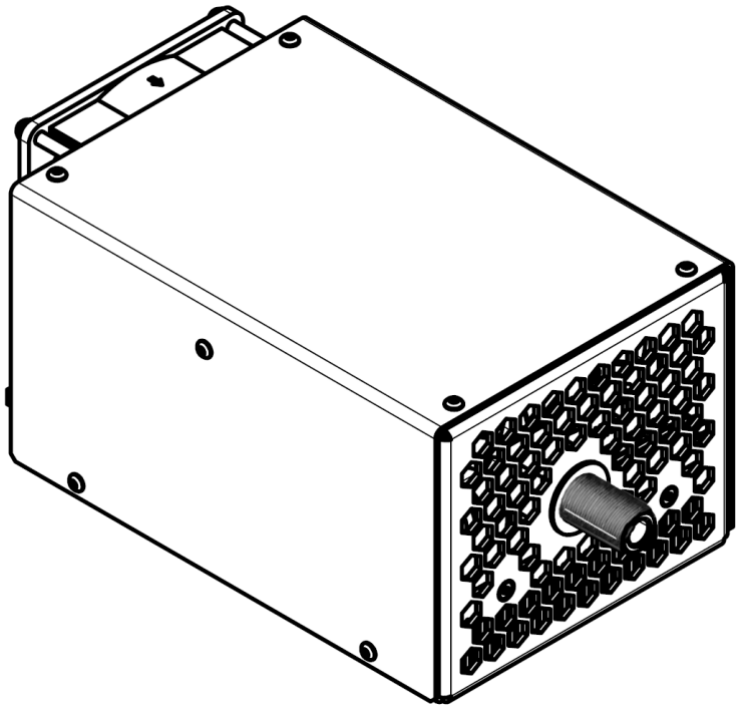
rev 2.10 / 2023 09 28

RFGM-series RF power modules

User manual



Warning! This equipment may be dangerous.
Please read the entire user manual carefully before using the product.

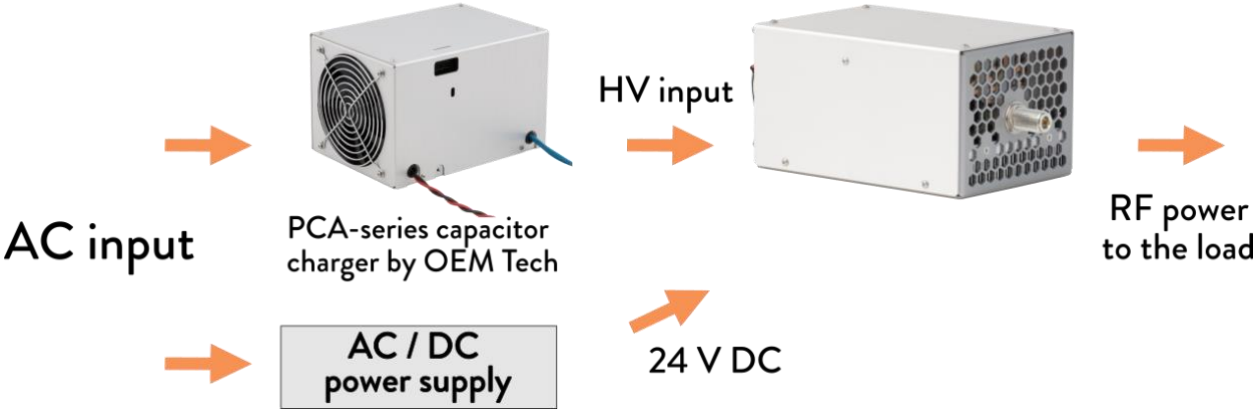
Table of content

Description

RFGM is a series of RF power modules providing at its output high voltage sine wave in a single frequency mode from radio-frequency range. Output frequency is selectable at the moment of order from sub-megahertz range to 81.36MHz, factory fixed. Output power varies from 300W to 1500W in dependence on model. See also *How to order?* section on page 12 for details and list of models available.

All modules are cooled with a built-in fan. Rotation speed of the fan in controlled by module's MCU.

Please note, the modules are not a stand-alone solution and for proper operation they need external sources of high (300-500VDC) and low (24VDC) voltage of the appropriate power. A typical application schema is given below:



An average output power of the module can be regulated in two different ways:

- by varying the input DC voltage (an output power of RFGM module increases with the rise of its input voltage)
- by multi-kilohertz PWM of the output (set either by Power control signal or via RS-485). An average output power in this case is linear with duty cycle.

A power combining of multiple modules is possible on request. An output power obtained in this case can reach 3000W and beyond.

RFGM-series power modules can be controlled in two different ways – either via RS-485 digital interface or, alternatively, via signals of INTERFACE connector.

Appearance and layout

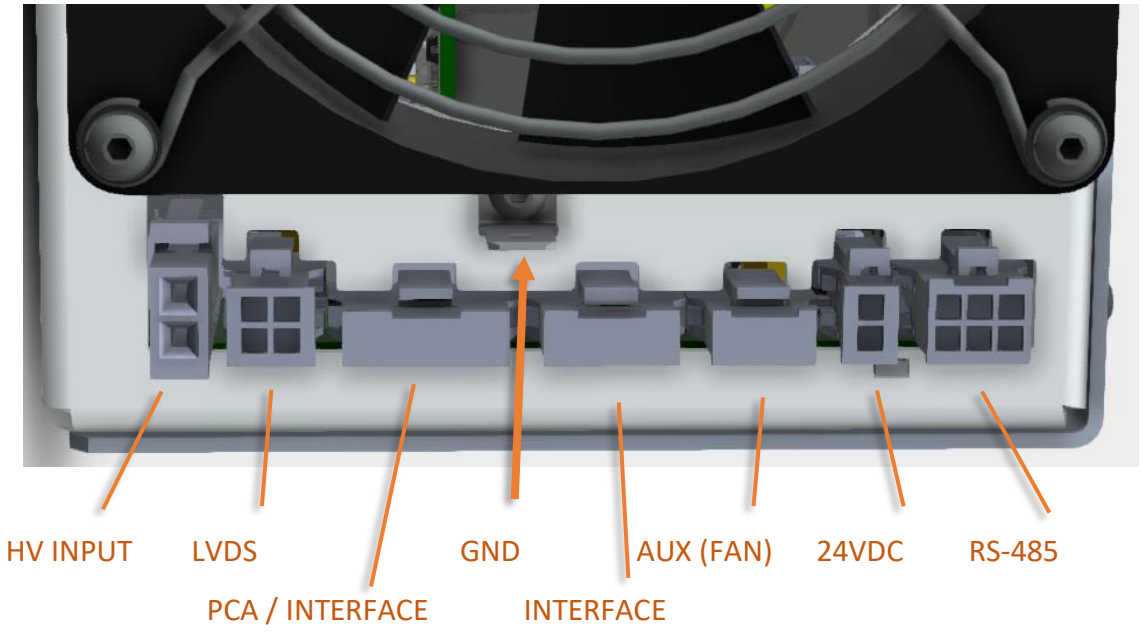
Side 1: Inputs and interfaces

Side 1 contains high voltage input to the module (300VDC-500VDC),
low voltage input to the module (24VDC), all the interfaces connectors (both digital and analogue)
as well as a grounding stud

Side 2: RF Output

Side 2 contains RF output only

Connectors / Pins / Interface signals



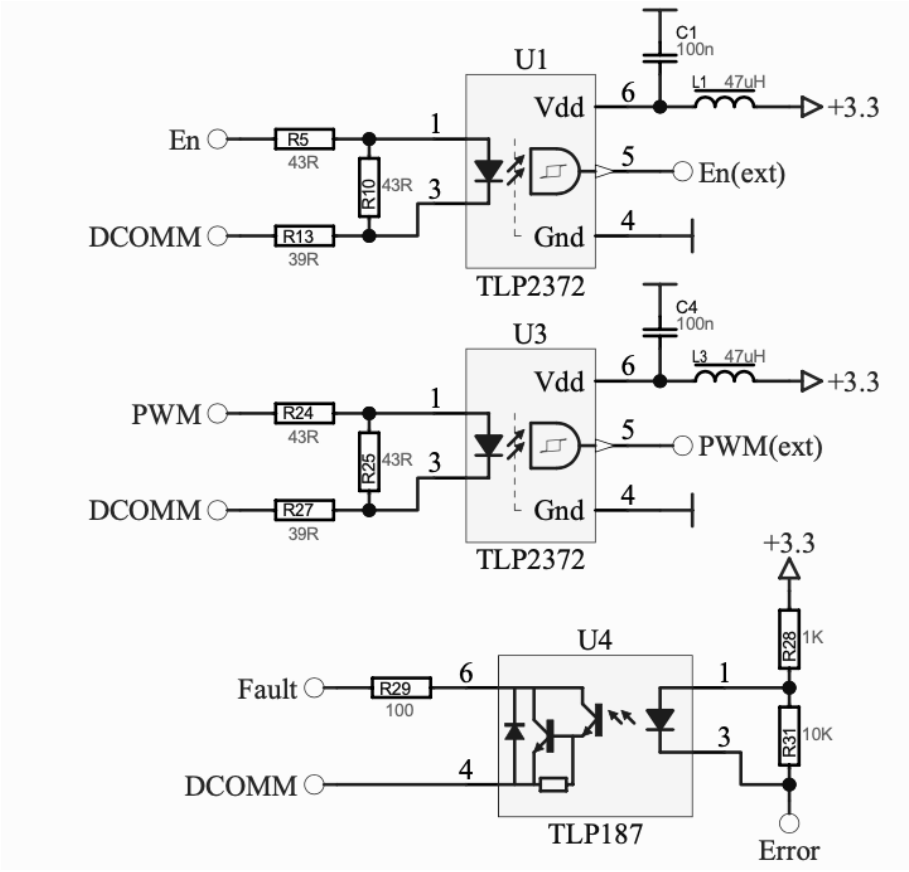
RS-485: Molex 43045-0601

Designation	Pin	Description
-	1, 4	Reserved for future use
RS485 B	2	Inverting Driver Output/Receiver Input
RS485 A	3	Non-inverting Driver Output/Receiver Input
RS485 SCREEN	5	Ground point for electrical screen of RS485 cable (N/C by default, available on request)
RS485 COMM	6	Common wire for 'RS485 A' and 'RS485 B' signals

INTERFACE: Molex 43650-0400

Designation	Pin	Description
Fault	1	Logic output, open collector, active low – indicates either an internal failure of the module or that the module isn't ready to work Once Fault occurs, 'Enable' should be reactivated to reset the Fault state
Interface return (DCOMM)	2	Common wire for 'Enable', 'Power control' and 'Fault' signals
Enable (En)	3	Logic input, 5V TTL/CMOS, active high – general enable to the module Input impedance – approx. 120 Ohm

Power control (PWM)	4	Logic input, 5V TTL/CMOS , active high – module generates RF power when both 'Enable' and' Power control' signals are 'high' state Switching of Power control signal with multi-kilohertz frequency can be used to adjust the average output power of RFGM module Input impedance – approx. 120 Ohm Nominal frequency range from 1 kHz to 10 kHz. Duty cycle limitations are as follows: '1' state – 3 us min '0' state – 10 us min



Circuits of INTERFACE signals

PCA/INTERFACE: Molex 43650-0500

Capacitor charger of PCA-series is to be connected here.

Designation	Pin	Description
Interface return	1	See user manual of PCA-series capacitor charger for the detailed signal description
Fault	2	
Inhibit	3	
Voltage program	4	
15V DC	5	

AUX (FAN): Molex 43650-0301

An auxiliary connector exclusively used to connect the fan cooling RFGM module.

24VDC: Molex 43045-0202

Low voltage to the module

Designation	Pin	Description
+24VDC	1	24VDC power supply connection Maximal current consumption – 1A
COMM 24VDC	2	

HV INPUT: Molex 2601-3114

High voltage (up to 500VDC) to the module

Designation	Pin	Description
HV	1	High voltage power supply connection Maximal input voltage – 500VDC Nominal input voltage is model dependent
COMM HV	2	

LVDS: Molex 43045-0401

LVDS input is used either to run module in external synchronization mode or to organize a parallel connection of multiple modules. By default, LVDS connector in non-functional, but available on customer's request (see also *How to order?* section, p.12).

Designation	Pin	Description
+IN for 'slave' modules +OUT for 'master' modules	1	Logic input, LVDS – external oscillator non-inverting input (output)
-IN for 'slave' modules -OUT for 'master' modules	2	Logic input, LVDS – external oscillator inverting input (output)
LVDS COMM	3	Common wire for external oscillator input (output)
LVDS SCREEN	4	Ground point for electrical screen of external oscillator cable (N/C by default, available on request)

GROUND: 6.35mm Quick-Connect terminal, male

Protective grounding should be organized by using this stud.

RF OUTPUT: N-TYPE

N-TYPE RF connector by Amphenol (5/8-24 thread, female).
RF Output return is interconnected to RFGM chassis.

Grounding policy

The following considerations should be taken into account:

1. RF Output return is interconnected to RFGM chassis.
2. Due to safety reasons, RFGM chassis must be protectively grounded.

Specifications

ELECTRICAL

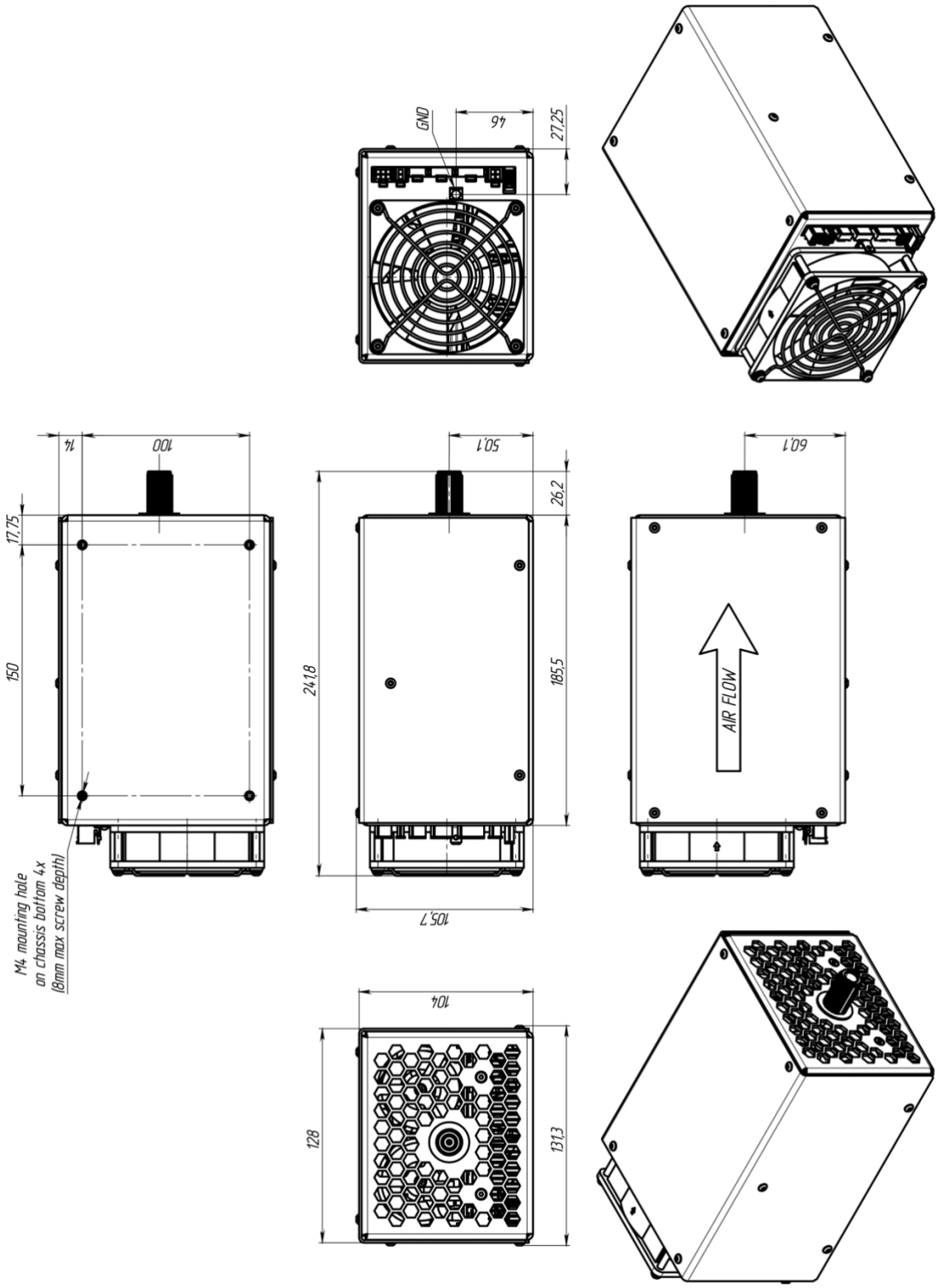
General	
Product	RF power module
Schematics	Class E power generator
Input	
HV Input	DC voltage, regulated, 300V-500V max (model dependent)
HV power consumption	2000W max (model dependent)
LV Input	24VDC
LV current consumption	1A max
Output	
Load impedance	50 Ohm
Frequency	6.78MHz, 13.56MHz, 27.12MHz, 40.68MHz, 81.36MHz (other on request), fixed, selectable at the moment of order
Peak power (W_{MAX})	1500W max (model dependent)
Duty cycle	0-100%
Average power	0-W_{MAX}
Output connector	N-TYPE RF connector by Amphenol (5/8-24 thread)
Interfaces	
Analogue	+ (a set of TTL signals)
Digital	+ (RS-485 by default, other on request)

Other	
Protections	- Overtemperature protection - Short-circuit tolerance - Open-circuit tolerance (short-time) - Protection from too high reflected power
Safety features	Power monitors Capacitive coupling of the output
Grounding	Output return is connected to the chassis
Cooling	Forced air cooling with built-in fan
Power combining of multiple modules	+ (two modules can be connected in master-slave mode; for connection of three and more modules an appropriate controller is needed; an appropriate power combiner is needed in all cases)

MECHANICAL

Dimensions	See dimensional drawing below
Weight	Approx. 2.5 kg

Dimensional drawing



How to order?

RFGM-XXX-YYY-ZZ, where:

- XXX means the working frequency of the module;
  the most standard frequencies are 6.78MHz, 13.56MHz, 27.12MHz, 40.68MHz and 81.36MHz, other frequencies are available on request
- YYY means the maximal output power of the module;
  typically the maximal power is in range from 300W to 1500W, other output power values can be considered on request
- ZZ means the type of the module;
  none or 0 – stand-alone module (not suitable for master-slave operations)
  M – master (master unit for master-slave operations)
  S – slave (master unit for master-slave operations

Master-slave connection of two modules allows to increase the maximal output power twice and achieve 1000W to 3000W power levels.

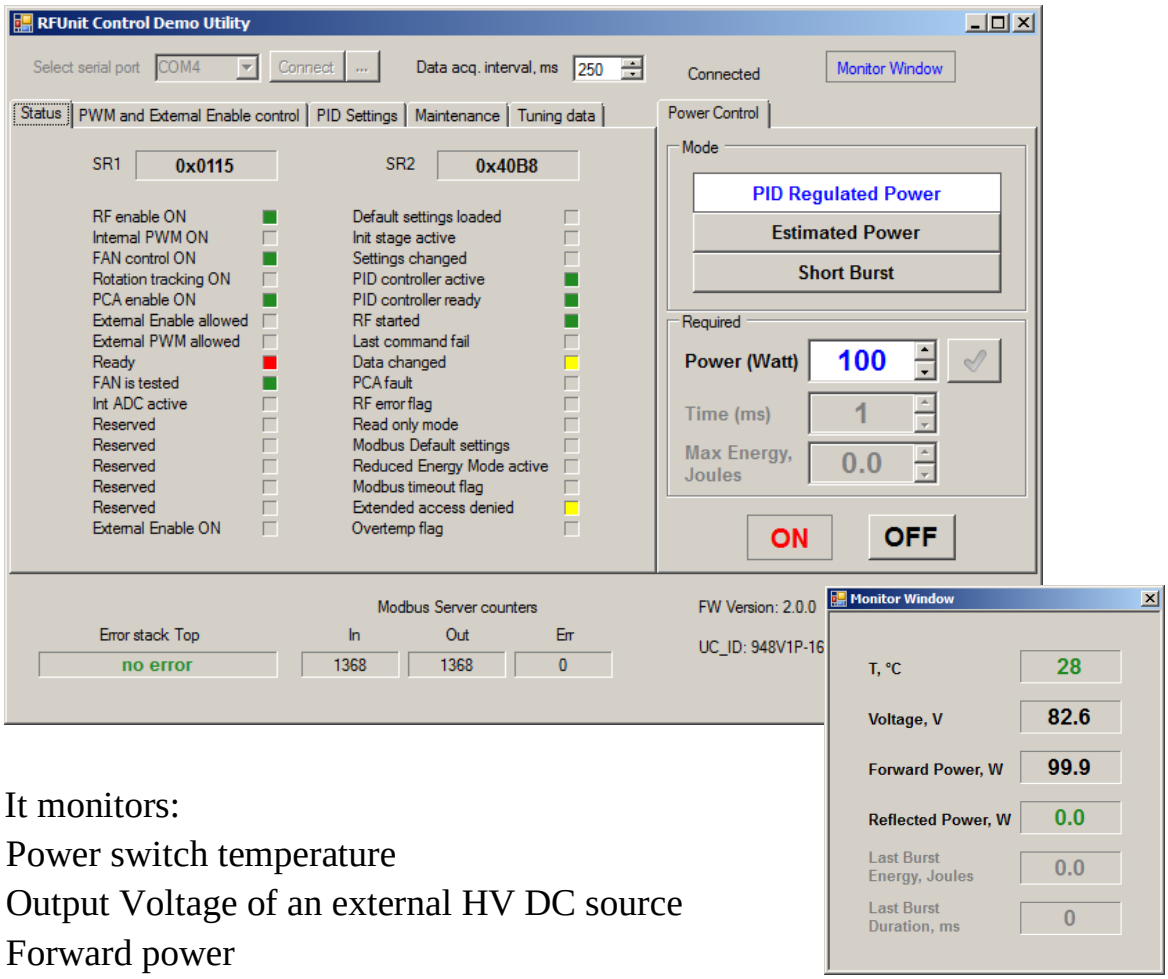
Examples (the most popular modifications):

Frequency	Output power	Description	Part numbers
0.5-4MHz	Up to 1500W	Easily available as modifications of 6.78MHz model All parameters are configurable	Custom
6.78MHz	800W	Suggested HVDC source - PCA-10-300V-PD	RFGM-6.78-800
	1500W	Suggested HVDC source - PCA-20-500V-PD	RFGM-6.78-1500
13.56MHz	800W	Suggested HVDC source - PCA-10-300V-PD	RFGM-13.56-800
	1500W	Suggested HVDC source - PCA-20-500V-PD	RFGM-13.56-1500
27.12MHz	500W	Suggested HVDC source - PCA-10-300V-PD	RFGM-27.12-500
	1000W	Suggested HVDC source - PCA-10-300V-PD for 800W operations and below or PCA-20-500V-PD for 1000W operations	RFGM-27.12-1000
40.68MHz	500W	Suggested HVDC source - PCA-10-300V-PD	RFGM-40.68-500
81.36MHz	300W	Suggested HVDC source - PCA-10-300V-PD	RFGM-81.36-300

Other modifications with different output power, operating frequency as well as other parameters are available on request.

Appendix 1. Software description

Software tool ***RFUnit2GenDemo***, a service and demo utility for *Microsoft Windows* operating system, is supplied with every RFGM-series module to control it.



It monitors:

- Power switch temperature
- Output Voltage of an external HV DC source
- Forward power
- Reflected power
- Transferred energy (in some modes)
- Onboard subsystems status
- Communication statistics

And also allows to control:

- Power generating mode
  - Embedded PID Controller's regulated Forward Power
  - Estimated (Forward) Power
  - Short Burst (for a given time)
- *Required (Forward) power* level
- *External Enable* use
- External/Internal *PWM* source
- *Internal PWM* source parameters

- *Embedded PID Controller*'s settings
- Communication port settings and nonvolatile memory.

Power generating modes:

PID Regulated

Required forward power (can be preset or changed on the go, Modbus registers 36-37) is regulated by embedded PID controller. This mode allows using *External Enable* and doesn't allow to activate PWM.

Estimated Power

Required forward power (can be preset or changed on the go, Modbus registers 36-37) is achieved by settings the appropriate PCA voltage (firmware calculated). This mode allows using *External Enable* and allows *PWM* applying.

Short Burst

Required forward power (should be preset, Modbus registers 36-37) is achieved by setting the appropriate PCA voltage (firmware calculated). Power generation lasts no longer than the set *Time* (in milliseconds, Modbus register 109) and is limited by the set *Max Energy*, transferred to the load (in Joules, Modbus registers 110-111) during the "burst". After "burst" completion, amount of transferred energy and actual "burst" duration may be read from Modbus registers 140-141 (Joules) and 112 (milliseconds). This mode allows using *External Enable* and doesn't allow to activate *PWM*.

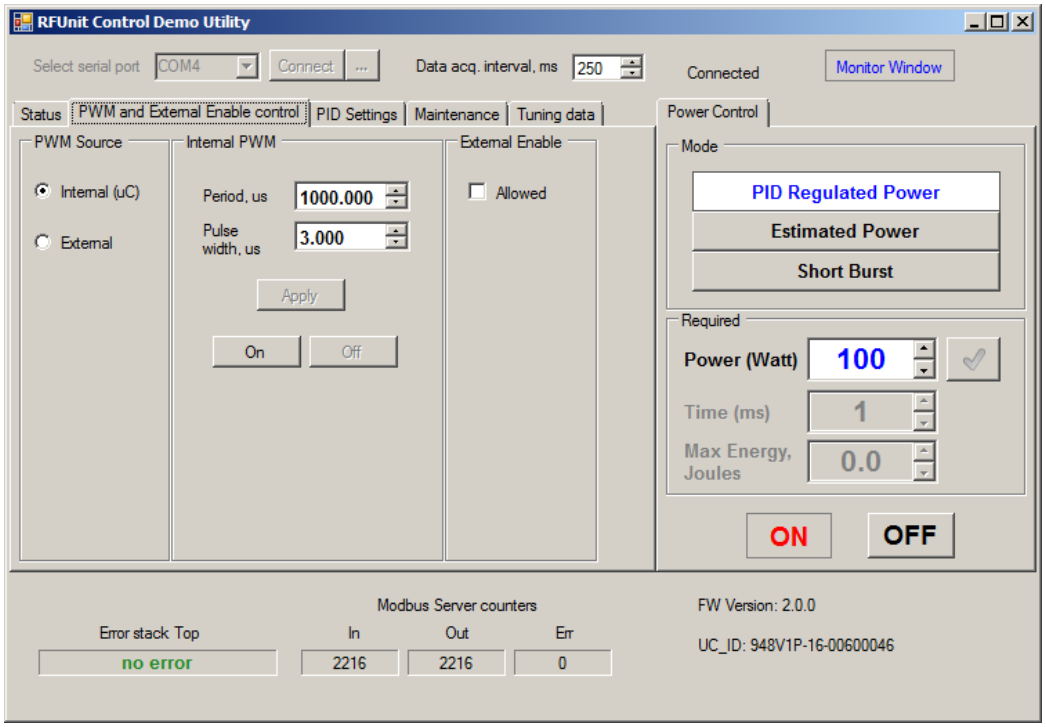
External Enable and PWM control

External Enable (external hardware provided logic) signal works as hardware **ON**(high level)/**OFF**(low level) button like software buttons "ON" and "OFF" demo utility's *Power Control* panel. It starts/stops power generation if allowed (write Modbus register 34 or use demo utility's *PWM and External Enable control* tab to allow/deny select).

If use power generating mode ***Estimated Power,*** it is possible to apply ***Power control*** (**PWM)** to RF power output:

- Internal, with selected period (Modbus registers 46-47) and pulse width (Modbus registers 44-45). PWM start/stop with command (Modbus register 32) or click ***On*** and ***Off*** buttons demo utility's *PWM and External Enable Control* tab.
- External (external hardware provided logic)

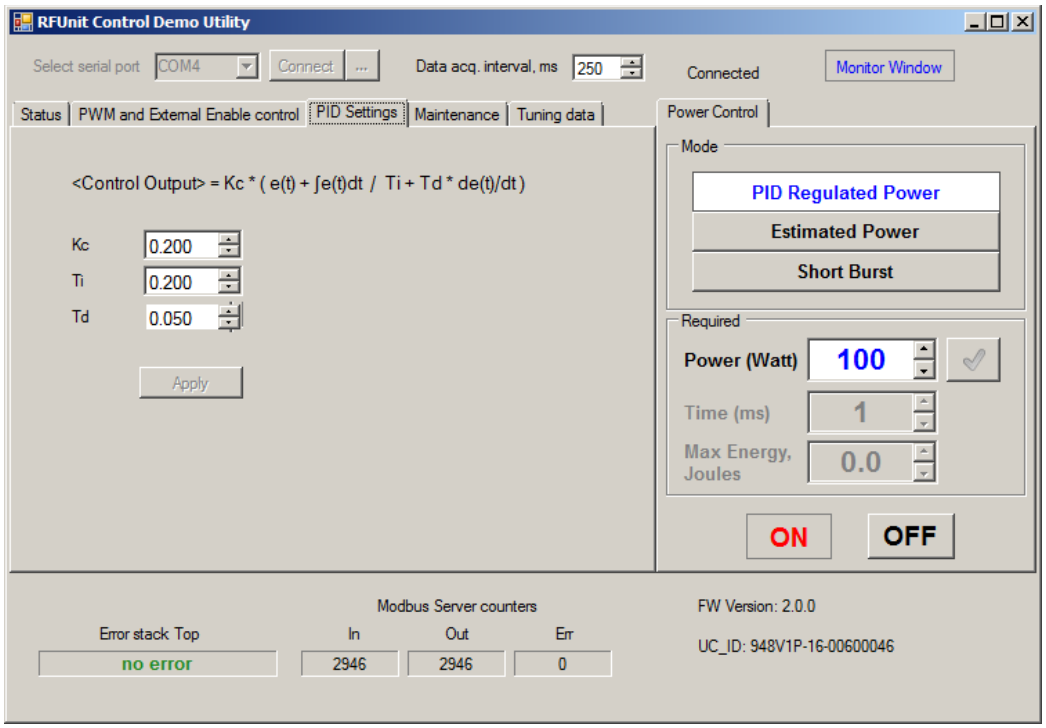
Write Modbus register 33 to select PWM source.



PID controller

PID (proportional–integral–derivative) controller settings are factory adjusted and may be corrected in accordance with the load's characteristics.

Use demo utility or write Modbus registers 38-43.

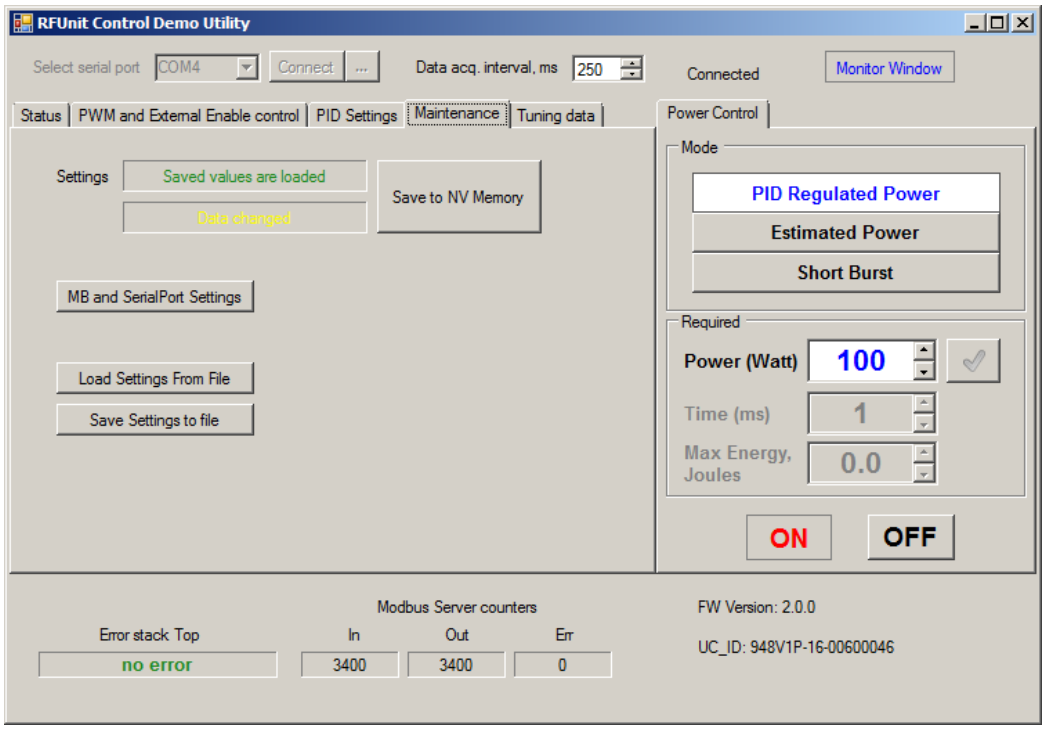


Communication port settings and nonvolatile memory

Modbus **Node ID** (1..247), **Baud rate** (up to 230400) and **Parity** (Odd, Even, None) may be adjusted (use "MB and SerialPort Settings" button on Tab Page "Maintenance" of the demo utility).

New settings (for communication port, power generating mode, required power and so on) made using demo utility or writing to Modbus registers will be used as default on next power up if save it to module's nonvolatile memory (click button "Save to NV Memory" on Tab Page "Maintenance" of the demo utility or write Modbus register 35).

Current settings may be saved to file or early saved may be loaded if click buttons "Save Settings to file" and "Load Settings From File" accordingly.



Operations (via RS-485 interface)

1. Connect RFGM module to low voltage power supply, high voltage power supply, to the load and to your PC
2. Apply low voltage to RFGM module, run the software
3. **Select serial port**, where the module is connected to, press **Connect** button (in case of using demo utility)
4. Apply mains to high voltage power supply
5. Select power generating mode (write Modbus register 30), output power value (write Modbus registers 36-37), *External Enable* allowance and *PWM* source (if need)
6. Press **ON/OFF** buttons (in case of using demo utility) or write Modbus register 31 to start/stop RF generating and provide power to the output.

LEDs

Two colors (red and green) LEDs on module's Side 1 light as follows:

- Green continuous – module is powered up, RS-485 and Modbus were initialized with custom settings, no serial communication.

- Green blinking – module is powered up, RS-485 and Modbus were initialized with custom settings, serial exchange with host is in progress.
- Green/Red toggling – like previous, but module isn't ready (PCA fault active, or RF error active, or overheat).
- Yellow continuous – module is powered up, RS-485 and Modbus were initialized with factory default settings, no serial communication.
- Yellow blinking – module is powered up, RS-485 and Modbus were initialized with factory default settings, serial exchange with host is in progress.
- Yellow/Red toggling – like previous, but module isn't ready (PCA fault active, or RF error active, or overheat).
- Red blinking – RF generating is in progress.
- Red continuous – main flash memory test fail, module is unworkable.

Appendix 2. RS-485 interface description

Embedded Modbus RTU server expects **periodic activity** (at least one valid Modbus package per second) to continue power generation. Else RF power generation is stopped emergently.

Embedded Modbus RTU server supports following functions:

Function code	Description
03 (0x03)	Read Holding Registers
16 (0x10)	Preset Multiple Registers

It is possible to use different software for RS-485 digital interface testing - for example ***RFUnit2GenDemo*** (an utility, provided by OEM Tech, see also *Software description* section), **QModBus** (a free Modbus master application) or your own

Modbus Register Mapping.

Address (Base 0), decimal	R/W(1)	Description	Data format
0	R	Status Register 1 (SR1)	Unsigned integer 16 bits: Bit 0: Internal RF “Enable” state 0-off, 1-on. Bit 1: Internal PWM state 0-off, 1-on. Bit 2: FAN control state 0-off, 1-on. Bit 3: Reserved. Bit 4: PCA “Enable” state 0-off, 1-on. Bit 5: External “Enable” allowance 0-not allowed, 1-allowed. Bit 6: PWM source 0-internal, 1-external. Bit 7: Ready (to start power generating) 0-not ready, 1-ready. Bit 8: FAN is tested 0-test fail, 1-test passed. Bit 9 – Bit 14: Reserved

			Bit 15: External “Enable” state 0-off, 1-on.
1	R	Status Register 2 (SR2)	Unsigned integer 16 bits: Bit 0: **Default settings loaded** flag 0-not loaded, 1-loaded. Bit 1: **Init stage** flag 0-not active, 1-active. Bit 2: **Settings changed** flag 0-not changed, 1-changed (communication parameters and other) Bit 3: **PID controller run** flag 0-not running, 1-running. Bit 4: **PID controller ready** flag 0-not ready, 1-ready. Bit 5: **RF power generating started** flag 0-not started, 1-started. Bit 6: **Last command failed** flag 0-not failed, 1-failed. Bit 7: **Data changed** flag 0-not changed, 1-changed (sources select, power mode, PWM, required power) Bit 8: **PCA Fault is active** flag 0-not active, 1-active. Bit 9: **RF error is active** flag 0-not active, 1-active. Bit 10: **Read only mode** flag 0-read/write registers, 1-ready only. Bit 11: **Modbus default settings** flag 0-user settings, 1-factory default. Bit 12: **REM is active** flag 0-not active, 1-active (**R**educed **E**nergy **M**ode, auto-activated if reflected power

			threshold exceeded for a long time, factory tuned) Bit 13: **Modbus timeout** flag 0- timeout not exceeded, 1- timeout exceeded. Bit 14: **Extended access** flag 0- granted, 1- denied. Bit 15: **Overheat** flag 0-not overheated, 1- Power switch overheated.
2	R/W	Error Stack Top value	Unsigned integer 16 bits. Error codes (**Read**): 0 – no error 1 – HV PS Fault 2 – RF error 3 – reflected power threshold exceeded 5 – overheat 7 – default settings was set 8 – heart beat timeout exceeded (1 second) 9 – HV PS output voltage is too high. **Write** any value to pop an Error Stack by one
3	R	Power switch temperature, °C	Unsigned integer 16 bits.
4 5	R	HV PS output voltage, Volts	Single precision float (IEEE754), little endian: Address 4 – low 16 bits, address 5 – high 16 bits.
6 7	R	Forward power monitor value, Watts	Single precision float (IEEE754), little endian: Address 6 – low 16 bits, address 7 – high 16 bits.
8 9	R	Reflected power monitor value, Watts	Single precision float (IEEE754), little endian: Address 8 – low 16 bits, address 9 – high 16 bits.
10 11	R	Modbus server: received requests counter (reset on power up)	Unsigned integer 32 bits, little endian: Address 10 – low 16 bits, address 11 – high 16 bits.

12 13	R	Modbus server: transmitted answers counter (reset on power up)	Unsigned integer 32 bits, little endian: Address 12 – low 16 bits, address 13 – high 16 bits.
14 15	R	Modbus server: error counter (reset on power up)	Unsigned integer 32 bits, little endian: Address 14 – low 16 bits, address 15 – high 16 bits.
16	R	Modbus server: buffer overflow errors count	Unsigned integer 16 bits.
17	R	Modbus server: bad CRC errors count	Unsigned integer 16 bits.
18	R	Modbus server: bad size errors count	Unsigned integer 16 bits.
19	R	Modbus server: bad function code errors count	Unsigned integer 16 bits.
20	R	Modbus server: address range errors count	Unsigned integer 16 bits.
21	R	Modbus server: registers quantity errors count	Unsigned integer 16 bits.
22	R	Firmware Version	Unsigned integer 16 bits. 10203 means version 1.2.3
23	R	Product ID	Unsigned integer 16 bits.
24 25 26 27 28 29	R	Embedded microcontroller's Device ID.	96-bit unique microcontroller ID (STM32G0x1 Device electronic signature)
30	R/W	Power generating mode	Unsigned integer 16 bits. 0 - Embedded PID Controller's regulated 1 - Estimated Power 2 – Short Burst (for a given time)
31	W	Power generating Start/Stop Command	Unsigned integer 16 bits. 0 – Stop, 1 – Start (in mode selected earlier)
32	W	Internal PWM Start/Stop Command	Unsigned integer 16 bits. 0 – Stop, 1 – Start (with PWM timing selected earlier)

33	W	PWM source select command	Unsigned integer 16 bits. 0 – Internal, 1 – External
34	W	External “Enable” allow/deny command	Unsigned integer 16 bits. 0 – deny, 1 – allow
35	W	Save ALL modified parameters to NV memory command(to use as defaults after next power up	Unsigned integer 16 bits. Write any value.
36 37	R/W	Required output power value	Single precision float (IEEE754), little endian: Address 36 – low 16 bits, address 37 – high 16 bits.
38 39	R/W	**PID** controller’s **Kc** parameter	Single precision float (IEEE754), little endian: Address 38 – low 16 bits, address 39 – high 16 bits.
40 41	R/W	**PID** controller’s **Ti** parameter	Single precision float (IEEE754), little endian: Address 40 – low 16 bits, address 41 – high 16 bits.
42 43	R/W	**PID** controller’s **Td** parameter	Single precision float (IEEE754), little endian: Address 42 – low 16 bits, address 43 – high 16 bits.
44 45	R/W	Internal PWM generator’s pulse width (microseconds)	Single precision float (IEEE754), little endian: Address 44 – low 16 bits, address 45 – high 16 bits.
46 47	R/W	Internal PWM generator’s period (microseconds)	Single precision float (IEEE754), little endian: Address 46 – low 16 bits, address 47 – high 16 bits.
109	R/W	Required time interval for **Short Burst** power generating mode (milliseconds)	Unsigned integer 16 bits.
110 111	R/W	Max Energy for **Short Burst** power generating mode (Joules)	Single precision float (IEEE754), little endian: Address 110 – low 16 bits, address 111 – high 16 bits.
112	R	Last “shoot” actual duration for **Short Burst**	Unsigned integer 16 bits.

		power generating mode (milliseconds)	
140 141	R	Transferred energy (Joules), for last “burst” in **Short Burst** power generating mode.	Single precision float (IEEE754), little endian: Address 140 – low 16 bits, address 141 – high 16 bits.

1. R – read only, W – write, R/W – read and write.

Non**V**olatile **Memory**

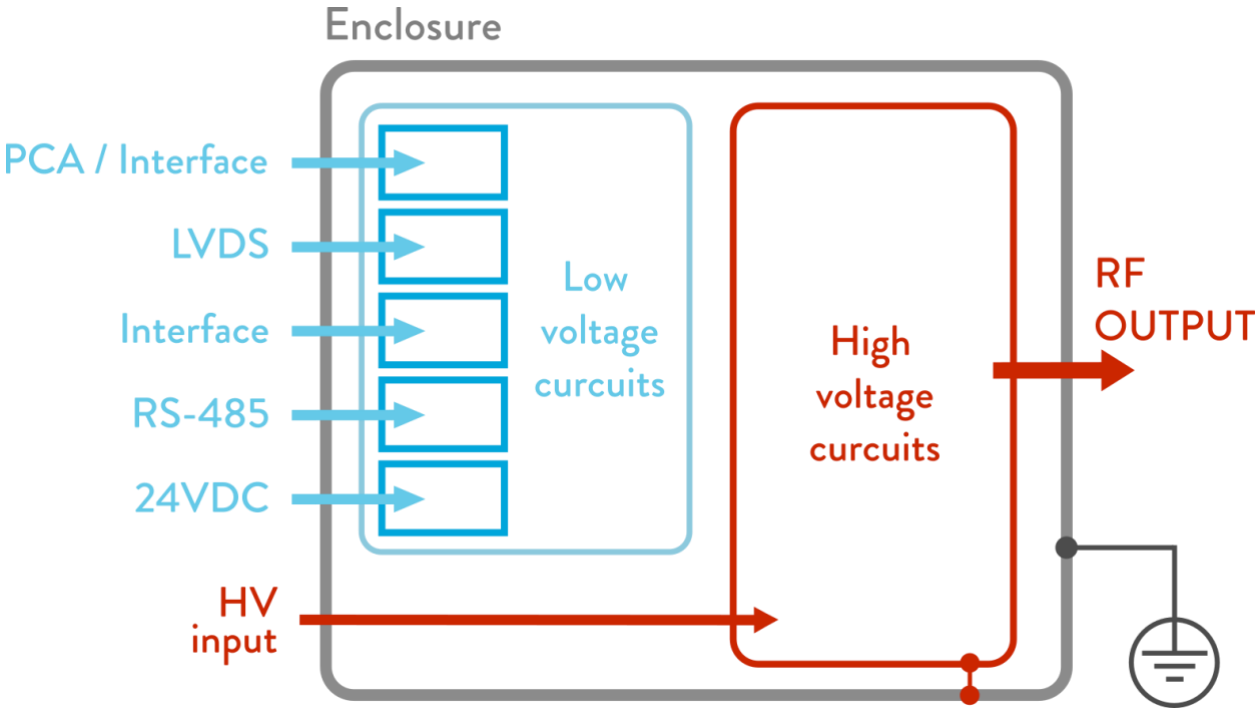
At power up all writable Modbus registers are initialized with values stored in module’s nonvolatile memory. Any changes in settings (power mode, required power, External Enable, PWM settings, Modbus parameters and so on) may be saved to NV Memory to use as default after next power up (write Modbus register 35 or use “Save to NV Memory” button on Tab Page “Maintenance” of the demo utility).

Current settings may be saved to external file (use demo utility, Tab Page “Maintenance”, click “Save Settings to file” button and follow instructions) for a future using.

It is possible to initialize module’s nonvolatile memory with data from factory provided or previously saved custom external file (use demo utility, Tab Page “Maintenance”, click “Load Settings From File” button and follow instructions).

Open demo utility’s Tab Page “Tuning data” to see some factory and custom settings.

Appendix 3. Insulation diagram (safety diagram)



Gray – chassis (must be protectively grounded)

Red – high voltage circuits and circuits with no galvanic insulation from high voltage circuits

Blue – low voltage circuits; insulation of low voltage circuits from high voltage circuits is 4mm creepages, 4mm clearances, 1500V test voltage; insulation of low voltage circuits from other low voltage circuits is 2.5mm creepages, 2.5mm clearances, 1500V test voltage

Grounding policy

The following considerations should be taken into account:

1. RF Output return is interconnected to RFGM chassis.
2. Due to safety reasons, RFGM chassis must be protectively grounded.