Y-1950647

Multi Channel
Flow Ratio/Pressure Controller

Type 647C

Instruction Manual

MKS Instruments
Deutschland GmbH

Rev. 2012-06

Contents

1. General

1.1 The Multi Gas Controller (MGC) Type 647C

The 647C is designed to control Mass Flow Controllers (MFC) with complex requirements to the process. It allows different configurations.

- Various master/slave configurations within several groups of channels.
- External control of mass flow controllers.
- Regulation of the pressure with a constant gas flow ratio.

Warning 

The safety instructions in this document must be followed. Please, take also a special note of all highlighted text in this document.

1.2 CE conformity

The unit complies with the European standards and thus it is labeled with the CE-mark. To fullfill the above listed guidelines it is mandatory to use the appropriate interconnection cables.

Note 

The instrument complies to EN 61326-2-2 with the requirements for industrial applications. Braided shielded cables must be used.

We recommend to use the cables offered by MKS Instruments.

Cables which are in compliance with the CE guidelines are marked with an „E“ or „S“ (example: CB259E-... or CB259S-...).

1.3 Options

The available options are identified in the model code: 647C – X – Y – C – R
where:

Options	Designation
Channels (X):	
Four	4
Eight	8
Interface (Y):	
RS-232	R
Control Option (C):	
None	0
PID	1
Relay Option (R):	
None	N
Relays	T

1.4 Software

This user manual meets software version V3.0

1.5 Technical Specifications

channels for gas flow - max. number of channels - input voltage - output voltage - error range - temperature drift	 4 (optional 8) -0.5 ... 5.5 V -0.5 ... 5.5 V +/- 1 digit 0.075 % / °C (5)
pressure channel: - input voltage - output voltage - resolution - error range - temperature drift	max. 1 channel -0.5 ... 10 V -0.5 ... 5 V 16 bit +/- 3 digit 0.075 % / °C (5)
external setpoint	-0.5 ... 5.5 V
measuring rate output rate	20 Hz / channel 20 Hz / channel
operation temperature humidity	15 ... 40 °C < 70 % (3) (4)
Power supply: - voltage - fuse - frequency - consumed power power supply for sensors: - voltages - max. current per sensor - max. total current	 100 - 240 V T2 A, 250 V (slow blow) 50 - 60 Hz 200 W +/- 15 V; +/- 5 % 500 mA (1) 3,3 A (2)
Housing Rack depth (without connectors) Total depth with handles mounted Weight	19” x 3 HE 245 mm 285 mm 5,0 kg 4 channel 5.3 kg 8 channel

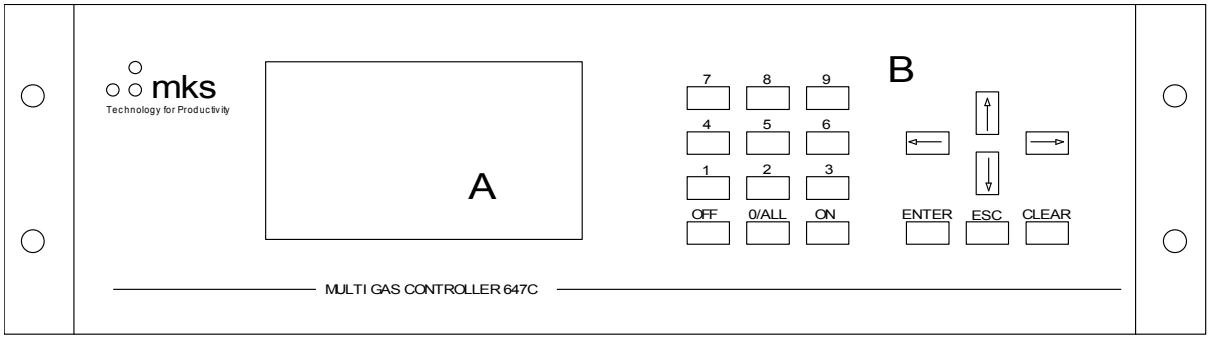
(1) Consider also the warm up period of the sensors.
(2) For all channels, i.e. gas flow and pressure
(3) Relative humidity within the specified temperature range.
(4) For use in closed heatable rooms, without condensation.
(5) of max. signal, within the range of operation temperature.

Fuses inside the instruments may only be replaced by service people from MKS Instruments.

Figure 1: Technical Specifications

1.6 Drawings

1.6.1 Front Panel

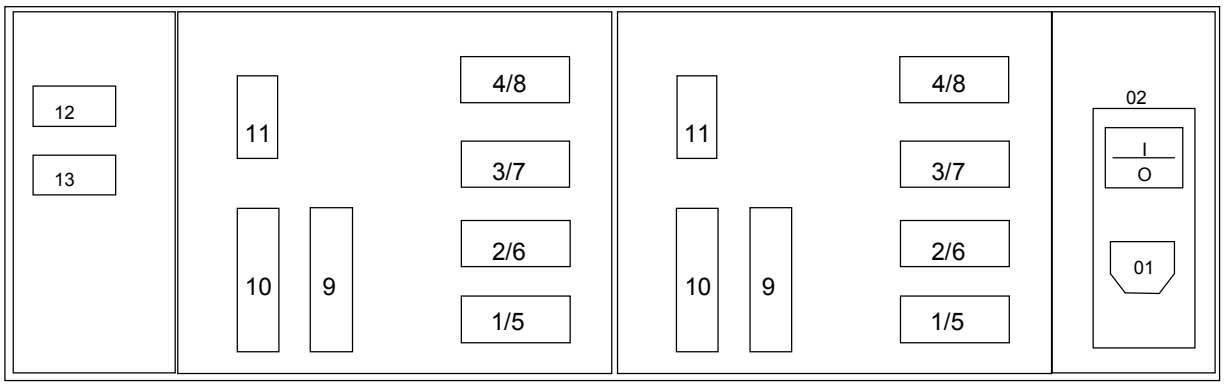


A = Monitor (LCD Display)

B = Keyboard

Figure 2: Front Panel

1.6.2 Rear Panel



Channel 5 to 8 Channel 1 to 4

01 = Power Supply Connector
02 = Power Switch

1/5 = Channel 1 or 5 for MFC
2/6 = Channel 2 or 6 for MFC
3/7 = Channel 3 or 7 for MFC
4/8 = Channel 4 or 8 for MFC

9 = Connector ACCESS
10 = Connector RELAY
11 = Connector PRESSURE
12 = Connector RS232
13 = Connector SERVICE (to be used only by MKS)

Figure 3: Rear Panel

1.7 Safety Information

1.7.1 Symbols Used in this Instruction Manual

Definitions of WARNING, CAUTION, and ATTENTION messages used throughout the manual.

Warning 

The WARNING sign denotes a hazard. It calls attention to a procedure, practice, condition, or the like, which, if not correctly performed or adhered to, could result in injury to personnel.

Caution 

The CAUTION sign denotes a hazard. It calls attention to an operating procedure, practice, or the like, which, if not correctly performed or adhered to, could result in damage to or destruction of all or part of the product.

Attention 

The NOTE sign denotes important information. It calls attention to a procedure, practice, condition, or the like, which is essential to highlight.

1.7.2 Safety Instructions

This device is state of the art and save. But danger may appear by the device, if not used according to the instructions or the professional knowledge.

Only spare parts of the manufacturer may be used for replacements.

The device must not be used in explosive environments.

Safety and reliability is only given in the following cases:

- the device is used according to the manual
- the device is serviced by personal of the manufacturer only.
- The installation of the device complies to the national directives and standards.

Cleaning of the device must performed, if it is disconnected from power supply and if the cleaning is performed dry.

Warning 

The device may be opened by MKS service personal only. If the device is open, danger for life (by high voltage) may occur.

Attention 

Please read this instruction carefully and follow it before using this device.

1.8 Installation

The device must be used in a dry and heated room (see ambient temperature).

The device produces heat due to the power consumption. In order to avoid overheating do not mount it close to other hot instruments or devices. Position the unit with proper clearance, to allow air cooling, so that the unit can operate within the product temperature specifications listed above. Keep the air inlet slots at the bottom of the housing free so that air can enter the instrument for cooling.

Attention  Check the line voltage to meet the specified power supply voltage of the 647C.

Follow the steps below. For installation of the device:

- Hook the device to the power plug. If you use a transformer, it must be able to supply 200 Watt.
- Hook the instruments to the device, according to the pinout of the connectors or use the appropriate cables.
- Switch the device on, and perform the setup in the menues INSTRUMENT SETUP and SYSTEM SETUP.
  If the digital interface is used (RS232), the setup in the SYSTEM SETUP menu is of special importance.

Powering On

Switch on the unit with the rear panel power switch: Press the side marked with “I” down. The LCD will be illuminated and after about 10 s the boot cycle is completed. During the booting some messages appear on the screen and finally the main menu will be displayed.

If you have problems booting the system, you should refer to the chapter “Reset of System” and “Applications of the 647C”.

Powering Off

Before switching off the instrument it is recommended to switch off all flow channels and (if necessary) the pressure control mode. Activate the menu (0) POWER OFF in the main menu. The ±15 V power supply to all channels will be switched off immediately and the display shows:

Please Wait ...

and a few seconds after:

Switch Power on with [ESC]

In the status line the message IDLE appears. The unit is now in a standby state and after about 30 s more the LCD backlight is switched off. All settings remain stored.

To switch the unit on again press the]ESC] key once or twice until the main menu appears. The ±15 V power supply voltage is switched on simultaneously, e.g. external devices will be powered again. All setpoint outputs are switched to –0.5 V to prevent any erratic gas flow or pressure control.

Caution 

When switching off the unit via the (0) POWER OFF menu/function the power supply to the flow devices and pressure transducer is de-activated. Consider that the units may need certain warm up time when being re-powered.

To switch off the instrument completely use the rear panel power switch (press side “0”). All settings remain stored and after switching power on again the setpoint outputs of all channels are pulled down to –0.5 V.

Note: Do not switch off the line power as long as the message “Please Wait” appears on the screen. If you do so all settings are completely reset. You would have to configure the unit again completely.

Note: The display is switched off automatically after the time out period as set in the menu SYSTEM SETUP, LCD ON TIME has passed. If you are not certain in which state the unit is with LCD being dark, you can first press the [ESC] key and use the line power switch only when you are sure that the unit was switched off completely.

1.9 Symbols at the case

The device may show some symbols, which are explained here:

- The “!” (⚠) says to watch the documentation/manual.
- The type label gives information about the device type, the serial number and some technical date.
- The label close to the fuse holder tells the specification of spare fuses: T2A, 250V.

1.10 Accessories

The 647C comes with the following accessories:

- Sub-D connector sets for the instruments:

  4 channel device: ZB-19
  8 channel deivce: ZB-20
- Power cable: Y-0984492
- Manual: Y-1957647
- 2*handles for the case: Y-5150011
- 4*screws for the handles: Y-1600005

1.11 Cables

Refer to the instruction manuals of the respective mass flow meters, mass flow controllers and pressure transducers for cable information. The cables listed for type 647A and 647B are the same as for the type 647C.

1.12 Service

In case of problems or failure of the device, please contact your local MKS representative. The last page of this manual contains a list of service and calibration centers.

Fuses

On units with serial number 104783G40 and up the fuses for the ± 15 V supply are accessible on the rear panel.

Type:	TR5-2A
MKS part number:	Y0250004

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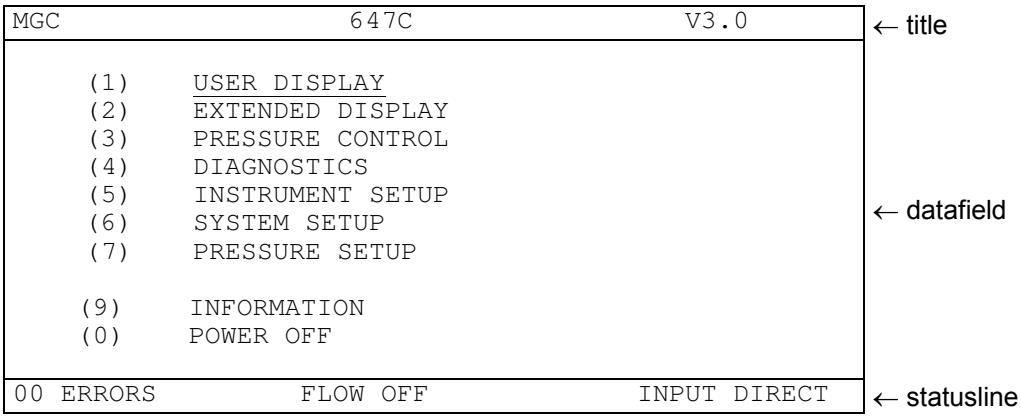
2. Operating Instructions

2.1 The User Interface

The device is operated via menus. A menu consists of submenus, input fields or display fields. Submenus can be reached by typing the number labeling them on the screen or selecting them with the cursor and typing ENTER. They can be exited pressing the <ESC> button. Input fields are highlighted by a cursor frame, when they are selected for input. Using the cursor keys different input fields can be selected (i.e. the cursor keys move the cursor on the screen). The input fields allow values to be edited or selected by scrolling up and down through a table. In some cases certain input fields are not active.

The top line of the screen (title) displays the device type (MGC = **M**ulti **G**as **C**ontroller) and software version. The status line on the bottom of the screen displays the number of errors, the status of the main valve and the input status of the keyboard (see also MAIN MENU).



(comment: the cursor is shown as underline in this document)

Figure 4

If errors occurred, detailed error descriptions are available through the menu ERROR LISTING, see page 16.

In order to turn off all gas flows at once there are the main valve functions. The main valve is switched on with the key combination <ON><ALL> and switched off with key combination <OFF><ALL>. The current state of the main valve is displayed as FLOW ON (open) and FLOW OFF (closed), respectively.

The state of the keyboard is displayed in the “INPUT” field of the status line.

DIRECT	= input from keyboard enabled
ON	= last input was <ON>
OFF	= last input was <OFF>
LOCKED	= The keyboard is locked through RS232
MEMORY	= A stored gas menu is active
IDLE	= No commands will be accepted

In the 8 channel version, it is not possible to display all channels simultaneously on the display. Therefore it is possible to scroll through the channels display horizontally.

2.2 The Menu Tree

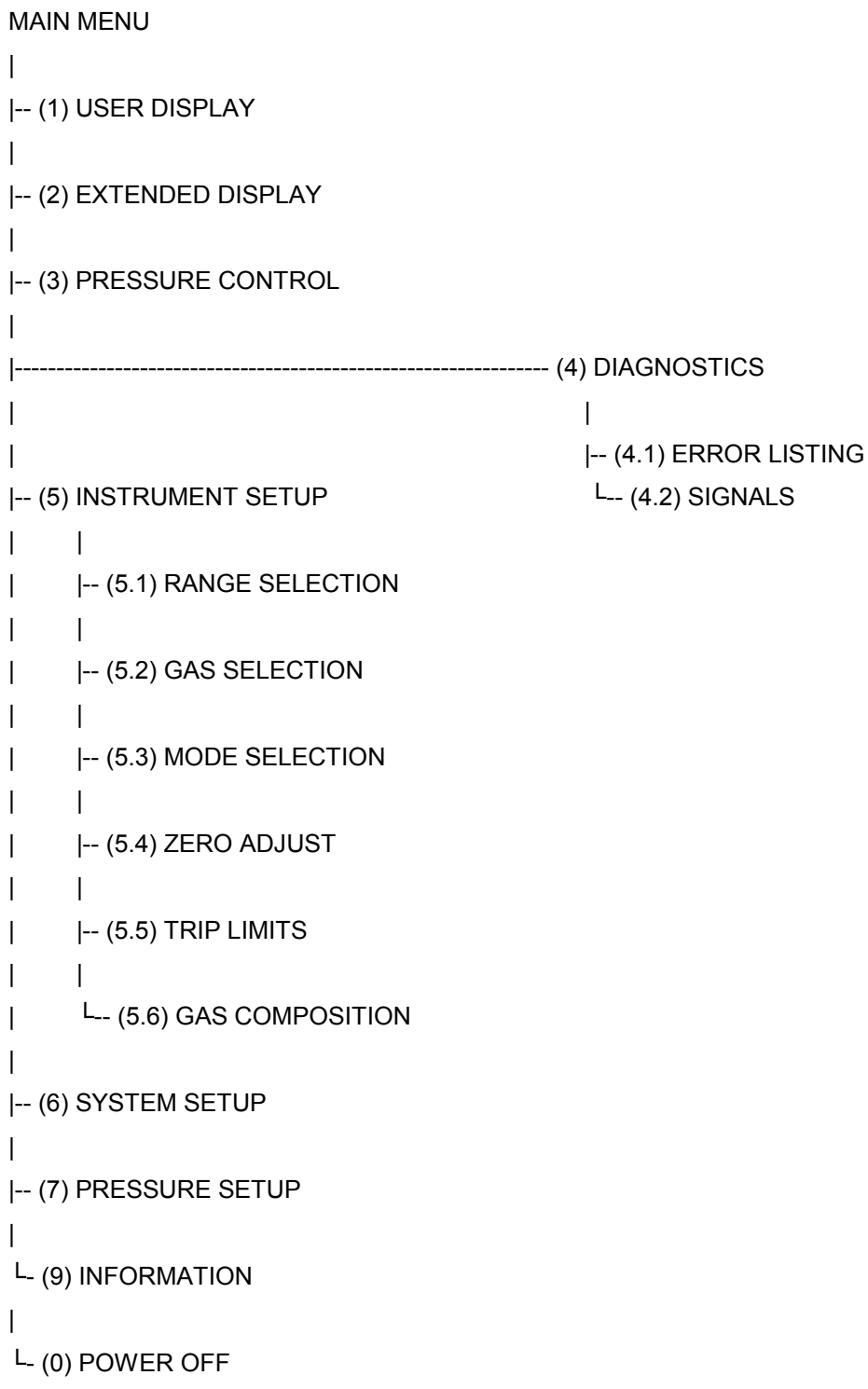


Figure 5

2.3 Reset of System

There are three types of Reset:

- Power Up Reset
- Hardware Reset
- Reset to Default

Attention  All of the above resets will switch off all gas flow controllers.

If the device refuses to come up on power on, press button <8> while switching the device on in order to perform a total reset (equal to First Start Reset). This problem can have 2 reasons:

- Data in memory was destroyed through a transient. The described procedure will fix this problem.
- There is an error in the hardware. If the Start Up problem occurs more than once contact your local MKS service center.

Power Up Reset is performed every time the system is switched on. It resets all data which are needed for system administration. Data of process parameters are not affected.

Hardware Reset is similar to Power Up Reset. It is triggered by the keys <OFF> and <cursor right> pressed at the same time. In any case Power Up or Hardware Reset leads to the MAIN MENU.

Reset to Default sets all process parameters to their default value. This reset is triggered in SYSTEM SETUP menu.

After the device has been turned off, one should wait for ca. 15 seconds before turning it on again.

2.4 Display adjustment

The viewing angle of the LCD display and the timeout setting of its back light saver, may be set in SYSTEM BACKUP menu.

3. Functionality

3.1 The MAIN MENU

After turning on the power switch (1) the MAIN MENU is displayed. From this menu the different submenus are accessible. (See also figure 4).

3.2 The USER DISPLAY menu

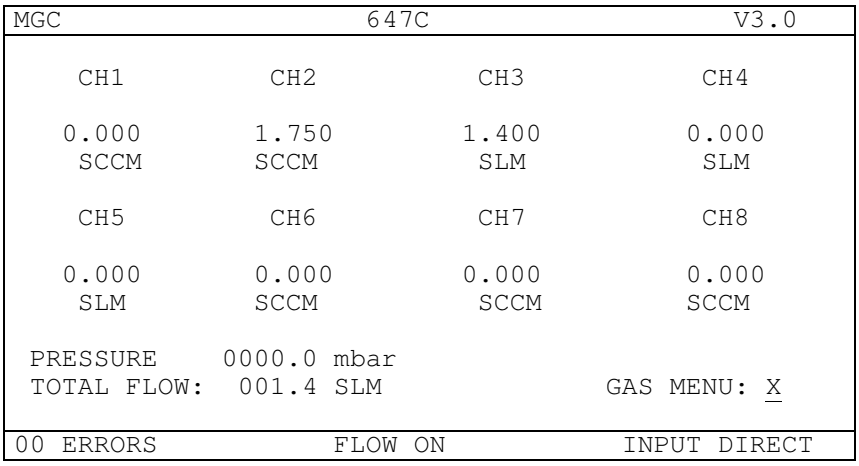


Figure 6

The USER DISPLAY menu allows monitoring the system during operation. It displays all gas flows of the connected Mass Flow Controllers.

All gas flow values are displayed in a 4 digit format without limiting the resolution. Additionally the physical unit of the gas flow is shown below. The sum of all gas flow values (TOTAL FLOW) is displayed additionally. The unit of the total flow can be selected through the keyboard.

The user can select one out of five predefined composition ratios (see also GAS COMPOSITION menu) through the GAS MENU parameter. The stored composition ratios are labeled with numbers 1 to 5. X means that none of the stored ratios is activated. In this case the setpoints for the mass flow controllers are the ones defined in EXTENDED DISPLAY.

The displayed value of TOTAL FLOW is the sum of all single gas flows. Because flow units of different decades (e.g. SCCM and SLM) are added, it might come to discrepancies between the two displays, which are due to rounding errors. Step through the flow units of the TOTAL FLOW, in order to optimize TOTAL FLOW display.

Since negative flow values are not added to TOTAL FLOW, channels which are turned off can not cause errors.

3.3 The EXTENDED DISPLAY menu

MGC	647C			V3.0
	CH1	CH2	CH3	CH4
ACT.FLOW	0.000	1.750	1.400	0.000
SETPOINT	4.500	1.750	1.400	0.728
UNIT	SCCM	SCCM	SLM	SLM
RANGE FS.	5.000	5.000	1.4000	1.450
GAS	USER	AIR	CO_2	He
MODE	INDEP.	INDEP.	INDEP.	SLAVE
STATUS	OFF	ON	ON	ON
PRESSURE	0000.0 mbar			
00 ERRORS	FLOW ON		INPUT DIRECT	

Figure 7

The EXTENDED DISPLAY menu allows controlling the system before and during operation. It contains the most important information needed to control the system.

Here the setpoints of all channels can be set and changed. The setpoints are selected by using the cursor keys. The input is done either numerically by typing in the values or by scrolling using the cursor keys. If MEMORY is displayed in the INPUT field of the status line, a predefined gas menu has been selected in the previously described USER DISPLAY menu. In this case the set points of the channels cannot be changed.

Due to instabilities at the lower end of MFC range, the lowest setpoint is limited to 1%. Setpoints less than that are displayed as zero and an output value of –0.5 V is transferred to the MFC.

The displayed full scale ranges (RANGE FS.) are the ranges of each controller scaled with the gas correction factors. E.g. channel 4 controls a MFC with a range of 1 slm, calibrated in nitrogen. The regulated gas is helium and has a correction factor of 1.450 with respect to the calibration gas nitrogen, i.e. the actual full scale range is: RANGE FS. = 1 * 1.45 = 1.45 slm.

The actual gas flow of each channel is displayed in the line ACT.FLOW. Here the correction factors and ranges of the selected gases are also automatically taken into account. Values higher than 110% are displayed as an overflow through dashes: “-.---“. The lowest displayed flow value is –10%. (See also Zero Adjust).

Typing <ON><x> turns on the valve of channel x and causes its set point to be sent to the mass flow controller. In addition to provide the possibility of turning on and off all controllers at the same time, there is the switch <ON/OFF><ALL>.

3.4 The PRESSURE CONTROL menu

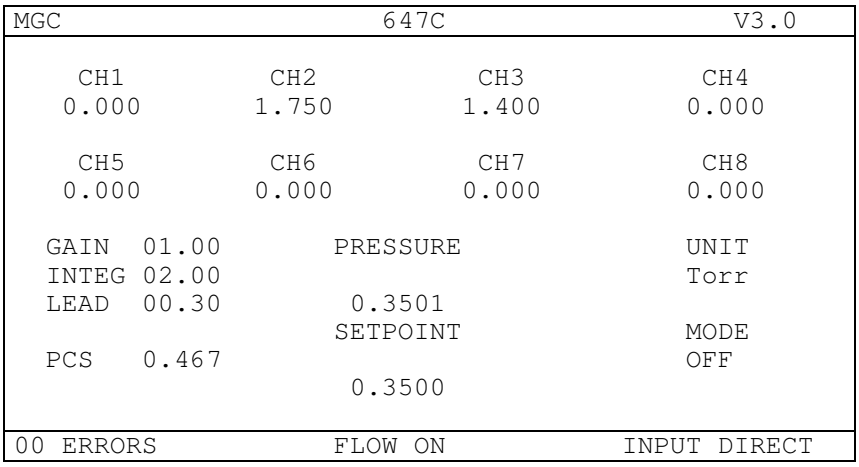


Figure 8

The PRESSURE CONTROL menu displays the actual flows and the actual pressure with its unit. During an application with an external pressure controller, the corrective action is also shown in PCS (**P**ressure **C**ontrol **S**ignal).

The pressure is controllable through the pressure setpoint and the two pressure modes:

OFF - set point for pressure regulation is turned off.

AUTO - set point for pressure regulation is turned on.

All parameters are edited as usual.

3.5 Tuning the PID Controller

There are three additional parameters to setup the PID algorithm, with the PID optional only.

The best procedure to tune the PID controller, is to make the step response of the application, evaluate the parameters dead time (Tt) and rise time (Ts) and then calculate the PID parameters.

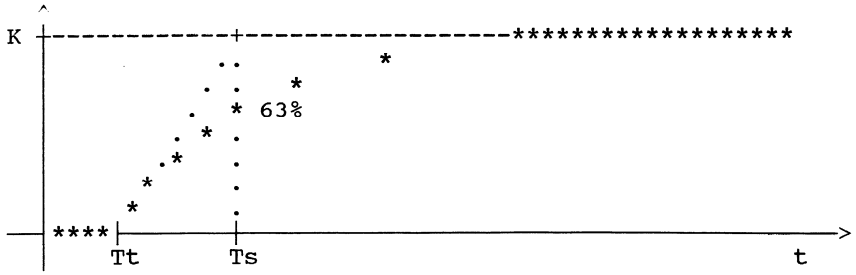


Figure 9

tuning for optimal step response:

- gain = 0.6 / K
- integral action = 1 * Ts
- lead = 0.5 * Tt

tuning for optimal disturbance response:

- gain = 0.95 / K
- integral action = 2.4 * Ts
- lead = 0.42 * Tt

K is the relation of actual pressure to actual total flow, both are to be taken as percent of full scale.

To improve the speed of your application, first increase the value of the gain parameter, then change the integral action.

If you cannot record a step response of your process, it is also possible to estimate the necessary values. Measure the time between the opening of the valves and the beginning change of the actual pressure as Tt. Then measure the time until pressure has gained 63% of the final pressure value.

Configuration of an Application (see next page):

Typical Configuration:

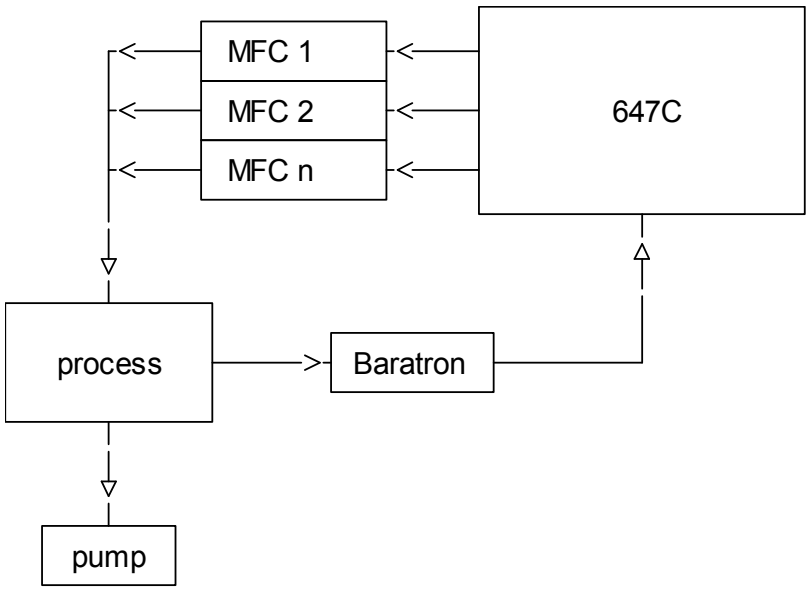


Figure 10

Configuration of a typical system with three flow controllers (MFC) plus pressure control with a Baratron capacitance manometer. No extra pressure control unit is required. The gas flow rates are kept at a constant ratio.

3.6 Diagnosis of System

3.6.1 The ERROR LISTING menu

If the status line indicates the occurrence of errors, details about these errors and the affected channels can be retrieved from the ERROR LISTING menu.

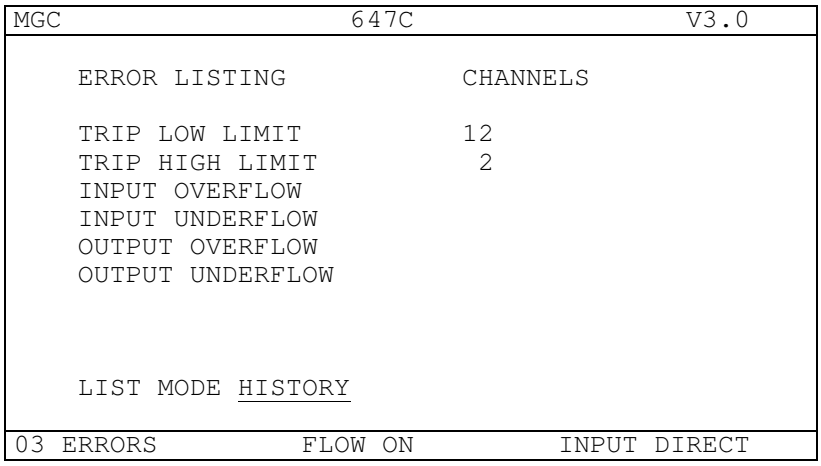


Figure 11

Error messages:

- TRIP LOW LIMIT
  The actual flow is lower than the low limit. (see also TRIP LIMITS menu, page 22)
- TRIP HIGH LIMIT
  The actual flow is higher than the high limit. (see also TRIP LIMITS menu, page 22)
- INPUT OVERFLOW / INPUT UNDERFLOW
  The input signal of the displayed channel is higher than 10V or lower than –10V.
- OUTPUT OVERFLOW / OUTPUT UNDERFLOW
  The output signal is higher than 10 V or lower than –10V.
  Since the calculated value cannot be transmitted to the controller, this can disturb the regulation behavior of closed loops.

Two display modes are possible in ERROR LISTING. The HISTORY mode stores all errors having occurred until leaving the error listing. In the ACTUAL mode only actual valid errors are displayed.

3.6.2 The SIGNALS menu

```
MGC                    647C                    V3.0

          OUTPUT     INPUT     EXTERN
CH1       -00250     -0250     -0250
CH2       001746     01746     01746
CH3       005002     05002     05002
CH4       -00500     -0500     -0500
CH5       -00500     -0500     -0500
CH6       -00500     -0500     -0500
CH7       -00500     -0500     -0500
CH8       -00500     -0500     -0500
PRES      -00250     -0015
PCS                  -0250

SIGNAL PROCESSING RUNNING

00 ERRORS          FLOW ON          INPUT DIRECT
```

Figure 12

Attention  When stopping signal processing the process is also stopped.

This menu is designed for test and maintenance purposes only. It displays all signals of the interface to the process. The display unit is mV. It is possible to enter setpoints in mV directly, if the signal processing is stopped. If you leave the signals menu then signal processing is restarted. This avoids problems concerning general 647C usage.

3.7 Instrument Setup

```
MGC                    647C                    V3.0

     (1)   RANGE SELECTION
     (2)   GAS SELECTION
     (3)   MODE SELECTION
     (4)   ZERO ADJUST
     (5)   TRIP LIMITS
     (6)   GAS COMPOSITION

00 ERRORS          FLOW ON          INPUT DIRECT
```

Figure 13

The instrument setup contains all parameters which are related to the process.

3.7.1 Range Selection

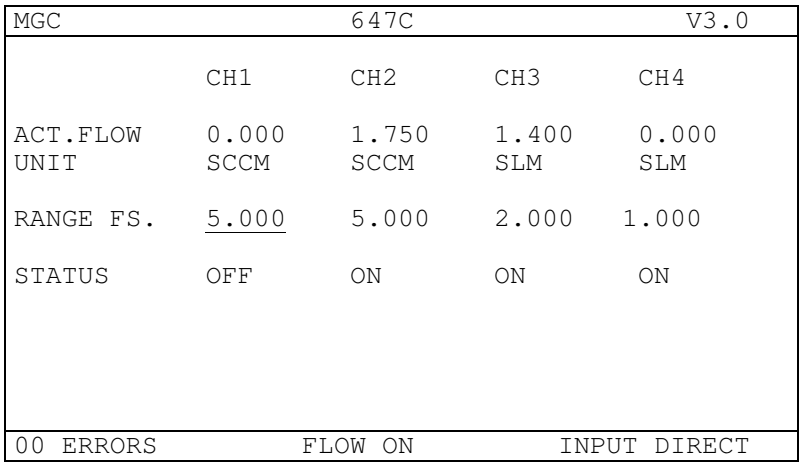


Figure 14

The following ranges are available:

1 sccm,	2 sccm,	5 sccm,		
10 sccm,	20 sccm,	50 sccm,		
100 sccm,	200 sccm,	500 sccm,		
1 slm,	2 slm,	5 slm,		
10 slm,	20 slm,	30 slm,	50 slm,	
100 slm,	200 slm,	300 slm,	400 slm,	500slm,
1 scmm,				
1 scfh,	2 scfh,	5 scfh,		
10 scfh,	20 scfh,	50 scfh,		
100 scfh,	200 scfh,	500 scfh,		
1 scfm,	2 scfm,	5 scfm,		
10 scfm,	20 scfm,	50 scfm,		
100 scfm,	200 scfm,	500 scfm,		

sccm = standard cubic centimeter per minute
slm = standard cubic liter per minute
scmm = standard cubic meter per minute
scfh = standard cubic feet per hour
scfm = standard cubic feet per minute

3.7.2 Gas Selection

MGC		647C		V3.0
	CH1	CH2	CH3	CH4
ACT.FLOW	0.000	1.750	1.400	0.000
UNIT	SCCM	SCCM	SLM	SLM
GAS	USER	AIR	CO_2	He
FACTOR	1.000	1.000	0.700	1.450
STATUS	OFF	ON	ON	ON
00 ERRORS		FLOW ON		INPUT DIRECT

Figure 15

This menu contains the table of Gas Correction Factors (GCF) for mass flow controllers, which are calibrated in nitrogen under standard conditions (DIN 1871). In this case standard pressure means 1013 mbar and standard temperature is 0 degree centigrade.

The cursor keys (UP/DOWN) are used to scroll through the table entries of each channel.

For gases which are not included in the table, there is the position USER, which allows a direct numerical input of the GCF of any gas. For a description how to calculate GCF see the manual of the mass flow controllers. A direct numerical input of the GCF is also allowed for the gases helium and hydrogen, which are normally calibrated directly with these gases.

The 647C automatically calculates the actual range of each mass flow controller (RANGE FS.) from the product GCF x RANGE. E.g. for a flow controller, which is calibrated in 1 slm nitrogen, at a correction factor of 0.72 (methane) the actual flow range (RANGE FS.) displayed in EXTENDED DISPLAY menu is 0.720 slm.

3.7.3 Mode Selection

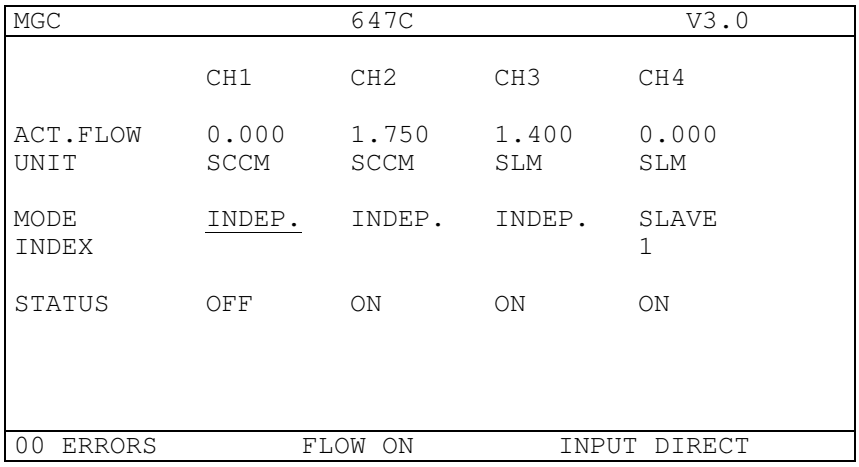


Figure 16

The Mode Selection defines the source of setpoint for each MFC channel. Possible modes are:

- INDEP = independent
- SLAVE = dependent to the actual flow of another channel
- EXTERN = external source for setpoint
- PCS = external controller
- PID = built in PID controller
- TEST = test for maintenance and installation

3.7.3.1 Independent Mode

In the independent mode a MFC is driven by the entered setpoint which is constant.

3.7.3.2 Slave Mode

In the Master/Slave configuration the ratio between the setpoints of the slaves and the setpoint of the master is kept at the selected ratio of gas composition. If the setpoint of the master is changed, the 647C also changes the setpoints for the slaves according to this ratio. Additionally in this mode the master channel governs the gas flows of the slave channels. I.e. the setpoints for the slave channels are calculated from the ACTUAL FLOW of the master channel according to the desired composition ratio and transmitted to the controllers, instead of the setpoints displayed on the screen. If, for instance, the gas flow of the master decreases because of a fault in the process, the gas flows of the slaves are also brought down, as can be seen from the ACT.FLOW display. If the gas flow of a slave is disturbed, however, the composition ratio for this channel is incorrect.

E.g. a ratio of 5:1 (master:slave) means:

Setpoint of slave = act. flow of master * 0.2

The master channel is determined by the index which is associated with the slave channel. The advantages hereby are that the master remains free for declaration in other modes and more than one master is possible. With this declaration technique, however, useless circular reference chains, which might even be dangerous for the application, could appear. In order to avoid this, the software checks out each input and rejects it if necessary. Therefore, this solution offers full advantages without risks.

Example 1: (menu extract)

	CH1	CH2	CH3	CH4
MODE	INDEP.	SLAVE	SLAVE	INDEP.
INDEX		1	2	

In this example channel 1 is master of channel 2, which is master of channel 3. This is an open reference chain. The index number of a slave indicates its master channel. This declaration technique applicated to channel 2 as master has the advantage, that this channel may be declared as slave while being a master. Channel 4 is independent.

Example 2: (menu extract)

	CH1	CH2	CH3	CH4
MODE	SLAVE	SLAVE	SLAVE	INDEP.
INDEX	3	1	2	

This example shows a circular reference chain, which will never appear on 647C screen. The software prevents its appearance by consequently rejecting wrong input. This is the reason why some of the user's input might be rejected.

3.7.3.3 External Mode

This mode enables external control of the MFCs through the auxiliary connector. The MFC's setpoint is calculated as the product of setpoint in menu EXTENDED MENU and the signal at the auxiliary input. E.g.

Setpoint of MFC = setpoint in EXTENDED MENU * auxiliary input / 5 V

3.7.3.4 PCS Mode

In the PRESSURE CONTROL mode (PCS) the 647C serves as the regulating unit for a pressure controller (e.g. type 250). All gas flow channels which are configured in the PCS mode are regulated through the pressure control signal (PCS) according to the ratio of their set points.

3.7.3.5 PID Mode

In this mode MFCs are driven by a PID algorithm (see also menu: PRESSURE CONTROL). This mode is only available with the PID option.

3.7.3.6 Test Mode

In this mode the 647C generates a test signal, which may be useful for installation procedures. The test signal is a saw tooth between zero and 100% with a period of 4 sec.

3.7.4 Zero Adjustment

```
MGC                    647C                    V3.0

             CH1       CH2       CH3       CH4

ACT.FLOW     0.000     1.750     1.400     0.000
UNIT         SCCM      SCCM      SLM       SLM

ZERO VALUE   0.005     -.004     0.002     -.002
ZERO ADJUST  EXEC      EXEC      EXEC      EXEC

STATUS       OFF       ON        ON        ON




00 ERRORS          FLOW ON          INPUT DIRECT
```

Figure 17

To trigger the Auto Zero function, the status needs to be changed from EXEC (executable) to ACT (active) through the cursor keys. The status DONE or FAIL displays the completition of the function. The status FAIL indicates that the offset was too large and a new zero value was not generated. FAIL status may also appear if the channel is switched on. The status ACT appears on the screen for a very short time, so that it is usually not noticed.

The measured value (the zero offset of the sensor of the mass flow controller) is displayed in the field ZERO VALUE. In order to correct the zero offset, this value is subtracted from actual flow and added to the setpoint output. This way the controller gets a corrected setpoint and thus equalizing the sensor signal's error.

If necessary, one can enter the zero offset directly.

3.7.5 Trip Limit Supervision

```
MGC                    647C                    V3.0

             CH1       CH2       CH3       CH4

ACT.FLOW     0.000     1.750     1.400     0.000
UNIT         SCCM      SCCM      SLM       SLM

MIN.LIMIT    3.000     0.750     0.000     0.000
MAX.LIMIT    4.000     0.250     1.400     1.450
SUPERVIS.    LIMIT     BAND      SLEEP     SLEEP

STATUS       OFF       ON        ON        ON




00 ERRORS          FLOW ON          INPUT DIRECT
```

Figure 18

There are three modes to supervise the process gas flows.

- SLEEP mode
- LIMIT mode
- BAND mode

In SLEEP mode no supervision is performed. In LIMIT mode the actual flow is supervised to remain between the trip limits. If the actual flow exceeds the high limit or falls below the low limit an error will be generated. The limits are considered as absolute values. The BAND mode is similar to LIMIT mode, but the limits are considered as deviation to the setpoint. The low limit represents negative deviation.

The supervision becomes active 1 second after the selection of a mode.

Two relays are driven by each channel, if the Relay Option is used. The logic of the relays depends on the actual Supervision Mode:

- SLEEP mode
  In this mode relay 1 represents the status of the channel's valve. Relay 2 is idle.
- BAND mode
  In this mode relay 1 also represents the status of the channel's valve. Relay 2, however, will become active if the actual flow is outside of the defined band.
- LIMIT mode
  If the actual flow is below low limit, relay 1 will become active, and if it is above high limit relay 2 will become active.

Truth Table:

Mode	Relay #	Valve	Low limit	High limit	Relay status
SLEEP	1	OFF	X	X	inactive
SLEEP	1	ON	X	X	active
SLEEP	2	X	X	X	inactive
BAND	1	OFF	X	X	inactive
BAND	1	ON	X	X	active
BAND	2	X	not exceeded	not exceeded	inactive
BAND	2	X	X	exceeded	active
BAND	2	X	exceeded	X	active
LIMIT	1	X	not exceeded	X	inactive
LIMIT	1	X	exceeded	X	active
LIMIT	2	X	X	not exceeded	inactive
LIMIT	2	X	X	exceeded	active

X = any condition

Figure 19

3.7.6 Gas Composition

```
MGC                    647C                    V3.0

             CH1       CH2       CH3       CH4

SET 1        1.000     1.700     0.000     0.000
SET 2        1.010     1.750     0.000     0.000
SET 3        1.020     1.800     0.000     0.000
SET 4        1.040     1.850     0.000     0.000
SET 5        0.000     0.000     0.000     0.000

UNIT         SCCM      SCCM      SLM       SLM

STATUS       OFF       ON        ON        ON


00 ERRORS            FLOW ON            INPUT DIRECT
```

Figure 20

Up to 5 different gas compositions (SET 1 to SET 5) can be defined here, which can be selected in the menu USER DISPLAY through the item GAS MENU.

3.8 System Setup

3.8.1 RS232 Setup

```
MGC                    647C                    V3.0

   BAUDRATE                    9600
   PARITY                      ODD
   BITS                        8 bit
   STOPBITS                    1 bit
   HANDSHAKE                   NONE
   RS232 STATUS                -- -- --

   LCD VIEW ANGLE [°]          023
   LCD ON TIME [min]           010
   HOST MODE                   C-MODE
   RESET                       EXEC

00 ERRORS          FLOW OFF          INPUT DIRECT
```

Figure 21

The 647C implements a standard V24, RS232 interface with standard parameters.

3.8.1.1 Baudrate

The baudrate defines the transfer speed of characters on the line. The transfer rate of commands and data is determined by this baudrate and by the processing speed of 647C. The first 30 commands will be directed to a buffer at maximum speed, while the transfer of further commands is controlled by a handshake protocol. The baudrate must fit to the baudrate of the host computer.

- supported baud rates:
  50, 75, 110, 150, 300, 600, 1200,
  1800, 2000, 2400, 3600, 4800, 7200, 9600 Baud

3.8.1.2 Data Link Parameters

The data link parameters must fit to setup of the host computer. Change it according to the setup of the host.

- word length
  7 bit
  8 bit
- parity
  NONE
  EVEN
  ODD

stop bits
1 bit
2 bit

3.8.1.3 Handshake Protocol

The handshake protocol synchronizes different processing speeds of 647C and host computer. If the receiving device is busy with calculating and therefore not ready to accept more date it stops the transfer through a handshake protocol. The 647C can accept 30 commands at maximum speed until it stops the transfer.

There are three kinds of handshake modes for the communication with the host computer:

- no handshake
- software handshake (XON, XOFF)
- hardware handshake (RTS, CTS)

The usage of one of the above modes depends on the connection to the computer. If the communication is run without handshake and the calculating speed do not match, loss of data may appear.

3.8.1.4 Interface Connections

When the 647C software is booting (e.g. at power on or hardware reset) it detects the handshake mode through the cable type on the RS232 line. This mode is displayed in the menu.

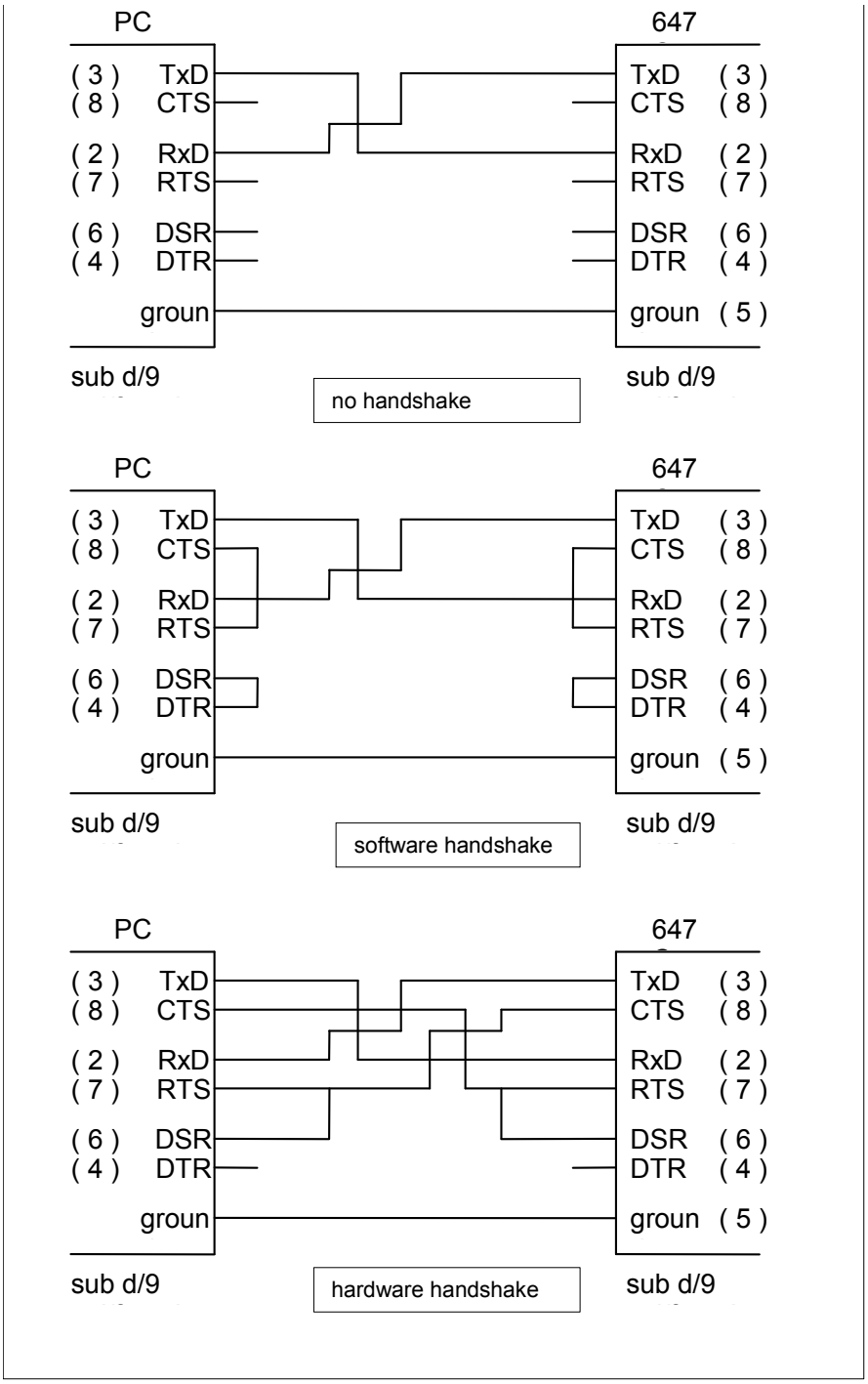


Figure 22

A typical error in handling the RS232 line is to plug in the cable, after having switched the device on before. As a result, the 647C works with no handshake although the host computer expects a handshaking. At installation time it may be helpful to check the actual handshake mode.

3.8.1.5 RS232 Line Status

In order to make the debugging of a RS232 installation easier, a status display is inserted in the SYSTEM SETUP menu. The so called RS232 STATUS display three events on the RS232 line:

- OE: overrun error: (bytes were lost)
  Bytes were lost on the input line of 647C. This is typical if the handshake protocol does not work. Check for the correct connection on the line and for fitting handshake protocols.
- PE: parity error: (the parity check failed)
  A byte was transferred with a parity error. This is typical for noise on the line. Check the ground line.
- FE: framing error: (recognition of stopbit failed)
  Synchronization of bytes did not work (i.e. stop bit was not present). This is typical for noise on the line. Check the ground line.
- "- -": "two dashes"
  no error occurred

3.8.1.6 Example

The following examples show the usage of a 647C through the RS232 interface. The examples are given in Power BASIC.

Program to display the act. flow of channel 1:

```
10   OPEN "COM2: 9600, 0, 8, 1" AS #1
20   PRINT #10, "ID"
30   INPUT #10, A$
40   PRINT A$
50   PRINT #10, "FS 1 0500"
60   PRINT #10, "ON 1"
70   PRINT #10, "ON 0"
80   PRINT #10, "FL 1"
90   INPUT #10, A$
100  PRINT A$
110  GOTO  80
120  END
```

3.8.2 System Parameters

For description of the parameter HOST MODE see chapter "Remote Control", page 30.

For the description of RESET function in SYSTEM SETUP menu, see the chapter "Reset of System", page 9.

3.9 Pressure Setup

```
MGC                    647C                    V3.0


   PRESSURE                    0.0000

   RANGE FS.                   1.0000 Torr
   ZERO VALUE                  0.001
   ZERO ADJUST                 EXEC

   CONTROLLER                  STD

   GAIN                        01.00
   INTEG.ACT.[s]               02.00
   LEAD [s]                    00.30


00 ERRORS          FLOW OFF          INPUT DIRECT
```

Figure 23

The 647C supports several pressure ranges listed below (5 digits)[1]:

1, 2, 5, 10, 20, 50, 100, 200, 500, 1000, 2000, 5000	mTorr
1, 2, 5, 10, 20, 50, 100, 200, 500, 1000, 2000, 5000	Torr
1, 2, 5, 10, 20, 50, 100	kTorr
1, 2, 5, 10, 20, 50, 100, 200, 500, 1000, 2000, 5000	µBar
1, 2, 5, 10, 20, 50, 100, 200, 500, 1000, 2000, 5000	mBar
1, 2, 5, 10, 20, 50, 100	Bar
1, 2, 5, 10, 20, 50, 100, 200, 500	Pa
1, 2, 5, 10, 20, 50, 100, 200, 500, 1000, 2000, 5000	kPa
1, 2, 5, 10	MPa

The zero adjust works similar to that of an MFC channel (see chapter “Zero Adjust”, page 20).

Different external pressure controllers such as 250, 152, 153, 652 or 146 type may be used. The setup must show the applicated controller type. (652 is valid also for 651 controller).

For the parameters of the PID controller see chapter Pressure Control, page 13.

[1] The pressure ranges are programmed in a different order. See therefore the RS232 code page 37/38.

3.10 Information about the System

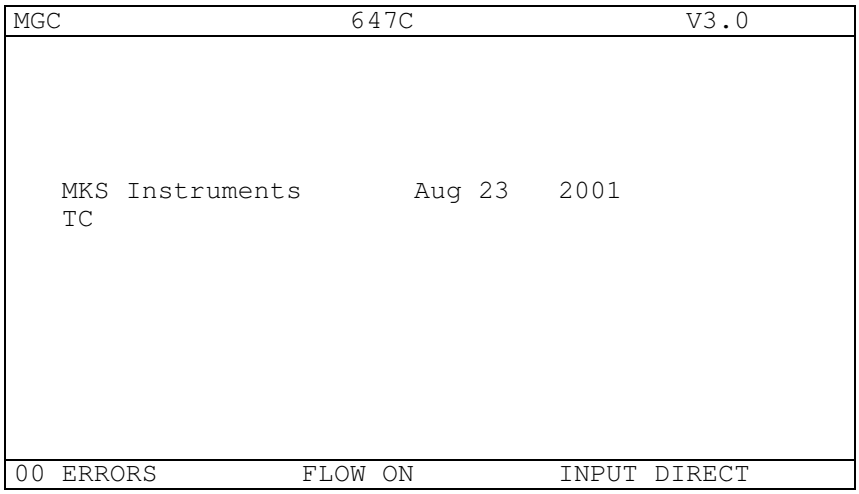


Figure 24

This menu gives information about the device such as:

- company
- software release code
- internal code

If you call MKS for support in case of problems, please be prepared to give this information to MKS.

4. Remote Control

4.1 Compatibility

647B

The 647C uses the same software as its predecessor 647B, except the menu POWER OFF (and some internal functions) but is incorporated in a more compact housing with improved shielding properties. Also the RS232 communication is fully compatible.

147C

The 647C as well as the 647B offers more functionality than the 147B, which leads to some incompatible constructs in the remote control syntax. To avoid this incompatibility, the 647C distinguishes two host modes:

- C-MODE offers actual 647C (and B) commands
- B-MODE offers 147B commands

In B-MODE the device is compatible with 147B, so it is possible to use old configuration software without any changes. The full 647C functionality is only available in C-MODE.

In the beginning the C-MODE will be initialized and the device will act like an actual 647C. If a 147B command is used, the 647C will switch to B-MODE (e.g.: MO c 1, PL 1 3). It is also possible to switch to B-MODE through menu SYSTEM SETUP and vice versa.

For setup see section System Parameters, page 32.

4.2 Command Syntax

In general all commands are transmitted in ASCII format. Each command string must be terminated by a carriage return and there is no discrimination between upper and lower case letters. In order to improve readability, blanks (20 hex) may be included as delimiters between command, channel number and command parameters, however, this is not necessary. All parameters can be read by the host. For this purpose a “R” (for “Request”) is transmitted instead of the command parameter.

Cmd cn {R | p1 [p2] [p3]} <cr> [<nl>]

Cmd	= command, 2 bytes (see table of commands)
Cn	= channel number (1 – 4/8)
P1, p2, p3	= parameters, numerical input is always in decimal ASCII format
R	= request of the parameters
<cr>	= carriage return (0D hex) for terination
<nl>	= new line (0A hex) optional

4.3 Table of Commands

```
GM s              Select gas menu
  s = 0             gas menu X, normal setpoints are used
  s = 1..5          gas menu 1-5
GM R              check for gas menu, result: s

FS c xxxx         enter setpoint of a channel
  c = 1..8          channel
  x = 0..1100       setpoint in 0.1 percent of full scale
FS c R            check for setpoint, result: xxxxx

FL c              check for actual flow of a channel, result: xxxxx

  c = 1..8          channel
  x = 0..1100       actual flow in 0.1 percent of full scale

PS xxxx           enter pressure setpoint
  x = 0..1100       setpoint in 0.1 percent of full scale
PS R              check for pressure setpoint, result: xxxxx

PR                check for pressure, result: xxxxx
  x = 0..1100       actual pressure in 0.1 percent of full scale

PC                check for PCS, result: xxxxx
  x = 0..1100       actual PCS signal in 0.1 percent of full scale

PM m              enter pressure mode
  m = 0             mode = off
  m = 1             mode = auto
PM R              check for pressure mode, result: m

RA c rr           enter range
  c = 1..8          channel
  r = 0..39         range code:
                         0 = 1.000 SCCM,    20 = 1.000 SCFH
                         1 = 2.000 SCCM,    21 = 2.000 SCFH
                         2 = 5.000 SCCM,    22 = 5.000 SCFH
                         3 = 10.00 SCCM,    23 = 10.00 SCFH
                         4 = 20.00 SCCM,    24 = 20.00 SCFH
                         5 = 50.00 SCCM,    25 = 50.00 SCFH
                         6 = 100.0 SCCM,    26 = 100.0 SCFH
                         7 = 200.0 SCCM,    27 = 200.0 SCFH
                         8 = 500.0 SCCM,    28 = 500.0 SCFH
                         9 = 1.000 SLM,     29 = 1.000 SCFM
                        10 = 2.000 SLM,     30 = 2.000 SCFM
                        11 = 5.000 SLM,     31 = 5.000 SCFM
                        12 = 10.00 SLM,     32 = 10.00 SCFM
                        13 = 20.00 SLM,     33 = 20.00 SCFM
                        14 = 50.00 SLM,     34 = 50.00 SCFM
                        15 = 100.0 SLM,     35 = 100.0 SCFM
                        16 = 200.0 SLM,     36 = 200.0 SCFM
                        17 = 400.0 SLM,     37 = 500.0 SCFM
                        18 = 500.0 SLM,     38 = 30.00 SLM
                        19 = 1.000 SCMM,    39 = 300.0 SLM

RA c R               check for range, result: rr


GC c fff          enter gas correction factor
  c = 1..8          channel
```

```
  f = 10.180        factor in percent
GC c R              check for gas correction factor, result: fffff

MO c m [i]          enter mode
  c = 1..8            channel
  m = 0               mode = independent
  m = 1               mode = slave
  m = 2               mode = extern
  m = 3               mode = PCS
  m = 9               mode = test
  i = 1..8            modeindex, reference to master
                        (only if m equal 1)
MO c R              check for mode, result: m [i]

AZ c                zero adjust MFC, result: xxxxx
  c = 1..8            channel
  x = -500..500       offset value in mV
  x = "E5"            error occurred

HL c xxxx           enter high limit
  c = 1..8            channel
  x = 0..1100         high limit in 0.1 percent of full scale
HL c R              check for high limit, result: xxxxx

LL c xxxx           enter low limit
  c = 1..8            channel
  x = 0.1100          low limit in 0.1 percent of full scale
LL c R              check for low limit, result: xxxxx

TM c m              enter mode for trip limits
  c = 1..8            channel
  m = 0               mode = SLEEP
  m = 1               mode = LIMIT
  m = 2               mode = BAND
TM c R              check for trip limit mode, result: m

GP c s xxxx         enter setpoint in a gas set
  c = 1..8            channel
  s = 1..5            gas set 1 to 5
  x = 0..1100         setpoint in 0.1 percent of full scale
GP c s R            check for setpoint in gas set, result: xxxxx

PZ                  zero adjust pressure, result: xxxxx
  x = -500..500       offset value in mV
  x = "E5"            error occurred

GT c                pressure controller
  c = 0..5            controller code
                         0 = STD (i.e. standard)
                         1 = 250
                         2 = 152
                         3 = ---
                         4 = 652
                         5 = 146
CT R                check for pressure controller, result: c
```

Pu uu	Pressure unit	
U = 0 .. 86	Unit code	
0 : 1 mTorr	29 : 2 mTorr	58 : 5 mbar

1 : 10 mTorr	30 : 5 mTorr	59 : 20 mbar
2 : 100 mTorr	31 : 20 mTorr	60 : 50 mbar
3 : 1000 mTorr	32 : 50 mTorr	61 : 200 mbar
4 : 1 Torr	33 : 200 mTorr	62 : 500 mbar
5 : 10 Torr	34 : 500 mTorr	63 : 2000 mbar
6 : 100 Torr	35 : 2000 mTorr	64 : 5000 mbar
7 : 1000 Torr	36 : 5000 mTorr	65 : 2 bar
8 : 1 kTorr	37 : 2 Torr	66 : 5 bar
9 : 10 kTorr	38 : 5 Torr	67 : 20 bar
10 : 100 kTorr	39 : 20 Torr	68 : 50 bar
11 : 1 µBar	40 : 50 Torr	69 : 2 Pa
12 : 10 µBar	41 : 200 Torr	70 : 5 Pa
13 : 100 µBar	42 : 500 Torr	71 : 20 Pa
14 : 1000 µBar	43 : 2000 Torr	72 : 50 Pa
15 : 1 mBar	44 : 5000 Torr	73 : 200 Pa
16 : 10 mBar	45 : 2 kTorr	74 : 500 Pa
17 : 100 mBar	46 : 5 kTorr	75 : 2 kPa
18 :1000 mBar	47 : 20 kTorr	76 : 5 kPa
19 : 1 Bar	48 : 50 kTorr	77 : 20 kPa
20 : 10 Bar	49 : 2 µbar	78 : 50 kPa
21 : 100 Bar	50 : 5 µbar	79 : 200 kPa
22 : 1 Pa	51 : 20 µbar	80 : 500 kPa
23 : 10 Pa	52 : 50 µbar	81 : 2000 kPa
24 : 100 Pa	53 : 200 µbar	82 : 5000 kPa
25 : 1 kPa	54 : 500 µbar	83 : 1 Mpa
26 : 10 kPa	55 : 2000 µbar	84 : 2 Mpa
27 : 100 kPa	56 : 5000 µbar	85 : 5 Mpa
28 : 1000 kPa	57 : 2 mbar	86 : 10 Mpa

```
PU R                check for pressure unit, result: rr

ON c                open valve
  c = 0               main valve (corresponds to: ON ALL)
  c = 1..8            channel valve

OF c                close valve
  c = 0               main valve (corresponds to: OFF ALL)
  c = 1..8            channel valve

ST c                check for status of a channel, result: xxxxx
                      (incompatible)
  c = 1..8            channel
  x = 0..FFFFH        status value: bit 0  <- 0/1 channel off/on
                                    bit 4     <- trip limit low
                                    bit 5     <- trip limit high
                                    bit 6     <- overflow in
                                    bit 7     <- underflow in
                                    bit 8     <- overflow out
                                    bit 9     <- underflow out
```

```
                                    bit 15    <- not used

KD                  keyboard disable, display is switched to user
                      menu

KE                  keyboard enable, display is switched back to previous
                    menu

DF                  sett all parameters to default

RE                  perform a hardware reset (like power up)

ID                  check for identification,
                      result: MGC 647C V2.2 - mm dd yyyy
  mm                  month of release
  dd                  day of release
  yyyy                year of release
```

The following host commands, respectively the command extensions, are only available with the PID option.

```
GN xxxx             enter PID parameter, gain
  xxxx = 0..9999      gain in percent
GN R                check for PID parameter gain, result: xxxxx

IA xxxx             enter PID parameter, integral action
  xxxx = 0..9999      integral action in 10 ms
IA R                check for PID parameter integ. act.,
                      result: xxxxx

LD xxxx             enter PID parameter, lead
  xxxx = 0..9999      lead in 10 ms
LD R                check for PID parameter lead, result: xxxxx

MO c m [i]          enter mode                    (extended command)
  c = 1..8            channel
  m = 0               mode = independent
  m = 1               mode = slave
  m = 2               mode = extern
  m = 3               mode = PCS
  m = 4               mode = PID    (PID extension)
  m = 9               mode = test
  i = 1..8            mode = mode index, number of master channel
                             (for m = 1 only)
  MO c R              Check mode, result: m [I]
```

Contact MKS Instruments if you have questions concerning the 147B syntax in case of using 647C to emulate a type 147B.

4.4 Response Syntax

The 647C typically responses with an ASCII integer value, terminated with <cr> and <nl> and new line. If no result value is available also an empty response (<cr> <nl>) is possible.

If an error has been detected in the command string, an error message is sent before the acknowledge signal. In this case the command has not been executed.

[{v1 [v2]} | {E ec}] <cr> <nl>

v1, v2 = result values
E = indicator for an error
ec = error code
0 = Channel error:
A invalid channel number was specified in the command or the channel number is missing.
1 = Unknown Command:
A command has been transmitted which is unknown to the 647C.
2 = Syntax error:
Only one character has been sent instead of the expected 2 byte command.
3 = Invalid expression:
The command parameter does not have decimal form, or invalid characters were found within the parameter (e.g. 100.3: the decimal point is an invalid character).

4 = Invalid value:
The transmitted parameter is outside the parameter range (e.g. 1200 is outside the range of a set point)
5 = Autozero error:
There was a trial to set the zero offset of an active channel. Before setting the zero offset, either the channel (OF #) or the gas (OF 0) has to be switched off.

<cr> = carriage return (0D hex) for termination
<nl> = new line (0A hex)

5. Application of the 647C

5.1 Mass Flow Controllers

The mass flow controllers must have a linear DC voltage output of 0 – 5 V. The input impedance must not be lower than 1 MOhms. Some mass flow controllers of other manufacturers can be damaged by a constant set point < 0 V. Other possible symptoms are undesired oscillations, when the setpoint is varied, or disturbances of the regulation loop.

To operate mass flow controllers it is important, that the allowed maximum of input signals are not exceeded. The mass flow controllers must have a linear DC voltage input and output of 0 – 5 V. MKS mass flow meters types 0258A/B/C, 579A , 179A can be operated with the same cables as for MKS mass flow controllers types 259, 1259, 2259, 1179, 2179, 1479, 1579, 1559 and MF1.

5.2 Trouble Shooting

Symptom	Possible Causes and Remedies
1. No display.	Power Failure - Wrong position of voltage selector switch. - Loose mains connection. - No power in the outlet - Fuse is defective - Power supply is broken.
2. Display of gas flow is close to zero or not correct.	- Loose connection. - Power supply is broken. - Mass flow controller is warming up. - Set point is not being transmitted. - Valve in the supply line is closed.
3. Display of gas flow is on for a short time and goes back to zero.	Defect in the pipe line system. - Supply line valve is closed. - Pressure is down (check gas supply). - No differential pressure (e.g. pump is turned off).
4. There are periodical peak pulses at constant gas flow.	- Pressure regulator is defect, (frequent defect, varying supply pressure may help. It is recommended to replace the pressure regulator) - Disturbance by external sources (change the path of power lines, screen sources of disturbance).
5. Entering data is not possible or there are unreadable characters on the display	- There is probably inconsistent data in battery backuped RAM. The First Start Reset will fix this problem.

If the trouble is limited to a part of the eight possible channels, it is recommended to localize the source of trouble by exchanging mass flow controllers and their connecting cables.

In any case check the setup of the device.

6. Pin Assignment of rear connectors

6.1 RS232 connector

Sub-D male 9 pol.

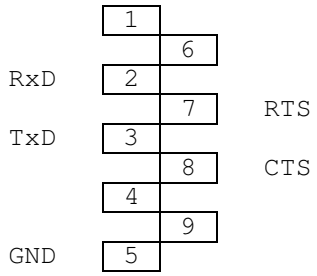


Figure 25

6.2 Service connector

Sub-D male 9 pol.

This connector is for use only by MKS personal.

6.3 RELAYS connector

Two relays are available for each channel. The relay data are:

- type of relay: 1 switch with n.o. and n.c. position (SPDT)
- max. switch voltage: 28 VDC (AC not specified)
- max. power: 3 W
- max. switch load: 250 mA
- max. response time: 55 ms

Sub-D female 25 pol.

relay 11, nc	1		
		14	relay 11, cmn
relay 11, no	2		
		15	relay 12, nc
relay 12, cmn	3		
		16	relay 12, no
relay 21, nc	4		
		17	relay 21, cmn
relay 21, no	5		
		18	relay 22, nc
relay 22, cmn	6		
		19	relay 22, no
relay 31, nc	7		
		20	relay 31, cmn
relay 31, no	8		
		21	relay 32, nc
relay 32, cmn	9		
		22	relay 32, no
relay 41, nc	10		
		23	relay 41, cmn
relay 41, no	11		
		24	relay 42, nc
relay 42, cmn	12		
		25	relay 42, no
chassis	13		

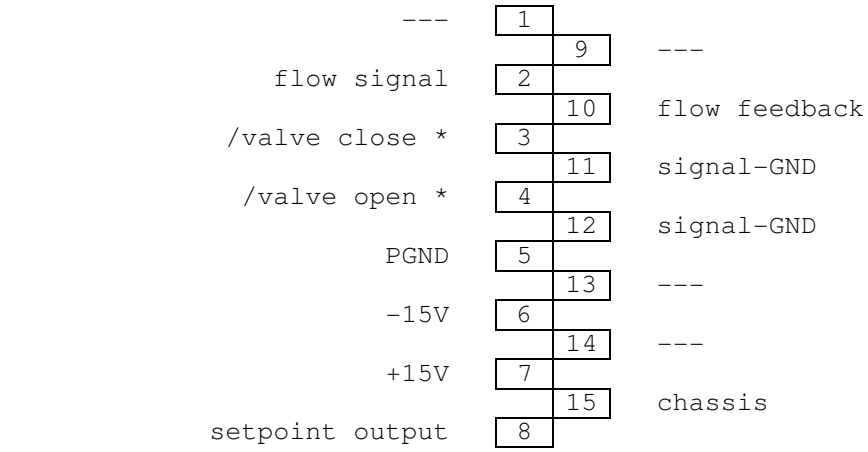
legend: nc = normally closed
no = normally open
cmn = common pin

relay 12 = relay 2 of channel 1

Figure 26

6.4 MFC connector: CH1 to CH8

Sub-D female 15 pol.



* = for use with cable type CB147-1 or CBE259-5

Figure 27

6.5 PRESSURE connector

Sub-D female 9 pol.

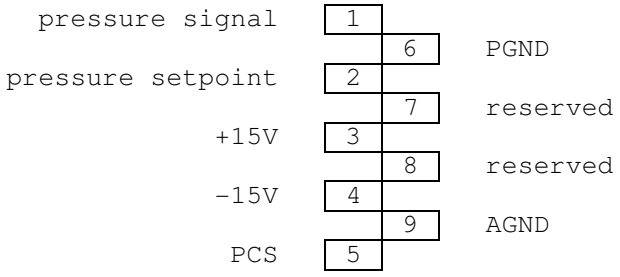


Figure 28

6.6 ACCESS connector

Sub-D female 25 pol.

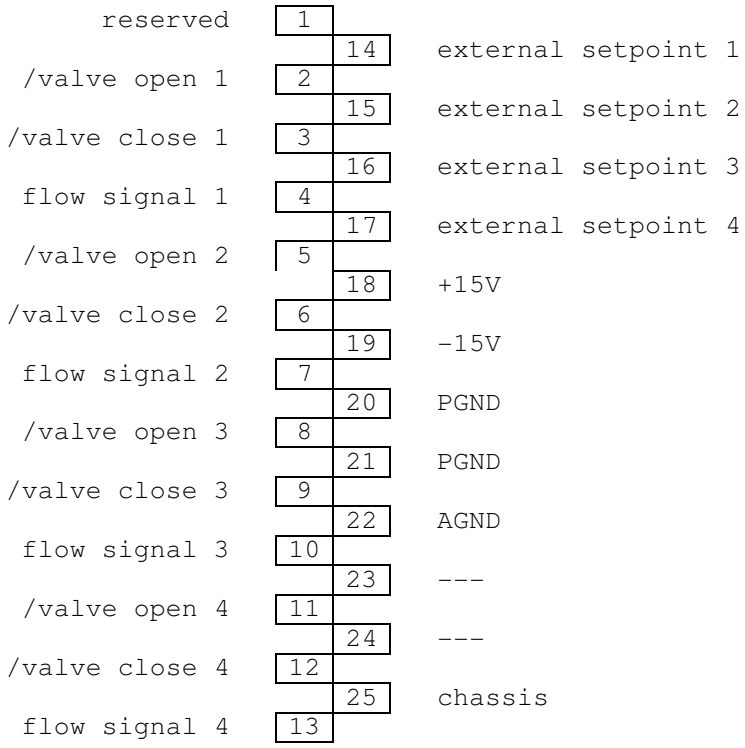


Figure 29

7. Gas Correction Table

Conversion factors are related to calibration with nitrogen or air.

GAS	SYMBOL	SPECIFIC HEAT, Cp cal/g^{O}C	DENSITY g/l @ 0^{O}C	CONVERSION FACTOR
Acetylene	C_2H_2	0.4032	1.161	0.58
Air	- - -	0.240	1.293	1.00
Ammonia	NH_3	0.492	0.760	0.73
Argon	Ar	0.1244	1.782	1.39[1]
Arsine	AsH_3	0.1167	3.478	0.67
Boron Trichloride	BCl_3	0.1279	5.227	0.41
Bromine	Br_2	0.0539	7.130	0.81
Carbon Dioxide	CO_2	0.2016	1.964	0.70[1]
Carbon Monoxide	CO	0.2488	1.250	1.00
Carbon Tetrachloride	CCl_4	0.1655	6.86	0.31
Carbon Tetraflouride (Freon - 14)	CF_4	0.1654	3.926	0.42
Chlorine	Cl_2	0.1144	3.163	0.86
Chlorodifluoromethane (Freon - 22)	$CHClF_2$	0.1544	3.858	0.46
Chloropentafluoroethane (Freon - 115)	C_2ClF_5	0.164	6.892	0.24
Chlorotrifluoromethane (Freon - 13)	$CClF_3$	0.153	4.660	0.38
Cyanogen	C_2N_2	0.2613	2.322	0.61
Deuterium	D_2	1.722	0.1799	1.00
Diborane	B_2H_6	0.508	1.235	0.44
Dibromodifluoromethane	CBr_2F_2	0.15	9.362	0.19
Dichlorodifluoromethane (Freon - 12)	CCl_2F_2	0.1432	5.395	0.35
Dichlorofluoromethane (Freon - 21)	$CHCl_2F$	0.140	4.592	0.42
Dichloromethysilane	$(CH_3)_2SiCl_2$	0.1882	5.758	0.25

(Table continued on next page)

GAS	SYMBOL	SPECIFIC HEAT, Cp cal/g^{o}C	DENSITY g/l @ 0^{o}C	CONVERSION FACTOR
Dichlorosilane	SiH_2Cl_2	0.150	4.506	0.40
1,2-Dichlorotetrafluoroethane (Freon - 114)	$C_2Cl_2F_4$	0.160	7.626	0.22
1,1-Difluoroethylene (Freon - 1132A)	$C_2H_2F_2$	0.224	2.857	0.43
2,2-Dimethylpropane	C_5H_{12}	0.3914	3.219	0.22
Ethane	C_2H_6	0.4097	1.342	0.50
Fluorine	F_2	0.1873	1.695	0.98
Fluoroform (Freon - 23)	CHF_3	0.176	3.127	0.50
Freon - 11	CCl_3F	0.1357	6.129	0.33
Freon - 12	CCl_2F_2	0.1432	5.395	0.35
Freon - 13	$CClF_3$	0.153	4.660	0.38
Freon - 13 B1	$CBrF_3$	0.1113	6.644	0.37
Freon - 14	CF_4	0.1654	3.926	0.42
Freon - 21	$CHCl_2F$	0.140	4.592	0.42
Freon - 22	$CHClF_2$	0.1544	3.858	0.46
Freon - 23	CHF_3	0.176	3.127	0.50
Freon - 113	$C_2Cl_3F_3$	0.161	8.360	0.20
Freon - 114	$C_2Cl_2F_4$	0.160	7.626	0.22
Freon - 115	C_2ClF_5	0.164	6.892	0.24
Freon - 116	C_2F_6	0.1843	6.157	0.24
Freon - C318	C_4F_8	0.1866	8.93	0.164
Freon - 1132A	$C_2H_2F_2$	0.224	2.857	0.43
Helium	He	1.241	0.1786	- - - 2
Hexafluoroethane (Freon - 116)	C_2F_6	0.1843	6.157	0.24
Hydrogen	H_2	3.419	0.0899	- - - 2
Hydrogen Bromide	HBr	0.0861	3.610	1.00

(Table continued on next page)

GAS	SYMBOL	SPECIFIC HEAT, Cp cal/g^{o}C	DENSITY g/l @ 0^{o}C	CONVERSION FACTOR
Hydrogen Chloride	HCl	0.1912	1.627	1.00
Hydrogen Fluoride	HF	0.3479	0.893	1.00
Isobutylene	C_4H_8	0.3701	2.503	0.29
Krypton	Kr	0.0593	3.739	1.54
Methane	CH_4	0.5328	0.715	0.72
Methyl Fluoride	CH_3F	0.3221	1.518	0.56
Molybdenum Hexafluoride	MoF_6	0.1373	9.366	0.21
Neon	Ne	0.246	0.900	1.46
Nitric Oxide	NO	0.2328	1.339	0.99
Nitrogen	N_2	0.2485	1.250	1.00
Nitrogen Dioxide	NO_2	0.1933	2.052	.- - -2
Nitrogen Trifluoride	NF_3	0.1797	3.168	0.48
Nitrous Oxide	N_2O	0.2088	1.964	0.71
Octafluorocyclobutane (Freon - C318)	C_4F_8	0.1866	8.93	0.164
Oxygen	O_2	0.2193	1.427	1.00
Pentane	C_5H_{12}	0.398	3.219	0.21
Perfluoropropane	C_3F_8	0.194	8.388	0.17
Phosgene	$COCl_2$	0.1394	4.418	0.44
Phosphine	PH_3	0.2374	1.517	0.76
Propane	C_3H_8	0.3885	1.967	0.36
Propylene	C_3H_6	0.3541	1.877	0.41
Silane	SiH_4	0.3189	1.433	0.60
Silicon Tetrachloride	$SiCl_4$	0.1270	7.580	0.28
Silicon Tetrafluoride	SiF_4	0.1691	4.643	0.35
Sulfur Dioxide	SO_2	0.1488	2.858	0.69

(Table continued on next page)

GAS	SYMBOL	SPECIFIC HEAT, Cp cal/g^{O}C	DENSITY g/l @ 0^{O}C	CONVERSION FACTOR
Sulfur Hexafluoride	SF_6	0.1592	6.516	0.26
Trichlorofluoromethane (Freon - 11)	CCl_3F	0.1357	6.129	0.33
Trichlorosilane	$SiHCl_3$	0.1380	6.043	0.33
1,1,2-Trichloro - 1,2,2-Trifluoroethane (Freon - 113)	CCl_2FCClF_2 or ($C_2Cl_3F_3$)	0.161	8.360	0.20
Tungsten Hexafluoride	WF_6	0.0810	13.28	0.25
Xenon	Xe	0.0378	5.858	1.32

[1] Empirically defined

[2] Consult MKS Instruments, Inc. for special applications.

NOTE: Standard Pressure is defined as 760 mmHg (1013.25 mbar). Standard Temperature is defined as 0^{O}C.

NOTE: This table may contain more (or less) gases than that of the unit.

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