

IN-FLOW

Industrial Style Digital Mass Flow Meters and Controllers for Gases

> Introduction

Bronkhorst High-Tech B.V., the European market leader in low flow thermal and Coriolis Mass Flow Meters/Controllers, has many years experience in designing and manufacturing precise and reliable measurement and control devices. With a wide range of instruments, Bronkhorst offers innovative solutions for many different applications in many different markets. The instruments are made to customers' specification, in various styles, suitable for use in laboratory, industrial environment, hazardous areas and production machinery.

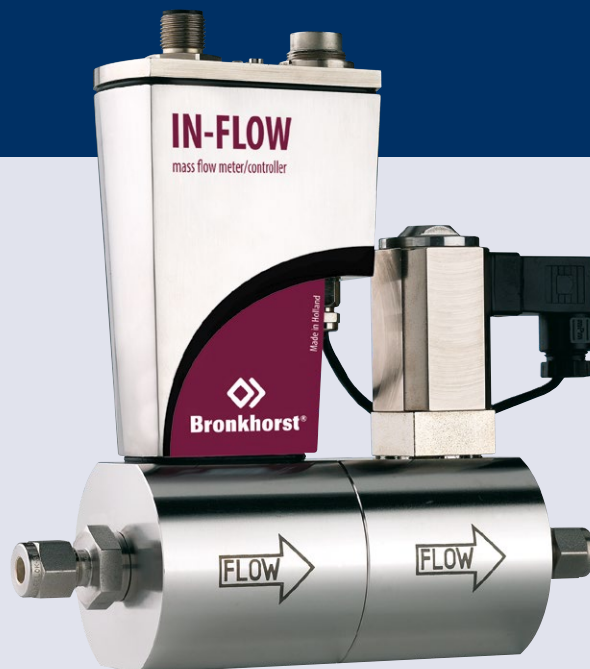
> IN-FLOW series for industrial environments

The Mass Flow Meters of the IN-FLOW series are of rugged design (IP65) for use in pilot and production plants in industrial environments or even Zone 2 hazardous areas, with optional ATEX Category 3 approval. Mass Flow Meters can be supplied in ranges starting from 0,014...0,7 ml_n/min up to 11000 m³_n/h air-equivalent, with pressure rating between vacuum and 700 bar. In combination with control valves, either integrated or separate, Mass Flow Controllers can be offered up to 10...500 m³_n/h air-equivalent.

Today's IN-FLOW series are equipped with a digital pc-board, offering high accuracy, excellent temperature stability and fast response (settling times t_{90} down to 500 msec). The main digital pc-board contains all of the general functions needed for measurement and control. In addition to the standard RS232 output the instruments also offer analog I/O. Furthermore, an integrated interface board provides DeviceNet™, PROFIBUS DP, Modbus or FLOW-BUS protocols.

> Selectable gases and flow ranges

The IN-FLOW design features optional Multi-Gas / Multi Range functionality, providing (OEM-) customers with extra flexibility and process efficiency. Users of MFC's in pilot plants or laboratories can rescale their instruments on site, saving time and money; substantial costs for stock keeping, (dis)mounting and also for service and recalibration are no longer applicable. Our free and easy-to-use software tool "FlowTune" enables the user to change the instrument's configuration swiftly via the RS232 port of a lap-top.



> Mass Flow Controllers for every application

The control valve can be furnished as integral part of an IN-FLOW MFC, or as separate component. It is a proportional, electromagnetic control valve with extremely fast and smooth control characteristics. With reference to the specific field of application there are different series of control valves. There is a standard direct acting valve for common applications, a pilot operated valve for high flow rates, the so-called Vary-P valve with pressure rating 400 or 700 bar, that can cope with up to 400 bar ΔP and a bellows valve for applications with very low differential pressure.

> General IN-FLOW features

- ◆ Weatherproof IP65 housing
- ◆ Optional: ATEX approval Cat.3, Zone 2
- ◆ Fast response, excellent repeatability
- ◆ Pressure ratings up to 700 bar
- ◆ Compliant with RoHS directives

> Digital features

- ◆ Fieldbus interface options: DeviceNet™, PROFIBUS DP, Modbus-RTU, FLOW-BUS
- ◆ Control characteristics user-configurable
- ◆ Optional Multi Gas / Multi Range functionality up to 10 bar
- ◆ Alarm and counter functions

> Technical specifications

Measurement / control system

Accuracy (incl. linearity)	: standard: $\pm 0,5\%$ Rd plus $\pm 0,1\%$ FS;
(based on actual calibration)	: $\pm 0,8\%$ Rd plus $\pm 0,2\%$ FS for F-110CI-005/ F-200CI-005;
	$\pm 2\%$ FS for F-110CI-002/F200CI-002;
	$\pm 1\%$ FS for ranges > 1670 l _v /min;
	for ranges > 1100 m ³ /h contact factory
Turndown	: 1:50 (in digital mode up to 1:187,5)
Repeatability	: $< 0,2\%$ Rd
Settling time (controller)	: standard: 1...2 seconds
Operating temperature	: -10...+70°C
	for ATEX cat. 3: 0...50°C
Temperature sensitivity	: zero: $< 0,05\%$ FS/°C;
	span: $< 0,05\%$ Rd/°C
Pressure sensitivity	: 0,1% Rd/bar typical N ₂ ; 0,01% Rd/bar typical H ₂
Leak integrity	: tested $< 2 \times 10^{-9}$ mbar l/s He
Attitude sensitivity	: max. error at 90° off horizontal 0,2% at 1 bar, typical N ₂
Warm-up time	: 30 min. for optimum accuracy 2 min. for accuracy $\pm 2\%$ FS

Mechanical parts

Material (wetted parts)	: stainless steel 316L or comparable
Process connections	: compression type or face seal couplings; wafer type on series F-106; DIN or ANSI flanges on series F-107
Seals	: standard: Viton®; options: EPDM, Kalrez® (FFKM)
Ingress protection (housing)	: IP65

Electrical properties

Power supply	: +15...24 Vdc
Power consumption	: meter: 70 mA; controller: max. 320 mA; add 50 mA for Profibus, if applicable
Analog output/command	: 0...5 (10) Vdc or 0 (4)...20 mA (sourcing output)
Digital communication	: standard: RS232 options: PROFIBUS DP, DeviceNet™, Modbus-RTU, FLOW-BUS

Electrical connection

Analog/RS232	: 8 DIN (male);
PROFIBUS DP	: bus: 5-pin M12 (female); power: 8 DIN (male)
DeviceNet™	: 5-pin M12 (male)
Modbus-RTU/FLOW-BUS	: 5-pin M12 (male)

Technical specifications subject to change without notice.



F-201CI Compact IP65 Mass Flow Controller for low flow ranges

> Models and flow ranges (based on air)

Mass Flow Meters (MFM);

PN100 (pressure rating 100 bar)

Model	min. flow	max. flow
F-110CI *	0,014...0,7 ml _v /min	0,06...9 ml _v /min
F-111BI *	0,16...8 ml _v /min	0,16...25 l _v /min
F-111AI *	0,4...20 l _v /min	0,6...100 l _v /min
F-112AI *	0,8...40 l _v /min	1,4...250 l _v /min
F-113AI *	4...200 l _v /min	8...1670 l _v /min

For ranges of 200, 400 or 700 bar rated MFMs please see our website.

High-Flow MFMs;

PN10 / PN16 / PN25 / PN40 / PN100

Model	min. flow	max. flow
F-116AI	0,4...20 m ³ /h	4...200 m ³ /h
F-116BI	1...50 m ³ /h	10...500 m ³ /h
F-106AI/F-107AI/F-117AI	0,4...20 m ³ /h	4...200 m ³ /h
F-106BI/F-107BI/F-117BI	1...50 m ³ /h	10...500 m ³ /h
F-106CI/F-107CI/F-117CI	2...100 m ³ /h	20...1000 m ³ /h
F-106DI/F-107DI/F-117DI	3,6...180 m ³ /h	36...1800 m ³ /h
F-106EI	8...400 m ³ /h	80...4000 m ³ /h
F-106FI	14...700 m ³ /h	140...7000 m ³ /h
F-106GI	22...1100 m ³ /h	220...11000 m ³ /h

Mass Flow Controllers (MFC); PN64 / PN100

Model	min. flow	max. flow
F-200CI/F-210CI ¹⁾	0,014...0,7 ml _v /min	0,18...9 ml _v /min
F-201CI/F-211CI ¹⁾ *	0,16...8 ml _v /min	0,16...25 l _v /min
F-201AI/F-211AI ¹⁾ *	0,4...20 l _v /min	0,6...100 l _v /min
F-202AI/F-212AI ²⁾	0,8...40 l _v /min	1,4...250 l _v /min
F-203AI/F-213AI ³⁾	4...200 l _v /min	8...1670 l _v /min
F-206AI/F-216AI ³⁾	0,4...20 m ³ /h	4...200 m ³ /h
F-206BI/F-216BI ⁴⁾	1...50 m ³ /h	10...500 m ³ /h

¹⁾ K_{v-max} = 6,6x10⁻² ²⁾ K_{v-max} = 0,4 ³⁾ K_{v-max} = 1,5 ⁴⁾ K_{v-max} = 6,0

Mass Flow Controllers (MFC); PN200

Model	min. flow	max. flow
F-221MI ⁵⁾	0,3...15 ml _v /min	0,16...25 l _v /min

⁵⁾ K_{v-max} = 6,65x10⁻³

MFCs for high-pressure / high-ΔP applications; PN400

Model	min. flow	max. flow
F-230MI	0,2...10 ml _v /min	10...500 ml _v /min
F-231MI	10...500 ml _v /min	0,2...10 l _v /min
F-232MI	0,2...10 l _v /min	2...100 l _v /min

For ranges of 700 bar rated MFCs please see our website.

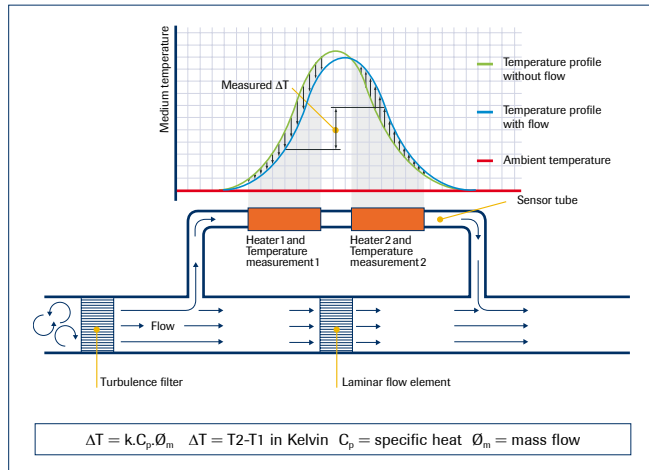
* For these models the Multi Gas / Multi Range option is available on request.



F-107BI Mass Flow Meter for high flow ranges

> Thermal mass flow measuring principle

The heart of the thermal mass flow meter/controller is the sensor, that consists of a stainless steel capillary tube with resistance thermometer elements. A part of the gas flows through this bypass sensor, and is warmed up by heating elements. Consequently the measured temperatures T1 and T2 drift apart. The temperature difference is directly proportional to mass flow through the sensor. In the main channel Bronkhorst applies a patented laminar flow element consisting of a stack of stainless steel discs with precision-etched flow channels. Thanks to the perfect flow-split the sensor output is proportional to the total mass flow rate.



> Fields of application

The IN-FLOW series have been successfully applied in a wide variety of industrial applications, such as:

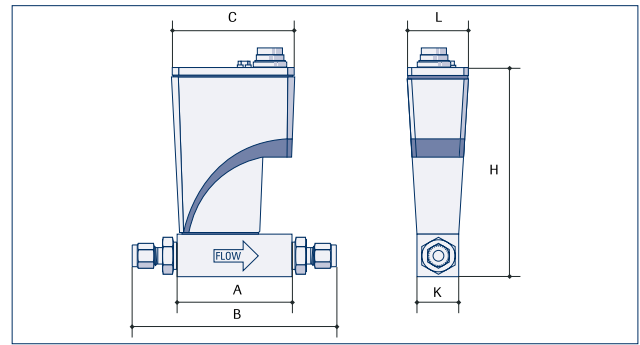
- ◆ Process gas measurement or control in food, pharmaceutical and (petro) chemical industries, in fermentation installations and in fuel cell technology
- ◆ Sample gas measurement
- ◆ Burner control
- ◆ Gas consumption measurement for internal accounting
- ◆ Making of defined gas mixtures

> For low pressure drop and corrosive gases

For applications with only little differential pressure, Bronkhorst developed the LOW- ΔP -FLOW series mass flow meters and controllers, which can also be supplied with an IP65 (IN-FLOW) housing. In these instruments the flow resistance is minimized by using a large bore sensor in combination with a cylindrical flow splitter. Except for the resulting lower pressure drop, this construction also minimises the risks of clogging and facilitates the cleaning and purging of these instruments. Up to 50 l_r/min air-equivalent, flow control applications with restricted delta-P can be handled with integrated LOW- ΔP -FLOW Mass Flow Controllers. For the control of higher flow rates at very low differential pressures Bronkhorst has devised special control valves with pressure compensation bellows (series F-004). These control valves are piped on to the flow meter while the electronic PI-control function is an integral part of the flow meter.

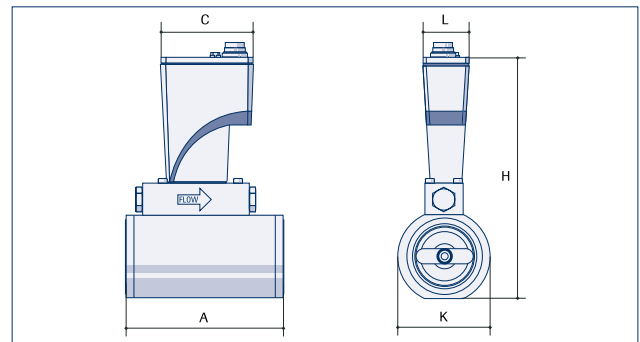
Dimensions subject to change without notice. For certified drawings, dimensions of high pressure instruments (PN200/PN400/PN700) and of the F-107 series (flanged type MFMs) please contact factory.

> Dimensions (mm)



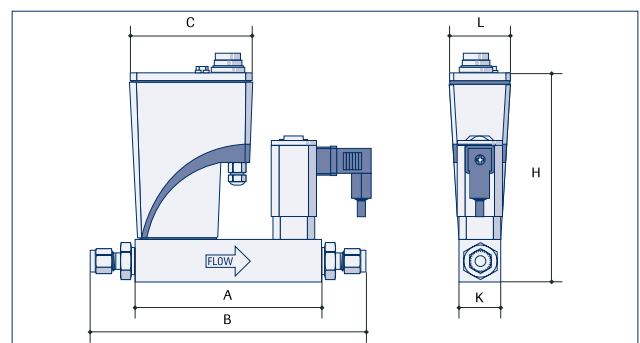
Mass Flow Meters

Model	A	B	C	H	K	L	Weight (kg)
F-110CI (1/8" OD)	47	98	74	125	25	36	0,8
F-111BI (1/4" OD)	69	126	74	125	25	36	0,9
F-111AI (1/4" OD)	69	126	74	137	26	36	1,0
F-112AI (1/2" OD)	65	130	74	153	59	36	1,8
F-113AI (1/2" OD)	112	189	74	167	74	36	3,3
F-116AI (1/2" OD)	174	241	74	192	74	36	5,0
F-116BI (1" OD)	192	275	74	209	89	36	8,0



Mass Flow Meters, high flow, wafer type

Model	A	C	H	K	L	Weight (kg)
F-106AI (DN40/1,5")	125	74	192	75	36	4,0
F-106BI (DN50/2")	125	74	205	85	36	4,6
F-106CI (DN80/3")	125	74	234	115	36	6,8
F-106DI (DN100/4")	125	74	264	145	36	9,5
F-106EI (DN150/6")	125	74	319	198	36	13,3
F-106FI (DN200/8")	125	74	371	249	36	18,1
F-106GI (DN250/10")	125	74	436	313	36	27,0



Mass Flow Controllers

Model	A	B	C	H	K	L	Weight (kg)
F-200CI/F-210CI (1/8" OD)	112	164	74	125	25	36	1,3
F-201CI/F-211CI (1/4" OD)	112	169	74	125	25	36	1,4
F-201AI/F-211AI (1/4" OD)	112	169	74	137	26	36	1,5
F-202AI/F-212AI (1/4" OD)	112	169	74	153	59	36	3,0
F-203AI/F-213AI (1/2" OD)	171	238	74	160	74	36	5,0
F-206AI/F-216AI (1/2" OD)	233	300	74	192	74	36	6,7
F-206BI/F-216BI (1" OD)	251	334	74	209	89	36	10,0

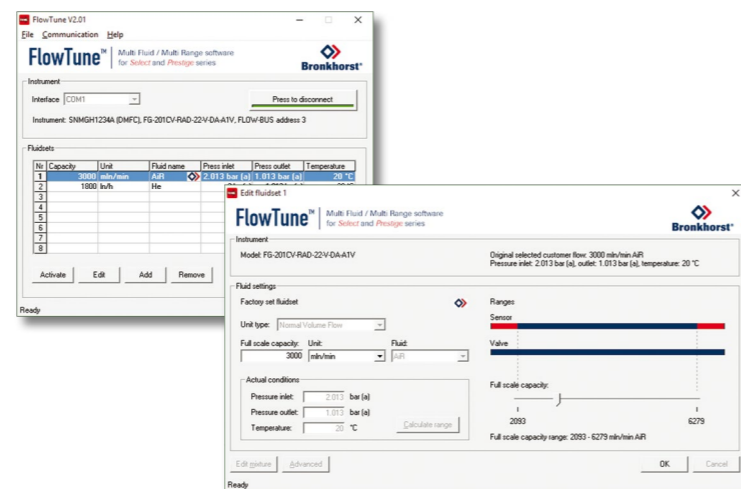
> **Table with minimum and maximum flow ranges for IN-FLOW instruments suitable for Multi Fluid / Multi Range functionality** (valid for operating conditions from 0.8 to 10 bar abs and 0 to 70°C)

IN-FLOW MFM Model #	IN-FLOW MFC Model #	Air flow ranges Minimum/Nominal/Maximum	Min/Max flow ranges for other gases										
			Ar	CH ₄	C ₂ H ₆	CO	CO ₂	H ₂	He	N ₂	N ₂ O	O ₂	
F-110CI - 002	F-200CI - 002 ¹⁾	Min. 0.014 - 0.7 ml _r /min Nom. 0.014 - 2 ml _r /min Max. 0.014 - 5 ml _r /min	Min	0.02 - 1	0.012 - 0.6	0.008 - 0.4	0.014 - 0.7	0.012 - 0.6	0.014 - 0.7	0.02 - 1	0.014 - 0.7	0.012 - 0.6	0.014 - 0.7
F-110CI - 005	F-200CI - 005 ¹⁾	Min. 0.06 - 3 ml _r /min Nom. 0.06 - 5 ml _r /min Max. 0.06 - 9 ml _r /min	Min	0.07 - 3.5	0.04 - 2	0.028 - 1.4	0.06 - 3	0.04 - 2	0.06 - 3	0.07 - 3.5	0.06 - 3	0.04 - 2	0.06 - 3
F-111BI - 020	F-201CI - 020	Min. 0.16 - 8 ml _r /min Nom. 0.16 - 20 ml _r /min Max. 0.16 - 30 ml _r /min	Min	0.2 - 10	0.11 - 5.5	0.08 - 4	0.16 - 8	0.14 - 7	0.144 - 7.2	0.2 - 10	0.16 - 8	0.12 - 6	0.16 - 8
F-111BI - 050	F-201CI - 050	Min. 0.4 - 20 ml _r /min Nom. 0.4 - 50 ml _r /min Max. 0.4 - 75 ml _r /min	Min	0.54 - 27	0.34 - 17	0.22 - 11	0.4 - 20	0.3 - 15	0.42 - 21	0.56 - 28	0.4 - 20	0.3 - 15	0.4 - 20
F-111BI - 100	F-201CI - 100	Min. 0.8 - 40 ml _r /min Nom. 0.8 - 100 ml _r /min Max. 0.8 - 150 ml _r /min	Min	1.12 - 56	0.64 - 32	0.42 - 21	0.8 - 40	0.62 - 31	0.84 - 42	1.12 - 56	0.8 - 40	0.6 - 30	0.8 - 40
F-111BI - 200	F-201CI - 200	Min. 1.6 - 80 ml _r /min Nom. 1.6 - 200 ml _r /min Max. 1.6 - 300 ml _r /min	Min	2.4 - 120	1.3 - 65	0.88 - 44	1.6 - 80	1.22 - 61	1.68 - 84	2.4 - 120	1.6 - 80	1.2 - 60	1.6 - 80
F-111BI - 500	F-201CI - 500	Min. 4 - 200 ml _r /min Nom. 4 - 500 ml _r /min Max. 4 - 750 ml _r /min	Min	5.4 - 270	3.2 - 160	2.2 - 110	4 - 200	3 - 150	4.2 - 210	5.6 - 280	4 - 200	3 - 150	4 - 200
F-111BI - 1K0	F-201CI - 1K0	Min. 8 - 400 ml _r /min Nom. 8 - 1000 ml _r /min Max. 8 - 1500 ml _r /min	Min	11.2 - 560	6.4 - 320	4.2 - 210	8 - 400	6.2 - 310	8.4 - 420	11.2 - 560	8 - 400	6 - 300	8 - 400
F-111BI - 2K0	F-201CI - 2K0	Min. 16 - 800 ml _r /min Nom. 16 - 2000 ml _r /min Max. 16 - 3000 ml _r /min	Min	24 - 1200	13 - 650	8.8 - 440	16 - 800	12.2 - 610	16.8 - 840	24 - 1200	16 - 800	12 - 600	16 - 800
F-111BI - 5K0	F-201CI - 5K0	Min. 0.04 - 2 l _r /min Nom. 0.04 - 5 l _r /min Max. 0.04 - 7.5 l _r /min	Min	0.054 - 2.7	0.032 - 1.6	0.022 - 1.1	0.04 - 2	0.03 - 1.5	0.042 - 2.1	0.056 - 2.8	0.04 - 2	0.03 - 1.5	0.04 - 2
F-111BI - 10K	F-201CI - 10K	Min. 0.08 - 4 l _r /min Nom. 0.08 - 10 l _r /min Max. 0.08 - 15 l _r /min	Min	0.112 - 5.6	0.064 - 3.2	0.042 - 2.1	0.08 - 4	0.062 - 3.1	0.084 - 4.2	0.112 - 5.6	0.08 - 4	0.06 - 3	0.08 - 4
F-111BI - 20K	F-201CI - 20K	Min. 0.16 - 8 l _r /min Nom. 0.16 - 20 l _r /min Max. 0.16 - 25 l _r /min	Min	0.2 - 10	0.13 - 6.5	0.088 - 4.4	0.16 - 8	0.122 - 6.1	0.168 - 8.4	0.24 - 12	0.16 - 8	0.12 - 6	0.16 - 8
F-111AI - 50K	F-201AI - 50K	Min. 0.4 - 20 l _r /min Nom. 0.4 - 50 l _r /min Max. 0.4 - 75 l _r /min	Min	0.54 - 27	0.32 - 16	0.22 - 11	0.4 - 20	0.3 - 15	0.42 - 21	0.56 - 28	0.4 - 20	0.3 - 15	0.4 - 20
F-111AI - 70K	F-201AI - 70K	Min. 0.6 - 30 l _r /min Nom. 0.6 - 70 l _r /min Max. 0.6 - 100 l _r /min	Min	0.9 - 45	0.5 - 25	0.4 - 20	0.6 - 30	0.5 - 25	0.6 - 30	0.9 - 45	0.6 - 30	0.5 - 25	0.6 - 30
F-112AI - M10	F-202AI - M10 ¹⁾	Min. 0.8 - 40 l _r /min Nom. 0.8 - 100 l _r /min Max. 0.8 - 150 l _r /min	Min	1.12 - 56	0.64 - 32	0.42 - 21	0.8 - 40	0.62 - 31	0.84 - 42	1.12 - 56	0.8 - 40	0.6 - 30	0.8 - 40
F-112AI - M20	F-202AI - M20 ¹⁾	Min. 1.4 - 70 l _r /min Nom. 1.4 - 200 l _r /min Max. 1.4 - 250 l _r /min	Min	2 - 100	1.1 - 55	0.7 - 35	1.4 - 70	1 - 50	1.4 - 70	2 - 100	1.4 - 70	1 - 50	1.4 - 70
F-113AI - M50	F-203AI - M50 ¹⁾	Min. 4 - 200 l _r /min Nom. 4 - 500 l _r /min Max. 4 - 750 l _r /min	Min	5.4 - 270	3.2 - 160	2.2 - 110	4 - 200	3 - 150	4.2 - 210	5.6 - 280	4 - 200	3 - 150	4 - 200
F-113AI - 1M0	F-203AI - 1M0 ¹⁾	Min. 8 - 400 l _r /min Nom. 8 - 1000 l _r /min Max. 8 - 1670 l _r /min	Min	11.2 - 560	6.4 - 320	4.2 - 210	8 - 400	6.2 - 310	8.4 - 420	11.2 - 560	8 - 400	6 - 300	8 - 400

¹⁾ Multi Gas / Multi Range option not available for these models

> **Multi Gas / Multi Range features**

- ◆ Rangeability up to 187,5 : 1
- ◆ Flexible, user-programmable ranges and gas types
- ◆ Easy-to-use configuration software
- ◆ Multi Gas / Multi Range functionality up to 10 bar; pressure rating up to 100 bar
- ◆ High accuracy and repeatability



> **Notes**

- ◆ Multi Gas / Multi Range is optional on low-flow IN-FLOW series and must be requested at the point of ordering
- ◆ Extended rangeability for digital communication only; turndown 50:1 when using analog I/O options
- ◆ The selected orifice of the control valve may limit the rangeability
- ◆ Standard accuracy (based on actual calibration): ±(0,5% RD + 0,1% FS); ±0,8% Rd plus ±0,2% FS for F-110C-005/F-200CV-005; ±2% FS for F-110C-002/F-200CV-002
- ◆ Maximum range for gases not mentioned in this list; rule of thumb: nominal range for Air x Conversion Factor; e.g. F-111B - 1K0: maximum range for SF₆ = 1000 x 0.27 = 270 ml_r/min
- ◆ Minimum range for gases not mentioned in this list; rule of thumb: minimum range for Air x Conversion Factor; e.g. F-111B - 1K0: minimum range for SF₆ = 400 x 0.27 = 108 ml_r/min
- ◆ The Conversion Factors for these calculations can be extracted from Fluidat on the Net (www.fluidat.com): Go to 'Flow calculations' and select 'Gas Conversion factor'. Select 'Fluid from' and make sure 'Fluid to' is Air. Select the applicable instrument model from the pulldown menu. Then press 'Calculate' and look up the conversion factor from the table.

> Model number identification

F - N N NAA - NNN - A A A - NN - A

Base

0	Valve only
1	Meter
2	Controller

Pressure rating

0	64 bar
1	100 bar
2	200 bar
3	400 bar
4	700 bar

Ranges

for PN64/PN100 Flow Meters/Controllers

0CI	0...0.7 / 0...9 ml _v /min
1BI/1CI	0...8 / 0...25000 ml _v /min
1AI	0...20 / 0...100 l _v /min
2AI	0...40 / 0...250 l _v /min
3AI	0...200 / 0...1670 l _v /min
6AI/7AI	0...20 / 0...200 m ³ _v /h
6BI/7BI	0...50 / 0...500 m ³ _v /h
6CI/7CI	0...100 / 0...1000 m ³ _v /h
6DI/7DI	0...180 / 0...1800 m ³ _v /h
6EI	0...400 / 0...4000 m ³ _v /h
6FI	0...700 / 0...7000 m ³ _v /h
6GI	0...1100 / 0...11000 m ³ _v /h

for PN200/PN400 Flow Meters

0MI	0...10 / 0...15 ml _v /min
1MI	0...15 / 0...15000 ml _v /min
2MI	0...10 / 0...250 l _v /min
3MI	0...200 / 0...1250 l _v /min

for PN200 Flow Controllers

1MI	0...15 / 0...20000 ml _v /min
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for PN400 Flow Controllers

0MI	0...10 / 0...500 ml _v /min
1MI	0...0.5 / 0...10 l _v /min
2MI	0...10 / 0...100 l _v /min

Nominal range

Factory selected

Communication (I/O)

A	RS232 + analog (n/c control)
B	RS232 + analog (n/o control)
D	RS232 + DeviceNet™ (n/c control)
E	RS232 + DeviceNet™ (n/o control)
M	RS232 + Modbus-RTU (n/c control)
N	RS232 + Modbus-RTU (n/o control)
P	RS232 + PROFIBUS DP (n/c control)
Q	RS232 + PROFIBUS DP (n/o control)
R	RS232 + FLOW-BUS (n/c control)
S	RS232 + FLOW-BUS (n/o control)

Analog output

A	0...5 Vdc
B	0...10 Vdc
F	0...20 mA sourcing
G	4...20 mA sourcing

Supply voltage

D	+15...24 Vdc
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Connections (in/out)

1	1/8" OD compression type
2	1/4" OD compression type
3	6 mm OD compression type
4	12 mm OD compression type
5	1/2" OD compression type
6	20 mm OD compression type
8	1/4" Face seal male
9	other

Mounting between flanges

01	mounting betw. flange	DIN PN10
02	mounting betw. flange	DIN PN16
03	mounting betw. flange	DIN PN40
06	mounting betw. flange	ANSI 150 lbs
07	mounting betw. flange	ANSI 300 lbs
13	Flanged connections	DIN PN40
15	Flanged connections	DIN PN100
26	Flanged connections	ANSI 150 lbs
27	Flanged connections	ANSI 300 lbs
28	Flanged connections	ANSI 600 lbs
99	other	

Internal seals

V	Viton®
E	EPDM
K	Kalrez® (FFKM)



F-106CI Mass Flow Meter for high flow ranges (wafer type)



F-112AI Mass Flow Meter



F-116AI Mass Flow Meter with BRIGHT Local Readout/Control Module



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- INTEGRATED SYSTEMS • RENTALS • SERVICE
- ENVIRONMENTAL • INSTRUMENTATION • MATERIALS TESTING

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