

Manual for Remote Control of the RF Generator from Coaxial Power Systems

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1 Introduction

Atmospheric pressure plasmas are often operated at high frequencies in the RF regime. For example, the COST reference atmospheric pressure plasma jet developed by Golda et al. is driven at a frequency of 13.56 MHz [1].

One possible generator model for RF frequencies at 13.56 MHz is provided by the company Coaxial Power Systems Ltd (E Sussex, UK) namely the RFG 50-600W. The data sheet of the generator can be found under <https://www.coaxialpower.com/documents/RFG-50-600.pdf>.

The RFG 50-600 offers the possibility for remote control. This is quite useful as most equipment in laboratories is digitally controlled, such as mass flow controllers or oscilloscopes. With a remote control of the generator, all devices can be controlled remotely and the experiment can be controlled automatically.

The company offers a cable to connect the RFG 50-600W generator to a RS-232 interface. However, the control of the generator via the RS-232 interface and using LabView as software tool turned out be tricky and did not work at all. To overcome this problem, the generator can also be controlled remotely by directly addressing the pins of a 25-pin D-connector on the back of the generator. The functions of the 25-way D type connector of the generator, the use of an Arduino board to perform the communication with the generator and a software programmed in LabView or python are explained in this manual.

2 Remote Control

The remote control connector on the rear panel of the RFG 50-600W generator consists of 25 pins with various functions. The required pins to control the generator remotely are explained in the following and can be found on page 13 in the manual of the generator provided by the company (attached to this manual):

- Pin 1 "Remote power negative": Reference point to pin 2 (just ground this one).
- Pin 2 "Remote power positive": The set point or control is a positive voltage in the range 0 V to 5 V. 0 V gives zero output power and 5 V gives maximum output power.
- Pin 3 "Forward power": Measure of incident power with an analogue output voltage 0 - 5 V representing zero to maximum output power.
- Pin 4 "Reflected power": Measure of reflected power with an analogue output voltage 0 - 5 V representing zero to maximum.
- Pin 5 "Remote RF on": To switch RF on and off connect this pin to a ground pin, via a switch, transistor or relay.
- Pin 6 "Pulse Mode": Indicator whether the pulse mode is turned off or on. It is a pen collector transistor that grounds with RF Off. This can sink 20 V and 45 mA.
- Pin 7 and Pin 8 "Ground": Ground from generator.
- Pin 13 "External interlock": When this pin is connected to +12v it allows the generator output to be switched on. When this pin is open-circuit the "External" warning light will illuminate.
- Pin 14 "RF off indicator": Indicator whether the RF power is turned off. It is a pen collector transistor that grounds with RF Off. This can sink 20 V and 45 mA.
- Pin 15 "Enable Remote RF on": Ground this pin to enable the remote RF On/Off control function, when it is enabled the remote indicator on the front panel is illuminated.
- Pin 17 "Enable Remote Setpoint": Ground this pin to enable the remote setpoint control, when it is enabled the remote indicator on the front panel is illuminated.
- Pin 19 "RF on Indicator": Indicator whether the RF power is turned on. It is a pen collector transistor that grounds with RF Off. This can sink 20 V and 45 mA.

- Pin 20 "5 V 500 mA": This is a 5 V 500 mA Output.
- Pin 21 "Enable True Power":
- Pin 25 "12 V/24 V 500 mA": Positive supply, 12 V or 24 V depending on specific RFG model.

All other pins are useless for the remote control described in this manual.

3 Arduino

The read out of pins 3 and 4 (forwarded power and reflected power) and the write of pin 2 (set power) are based on 5 V signals. An Arduino board can be used to provide the signal. The Arduino was developed as a simple tool for controlling various tasks without requiring deep knowledge about electronics or programming. It is inexpensive and the software is available as open source. The Arduino can be connected to a computer via USB connection and provides the required 5 V signal. Some pins of the remote control need higher signals than 5 V. For example, to enable the remote RF ON/OFF function, pin 15 must be connected to ground. This can be done by the Arduino board, however, in the disabled state, the pin has a signal of 12 V. If the 5 V signal of the Arduino is used, this pins would always be in the enabled state, as 5 V is still ground for the generator. To overcome this problem, optocouplers are used. The Arduino is connected to one side of the optocoupler (using 5 V signal). The other side of the optocoupler is connected to the desired pin of the 25-way D type connector and pin 25 which provides 12 V.

Schaltplan

4 LabVIEW

With the 25-pin D connector, a corresponding 25-pin cable, the Arduino board and a board containing the electrical circuit with optocouplers, the hardware for remote control of the generator is complete. One possible software to control the Arduino is LabVIEW. To establish communication between LabVIEW and the Arduino, the following steps must be carried out:

- Download the "Arduino IDE" software from <https://www.arduino.cc>
- Using the LabVIEW package manager (VIPM), install the Arduino package "LabVIEW Interface for Arduino"
- Load the LIFA Base file in the Arduino software (can be found in the following folder: C:\Program Files\National Instruments\LabVIEW 2021\vi.lib\LabVIEW Interface for Arduino\Firmware\LIFA_Base).
- Select the right board type and serial port
- Upload LIFA Base program on the Arduino

The LabView program is available on github: <https://github.com/st3ff3n96/Coaxial-RF-Generator-Control.git>. A picture of the user interface is shown in figure 1. At the top right, the generator can be switched ON and OFF. The plasma can be turned ON and OFF with the button at the bottom right. The status of the plasma (ON or OFF) is indicated by two LEDs at the bottom left, a green LED for OFF and a red LED for ON. Above the "Turn plasma ON" button, the generator power can be set. The set value corresponds to the percentage of the maximum generator power. If the set value is higher than 50 %, a pop-up window appears asking the user if this high power value should be set. If the user agrees, the value is set; if "No", the power is set to 50 %. The forwarded and reflected power are displayed on two gauges in watt. An LED in the center of the user interface indicates the status of the emergency switch. If this LED is red, the emergency button is activated and no plasma can be ignited. The general function to enable the power setting and to activate the plasma ON and OFF function is given at the top left.

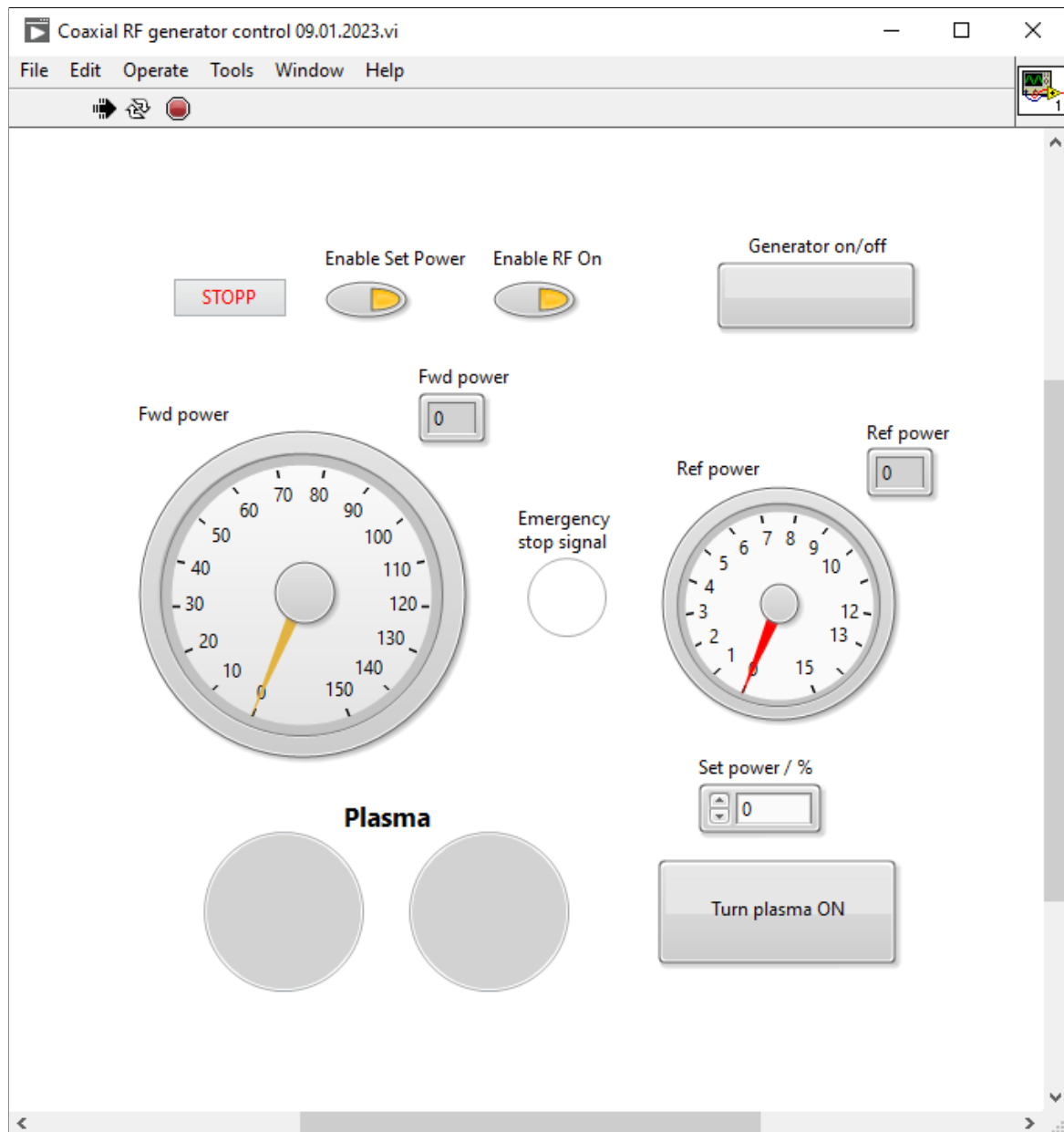


Figure 1: User interface of the LabView program to control the RF generator.

5 Python

References

- [1] J. Golda et al. “Concepts and characteristics of the ‘COST Reference Microplasma Jet’”. In: *Journal of Physics D: Applied Physics* 49.8 (Mar. 2, 2016), p. 084003. DOI: 10.1088/0022-3727/49/8/084003.

RFG 50W-600W

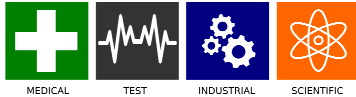
RF Generator / RF Power Supply

INSTALLATION AND OPERATING INSTRUCTIONS



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RFG 50-600



The **RFG 50-600 (0-600W)** RF generator is a precision unit intended for both scientific and industrial applications. The robust construction using the latest in switch mode and solid-state design techniques ensure a long and trouble free life even in harsh environments.

The generator is totally air-cooled which considerably reduces its service requirements and allows simple installation.

The small size of the unit makes it ideal for use where there is restricted rack space.

It is recommended that the generator be used in conjunction with either a manual or automatic impedance matching network. Both types are available from Coaxial Power Systems Ltd – please see the separate brochure for details.

Available models

RFG 050-370,380,2,4,13 or 27MHz.
RFG 100-370,380,2,4,13 or 27MHz
RFG 150-370,380,2,4,13 or 27MHz
RFG 300-370,380,2,4,13 or 27MHz
RFG 600-370,380,2,4,13 or 27MHz

Main features


- Efficient Class-E design
- Rack-mount design as standard.
- Compact (ideal for restricted rack space).
- Analog and RS-232 interfaces available.
- 110/240 VAC single phase – As standard (other voltages are available)
- Half-rack, 2U (89mm) high
- External control of output voltage. (Useful in sputter coating applications).
- Feedback control system ensures that the set output power remains constant and repeatable.
- Microprocessor display of incident (forward) power, reflected power and unit status
- Precision power control +/- 1% of set point.
- Fast pulse operation from TTL/CMOS input
- 370KHz, 380KHz, 2MHz, 4MHz, 13.56MHz and 27.12MHz frequencies available as standard.

(Non-standard frequencies are available - please contact factory for details).

The output power of each generator is fully adjustable between zero and maximum power. The feedback control system ensures that the set output power remains constant and repeatable.

Option (please enquire)

An external voltage of 0 to 5Volts can be used to control the output. This is particularly useful in sputter coating applications where the DC voltage developed across the plasma dark space can be controlled rather than the RF power.

Physical	
Model Variants	RFG 50/100/150/300/600-370 (370 KhZ) RFG 50/100/150/300/600-380 (380 KhZ) RFG 50/100/150/300/600-2 (2MHz) RFG 50/100/150/300/600-4 (4MHz) RFG 50/100/150/300/600-13 (13.56MHz) RFG 50/100/150/300/600-27 (27.12MHz) RFG 50/100/150/300/600-40 (40.68MHz)
Dimensions	Half rack mounting - 2U high Length: 502 mm, Height: 89mm, Width (Not inc Front Panel) 210mm Width (Inc Front Panel) 241mm
Weight	8 Kg (18 lb) max.
Front panel Material / Colour	Aluminium, RAL7135 Light Grey.
Chassis and Cover Material	Stainless Steel.
Connector and Cable Specifications	
RF Output Connector	N type / 50 Ω
User Port Connector (Analogue & RS-232)	25-pin, Sub-Miniature 'D' Female, with 8mm 4-40 jack post
AC Power Input Connector / Cable	IEC Socket
Input + Ouput CEX / Drive Connector	Input: SMA, Coaxial Sub-Miniature / Output: SMA, Coaxial Sub-Miniature
Pulse Input Connector	SMA, Coaxial Sub-Miniature
AMNC Readout connector (Optional)	Lemo – Circular Connector, 3 contacts.
Earth Connection	M4 Threaded Bush
Electrical	
Input Power	110-240 VAC, Single Phase (50/60Hz) Other options are available; please contact us for more information.
Output Power / Impedance	600-Watts MAX Continuous / 50 Ω (Variants inc 0-50W / 0-100W / 0-150W / 0-300W / 0-600W)
RF Frequency Stability	+/- 0.005%
Interface Options	Analogue (Standard), RS-232 (Optional), Device-Net (Optional).
Power control resolution - Local	50-100W models ONLY (0.1W Increment resolution) 100-600W models ONLY (1W Increment resolution). 1000W+ models ONLY (5W Increment resolution).
Power control resolution - Remote	Higher resolutions are achievable via Analogue remote power control i.e 0.1W resolution on 1000W+
Efficiency	Up to 90%
Output Envelope Ripple	Less than 1% of full amplitude.
VSWR Capability	Can withstand VSWR at any phase angle.
Harmonic Output	Better than 40 dB below fundamental.
Pulse Operation via SMA input on rear panel	Minimum pulse width 40 μ s (micro-seconds). The external power control signal should vary the peak output from 0 to MAX-power with a pulse-on duty cycle from 0 to continuous (100% duty cycle).
Local Control and Remote Interface	
Local Control	Accessed via Front-Panel Controls: Line ON/OFF. RF ON/OFF. Digital output power set / Menu Control dial. Menu Switches. Remote switches: RF on/off control enable, O/P set on/off. Local switches: x0.1 / x1 (output range), CEX-OSC, PULSE-CW. Timer. VFD display showing: Forward (Incident) power / Reflected power / Reflected power exceed limit. Remote operation. Timer. Interlock status (cooling and external) AMN Readout on main display (optional)
Remote Interface	Accessed via User-Port. RF ON/OFF Incident Power indication Reflected Power indication Output set 0-5volts = 0-100% Remote output set request.
Specification is continued on the following page 	

Environmental	
Operating Temperature	0-40°C (32°F-104°F)
Storage Temperature	0-20°C to +65°C (-4 to 149°F)
Cooling Requirements	
Cooling	Forced-Air
Other	
Standards	CE Certification BS EN ISO 9001:2008 EN61000-3-2: 2006 EN6100-3-3/A2: 2005 EN61326-1: 2006 EN61010-1: 2001

Notes & Revision History
RS232 SECTION UPDATED – V.4.01 (27.04.17)

Warranty

Coaxial Power Systems Ltd offer a warranty for parts and labour (if returned to factory) for 1 year from date of despatch. The warranty is invalidated if the generator has suffered inappropriate treatment i.e. excessive vibration, mechanical denting or dropping, accidental liquid spill, excessive applied voltage to remote connectors etc. Coaxial Power Systems Ltd should be notified of all warranty claims before return of equipment.

Contact

Coaxial Power Systems LTD
 Spectrum House
 Unit 2 Finmere Road
 Eastbourne
 East-Sussex
 BN22 8QL

Tel: (+44) 01323 639974
 Email: sales@coaxialpower.com
 Web: www.coaxialpower.com



Unpacking and Installation

Items included in carton.

- RF Generator.
- 25 Way remote connector (supplied as standard).
- 3.2ft (1 Metre) RS-232 cable (only supplied if RS-232 Generator is ordered).
- IEC 10 Amp line connector with UK plug attached .
- 12ft (3.65M) RF output cable (RFG to AMN).
- Instruction Manual.

Remove all contents from carton and inspect generator for shipping damage. If there is any evidence of damage contact Coaxial Power Systems Ltd within 5 days of receipt.

**Installation must only be performed by suitably qualified authorised personnel.
This generator is designed to be fitted inside a suitable 19" rack enclosure. It should not be operated unless so fitted.**

- Place the generator inside a suitable 19-inch enclosure, which must include adequate runners for support.
- Ensure adequate ventilation is available at fan outlet rear panel (100mm clearance) and top and side vents (20mm clearance.)
- Ensure that the IEC Mains Inlet is accessible
- Connect the 25-Way remote connector into socket on rear panel (factory wired to bridge external interlock)
- Connect the earth stud on the rear panel to a safe reliable earth using a green/yellow insulated wire (14-gauge minimum) which should be as short as practical.
- Connect the generator to the mains supply using the supplied mains IEC connector. Always ensure that this connector is easily accessible. This generator operates from voltages in the range of 110V to 230V at 50 or 60Hz without the need for adjustment.
If a different mains connector is required then the moulded plug may be cut off and disposed of, and a suitable connector fitted.
- Ensure Pulse/CW switch on the front panel is in the CW position
- Switch on line breaker on rear panel. Front display, and RF Off light should illuminate.
- Rotate power set control to zero, press RF On. Rotate power set control towards maximum and output power should increase. Continue to rotate control to maximum and check that maximum obtainable power is correct. Press RF Off.

Safety Information

Labels denote potentially hazardous conditions such as mains voltages or significant RF power levels.

Caution



The black exclamation point within a yellow triangle is used on the RF PA module. The RF PA module should not be operated with the module lid removed.

Electric Shock Warning



A black electric flash within a yellow triangle is used to warn service and operating personnel of the presence of exposed contact areas where mains voltages or comparable hazards are present, which could cause severe electric shock if touched.

Safety Earth Warning



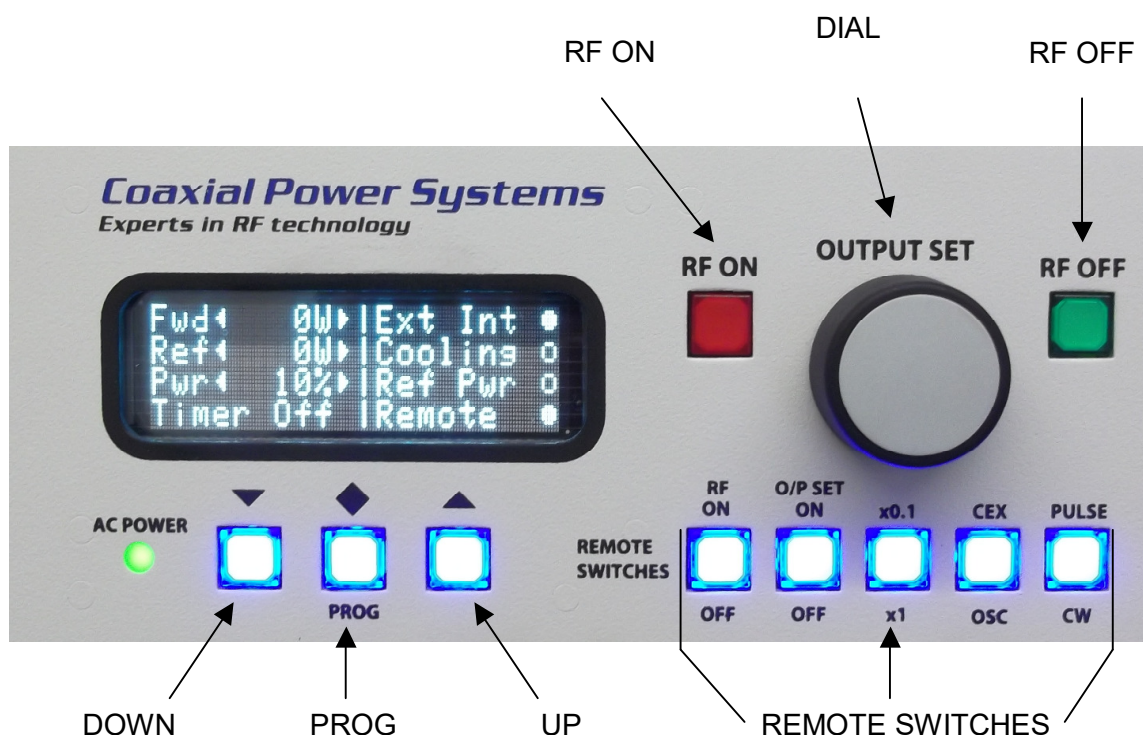
This symbol is used to indicate a safety earth attachment point/stud on the rear panel of the generator. **This safety earth connection must be made, using a green/yellow insulated wire (14-gauge minimum) and should be as short as practical**

Isolate before removing cover

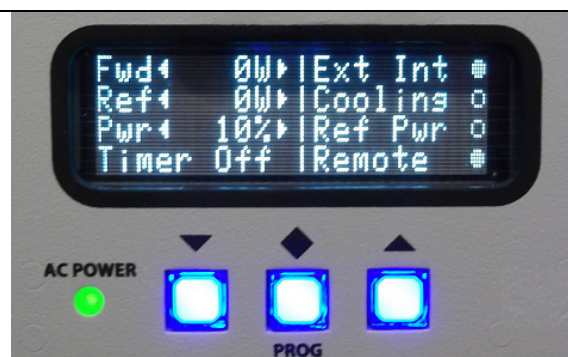


It is strongly recommended to remove mains power before removing a RFG cover, even if the unit is going to be powered up with the lid off for test purposes.

Front Panel Controls – Basic Description



Operating Modes



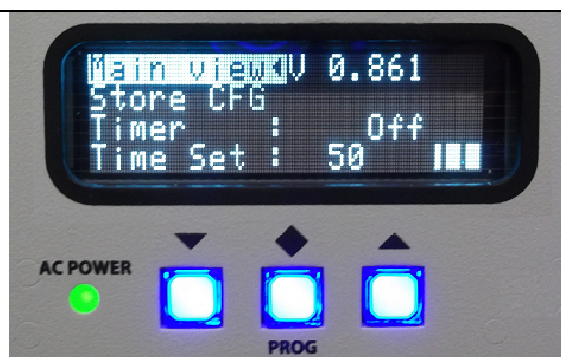
Main View

While operating in this mode, you are able to adjust the power with the **DIAL** and also long pressing the **UP** and **DOWN** buttons will adjust power with increments of 1%.

Power set percentage can be pre-set prior to turning the RF ON.

FWD and REF power are indicated once RF is turned on.

To reach the **MENU VIEW** you need to press the **PROG** button.



Menu View

To reach this menu, you need to press the **PROG** button.

This menu can be navigated either with the **UP** or **DOWN** buttons and also the **DIAL**.

To adjust settings on any option in the menu, press **PROG** then select mode with the **UP** and **DOWN** buttons or the **DIAL**, confirming action again with the **PROG** button.

To return to **MAIN VIEW** you need to highlight Main view at the top of the list and press the **PROG** button.

Front Panel Controls – Function Detail

Dial – Dual Functionality

Output set (Main view)

The control dial sets the output power, provided the unit is in “local power set” mode, meaning the remote power switch is in the off position and the remote power link is not made in the remote control connector.

Menu control (Menu view)

The control dial acts as a navigation button while in the **MENU VIEW** in the same way the **UP** and **DOWN** keys navigate

RF On and Off switches

The switches turn the RF output on and off, provided the unit is in “local on/off” mode, meaning the remote on switch is in the down position and the remote on/off link is not made in the remote control connector. The RF off switch is also used to reset a latched interlock condition when the unit is in “local on/off” mode, and to reset the initial “splash screen”.

Remote Switches

The blue pushbuttons work as toggle controls, press to enable a function (Lit) and press again to disable (Unlit).

These controls can also be enabled/disabled in the **MENU VIEW** state of the generator.

1. **RF ON / OFF - Remote control of RF On/Off**

Operating this switch locks out the RF on and off switches on the front panel so that RF is activated by a circuit on the remote connector.

2. **OP SET ON / OFF - Remote control of RF power**

Operating this switch locks out the Output set control on the front panel so that RF power is controlled by a voltage on the remote connector.

3. **x0.1 / x1 - Power control divide by ten**

This simply reduces the voltage span of the output set control to allow the setting of powers up to 10% with finer resolution.

4. **CEX / OSC - Common exciter enable**

On units that support this facility this enables a phase-locked-loop that synchronizes the RF output to a signal on CEX-in.

5. **PULSE / CW - Pulse operation enable**

This enables the pulse input facility. If this switch is up then RF can be rapidly gated by a “TTL” (5v logic) signal on the rear panel pulse input.

Main View – Display and menu controls



The display panel shows the following information:

- Forward RF power
- Reflected RF power
- Set power as a percentage
- Timer status and progress
- External Interlock
- Cooling interlock
- Reflected power cutback warning
- Remote control flag
- Matching network tune + load position

Note that in the event of the RF connector interlock being open this does not generate a specific warning, however the display will switch to its alternate “interlock” layout until the connector guard is refitted and the condition reset.

Interlock and Status Indicators

Ref Pwr: this is a warning of a high-reflected power level and illuminates if the reflected power exceeds the set limit, typically 10% of the maximum rated generator output.

Cooling: this indicates an over-temperature shutdown of the internal power amplifier module. The cooling interlock usually indicates inadequate ventilation.

Ext interlock: this indicates that the external interlock loop on the 25 way “Remote” D connector (Pin 13 to Pin 25) is not made. See Remote connector documentation.

Remote: this operates when either remote output set or remote RF On/Off request are enabled. A “Remote” condition indicates that the unit’s controls have been overridden.

In the event that RF operation is interrupted by an interlock the RF Off light will not illuminate and RF may not be enabled. The interlock state will latch until cleared by pressing RF off or removing the “Remote RF on” signal.

Menu View (RFG Setup Menu)

Pressing the PROG button enters the timer setup menu.

IF A PASSWORD HAS BEEN SET THEN THE UNIT WILL PROMPT FOR A PASSWORD BEFORE THE SETUP MENU CAN BE ACCESSED. THE PASSWORD IS A SEQUENCE OF UP TO EIGHT KEY PRESSES (UP, PROG or DOWN).

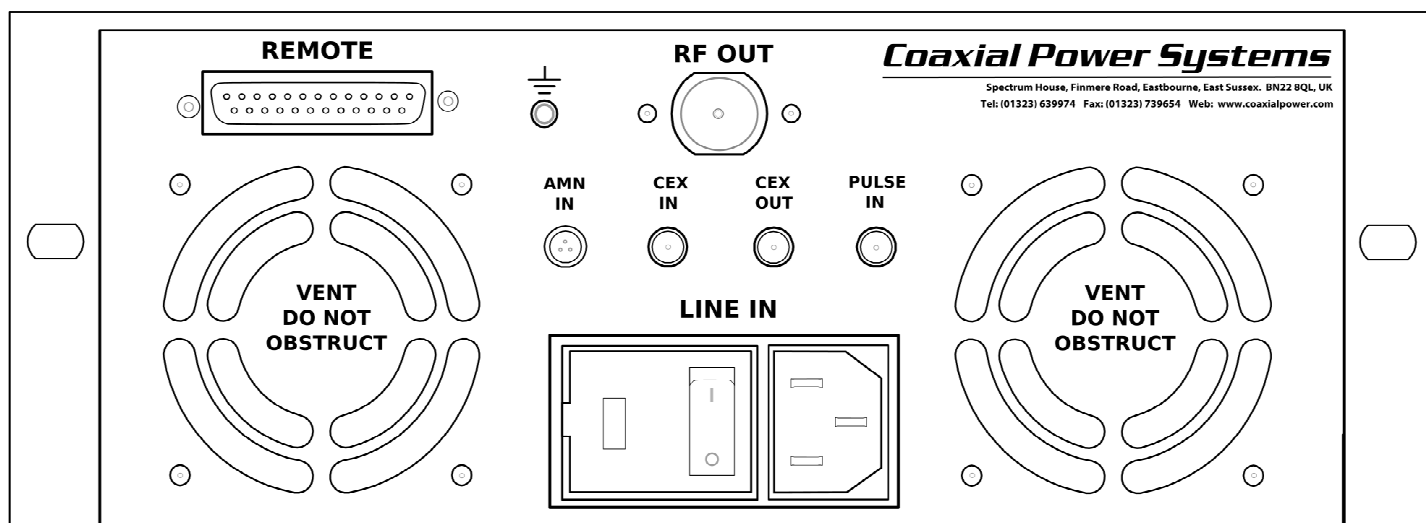
List of menu options:

Main view	Leave menu mode and return to main view.
Store CFG	Saves current configuration settings for future operation.
Timer select	Enable or Disable the run timer.
Time Set	Set the duration of the run timer 0-100 seconds/minutes.
Time Range	Select seconds or minutes scale for timer.
Cooldown	Enable or Disable the cool down timer, this inhibits RF for a time equal to the run time for applications with a duty limit.
Power Set	Set the power (or bias) level in units of 0.1% of full scale (0-1000). 100 units equates to roughly 10% of max power.
Ramp	Set the ramp time taken to reach full power in tenths of a second (200 max), set 0 to disable.
Tune and Load display	Select whether load, tune, and bias values should be displayed (OPTION).
Bias control/ Remote FB	Select bias-controlled operation.
Remote ON select	Select automatic/remote control of RF On.
Remote SET select	Select analog remote control of RFG power setting.
Divide 10 select	Limits the front panel control to 10% of RFG power.
CEX input select	Selects CEX modes e.g. synchronize to an external source.
Pulse select	Selects Pulse mode e.g. RFG output can be gated/modulated by a TTL pulse input.
Key Lock	Locks the five remote switches to prevent tampering.
Dial Lock	Locks the dial (except for in menu mode) to prevent tampering.
Display brightness	Allows the display intensity to be varied.
Tune	Diagnostic Value.
Load	Diagnostic Value.
Bias	Diagnostic Value.
User Pass	Sets a pass code consisting of a sequence of up to 8 button presses. To end the sequence wait for 5 seconds. The sequence must be re-entered to confirm correct entry
Show pass	If show pass is selected the key symbols will be shown as the password is entered. If hide is selected then stars are shown

Note if you do not STORE CFG before turning off the generator your most recent settings will be lost.

If the settings are important please make sure to STORE CFG.

RFG Rear Panel



Rear panel connectors

Remote: 25 way D-type, for analog/RS-232 remote control and monitoring functions (RS-232 is optional).

RF Output: N type socket,

AMN-Readout (Optional): This connection is used when the capacitor positions and dc developed bias voltage are to be displayed on the generator display. This can only be used if a suitably equipped CPS automatic impedance matching network is being used.

CEX In: SMA socket, for synchronizing multiple RFG outputs

CEX Out: SMA socket, for synchronizing multiple RFG outputs

Pulse Input: For fast “blanking” type switching of the RF output

Earth: M4 Screw-Bush

Common Exciter Operation

Common Exciter operation is selected by the switch on the front panel designated CEX.

The CEX input when selected will allow the generator to be synchronised to an external source (nominally 7dBm, 20dBm max.).

The CEX output can be used as a reference or to drive another generator. The output is 10dBm +/-3dBm.

Pulse Operation

Pulse mode is selected by the switch on the front panel designated Pulse / CW.

The pulse signal should be TTL (active high). Minimum pulse width is 40 μ s and with duty cycle from 1% to CW (duty cycle below 1% will cause power level to deviate from set value). The front panel displays (and remote outputs) store the last value of output power from the pulse, maintaining the reading for the duration of the off time.

Note that holding the pulse input low for extended periods of time greater than 10s may cause the hold system to drift leading to abnormal display operation.

Remote Control Operation

An external device, either an external switch or power dial to allow manual control from another location, or a computer or PLC for full automation, may optionally control a CPS RFG.

Remote control operation may be selected from the front panel or hardwired by means of links in the Remote Connector.

The RFG may be operated manually by fitting the pre-wired plug as supplied.

Remote control selection from the front panel

Where the RFG is to be used with partial remote control the remote mode may be selected from the RFG front panel, allowing for manual override when required.

There are two separate remote control options:

Remote On/Off disables the RF On and RF Off controls and instead the RF output turns on in response to an external "ON" signal.

Remote Power Set disables the Power control dial and instead takes the power setting from an external signal.

Remote control selection from the Remote connector

In some cases it is desirable to "lock" the RFG into remote control mode, particularly when the RFG is used with automation and operators are not to be allowed to use manual control.

In this case Remote Control may be "Forced" by making one or more "Enable" links in the connector. The links takes priority over the front panel. In this case the front panel switch is overridden and will not return the unit to manual control.

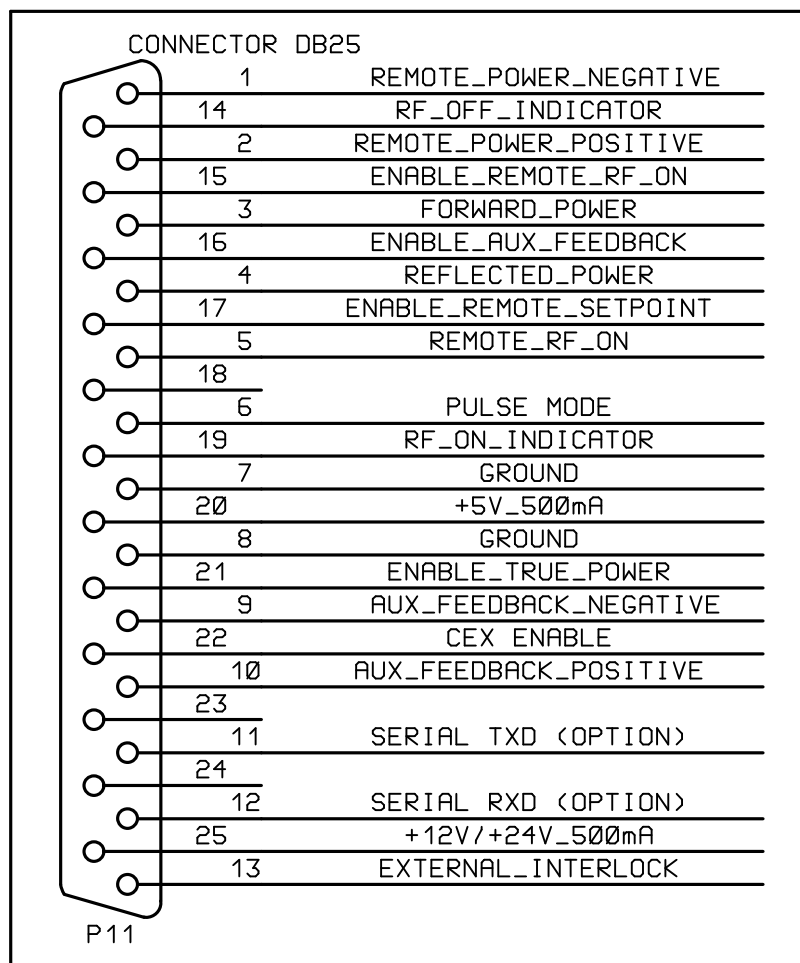
Manual operation of the RFG

To return an RFG to manual mode disconnect the remote control cable and fit a minimal Remote plug, either the CPS-supplied plug or a replacement 25 way D plug with a link from pin 13 to 25, then deselect the two remote control functions on the front panel.

Computer control and monitoring of RFG (Option)

The interface is implemented as RS232 using two pins of the "remote" connector. The protocol is described in another section.

Remote Control connector

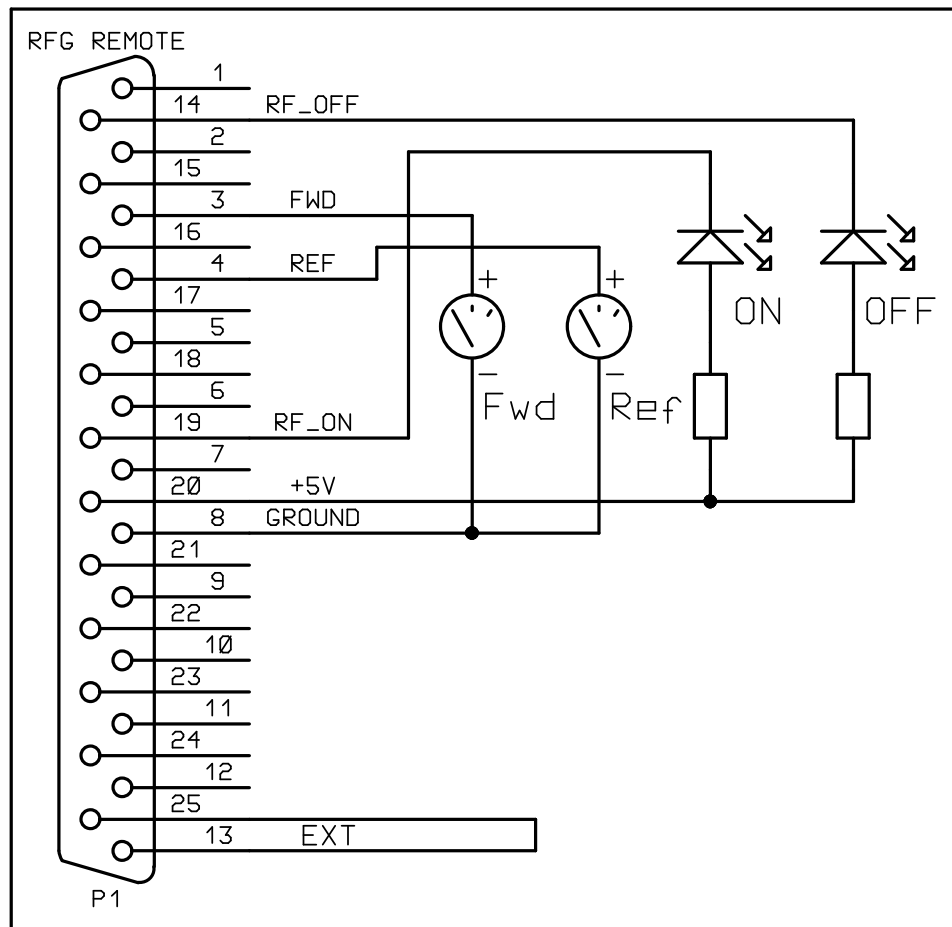


The 25-way D type connector on the rear panel allows remote control of the generator. Below is a description of the various remote functions.

Pin	Function		
1	Remote Set point negative	14	RF Off light
2	Remote Set point positive.	15	Enable Remote ON
3	Forward power	16	Enable Auxiliary Feedback
4	Reflected power	17	Enable Remote Set point
5	Remote RF On	18	-
6	Pulse mode *	19	RF On light
7	Ground	20	+5V out
8	Ground	21	Enable True Power mode
9	Auxiliary feedback negative	22	CEX mode *
10	Auxiliary feedback positive	23	-
11	Serial TXD *	24	-
12	Serial RXD *	25	+12V out for interlock
13	External interlock		

*Not on all RFG models

Description Of Remote Status Connections / Functions



Pin 3 Incident power. Pin 3 is an analogue output voltage 0-5 volts representing zero to maximum output power.

N.B. This output can source 5mA.

Pin 4 Reflected power. Pin 4 is an analogue output voltage 0-5 volts representing 0-maximum output power.

N.B. This output can source 5mA.

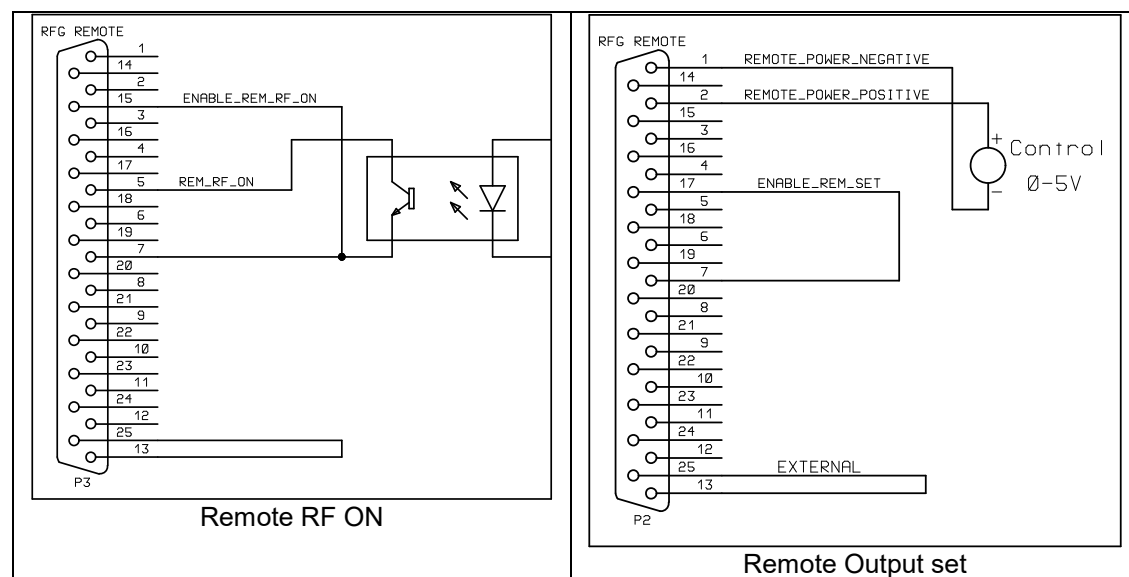
Pin 14 RF Off light. Pin 9 is an open collector transistor that grounds with RF Off. This can sink 45mA 20V.

Pin 19 RF On light. Pin 9 is an open-collector transistor that grounds with RF On. This can sink 45mA 20V.

Pin 20 +5V. This is a +5V 500mA Output.

Pin 7,8 Ground

Description Of Remote Switching and Power control



Pin 5 RF On/Off. To enable this function connect pin 10 to a ground pin. To enable RF connect pin 5 to a ground pin, via a switch, transistor or relay. This is not latching, grounding pin 5 will switch RF On, and removing this ground will switch RF Off.

N.B. Interlock functions will operate normally when using this function.

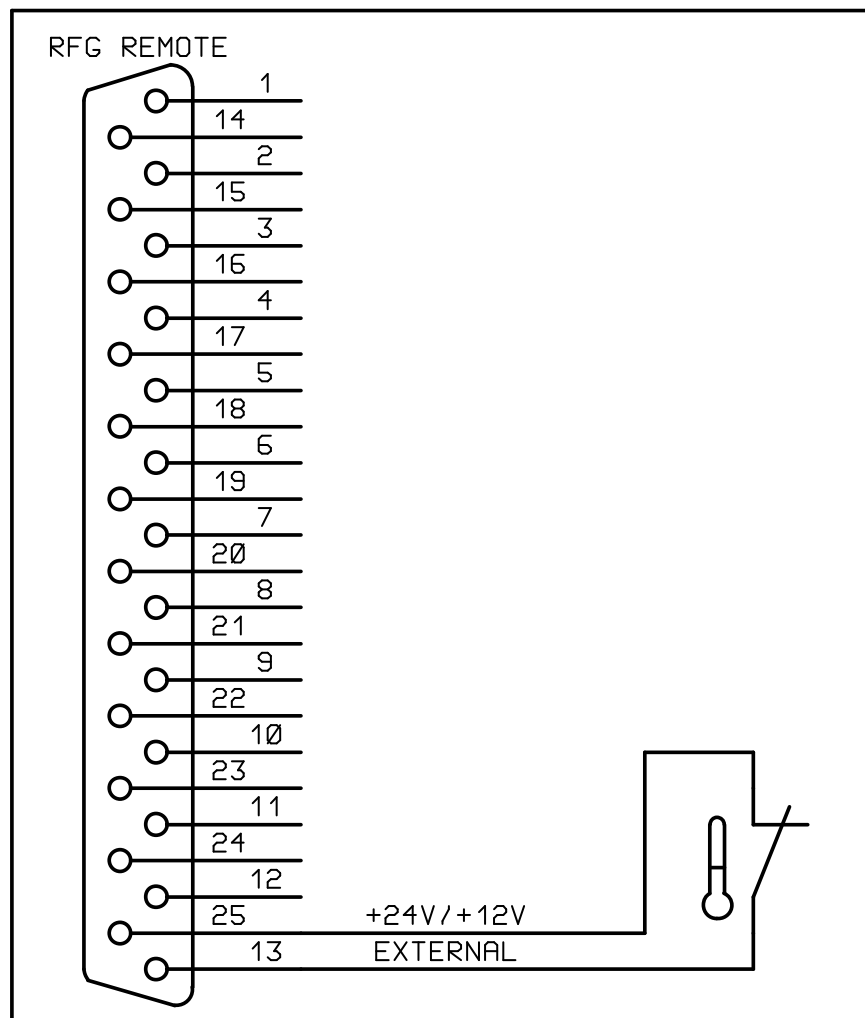
Pin 15 Remote RF On/Off Switch Enable. Ground this pin to enable the remote RF On/Off control function, when it is enabled the remote indicator on the front panel is illuminated.

Pins 1,2 Remote power set. To enable this function connect pin 17 to a ground pin. The set point or control is a positive voltage in the range 0v to 5v. 0 volts gives zero output power and 5 volts gives maximum output power.

Pin 17 Remote RF setpoint enable. Ground this pin to enable the remote setpoint control, when it is enabled the remote indicator on the front panel is illuminated.

Pins 7,8 Ground

Description Of Remote Interlock Connection / Function



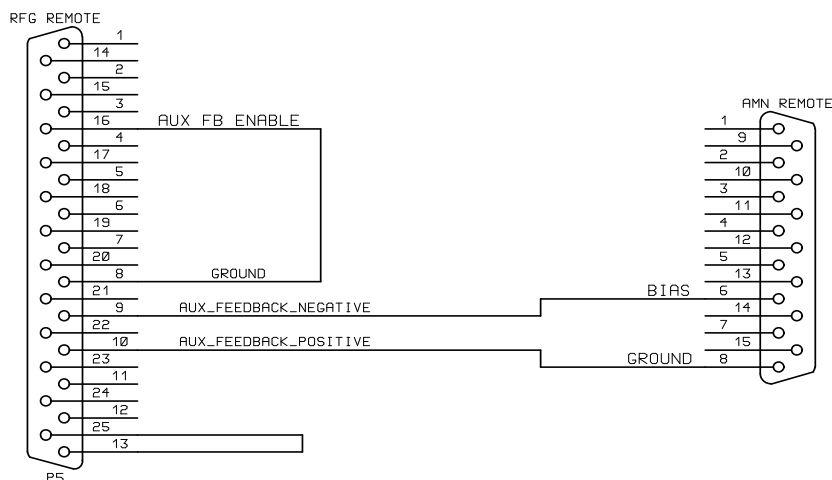
Pin 13 External Interlock. When this pin is connected to +12v it allows the generator output to be switched on. When this pin is open-circuit the "External" warning light will illuminate.

Pin 25 Positive supply, +12V or +24V depending on specific RFG model.

Pin 7,8 Ground

Description Of Auxiliary feedback Connection / Function

Auxiliary feedback is typically used in vacuum processes in order to control the dark space bias potential. The following drawing shows the connections to link the CPS RF generator to a CPS automatic matching network controller.



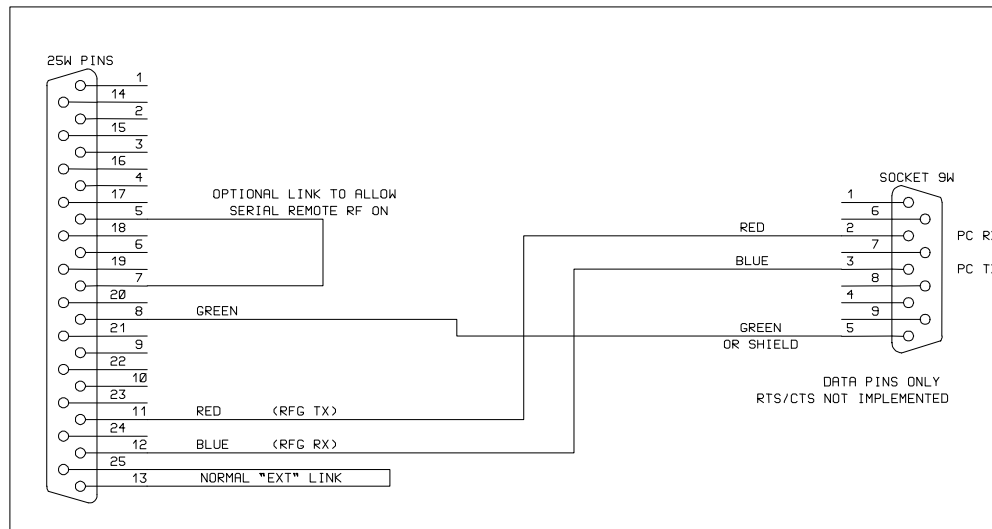
- Pin 9 Auxiliary feedback negative. To enable this function connect pin 16 to a ground pin. The feedback signal should be a negative voltage in the range 0v to –5v. This function is mainly used for plasma dark-space potential (bias) control.
- Pin 10 Auxiliary feedback positive. To enable this function connect pin 16 to a ground pin. Connect this pin to ground at the AMN controller
- Pin 16 Remote feedback enable. Ground this pin to enable the Pin1 Auxiliary feedback function.
- NB. When using the auxiliary feedback facility, if feedback voltage is not present then RF power will rise to maximum. On plasma systems this is often advantageous as it allows the generator to supply high power to strike plasma, then cut back to operating level as soon as plasma is struck.

Other functions

- Pin 6 Pulse mode. Ground to select pulsed RF operation.
- Pin 22 CEX mode. Ground to select CEX (Common exciter or synchronised) operation.
- Pin 20 +5V. This is a +5V 500mA Output. This may be used as a power source to illuminate LEDS or power small adapter circuits or displays.
- Pin 6 Not Used
- Pin 7,8 Ground

Serial/RS232 Control and Monitoring (Where fitted)

A serial connection may be used to connect the RFG to a computer or other control device. The 25-way connector is NOT directly compatible with a computer serial connector and an adapter lead is required. The interface has a common ground with the RFG, and in noisy environments an external optical isolator may be added.



- Pin 5 RF on/off. In order for RF to be enabled by a serial command this pin must be grounded. If the serial interface will not be used to enable RF then this pin may still be used as a remote input as per page 15 or should be left disconnected.
- Pin 11 RFG TXD needs to connect to RXD of a computer or controller
- Pin 12 RFG RXD needs to connect to TXD of a computer or controller
- Pin 7,8 Ground

RFG Serial communication Protocol (Where fitted)

The RFG uses MODBUS-RTU, using 9600 baud, 8 bits, one stop bit and no parity. The connection is made via spare pins of the remote connector.

The RFG implements only part of the protocol, specifically the commands for reading and writing of "coils" and "registers". Coils are used for the On/Off status of the unit, and Registers are used for other parameters as shown in the table further down. There are limits to the number of registers that may be read or written in one operation. Currently the limit is read 12, write 10.

As of version 0.880 it is possible to set a "slave" address, potentially allowing multiple RFGs on one port. A diagnostic feature will echo single characters back, allowing serial connection to be confirmed without the use of a MODBUS master. This feature is disabled if a device address is set

Command	Function	Notes
1	Read coils	Coils=bits
2	Read inputs	Duplicates "1"
3	Read holding registers	Limit 12 in one operation
4	Read input registers	Duplicates "3"
5	Force single coil	
6	Force single register	
15	Force multiple coils	
16	Force multiple registers	Limit 10 in one operation

The "register" map used is set out at the end of the document. In essence each controllable function is given a number, so a write command consists of a register and a data value. A read command sends a register number and receives a data value.

Register map for version 0.880

The following is the register map in use in the 0.880 release of the software. This is based on the layout of the RFG set-up menu.

Coil (bit) map

Bit	Function	
0	Cooling Interlock	1=interlock broken, 0=clear
1	External Interlock	1=interlock broken, 0=clear
2	Not Used	
3	Spare/Rear panel Interlock	1=interlock broken, 0=clear
4	Not Used	
5	Not Used	
6	Timer ended	1=timer run out
7	Cool-down period	1=cool down in progress
8	Not Used	Writable
9	Not Used	Writable
10	Not Used	Writable
11	Not Used	Writable
12	Remote RF Off	Writable, 1 sets RF Off, self-clearing
13	Remote RF On *	Writeable, 1 sets RF On, self-clearing
14	RF Off light/Ready	1=on, 0=off
15	RF On light/RF is ON	1=on, 0=off

*Important: Remote RF On works by pulsing the Remote On/Off function so a link is needed on the remote connector, pin 5 to ground (pin 7) to enable Computer control of RF On. Conversely if the link is omitted then RF can only be enabled manually or by a remote contact-closure.

Register (16 bit word) map for version 0.880

Note that the map closely matches the RFG's menu options. As a result some registers are of little interest but are still accessible e.g. registers 12, 21 and 29.

Register	Function	
0	Version number	Example 880 for ver. 0.880
1	Offset to forward power reading	4
2		
3	"Coil" map as a number	16 bit value
4	Forward power	Value (Read-only)
5	Reflected Power	Value (Read-only)
6	Timer select	1=on, 0=off
7	Time Set	0-100
8	Time Range	0=seconds, 1=minutes
9	Cool-down	1=on, 0=off
10	Power Set	0-1000
11	Ramp	0-200 in tenths of a second
12	Tune and Load display	0=no, 1=show load and tune, 2=also show bias
13	Bias control/ Remote FB	Not implemented see below
14	Remote ON select	1=on, 0=off
15	Remote SET select	1=on, 0=off
16	Divide 10 select	1=on, 0=off
17	CEX input select	1=on, 0=off
18	Pulse select	1=on, 0=off
19	Pulse Frequency Select	0=External, 1=500Hz, 2=1kHz, 3=2kHz, 4=5kHz, 5=10kHz
20	Pulse Duty %	0-100 (10us minimum)
21	Key Lock	1=on, 0=off
22	Dial Lock	1=on, 0=off
23	Device Address	0-255 (0=Ignore address)
24	Display brightness	0-3, no immediate effect
25	Tune	Value
26	Load	Value
27	Bias	Value
28	User Pass (Unimplemented)	Ignored
29	Show pass	0=Hide (use stars), 1=show

Bias control function is not software selectable, if required it must be enabled using the remote connector link.

Pulse Generation is an option and may not be equipped on all RFGs. On an unequipped unit the setting will always revert to 0 (External).

Register map for version 0.870

The following is the register map in use in the 0.870 release of the software. This is based on the layout of the RFG set-up menu.

- The Coil (bit) map is the same as for version 0.880

Bit	Function	
0	Cooling Interlock	1=interlock broken, 0=clear
1	External Interlock	1=interlock broken, 0=clear
2	Not Used	
3	Spare/Rear panel Interlock	1=interlock broken, 0=clear
4	Not Used	
5	Not Used	
6	Timer ended	1=timer run out
7	Cool-down period	1=cool down in progress
8	Not Used	Writable
9	Not Used	Writable
10	Not Used	Writable
11	Not Used	Writable
12	Remote RF Off	Writable, 1 sets RF Off, self-clearing
13	Remote RF On *	Writeable, 1 sets RF On, self-clearing
14	RF Off light/Ready	1=on, 0=off
15	RF On light/RF is ON	1=on, 0=off

*Important: Remote RF On works by pulsing the Remote On/Off function so a link is needed on the remote connector, pin 5 to ground (pin 7) to enable Computer control of RF On. Conversely if the link is omitted then RF can only be enabled manually or by a remote contact-closure.

Register (16 bit word) map for version 0.870

Note that the map closely matches the RFG's menu options. As a result some registers are of little interest but are still accessible e.g. registers 12, 21 and 26.

Register	Function	
0	Version number	Example 870 for ver. 0.870
1	Offset to forward power reading	4
2		
3	"Coil" map as a number	16 bit value
4	Forward power	Value (Read-only)
5	Reflected Power	Value (Read-only)
6	Timer select	1=on, 0=off
7	Time Set	0-100
8	Time Range	0=seconds, 1=minutes
9	Cool-down	1=on, 0=off
10	Power Set	0-1000
11	Ramp	0-200 in tenths of a second
12	Tune and Load display	0=no, 1=show load and tune, 2=also show bias
13	Bias control/ Remote FB	Not implemented see below
14	Remote ON select	1=on, 0=off
15	Remote SET select	1=on, 0=off
16	Divide 10 select	1=on, 0=off
17	CEX input select	1=on, 0=off
18	Pulse select	1=on, 0=off
19	Key Lock	1=on, 0=off
20	Dial Lock	1=on, 0=off
21	Display brightness	0-3, no immediate effect
22	Tune	Value
23	Load	Value
24	Bias	Value
25	User Pass (Unimplemented)	Ignored
26	Show pass	0=Hide (use stars), 1=show

Bias control function is not software selectable, if required it must be enabled using the remote connector link.

Packet format of the CPS communication interface

The packet format is based on Modbus RTU to enable the use of Modbus utilities and libraries. The following describes the functions actually implemented by current CPS equipment (RFG Firmware 0.872):

CRC Error check

All communications packets end in a 16 bit CRC Error check code. Packets that fail the check are ignored. It is important to be able to correctly add CRC to a command packet otherwise there will be absolutely no response.

The CRC code is sent low byte first, which has the useful effect that calculating the CRC of an entire valid packet yields zero. Elsewhere in the Modbus protocol the convention is that a 16 bit integer is sent high byte first. This results in confusing references to swapping the bytes in the official documentation. My recommendation is to just treat the CRC as two 8-bit-bytes sent in the order of low-byte then high-byte.

CRC calculation will be explained in further depth later.

Packet formats

Command packet format

Start Silence
Address 1 Byte
Function 1 Byte
Data variable number of bytes, subdivided
CRC
End Silence

Valid response packet

Start Silence
Address 1 Byte This is the address of the responding device not the computer
Function 1 Byte This is the function byte echoed back
Data variable number of bytes, subdivided
CRC
End Silence

Exception or Error packet

Start Silence
Address 1 Byte This is the address of the responding device
Function 1 Byte This is the function code with the top bit set to indicate an error
Data 1 byte error code The CPS RFG only sends code 1 "Illegal function"
CRC
End Silence

The silence is defined as a minimum of 3.5 byte intervals, which for 9600 baud equates to approximately 3.5ms. The RFG will interpret a silence of >3.5ms as packet end.

Current RFG Firmwares (up to 0.872) respond to all addresses. Versions 0.880 onwards implement a configurable device address enabling multiple RFG units to share a communication port.

A diagnostic feature will echo single characters back, allowing serial connection to be confirmed without the use of a MODBUS master. This feature is disabled if a device address is set

Command types implemented by the RFG

01 Read Coil Status
02 Read Input Status
03 Read Holding Registers
04 Read Input Registers
05 Force Single Coil
06 Preset Single Register
15 Force Multiple Coils
16 Preset Multiple Registers

01 Read Coil Status

02 Read Input Status

Commands 1 and 2 allow multiple bits to be read.

The command data consists of the address of the bit to be read followed by the number of bits. Both are sent in 16 bit Big-endian form (MSB first).

The response data consists of a byte count followed by the bits sent as 8 bit bytes, least significant bit first and padded with zeros.

03 Read Holding Registers

04 Read Input Registers

Commands 3 and 4 allow multiple registers to be read.

The command data consists of the address of the bit to be read followed by the number of bits. Both are sent in 16 bit Big-endian form (MSB first).

The response data consists of a byte count followed by the registers sent in 16 bit Big-endian form.

05 Force Single Coil

Command 5 allows a single bit to be written and has largely been superseded by command 15.
The command data consists of the address of the bit to be written followed by the value of the bit. Both are sent in 16 bit Big-endian form (MSB first).
Value 0x0000 is defined as off
Value 0xFF00 is defined as on
The RFG will regard a non-zero value in the first/upper byte as indicating “on”

The response is simply the command “echoed” back

06 Preset Single Register

Command 6 allows a single register to be set and has largely been superseded by command 16.
The command data consists of the address of the register to be written followed by the value of the register. Both are sent in 16 bit Big-endian form (MSB first).

The response is simply the command “echoed” back

15 Force Multiple Coils

Command 15 allows a series of bits to be written.
The command data consists of the address of the first bit to be written followed by the number of bits to be set (Both are sent in 16 bit Big-endian form) then the actual bits packed into 8 bit bytes, least significant bit first, padded with zeroes. There is no byte-count as this is implied from the number of bits.

The response data is the address and number of bits echoed back. Note that the bit values are not returned

16 Preset Multiple Registers

Command 16 allows a series of registers to be written.
The command data consists of the address of the first register to be written followed by the value of the bit, then followed by the register values. All are sent in 16 bit Big-endian form. There is no byte-count as this is implied from the number of registers.

The response data is the address and number of registers echoed back. Note that the register values are not returned

Communications example

In this example a RFG's output is switched on and then off again.

Sending the same exact byte sequence to a CPS RFG (configured for address of "any" or 1) should return the same result.

Bit 12 RF Off command/function

Bit 13 RF On command/function

Bit 14 RF Off Status

Bit 15 RF On Status

Command 1 reading coils/bits 0-15									
Sent:	01	01	00	00	00	10	3D	C6	
Returned:	01	01	02	00	40	B8	0C		
Interpretation: 00 40 is interpreted LSB first giving Coil 14=1 all others 0									
Command 5 write coil/bit 13 (RF-on)									
Sent:	01	05	00	0D	FF	00	1D	F9	
Returned:	01	05	00	0D	FF	00	1D	F9	
Interpretation: Same bytes echoed back means success									
Command 1 reading coils/bits 0-15									
Sent:	01	01	00	00	00	10	3D	C6	
Returned:	01	01	02	00	80	B8	5C		
Interpretation: 00 80 is interpreted LSB first giving Coil 15=1 all others 0									
Command 5 write coil/bit 12 (RF-off)									
Sent:	01	05	00	0C	FF	00	4C	39	
Returned:	01	05	00	0C	FF	00	4C	39	
Command 1 reading coils/bits 0-15									
Sent:	01	01	00	00	00	10	3D	C6	
Returned:	01	01	02	00	40	B8	0C		

Calculating the CRC

A 16 bit CRC register needs to be initialised with a "seed" of 0xFFFF before a packet is sent or received. Then for each byte the following procedure is followed:

Exclusive-or the byte with the CRC register

Then do the following 8 times:

- Right-shift the CRC
- If the bit shifted out is non-zero then add 0xA001 to the CRC

After sending a packet the CRC is sent low byte first then high byte

After receiving a packet a valid CRC "cancels out" the value in the CRC register leaving zero. A non-zero value indicates a corrupted transmission.

It is possible to refine the process for greater performance.

The modbus specification gives a procedure that uses two 256 byte lookup tables to avoid the need to loop through the bits. The procedure is optimised for speed not memory on an 8 bit CPU.

The following is a simple looping implementation that calculates a CRC for data pointed to by the pointer "Msg"

```
unsigned int CRC16(unsigned char *Msg , unsigned int DataLen)
{
    unsigned int CRC = 0xFFFF ; /* CRC byte initialized */
    unsigned char Loop ;
    while (DataLen--) /* pass through message buffer */
    {
        CRC = CRC ^ (*(Msg++)) ; /* calculate the CRC */
        for(Loop=0; Loop<8; Loop++)
        {
            if (CRC & 1)
            {
                CRC >>= 1;
                CRC ^= 0xA001;
            }
            else
            {
                CRC >>= 1;
            }
        }
    }
    return (CRC);
}
```

Fault Diagnosis

Display blank, Fans do not operate, unit silent	Check mains supply
Display blank, Fans do not operate, unit silent	Check input fuses in mains connector
Display is lit, fans operate and RF Off light does not illuminate	Check interlocks
Display shows External Interlock	Check that a valid remote connector is fitted
Display shows Cooling Interlock	Unit may be overheated: Press 'RF OFF' and allow time to cool down, if interlock does not reset consult factory
Display shows an "x" by External interlock RF Off does not illuminate Fan runs slow	Check internal 12v power rail, this may be accessed on remote connector pin 25. A 12v rail fault is generally field-repairable
RF Off light operates but RF On will not operate	Check remote connector Check front panel local/remote switches
RF On light operates but no RF is produced	Check remote connector Check front panel local/remote switches
Display values drift slowly	Check Pulse mode and Pulse input signal

Warranty

Coaxial Power Systems Ltd offer a warranty for parts and labour (if returned to factory) for 1 year from date of despatch. The warranty is invalidated if the generator has suffered inappropriate treatment i.e. excessive vibration, mechanical denting or dropping, accidental liquid spill, excessive applied voltage to remote connectors etc. Coaxial Power Systems Ltd should be notified of all warranty claims before return of equipment.

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