

FP0113RK  
10/31/97 G.E.C.

**CPS-500AS**  
**13.56MHz RF GENERATOR**  
**Operator's Manual**

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FP0113RX	CPS 500AS Control Drawing
FA0401RX	Oscillator Control Board
FA0637RX	Integrated Meter Board

**NOTE: Before installing equipment, carefully read and familiarize yourself with the entire operations manual. Observe and obey all WARNING and CAUTION notes provided.**

## I. Safety Information

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### Warning Label and Safety Marking Explanations:

The following symbols and terms may be found on an instrument or used in this manual.



The CE mark indicates compliance with all currently applicable directives and standards.



This label indicates a general warning or caution condition.



This symbol indicates the presence of high voltages in or around the unit.



This symbol indicates that the component or circuit is short circuit protected.



This symbol indicates the presence of RF energy in or around the unit.



This symbol indicates a protective earth ground connecting point.



This label indicates a presence of high voltage in or around the equipment, which may cause severe injury or death. All appropriate precautions should be observed when installing, operating or servicing this equipment.



This label indicates the presence of Radio Frequency energy in and around the equipment, which may cause burns or other injuries. All appropriate precautions should be followed when installing, operating or servicing this equipment.

The **WARNING** heading used in this manual explains dangers that might result in personal injury or death. **Always read the associated information** very carefully before performing the indicated procedure.

The **CAUTION** heading used in this manual explains hazards that could damage the unit. Such damage may invalidate the warranty.

**MUST** – This word is understood to indicate a mandatory condition.

**HIGH VOLTAGE** – Voltages greater than 50 volts DC or 25volts AC and known to cause death or serious injury if contacted.

**SERVICE** – Any operation of maintenance, repair, calibration or similar activity other than the normal operation of the unit.

**QUALIFIED SERVICE TECHNICIAN, QUALIFIED ELECTRICIAN, QUALIFIED PERSONELL** These terms indicate persons specifically trained to install, service or other wise handle electronic equipment of the character and hazard potential of this unit.

### End User Labeling

The system installer should obtain and apply all appropriate safety and warning labels required by the end user's local fire department jurisdiction and Occupational Health and Safety Administration over and above those supplied by the generator manufacturer.

## **Read And Understand This Section Fully Before Installing or Operating This Equipment.**

**WARNING: This equipment must be installed, operated and serviced only by trained, qualified persons.**

### General Safety Requirements



- **WARNING:** Hazardous Voltages and RF voltages are present inside this unit, which may cause injury or death. To prevent electrical shock and or RF burns, never operate this equipment with the covers removed. Never operate without an appropriate cable connected between the RF output connector on the rear panel and the load.
- **CAUTION:** There are no user or operator serviceable parts inside this equipment. Refer all service to a qualified service technician.
- This equipment must be bonded to Protective Earth (safety ground) prior to operating the unit. Safety ground connection must be made at the unit's rear panel designated 1/4" - 20 threaded ground stud. The ground wire should be a #14 awg or equivalent (minimum) green/yellow lead.
- There is no reset required to restore operation after a shutdown due to over-temperature. If the cause of an overtemp shutdown is to be investigated, primary power should be removed from unit or RF will restart as soon as heat sinks cool below 75° C.



- **HEAVY OBJECT CAUTION:** A heavy object caution exists for equipment weighing more than 51 lbs or 23 kg. Use lifting aids to install unit, such as chain lifts or hooks and straps, attached to the four handles at the sides and front of unit. Guide unit into final location using care to keep hands and body parts clear of unit.

### **CE Mark Specific Safety Requirements**

- This equipment meets all applicable safety directives (as specified in prEN50178) required to qualify for the application of the CE marking.
- This equipment must be installed in accordance with the applicable requirements, or prEN50178 and EN60204-1 / IEC-204-1.
- This equipment is qualified to operate at Pollution Degree II and Insulation Category II.
- The installation of this equipment must assure that the AC power input connector (UL/CSA) is not accessible to the user/operator. Access may be gained only by a qualified service technician. AC Mains connector installation must be in accordance with local requirements.
- This unit provides appropriate separation between all interface, mains and output circuits in accordance with 5.2.18 of prEN50178.

## II. Description / Specification

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The CPS-500AS is a 500 watt R.F. generator operating at a fixed frequency of 13.56 MHz. The generator is designed to produce maximum power into a 50  $\Omega$  load.

**NOTE: This generator has been customized to run at 100w, but is capable of operation up to 500 watts.**

The primary features of the CPS-500AS are a solid-state design, small physical size and the ability to withstand large changes in load impedance without failure. The CPS-500AS can be examined as two separate sections, the DC Power Supply and the RF section.

The DC Power supply provides +40 VDC and +/- 15 VDC required to operate and control the RF Section. The DC Power Supply (as supplied) is powered by 120 VAC single phase 50-60Hz with line current of 6A. This supply can be operated on several line voltages by changing primary transformer taps, as explained in Section 2.3.

The RF Section operates on +40 VDC and +/- 15 VDC and generates 500 watts into 50 $\Omega$ . There are five basic parts in this section. They are: oscillator and control circuitry, driver, power amplifier, low-pass filter and directional coupler. The CPS-500AS RF Generator is designed for long life and low maintenance operation.

## III. Unpacking and Inspection

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1. Carefully unpack the unit and inspect for any obvious signs of physical damage that might have occurred during shipment. Notify the shipping agent of any damage immediately.
2. Check the outside of the unit for missing or loose mounting screws or broken parts.
3. If there is shipping damage or the unit fails to operate properly upon receipt, report damage to the carrier and Comdel immediately.

**CAUTION:** Breaking the seal or removing the warranty decal from this unit will void the warranty. If internal damage is suspected, contact factory for assistance.

## IV. Maintenance

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The CPS-500AS is designed to run unattended for long periods of time. Should service be required, the system is modularly designed for quick repair. The whole RF section could be replaced in less than thirty minutes.

After a time, scale may build up on the inside of the cooling tubes. This could greatly reduce the cooling capacity of the system. It is recommended that the system be flushed with a descaling agent. A cleaning agent that does not damage copper, brass, stainless-steel and nylon tubing should be chosen.

## **V. Preparation for Use**

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### **A. Power Requirements**

The CPS-500AS RF Generator is designed to operate at several different line voltages. Unless otherwise specified the generator is configured to operate at 115VAC at the factory.

### **B. Cooling Requirements**

The CPS-500AS is forced air-cooled by two fans. All air inlets and exits to the generator should be unobstructed. The ambient air temperature should not exceed 25° C.

### **C. Controls And Indicators**

1. Circuit Breaker - Interrupts power to the primary of the transformer.
2. Remote/Local Switch - When the switch is in the “Remote” position, the generator will be controlled by the signal fed into Connector J1. When the switch is in the “Local” position, the generator will be controlled by the power control knob on the front panel.
3. Power Control - Local power control is accomplished by means of a ten turn potentiometer. Full counter-clockwise is 0 watts output.
4. Power On Indicator - This indicator lights when circuit breaker is in the ON position.
5. Over-temp Indicator - This indicator turns on when an over-temperature situation occurs.

## **VI. Operating Instructions**

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Before the AC power is connected, make sure the local power control potentiometer is turned fully counter-clockwise and the local/remote switch is in the LOCAL position. On Connector J1, Pin 11 should be connected to Pin 12 to RF enable. Pin 4 of J1 must be returned to Pin 9.

### **A. Local Control**

Local Control is accomplished by turning power control pot clockwise to increase the output power. When the pot is in its full clockwise position, power output will be 500W +10% -0%.

### **B. Remote Control**

Operating the CPS-500AS in the Remote condition requires a 0 to +10 VDC power supply connected positive to Pin 5 J1 and negative to Pin 6 J1.

### C. J1 Connector Pin Designations

Pin 1	NC	
Pin 2	Reflected Power Ind.	10 VDC for 500W *
Pin 3	Forward Power Ind.	10 VDC for 500W *
Pin 4	RF Enable	(Ground to operate)
Pin 5	Power Control	10 VDC for 500W *
Pin 6	Ground	(Remote Power Control Return)
Pin 7	RF Enabled	+5 VDC shows RF Enabled
Pin 8	Overtemp Indicator	(Pulled to ground on temperature rise)
Pin 9	RF Enable return	
Pin 10	NC	
Pin 11	Interlock - connection to Pin 12 enables system	
Pin 12	Interlock - connection to Pin 11 enables system	
Pin 13	NC	

\* Other input and output voltages are available. Consult factory for other options.

### D. RF Keying (Pulsing)

Operating the CPS-500AS in the Remote Pulse condition requires a pulse whose amplitude is proportional to output pulse power (10V = 500W) and whose duty cycle and rep rate are as required in the output power wave form. Minimum pulse width is 50 microseconds, max rep rate is 5 KHz. The pulse supply is connected with Pin 5 J1 as pulse input and Pin 6 J1 as the return.

### E. Forward and Reflected Power Monitoring

Forward and Reflected Power Monitoring access is gained through Pins 3 and 2 (J1). Pin 3 is forward and Pin 2 is reflected. These provide a DC voltage proportional to power.

## VII. Theory of Operation

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The CPS-500AS is a source of radio frequency energy for use in RF plasma applications. It consists of six stages and associated control systems and monitoring circuits as shown in the CPS-500AS functional block diagram (FP0113RX).

The radio frequency signal is generated in the oscillator and amplified by the driver. From the driver, the signal is fed into the power amplifier. The signals from the power amplifier are then passed through a low-pass filter. From the filter, the signal travels through the directional coupler to the power output connector.

### A. DC Power Supply

The DC Supply consists of a transformer, two full wave rectifiers and two low-pass filters. The output of this stage is:

1	40 VDC - 45 VDC 33 VDC min	Unloaded Loaded (25 A max)
1	+/- 15 VDC	Regulated



## **B. Oscillator Control Board**

The CPS-500AS oscillator module has four parts: The clock oscillator, three stages of gain and gain control circuitry. The clock oscillator is a purchased standard TTL output device. This circuit is utilized because of its frequency stability and immunity to fluctuations in both temperature and output load impedance.

The gain control circuitry has several functions: it smoothes output control, stabilizes output power against variations in the power line or load and pulses the oscillator under high VSWR conditions. This is accomplished by using a LF356 op-amp connected as a comparator. The inverting terminal is related to the forward power while the non-inverting terminal supplies the DC reference voltage. Also connected to the non-inverting terminal is the reverse power shut down, which is controlled by the pull down transistor whose signal is supplied by the reflected power detector.

### **Typical Specifications (OCB)**

Output load impedance	50 ohms
Output RF power level	1 watt (max)
Input Voltages Pin 5	-15 V min
Pin 9	+15 V min
Input Currents Pin 5	250mA
Pin 9	250mA
Reflected power limit	Internally set to 100W reflected

## **C. Driver**

The driver is a Class “C”, two stage amplifier with feedback. The first transistor operates with approximately 1 watt input from the oscillator and amplifies this to 10 watts. The circuitry between the first and second transistor contains more impedance matching and a loss section for stability and isolation. The output of this stage is 25 watts. There are no adjustments or tuning required for this stage.

### **Typical Specifications (Driver)**

Gain	14dB
Input power	1 watt
Output RF power	25 watts
Input impedance	50 Ohms
Output load impedance	50 Ohms
Collector voltage (at full output)	33 VDC
Collector current (at full output)	4 ADC

## **D. Power Amplifier**

The power amplifier stage utilizes four transistors arranged into two pairs of push-pull Class “C” amplifiers. The input requirements of this stage are met by the 25 watts into 50Ω produced by the driver stage. At the input there is an impedance matching network, a hybrid splitter which then feeds into two push-pull transistor driving transformers. Each of these transformers drives the bases of two transistors. These transistors are operated common emitter with feedback. Each collector signal is coupled together by means of a push-pull combiner. The signals from each of these push-pull combiners are then added again with a hybrid combiner. The output of this stage is typically 550W into 25Ω.

### Typical Specifications

Gain	12 dB (min)
Input power	25 watts (typical)
Output power	550 watts
Input impedance	50 ohms
Output load impedance	25 ohms
Collector voltage (at full output)	33 VDC
Collector current (at full output)	22 ADC

#### **E. Low Pass Filter**

The low-pass filter is designed to filter the higher order harmonics and leave a low distortion carrier signal. This stage also matches the terminating impedance of the amplifier 25 ohms to 50 ohms load impedance. The filter is a “T” configuration.

#### **F. Directional Coupler**

The directional coupler stage produces voltages, which are proportional to the square of both the forward and reflected power. This stage utilizes inductive (current) and capacitive (voltage) taps to determine the forward and reflected power. This stage is factory fitted and needs no further adjustment.

## **VIII. Adjustments and Calibration**

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The only adjustments required on the CPS-500AS are made to the monitoring and transistor protection circuitry. All of these adjustments have been performed at the factory and generally will never have to be reset.

#### **A. Over Voltage / Over Current Adjustment**

The OV OC potentiometer adjustments are located on the integrated meter assembly FA0637RX. These adjustments should be altered only when the generator is operating into a 50  $\Omega$  real load. The procedure for adjustment is as follows:

1. See instructions “Operating into 50 $\Omega$ ”
2. Set generator at maximum output power
3. Turn all adjustments to their maximum counter-clockwise limit
4. Set input ac voltage to low line. Then start turning current limit adjustment R21 clockwise until output power drops to 550W.
5. Set input ac voltage to high line. Then turn the voltage limit adjustment R22 clockwise until output power just starts to drop. The output power should be 550 watts.

#### **B. VSWR Adjustment**

The VSWR set is located in the oscillator module and is adjusted by R1. See FA0401RE. Under high VSWR conditions, Q6 is biased on and pulls the reference voltage low. When this circuitry is activated, the unit will go into a pulsed operation until the high VSWR condition is eliminated. The oscillator module is set to go into limit operation when there is 100W reflected. The procedure for adjustment is as follows.

1. See operating instructions, Section 3.
2. Adjust generator so that it produces 100W into 50Ω.
3. Turn off line power.
4. Remove coaxial cable on the load side of the watt meter.
5. Turn on line power.
6. Turn adjustment (R39) until the reflected power indication on the watt meter just starts to drop.

### **C. Thermal Set**

The thermal set on the CPS-500AS is pre-set to operate at a power amplifier block temperature of 80° C. The temperature sensor is mounted on the power amplifier. This sensor pulls down to ground and turns generator off when set temperature is exceeded.

### **D. Forward RF Power Calibration**

1. Connect unit to RF dummy load with an accurate (customer's standard) external power meter to monitor the RF output power.
2. With RF disabled, measure the local power control pot voltage at "SETPT" test point on OSCILLATOR CONTROL BOARD with the DVM and set for 10 VDC.
3. Enable RF and adjust FORWARD OUT CALIBRATION pot R34 on the Oscillator Control Board on right side of unit until the forward readback voltage out of the rear panel connector, Pin 3 reads 10V with respect to ground.
4. Adjust pot located behind front panel FORWARD meter so that meter reads 500W.
5. Adjust ACTUAL CALIBRATION POT R44 on the Oscillator Control Board until external power meter reads 500W.

### **E. Reflected RF Power Calibration**

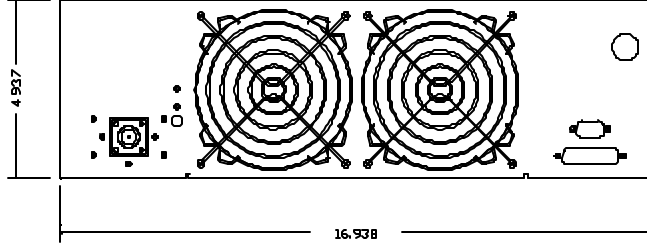
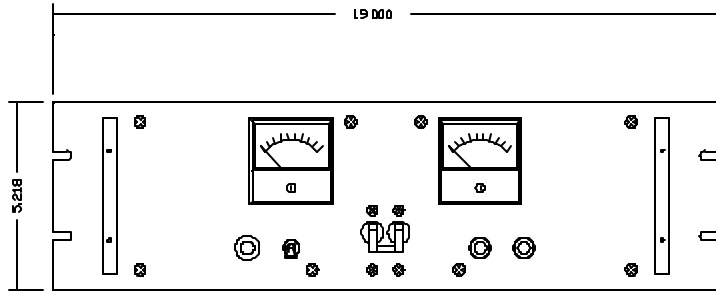
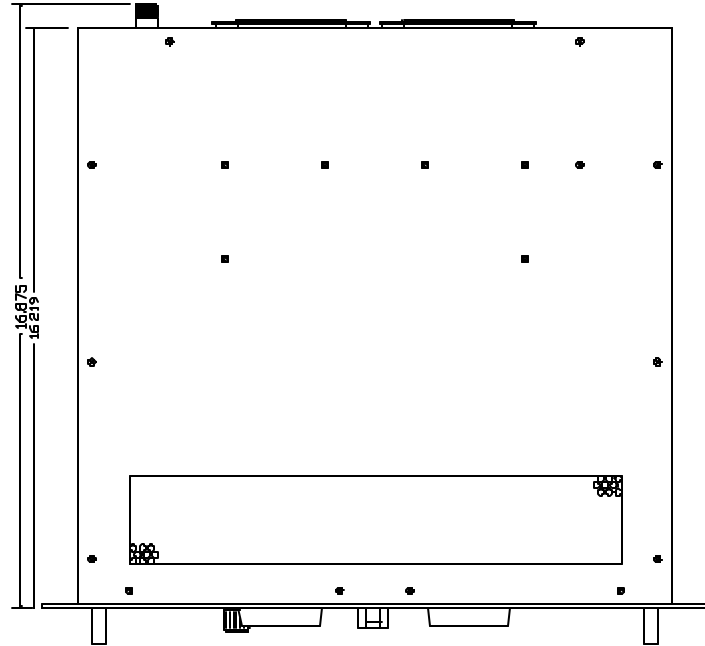
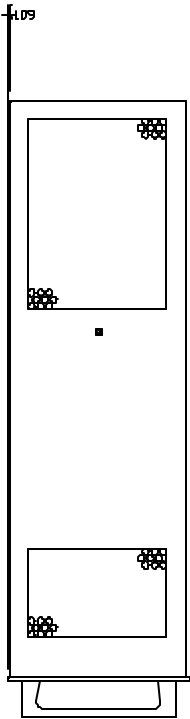
1. Disconnect RF cable from RF output connector.
2. Set power for 100 watts and enable RF power into the open load.
3. Adjust REFLECTED CAL pot R67 on Oscillator Control Board until the voltage at Pin 2 or rear panel connector matches the voltage on Pin 3.
4. Adjust REFLECTED METER pot located behind front panel meter until the reflected meter reading matches the forward meter reading.

### **F. Enable**

Pin 4 on J1 is provided for remote enable or disable. A ground applied to Pin 4 enables the RF output.

### **G. Interlocks**

An internal interlock loop is provided. Pin 11 must be tied to Pin 12 through the external interlock loop in order to enable the generator. Also, an RF Safety Interlock has been installed near the RF connector, for added safety.



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