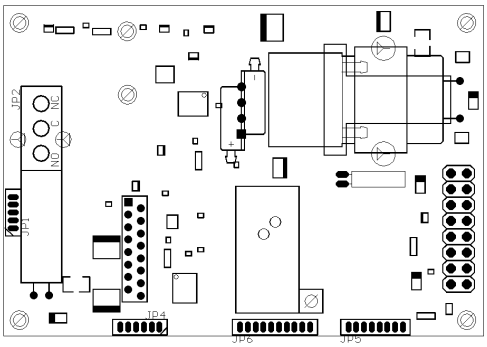
Capnography OEM board

EG 01200

Technical Manual

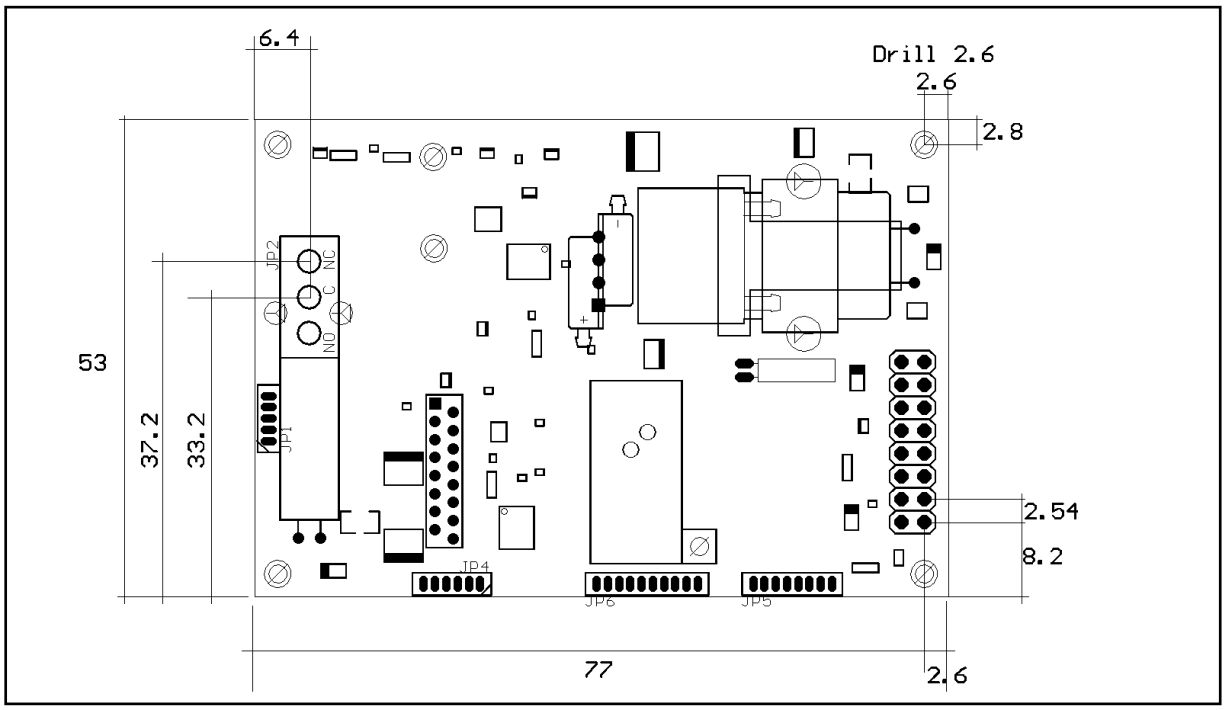


Version 1.55

Medlab medizinische Diagnosegeräte GmbH
Helmholtzstrasse 1a
76297 Stutensee
Germany
Tel.+49(0)7244741100
oemsales@medlab.eu
www.medlab.eu

Contents:

Mechanical Dimensions



Top view of the PCB (Dimensions in mm)

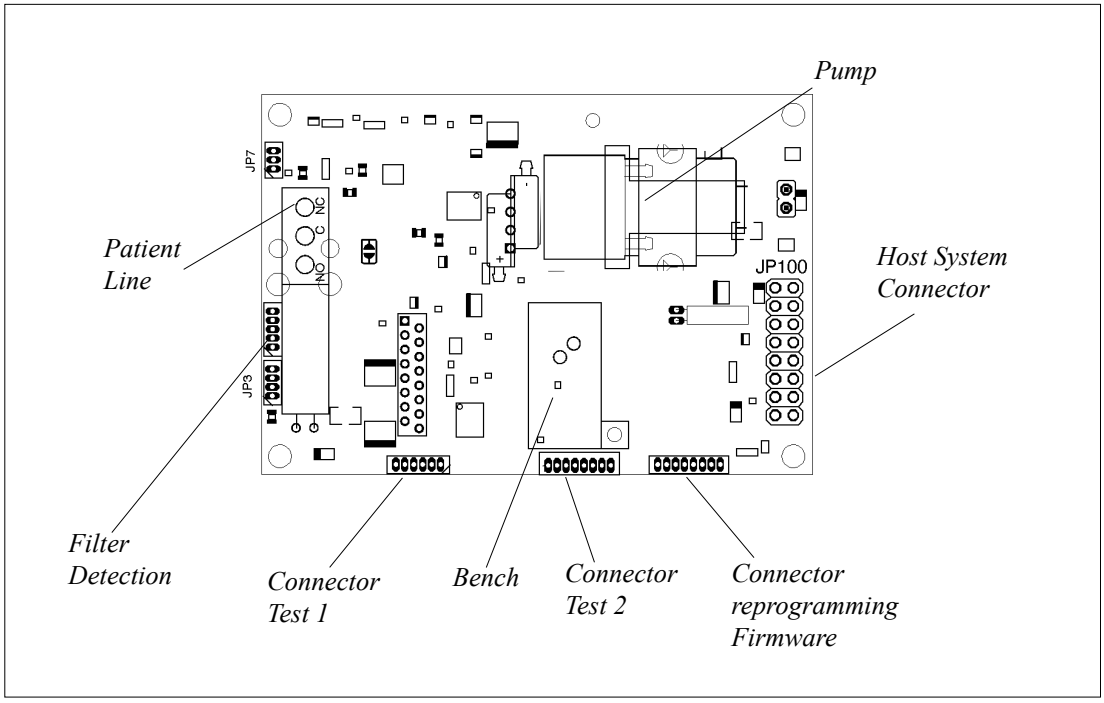
Overview

The scope of this document is the description and specification of Medlab's capnography board EG01200. It shall help anybody who is familiar with programming and medical electronics both to select the proper hardware and software version for their application as well as to help them integrate the board into their medical electronic system.

The EG01200 uses infrared spectroscopy (NDIR, "non-dispersive infrared"), to determine the content of CO_2 in a mixture of gases, the mixture that is typically present in the inhaled and exhaled breath of a human.
It does this by sampling a specific amount of the gas with the help of a small pump and passing this small sample through a miniature cuvette. The amount of sample gas is regulated by a flow sensor.
On one side of the cuvette there is an infrared source that emits a broad band of infrared radiation. This radiation is passed through a filter that only lets through a radiation of a specific wavelength. This wavelength is one of the specific wavelengths where CO_2 molecules absorb energy in the infrared band. On the other side of the cuvette, a receiver measures the amount of infrared radiation that can pass the cuvette. The higher the CO_2 content in the gas, the more radiation is absorbed in the cuvette.
The relation of absorption to CO_2 content is nonlinear, highly temperature and pressure sensitive. The module therefore also measures these two parameters and corrects the measured values accordingly by proprietary algorithms.

The EG01200 measures and transmits the following values to the host system:

- Current CO_2 value (can be used for displaying the so-called "Capnogram")
- Temperature in the bench
- Ambient pressure in the bench
- Current flow rate
- etCO_2 value (averaged) end tidal CO_2
- inCO_2 values (averaged) inspired CO_2
- Breath rate (averaged, in breaths per minute)
- Info strings (english, ASCII)
- Error strings (english, ASCII)
- Info, coded as hex bytes
- Errors, coded as hex bytes

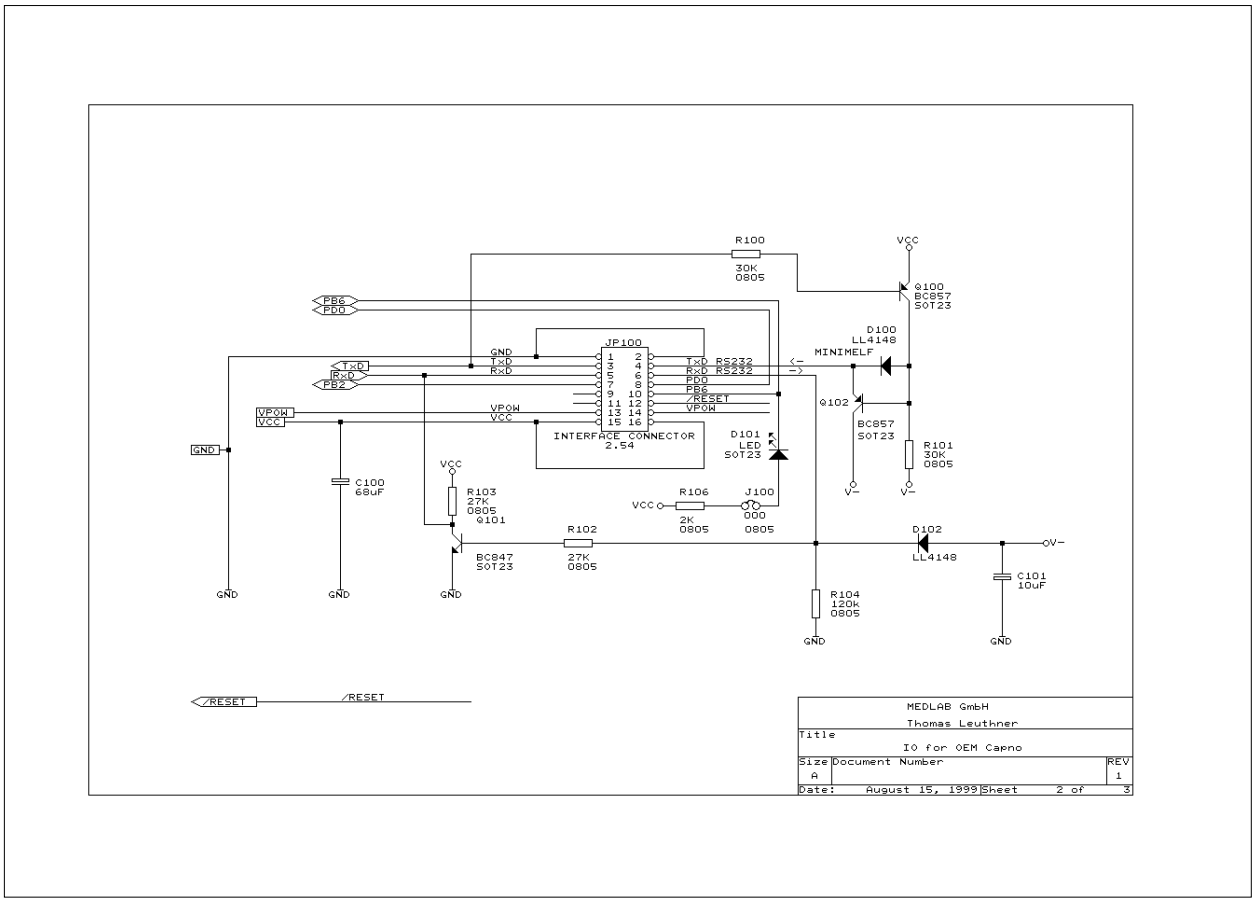


Location of main parts of the module

Technical Data (Specifications)

Operating Principle:	Infrared Absorption Spectroscopy (NDIR)
Measuring Range:	0..80 mmHg CO_2 in air @ 760 mmHg ambient air press.
Accuracy:	± 2 mmHg CO_2 @ CO_2 < 36mmHg (5 %) ± 5 % of reading @ CO_2 concentrations > 5 %
Operating Temperature:	0 °C to 45 °C, automatic temperature compensation of measurement
Operating Pressure:	800.. 350 mmHg = sea level <-> 5000 m altitude, automatic compensation
Power Consumption:	450 mW @ 5 Volt, <1000 mW for about 5 seconds during warm up and zero calibration
Warm-up Time:	15 seconds, full accuracy reached after 5 minutes
Calibration:	STPD, Automatic zero-calibration through ambient air sampling valve with CO_2 absorber 5 % gas calibration every 24 weeks or 2000 hours of runtime
Sampling:	60 ml - 100 ml - 150 ml per minute, tolerance: +20/-10 ml/min user selectable in three stages, regulated on board, by differential pressure transducer
Interface:	Digital, serial interface receives commands; outputs: temperature, ambient pressure, CO_2 trace (capnogram), etCO_2 values, breath rate. The CO_2 values can be transmitted in mmHg or %Vol.
Baud Rate:	9600 baud, asynchronous, TTL level and RS232 level (connects to each PC's serial port)
Electronic:	Uses highly integrated, single chip digital signal processin-
Pneumatic:	Long-lifetime pump with coreless and brushless motor
Size:	77 x 57 mm, maximum height 28 mm
Weight:	50 g, including pump and valve

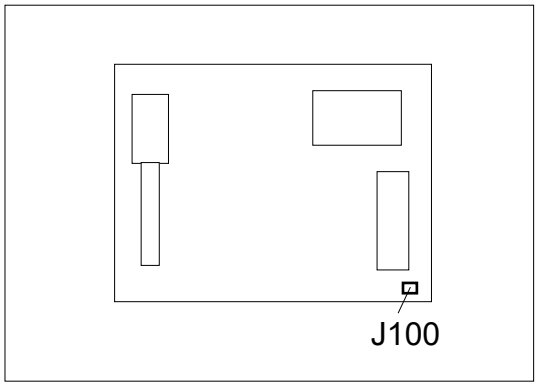
Hardware Interface



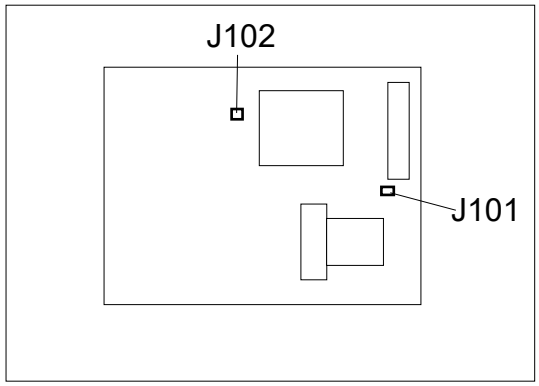
Interface part of the capnograph's electronics

Jumper:

J100	disables the LED on the board if not needed
J101	connect if VCC and VPOW shall be supplied by one source
J102	connects analog and digital ground (always has to be closed)



Top View



Bottom View

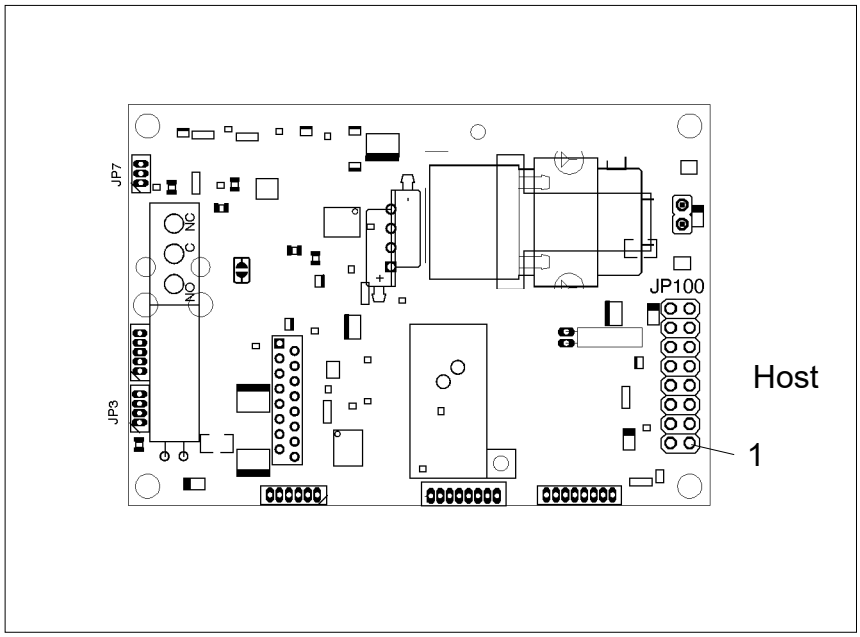
Power Consumption

The EG01200 is one of the lowest powered gas analyzers in the market. During normal operation, the module draws around 90 mA (450 mW) at 5 volt. This includes the pump and the infrared source. However, during the purge process used for the zero reference calibration, the pump works at full speed and the valve that switches between patient and ambient line is powered up, too. The module draws approx. 180 mA (900 mW) at 5 volt for around five seconds in this case. The zero calibration is repeated automatically every 15-20 minutes. The maximum energy which can be delivered by the user's power supply has to be adjusted to these values.
It is possible to use a highly regulated, 5 volt supply for VCC and another supply of 4.5 to 6 volt for VPOW. VPOW is supplying the valve and the pump only. These two voltages can be connected by Jumper 101 on the board, so one needs to connect only one regulated voltage of 5 volts for both voltages. The 12 bit AD converters are supplied by their own reference voltage, so the VCC supply does not influence the measurement directly.

Serial interface

The normal connection to the board is done via serial, asynchronous communication with a speed of 9600 baud, 1 start bit, 8 data bits, one stop bit, no parity. Both TTL and RS232 (+/- 5 Volt level) voltage levels are available. The RS232 levels are helpful during the evaluation of the board, which can be done by using an ordinary PC and a special test software. The connection in the customer's final system could be done through TTL levels, which saves electronic parts on the host side of the data stream. In the standard protocol, only a unidirectional interface (EG01200 ---> host system) is necessary. However, the module also understands some commands that are described in the software interface part. The usage of these commands is optional.

Connector



JP100, Host Connector

1	GND	
2	GND	
3	TxD	(TTL level) data output
4	TxD	(RS232 level)
5	RxD	(TTL level) data input
6	RxD	(RS232 level)
7	PB2	(not used)
8	PD0	(not used)
9	N.C.	
10	PB6	(not used)
11	N.C.	
12	/RESET	(active low)
13	VPOW	Power supply for pump and valve (4.5-6 volt DC)
14	VPOW	
15	VCC	Power supply for electronics (5 volt regulated +/- 5 %)
16	VCC	

For using JP3 (filter detection), please contact Medlab for additional information.

Software Protocol

Output of the module

- Data is always transmitted in two byte blocks
- The first and the second byte of a block can be recognized when checking the highest bit: in the first byte of a block, the highest bit is always set, in the second byte, the highest bit is always cleared. If one byte is not received correctly, the protocol resyncs after the next received byte.
- values that are transmitted can be up to 10 bits long (0x0000.. 0x03FF)
- Bit 16 15 14 13 12 11 10 09 08 07 06 05 04 03 02 01
- 1 A A A A B7 B9 B8 0 B6 B5 B4 B3 B2 B1 B0
- the AAAA bits code up to 16 different meanings of the two byte block
- Bit 16 is always one, Bit 8 is always Zero
- B0 to B9 form a number between 0 and 1023. B7 is moved to the higher byte and always zeroed at its original place in the lower byte.

AAAA code for the value B9..B0

0000	$etCO_2$
0001	Temperature
0010	Ambient pressure
0011	Start of ASCII Info Message (see list of info messages)
0100	End of ASCII Info Message
0101	CO_2 curve sample (Capnogramm)
0110	Breaths per minute
0111	Start of ASCII Error Message (see list of error messages)
1000	Stop of ASCII Error Message
1001	Not used, reserved
1010	Start of ASCII parameter list
1011	End of ASCII parameter list
1100	Flow rate
1101	Inspired CO_2
1110	Breath Trigger (indicates recognized breath, B**X** not meaningful)
1111	FiO_2 value in "%" *10 (example "254" means 25.4%)

The values after the codes have the following meaning:

$etCO_2$:	0 .. 800	is	0.0 ... 80.0 mmHg
Temp:	0 .. 500	is	0.0 ... 50.0 °C
Pressure:	300 .. 800	is	300 ... 800 mmHg
CO_2 trace:	0 .. 800	is	0.0 ... 80.0 mmHg
ASCII:	the following are ASCII Bytes, until ASCII end message received		
Breath:	0 .. 100	is	0 ... 100 breaths per minute
Flow:	0 .. 255	is	only informational, no physical unit

Example:

1 0101 0 01 **0** 000 1011 = 0xA90B CO_2 Trace, 267 = 26.7 mmHg

1 0101 1 01 **0** 000 1011 = 0xAD0B CO_2 Trace, 395 = 39.5 mmHg

1 0010 1 10 **0** 101 0001 = 0x9651 Pressure, 721 = 721 mmHg

1 0001 0 00 **0** 111 1111 = 0x887F Temperature, 127 = 12.7 °C

Commands to the module

Commands to the module are transmitted as one or two ASCII bytes:

„**f**x“ : where x is 0,1 or 2, sets the flow rate of the module to 60, 100, and 150 ml/min
„**p**“ : send parameter list
„**s**x“ : where x is 0 or 1, set speed of curve (Capnogram) transmission to 25 (1) or 50 (0) samples /sec
„**m**“ : set CO_2 unit to mmHg
„**v**“ : set CO_2 unit to vol%, values 0..800 == 0..8 vol %
„**z**“ : force zero calibration
„**5**“ : force 5 % calibration
„**n**x“ : set N_2O correction. X can be 0 to 8, which means 0 % to 80 %, in 10 % steps
„**o**x“ : set O_2 correction. X can be 2 to 10, which means 20 % to 100 %, in 10 % steps
„**i**“ : set FiO_2 calibration to 20.9 %. The sensor has to be placed in ambient air
„**t**x“ : where x can take any value from 0 to 0x0f
the bits in this byte control the sending of less important parameters:
bit 0 : if set to 1, send temperature of bench, if 0, don't send temp.
bit 1 : if set to 1, send capnogram, if set to 0, don't send capnogram.
bit 2 : if set to 1, send gas flow, if set to 0, don't send gas flow
bit 3 : internal, do not use, set to zero
bit 4..7: don't care

After power up, **all** parameters are sent. The user then can turn off the parameters he does not need by transmitting a „t“ command followed by a parameter whose lowest four bits control transmission of the described parameters. The most important parameters, end tidal CO_2, ambient pressure, and respiration rate, cannot be disabled.

Except for the capnogram, all values are sent once per second. The capnogram is sent with 50 or 25 values per second, according to the last „s“ command. Default is 50 values per second after power up.

Example : Sending „t“ „6“ (ASCII „6“ == 0x36), means bit 0 is „0“, bit 1 and 2 are „1“ and bit 3 is „0“

Send Capnogram, Flow, etCO_2, Respiration Rate and Pressure.

List and Codes of error messages

	0x00	reserved
FLASH_CHECKSUM	0x01	program flash checksum corrupted
BENCH_CHECKSUM	0x02	bench calibration eeprom corrupted
EEPROM_CHECKSUM	0x03	program EEPROM checksum corrupted
	0x04	reserved
EEPROM_DATA	0x05	the EEPROM's two mirrored data copies are not identical
LINE_OCCLUDED	0x06	sample line is occluded
	0x07	reserved
	0x08	reserved
	0x09	reserved
	0x0A	reserved
	0x0B	reserved
CAL_GAS_WRONG	0x0C	wrong calibration gas connected
CORR_GAS_WRONG	0x0D	N2O/O2 correction setting wrong
CAL_GAS_ZERO	0x0E	no calibration gas connected

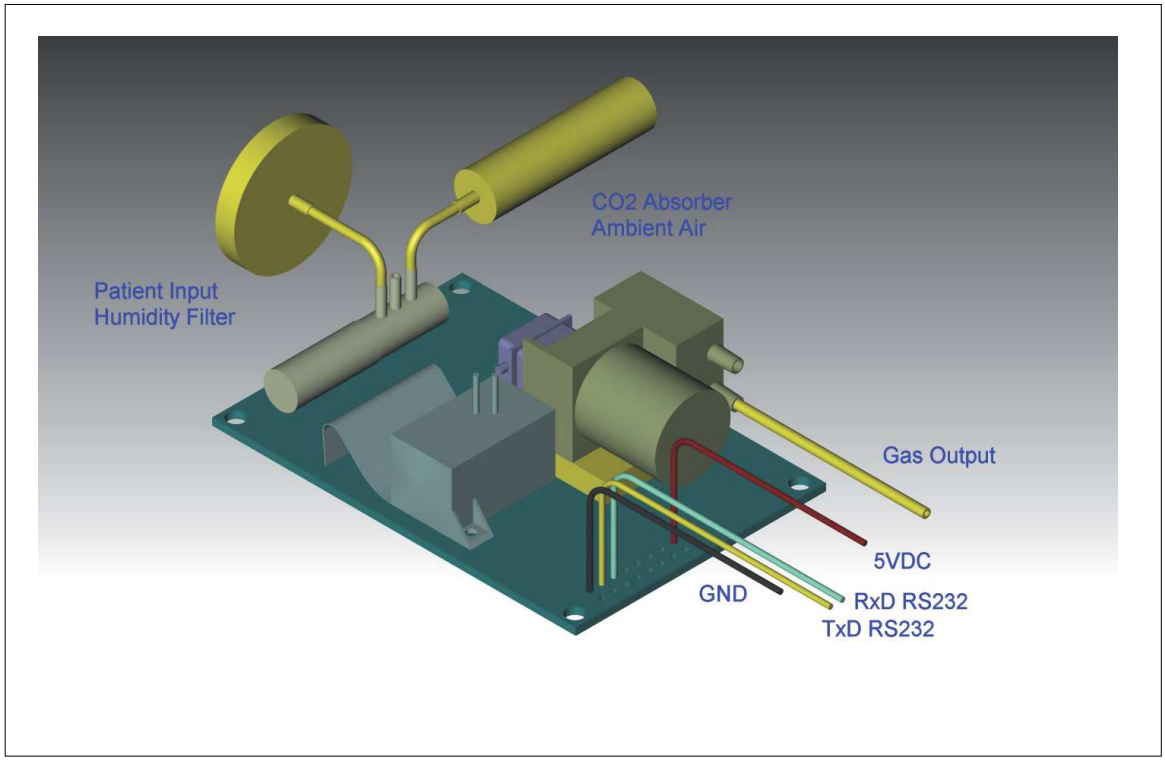
List and Codes of info messages

	0x00	reserved
ZERO_CORR	0x01	zero correction started
ZERO_CORR_END	0x02	zero correction ended
CAL_5_PER	0x03	5 % calibration started
CAL_5PER_END	0x04	5 % calibration ended
	0x05	reserved
FLASH_CHECKSUM_OK	0x06	program memory checksum ok
BENCH_CHECKSUM_OK	0x07	bench calibration EEPROM checksum ok
START_SAMPLING	0x08	gas sampling started
NO_FILTER	0x09	no filter connected to the input of the instrument
CORR_FACT_SET	0x0A	correction factor set *
GAIN_FACT_SET	0x0B	gain factor set *
INIT_PUMP_PWM	0x0C	init pump pwm *
	0x0D	reserved
	0x0E	reserved
	0x0F	reserved
FLOW_OFFSET	0x10	offset of flow sensor *
START_PROG	0x11	EG1200 startup message*
START_TRANS	0x12	transmission of measured value starts*
FIRST_INIT	0x13	unit powered up for the first time after reprogramming *
CAL_OK	0x1B	calibration successful

* should be ignored by user

Testkits

To ease the work of evaluating the unit, there is a complete, ready-to-run testkit availab-le: the kit comes with a PC software that reads and decodes the interface protocol of the module and displays these values on a PC. All relevant data which is transmitted in the protocol is displayed. Also a complete set of cables is included in this kit, together with a set of filters and sample lines.



Connection of the EG01200 to the PC

Usage:

Connect the serial cable to COM1 or COM2 of a computer. Only Ground, TxD and RxD are used in the interface. The voltage levels of the signals are ±5 volts.

- connect the other side of the cable to the PCB like shown in the drawing
- connect the sample line with the filter
- connect the 5 volt cable to the power supply
- turn on the power supply
- turn on PC

Start the program on the PC.

The software is written in VB6, and the source codes are included.

Regulatory considerations:

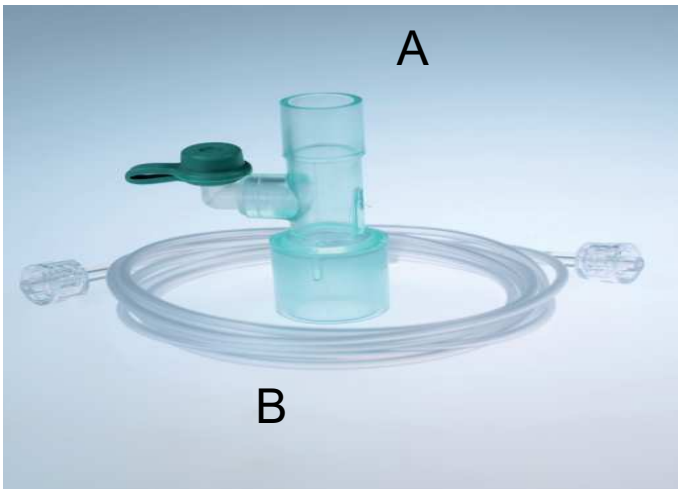
The module that is described in this document is not a final medical product. That means that it can not be used as a standalone unit to do measurements on a patient. Therefore, the OEM capnograph has not to be CE-marked. The customer has to undertake the procedure of CE-marking with the final product that he builds up with the PCB.

Second, the device is not FDA approved, which is also not possible for a module. Only final products that will be sold in the USA have to - and can - undertake the process of a 510K approval.

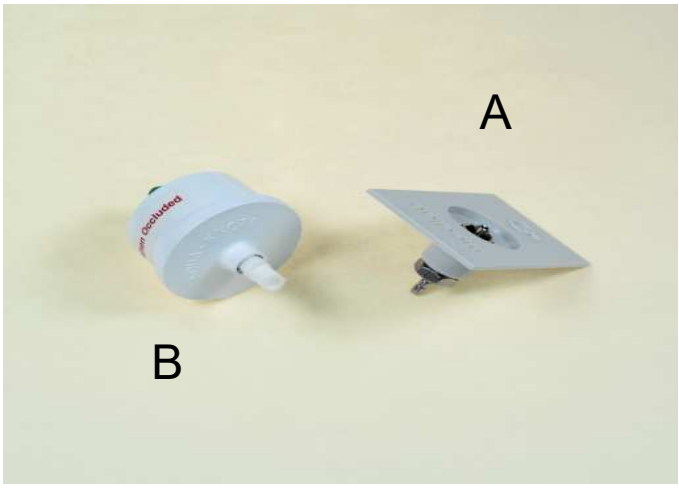
Appendix A

Available sample lines

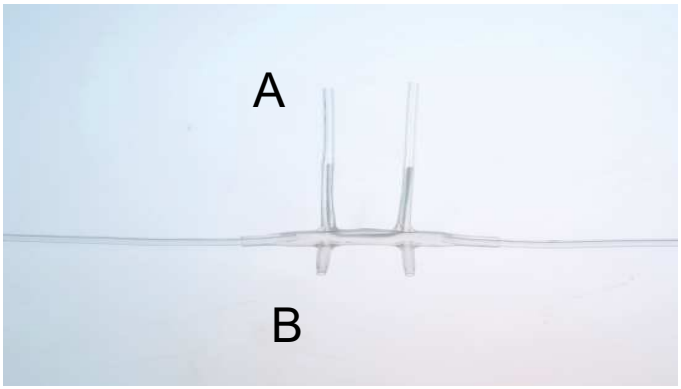
T-adapter (A) for intubated patients.Sample line (B) Connects to the breathing circuit. The monitor should be equipped with a filter system described below. Disposable.



Watertrap sytem. The right part (A) is integrated in the customer's monitor. The left part (B) is disposable and collects the moisture. Can be used for long-term monitoring.



This part can be used for non-intubated patients and collects gas from nostrils (A) and mouth (B). Disposable.



Appendix B

C Source Code Examples for Protocol 1

The following C source codes are intended to help integrate the Medlab OEM board into the customer's system. The data is received in a serial interrupt and the values are copied in a data queue that is processed during the main program. The example is part of the source code we used for writing our PC demo program and it is written in TurboC.

```
while(!((datum = getccb()) & 0x80));     /*wait for high bit set*/

  command = (datum / 8) & 0x0F;          /*prepare command byte */

  datum = 256*datum + getccb();          /*make data by read.next byte */
  if (datum & 0x0400)                    /* get bit number 7 */
       datum |= 0x80;                    /* put it to its original place*/
       datum &= 0x3FF;                   /* make ten bits max data */
       switch(command)                   /* decode command */
        {
         case  0: Etco2 = datum;         /* is etCo2 */
                  gotoxy(60,21);
                  printf("etCO2: %u.%u",Etco2/10,Etco2%10);
                  return 0;
                  break;
         case  1: Temp = datum;                /* is temperature */
                  gotoxy(60,18);
                  printf("Temp:  %02u",(Temp));
                  return 0;
                  break;
         case  2: Baro = datum;                /* is ambient pressure */
                  gotoxy(60,19);
                  printf("Druck: %04u",Baro);
                  return 0;
                  break;
         case  3: i=0;                         /* info message    */
                  for (i=0;i<25;i++)
                  {
                   string[i] = getccb();     /* save it       */
                   if (kbhit())
                   break;
                   if(string[i] == 0x0A)
                     {
                      string[i] = 0;
                      break;
                     }
                  }
         }
         getccb();.............
         ..............
         ...........
```

/ getccb() returns the next serial value from a queue that gets filled during the serial interrupt */*

Appendix C

Calibration

As each other single beam NDIR analyzer, the module has to be calibrated from time to time. Zero calibrations are performed regularly, without user interaction, by sampling ambient air through the second inlet of the valve on the board. The ambient air can be seen as having zero percent of CO_2 usually, since it passes a CO_2 absorber in front of the second inlet.

As a second point on the calibration curve, the 5% point of the bench has to be recalibrated regularly. We recommend recalibrating at least every 2000 hours of runtime of the module or every six months, whatever is reached first.

Calibration is very simple:

A reference gas containing 5 % CO_2 in synthetic air is connected to the normal input of the module. User issues a "5% calibration command". The module inserts an automatic zero calibration cycle, and, after that, a 5 % calibration cycle. After this cycle ends, the user is informed by a specific info message. For best results, the gas should not be introduced directly from the high pressure gas cylinder. It is better to fill an empty plastic bag with the gas and let the module sample the gas from that bag.

The constants calculated during this calibration cycle are stored in the internal EEPROM of the module and are secured by checksums and double storage of the data. During
power up, the module automatically tests these data fields and corrects any errors, as long as not both copies of the calibration data are corrupted.

History

Rev. 1.0:	Initial Version
Rev. 1.1:	Error and Info messages reorganized
Rev. 1.2:	Some technical data has been changed. Module accepts more commands Flow is transmitted addtionally Inspired CO_2 transmitted also
Rev. 1.3:	Corrected some typing errors
Rev. 1.4:	Added O_2 and N_2O correction commands
Rev. 1.41:	Minor graphical changes
Rev. 1.42:	Moved File Format to Pagemaker 7
Rev. 1.43:	Added FiO_2 commands
Rev. 1.44:	Change of company address
Rev. 1.45:	Changed filter description, graphical adjustments
Rev. 1.46:	Added new PCB drawings
Rev. 1.47:	Added description of info code CAL_OK
Rev. 1.48:	Corrected typing errors
Rev. 1.49:	Changed manufacturer address
Rev. 1.50:	Changed calibration procedure description, changed test kit drawing
Rev. 1.51:	Added gas output in picture on page14
Rev. 1.52:	Change of technical data
Rev. 1.53:	Added flow rate tolerances
Rev. 1.54:	Update list and codes of error and info messages
Rev. 1.55:	Corrected layout

Medlab medizinische Diagnosegeräte GmbH
Helmholtzstrasse 1a
76297 Stutensee
Germany
Tel.+49(0)7244741100
oemsales@medlab.eu
www.medlab.eu