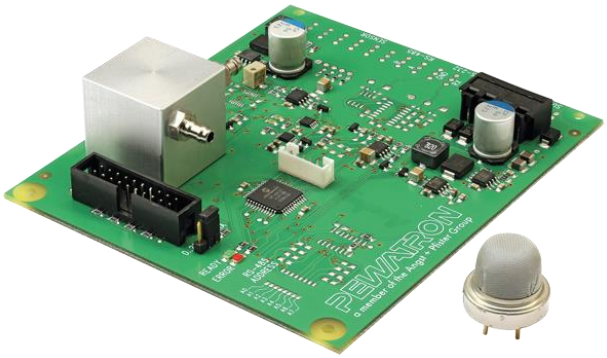
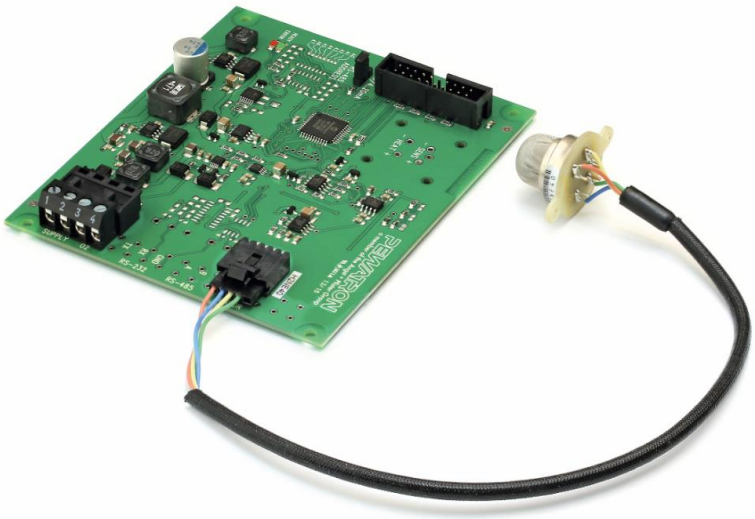
Operating manual

Angst+Pfister Sensors and Power
oxygen sensor modules

FCX-MC05, FCX-MC25 & FCX-MC95
OEM module platform





This manual contain information on how to operate the standard Angst+Pfister Sensors and Power AG OEM FCX-MCxx-FLOW, FCX-MCxx-DIFF and FCX-MCxx-EXT products. The standard FCX-MCxx-FLOW configuration always have the oxygen sensor soldered onto the PCB and covered with an aluminium flow housing. The standard FCX-MCxx-EXT-STD configuration have the oxygen sensor connected to the PCB via a 30 cm long cable. The oxygen sensor can be chosen from a selection of 3 sensors;

1) the FCX-UL 0…5% (xx = 05)
2) the FCX-UC 0…25% (xx = 25) and
3) the FCX-UWC 0…95% (xx = 95)

As an example the FCX-MC95-FLOW-A-CH Module is a 0…95%/(0)4-20 mA oxygen sensor module used in flow applications or in applications where a gas sample is extracted for analysis.
Other configurations of sensor, sensor termination and cable lengths are available upon request. Please refer to the product configurator in the datasheet for the FCX-MCxx series of produtcs.

Products mentioned in this manual may possibly be trademarks used only for the purposes of identification.

Protocol

Version	Month / Year	Change protocol
1.1	October 2010	Initial launch
1.2	October 2014	Change to SMD version
1.3	October 2015	New software
1.4	April 2016	New software
1.5	December 2019	New product codes

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Output 1.5
Release 12.2019

1 Table of contents

2 Customer service

At Angst+Pfister Sensors and Power AG, we want to offer you the best customer service possible. If you have any questions or comments about your FCX-MCxx, we would appreciate very much your feedback. Should you have any problems with the modules, please contact us for advice and support. We recommend that all service and repair work on the unit be done exclusively by our customer service or trained personnel.

You can reach us at the following addresses:

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Please send any returns to our Logistics Centre:
Before returning anything, please request an RMA number from us.

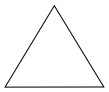
Angst+Pfister Sensors and Power AG
Logistics Centre
Hardhofstrasse 31
8424 Embrach/ZH
Switzerland

3 Safety instructions

Danger sources that could result in personal injury or damage to machinery are explicitly indicated in the appropriate places in the user documentation.
Before installing the machine, please read this operating manual carefully. Pay particular attention to the sections explaining possible hazards.
Warnings and instructions are shown as follows:

Means that failure to follow the instruction indicated can lead to personal injury.

Warning

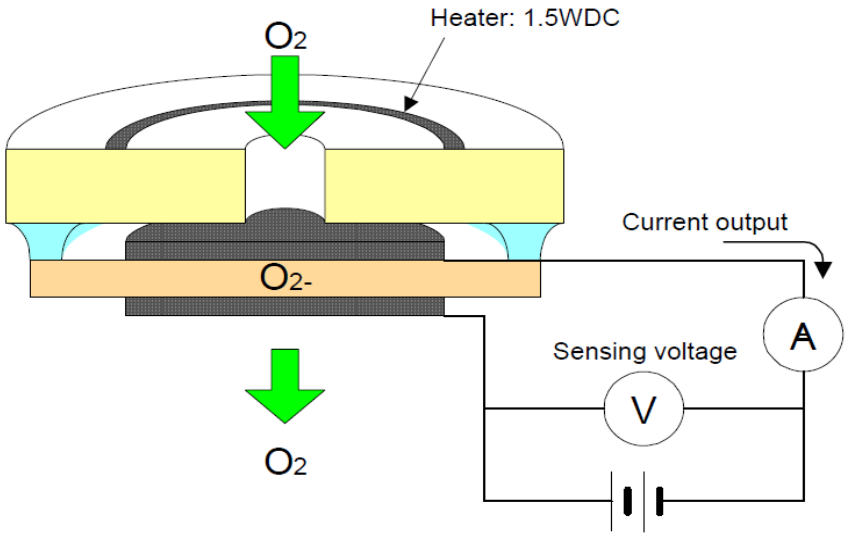


Means that the instruction indicated must be followed exactly to prevent damage to the machine.

Caution

4 Measurement principle

The FCX-MC sensor module is a complete solution for fast and accurate oxygen concentration measurements in the range 0…5%, 0…25% or 0.1…95%. The sensor and the measurement electronics are located on a PCB (FCX-MCxx-FLOW and FCX-MCxx-DIFF). Alternatively, the oxygen sensor can be connected to the PCB via a cable (FCX-MCxx-EXT). The microcontroller on the PCB linearizes the sensor signal and outputs it in analogue form as current or voltage (current signal (0)4–20 mA according to IEC 60381, or 0–10 VDC). The sensor signal can also be fed as a digital output using an RS232/RS485 interface.



Zirconium oxide, heated to about 450 °C, is penetrable for oxygen ions (see principle of operation in the picture above). A voltage applied to the sensor pumps the oxygen out of the inner chamber. At a constant gas pressure, the quantity of oxygen pumped out is equal to the quantity of oxygen molecules diffusing in through the capillary, and within a certain range it is independent of the voltage applied between the electrodes. The measurement current it proportional to the quantity of oxygen molecules pumped away. The relationship between the oxygen partial pressure and sensor current is given by the formula

$$I_s = c \ln (1 - p_{O2} / p_t)$$

where:

I_s : Sensor current
c : Constant (sensor-specific)
p_{O2} : Oxygen partial pressure
p_t : Gas pressure (total)

The sensor module performs four tasks:

- Regulation of the heating power of the sensor
- Amplification of the microampere signal from the sensor
- Linearization of the relation between oxygen partial pressure and sensor current
- Conversion of the amplified signal into standardised voltage/current output signals

The sensor and module are calibrated to one another at the factory. The heating voltage must be custom-adjusted for each sensor to bring the temperature to exactly 450 °C. The sensor is not directly replaceable, and cannot be used with other modules. All modules have a label on the PCB with the sensor batch number and the module batch number.

5 Commissioning

5.1 Mechanical installation

The PCB has dimensions 117 x 100 x 28 mm (including the flow housing) (Fig.1.). There are two different variants for how the sensor can be connected to the module: Soldered directly onto the PCB or using a plug cable connector. In Fig. 1 below is shown the PCB with a sensor soldered directly onto the PCB and covered with an aluminium flow housing. In Fig.2 below is shown the PCB without a sensor, but with a plug cable connector.

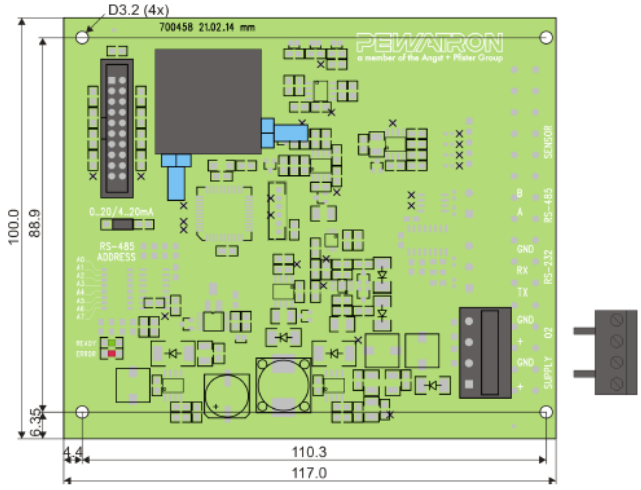


Fig. 1. PCB electronic layout for FCX-MCxx-FLOW modules

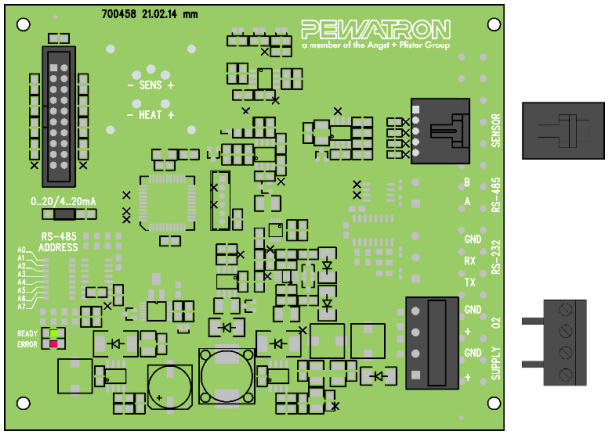


Fig. 2. PCB side with plug cable connector; FCX-MCxx-EXT

In each corner of the PCB, there are mounting holes with a diameter of 3.5 mm. The distance between the centre of mounting holes are 110.3 and 88.9 mm, respectively.

Caution

The PCB has highly sensitive circuitry. During installation, be careful that none of the components are damaged mechanically.

5.2 Pneumatic connections

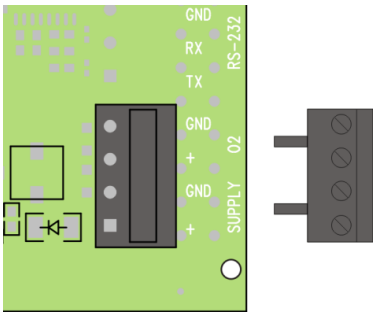
The flow housing has two hose connectors with a diameter of 5 mm. The direction of flow can be chosen arbitrarily.

Caution

Hoses containing silicone should not be used. Gases containing silicon destroy the sensor

5.3 Electrical connections

5.3.1 Supply voltage



4 - GND
3 - Analogue output
2 - GND
1 - Supply voltage

The 9–28 VDC power for the module is supplied through terminals 1 (+) and 2 (GND), at about 250 mA (24 VDC). For the lower limit of the power supply voltage, please take into account the resistance between the current output terminals. As an example; using a 500 Ohm resistance between the output terminals will cause of 10 V voltage drop at an output current of 20 mA. If the supply voltage is only slightly above this voltage drop, the required current for operating the module may be too low, which will then cause erroneous measurement output values.

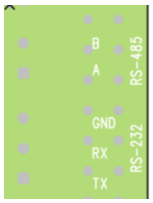
5.3.2 Analog and digital output

The output signal is available to the user on terminals 3 (+) and 4 (GND).

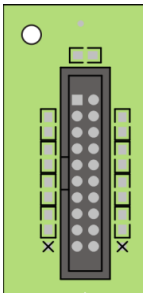
The module can optionally be operated with a 4–20 mA or a 0–20 mA output. The jumpers should be connected accordingly.

In the 0–20 mA configuration, an external 500 Ω shunt can be used with a minimum power supply voltage of 15 VDC to implement an output signal of 0–10 VDC. Alternatively, modules with a built-in voltage output can also be ordered from the factory (see product code in the datasheet).

Upon request, the user can be provided with digital output signals (RS232 or RS485). The appropriate connector will be installed on the PCB when ordered (see product code in the datasheet).



5.3.3 Connecting the display box



The interface can be used to connect the display box, available separately, to correct ZERO, SPAN and the heating voltage. See 9.2 Display box.

5.3.4 DIN 41612-F connector

Optionally, the module can also be delivered with a DIN 41612-F connector:

Power feed	+	32 d, b, z
Power feed	-	30 d, b, z
Signal	+	28 d, b, z
Signal	-	26 d, b, z

6 Environmental conditions

See also under 11. Specifications, in particular for the temperature and humidity ranges (not condensing).

- Operation outdoors not permitted.
- Protect from moisture

The sensor temperature is about 450 °C. Please note in any case the resulting hazards for applications with reactive gas mixtures.

Warning

Potentially explosive atmospheres
The unit may under no circumstances be operated in or with potentially explosive atmospheres.

7 Warm-up time

The module requires a warm-up time of about 5 minutes; during this time the green LED will blink. (■□■□■□■□■□…). The oxygen output will show 0 (Analog output = 0 mA).

When the module is ready to measure, the green LED will be almost continuously on (■□■■■■■■■■■□■…). The short off-states (blinking with 5-10 seconds interval) indicate that the module is working properly.
In this mode, the oxygen sensor is heated with the specified heat voltage and the oxygen output is a linear relationship between the oxygen concentration and the sensor current.

8 Gas flow

The following points should be noted:

- The flow should not be less than 0.1 l/min and no greater than 3.0 l/min; ideally, it should be 0.5 l/min.
- We recommend placing an appropriate filter upstream of the module, since contaminants brought in by the flow can significantly shorten the service life of the sensor.
- Avoid condensation (H_2O) in the sensor housing.

9 Failure mode

When the red LED is blinking (■□■□■□■□■□…), the oxygen module is in a failure mode. One of the possible two failures have been detected:

- Oxygen sensor heat voltage is interrupted.
- Oxygen sensor heating circuit is short-circuited.
- **IMPORTANT!** The oxygen output value will show an output of 0 (Analog output = 0 mA) in the failure mode.

10 Calibration and adjustment

10.1 Factory calibration (default)

All compensations and calibrations needed for operation have been carried out at the factory. The output signal should be interpreted as follows:

0–20 mA mode:

$pO2\ ([\%]) = \ \ 5\ [\%] \cdot \frac{I_{out}\ (mA)}{20\ [mA]}$, for oxygen sensors in the range 0…5%

$pO2\ ([\%]) = 25\ [\%] \cdot \frac{I_{out}\ (mA)}{20\ [mA]}$, for oxygen sensors in the range 0…25%

$pO2\ ([\%]) = 95\ [\%] \cdot \frac{I_{out}\ (mA)}{20\ [mA]}$, for oxygen sensors in the range 0.1…95%

4–20 mA mode:

$pO2\ ([\%]) = \ \ 5\ [\%] \cdot \frac{I_{out}\ (mA) - 4\ [mA]}{16\ [mA]}$, for oxygen sensors in the range 0…5%

$pO2\ ([\%]) = 25\ [\%] \cdot \frac{I_{out}\ (mA) - 4\ [mA]}{16\ [mA]}$, for oxygen sensors in the range 0…25%

$pO2\ ([\%]) = 95\ [\%] \cdot \frac{I_{out}\ (mA) - 4\ [mA]}{16\ [mA]}$, for oxygen sensors in the range 0.1…95%

where:

pO_2: Oxygen partial pressure as percentage of total pressure
I_{out}: Output current in mA

For modules with a digital output, the conditioned and compensated signal is taken directly from the AD converter and fed to the digital output port. The AD converter has a output resolution of 10 bit.

10.2 Recalibration and adjustments

We recommend checking the unit periodically by operating it under normal laboratory conditions. For the check, we recommend flushing the sensor with normal room air (20.95% O_2). For the 0…5% sensor this is not possible and the check should be down using a gas within the measurement range of the sensor. Note that most certified test gases have a tolerance of +/-2% full scale (FS)

Recommendations:

Flush with air at about 0.5 l/min. At an ambient temperature of 25 °C, for the 0…25% sensor the measurement should return a value of 20.95% O_2 ±0.25% O_2, and in the case of the 0.1…95% sensor, a value of 20.95% O_2 ±0.5% O_2. If greater deviations are observed, we ask that you return the module for testing and recalibration or to use the display box (see below) for small adjustments.

Display box

10.3 Display box

A display box can be purchased together with the module in order for the customer to make individual small adjustments to the oxygen sensor output. This could be in cases where a higher accuracy is needed in a certain measurement range or for periodically checking the output of the module.

In the normal operation defined here, the display box is connected to the oxygen module and no buttons are pressed. If the power supply is connected to the module, the display shows the following sequence:

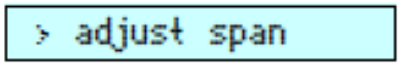
02 25% v jjmmtt	The sensor type is displayed with the measurement range and software version in the format "yymmdd", that is, two digits for the year, two digits for the month, and two digits for the day.
span (s) 100	The calibration value "span" is displayed. For new modules the displayed value is the factory setting full scale span value; i.e. 5%, 25% or 95% O_2. See detailed explanation in text below
zero (z) 100	The calibration value "zero" is displayed. For new modules the displayed value is the factory setting zero value. See detailed explanation in text below
ramp heatvoltage	The heating phase is displayed.
02 % 19.85	The linearized measured oxygen value is displayed. Please note that the 5% O_2 module is not able to display the correct O_2 concentration in air.

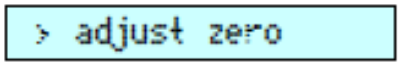
If a deviation occurs during monitoring of the heating current for the sensor, the display shows the following:

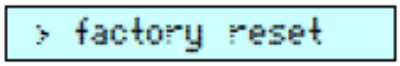
sensor broken	The heating current is much too low; the connection to the sensor heating has been broken.
sensor shorted	The heating current is much too high; there is a short circuit in the connection to the sensor heating.

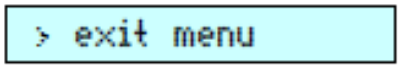
The display unit enters into the calibration menu if both buttons are pressed simultaneously during normal operation. In calibration menu, the values for zero and span can be adjusted.

In calibration mode, the display shows the following sequence:





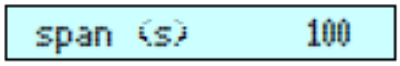


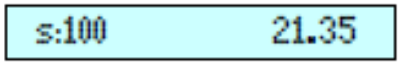


First the current *span* value is shown. By use of the *up* and *down* buttons, the following menu points are displayed:

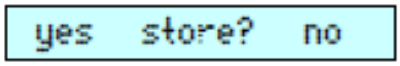
- Span
- Zero
- Factory reset (explained above)
- Exit menu

In order to change either the span or zero value, both buttons must be pressed simultaneously in order for the new value to be stored in the EEPROM. The following example shows how to change the span value:

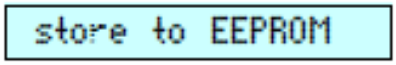


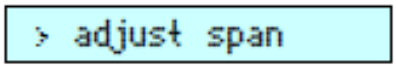


In the *adjust span* menu, the actual span value as the oxygen concentration value is shown. By use of the *up* and *down* buttons the span value can be changed.
Important is that any change must be confirmed by simultaneously pressing the two buttons on the display box.



In order to store the span value to the EEPROM, press yes. Else, press no. When *yes* is pressed, the text *store to EEPROM* is shown and after a couple of seconds the main menu is shown in the display.





For adjustment of the zero value, the procedure is identical to the procedure for changing the span value. Choose *adjust zero* from the main menu.

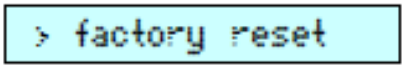
Adjustment of zero and span using the display box can be used for calibration purposes, but also for adjustments of the output close to the desired working point of the sensor. We recommend the following rules to be followed for span and zero setting:

a) Span calibration
   a. 0…5% sensor
      i. Use a oxygen gas concentration close to, but not above 5%
   b. 0…25% sensor
      i. Use a oxygen gas concentration > 18% (optimally 20.95%/air)
   c. 0…95% sensor
      i. Use a oxygen gas concentration > 80%

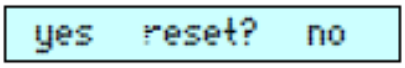
b) Zero calibration
   a. 0…5% sensor
      i. Use a oxygen gas concentration < 1% (optimally pure N_2)
   b. 0…25% sensor
      i. Use a oxygen gas concentration < 18% (optimally 1.0%)
   c. 0…95% sensor
      i. Use a oxygen gas concentration < 25% (optimally 20.95%/air)

Please note that the new span and zero values overwrites the previous values in the EEPROM. There is no limit as to how many times this procedure can be repeated. First time the oxygen module and the display box are used, the span and zero are the factory calibrated values.

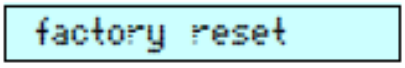
The gas sensor calibration values can be reset to the factory settings using the display box.



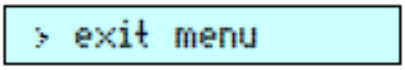
The gas sensor calibration values can be reset to factory values. Chose the *factory reset* option in the menu and confirm by holding both buttons down.



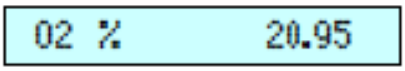
In order to reset to factory settings press the *yes* button. Else press the *no* button if no reset is wanted



If the *yes* button is being pressed, the display shows *factory reset* as a confirmation that the values are reset to factor levels. After a few seconds the display return to menu mode



In order to exit the calibration menu, please go to the *exit menu* point and press the two buttons simultaneously. On the display is hereafter show the actual concentration of the oxygen.



Please note Please note that the 5% O_2 module is not able to display the correct O_2 concentration in air.

11 Important notes

11.1 Restrictions

Please refer to separate application note on gases that influence the performance of the zirconia oxygen sensor.

12 Specifications

Measurement range	:	0…5 %, 0…25 % or 0…95 % O_2
Supply voltage	:	24 VDC nominal (9–28 VDC)
Power current	:	type 250 mA (24 VDC). Power-on peak about 0.7 A
Power consumption	:	< 2 W
Output signal	:	Optionally 0 / 4–20 mA current loop At a load of 500 Ω power supply at least 15 VDC
Resolution	:	On input side : 10bit AD : On output side : 12bit DAC
Accuracy	:	±0.5 % FS (Typical), FS = 25 % O_2, 95 % O_2 : ±.0 % FS (Typical), FS = 5 % O_2 : The accuracy that can be achieved is very much dependent on the application and the mode of operation.
Stability	:	< ±0.5 % FS/year FS = 25 % O_2, 95 % O_2 : < ±2 % FS/year FS = 5 % O_2
Repeatability	:	±0.5 % of the value displayed (> 5 % O_2)
Temperature influence (air)	:	O_2 Concentration = -0.01*T_e + 20.95 %O_2 (-10 °C < T_e < 37°C) O_2 Concentration = -0.004*T_e + 22.2 %O_2 (37 °C < T_e < 50°C) T_e = Environmental temperature of the sensor @ 40%RH
Response time (diffusion)	:	< 30 seconds T_{90}
Response time (flow)	:	< 8 seconds T_{90} ($T_{10/90}$ < 1.5 seconds)
Gas temperature	:	-10...+50 °C (For externally connected sensors, the sensors can be configured for gas temperatures up to 300°C)
Environmental temperature	:	-20...+70 °C (MC electronics)
Rel. humidity	:	98% RH, not condensing
Pressure influence	:	The oxygen sensor itself has no static pressure influence between 200 mbar and 50 bar absolute. The minimum/maximum pressure that can be applied to the sensor module is very dependent of the sensor integration. Please consult us for advice and appropriate sensor integration for high and low pressure applications Sudden pressure changes causes the signal to strongly oscillate. The oscillations are damped over time, but the relaxation time is long
Dimensions L x W x H	:	117.0 x 100 x 28 mm (including flow housing)
Weight	:	200 g

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Sensors and Power

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