined volume, pressure and speed. During expiation, the piston fills with the gas expired by the patient and with the fresh gas stored in the breathing bag. During inspiration, this piston volume is administered to the patient by an accurate stroke. Before reaching the patient, it flows through a $CO_2$ absorber. To ensure this gas flow, the control system switches the valves of the breathing system accordingly.

The most important elements of the piston cylinder unit area piston which is moved by a drive unit located in the rear part of the ventilator and a double roller diaphragm which is filled with gas during operation and which functions as a sliding bearing. The double roller diaphragm moves the piston along the inside walls of the cylinder. The front cylinder part separates the ambient atmosphere from the respiratory gas of the patient. Several interfaces are located on the underside facing the ventilator. The airway pressure is measured via a pressure measurement connection and a pressure sensor. The pressure connection provides the double roller diaphragm with the required positive pressure of approximately 160 mbar. The patient gas is supplied to the compact breathing system via a large lateral outlet port.

B) Drive Unit and Fan:

The fan and the drive unit are located at the rear part of the ventilator. To access the drive unit for repair purposes, it is necessary to remove the complete ventilator from the Cato basic unit. Besides cooling the power electronics, the fan has to keep the area of the control pneumatics and control electronics free from combustion-supporting gases. In the event of AIR failure $O_2$ can be used as drive gas. The fan function is monitored during the self-test and during operation. The control and the power electronics for the fan and the drive unit is located on the Motherboard PCB[1] on the basic board and is connected via cable harnesses. The drive unit essentially consists of a DC motor with a low wear rate. It is connected to an incremental encoder and a 2-stage synchronous belt drive. This belt drive moves the two parallel tooth belts. The catch for the piston rod of the piston cylinder unit attached to these belts can travel very short distances (small respiratory volumes). The position of the catch is determined both by the relative incremental encoder position and the mechanical stop. The removal position of the piston cylinder unit is also determined in this manner.

C) Compact Breathing System:

The compact breathing system consists of a control valve plate with the diaphragm valves which are pneumatically triggered by the solenoid valves. The inspiratory and the expiratory valves which are responsible for the respiratory phase and the valve craters are located in the respiratory valve base. The APL valve for pressure control of the airway pressure during manual ventilation is located in the respiratory gas branch. A check valve and an emergency ventilation valve are integrated in the airway. The flow sensor element of the PM 8050 cd is found at the connection of respiratory hoses. The fresh gas from the flow-meter block flows into the breathing system via the fresh gas terminal and is stored in the breathing bag. In the inspiratory phase, it is administered to the patient through the inspiratory valve by a piston stroke. In the expiratory phase, the gas flows through the expiratory valve and the absorber element into the $CO_2$ absorber container. The absorber element makes sure the expiratory gas flows evenly through the entire surface of the soda lime in absorber.

[1] PCB: Printed Circuit Board.

D) Heater (Respiratory Gas):

The heater's contact surface for indirect heating of respiratory gas is located immediately under the built-in compact breathing system. The heater is permanently on during operation. In case of a malfunction, a spring-loaded contact switch causes the heater to be immediately switched off. The heater electronics are mounted immediately under the contact surface. The maximum heating temperature is set such that the respiratory gas temperature at the Y-piece does not exceed 30º C. The maximum temperature of the heating plate is 65º C.

E) Electronic Control:

The following modules are monitored and/or controlled by the ventilator:

- Motor drive for the piston cylinder unit.
- Solenoid valves for the pneumatic control of the valves in the compact breathing system.
- PEEP controller.
- Pressure sensors (airway, piston pressure, roller diaphragm pressure).
- Fan, horn, flow-meter, and background illumination.

The voltages required for electronic control are supplied from a separate power supply unit. External data exchange with the operator is carried out via the front panel. Data exchange with the PM8050 cd takes place via the signal line / RS232 interference.

F) Electronic Components:

- Central Electronics:

The principle printed circuit board (PCB) of the system electronics is the Motherboard PCB. The CPU Standard 2 PCB and the CPU Monitoring PCB are the 2 brain cells of the ventilator and use the concept of mutual data checking. The CPU Standard 2 PCB, in conjunction with the output, input board ADDA generates the majority of the control and actual-value signals for the peripherals such as motor control, valve control and Front Panel PCB. Almost all the control signals are used to produce a quit (acknowledgement) signal in the corresponding peripheral hardware. This quit (acknowledgment) signal is then read in parallel by the ADDA PCB and CPU Monitoring PCB using parallel ports. The analog signals for actual values and pressures are likewise picked up by both the ADDA PCB and the CPU Monitoring PCB. They do this independently of one another with A/D converters.

In contrast to the ADDA PCB and the CPU Standard 2 PCB, the independent CPU Monitoring PCB is responsible almost exclusively for the check function described above and constantly exchanges data with the CPU Standard 2 PCB via communication ports for the purpose of verifying the quit and analog signals. The Motherboard PCB is located on a base plate which accommodates the solenoid valves for the valve controller of the compact breathing system, the electronic PEEP valve and other pneumatic elements. Also located on the Motherboard PCB are the pressure sensors for the airway, piston and roller diaphragm pressures, the rechargeable battery and the horn.

- Peripheral Electronics:

The remaining peripherals, including the motor, are connected to the motherboard by the wiring harness. The Front Panel PCB is connected up to the motherboard by a ribbon cable.

The Peripheral PCBs are:

1. Front Panel PCB with:

    - Alphanumeric PCB (LED display).
    - Display PCB (7-segment display, bar graph)

2. Incremental Encoder PCB (piston position).
3. Pulse Generator PCB (pulse generator at the motor).
4. Heater PCB (patient – system heating).

- Motherboard PCB:

The Motherboard PCB accommodates the 3 PCBs: ADDA, CPU Monitoring and CPU Standard 2.

The Motherboard PCB includes the following functional units:

- Motherboard for ADDA PCB, CPU Standard 2 (CPU 1), and CPU Monitoring (CPU 2).
- Motor controller and PEEP controller.
- Supply voltage monitor.
- Valve controller, horn, RS232, and rechargeable battery.
- Turning off the flow-meter background illumination.
- Interfaces.

- Motor Controller:

The task of the motor controller is to affect the movement of the piston in the piston cylinder unit with the correct time and amplitude by the motor and the gears. The control variable is the position of the piston. The target value for the piston position is an output of the ADDA PCB as the motor target value. The "travel" is defined by impulses which are measured by the shaft encoder. The Incremental Encoder PCB determines, from these impulses, the actual piston position value (motor actual value) as an analog voltage.

- PEEP Controller:

  The PEEP pressure in the expiratory airway is generated by a PEEP value which is supplied with a variable control pressure between 0 and 40 mbar. A plunger-coil system, an essential part of the PEEP control pressure potentiometer, is driven by a current source, namely the PEEP controller. The target current corresponds to the analog value, PEEP-target, specified by the ADDA PCB. This is adjusted in the controller to the actual current, PEEP-actual.

- Supply Voltage Monitor:

  The task of the supply voltage monitor is to constantly compare all operating voltages (+5 V, +15 V, -15 V, +24 V) to corresponding ranges of voltage deviations. If a supply voltage deviates from the given tolerance, the signals for emergency off, horn and motor disconnection are immediately generated.

- Valve Controller:

  The solenoid valves can only be switched if the "Emergency Off" signal is not active and thus the voltage supply is guaranteed. All eight possible values are enabled by transistor stages by signals. The signal acknowledgements are trapped at the collectors of the switching transistors via single-state transistor amplifiers.

- Horn:

  The horn can be actuated by the ADDA PCB, the Monitoring PCB and by the supply voltage monitor. It is supplied with power from the +15 V voltage of from the 9 V rechargeable battery.

- RS232, Rechargeable Battery Charging:

  The driver ICs for RXD/DCD/TXD/DTR signals are found on the Motherboard PCB. The signals RXD and TXD are generated by the CPU Standard 2 PCB, while DCD and DTR originate on the ADDA PCB. The charging circuit for the 9 V rechargeable battery is likewise located on the Motherboard PCB. It ensures that the rechargeable battery is charged correctly.

- Fan Controller:

  In the case of a failure in the compressed air supply, Divan will operate in oxygen. The fan inhibits any oxygen leaking into the electronic are of Divan. The function of the fan is tested.

- CPU Monitoring PCB:

  Opening the upper cover of the Divan reveals a right-hand cover plate under which 3 PCBs are located. All three are of the plug-in type, with the left one being the CPU Monitoring PCB. The task of the CPU Monitoring PCB is to make sure the anesthesia ventilator is functioning properly. For this purpose, all signals relevant to equipment safety – both analog and digital – are read in via 2 PIOs and an 8-bit A/D converter and evaluated by the microprocessor by various digital control lines. The microprocessor is capable of influencing the equipment status in the event of a fault. The CPU 6802 of CPU Monitoring PCB works independently and in parallel with the ADDA PCB / CPU Standard 2 PCB; it is however connected with the latter for the purposes of exchanging information. System errors and faults are detected by mutual checking of the measurement and control data and result in shutdown. The PCB-interval hardware is also checked and faults are recognized as long as the microprocessor itself is not shut down. In such a situation, a watch dog – a monitoring logic – is activated and generates not only a system reset, but also various emergency-off signals which shut down the motor and the valves and switch the Divan to MAN/SPONT. The emergency-off signals and the horn switch on are also generated by the software in the event of a general fault.

- CPU Standard 2 PCB:

  Opening the upper cover of the reveals a right-hand cover under which 3 PCBs are located. All are of the plug-in type, with the right-hand being the CPU Standard 2 PCB.

- ADDA PCB:

  Opening the upper cover of the machine reveals a right-hand cover under which 3 PCBs are located. All are of the plug-in type, with the center one being the ADDA PCB.

  The name of this PCB is the abbreviation of the terms “A/D, D/A Converter”. Several parallel I/O ports are located on the PCB in addition to these elements. The signals supplied by the sensors and controllers are converted on the ADDA PCB in such a manner that they can be processed and evaluated by the microprocessor of the CPU Standard 2 PCB. The PCB also serves to switch the valves, normalize the pressure signal of the airway pressure sensors for the analog output and to generate the target values for the motor and PEEP controllers.

- Front Panel PCB; Alphanumeric PCB; Display PCB:

  The Front Panel PCB is located behind the touch-sensitive controls / display unit and serves as the main board for the Display and Alphanumeric PCBs. This assembly forms the interface between the keypad and display (Display PCB, LP

Alphanumeric) and the microprocessor on CPU Standard 2 PCB. The data coming from the processor is transferred to the Display PCB in such a manner that it can be indicated on the 7-segment LED displays and on the bar graph. Furthermore, the control signals for the alphanumeric display are generated here. The key matrix of the touch sensitive controls is made accessible to the processor by a keypad encoder. The Front Panel PCB also features the actuator and the driver stages for the key LEDs, as well as the evaluation circuitry for the incremental counter.

- Incremental Encoder PCB; Pulse Generator PCB:

  The Incremental Encoder PCB is located – viewed from front – behind the piston cylinder unit in the area of the drive unit. It is mounted on the right-hand carrier plate above the drive belt. The Pulse Generator PCB is located immediately at the motor of the drive and carries out control functions with an incremental encoder. The Incremental Encoder PCB is used to transfer the signals received from the incremental encoder attached to the piston drive unit and serves to determine the position of the piston. The piston receives the absolute position during the power-on test. The Incremental Encoder PCB supplies the output signal for the actual value of the piston position.

- Heater PCB:

  The Heater PCB is located under the heating plate of the compact breathing system. It is accessible from below. The heater is switched ON/OFF by the contact pressure of the compact breathing system. The heater is operated by DC voltage. Polarity reversal can lead to the destruction of the PCB.

III) Functional Description of PM8050 and PM8050 cd:

The PM 8050 (cd) is an airway monitor with the following parameters:

1. Inspiratory $O_2$ concentration.
2. High-speed inspiratory and expiratory $O_2$ concentration by way of fast $O_2$ measurement.
3. Airway pressure and derived variables ($P_{aw}$, Peak, $P_{plat}$ and PEEP).
4. Tidal and minute volume as well as expiratory flow.
5. Frequency.
6. $CO_2$.
7. Anesthetic gases (enflurane, halothane, isoflurane, desflurane, and sevoflurane).
8. $N_2O$.

The available options are:

1. Airway temperature.
2. $SpO_2$, pulse, and plethysmogram.

The PM 8050 is intended for use on Sulla, SA2, while PM 8050 cd on Cato.

The PM 8050 comprises the following assemblies:

1. CPU PCB (location 1):

   The CPU PCB is the main processing unit of the PM 8050 and is responsible for central tasks such as communication with the Andros bank, serial interfaces, measured value PCB, front PCB, analog output and monitor bus. It provides the bus for communication with the other printed circuit boards. Reset of processor 68000 acts on the other two processors in the PM 8050 (measured value PCB and front PCB).

2. Measured Value PCB (location 2):

   The function of the Measured Value PCB is to record the signals for airway pressure, expiratory flow, inspiratory/expiratory oxygen concentration and breathing gas temperature and to use them to calculate / monitor important parameters (Peak, PEEP, $P_{plat}$, $V_T$, MV, etc…). No alarms are generated here with the exception of Apnoea alarm induced by flow. Data exchange with the CPU PCB takes place by way of dual port RAM.

3. $SpO_2$ PCB (location 3):

   This PCB is not part of the basic unit but is available as an option. It determines the parameters “oxygen enrichment and pulse rate” and communicates with the I/O PCB via a serial interface.

4. I/O PCB (location 4):

   The I/O PCB performs the function of an interface between the PM 8050 and internal/external devices (printer, analog recorder).

5. Front PCB (location 5):

   The Front PCB is responsible for screen output, the generation of acoustic / visual alarms and keyboard enquiry. It has a separate graphics processor (TMS 34010) with its own RAM area which drives the EL (electroluminescence) display.

6. Cicero PCB (location 6):

   This PCB permits communication with Divon.

7. Front Panel:

   This consists of EL display, loudspeaker, rotary transducer and touch-sensitive keys.

8. Power Supply PCB:

   This provides the necessary supply voltages. There are 2 different power supplies at present but these can be readily interchanged.

9. Optical Bench:

   The optical bench determines the concentration of the anesthetic gases halothane, enflurane, isoflurane, $N_2O$, and $CO_2$ as well as the new anesthetic gases sevoflurane and desflurane (suprane). It communicates with the I/O PCB via a serial interface. As a fully functional unit, the optical bench is mounted plate and can also be replaced as a complete unit together with this plate.

10. Motherboard PCB:

   The Motherboard PCB interconnects the printed circuit boards and other components. It also measures the temperature inside the housing via an NTC and serves as a mount for fan and pressure module. The Motherboard PCB features a debug interface for repair purposes.

IV) Subsystems:

1. CPU PCB:

   The CPU PCB consists of a 68000 microprocessor form Motorola which can be toggled between 8 and 16 MHz. The memory consists of a 256 kB battery-backed RAM, a 256 kB RAM and a 2 MB EPROM. Furthermore, the PCB comprises a debug 2 k x 8 bit real-time clock. The CPU PCB also comprises a debug interface which can be activated from the service mode or by a jumper. The service LEDs located on this board indicate error conditions. The timekeeper RAM stores the data for the clock, dates limit values and the calibration data for pressure, flow and $O_2$. The battery-backed RAM contains configurable data such as alarms, screen set-up, and suction rate. The battery must be replaced while the device is switched on to avoid loss of configurable data (if used).

2. Measured Value PCB:

   The Measured Value PCB consists of a Z80 microprocessor and the circuitry for measurement of flow, temperature, $O_2$ and pressure. The pressure module is not located on the Measured Value PCB but on the Motherboard PCB. The Measured Value PCB contains a Z80 microprocessor which communicates with CPU PCB via a dual port RAM (1 k x 8 bit). The Z80 calculates the flow, the pressure, the temperature, and the $O_2$ values which are supplied via a multiplexer, a “Sample and Hold” IC and a subsequent A/D converter.

3. I/O PCB:

The I/O PCB is used for communication between the CPU PCB and peripheral units such as optical measurement bench, Divan, $SpO_2$ module, 2 serial interfaces as well as an analog interface. The analog interface and external RS232 interfaces are isolated from the remaining equipment electronics by optocouplers (2.5 kV). The I/O PCB also provides the functions horn control, battery charge, temperature monitoring and +5 V monitoring (digital). The external interfaces and the interface of the optical bench are implemented via the MAX-232 driver. These interfaces are sensitive to electrostatic discharges (risk of damage). The new version of this printed circuit board uses a high-capacity capacitor (0.22 F) as storage element for the power fail alarm instead of a 9 V battery.

- Side-stream $O_2$ Measurement:

    - Function:

      The fast $O_2$ sensor is located behind the cuvette of the optical bench. An A/D converter converts the $O_2$ sensor signal. The A/D converter has a resolution of 12 bits and belongs to the Z80 processor system on the Measured Value PCB. The respiratory phase recognition occurs with the $CO_2$ signal form the optical bench. If an error occurs in the optical bench or if the communication is interfered, the $O_2$ value can fail or an $O_2$-INOP occurs. The $O_2$ sensor supplies a voltage with a great offset and a small signal amplitude. An IC on the Measured Value PCB deducts the offset from the voltage. Thus the dynamic range of the A/D converter is set optimally to the $O_2$ sensor. The $O_2$ sensor can be disconnected with an electronic switch and the input of the sampling circuitry short-circuited. The offset of the circuitry can thus be measured. The software can compensate for this offset. The resolution of the signal is 12 bit for approximately 150 mV.

    - Calibration:

      The sensor must be calibrated ever 24 hours. Since the breathing system must be opened in order to be able to carry out the calibration, it is not possible to perform a calibration during anesthesia. The time of the cyclic zeroing of the Andros bank is not sufficient (because of the delay until the other gas residues are purged, the $T_{99.9}$ time of the $O_2$ sensor is about 90 seconds). During each cold start, the automatic 21% calibration of the $O_2$ sensor occurs after approximately 3 minutes. The calibration factor is stored in the TK-RAM for warm starts. A manual calibration is still possible. It can be initiated from the operating menu. The 100% calibration is required for the linearity test. The measured value for the oxygen (as of 60% $O_2$ level) is more precise than with a 21% calibration (approximately factor 4).

- Inspection:

  A zeroing of the Andros bank occurs at least once per hour. The $O_2$ sensor is checked during this procedure. The measured value must be between 18 and 24%. If the measured value is outside tolerance, $O_2$-INOP is displayed.

- Temperature Measurement:

The AWT01 sensor measures the respiratory gas temperature. The AWT01 sensor is an NTC with the following specifications:

- $R_{30^\circ C}$ = 42.58 kΩ
- $R_{41^\circ C}$ = 31.38 kΩ
- Linearity = 770 Ω/K

Signal processing is carried out by a temperature hybrid which is also used in the PM 8030. The output signal of the temperature hybrid (1.4333 V at 30º C, 0.7535 V at 41º C) is sent to the multiplexer.

- Pressure Measurement:

The pressure module is located on the Motherboard PCB. It generates the pressure signal which is transmitted to the multiplexer via the Measured Value PCB. The pressure module provides a linear output voltage between 0.11 V and 2.45 V for a pressure range between -20 mbar and 100 mbar. The pressure module is supplied with a voltage of +5 V. It should be calibrated at 6-months intervals. Since the pressure module is a differential pressure sensor, possible drifts can be compensated by measuring against ambient air. This can be performed from the service mode.

1. Multiplexer:

   All analog measurement signals and input voltages are controlled via a 16:1 multiplexer and sent to the Z80 CPU. The multiplexer is controlled by the PIO. Its input range is ±5 V. A “Sample and Hold” IC is connected after the multiplexer.

2. Sample and Hold Amplifier:

   Since the measured values for pressure and flow change quickly, a "Sample and Hold" IC buffers the fast-changing signals. The low-loss capacitor C71 is used as a storage element. The functions "Sample" and "Hold" are controlled by the Z80 PIO. During the boot or reset routine, the IC is set to "Sample" by a pull-up resistor.

3. A/D Converter:

   A 12-bit A/D converter is used (AD574A). It works accordingly to the successive approximation principle. It processes input signals of ±5 V. Offset and amplification are adjusted by $R_{sel}$ (R99 to R102).

4. Data Bus Driver:

   To allow for accurate A/D conversion, it must be ensured that no data is returned via the data bus outputs of the ADC during the conversion procedure. Therefore, these outputs are decoupled via a data bus driver in order to inactive the outputs during the ADC conversion sequence.

5. Z80 CPU:

   A CPU clocked with 8 MHz (84C00) is used. The clock is generated by a 12 MHz clock generator. All processor lines are kept to defined potentials via pull-up resistors. The CPU can be reset by the master reset of the 68000 processor or the Z80 watchdog.

6. Memory:

   The Measured Value PCB has the following memory:

   - 64 k x 8 bit EPROM (0000 H – BFFF H)
   - 32 k x 8 bit CMOS RAM (C000 H – CFFF H)
   - 1 k x 8 bit DPR (D000 H – D3FF H)

   Decoding is carried out by a 8 from 3 line decoder.

- Automatic Flow Calibration:

  1. Calibration:

     In the past, the flow calibration was carried out manually. The flow sensor was removed and sealed with the hand. This corresponds to a zero flow and the gas used in the sensor was air.

Now with the automatic flow calibration, the calibration occurs in a time window during ventilation at the end of expiration. The composition of the gas in the sensor is defined by the sampling measurement of the optical bench and is thus considered during calibration ($O_2$ = 100% – BM $N_2O$ – anesthesia gas). However, this calibration value (flow minimum signal) must be filtered. The signal is filtered as follows:

- The time-averaging of the sensor signal over 32 ms suppresses the electrical disturbance.
- The time-averaging of the flow minimum over the last 4 respirations suppresses the pneumatic disturbances.

The user may carry out the usual manual calibration. To carry out the manual calibration, the sensor must be removed or it must be ensured that air is in flow sensor (flush with air). A manual calibration suppresses an auto-calibration until the next cold start. Auto-calibration is suppressed for a maximum of 24 hours.

2. Continuous Correction:

With each respiration, the flow minimum signal is compared with the target value with which is determined from gas composition. If deviation occurs, the calibration value is changed such that the deviations become 0. If no respiratory phases are detected, the flow minimum search is carried out every 15 – 60 seconds. The determined calibration value is stored in the TK-RAM. This calibrating value is used when switching on the PM 8050. If $O_2$ goes to INOP, the flow calibration value cannot be readjusted any more. If the anesthetic gas measurement fails, the calibration value is retrieved from the TK-RAM (no readjustment).

- $O_2$ Measurement:

There are 3 sampling channels for the $O_2$ measurement:

One channel is provided for measurement of the inspiratory and expiratory $O_2$ in the side-stream using a side-stream $O_2$ sensor (suction-type, optical measurement bench). The other 2 channels are used for the conventional measurement with the $O_2$ sensor capsule. Due to different amplification factors (V = 23.5 or V = 11.75), the multiplexer can detect whether a short circuit is present between the 2 sampling channels. At 21% vol., the measurement cell provides a voltage between 9.3 mV and 21.6 mV. At 100% vol., the cell supplies 45 mV to 105 mV. A sensor test is performed upon start-up of the device. For this purpose, a cell is loaded by a 1 kΩ resistor and the response of the second cell is checked (Teledyne test).

- Flow Measurement:

  A Spiralog sensor is used for measurement of the flow. It works according to the hot-wire flow-measurement principle. The sensor forms a bridge between the two resistors R94 and R86. The OP N7 forms a closed-loop control system with the transistor V17 which keeps the temperature of the hot branch at a constant level (125º C at a flow equals to zero). If heat is dissipated form the hot wire by a specific flow, the resistance in the hot wire will change. This will detune the bridge. As a result, the control increases the current and compensates for the heat loss. $N_2O$ compensation can be carried out since zero calibration is performed with air. A working resistor R86 with a narrow tolerance is located in the hot branch of the bridge. The voltage decrease in this branch is a non-linear measure for the flow. Amplified by a factor of 4 (FL – HIGH), the voltage is used to adjust the sensor. Amplified by a factor 2 (FL – LOW), it is used as a measurement signal for the flow. The cold branch of the bridge is used for temperature compensation. The Spiralog sensor is subject to producing tolerances and ageing tolerances and must therefore be calibrated. Calibration is carried out with a D/A converter (FL – NIOP signal) which is controlled via a microprocessor. The D/A converter applies a voltage to the resistor R94 which is proportional to the measurement voltage. This resistor is connected with the cold wire and makes sure the total resistance in the cold branch is variable. Impurities on the platinum wires can be eliminated by annealing the wires. Annealing is achieved by detuning the bridge in the cold branch such that a high current is allowed to flow through the wires. A current limiter ensures that the current flows at a defined level. The resistors R68 – R71 make sure the circuit starts safely. The signal FL – SENSE evaluates the FGND.

  Figure 20 illustrates the diagram described above.

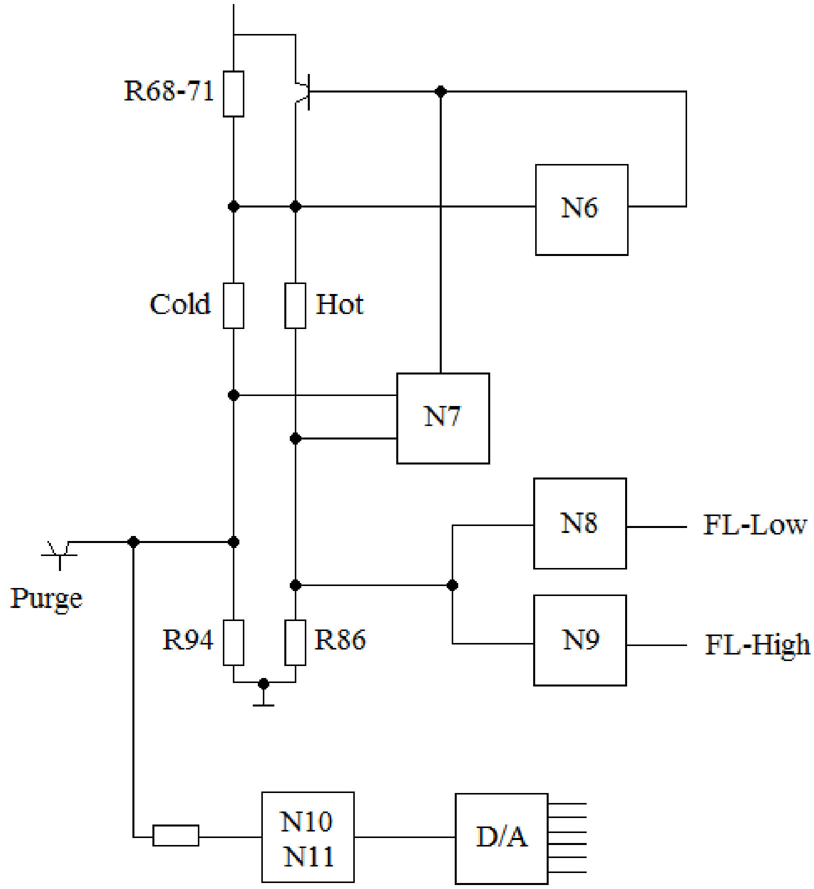


**Figure 4 -** *Diagram of Flow Measurement in Dräger Cato Ventilator*

4. Optical Measurement System:

- The optical measurement system (Andros bench 4610) consists of a pump module (1401) is used for transporting the sample gas and a changeover value is used for zero calibration. All components required for gas measurement are arranged on an angular mount so that the complete optical measurement system can be easily replaced in the field. Further spare parts are:

  1) Solenoid valve
  2) Processor PCB
  3) Cuvette with holder
  4) Pump PCB
  5) Pump

- Figure 21 shows the block diagram of the optical measurement system.

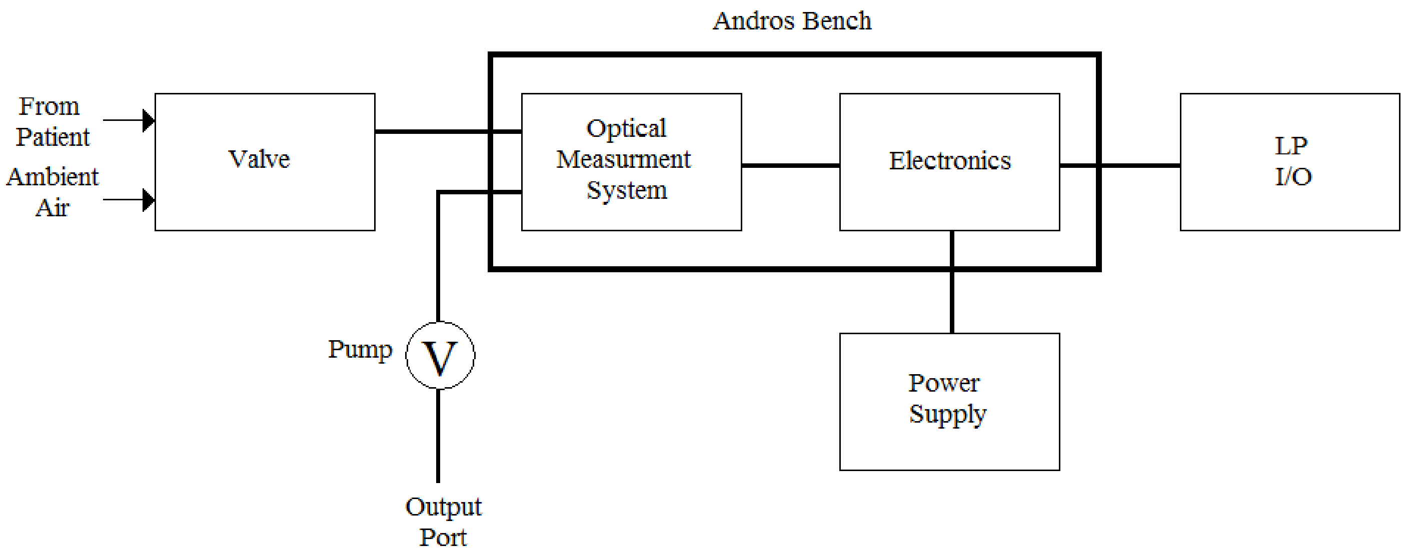


**Figure 5 -** *Block Diagram of Optical Measurement System in Dräger Cato Ventilator*

- Measurement:

  The pump module supplies the sample gas (60 mL/min or 200 mL/min) to the measurement bench. It is analyzed there by an infrared absorption technique. For this purpose, different filters (reference, anesthetic gas, $N_2O$, $CO_2$, and dark filters) arranged on a filter disc are positioned in the beam path. Figure 22 illustrates this beam path.

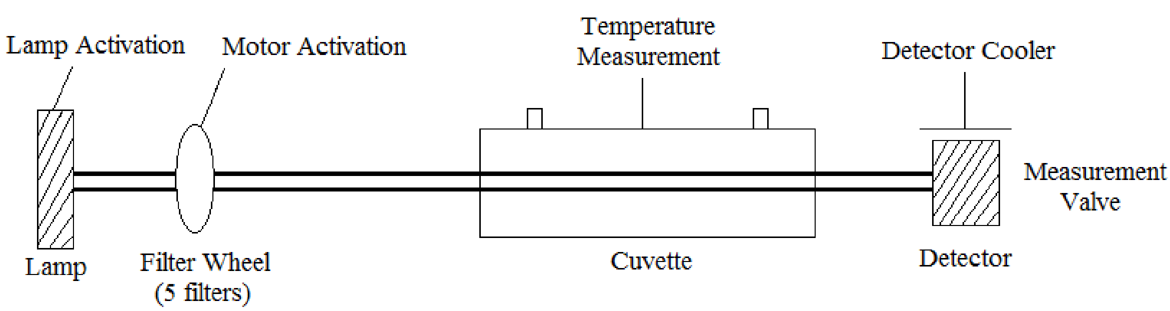


**Figure 6 -** *Beam Path of Optical Measurement System in Dräger Cato*

- Electronic Components of the Optical Measurement Bench:

  There are three PCBs provided for the optical bench:

  1. Processor PCB:

     The Processor PCB provides functions for:

     - Communication
     - Evaluation of the measurement signal
     - Pump control
     - Measurement and evaluation of pressure and $O_2$

     Note that the calibrated data of the measurement system are stored in NVRAM. Thus, the NVRAM containing the calibrated data requires transferring when replacing this board with a new board.

  2. SMR PCB:

     The SMR PCB provides functions for:

     - Control of the motor
     - Control of the heating circuits
     - Generation of internal voltages

     This printed circuit board cannot be replaced in the field since the control loops are specifically adjusted to each individual bench.

  3. Pump PCB:

     The Pump PCB is used to control the pump. It has potentiometers for the adjustment of the flow. These potentiometers can be accessed with a loop adjustment screwdriver after removing the front panel. Further replaceable components are:

     1) Pump
     2) Cuvette
     3) Solenoid valve

     The resulting signals are used by the electronics to generate the values for $CO_2$, $N_2O$, and the anesthetic gases (halothane, enflurane, isoflurane, desflurane, and sevoflurane). The values for each respiration are first sent to the I/O PCB via the RS232 interface and from these to the CPU PCB. An $O_2$ correction must be performed to ensure an accurate $CO_2$ measurement. This is achieved by transforming the $O_2$ values of the PM 8060 to the bench. Only +12 V is required as voltage supply.

- Power Pack:

  The power pack in the PM 8050 provides the supply voltages: +5 V, ±15 V, and +12 V. There are 2 power packs from different manufacturers. They supply the same output voltages but differ from a technical point of view. One power pack is of the conventional type (can be seen from fuse holder on back), whereas the other is a secondary switched-mode power supply unit.

- $SpO_2$ PCB (optional):

  The $SpO_2$ PCB is not a standard feature of PM 8050. It essentially consists of a bought-in $SpO_2$ module and electrical-isolation components. The $SpO_2$ module communicates with the $SpO_2$ PCB via a serial interface. Signals RX and TX are required in addition to a RESET. +5 V and ±15 V are also needed. The voltages are isolated by a DC/DC converter which runs off 5 V. ±15 V are generated from the +5 V by way of MAX 743. These are fed to the $SpO_2$ module by way of the connector X3. X3 is likewise responsible for supplying the module with RX, TX and RESET. In this case electrical isolation is performed with optocouplers. ECG synchronization to reduce interference is implemented via the connector X4. A signal derived from the ECG is fed in. The level should be between 3 and 30 V. Here again optocouplers are used for electrical isolation.

- Recalibrating the Optical Measurement Bench (Span Factor):

  Recalibration is necessary if the values of the bench are no longer accurate. Inaccuracy may result from drifts, contamination of the cuvette or some such similar effect. Calibrate the optical measurement bench using a laptop and the appropriate calibration software. For this purpose, connect the laptop to the PC interface using a communication cable. To perform recalibration, access the service mode on the PM 8060.