



Navio[™] Match Network

User Manual

December 2013 57020137-00E





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Safety and Product Compliance Guidelines

PRODUCTS COVERED BY THIS MANUAL

This manual documents the Navio match network. [Figure 1-1](#) shows how to interpret certain specifications based on the part number. The part number is located on the serial tag on the unit.

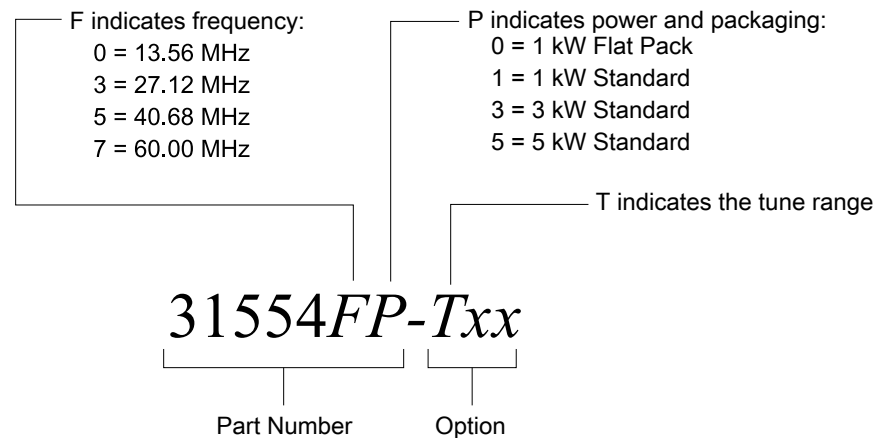


Figure 1-1. Navio part number and option description

RF peak and DC bias sensors are optional on the Navio match network. To find out if your unit includes these options, call AE Global Services with your 315XXXX number.

RELATED DOCUMENTATION

This manual refers to the Virtual Front Panel (VFP) software, which ships with some Navio match networks. Virtual Front Panel software allows you to control and monitor the Navio match network from a personal computer. Virtual Front Panel software includes complete documentation as a printable PDF and as an embedded help system. If you are unable to locate the documentation for your version of Virtual Front Panel software, contact AE Global Services.

IMPORTANT SAFETY INFORMATION

To ensure safe installation and operation of the Advanced Energy Navio unit, read and understand this manual before attempting to install and operate this unit. At a minimum, read and follow the safety guidelines, instructions, and practices.

DANGER, WARNING, AND CAUTION BOXES IN THE MANUAL



1027

This symbol represents important notes concerning potential harm to people, this unit, or associated equipment. Advanced Energy includes this symbol in Danger, Warning, and Caution boxes to identify specific levels of hazard seriousness.



DANGER:

DANGER indicates an imminently hazardous situation that, if not avoided, will result in death or serious injury. **DANGER** is limited to the most extreme situations.



WARNING:

WARNING indicates a potentially hazardous situation that, if not avoided, could result in death or serious injury, and/or property damage.



CAUTION:

CAUTION indicates a potentially hazardous situation that, if not avoided, could result in minor or moderate injury, and/or property damage. **CAUTION** is also used for property-damage-only accidents.

SAFETY GUIDELINES

Review the following information before attempting to install and operate the product.

Rules for Safe Installation and Operation

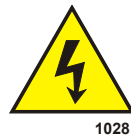
Please note the following rules:

- Do not attempt to install or operate this equipment without proper training.

- Ensure that this unit is properly grounded.
- Ensure that all cables are properly connected.
- Verify that input line voltage and current capacity are within specifications before turning on the power supplies.
- Use proper electrostatic discharge (ESD) precautions.
- Always be careful around this equipment.

INTERPRETING PRODUCT LABELS

The following labels may appear on your unit:



Hazardous voltage



Hot surface



Nonionizing radiation



CE label

PRODUCT COMPLIANCE

The following sections include information about unit compliance and certification, including the conditions of use required to be in compliance with the standards and directives.

Product Certification

Certain options of this product may be certified according to the list below.

For more information, refer to the Certificate or Letter of Conformity (US) or Declaration of Conformity (EU) accompanying the product.

- CE Marking – Self-declaration, assessed by AE Corporate Compliance
- EMC measurements – Verified by the AE Corporate Compliance Lab and/or an accredited third party lab

Safety and EMC Directives and Standards

Certain options of this unit have been tested for and comply with the following electromagnetic compatibility (EMC) and safety directives and standards and industry guidelines.



Important

This device must be installed and used only in compliance with the directives and standards listed in addition to EN 60204 (IEC 60204) and applicable requirements.



Important

This equipment must be installed and used in accordance with the Conditions of Use described in this manual. If this equipment is expanded, modified, or installed into a larger system, the user is responsible to guarantee the compliance of the overall system. If this equipment is used with external components, the user must ensure that the Safety and EMC requirements are not violated.

ELECTROMAGNETIC COMPATIBILITY (EMC) DIRECTIVES AND STANDARDS

- **2004/108/EC**

EC Council directive on the approximation of the laws of the Member States relating to electromagnetic compatibility (EMC Directive)

- **47 CFR Part 18**

Code of Federal Regulations—Limits and methods of measurement of radio interference characteristics of industrial, scientific, and medical equipment

- **EN 55011**

Limits and methods of measurement of radio disturbance characteristics of industrial, scientific, medical (ISM) radio frequency equipment (Class A, Group 2) (CISPR 11)

- **EN 61000-6-2**

Electromagnetic Compatibility (generic immunity standard—industrial)

SAFETY DIRECTIVES AND STANDARDS

- **2006/95/EC**

EC Council directive on the harmonization of the laws of the Member States relating to electrical equipment designed for use within certain voltage limits (LVD - Low Voltage Directive)

- **EN 61010-1**

Safety requirements for Electrical Equipment for Measurement, Control, and Laboratory Use - Part 1: General Requirements

INDUSTRY GUIDELINES

- **SEMI S2-0706**

Environmental, health, and safety guidelines for semiconductor manufacturing equipment

- **SEMI F47**

Specification for Semiconductor Processing Equipment Voltage Sag Immunity



Important

Maintains operation through voltage sag event.

Conditions of Use

To comply with the stated directives and standards, you must meet the following conditions of use:

- Install and operate this device in an overvoltage category II or better installation.
- Install and operate the RF section of this device in an overvoltage II installation.
- Use this device only with RF generators that are short-circuit protected.
- Before making any other connection, ensure that the unit is properly bonded to Protective Earth ground; make this connection during grounding and installation.
- Install and operate this device only in a pollution degree 1 environment, which means an indoor location such as a computer room, office, or factory floor where either no pollution or only dry, nonconductive pollution occurs. (The pollution has no effect on operation.)
- Non-standard connectors for input and/or output power must be inaccessible to the user.
- Limit the system input power to the maximum specified level for the unit.
- Limit the system load current to the maximum specified level for the unit.
- Use a high quality coaxial cable, such as semirigid coaxial cable, for the interconnection between the generator and the match network.
- Use shielded cable for the power supply connector and ground the cable shield.
- For units with the CF 2-3/4" flange mount RF output connector:

- Cooling-water tubing connections to be completed by the end user must be performed as follows:
 - Verify that all sources of energy are disconnected and locked-out tagged-out from this product before continuing.
 - Only AE part number 11900030, Zeus Industrial Products part number 86977 tubing is to be used in this tuner/match product.
 - Tubing must be fixed to both the user-supplied and AE-provided fittings as per manufacturer's instructions.
 - The connection can be checked with Swagelok inspection gauge P/N MS-IG-400, or MS-IG-612M for the 6 mm fittings.
- All screws that bond the enclosure cover to the chassis must then be reinstalled and tightened to 0.67 Nm (6 in-lb).
- Once assembled, the system is to be verified with a static-pressure test of 6 bar for one minute without pressure loss.

MATCH NETWORK INTERLOCKS



WARNING:

Advanced Energy products only include interlocks when required by product specification. Interlocks in Advanced Energy products are not intended to meet or satisfy safety requirements. Where interlocks exist, you must still meet and satisfy safety requirements. The presence of interlocks does not imply operator protection.

Interlock Description

You must make the interlock connections for the entire power delivery system. On the Navio, you can detect an interlock condition by using AE Bus command **254** to read fault conditions.

Product Overview

PRODUCT DESCRIPTION

The Navio match network represents a cornerstone in match development, providing rapid, accurate, and reliable impedance matching across a defined load range. This air-cooled, microprocessor-controlled match network automatically tunes, or matches, the complex impedance of a coupled plasma at 13.56 MHz, 27.12 MHz, 40.68 MHz, or 60.00 MHz (depending on the unit) to a desired impedance at the match input (default is 50-ohm resistive). The Navio match network detects the initial load impedance, calculates the electrical characteristics, and adjusts the tuning elements to achieve the desired impedance load.

Control Modes

The Navio match network can operate in the following modes:

- Automatic tune mode
- Host control mode

Allows manual control of capacitor position through the following ports:

- **Host**
- **PROFIBUS**
- User control mode

Allows manual control of capacitor position through the **Analog I/O** port (not available on all units).

THEORY OF OPERATION

Block Diagram

Figure 2-1 is a block diagram describing the theory of operation of the Navio match network. Other sections of the diagram may differ from model to model. The illustration is followed by information describing each of the unit's major operational sections.

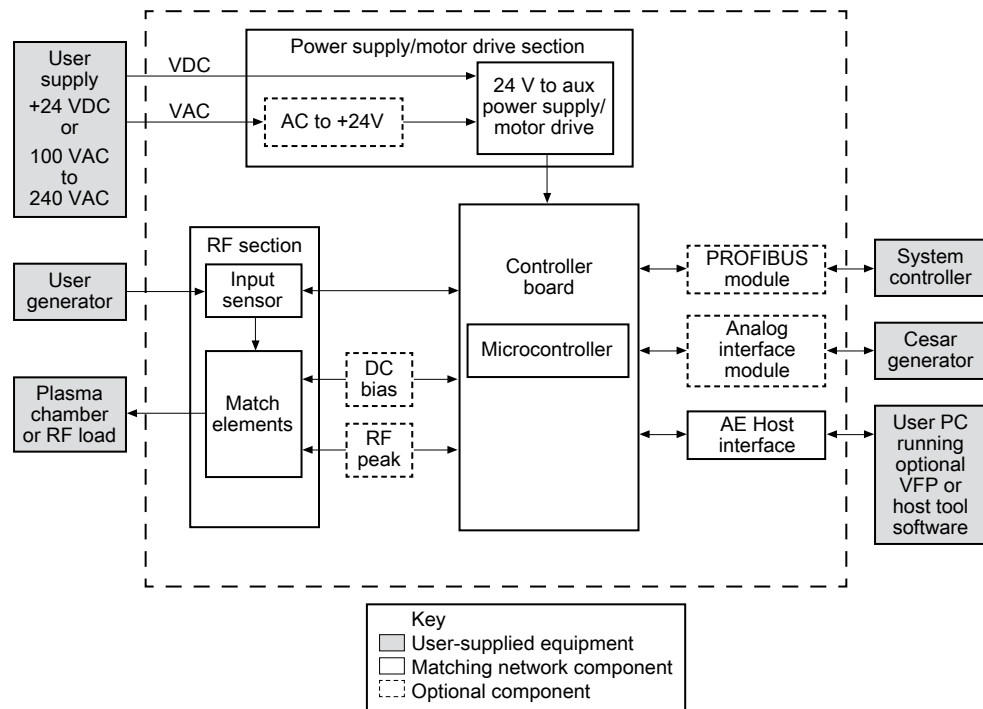


Figure 2-1. Navio match network block diagram

RF Section

The RF section of the Navio match network includes the following components:

- 3X input sensor
- Match (tuning) elements
- RF peak voltage sensor (some units)
- DC bias sensor (some units)

Table 2-1. RF section components

Component	Description
3X input sensor	The 3X input sensor detects the relationship between current and voltage waveforms at the input of the match network. It detects the current as well as the real and reactive power to determine the input impedance. It sends these values to the microcontroller on the mother board.
Match (tuning) elements	The match elements consist of: • Fixed and variable capacitors • Fixed inductors

Table 2-1. RF section components (Continued)

Component	Description
RF peak voltage sensor	The peak RF voltage is sampled from the output of the unit and fed into the controller.
DC bias sensor	The DC bias sensor (some units) consists of a resistive voltage divider and RF filtering components. The DC bias voltage is sampled from the output of the unit, indicating a plasma. The bias can be negative or positive. The output is fed into the DC bias module for further processing.

Control Section

Table 2-2. Control section components

Component	Description
Controller board	The controller board contains the microcontroller and the digital and analog circuitries that read sensor information and move the tune and load capacitors. The controller board also supplies information to and receives commands from the user system through a host port, such as the Host port, PROFIBUS port or Analog I/O port (not all units have all of these ports available). Microcontroller Inside the controller, the microcontroller determines the input impedance and has stepper motor control to move the variable tuning elements and convert the complex impedance to the desired input impedance. The microcontroller performs the match network algorithm that calculates the electrical characteristics (phase and magnitude) and determines how to control the variable tuning elements in order to convert the load impedance to 50 ohms. The phase value primarily directs tune capacitor movement, and the magnitude value primarily directs load capacitor movement. In the tuning algorithm, however, there can be some interaction or cross talk. That is, the phase can direct load capacitor movement, and the magnitude can direct tune capacitor movement. This interaction helps to improve the paths of the capacitor movement, or trajectories, enabling faster and more reliable tuning. The stepper motors drive the variable tuning elements, moving the tune and load capacitors to the calculated positions upon command from the microcontroller.
PROFIBUS module	The PROFIBUS module provides an interface to supply information to and receive commands from the user system through a PROFIBUS interface.
Analog module	The Analog module provides an interface to supply information to and receive commands from the system controller through a 15-pin Cesar interface. Not all units have the Analog interface.

Table 2-2. Control section components (Continued)

Component	Description
Power supply with motor drive circuitry	The power supply section accepts either a user-supplied +24 VDC or a user-supplied 100 VAC to 240 VAC, depending on the option. If the input is 100 VAC to 240 VAC, the unit includes an AC-to-+24 V converter. The 24 V to auxiliary power supply converts the +24 VDC to the required voltages for the control system components. The motor drive circuitry controls the movement of the stepper motors attached to the variable capacitor match tuning elements. The required movement of the stepper motors is determined by the controller board and communicated to the motor drive circuitry through a digital interface.

Optional Virtual Front Panel (VFP) Software or Host Tool Software

You may control and monitor the Navio match network from a personal computer using the Advanced Energy Navio Virtual Front Panel software (which ships with some Navio units) or your own host tool software. To order Virtual Front Panel software, contact your AE sales representative.

Specifications

PHYSICAL SPECIFICATIONS

Table 3-1 shows physical specifications for the Navio match network.



Important

The serial tag on the unit includes the part number and option.

Table 3-1. *Physical specifications*

Description	Specification
Size	Dimensions depend on the unit: Standard Package: 15.0 cm (H) x 24.5 cm (W) x 37.4 cm (D) 5.9" (H) x 9.6" (W) x 14.7" (D) Flat Package: 11.2 cm (H) x 30.0 cm (W) x 39.4 cm (D) 4.4" (H) x 11.8" (W) x 15.5" (D) Dimensions do not include fans, mounting brackets, or RF connectors.
Weight	Weight depends on the unit: Standard Package: 6.6 kg (14.5 lb) Flat Package: 7.1 kg (15.6 lb)
Mounting	Mounting depends on the unit. Mounting holes can be located on bottom, rear, or sides of unit.
Connector and cable specifications	

Table 3-1. Physical specifications (Continued)

Description	Specification
RF input connection	Depends on unit: • C (female) • N (female) • HN (female) • 7-16 (female) • LC (female) • SQS (female)
RF output connection	Depends on unit: • CF 2-3/4" flange mount • B6N (female) • B20N ◦ with MC6 adapter (male, 6 mm threaded stud) ◦ with 6 mm socket (female) ◦ with 6 mm pin (male) ◦ 6 mm tapped hole only, no stud (female) • 7-16 (female)
AC power input connector (for units with AC power)	IEC60320-1
DC power input connector (for units with DC power)	9-pin CPC series connector, male (Tyco/Amp PN: 206486-1 or equivalent)
Host connector	RS-232, 9-pin, female, subminiature- D
Analog I/O connector (optional)	15-pin, female, subminiature-D, Cesar interface
PROFIBUS connector (optional)	9-pin, female, subminiature-D

Related Links

- [“Dimensional Drawings” on page 5-1](#)

ELECTRICAL SPECIFICATIONS

Table 3-2 shows the electrical specifications for Navio match networks.

**Important**

The serial tag on the unit includes the part number and option.

Table 3-2. Match network electrical specifications

Description	Specification
Frequency	Indicated by the <i>F</i> in the product part number 31554<i>FP</i>-xxx: • <i>F</i>=0: 13.56 MHz, $\pm 0.005\%$ • <i>F</i>=3: 27.12 MHz, $\pm 0.005\%$ • <i>F</i>=5: 40.68 MHz, $\pm 0.005\%$ • <i>F</i>=7: 60 MHz, $\pm 0.005\%$ For tuning ranges, see “Tune Ranges”.
Input power	Indicated by the <i>P</i> in the product part number 31554<i>FP</i>-xxx: • <i>P</i>=0: 1 kW, Flat Package • <i>P</i>=1: 1 kW, Standard Package • <i>P</i>=3: 3 kW, Standard Package • <i>P</i>=5: 5 kW, Standard Package For safe operating areas and power derating charts, contact AE Global Services.
DC input power (units with DC input)	• DC Voltage: 24 VDC nominal, $\pm 10\%$ • DC Current, maximum: 4.0 A • DC Current, idle: <2.0 A
Internal DC power supply voltage rating	• Voltage rating: +24 VDC • Current rating: 2.7 A maximum, 3.5 A peak
AC input (units with AC input)	• AC Voltage: 100 VAC to 240 VAC, single ϕ • Frequency: 50 Hz to 60 Hz • AC Current: < 1.4 Arms
DC bias accuracy	$\pm 1\%$ full range

Table 3-2. Match network electrical specifications (Continued)

Description	Specification
Reflected power	Depends on input power: • 1 kW units: 4 W or 1% maximum of forward power at 20 W to 1000 W, whichever is greater • 3 kW units: 5 W or 1% maximum of forward power at 30 W to 3000 W, whichever is greater • 5 kW units: 5 W or 1% maximum of forward power at 50 W to 5000 W, whichever is greater
Input impedance	50 Ω , nominal
Tuning time	< 3 seconds end-to-end < 2 seconds from proper preset point to matched condition
Tuning range	The tuning range depends on the unit frequency and on the tuning coil installed. To reach appropriate resistance and reactance values, you may need to change load and series coils. For the typical tuning range for your unit, see “Tune Ranges”.
Settling time	≤ 1 second, defined as the time for the match network to re-establish a return loss ≤ -20 dB when the load reactance is shifted sufficiently to introduce and instantaneous rise in the return loss to -10 dB
Stability	No oscillation of capacitor position for any stable load
Automatic/Preset threshold	Capacitor positions: relative position of each tuning element, scaled for incident RF power: 1 kW units: • Incident RF power ≤ 10 W, capacitors remain in preset positions • Incident RF power ≥ 20 W, unit remains in automatic tune mode (provided host control mode is not selected) 3 kW units: • Incident RF power ≤ 15 W, capacitors remain in preset positions • Incident RF power ≥ 30 W, unit remains in automatic tune mode (provided host control mode is not selected) 5 kW units: • Incident RF power ≤ 30 W, capacitors remain in preset positions • Incident RF power ≥ 50 W, unit remains in automatic tune mode (provided host control mode is not selected)

Table 3-2. Match network electrical specifications (Continued)

Description	Specification
DC bias scaling	For units with the Analog I/O port and the DC bias feature. For Navio units with detection of bipolar plasma bias, the output voltage is scaled down -400:1 V/V. Both positive and negative DC bias at the RF output is read back as a positive voltage at the Analog I/O port. Cesar generators expect to see a positive DC bias reading. For Navio units paired with Cesar generators, use the Analog I/O port to make sure the DC bias readback is a positive value.

RF Output Connector Specifications

Table 3-3. RF output connector specifications

RF output	Output voltage maximum	Output current maximum
B6N	4000 V peak	40 A _{rms} at 13.56 MHz
B20N	4000 V peak	70 A _{rms} at 13.56 MHz
B20N, with 6 mm stud	4000 V peak	40 A _{rms} at 13.56 MHz
B20N, with 6 mm socket	4000 V peak	40 A _{rms} at 13.56 MHz
B20N, with 6 mm pin	4000 V peak	40 A _{rms} at 13.56 MHz
7-16	2700 V peak	35 A _{rms} at 13.56 MHz 25 A _{rms} at 60.00 MHz
CF 2-3/4" flange	4000 V peak	55 A _{rms} at 13.56 MHz

COOLING SPECIFICATIONS

Table 3-4 lists the cooling specifications for the match network.

Table 3-4. Air cooling specifications

Description	Specification
Temperature	+5°C to +40°C +41°F to +104°F
Flow	less than 4274 lpm (150 cfm)
Heat load to air	At 70 A, less than 350 W

ENVIRONMENTAL SPECIFICATIONS

Table 3-5 and Table 3-6 describe the environmental specifications for the Navio match network.

Table 3-5. Environmental standard specifications

Description	Specification
Surface mounting temperature	50°C maximum
Overvoltage	Category II
Pollution degree	1

Table 3-6. Climatic specifications (per EN50178)

	Temperature	Relative Humidity	Air Pressure
Operating	5°C to +40°C +41°F to +104°F	5% to 85% ^{note 1} +1 g/m ³ to +25 g/m ³	78.8 kPa to 106 kPa 788 mbar to 1060 mbar Equivalent altitude: 2000 m to -500 m (6562' to -1640')
Storage	-25°C to +55°C -13°F to +131°F	5% to 95% +1 g/m ³ to +29 g/m ³	78.8 kPa to 106 kPa 788 mbar to 1060 mbar Equivalent altitude: 2000 m to -500 m (6562' to -1640')
Transportation	-25°C to +70°C -13°F to +158°F	95% ^{note 2} +60 g/m ³ ^{note 3}	65.6 kPa to 106 kPa 656 mbar to 1060 mbar Equivalent altitude: 3500 m to -500 m (11480' to -1640')
^{note 1} Non-condensing, no formation of ice ^{note 2} Maximum relative humidity when the unit temperature slowly increases, or when the unit temperature directly increases from -25°C to +30°C ^{note 3} Maximum absolute humidity when the unit temperature directly decreases from +70°C to +15°C			

Communication Controls

OVERVIEW

The Navio match network is equipped with communication ports. Depending on the option, your unit may be equipped with one or more of the following ports:

- **PROFIBUS**
- **Analog I/O**, 15-pin CESAR interface
- **Host**

To determine which communication port your unit has, look on the front of the unit for the port label.

HOST INTERFACE

The Navio unit provides a serial communications interface through the **Host** port. This interface allows the Navio unit to interface with a host computer using the AE Bus protocol.

AE manufactures a more full-function interface software for some products, called Virtual Front Panel, which allows you to use a host computer to communicate with the unit through the **Host** port. To find out more about this software, please call AE Global Services.

Related Links

- [“Host Connector” on page 4-1](#)
- [“Host Port Pin Descriptions” on page 4-2](#)
- [“AE Bus Transmission Parameters” on page 4-2](#)
- [“AE Bus Protocol” on page 4-3](#)
- [“Creating an Ideal Communications Transaction” on page 4-5](#)
- [“AE Bus Commands” on page 4-7](#)

Host Connector

The serial **Host** port connector is a 9-pin, female, shielded, subminiature-D connector for interfacing with a host computer.



Figure 4-1. *Host port connector*

Host Port Pin Descriptions

Table 4-1. *Host port pin descriptions*

Signal Pin	Name	Description
1	Reserved	Reserved for future use
2	<i>RS-232 TXD.D</i>	RS-232 transmit data to the host
3	<i>RS-232 RXD.D</i>	RS-232 receive data from the most
4	Reserved	Reserved for future use
5	<i>COM.D</i>	Data common
6	Reserved	Reserved
7	Reserved	Reserved
8	Reserved	Reserved for future use
9	Reserved	Reserved for future use

AE Bus Transmission Parameters

The communications capability of the **Host** port is limited to the following parameters:

- RS-232 protocol
- RS-232:
 - 1200
 - 4800
 - 9600
 - 19,200
- Navio unit addresses 1 to 31
- Odd parity
- One start bit, eight data bits, one stop bit
- Low-order bytes transmitted before high-order bytes (little endian)

The time-out period for the Navio unit is 1 second (that is, no more than 1 second can elapse between bytes, or the unit will reset and begin searching for a new message packet).

The host computer must finish one transaction with the Navio unit before it initiates another one, either with the same unit or any other unit.

The Navio unit sends data through pin 2 (*TX RS-232*). This pin must be connected to the receive pin (*RX RS-232*) on the host computer's serial connector. The receive pin is normally pin 2 for a standard, 9-pin serial port.

AE Bus Protocol

The AE Bus protocol uses pure binary data (nothing is coded in ASCII) and is designed to facilitate direct communications between a host computer and the Navio unit. The AE Bus message packet combines a set quantity of bits and bytes in such a way that groups of information can be sent over communications lines at one time. Five types of information (fields) make up a communications message packet.

- Header (address and the length of Data field)
- Command Number
- Optional Length byte
- Data
- Checksum

Figure 4-2 shows the organization of these fields in the AE Bus message packet. The subsequent paragraphs describe each field in detail.

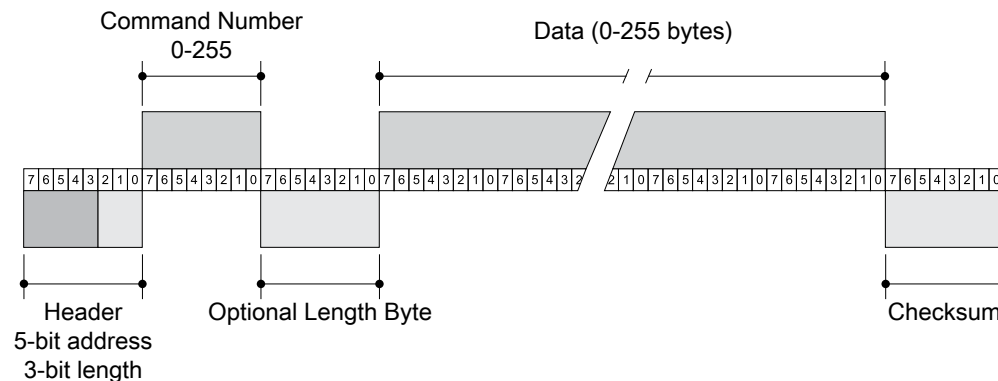


Figure 4-2. Graphic representation of a message packet

AE BUS HEADER BYTE

The first byte in each packet contains two pieces of information: five bits contain the packet address, and three bits contain the data byte count. If the message packet originates with the host computer, the address specifies the packet destination (to the Navio unit, for example). If the packet is going to the host, the address specifies the

packet origin (from the Navio unit). The address section of the Header field is five bits long (bits 3-7), which allows a total of 32 distinct addresses. Address 0 (zero) is reserved for the network broadcast address, which the Navio unit does not support.

The remaining three bits (bits 0, 1, and 2) are the length bits. These bits tell the receiving unit how long the Data field is so that the unit can determine when it has received the entire message. If the Data field contains more than six bytes, the value of these three bits will be set to 7 (07h), and the Optional length byte field will contain a value indicating the number of data bytes in the Data field.

**Important**

The value of these bits refers only to the number of actual data bytes in the Data field. Do not include the checksum byte when calculating the value for these bits.

AE BUS COMMAND NUMBER BYTE

This one-byte field contains an 8-bit value from 0 to 255 (00h to ffh) representing the command number. If the message packet originates with the host computer, this value specifies the purpose of the message packet. If the message originates with the Navio unit, the value specifies the command to which it is responding.

AE BUS OPTIONAL LENGTH BYTE

This field supplements the Header field and exists only when the length bits (bits 0, 1, and 2) in the Header field contain a value of 7 (07h). If the number of data bytes in the Data field is six or less, then the three length bits in the Header field are sufficient to represent this amount 0 to 6 (00h to 06h). Since the Data field may contain up to 255 bytes of information, the Optional Length byte is required when the Data field is larger than six bytes.

When the Data field is larger than six bytes, the length bits in the header (bits 0, 1, and 2) equals 7 (07h), and the Optional Length byte contains a one-byte value, from 7 to 255 (07h to ffh), representing the number of data bytes in the Data field.

AE BUS DATA BYTES

The Data field may contain from 0 to 255 bytes of binary data. This field contains command-related data or a command status response (CSR). Since some commands do not require data, sometimes the Data field is not present.

If the value specified in the length bits (bits 0, 1, and 2) of the Header field is 0 to 6, the Navio unit expects zero to six data bytes. However, if the value in the Header field is 7 (07h), the Navio unit looks for the Optional Length byte after the Command field and reads this value to calculate the data byte count.

Unless otherwise specified for individual commands, AE Bus protocol is little endian, which means that all values greater than 1 byte are sent in little endian order. For example, a command with 7 data bytes that included one 8-bit value, one 16-bit value, and one 32-bit value, would be sent as shown in [Table 4-2](#).

Table 4-2. *AE Bus byte structure*

Value to send	Byte configuration
8-bit value = 15	Byte 1 = 0x0F
16-bit value = 23450	Bytes 2 and 3 = 0x9A 0x5B
32-bit value = 147679	Bytes 4 through 7 = 0xDF 0x40 0x02 0x00

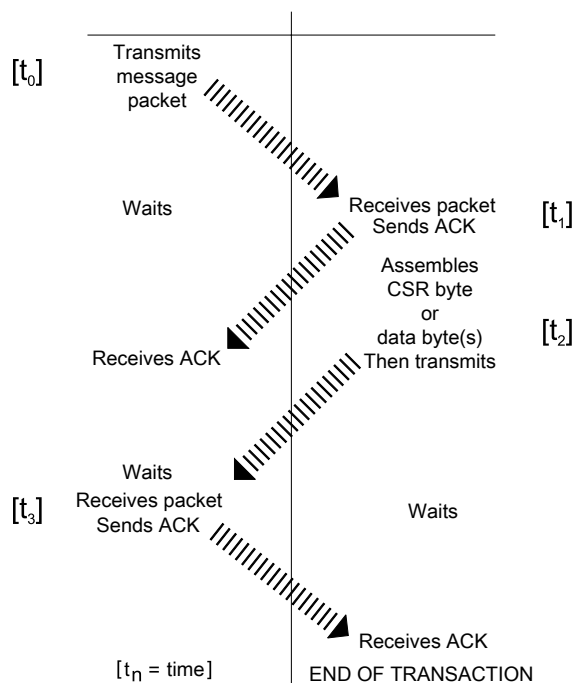
AE BUS CHECKSUM BYTE

This one-byte field is the last byte in the packet. The value of this byte depends upon the number of bytes in each of the preceding fields. The transmitting unit determines this value by accumulating the exclusive-or (XOR) of all bytes of the packet up to, but not including, the checksum value. The receiving unit accumulates the XOR of all bytes of the packet, including the checksum. If the result is zero, the unit has received the packet intact.

The unit will act on the message only if the address is valid and the checksum is validated.

Creating an Ideal Communications Transaction

Figure 4-3 illustrates the steps in an ideal communications transaction between a host computer and the Navio unit.

**Figure 4-3.** *AE Bus communications transaction*

T₀: HOST TRANSMITS MESSAGE PACKET

The host computer sends a message packet to the Navio unit. The packet contains one of the following:

- A command that requests data or status information
- A command and data that change a parameter setting
- An executable command

T₁: UNIT VERIFIES HOST TRANSMISSION PACKET

Once the Navio unit receives the host computer transmission message packet, the Navio unit verifies that the message is intended for it and not for another unit on the network. At this time, the Navio unit also analyzes the checksum to verify that the message was received correctly.

- If the address does not match, the Navio unit does not respond to the host computer; the Navio unit resets and resumes waiting for a message addressed to it. If the address matches but the exclusive-or (XOR) sum of the bytes in the packet (including the checksum) is not zero, the Navio unit sends a negative acknowledgment (NAK), hexadecimal 15h, to the host computer.
- If the address matches and the message is intact, the Navio unit sends an acknowledgment (ACK), hexadecimal 06h, to the host computer.

If the Navio unit receives a request for data or status information, it gathers and sends the requested information. Otherwise, it evaluates the incoming command and sends a message packet that contains a one-byte data value (CSR code) to the host. The power supply sends CSR code 0 when it has accepted the command.

If the host computer receives a NAK from the Navio unit, the host computer either retransmits the packet or does whatever else it has been programmed to do in this situation. If the host computer receives an ACK, it waits for the requested data or status information, or it waits for the CSR code telling it whether or not the new parameter was accepted. If the host computer receives no response within a reasonable period, it takes whatever action it has been programmed to take.

T₂: UNIT TRANSMITS RESPONSE TO HOST

The Navio unit prepares a response packet with the requested information or appropriate CSR code, which it then transmits to the host computer. The host computer then determines, by means of the checksum, if the response packet is complete. If the host computer detects an error in the transmission (the checksum is not validated), it can request the packet be sent again by transmitting a NAK.

T₃: HOST ACKNOWLEDGES UNIT RESPONSE

If the Navio unit receives an ACK from the host computer, it returns to the normal waiting state. If the Navio unit receives a NAK from the host computer, the unit retransmits the response packet. The Navio unit continues to retransmit in response to

NAK transmissions until the host computer stops the cycle. If the Navio unit receives no response, it assumes an ACK and returns to the waiting state.

AE BUS COMMUNICATIONS TRANSACTION EXAMPLE

Figure 4-4 illustrates the steps in an example communications transaction between a host computer and the Navio unit.

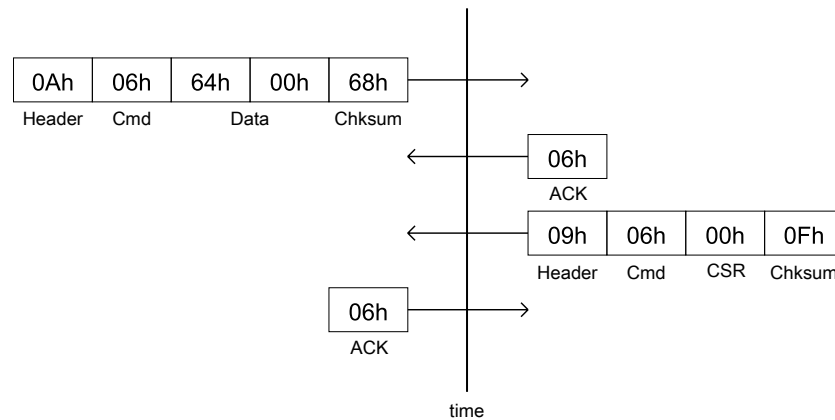


Figure 4-4. Communications transaction example

AE Bus Commands

The following sections describe the command status response (CSR) codes returned by the Navio unit in response to a command, as well as the AE Bus commands for the Navio unit.

AE BUS COMMAND STATUS RESPONSE (CSR) CODES

When the Navio unit receives a command requesting a change in unit operation (command numbers 1 through 127), or when the Navio unit receives any command that it rejects (command numbers 1 through 255), it responds with a command status response (CSR) code. The CSR is a single-byte number that indicates whether the unit accepted or rejected the command and, in the case of rejection, the reason the unit could not respond to the command.

Table 4-3. AE Bus command status response (CSR) codes

Code	Meaning
0	Command accepted
The following CSR codes are sent in response to a command that was rejected and indicate the reason for rejection.	
4	Parameter is out of its acceptable range
9	Data byte count is incorrect

Table 4-3. AE Bus command status response (CSR) codes (Continued)

Code	Meaning
31	Active preset is incorrect.
32	Automatic tune mode is active with RF output power on; therefore, command is invalid.
33	Selected serial digital to analog converter (SDAC) is invalid.
34	Selected SADC channel is invalid.
35	Serial control mode is inactive.
36	Selected potentiometer is invalid.
37	Selected preset is invalid.
38	Trajectory count is invalid.
39	Invalid sensor select parameter was received.
40	Invalid control mode parameters were received.
41	Serial communication address is invalid.
42	Service log sector is invalid.
43	Selected host command parameter is out of range.
47	Motor movement disabled.
48	Motor is already moving.
49	An invalid Xilinx® data byte count was detected.
50	Motor movement failed.
94	The unit is in ISP SEEPROM Xilinx configuration data loop.
95	The unit is in motor initialization off stop diagnostic loop. Contact AE Global Services.
96	Unit is in unit function pointer diagnostic loop. Contact AE Global Services.
97	Unit is in NOVRAM initialization host diagnostic loop. Contact AE Global Services.
98	Unit is in initialization host diagnostic loop. Contact AE Global Services.
99	Command is not implemented.

AE HOST PORT COMMAND SET

The Navio unit Host serial communication interface has two types of commands:

- Commands **1** through **127** request a change to the Navio unit, such as changing a setting in the unit. The unit responds to these commands by sending a command status response (CSR). This single-byte response indicates whether

the unit has accepted or rejected the command and, in the case of rejection, the reason the unit could not respond to the command.

- Command numbers **128** through **255** request information from the unit, such as unit settings. The unit responds to these commands by sending the data requested if the command was successful, and a CSR if the command was not successful.

Unless otherwise specified for individual commands, AE Bus protocol is little endian, which means that all values greater than 1 byte are sent least significant byte first.



Important

If you are not using the recommended handshaking protocol, do not send commands to the match network at a rate faster than 1 command every 50 milliseconds (20 commands per second) as this will cause the unit to either not respond or to respond in an improper manner.

Table 4-4. AE Bus commands

Command	Description	Data Bytes Sent	Data Bytes Returned
71 set impedance target	Sets the target impedance to which the match tunes. Send four data bytes (two 16-bit values), least significant byte first: • Bytes 0 and 1 = The real part of the target impedance (r_{target}) (converted from ohms); default value in ohms is 50 • Bytes 2 and 3 = The imaginary part of the target impedance (x_{target}) (converted from ohms); default value in ohms is 0 These values are converted by multiplying the desired value in ohms by 20.48. For example, to send 50 ohms, you would send 1024. Read back with command 148.	4	1 (CSR only)
82 autotune setup	Sets up automatic tuning parameters. Important Adjustments in the autotune setup parameters provide a powerful tool for customizing the operation of the match network. However, incorrect autotune setups can cause poor tuning performance and/or shortened life of the vacuum capacitors in the match network.	27	1 (CSR only)

Table 4-4. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	Send 27 bytes, least significant byte first. - Bytes 0 and 1 (16-bit value) = Converted VSWR tuning stop value. Range = 1 to 32. - Bytes 2 and 3 (16-bit value) = Converted VSWR tuning start value. Range = 1 to 32. VSWR values must be converted before being sent. First, convert the VSWR value to a gamma value: $\text{gamma} = (\text{VSWR} - 1) / (\text{VSWR} + 1)$. Second, square the gamma value and multiply it by 1024. For example, for a VSWR of 1.09: First calculate gamma: $(1.09 - 1) / (1.09 + 1) = 0.04306$. Second, square gamma and multiply by 1024: $(0.04306^2 * 1024 = 1.8989)$. Round to 2, which is the closest number that can be sent. - Bytes 4 through 7 = Reserved (default = 0) - Bytes 8 and 9 (16-bit value) = Maximum load percent capacitor position (in hundredths of percent). The automatic tuning algorithm uses this parameter (as well as those for bytes 12 through 15) to assist in capacitor movement control. - Bytes 10 and 11 = Reserved (default = 0) - Bytes 12 and 13 (16-bit value) = Maximum tune percent capacitor position (in hundredths of percent). - Bytes 14 and 15 (16-bit value) = Minimum tune percent capacitor position (in hundredths of percent). - Bytes 16 and 17 = Magnitude→load cross dependence coefficient (converted) This value and the next three values (all of the cross dependence coefficients) must be converted before being sent. To convert the value, multiply the desired coefficient by 1024, then send the closest round number. For example, to send a value of 0.2 $(0.2 * 1024 = 204.8)$, you would send 205.		

Table 4-4. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	• Bytes 18 and 19 = Phase→load cross dependence coefficient (converted) • Bytes 20 and 21 = Magnitude→tune cross dependence coefficient (converted) • Bytes 22 and 23 = Phase→tune cross dependence coefficient (converted) • Byte 24 = Algorithm number (0 = VSWR start/stop, which is the default). You must send a value of 0. • Byte 25 (8-bit value) = Hold load mode ◦ 0 = Turn off hold load mode ◦ 1 = Turn on hold load mode • Byte 26 (8-bit value) = Integrated value of gamma, which determines whether automatic tuning should start again. ◦ 0 = No integration ◦ 1 = Integrate 2 samples ◦ 2 = Integrate 4 samples ◦ 3 = Integrate 8 samples ◦ 4 = Integrate 16 samples ◦ 5 = Integrate 32 samples ◦ 6 = Integrate 64 samples ◦ 7 = Integrate 128 samples ◦ 8 = Integrate 256 samples Read back with command 152.		

Table 4-4. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
84 capacitor limits	Sets the minimum and maximum positions for the tune and load capacitors. The positions are used by the tuning algorithm. Send 8 data bytes (four 16-bit values), least significant byte first. The minimum position should always be less than the maximum position. The valid range is 0 to 10000, representing hundredths of percents of capacitor position (for 1000 = 10%). • Bytes 0 and 1 = Minimum load percent • Bytes 2 and 3 = Minimum tune percent • Bytes 4 and 5 = Maximum load percent • Bytes 6 and 7 = Maximum tune percent Read back with command 154.	8	1 (CSR only)

Table 4-4. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
88 set sensor parameters	Sets data for the specified sensor. Send 3 or 4 bytes (depending on which parameter you set), least significant byte first. • Byte 0 (8-bit value) = Sensor ◦ 0 = Input sensor ◦ 1 = Output sensor • Byte 1 (8-bit value) = Parameters to set ◦ 0 = Power off limit—sets the unit to detect whether power is on or off (and, therefore, the threshold when automatic tuning turns on and off) ◦ 1 = Sensor averaging control If you set byte 1 to power off limit: • Bytes 2 and 3 (signed integer) = Power limit (in watts) at which the Navio match network detects power on If you set byte 1 to sensor averaging control: • Byte 2 (8-bit value) = Number of sensor readings averaged by the Navio match network. (Averaging reduces the noise in the sensor reading.) ◦ 0 = 1 reading (no averaging) ◦ 1 = 2 readings ◦ 2 = 4 readings ◦ 3 = 8 readings Read back with command 158.	3 or 4	1 (CSR only)

Table 4-4. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
90 set presets and trajectories	Sets an initial preset position and, if desired, corresponding trajectory points. The number of data bytes depends on the number of trajectory positions. To set the initial position only, send six bytes. Send four additional bytes for each trajectory position (up to three additional trajectories).  Important You must establish trajectory pairs in order; a second pair cannot exist without the first pair, a third pair cannot exist without a first and second pair. Capacitor positions are set in hundredths of percent of potential capacitor position (1000 = 10%). • Byte 0 (8-bit value) = The preset to set (1, 2, 3, or 4) • Byte 1 (8-bit value) = Number of trajectories pairs in the packet (0, 1, 2, or 3) • Bytes 2 and 3 (16-bit value) = Initial load capacitor position • Bytes 4 and 5 (16-bit value) = Initial tune capacitor position • Bytes 6 and 7 (16-bit value) = First load trajectory position • Bytes 8 and 9 (16-bit value) = First tune trajectory position • Bytes 10 and 11 (16-bit value) = Second load trajectory position • Bytes 12 and 13 (16-bit value) = Second tune trajectory position • Bytes 14 and 15 (16-bit value) = Third load trajectory position • Bytes 16 and 17 (16-bit value) = Third tune trajectory position. For related settings, see commands 91, 94, and 100. Read back with command 160.	6, 10, 14, or 18, depending on the number of trajectory positions established	1 (CSR only)

Table 4-4. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
91 select preset	Selects a preset. Send 1 data byte (8-bit value) indicating the desired preset (1, 2, 3, or 4). For related settings, see commands 90, 94, and 100. Read back with command 161.	1	1 (CSR only)
93 set operating mode	Sets the operating mode. Send 1 data byte (8-bit value) indicating the operating mode: • 0 = Analog port control (manual mode available only on models with an analog port) • 1 = Automatic control • 2 = Serial port control (manual mode using a serial port) Read back with command 163.	1	1 (CSR only)
94 enable/disable presets	Enables/disables the presets. If you enable presets and the unit is in automatic tuning mode, the active preset takes effect at the next RF-off event. If RF is already off, the capacitors move to the preset positions when you enable presets. If you disable presets, no preset positions will be applied, and the capacitors remain in their current positions when RF is turned off. Send 1 data byte (8-bit value) to enable or disable presets: • 0 = Disable • 1 = Enable For related settings, see commands 90, 91, and 100. Read back with command 164.	1	1 (CSR only)

Table 4-4. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
98 disable motor movement	Disables or enables motor movement. Send 1 data byte (8-bit value): • 0 = Enable • 1 = Disable Read back with command 168.	1	1 (CSR only)
100 set preset/trajectory delays	Sets any one of four initial preset delays and, if desired, its corresponding trajectory delays. Send 3, 4, 5, or 6 data bytes, depending on the number of trajectory delays. • Byte 0 (8-bit value) = The preset number (1, 2, 3 or 4) • Byte 1 (8-bit value) = Number of trajectory delays included in the packet: ◦ 0 = Initial preset delay only ◦ 1 = First trajectory delay ◦ 2 = Second trajectory delay ◦ 3 = Third trajectory delay The third trajectory delay may not exist without the first and second trajectory delays. The second trajectory delay may not exist without the first. • Byte 2 (8-bit value) = Initial preset delay All delays are set in hundredths of seconds (for example, 250 = 2.5 s). • Byte 3 (8-bit value) = First trajectory delay • Byte 4 (8-bit value) = Second trajectory delay • Byte 5 (8-bit value) = Third trajectory delay For related settings, see commands 90, 91, and 94. Read back with command 170.	3, 4, 5, or 6	1 (CSR only)

Table 4-4. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
112 move load to position	Moves the load capacitor to the specified position. Send 2 data bytes (16-bit value) to move the load capacitor to a new position. Position is set in hundredths of percent of the total range of potential capacitor movement. The valid range is 0 to 10000 (0% to 100%). Read back with command 180 .	2	1 (CSR only)
117 set AE Bus baud rate	Sets the baud rate for AE Bus communications. Send 2 data bytes (16-bit value) representing the baud rate. - Valid baud rates for RS-232: 1200 4800 9600 19200 (default)  Important You must cycle power before the new baud rate takes effect.	2	1 (CSR only)
122 move tune to position	Moves the tune capacitor to the specified position. Send 2 data bytes (16-bit value) to move the tune capacitor to a new position. Position is set in hundredths of percent of the total range of potential capacitor movement. The valid range is 0 to 10000 (0% to 100%). Read back with command 180 .	2	1 (CSR only)
125 initialize capacitors	Moves all capacitors to their minimum positions.	0	1 (CSR only)
127 set AE BUS address	Sets the unit's AE Bus communications address. Send 1 data byte representing the AE Bus address. Valid address values: 1 through 31. Default = 2.  Important You must cycle power to the unit before this new setting takes effect.	1	1 (CSR only)

Table 4-4. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
128 report match type	Reports the match network type. Returns 20 data bytes (ASCII format) representing the following: • NAVIGATOR Auto Match	0	20
130 report software number	Reports the software part number. Returns 7 data bytes (ASCII format) representing a seven-digit software part number.	0	7
131 report status	Reports the Navio match network status. Returns 4 data bytes. If a specified bit is set, it indicates that the status is true or the feature is active. • 0x00000001 = RF on • 0x00000002 = Tuned • 0x00000004 = Automatic mode active • 0x00000008 = Serial port mode active (manual mode using a serial port) • 0x00000010 = Analog port mode active (manual mode available only on models with an Analog I/O port) • 0x00000020 = Presets enabled • 0x00000080 = Generic fault status • 0x00000100 = Preset mode active • 0x00000200 = Motor movement disabled • 0x01000000 = Low supply 24 V fault • 0x04000000 = NOVRAM hardware fault • 0x08000000 = Overtemperature fault • 0x20000000 = Tune voltage fault • 0x40000000 = Output current fault • 0x80000000 = Motor initialization fault	0	4

Table 4-4. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
135 report motor movement	Reports status of stepper motor movement. Returns 1 data byte. When set, the specified bits indicate that movement is active. • 0x01 = Tune motor moving • 0x02 = Load motor moving • 0x03 = Both tune and load motors moving	0	1
141 report target impedance	Reports the real and imaginary components of the target impedance. Returns 4 data bytes (two 16-bit values), least significant byte first.  Important The values reported by this command are converted from ohms. To convert the readback value to ohms, divide by 20.48. For example, if a value of 1024 is returned, the value in ohms is 50. • Bytes 0 and 1 = The real part of the target impedance (r_target) (converted from ohms); default value in ohms is 50 • Bytes 2 and 3 = The imaginary part of the target impedance (x_target) (converted from ohms); default value in ohms is 0 Set with command 71.	0	4
152 report autotune setup	Reports the automatic tuning parameters. Returns 27 bytes, least significant byte first: • Bytes 0 and 1 (16-bit value) = Converted VSWR tuning stop value • Bytes 2 and 3 (16-bit value) = Converted VSWR tuning start value. VSWR readback values are converted. To convert the value, first divide the value that is returned by 1024, then calculate the square root of that value. This calculation provides the gamma value. To convert gamma to VSWR, use the following equation: VSWR	0	27

Table 4-4. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	$= (1+\gamma)/(1-\gamma)$. For example, if the unit returns a value of 2: First calculate gamma: $\sqrt{2/1024} = 0.044194$ Second, calculate VSWR: $1.09247 = \frac{1 + 0.044194}{1 - 0.044194}$ • Bytes 4 through 7 = Reserved (default = 0) • Bytes 8 and 9 (16 bit value) = Maximum load percent capacitor position (in hundredths of percent) The automatic tuning algorithm uses this parameter (as well as those for bytes 13 through 16) to assist in capacitor movement control. • Bytes 10 and 11 = Reserved (default = 0) • Bytes 12 and 13 (16 bit value) = Maximum tune percent capacitor position (in hundredths of percent) • Bytes 14 and 15 (16 bit value) = Minimum tune percent capacitor position (in hundredths of percent) • Bytes 16 and 17 = Magnitude→load cross dependence coefficient (converted) This value and the next three values (all of the cross dependence coefficients) must be converted from the readback value to the coefficient value. To convert, divide the readback value by 1024. For example, if you receive a value of 205 ($205/1024 = 0.2$), the coefficient value is 0.2. • Bytes 18 and 19 = Phase→load cross dependence coefficient (converted) • Bytes 20 and 21 = Magnitude→tune cross dependence coefficient (converted) • Bytes 22 and 23 = Phase→tune cross dependence coefficient (converted)		

Table 4-4. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	• Byte 24 = Algorithm number (0 = VSWR start/stop, which is the default). • Byte 25 (8-bit value) = Hold load mode ◦ 0 = Turn off hold load mode ◦ 1 = Turn on hold load mode • Byte 26 (8-bit value) = Integrated value of gamma, which determines whether automatic tuning should start again ◦ 0 = No integration ◦ 1 = Integrate 2 samples ◦ 2 = Integrate 4 samples ◦ 3 = Integrate 8 samples ◦ 4 = Integrate 16 samples ◦ 5 = Integrate 32 samples ◦ 6 = Integrate 64 samples ◦ 7 = Integrate 128 samples ◦ 8 = Integrate 256 samples Set with command 82.		
154 report capacitor limits	Reports the minimum and maximum positions in hundredths of percents for the tune and load capacitors, which are used by the tuning algorithm. Returns 8 data bytes (four 16-bit values), least significant byte first. • Bytes 0 and 1 = Minimum load percent • Bytes 2 and 3 = Minimum tune percent • Bytes 4 and 5 = Maximum load percent • Bytes 6 and 7 = Maximum tune percent Set with command 84.	0	8

Table 4-4. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
158 report sensor setup	Reports the requested information for the selected sensor. Send 2 data bytes: • Byte 0 (8-bit value) = Sensor ◦ 0 = Input sensor ◦ 1 = Output sensor • Byte 1 = Parameter to read ◦ 0 = Power off limit (sets the unit to detect whether power is on or off) ◦ 1 = Sensor averaging control Returns 2 or 3 data bytes, depending on the selected parameter: • Return byte 0 = The parameter being returned ◦ 0 = Power off limit ◦ 1 = Sensor averaging control If you set send byte 1 to power off limit: • Return bytes 1 and 2 (signed integer) = Power off limit (in watts) at which the Navio match network detects power on If you set send byte 1 to sensor averaging control: • Return byte 1 (8-bit value) = Number of sensor readings averaged by the Navio match network. (Averaging reduces the noise in the sensor reading.) ◦ 0 = 1 reading (no averaging) ◦ 1 = 2 readings ◦ 2 = 4 readings ◦ 3 = 8 readings Set with command 88.	2	2, 3

Table 4-4. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
160 report presets/trajectories	Reports one of four initial preset positions and, if used, corresponding trajectory points. Send 1 data byte (8-bit value) indicating the desired preset (1, 2, 3, or 4). Returns 6, 10, 14, or 18 bytes. Capacitor positions are reported in hundredths of percent of potential capacitor position (1000 = 10%). • Byte 0 (8-bit value) = The requested preset (1, 2, 3, or 4) • Byte 1 (8-bit value) = Number of trajectory pairs included in the packet (0, 1, 2, or 3) • Bytes 2 and 3 (16-bit value) = Initial load capacitor position • Bytes 4 and 5 (16-bit value) = Initial tune capacitor position Bytes 6 through 17 may or may not be included. Byte 2 will indicate how many, if any, of these trajectory pairs will be included within the return packet. • Bytes 6 and 7 (16-bit value) = First load trajectory position • Bytes 8 and 9 (16-bit value) = First tune trajectory position • Bytes 10 and 11 (16-bit value) = Second load trajectory position • Bytes 12 and 13 (16-bit value) = Second tune trajectory position • Bytes 14 and 15 (16-bit value) = Third load trajectory position • Bytes 16 and 17 (16-bit value) = Third tune trajectory position. For related readbacks, see commands 161, 164, and 170. Set with command 90.	1	6, 10, 14, or 18, depending on the number of established trajectory positions

Table 4-4. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
161 report selected preset	Reports the preset/trajectory set that is currently selected. Returns 1 data byte (8-bit value) = Selected preset (1, 2, 3, or 4). For related readbacks, see commands 160, 164, and 170. Set with command 91.	0	1
163 report operating mode	Reports the operating mode. Returns 1 data byte (8-bit value) indicating the operating mode: • 0 = Analog port control (manual mode available only on models with an Analog I/O port) • 1 = Automatic control • 2 = Serial port control (manual mode available on a serial port) Set with command 93.	0	1
164 report preset status	Reports whether the presets are enabled or disabled. Returns one data byte (8-bit value): • 1 = Enabled • 0 = Disabled Set with command 94. For related readbacks, see commands 160, 161, and 170.	0	1

Table 4-4. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
166 report caps corresponding capacitance values	Reports the load and tune capacitors' minimum and maximum obtainable capacitance values. Returns 8 data bytes (16-bit values): • Bytes 0 and 1 = Minimum load capacitance in picofarads • Bytes 2 and 3 = Minimum tune capacitance in picofarads • Bytes 4 and 5 = Maximum load capacitance in picofarads • Bytes 6 and 7 = Maximum tune capacitance in picofarads	0	8
168 report motor disable status	Reports whether motor movement is enabled or disabled. Returns 1 data byte (8-bit value): • 0 = Motor movement enabled • 1 = Motor movement disabled Set with command 98.	0	1
169 report personality number	Reports the unit's personality identification number. Returns 4 data bytes (8-bit values, least significant byte first), indicating the personality identification number. If bit 17 is set (0x00020000) , then the controller returns 8 data bytes (8-bit values, least significant byte first) indicating: • Bytes 1 through 4 = Personality identification number • Bytes 5 through 8 = Extended personality identification number	0	4 or 8

Table 4-4. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
170 report presets/ trajectory delays	Reports any one of the four initial preset delays and its trajectory delays. Send one data byte (8-bit value) indicating the preset for which you want information (1, 2, 3, or 4). Returns 3, 4, 5, or 6 bytes depending on the number of trajectories associated with the preset. • Byte 0 (8-bit value) = Preset number (1 through 4) • Byte 1 (8-bit value) = Number of trajectories included in the packet (0 through 3) • Byte 2 = Initial preset delay  Important All delays are reported in hundredths of seconds (for example, 250 = 2.5 s). • Byte 3 = First trajectory delay • Byte 4 = Second trajectory delay • Byte 5 = Third trajectory delay Set with command 100. For related readbacks, see commands 160, 161, and 164.	1	3, 4, 5, or 6
180 report capacitor positions	Reports load and tune capacitor positions. Position is reported in hundredths of percent of the total range of potential capacitor movement. Returns 4 bytes: • Bytes 0 and 1 (16-bit value) = Load capacitor position • Bytes 2 and 3 (16-bit value) = Tune capacitor position	0	4

Table 4-4. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
184 report specified capacitor positions	Reports load and tune capacitor positions. Position is reported in hundredths of percent of the total range of potential capacitor movement. Send 1 data byte to select the capacitor type to report data for: • 0 = Current processor capacitor positions • 1 = Xilinx absolute capacitor positions Returns 5 bytes: • Byte 0 (8-bit value) = Capacitor type: ◦ 0 = Current processor capacitor positions ◦ 1 = Xilinx absolute capacitor positions • Bytes 1 and 2 (16-bit value) = Load capacitor position • Bytes 3 and 4 (16-bit value) = Tune capacitor position	1	5

Table 4-4. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
185 report sensors calculated data	Calculates r, x, gamma, and power for the specified sensor. Send 1 data byte indicating the sensor: • 0 = 3x input sensor • 1 = Output sensor Returns 9 data bytes: • Byte 0 (8-bit value) = The selected sensor: ◦ 0 = 3x input sensor ◦ 1 = Output sensor • Bytes 1 and 2 (16-bit value) = r (converted). This and the next value are converted. Two versions of the conversion equation: ◦ $\Omega = (\text{readback value} * 50)/1024$ ◦ $\text{Readback value} = (\Omega * 1024)/50.$ • Bytes 3 and 4 (16-bit value) = x (converted —see equation for bytes 2 and 3) • Bytes 5 and 6 (16-bit value) = Gamma (converted). The readback value is converted. Two versions of the conversion equation: ◦ $\text{Gamma} = \text{square root of } ((\text{readback value})/1024)$ ◦ $\text{Readback value} = ((\text{gamma} * \text{gamma})1024).$ • Bytes 7 and 8 (16-bit value) = Power in watts	1	9

Table 4-4. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
186 report RF peak and DC bias	Reports RF_{PEAK} and DC bias values, in volts.  Important This command is not present on all units; not all units support RF peak or DC bias. To find out whether a specific model supports RF peak or DC bias, see the unit's product specification. Returns 4 data bytes (two 16 bit values): • Bytes 0 and 1 = RF_{PEAK} value • Bytes 2 and 3 = DC bias value A positive DC bias is reported as a positive value, negative DC bias is reported as a negative value.  Important Cesar generators expect to see a positive DC bias read back. If the Navio unit is paired with a Cesar generator, use the Analog I/O port instead of this port to provide DC bias readback to the generator.	0	4
187 report high current or voltage	If your unit has RF output sensor, this command reports the controller board SADCs (serial analog to digital converter) high voltage or current value. Returns 2 data bytes (integer, LSB first) indicating the high voltage value in volts or the high current value in amperes.  Important This command is not present on all units. For some models, this command reads back high voltage, for others a high current value. To find out whether a specific model reads back voltage or current, see the unit's product specification to check whether it lists overcurrent or overvoltage as an interlock trip condition.	0	2
198 report software version	Reports the software version number string. Returns 3 data bytes (ASCII format) indicating the software version.	0	3

Table 4-4. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
231 report unit serial number	Reports the unit serial number. Returns 4 data bytes (three 8-bit values).	0	4
254 report fault status	Reports the fault status of the Navio match network. If a specified bit is set, it indicates that the status is true or the fault is active. • 0x0000000000000001 = Low 24 V supply fault • 0x0000000000000002 = Overvoltage fault • 0x0000000000000004 = Fan operating too slowly • 0x0000000000000008 = Overtemperature fault • 0x0000000000000020 = Tune Voltage Fault • 0x0000000000000040 = Output Current Fault • 0x0000000000002000 = Motor initialization fault • 0x0000000000004000 = Drip sensor fault • 0x0000000000010000 = PROFIBUS watchdog fault • 0x0000000000020000 = PROFIBUS master released slave fault • 0x0000000000040000 = PROFIBUS MAC reset fault • 0x0000000000080000 = PROFIBUS buffer overflow fault • 0x0000000000100000 = PROFIBUS DPRAM busy fault • 0x0800000000000000 = Xilinx initialization fault • 0x1000000000000000 = Reserved for AE internal use	0	8

Table 4-4. AE Bus commands (Continued)

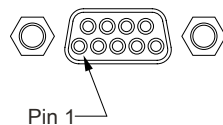
Command	Description	Data Bytes Sent	Data Bytes Returned
	0x2000000000000000 = Invalid unit pointer fault 0x8000000000000000 = NOVRAM hardware fault		

PROFIBUS INTERFACE

The Navio unit provides a serial communications interface through the **PROFIBUS** (Process Field Bus) port. This interface allows the Navio unit to interface with a PROFIBUS Master, which resides in a programmable logic controller (PLC).

PROFIBUS Connector

The serial **PROFIBUS** port connector is a 9-pin, female, shielded, subminiature-D connector for interfacing with a programmable logic controller (PLC). An eight-switch DIP (dual in-line package) is adjacent to the connector for setting the PROFIBUS address.

*Figure 4-5. PROFIBUS port connector*

PROFIBUS Port Pin and Signal Descriptions

Table 4-5. PROFIBUS port pin and signal descriptions

Signal Pin	Return Pin	Pin Name	Signal Type	Description
1	n/a	Unassigned	n/a	n/a
2	n/a	Unassigned	n/a	n/a
3	n/a	I/O port	Digital I/O	Differential I/O
4	n/a	Unassigned	n/a	n/a
5	n/a	Return	n/a	Isolated PROFIBUS return

Table 4-5. PROFIBUS port pin and signal descriptions (Continued)

Signal Pin	Return Pin	Pin Name	Signal Type	Description
6	5	+5 V	+5 VDC	Isolated PROFIBUS supply voltage
7	n/a	Unassigned	n/a	n/a
8	n/a	I/O port	Digital I/O	Differential I/O
9	n/a	Unassigned	n/a	n/a

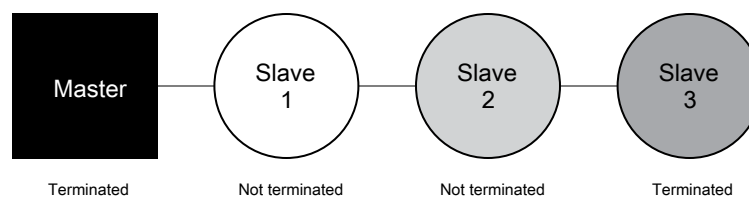
PROFIBUS Cabling and Termination

The cable used for the **PROFIBUS** interface must be RS-485 shielded twisted pair compatible with PROFIBUS standard communication requirements. Maximum segment lengths depend on the baud rate.

Table 4-6. Baud rate and cable lengths

Baud Rate	Length
1.5 M	200 meters
12 M	100 meters

Terminate each segment at both ends, and power the termination at all times. If a segment has more than 31 devices, then you must use a repeater. The termination resistors should be on the connector housing of the PROFIBUS cable (not included). Ensure that you follow proper termination procedures if your generator is the last slave on the PROFIBUS cable.

**Figure 4-6. Example of a segment**

AE PROFIBUS Protocol

The **PROFIBUS** port provides an interface that lets you communicate with the Navio unit from a PROFIBUS Master. AE manufactures a PROFIBUS interface compliant with PROFIBUS Masters described in the DIN 19245 PROFIBUS Standard DP, part III. Any PROFIBUS Master that complies with this standard can communicate with AE's PROFIBUS interface.



Important

AE's PROFIBUS protocol does not support the following functions: address changing, freeze/unfreeze modes, or sync modes.

PROFIBUS GSD FILES

GSD files are computer files that most programmable logic controllers (PLCs) use to configure PROFIBUS slaves. These files are device-specific and contain information on features found in that device.

The GSD file for your unit's PROFIBUS is available from Advanced Energy. For general PROFIBUS information and specific information about GSD files, visit the following Web site:

<http://www.profibus.com>

SETTING THE UNIT PROFIBUS NETWORK ADDRESS

You can set the Navio unit PROFIBUS address to an even-numbered address from 0 through 126.

To set the unit's PROFIBUS address, use the external DIP switch next to the **PROFIBUS** port.



Important

You cannot change the unit address from the PROFIBUS Master.

TO SET THE UNIT PROFIBUS ADDRESS THROUGH AN EXTERNAL DIP SWITCH

The following graphic shows a **PROFIBUS** port and DIP switch. As shown in the illustration, the DIP switch has numbered switch labels (1 through 8).

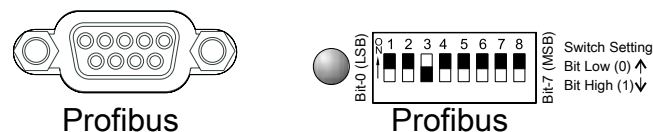


Figure 4-7. PROFIBUS port, LED, and DIP switch

One side of the DIP switch shows the switch numbers (1 through 8). Switch 8 is the msb. Positioning a switch toward the number indicates a “1” binary. To enter the unit address, set the DIP switch positions for binary representation of the desired address, with switch 8 as the msb. For example, to set an address of 4, set the switches to 00000100.

PROFIBUS STATUS LED

The PROFIBUS LED (light-emitting diode) on the rear panel indicates the status of data exchange with the PROFIBUS master:

- On = Data is being exchanged
- Off = No data is being exchanged

PROFIBUS MASTER RESET COMMAND

Send the master reset command, PROFIBUS command **119**, when the Navio unit experiences an explicit clear fault (such as a PROFIBUS error fault). AE also recommends sending this command at the startup of PROFIBUS communications to clear any existing fault indications.

BAUD RATE

The auto-baud feature of AE's **PROFIBUS** interface adjusts automatically to the rate of the PROFIBUS master system. Baud rates are available in discrete steps from 9600 bits (9.6 kbits) to 12 Mbits.

WATCH DOG TIMER

As a safety feature, the PROFIBUS maintains a watch dog timer that indicates an error (PROFIBUS WATCHDOG EXPIRED) if the PROFIBUS master stops communicating. The watch dog timer maintains a value for time (between 10 ms and 10 minutes) that the Navio unit waits between commands from the master. The timer counts down this time in 10 ms increments.

If your PROFIBUS system does not calculate the watch dog timer value for you or if you want to modify the existing watch dog timer value, then you may enter a timer value by using the PROFIBUS Set_Prm function call (see DIN 19245 PROFIBUS Standard Part III).

To get the actual wait time value, the unit's microprocessor uses the numbers you enter to octet 2 and 3 of Set_Prm, multiplies them together, and then multiplies the result by 10 ms. Therefore, when using the Set_Prm function call, calculate the numbers for octet 2 and 3 accordingly. The values for octet 2 and 3 must not equal or be zero.

You can disable the watch dog timer through the PROFIBUS master.

PROFIBUS-SPECIFIC ERRORS

In the event of a PROFIBUS error, the Navio unit sets the PROFIBUS fault status bit. All PROFIBUS errors are treated as “explicit clear” type faults, which means that you must send PROFIBUS command **119** (the “master reset” command) in the next download packet to clear the faults and resume operation.

PROFIBUS DATA CONSISTENCY

Some PLCs have a problem with data consistency, that is, the ability to complete the message packet construction before sending the packet to the Navio unit. Data inconsistency most often results in inappropriate value changes at the Navio unit.

This problem occurs because most PLCs share a memory block with the PROFIBUS interface. The PLC places data/packet information in the memory block, and the PROFIBUS interface reads the memory block for the next data/packet to transmit. Data inconsistency problems occur when the PLC updates the data from high to low memory locations without signaling the PROFIBUS interface that the update is complete. (If the PLC were to notify the PROFIBUS interface, then there would be data consistency.) As a result, the PROFIBUS interface sends the memory block regardless of where the PLC is in its update of that memory block.

You can create a work around to this problem with a command sequence that ensures the data for a command will not be changed before the next download packet is received. Here is an example procedure:

1. Send the null command (command 0). The Navio unit ignores this command.
2. Update the download packet with data for the desired command.
3. Update the packet with the desired command.
4. Send the download packet.
5. Repeat step 1, and continue as needed.

See your PLC documentation for additional information.

TRANSMISSION RATES AND THE HANDSHAKE FEATURE

It is possible for PLCs to send commands faster than the Navio unit can respond. This situation can cause the Navio unit to have intermittent failures in responding to or executing commands.

In response to this issue, AE has developed a handshake feature, which echoes back the last sent command in byte 13 of the upload packet. This feature allows you to send a command and wait for verification that the command was accepted before sending the next command. Using the handshake feature has the following benefits:

- It simplifies the programming of PLCs that interact with AE products.
- It increases the bandwidth of the PROFIBUS channel by eliminating wasted time.
- It provides immediate feedback regarding command execution.
- It increases the reliability of PROFIBUS communications.



Important

You can choose not to use the handshake feature, but if you do so, do not send commands to the Navio unit at a rate faster than one command per 20 milliseconds.

PROFIBUS Command Structure

The number command-based AE PROFIBUS protocol is designed to take advantage of the high transmission rates provided by the PROFIBUS standard. The download

packet (outbytes) and the upload packet (inbytes) as well as the AE PROFIBUS “handshake” feature are described in the sections that follow.

The execution time of all PROFIBUS commands is less than 1 millisecond.

PROFIBUS DOWNLOAD PACKET

The download packet for **PROFIBUS** contains four bytes.

Table 4-7. Configuration of **PROFIBUS** download packet bytes

Byte	Description
0	Command
1	Data byte (LSB)
2	Data byte
3	Data byte (MSB)

In the download packet, bytes 1, 2, and 3 make up the data field and contain information defined by the command.

When the data exceeds one byte, the packet sends the least significant byte (LSB) before the most significant byte (MSB).

PROFIBUS UPLOAD PACKET

During every **PROFIBUS** data exchange, the Navio unit supplies a 14-byte upload packet. This table defines the bytes contained in the upload packet.

Table 4-8. **PROFIBUS** upload packet bytes

Byte	Description
0	Status flags—first byte
1	Status flags—second byte
2	Load capacitor position low
3	Load capacitor position high
4	Tune capacitor position low
5	Tune capacitor position high
6	DC bias low
7	DC bias high
8	Data byte (LSB) or CSR code when applicable
9	Data byte
10	Data byte

Table 4-8. PROFIBUS upload packet bytes (Continued)

Byte	Description
11	Data byte
12	Data byte (MSB)
13	Command number (echo of command sent)

PROFIBUS UPLOAD PACKET DATA BYTES 0 AND 1

Bytes 0 and 1 of the upload packet contain information (in the form of status bit flags) about the status of the Navio unit:

Table 4-9. PROFIBUS upload packet status bit flags

Byte	Description
Byte 0—first status byte	Status bit flags • Bits 0 through 3 = Unused • Bit 4 = Tuned status—0 = not tuned, 1 = tuned • Bit 5 = Active toggle bit—Indicates the status of the PROFIBUS interface. After the Navio unit has powered up, this bit's continuous change indicates that the PROFIBUS interface is ready. During operation, a cessation of this change indicates that a communication problem exists. • Bit 6 = Unused • Bit 7 = RF output on status—0 = RF on, 1 = RF off
Byte 1—second status byte	Fault status bit flags—For each fault bit, 0 = fault not active, 1 = fault active • Bit 0 = Unit function pointer fault • Bit 1 = Overtemperature condition • Bit 2 = High current fault • Bit 3 = Low 24 V supply fault • Bits 4 through 6 = Reserved • Bit 7 = Unused

PROFIBUS UPLOAD PACKET DATA BYTES 8 THROUGH 13

In the upload packet, bytes 8, 9, 10, 11, and 12 make up the data field and contain information defined by byte 13, the command number.

When the reply data extends over more than one byte, the **PROFIBUS** sends the least significant byte (LSB) before the most significant byte (MSB). Byte 13 references the requesting command.

PROFIBUS Commands

The following sections describe the command status response (CSR) codes returned by the Navio unit in response to a PROFIBUS command as well as the PROFIBUS commands for the Navio unit.

PROFIBUS COMMAND STATUS RESPONSE (CSR) CODES

When the Navio unit receives a PROFIBUS command requesting a change in unit operation (command numbers 1 through 127), or when the Navio unit receives any PROFIBUS command that it rejects (command numbers 1 through 255), it responds with a command status response (CSR) code. The CSR is a single-byte number that indicates whether the unit accepted or rejected the command and, in the case of rejection, the reason the unit could not respond to the command.

Table 4-10. *PROFIBUS command status response (CSR) codes*

Code	Meaning
0	Command accepted
The following CSR codes are sent in response to a command that was rejected and indicate the reason for rejection.	
4	Parameter is out of its acceptable range
9	Data byte count is incorrect
31	Active preset is incorrect.
32	Automatic tune mode is active with RF output power on; therefore, command is invalid.
33	Selected serial digital to analog converter (SDAC) is invalid.
34	Selected SADC channel is invalid.
35	Serial control mode is inactive.
36	Selected potentiometer is invalid.
37	Selected preset is invalid.
38	Trajectory count is invalid.
39	Invalid sensor select parameter was received.
40	Invalid control mode parameters were received.
41	Serial communication address is invalid.
42	Service log sector is invalid.

Table 4-10. PROFIBUS command status response (CSR) codes (Continued)

Code	Meaning
43	Selected host command parameter is out of range.
44	Preset control mode is active; therefore, command is invalid.
47	Motor movement disabled.
48	Motor is already moving.
94	The unit is in ISP SEEPROM Xilinx configuration data loop.
95	The unit is in motor initialization off stop diagnostic loop. Contact AE Global Services.
96	Unit is in unit function pointer diagnostic loop. Contact AE Global Services.
97	Unit is in NOVRAM initialization host diagnostic loop. Contact AE Global Services.
98	Unit is in initialization host diagnostic loop. Contact AE Global Services.
99	Command is not implemented.
119	PROFIBUS reset command implemented

PROFIBUS COMMAND SET

The PROFIBUS interface has two types of commands:

- Commands **1** through **127** request a change to the Navio unit, such as changing a setting in the unit. The unit responds to these commands by sending a command status response (CSR). This single-byte response indicates whether the unit has accepted or rejected the command and, in the case of rejection, the reason that the unit could not respond to the command.
- Command numbers **128** through **255** request information from the unit, such as unit settings. The unit responds to these commands by sending the data requested if the command was successful and a CSR if the command was not successful.

Table 4-11. PROFIBUS commands

Command	Description	Data Bytes Sent	Data Bytes Returned
0 Null command	The Navio match network ignores this command, but will acknowledge receipt of command by returning CSR code zero.	0	1 (CSR only)

Table 4-11. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
71 set impedance target	Sets the target impedance to which the match tunes. Send 3 data bytes, least significant byte first: - Byte 0 (8-bit value) = Parameter to set: 0 = The real part of the target impedance (r_target) 1 = The imaginary part of the target impedance (x_target) - Bytes 1 and 2 (16-bit value) = The specified part of the target impedance (converted from ohms) These values are converted by multiplying the desired value in ohms by 20.48. For example, to send 50 Ω, you would send 1024. The default value for r_target = 50 Ω. The default value for x_target = 0 Ω. Read back with command 141.	3	1 (CSR only)
82 autotune setup	Sets up automatic tuning parameters.  Important Adjustments in the autotune setup parameters provide a powerful tool for customizing the operation of the match network. However, incorrect autotune setups can cause poor tuning performance and/or shortened life of the vacuum capacitors in the match network. Send 3 bytes, least significant byte first. - Byte 0 (8-bit value) = Parameter to send (see list and definitions of parameters below) - Bytes 1 and 2 (integer) = Parameter value. The following list describes these parameters. Automatic Tuning Parameters Each parameter is shown with the byte 0 value that selects it.	3	1 (CSR only)

Table 4-11. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	• 0 = Converted VSWR tuning stop value. Range = 1 to 32. • 1 = Converted VSWR tuning start value. Range = 1 to 32. VSWR values must be converted before being sent. First, convert the VSWR value to a gamma value: $\gamma = (\text{VSWR} - 1) / (\text{VSWR} + 1)$. Second, square the gamma value and multiply it by 1024. For example, for a VSWR of 1.09: First calculate gamma: $(1.09 - 1) / (1.09 + 1) = 0.04306$. Second, square gamma and multiply by 1024: $(0.04306^2 * 1024 = 1.8989)$. Round to 2, which is the closest number that can be sent. • 2 and 3 = Reserved • 4 = Maximum load percent capacitor position (in hundredths of percent). The automatic tuning algorithm uses this parameter (as well as selections 5, 6, and 7) to assist in capacitor movement control. • 5 = Minimum load percent capacitor position (in hundredths of percent). • 6 = Maximum tune percent capacitor position (in hundredths of percent) • 7 = Minimum tune percent capacitor position (in hundredths of percent) • 8 = Magnitude→load cross dependence coefficient (converted) This value and the next three values (all of the cross dependence coefficients) must be converted before being sent. To convert the value, multiply the desired coefficient by 1024, then send the closest round number. For example, to send a value of 0.2 $(0.2 * 1024 = 204.8)$, you would send 205. • 9 = Phase→load cross dependence coefficient (converted) • 10 = Magnitude→tune cross dependence coefficient (converted)		

Table 4-11. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	• 11 = Phase→tune cross dependence coefficient (converted) • 12 = 0 for VSWR start/stop • 13 = Hold load mode; the value sent indicates the selection ◦ 0 = Turn off hold load mode ◦ 1 = Turn on hold load mode • 14 = Integrated value of gamma; the value send indicates the selection ◦ 0 = No integration ◦ 1 = Integrate 2 samples ◦ 2 = Integrate 4 samples ◦ 3 = Integrate 8 samples ◦ 4 = Integrate 16 samples ◦ 5 = Integrate 32 samples ◦ 6 = Integrate 64 samples ◦ 7 = Integrate 128 samples ◦ 8 = Integrate 256 samples Read back with command 152.		

Table 4-11. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
90 set presets and trajectories	Sets an initial preset position and, if desired, corresponding trajectory points. Send 3 data bytes, least significant byte first. Capacitor positions are set in hundredths of percent of potential capacitor position (1000 = 10%). • Byte 0 (two 4-bit values) - Bits 0 to 3 = Preset number (1 through 4) - Bits 4 to 7 = Parameter to set for the selected preset ◦ 0 = Number of trajectories in this preset (0, 1, 2, or 3) ◦ 1 = Initial load position ◦ 2 = Initial tune position ◦ 3 = First load trajectory position ◦ 4 = First tune trajectory position ◦ 5 = Second load trajectory position ◦ 6 = Second tune trajectory position ◦ 7 = Third load trajectory position ◦ 8 = Third tune trajectory position • Bytes 1 and 2 (16-bit value) = Parameter value to set (the number of trajectories or capacitor positions) For related settings, see commands 91, 94, and 100. Read back with command 160.	3	1 (CSR only)
91 select preset	Selects a preset. Send 1 data byte (8-bit value) indicating the desired preset (1, 2, 3, or 4). For related settings, see commands 90, 94, and 100. Read back with command 161.	1	1 (CSR only)

Table 4-11. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
93 set operating mode	Sets the operating mode. Send 1 data byte (8-bit value) indicating the operating mode: • 0 = Analog port control (manual mode available only on models with an analog port) • 1 = Automatic control • 2 = Serial port control (manual mode using a serial port) Read back with command 163.	1	1 (CSR only)
94 enable/disable presets	Enables/disables the presets. If you enable presets and the unit is in automatic tuning mode, the active preset takes effect at the next RF-off event. If RF is already off, the capacitors move to the preset positions when you enable presets. If you disable presets, no preset positions will be applied, and the capacitors remain in their current positions when RF is turned off. Send 1 data byte (8-bit value) to enable or disable presets: • 0 = Disable • 1 = Enable For related settings, see commands 90, 91, and 100. Read back with command 164.	1	1 (CSR only)
98 disable motor movement	Disables or enables motor movement. Send 1 data byte (8-bit value): • 0 = Enable • 1 = Disable Read back with command 168.	1	1 (CSR only)

Table 4-11. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
100 set preset/ trajectory delays	Sets any one of four initial preset delays and, if desired, its corresponding trajectory delays. Send 3 data bytes, least significant byte first. • Byte 0 (two 4-bit values) - Bits 0 to 3 = Preset number (1, 2, 3, or 4) - Bits 4 to 7 = Delay to set ◦ 0 = Initial preset delay ◦ 1 = First trajectory delay ◦ 2 = Second trajectory delay ◦ 3 = Third trajectory delay • Bytes 1 and 2 = Delay time in hundredths of seconds. The valid range is 0.00 to 2.50 s (for example, enter 150 to represent 1.50 s). For related settings, see commands 90, 91 and 94. Read back with command 170.	3	1 (CSR only)
112 move load to position	Moves the load capacitor to the specified position. Send 2 data bytes (16-bit value) to move the load capacitor to a new position. Position is set in hundredths of percent of the total range of potential capacitor movement. The valid range is 0 to 10000 (0% to 100%). Read back with command 180.	2	1 (CSR only)
119 reset/explicit fault clear	Clears PROFIBUS faults	0	1 (CSR only)
122 move tune to position	Moves the tune capacitor to the specified position. Send 2 data bytes (16-bit value) to move the tune capacitor to a new position. Position is set in hundredths of percent of the total range of potential capacitor movement. The valid range is 0 to 10000 (0% to 100%). Read back with command 180.	2	1 (CSR only)
125 initialize capacitors	Moves all capacitors to their minimum positions.	0	1 (CSR only)

Table 4-11. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
128 report match type	Reports the match network type. Returns 4 data bytes (ASCII format) representing the following: • NAVI	0	4
130 report software number	Reports the software part number. Returns 5 data bytes (ASCII format) representing the last five digits of a seven-digit software part number. For example, if the command returns a value of 15005, then the software part number is 7415005.	0	5
131 report status	Reports the Navio match network status. Returns 4 data bytes. If a specified bit is set, it indicates that the status is true or the feature is active. • 0x00000001 = RF on • 0x00000002 = Tuned • 0x00000004 = Automatic mode active • 0x00000008 = Serial port mode active (manual mode using a serial port) • 0x00000010 = Analog port mode active (manual mode available only on models with an Analog I/O port) • 0x00000020 = Presets enabled • 0x00000080 = Generic fault status • 0x00000100 = Preset mode active • 0x00000200 = Motor movement disabled • 0x01000000 = Low supply 24 V fault • 0x04000000 = NOVRAM hardware fault • 0x08000000 = Overtemperature fault • 0x20000000 = Tune voltage fault • 0x40000000 = Output current fault • 0x80000000 = Motor initialization fault	0	4

Table 4-11. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
135 report motor movement	Reports status of stepper motor movement. Returns 1 data byte. When set, the specified bits indicate that movement is active. • 0x01 = Tune motor moving • 0x02 = Load motor moving • 0x03 = Both tune and load motors moving	0	1
141 report target impedance	Reports the real and imaginary components of the target impedance. Returns 4 data bytes (two 16-bit values), least significant byte first.  Important The values reported by this command are converted from ohms. To convert the readback value to ohms, divide by 20.48. For example, if a value of 1024 is returned, the value in ohms is 50. • Bytes 0 and 1 = The real part of the target impedance (r_target) (converted from ohms); default value in ohms is 50 • Bytes 2 and 3 = The imaginary part of the target impedance (x_target) (converted from ohms); default value in ohms is 0 Set with command 71.	0	4
152 report autotune setup	Reports the automatic tuning parameters. Send 1 byte (8-bit value), identifying the parameter that you want to read: • 0 = Converted VSWR stop value • 1 = Converted VSWR start value VSWR readback values are converted. To convert the value, first divide the value that is returned by 1024, then calculate the square root of that value. This calculation provides the gamma value. To convert gamma to VSWR, use the following equation: $VSWR = (1 + \gamma) / (1 - \gamma)$. For example, if the unit returns a value of 2:	1	3

Table 4-11. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	First calculate gamma: $\sqrt{2/1024} = 0.044194$ Second, calculate VSWR: $1.09247 = \frac{1 + 0.044194}{1 - 0.044194}$ • 2 and 3 = Reserved • 4 = Maximum load capacitor position • 5 = Minimum load capacitor position • 6 = Maximum tune capacitor position • 7 = Minimum tune capacitor position • 8 = Magnitude to load • 9 = Phase to load • 10 = Magnitude to tune • 11 = Phase to tune • 12 = Reserved • 13 = Hold load mode • 14 = Integrated value of gamma Returns 3 data bytes, least significant byte first: • Byte 0 (8-bit value) = The parameter that is being read • Bytes 1 and 2 (integer) = Value of the selected parameter. For parameter descriptions, including how to interpret the returned value, see command 82. Set with command 82.		

Table 4-11. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
158 report sensor setup	Reports the requested information for the selected sensor. Send 2 data bytes: • Byte 0 (8-bit value) = Sensor ◦ 0 = Input sensor ◦ 1 = Output sensor • Byte 1 = Parameter to read ◦ 0 = Power off limit (sets the unit to detect whether power is on or off) ◦ 1 = Sensor averaging control Returns 2 or 3 data bytes, depending on the selected parameter: • Return byte 0 = The parameter being returned ◦ 0 = Power off limit ◦ 1 = Sensor averaging control If you set send byte 1 to power off limit: • Return bytes 1 and 2 (signed integer) = Power off limit (in watts) at which the Navio match network detects power on If you set send byte 1 to sensor averaging control: • Return byte 1 (8-bit value) = Number of sensor readings averaged by the Navio match network. (Averaging reduces the noise in the sensor reading.) ◦ 0 = 1 reading (no averaging) ◦ 1 = 2 readings ◦ 2 = 4 readings ◦ 3 = 8 readings Set with command 88.	2	2, 3

Table 4-11. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
160 report presets/trajectories	Reports selected preset information. Send 1 data byte (two 4-bit values): • Bits 0 to 3 = The preset number (1, 2, 3, or 4) • Bits 4 to 7 = The parameter: ◦ 0 = Number of trajectories ◦ 1 = Initial load and tune positions ◦ 3 = First load and tune trajectory positions ◦ 5 = Second load and tune trajectory positions ◦ 7 = Third load and tune trajectory positions Returns 5 data bytes, least significant byte first. • Byte 0 (two 4-bit values), same as the send data byte above. • Bytes 1 and 2 (16-bit value) = Depending on the selected parameter, the number of trajectories or the load capacitor position. • Bytes 3 and 4 (16-bit value) = Depending on the selected parameter, a dummy value or the tune capacitor position.  Important Capacitor positions are reported in hundredths of percent of potential capacitor position (1000 = 10%). For related readbacks, see commands 161, 164, and 170. Set with command 90.	1	5
161 report selected preset	Reports the preset/trajectory set that is currently selected. Returns 1 data byte (8-bit value) = Selected preset (1, 2, 3, or 4). For related readbacks, see commands 160, 164, and 170. Set with command 91.	0	1

Table 4-11. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
163 report operating mode	Reports the operating mode. Returns 1 data byte (8-bit value) indicating the operating mode: • 0 = Analog port control (manual mode available only on models with an Analog I/O port) • 1 = Automatic control • 2 = Serial port control (manual mode available on a serial port) Set with command 93.	0	1
164 report preset status	Reports whether the presets are enabled or disabled. Returns one data byte (8-bit value): • 1 = Enabled • 0 = Disabled Set with command 94. For related readbacks, see commands 160, 161, and 170.	0	1
168 report motor disable status	Reports whether motor movement is enabled or disabled. Returns 1 data byte (8-bit value): • 0 = Motor movement enabled • 1 = Motor movement disabled Set with command 98.	0	1
169 report personality number	Reports the unit's personality identification number. Returns 4 data bytes (8-bit values, least significant byte first), indicating the personality identification number.	0	4

Table 4-11. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
170 report presets/ trajectory delays	Reports the selected delay value for the selected present. Send 1 data byte (two 4-bit values): • Bits 0 to 3 = The preset number (1, 2, 3, or 4) • Bits 4 to 7 = The delay parameter: ◦ 0 = Initial preset delay ◦ 1 = First trajectory delay ◦ 2 = Second trajectory delay ◦ 3 = Third trajectory delay Returns 3 data bytes: • Byte 0 (two 4-bit values) reports the same information requested by the send data byte. • Bytes 1 and 2 = Delay time in hundredths of seconds. The valid range is 0.00 to 2.50 s (for example, enter 150 to represent 1.50 s). For related readbacks, see commands 160, 161, and 164. Set with command 100.	1	3
180 report capacitor positions	Reports load and tune capacitor positions. Position is reported in hundredths of percent of the total range of potential capacitor movement. Returns 4 bytes: • Bytes 0 and 1 (16-bit value) = Load capacitor position • Bytes 2 and 3 (16-bit value) = Tune capacitor position	0	4

Table 4-11. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
185 report sensors calculated data	Calculates r, x, gamma, and power for the specified sensor. Send 1 data byte (two 4-bit values): • Bits 0 to 3 = The sensor ◦ 0 = 3x input sensor ◦ 1 = 3x output sensor • Bits 4 to 7 = The parameters to read: ◦ 0 = r and x ◦ 1 = gamma and power Returns 5 data bytes, least significant byte first: • Byte 0 (two 4-bit values) returns the values from the send data byte. If r and x were read: • Bytes 1 and 2 (16-bit value) = r This and the next value are converted. Two versions of the conversion equation: ◦ $\Omega = (\text{readback value} * 50) / 1024$ ◦ $\text{Readback value} = (\Omega * 1024) / 50$ • Bytes 3 and 4 (16-bit value) = x (converted —see equation for bytes 1 and 2) If gamma and power were read: • Bytes 1 and 2 (16-bit value) = Gamma (converted). The readback value is converted. Two versions of the conversion equation: ◦ $\text{Gamma} = \text{square root of } ((\text{readback value}) / 1024)$ ◦ $\text{Readback value} = ((\text{gamma} * \text{gamma}) / 1024)$. • Bytes 3 and 4 (16-bit value) = Power in watts	1	5

Table 4-11. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
186 report RF peak and DC bias	Reports RF_{PEAK} and DC bias values, in volts.  Important This command is not present on all units; not all units support RF peak or DC bias. To find out whether a specific model supports RF peak or DC bias, see the unit's product specification. Returns 4 data bytes (two 16 bit values): • Bytes 0 and 1 = RF_{PEAK} value • Bytes 2 and 3 = DC bias value A positive DC bias is reported as a positive value, negative DC bias is reported as a negative value.  Important Cesar generators expect to see a positive DC bias read back. If the Navio unit is paired with a Cesar generator, use the Analog I/O port instead of this port to provide DC bias readback to the generator.	0	4
187 report high current or voltage	If your unit has RF output sensor, this command reports the controller board SADCs (serial analog to digital converter) high voltage or current value. Returns 2 data bytes (integer, LSB first) indicating the high voltage value in volts or the high current value in amperes.  Important This command is not present on all units. For some models, this command reads back high voltage, for others a high current value. To find out whether a specific model reads back voltage or current, see the unit's product specification to check whether it lists overcurrent or overvoltage as an interlock trip condition.	0	2
198 report software version	Reports the software version number string. Returns 3 data bytes (ASCII format) indicating the software version.	0	3

Table 4-11. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
231 report unit serial number	Reports the unit serial number. Returns 4 data bytes (three 8-bit values).	0	4

ANALOG I/O PORT

The **Analog I/O** port on the Navio match network provides analog and digital signals for controlling and monitoring the unit. This port may not be available on some units.

15-pin Analog I/O Port—Cesar Interface

This port is optional and may not be available on all units.



Important

To optimize the capacitor movement in manual mode, make sure you have the following firmware installed on the Cesar generator:

- Version 1.19 or greater for Cesar generators with a C3 controller
- Version 1.22 or greater for Cesar generators with a C4 controller

Contact AE Global Services for the latest revision.

15-PIN ANALOG I/O PORT CONNECTOR—CESAR INTERFACE

The **Analog I/O** port to connect to the Cesar generator is a 15-pin, shielded, female, subminiature-D connector.

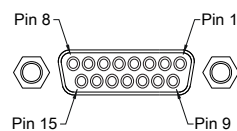


Figure 4-8. 15-pin Analog I/O port connector—Cesar interface

15-PIN ANALOG I/O PORT CABLING REQUIREMENTS—CESAR INTERFACE

The cable used to connect the 15-pin **Analog I/O** port to the Cesar generator must be a shielded, 15-wire I/O cable. Shielded, twisted-pair wiring may be used but is not mandatory. Signal losses should be minimized by keeping the cable length as short as

possible. To minimize interference from adjacent electrical equipment, the EMI shield in the cable must be terminated to the metal shells of the cable's connectors. Additionally, the chassis of the Navio match network must be tied to a local earth ground.

15-PIN ANALOG I/O PORT PIN DESCRIPTIONS AND WIRING DIAGRAMS—CESAR INTERFACE

15-Pin Analog I/O Port Pin Descriptions—Cesar Interface

This table provides the connector pin descriptions for the **Analog I/O** port. The pin numbers are arranged in signal pairs.

Table 4-12. 15-Pin Analog I/O port pin descriptions—Cesar interface

Signal Pin	Related Pin	Name	Signal Type	Description
1	GND	<i>GROUND</i>	Gnd	Connect to the shield of the cable (for example RC cable).
2	1 or 9	<i>DECREASE</i> C_{Load}	Input	Connect this +15 V input to ground to turn motor load counterclockwise and thus decrease C_{Load} . Interrupt the connection to ground when the desired position for C_{Load} is reached.
3	1 or 9	<i>INCREASE</i> C_{Load}	Input	Connect this +15 V input to ground to turn motor load clockwise and thus increase C_{Load} . Interrupt the connection to ground when the desired position for C_{Load} is reached.
4		<i>DECREASE</i> C_{Tune}	Input	Connect this +15 V input to ground to turn motor load counterclockwise and thus decrease C_{Tune} . Interrupt the connection to ground when the desired position for C_{Tune} is reached.
5		<i>INCREASE</i> C_{Tune}	Input	Connect this +15 V input to ground to turn motor load clockwise and thus increase C_{Tune} . Interrupt the connection to ground when the desired position for C_{Tune} is reached.
6	GND	<i>GROUND</i>	Gnd	Reference ground for DC bias and capacitor position signals.
7	N/A	<i>RESERVED</i>		

Table 4-12. 15-Pin Analog I/O port pin descriptions—Cesar interface (Continued)

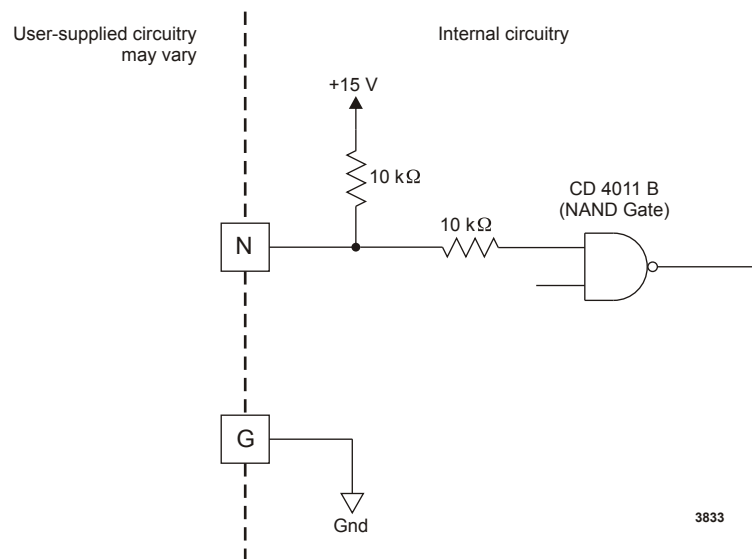
Signal Pin	Related Pin	Name	Signal Type	Description
8	1 or 9	<i>MANUAL MODE</i>	Input	Connect this +15 V input to ground to set the Navio match network into manual mode (manual mode is called user control mode on the Navio match network).
9	GND	<i>GROUND</i>	Gnd	Ground connect to the cable shield.
10	1 or 9	<i>+5V SUPPLY</i>	Output	+5 Volts DC from internal DC supply. For external use. Maximum current draw 100 mA.
11	1 or 9	<i>+15V SUPPLY</i>	Output	+15 Volts DC from internal DC supply. For external use. Maximum current draw 100 mA.
12	6	<i>DCSELFBIAS MONITOR</i>	Output	DC self bias test voltage. Provides a test voltage to monitor the DC self bias of the plasma electrode in the vacuum chamber. The output voltage is scaled down $\pm 400:1$ (± 400 V of DC bias results in 1 V output). The instrument used to measure the bias voltage should have an input impedance of at least 10 kΩ. Cesar generators expect to see a positive DC bias at the match (analog) port. For Navio match networks paired with Cesar generators, the behavior of this pin meets this requirement.
13	6	<i>C_{Tune} POSITION MONITOR</i>	Output	Series (tune) capacitor position signal. The voltage at this output is directly proportional to the position of the capacitor C_{Tune}. The minimum voltage is approximately 0.3 V representing the minimum capacity of C_{Tune}. The maximum voltage is approximately 9.7 V representing the maximum capacity of C_{Tune}.

Table 4-12. 15-Pin Analog I/O port pin descriptions—Cesar interface (Continued)

Signal Pin	Related Pin	Name	Signal Type	Description
14	6	C_{Load} POSITION MONITOR	Output	Shunt (load) capacitor position signal. The voltage at this output is directly proportional to the position of the capacitor C_{Load} . The minimum voltage is approximately 0.3 V representing the minimum capacity of C_{Load} . The maximum voltage is approximately 9.7 V representing the maximum capacity of C_{Load} .
15	1 or 9	MATCHING ACTIVITY STATUS	Output	This open collector output is pulled low when the Navio match network is active (the motors are running) and floats when the matching is done (the motors are not running). 30 V maximum, 20 mA maximum.

15-Pin Analog I/O Port Wiring Diagrams—Cesar Interface

The diagrams in this section provide wiring information to connect to the 15-Pin Analog I/O port.

**Figure 4-9. Pins 2, 3, 4, 5, 8**

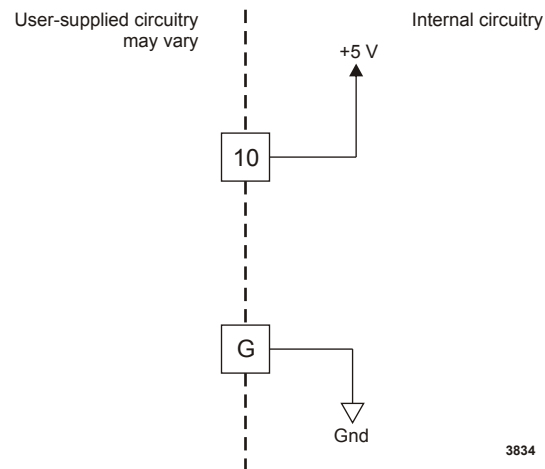


Figure 4-10. Pin 10

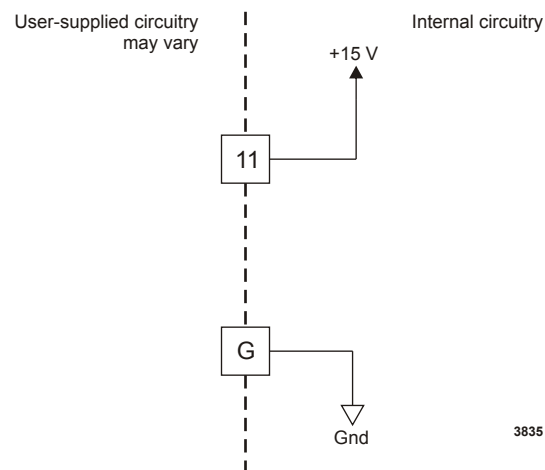


Figure 4-11. Pin 11

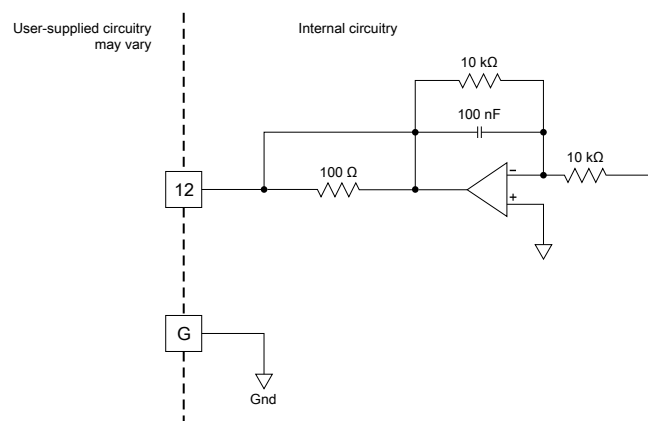


Figure 4-12. Pin 12

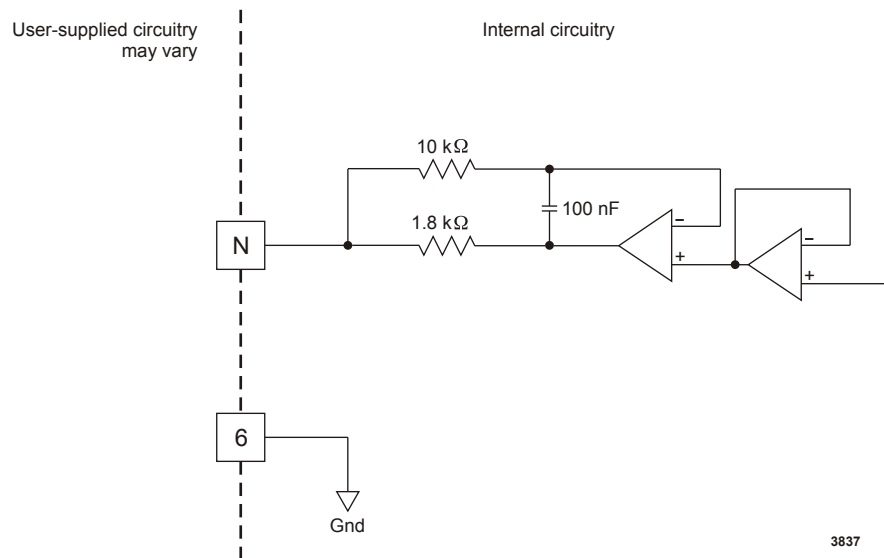


Figure 4-13. Pins 13, 14

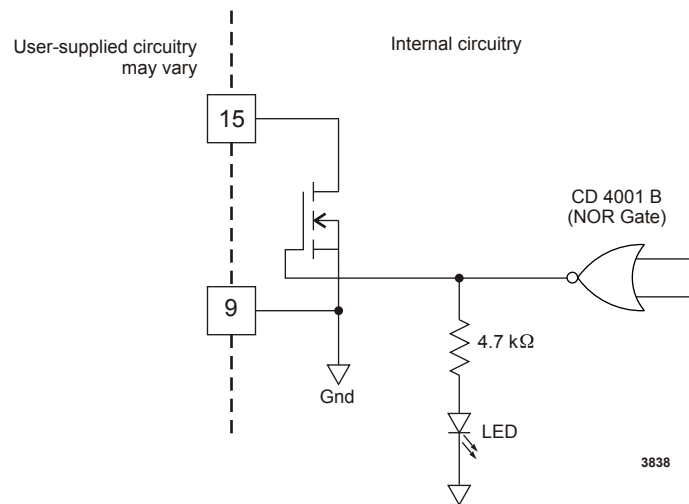


Figure 4-14. Pin 15

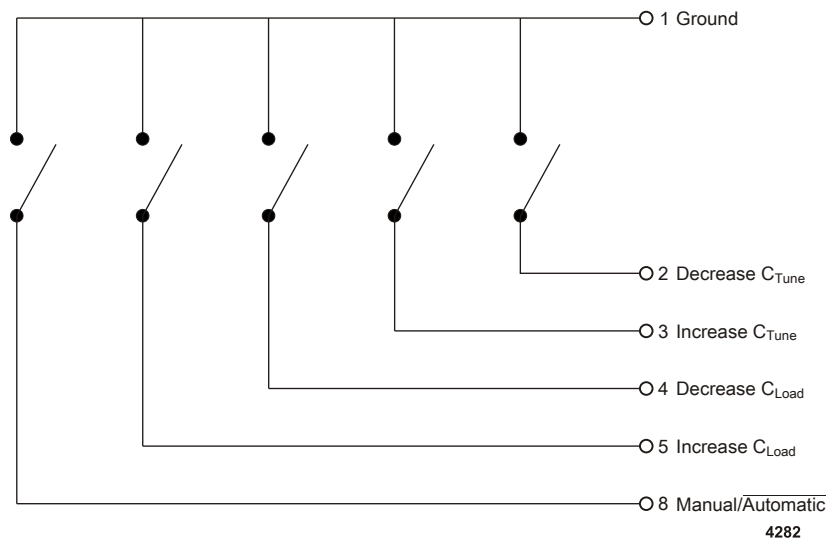
15-PIN ANALOG I/O—CESAR INTERFACE USING MANUAL SWITCHES

To construct a simple manual control, wire four normally open momentary switches for the motor drive and one on/off switch for auto/manual mode selection. To do so, connect the switch box to the Analog I/O using a shielded cable. The shield should be connected to ground at pin 1 of the D-connector. To avoid a ground loop, which could result in erratic operation of the remote control, do not connect the cable shield to any other ground in the system. [Table 4-13](#) describes the switches needed for the Cesar interface manual control.

Table 4-13. Cesar interface manual switch descriptions

Momentary switch	Motor drive	Results	Connect to Navio Pin #
Common connection of all 5 switches (Ground)			1
Switch 1	Motor 1	Run clockwise to decrease C_{Tune}	2
Switch 2	Motor 2	Run counter clockwise to increase C_{Tune}	3
Switch 3	Motor 3	Run clockwise to decrease C_{Load}	4
Switch 4	Motor 4	Run counter clockwise to increase C_{Load}	5
Unused for switch control box. Pin functionality the same as described in the 15-pin analog port description.			6, 7
Switch 5	On selects Manual mode; off selects Auto mode		8
Unused for switch control box. Pin functionality the same as described in the 15-pin analog port description.			9 through 15

Cesar Interface Manual Switch Wiring Diagrams

**Figure 4-15.** Cesar interface manual switch wiring diagrams

Installation, Setup, and Operation

PREPARING TO INSTALL THE UNIT

Spacing Requirements

See the physical specifications table for the unit dimensions and any clearance requirements.

**DANGER:**

RISK OF DEATH OR BODILY INJURY. Disconnect and lockout/tagout all sources of input power before working on this unit or anything connected to it.

Related Links

- [“Physical Specifications” on page 3-1](#)

Dimensional Drawings

The Navio match network is available with either standard or flat pack packaging. For dimensional drawings, see the section applicable to your option.

DIMENSIONAL DRAWINGS—STANDARD PACKAGE

The following illustrations show the product from multiple views.

Front View, Standard Package

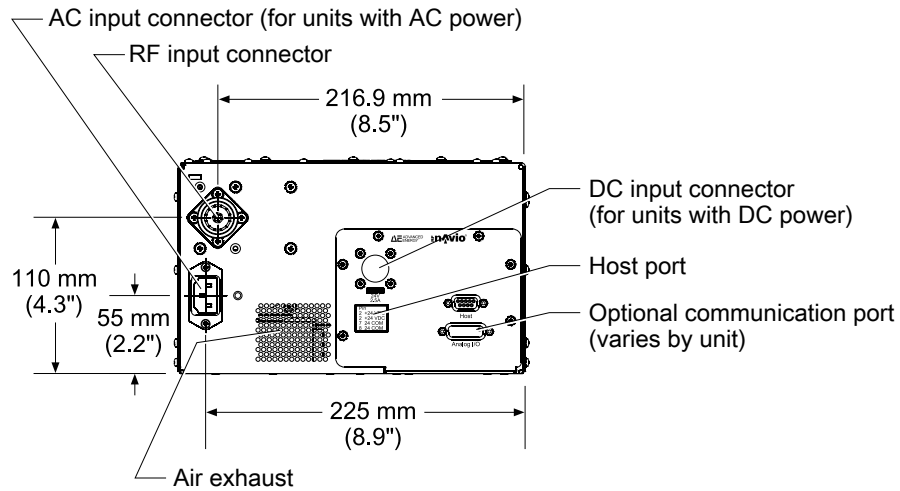


Figure 5-1. Front view (standard package)

Rear View, Standard Package

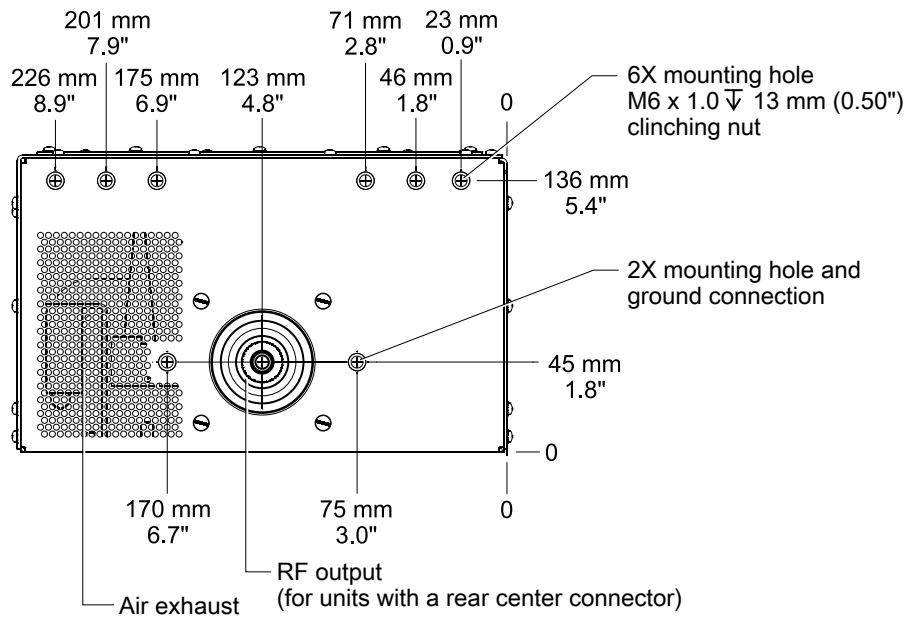


Figure 5-2. Rear view, rear center connector (standard package)

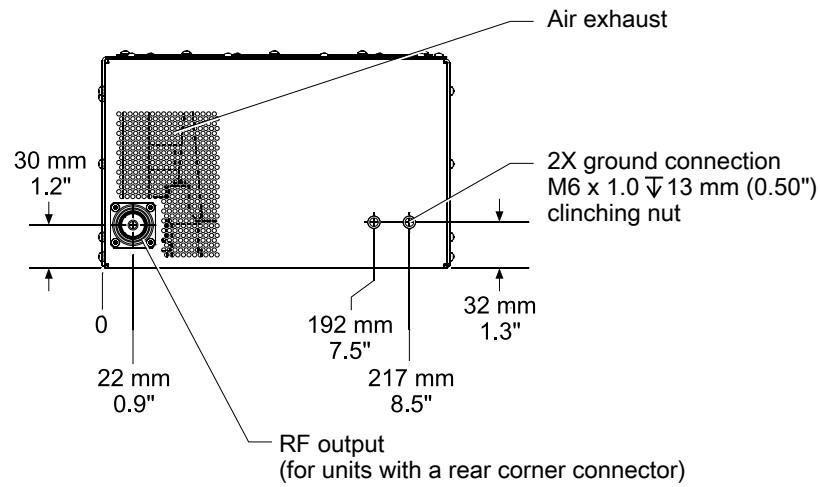


Figure 5-3. Rear view, rear corner connector (standard package)

Side Views, Standard Package

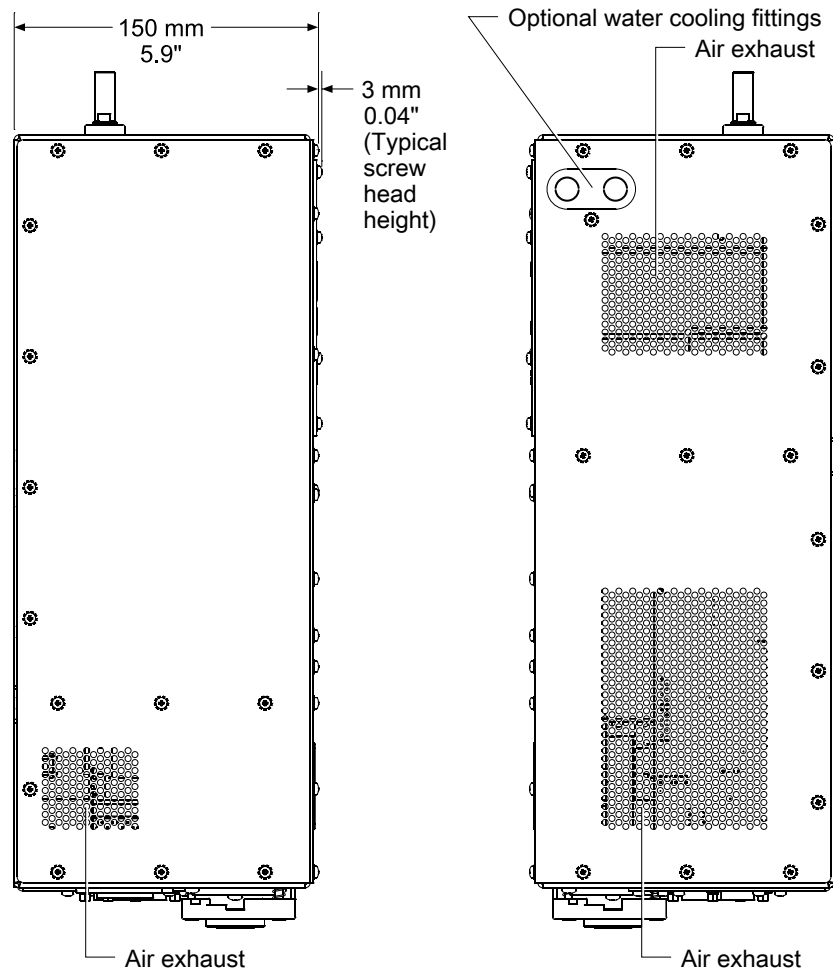


Figure 5-4. Side view (standard package)

Top View, Standard Package

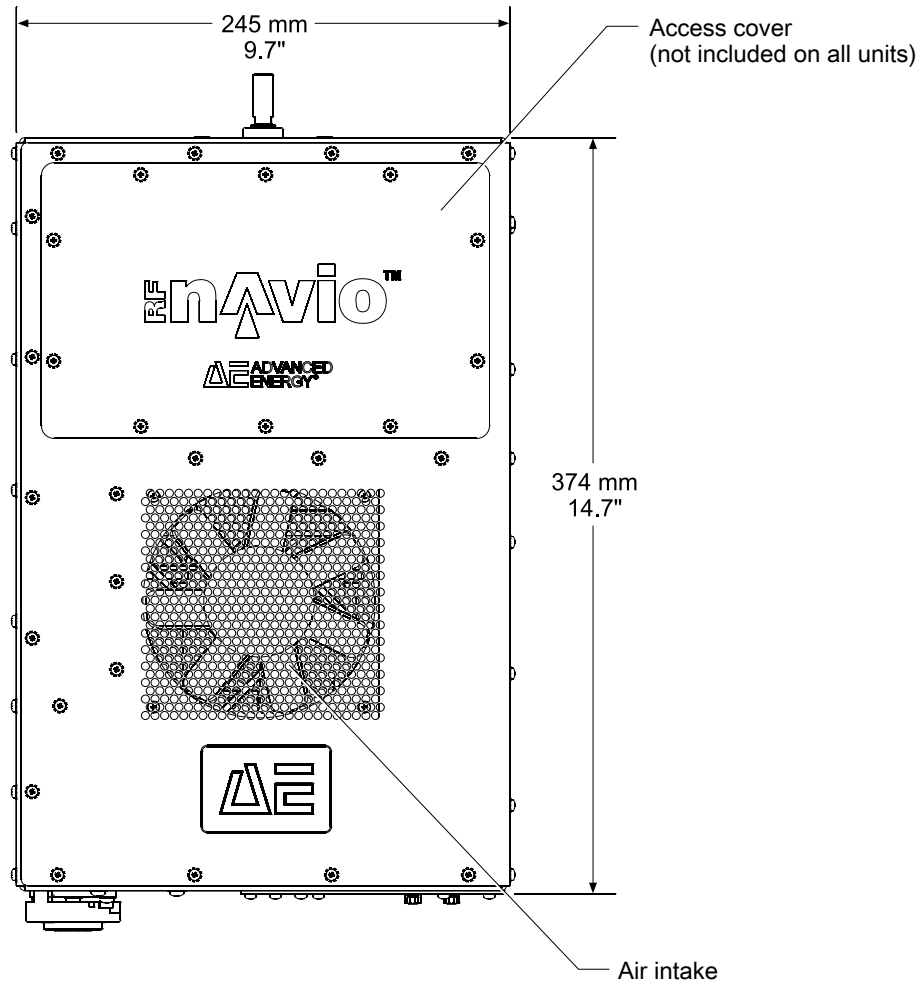


Figure 5-5. Top view (standard package)

Bottom View, Standard Package

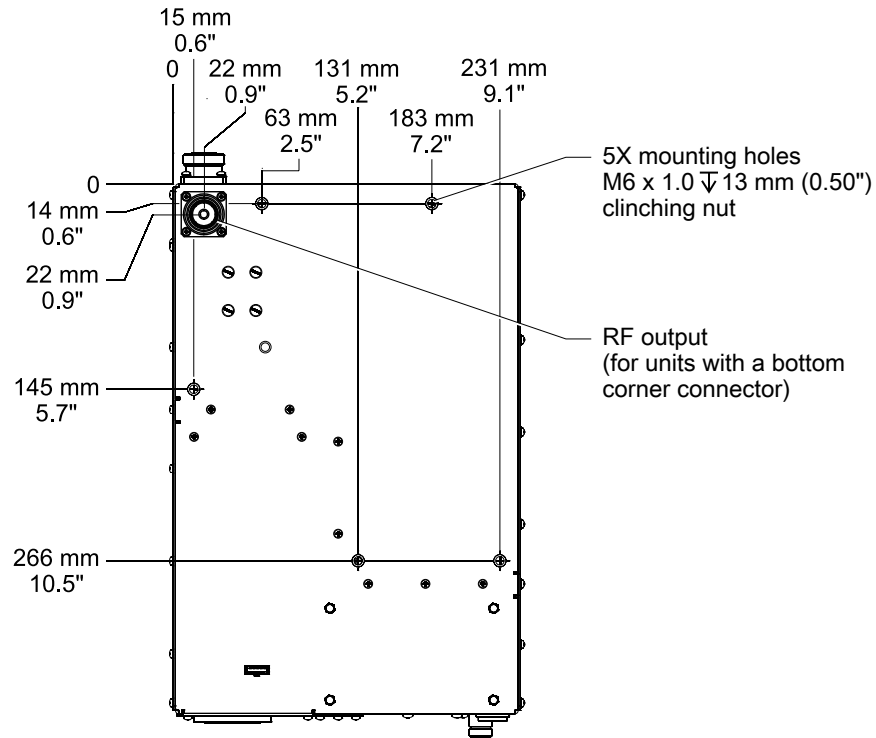


Figure 5-6. Bottom view, bottom corner connector (standard package)

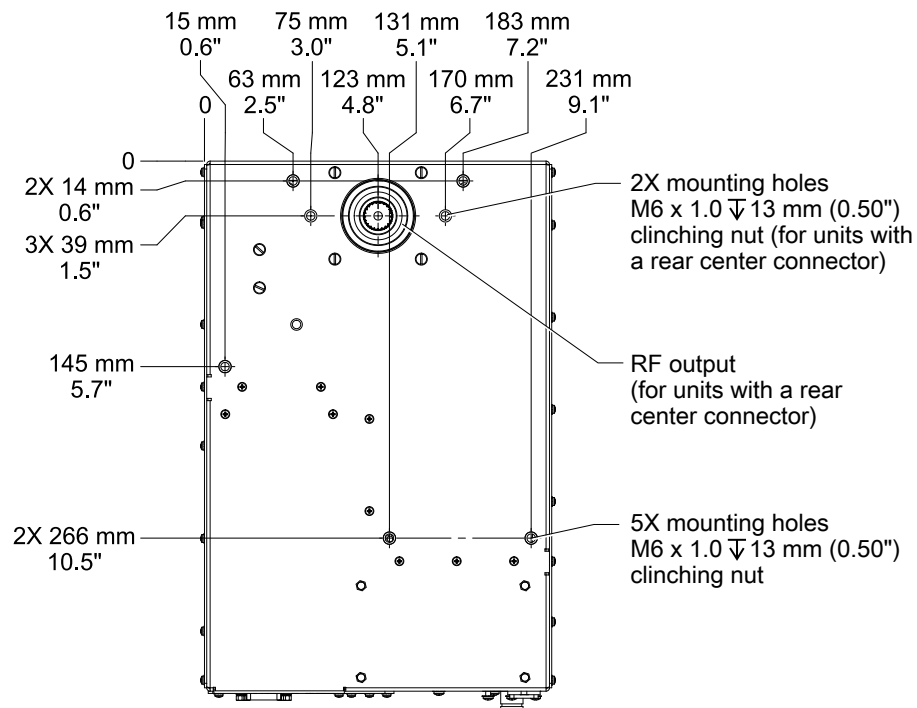


Figure 5-7. Bottom view, bottom center connector (standard package)

Isometric View, Standard Package

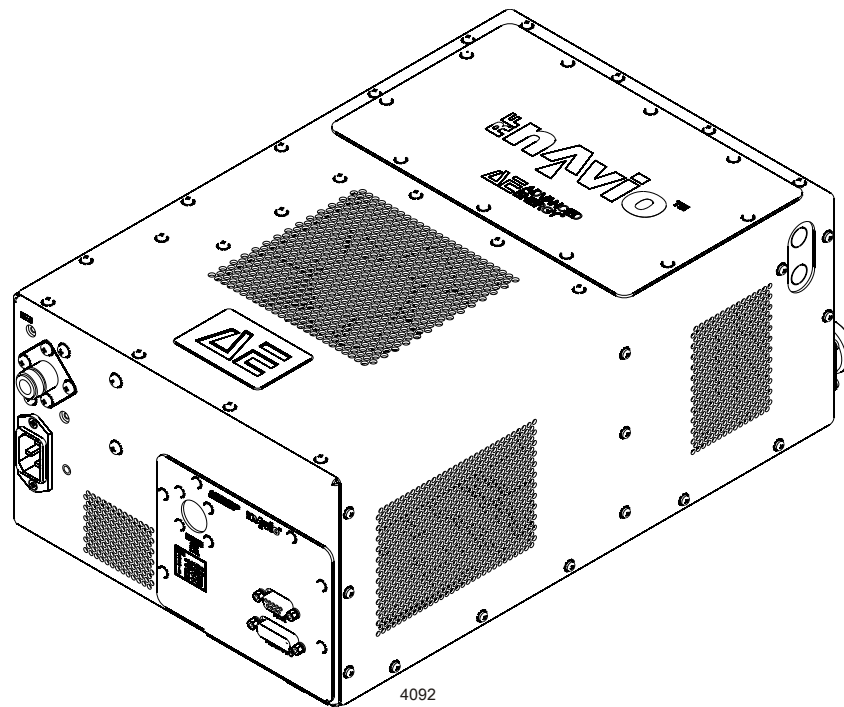


Figure 5-8. Isometric view (standard package)

DIMENSIONAL DRAWINGS—FLAT PACKAGE

The following illustrations show the product from multiple views.

Front View, Flat Package

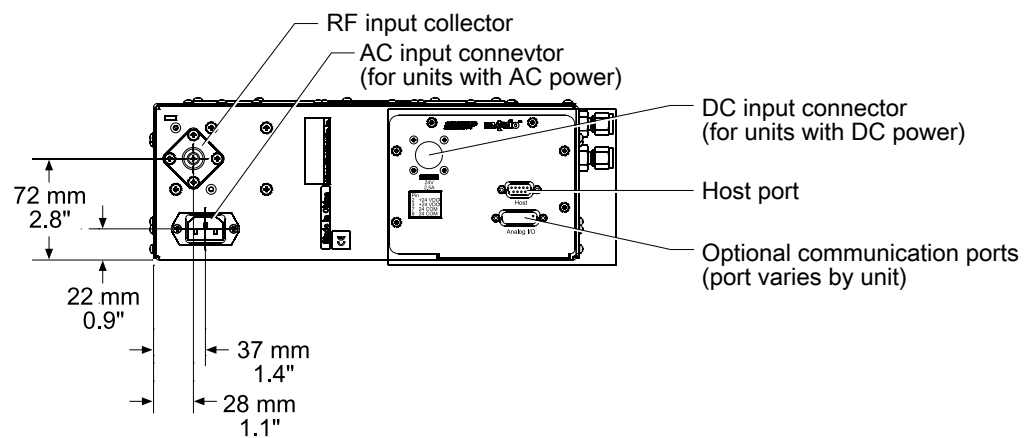


Figure 5-9. Front view (flat package)

Rear View, Flat Package

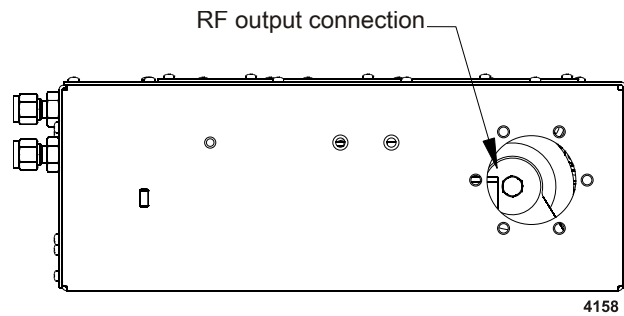


Figure 5-10. Rear view (flat package)

Side Views, Flat Package

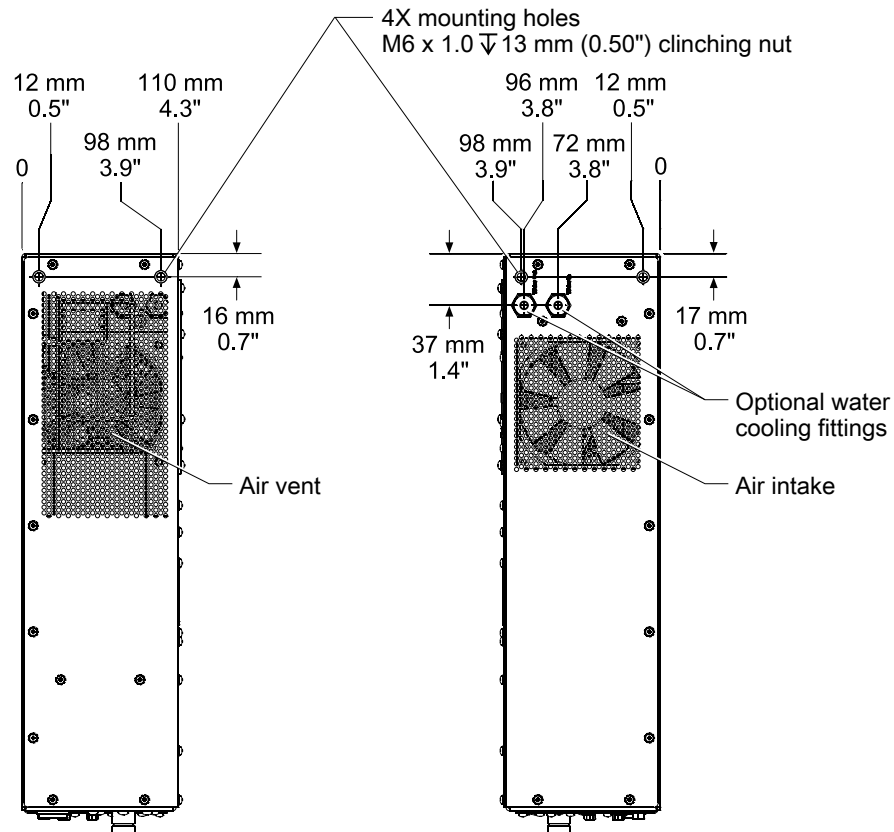


Figure 5-11. Side views (flat package)

Top View, Flat Package

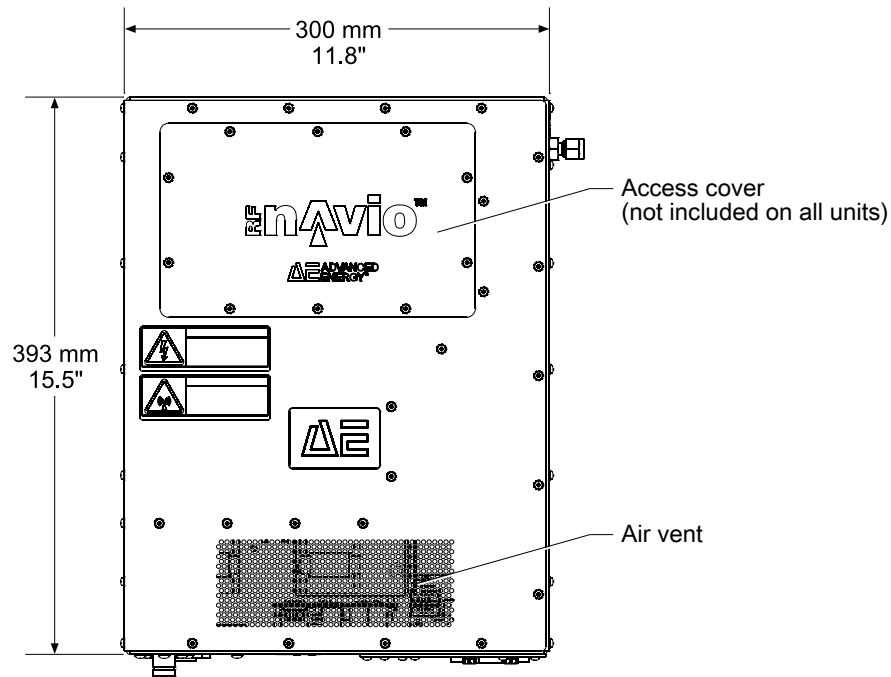


Figure 5-12. Top view (flat package)

Bottom View, Flat Package

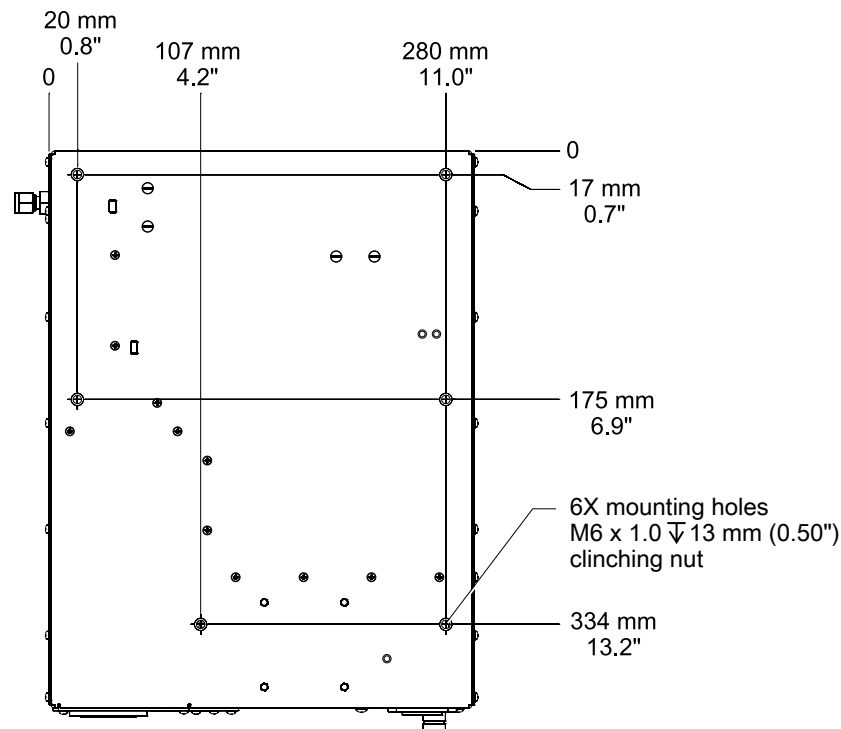


Figure 5-13. Bottom view (flat package)

Isometric View, Flat Package

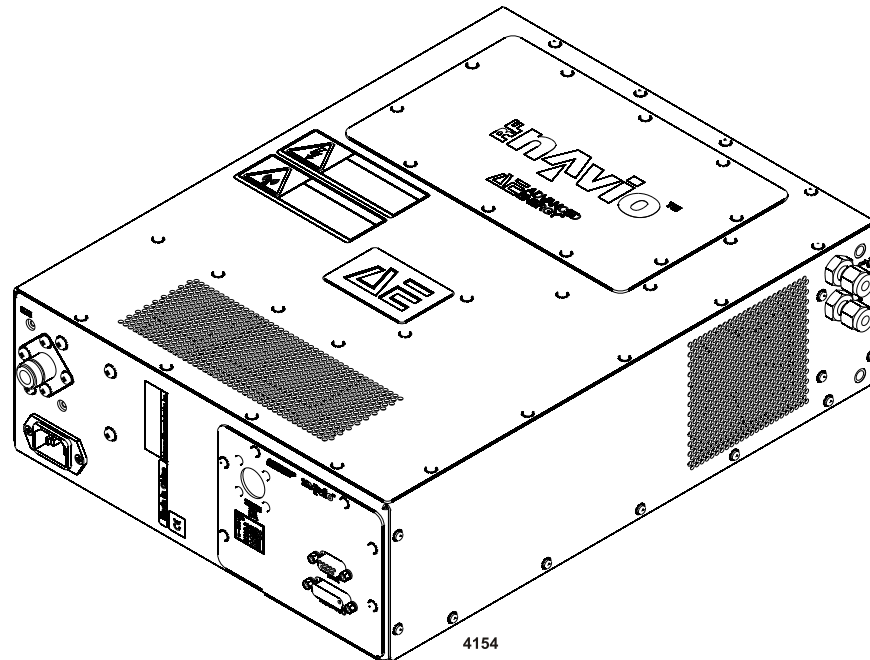


Figure 5-14. Isometric view (flat package)

Installation Requirements

Install this unit according to the following requirements.



DANGER:

RISK OF DEATH OR BODILY INJURY. Disconnect and lockout/tagout all sources of input power before working on this unit or anything connected to it.



WARNING:

Maintenance personnel must receive proper training before installing, troubleshooting, or maintaining high-energy electrical equipment. Potentially lethal voltages could cause death, serious personal injury, or damage to the equipment. Ensure that all appropriate safety precautions are taken.

COOLING REQUIREMENTS

The Navio match network is air cooled. Ensure that all cooling specifications are met. Also, ensure that exhausted air does not circulate back into the unit and become input air.

CABLE REQUIREMENTS

You must supply coaxial cable for RF input, as well as shielded, 1:1 serial cable less than 3 meters long. It is generally desirable to use RF input cable lengths that are at least one-half wavelength, which ensures the same potential at both ends of the cable. However, there may be instances where the effects of a different cable length are desirable.

Unpacking the Unit



Important

Some Navio units are double-bagged to prevent contamination. The labels on the packaging provide important handling information. In many cases, the inner bag should not be removed until the unit is in the cleanroom.

1. Unpack and inspect the unit carefully, looking for obvious physical damage.
2. If no damage is apparent, proceed with the unit installation and setup.
3. If you do see signs of shipping damage, contact Advanced Energy and the carrier immediately.

Save the shipping container for submitting necessary claims to the carrier.

INSTALLING THE UNIT

Guidelines for Mounting the Navio Match Network

When mounting the Navio match network, use the following guidelines:

- Mount the match network as close as possible to the vacuum chamber, leaving room to access all connectors.
- Ensure the unit will remain within the specified operating temperatures.
- For mounting points, see the unit dimensional drawings. Note that there are mounting holes on the bottom and the sides. Exact placement of the mounting holes depends on the unit.
- Ensure that exhausted air does not circulate back into the unit and affect input air flow.
- Position the unit so that it is easy to unplug the AC input power cord, unless you install another suitable disconnecting device that complies with the accessibility and other applicable requirements of EN 61010-1.
- Ensure that all removable panels are closed and secure.

Connecting RF Output

RF OUTPUT CONNECTORS

The RF output connector for the Navio match network can be located on the unit rear, side, or bottom, and is labeled **RF Out**.

To determine which RF output connector is on your unit, compare your unit to the illustrations in the sections that follow.

The RF output connector can be any of the following:

- CF 2-3/4" flange mount
- B6N (female)
- B20N
 - with MC6 adapter (male, 6 mm threaded stud)
 - with 6 mm socket (female)
 - with 6 mm pin (male)
 - 6 mm tapped hole only, no stud (female)
- 7-16 (female)

Related Links

- [“RF Output Connection, Type B6N” on page 5-11](#)
- [“RF Output Connector, Type B20N” on page 5-12](#)
- [“RF Output Connector, Type 7-16” on page 5-15](#)
- [“RF Output Connection, Type CF 2-3/4” Flange Mount” on page 5-16](#)

RF OUTPUT CONNECTION, TYPE B6N

See your internal procedures for installation instructions.

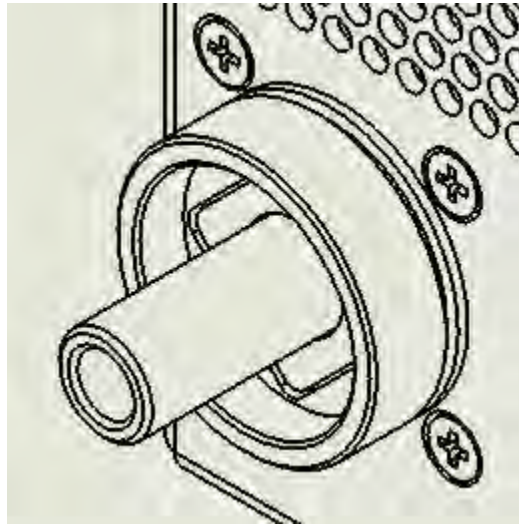


Figure 5-15. B6N connector

RF OUTPUT CONNECTOR, TYPE B20N

The Navio supports several options for the B20N connector, as shown here. See your internal procedures for installation instructions.

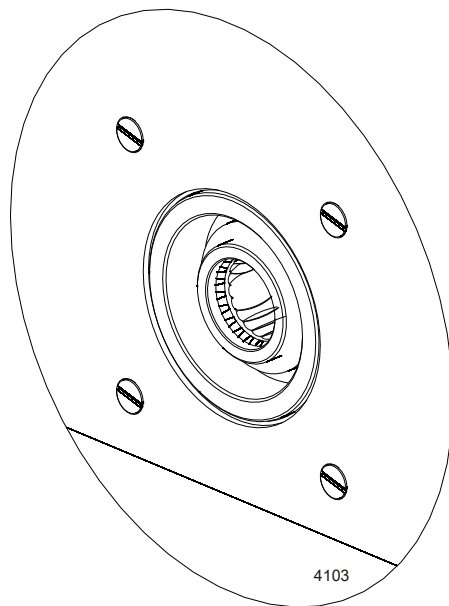


Figure 5-16. B20N connector

60 MHz Navio match networks must include a gasket applied to the area shown in [Figure 5-17](#). If your unit does not include an EMI nickel/copper conductive foam gasket, please contact AE Global Services before proceeding with installation.

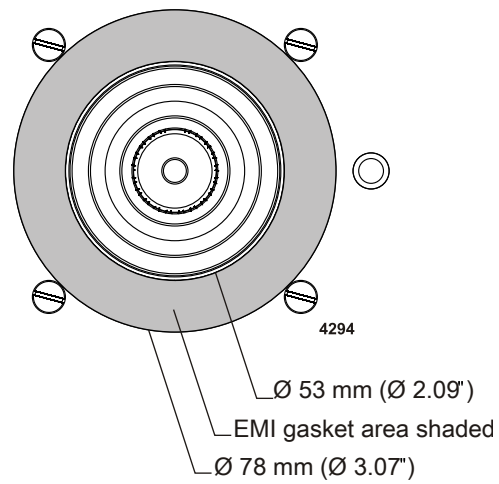


Figure 5-17. B20N connector, gasket area (60 MHz units)

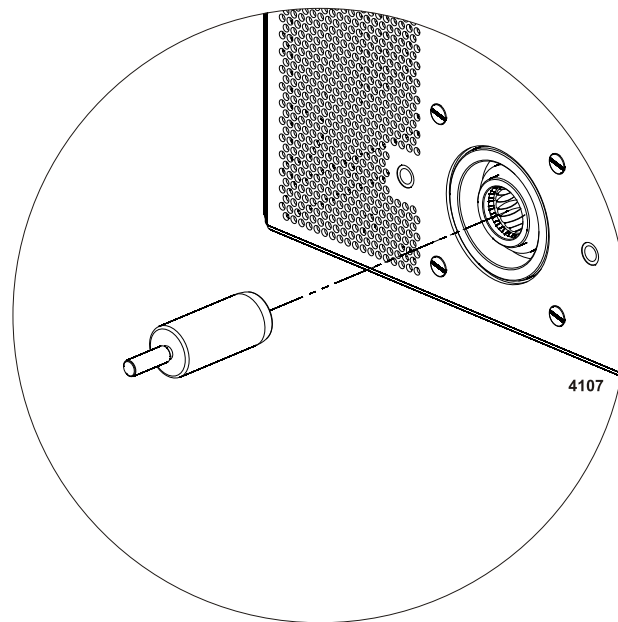


Figure 5-18. B20N connector with MC6 male adaptor and 6 mm threaded stud

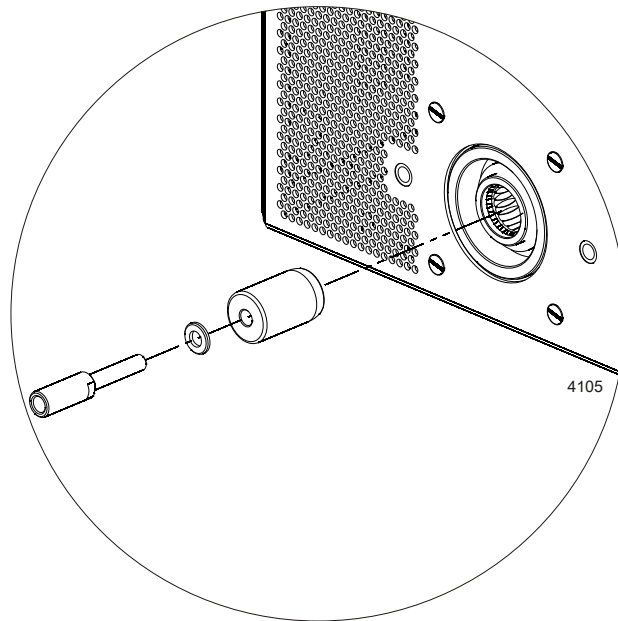


Figure 5-19. B20N connector with 6 mm socket

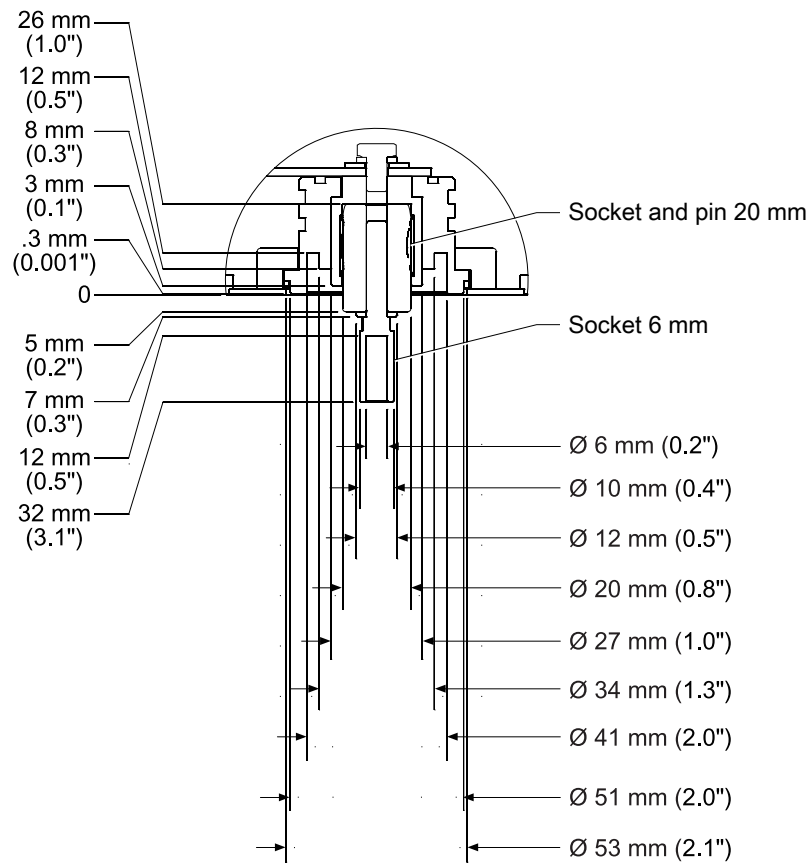


Figure 5-20. B20N connector: 6 mm socket details

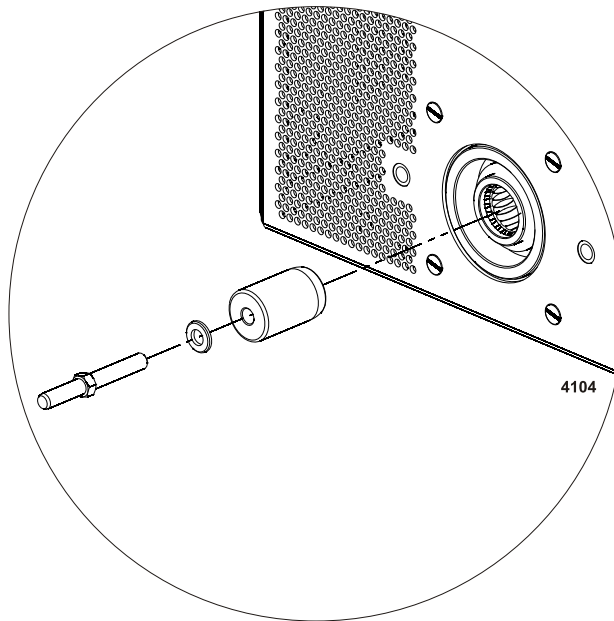


Figure 5-21. B20N connector with 6 mm pin

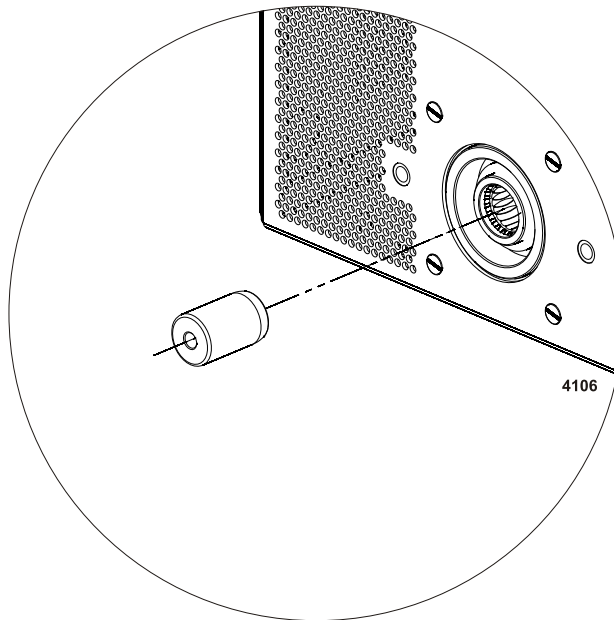


Figure 5-22. B20N connector, 6 mm tapped hole only, no stud (female)

RF OUTPUT CONNECTOR, TYPE 7-16

Connect one end of a user-supplied coaxial cable to the RF output connector on the match network. Attach the other end of the coaxial cable to the load.

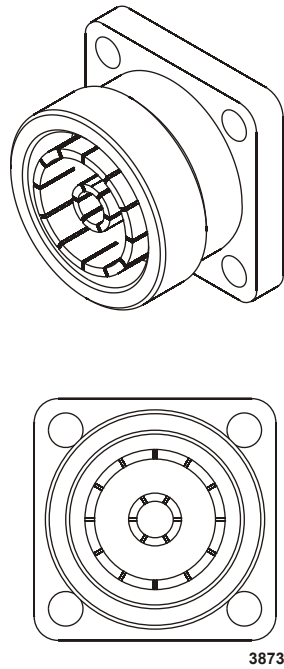


Figure 5-23. 7-16 connector

RF OUTPUT CONNECTION, TYPE CF 2-3/4" FLANGE MOUNT

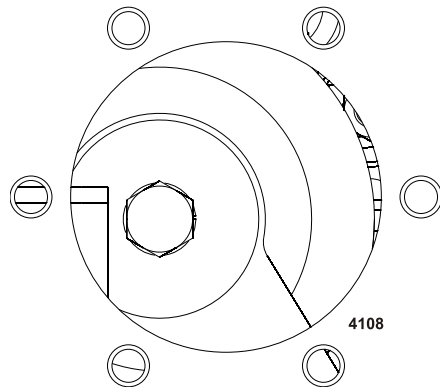


Figure 5-24. CF 2-3/4" flange mount

Guidelines for Connecting the CF 2-3/4" RF Output Connector



DANGER:

RISK OF DEATH OR BODILY INJURY. Disconnect and lockout/tagout all sources of input power before working on this unit or anything connected to it.

**WARNING:**

Maintenance personnel must receive proper training before installing, troubleshooting, or maintaining high-energy electrical equipment. Potentially lethal voltages could cause death, serious personal injury, or damage to the equipment. Ensure that all appropriate safety precautions are taken.

The following equipment is supplied by AE:

- Navio, with an opening for the RF output connector. The opening is located at the rear of the unit.
- Water fittings external to the unit.
- Water cooled RF feed flange

Note: Water fittings and hose are not intended to cool the unit. These are included at customer request and are used as part of installing the CF 2-3/4" RF output connector.

The following equipment is supplied by the customer:

- CF 2-3/4" plug
- Internal water fittings
- All other hardware, including all screws needed for the installation

Use your internal procedures and the following guidelines when connecting the RF out:

- Use [Figure 5-25](#), [Figure 5-26](#), [Figure 5-27](#), and [Figure 5-28](#) to help locate the cover, water fittings, flange, mounting holes, and opening.
- Using your internal procedures, feed the CF 2-3/4" plug through the hole labeled **RF Out** and connect the CF 2-3/4" plug to the inside metal piece connected to the coil, which has two screw holes.
- Using your internal procedures, connect the water fittings to the water tube located inside the unit, and to the CF 2-3/4" plug.
- For units with the CF 2-3/4" flange mount RF output connector:
 - Cooling-water tubing connections to be completed by the end user must be performed as follows:
 - Verify that all sources of energy are disconnected and locked-out tagged-out from this product before continuing.
 - Only AE part number 11900030, Zeus Industrial Products part number 86977 tubing is to be used in this tuner/match product.
 - Tubing must be fixed to both the user-supplied and AE-provided fittings as per manufacturer's instructions.
 - The connection can be checked with Swagelok inspection gauge P/N MS-IG-400, or MS-IG-612M for the 6 mm fittings.

- All screws that bond the enclosure cover to the chassis must then be reinstalled and tightened to 0.67 Nm (6 in-lb).
- Once assembled, the system is to be verified with a static-pressure test of 6 bar for one minute without pressure loss.

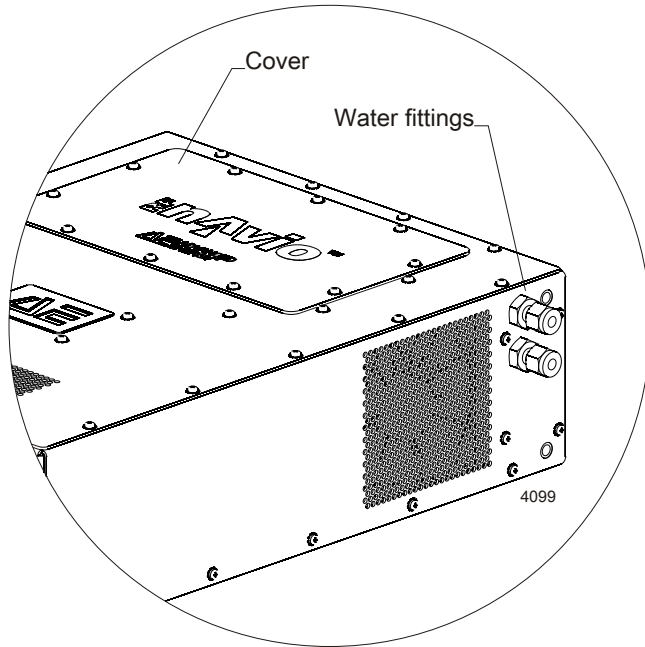


Figure 5-25. CF 2-3/4", cover and water fittings

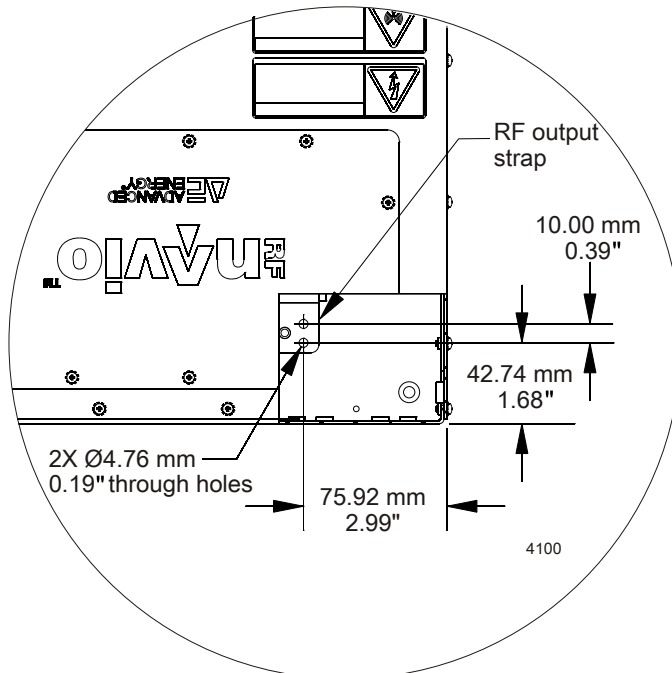


Figure 5-26. CF 2-3/4", location of two screw holes, cutaway view from top

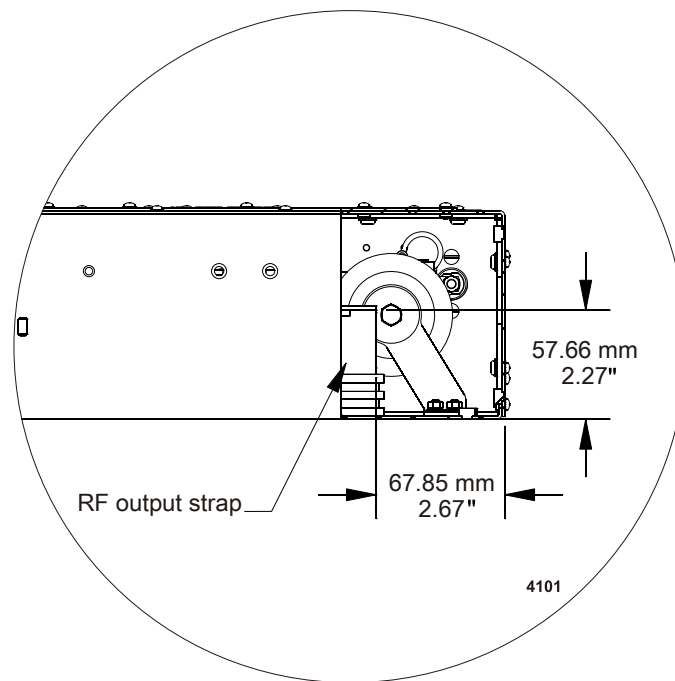


Figure 5-27. CF 2-3/4", location of metal flange, cutaway view from rear

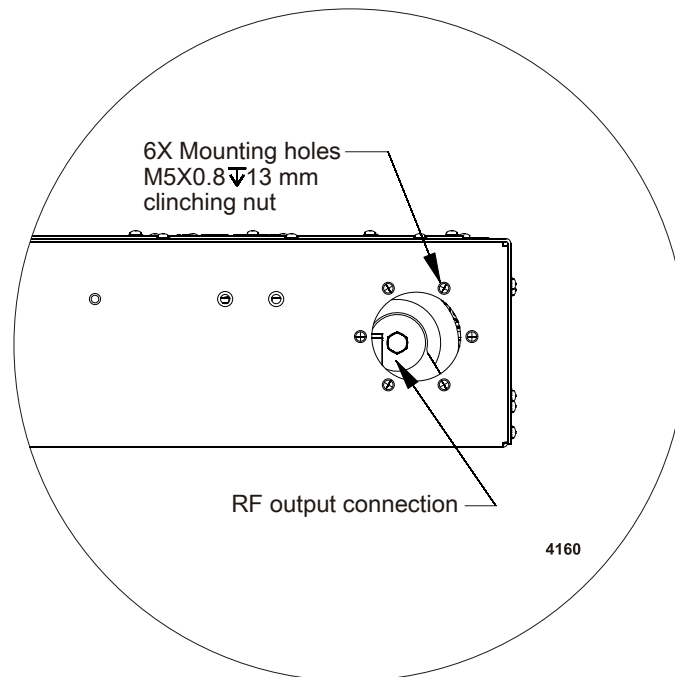


Figure 5-28. CF 2-3/4", location of mounting holes

To Ground the Unit



WARNING:

Do not attempt to turn on power until the Navio unit is grounded.



CAUTION:

Poor grounding or a long output strap can cause the match network to fail to tune properly.

Provide Protective Earth grounding with ampacity equal to or greater than the input RF cable.

A good ground connection is essential to achieve the best possible RF connection between the match network and the ground of the load. The Navio match network chassis must be intimately grounded to the plasma chamber. The ground lead must provide a low impedance RF path. If a proper RF ground is not achieved, the RF current flowing through the ground leads will cause ground bouncing.

- Connect the chassis of the match network to the chassis of the vacuum chamber.

It is important that you supply a known, low impedance RF return path within the system. Failure to do so may result in improper system operation, RF interference, and dangerous operating conditions.

Making Communications Connections

The following illustration shows representative communications and power connectors on the Navio match network. Your unit may not have all of the illustrated connectors. Your unit labels the connectors.

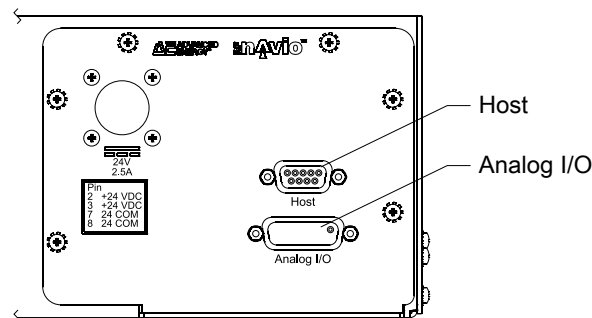


Figure 5-29. Navio match network connectors

Connecting the Power Supply

DETERMINING THE UNIT POWER SUPPLY TYPE

The power supply connection varies by model. Depending on the option, the Navio match network provides one of the following connections:

- IEC320 universal connector for AC input power
- 9-pin CPC connector for DC input power

To determine which power supply you have, compare the power input connector on the front of the unit to the illustrations in the following sections.

CONNECTING THE DC POWER SUPPLY

If your unit provides the 9-pin CPC connector for DC for DC input power, follow the recommendations and instructions in this section.

24 VDC Power Supply Recommendations

AE recommends the use of universal power supplies (85 VAC – 264 VAC to 24 VDC) with the Navio match network. Using these power supplies in 240 V nominal outlets improves the probability of their effectiveness. This kind of switching power supply can automatically respond to voltage sags, eliminating voltage drop in the supply output voltage. The result is constant voltage output to the Navio match network.

24 VDC System Wiring

AE recommends that you follow the guidelines shown in the following table for the 24 VDC power supply wire gauge and run length. These recommendations are for a single match where two wires are used for each of the positive and negative lengths (four wires total). Divide the wire run length by two if using only single positive and negative wires.

Table 5-1. Wire recommendations for 24 VDC power supply (3 amp draw)

Wire Gauge	Wire Run Length (3 Amp Draw)
24	3.1 m (10.3')
22	5.0 m (16.3')
20	7.1 m (23.3')
18	12.4 m (40.7')
16	19.8 m (64.9')
14	31.8 m (104.3')

Connecting DC Power

The Power connector on the Navio match network is a 9-pin, male circular plastic connector (CPC). To connect DC power, you must supply 24 V with an input current of 2.5 A. The mating connector and cable are not supplied.

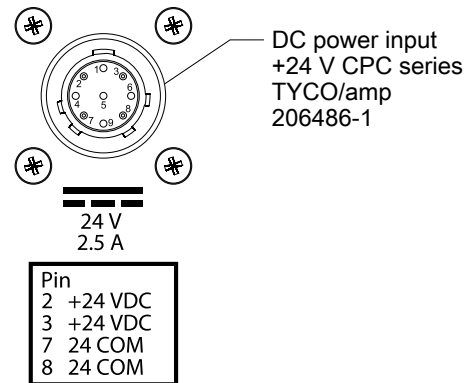


Figure 5-30. 9-pin CPC DC power connector

Table 5-2. DC power connector pin descriptions

Signal Pin	Name	Description
1	Reserved	Reserved for future use
2	+24 VDC	2.5 A maximum, 2 A idle
3	+24 VDC	2.5 A maximum, 2 A idle
4	Reserved	Reserved for future use
5	Reserved	Reserved for future use
6	Reserved	Reserved for future use
7	+24 V COMMON	Return for pins 2 and 3 (tied to chassis ground)
8	+24 V COMMON	Return for pins 2 and 3 (tied to chassis ground)
9	Reserved	Reserved for future use

Grounding the DC Power Connector (60.00 MHz Units Only)

To meet radiated emissions requirements on 60 MHz Navio match networks, AE recommends using a DC cable with group shielding. Attach the DC cable to a ground stud on the unit's chassis as shown in [Figure 5-31](#).

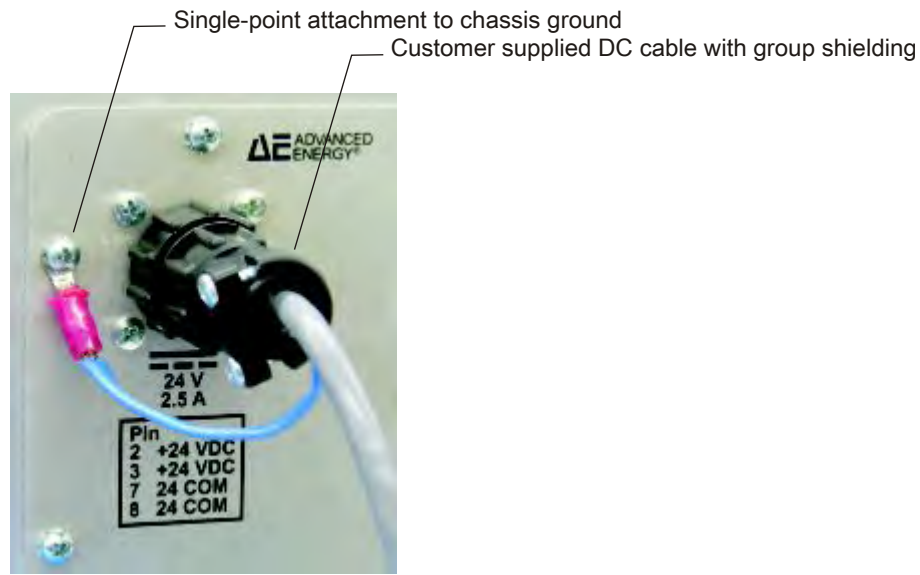


Figure 5-31. DC cable connection for 60 MHz units

CONNECTING THE AC POWER SUPPLY

If your unit provides the 3-pin IEC 320 connector for AC input power, follow the recommendations and instructions in this section.

Connecting the AC Power Supply

The Navio match network provides a 3-pin IEC 320 connector for AC power connection.

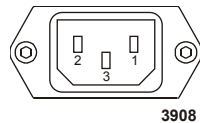


Figure 5-32. AC power connector

Table 5-3. AC power connector pin descriptions

Pin	Description
1	Line
2	Neutral
3	Protective Earth ground

Connecting RF Input

RF INPUT CONNECTORS

The RF input connector for the Navio match network can be any of the following. Compare your unit to the illustrations below to determine which RF input connector you have.

- C (female)
- N (female)
- HN (female)
- 7-16 (female)
- LC (female)
- SQS (female)

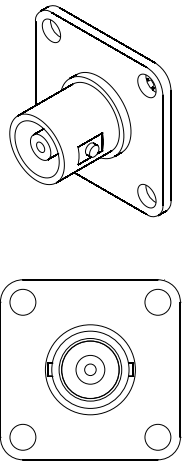
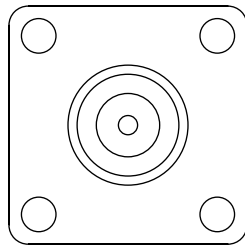
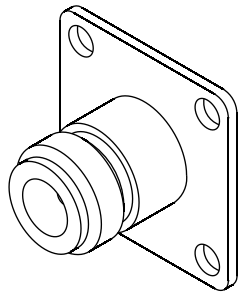
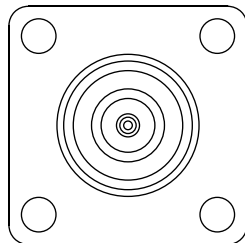
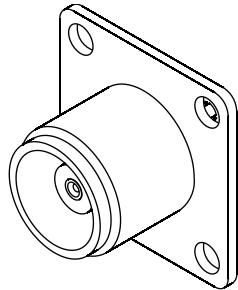


Figure 5-33. RF input connector, type C



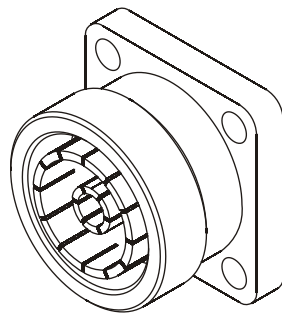
3872

Figure 5-34. RF input connector, type N



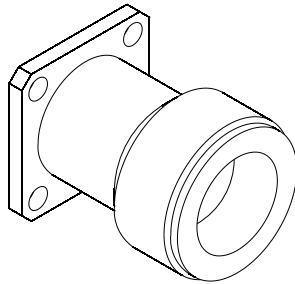
3871

Figure 5-35. RF input connector, type HN



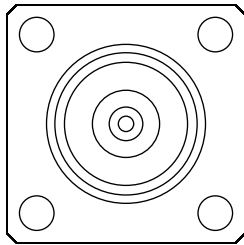
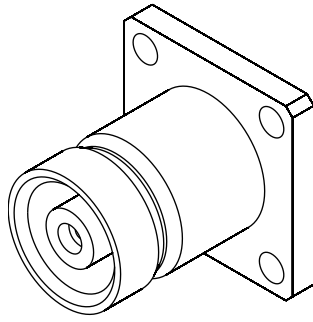
3873

Figure 5-36. *RF input connector, type 7-16*



4097

Figure 5-37. *RF input connector, type LC*



3870

Figure 5-38. RF input connector, type SQS

CONNECTION INFORMATION

Table 5-4 provides connection information for each type of RF input connector.

Table 5-4. Connection information by RF input connector type

Connector type	Connection information
SQS	Pull back on the collar, then slide the plug onto the connector. The collar snaps back into place when the plug is seated.
N, HN, 7-16, and LC	Screw the plug onto the connector until it is tight.
C	Slide the plug onto the connector, then twist the plug to the right until it stops.

GUIDELINES

Connect the RF input using the guidelines shown in this table. Make sure the RF connection is secure.

Table 5-5. RF input installation guidelines

Category	Guidelines
Connector pins	Pin descriptions: • Center = Input • Outer = Ground
Cable type	Coaxial (user-supplied)
Shielding	Shield all RF connections to prevent RF radiation and minimize safety hazards. Shielding is also important to communication, as excessive noise can corrupt the data packet and cause errors.

Completing Interlock and Limit Requirements

Ensure you have satisfied all interlock requirements and ensure you have met all conditions of use.

Related Links

- [“Conditions of Use” on page 1-5](#)
- [“Match Network Interlocks” on page 1-6](#)

FIRST TIME OPERATION



CAUTION:

Leaving the RF power on after turning off the input power to the match network may damage the unit.

To Operate the Navio Match Network for the First Time

1. Power on the unit.
2. Ensure that the cooling fan is operating.
3. Listen for the capacitor motors to initialize.

The length of the initialization will vary, depending on the location of the capacitors when the unit receives power.

4. Listen for the capacitor motors to stop after initialization.

If the motors continue to run, verify that RF is off. If it is off, contact AE Global Services.

5. Using AE Bus commands, cycle the capacitor position from end to end.

During transport or extended storage and depending on the capacitor orientation, gravity can cause the lubricating grease or oil to migrate. AE recommends that the capacitor position be cycled from end to end upon installation or initialization to prevent the potential binding or premature wear that can occur as a result of this migration.

6. For first-time use, verify that the Navio match network is in automatic tune mode.

To perform this step, you need AE's Virtual Front Panel software or other host tool software. Virtual Front Panel software ships with some Navio units or can be ordered from AE.

If you can not verify that the unit is in automatic tune mode, proceed to the next step.

7. Turn on the RF generator and adjust it to at least 10% of rated match network power.

A substantial amount of RF power is necessary for proper operation of the automatic detection circuitry and the control circuitry within the match network. The detector is adjusted at the factory to achieve $\leq 1\%$ reflected power within a defined forward power level.

8. Check for plasma. If you encounter any of the problems noted here, see the Navio match network troubleshooting information.

- Plasma not lit
- Plasma not stable (the plasma glow is not constant)
- Capacitors did not begin to move
- Reflected power did not decrease to within specifications
- Motors stopped moving

9. If you have Virtual Front Panel software, check the positions of the capacitors.

Optimally, the capacitor range should be between 5 percent and 95 percent. If the capacitor position falls outside this range, and the unit isn't performing to your requirements, then AE may need to optimize the unit. In this situation, contact AE Global Services.

If the capacitor positions are in the acceptable range, increase the power to the desired operating level. Recheck the capacitor positions to ensure that the impedance is midrange.

10. Vary the chamber conditions according to your process requirements, and verify that the match network can cover the required load impedance range.

NORMAL OPERATION

You can control and monitor the Navio match network with a system (user-supplied) controller or a Windows-based personal computer and the Advanced Energy Virtual Front Panel software (or other host tool software). To order Virtual Front Panel software, contact your AE sales representative.

Related Links

- [“Navio Control Modes” on page 5-30](#)
- [“Presets” on page 5-32](#)
- [“Adjusting Tuning Parameters” on page 5-34](#)
- [“Typical Tuning Parameters” on page 5-36](#)
- [“Set Up the Match for the Load” on page 5-37](#)
- [“Maintenance” on page 5-39](#)

NAVIO CONTROL MODES

The Navio match network can operate in several modes. The control mode is retained in nonvolatile memory. AE recommends using automatic tune mode for normal operation. In automatic tune mode, the Navio match network internally controls the impedance matching functions.

Related Links

- [“Automatic Tune Mode” on page 5-30](#)
- [“Host Control Mode” on page 5-31](#)
- [“User Control Mode” on page 5-31](#)

Automatic Tune Mode

Automatic tune mode is suggested for normal operation. In this mode, the match network internally controls the impedance matching functions.

Automatic tune mode requires no user interface. Depending on the settings you make, this mode can function in two different ways:

- With presets and trajectories enabled and set up—When the Navio match network detects RF power, the capacitors move through the trajectory positions. When the trajectories are completed, the unit begins operating according to the automatic tuning algorithm. When RF power is turned off, the capacitors return to the default preset positions.
- With presets and trajectories disabled—When the Navio match network detects RF power, the unit begins operating according to the automatic tuning

algorithm. When RF power is turned off, the capacitors retain their current positions.

The Navio match network presets can be used to position the load and tune capacitors to ensure the shortest possible plasma ignition time. Commands from one of the following ports determines the preset positions. (The Navio match network has preset positions that you may set with corresponding trajectories for each preset. The preset and its corresponding trajectories consist of up to four sequential capacitor positions.)

- **Host** port
- **PROFIBUS** port
- **Analog I/O** port

Host Control Mode

Host control mode is available for troubleshooting or for verifying that the positions set in automatic tune mode are optimum. In host control mode, the automatic tuning feature is disabled, and capacitor positions are controlled through one of the following ports:

- **Host** port
- **PROFIBUS** port

When the Navio match network is in host control mode, you can adjust the capacitor positions using the Advanced Energy Virtual Front Panel software or other host tool software. To order Virtual Front Panel software, contact your AE sales representative.



Important

The positions of the capacitors do not change when you switch from automatic to host control. However, when you switch from host control to automatic tune mode, if presets are enabled, the capacitors will move to their preset positions. If RF is on, the unit will start tuning automatically.

User Control Mode

User control mode is only available on models with the **Analog I/O** port. In user control mode, the automatic tune feature is disabled and capacitor position is controlled through the **Analog I/O** interface port on the match network. You can set the unit to user control mode through AE Bus command **93**.

INTERACTION WITH A CESAR GENERATOR CONNECTED VIA ANALOG INTERFACE

When the Navio match network is connected to a Cesar generator via the **Analog I/O** port and is in user control mode, you can control the Navio match network using either of the following two methods:

- Front Panel Display

You can control the Navio match network in either manual mode or automatic mode using a Cesar generator front panel. The front panel display on the Cesar generator will show the position of the capacitors, the mode (automatic or manual), the measured DC bias, and whether the match network is active or not. The front panel also allows you to change the mode (automatic or manual) via buttons and to move the capacitors manually. The information about the match network is shown on the Cesar front panel as soon as the Cesar generator detects a connection to the match.

- Host Port

You can use the Cesar generator **Host Port** to control the Navio match network.

See the Cesar generator user manual for additional information.

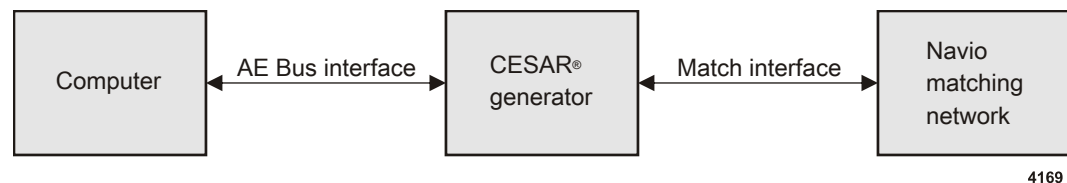


Important

To optimize the capacitor movement when using the **Analog I/O** port, make sure you have the following firmware installed on the Cesar generator:

- Version 1.19 or greater for Cesar generators with a C3 controller
- Version 1.22 or greater for Cesar generators with a C4 controller

Contact AE Global Services for the latest revision.



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Figure 5-39. Interfacing with Cesar

PRESETS

This section describes presets using one of the following ports:

- **Host** port
- **PROFIBUS** port

If you are connected to the Cesar generator via the **Analog I/O** port, then you can set presets from the Cesar generator. See the Cesar generator user manual for additional information.

In automatic tune mode, presets determine the position that capacitors return to when RF is turned off and the trajectory that they follow when RF turns on. Using presets allows you to position the capacitors so that they are close to the position they need to be in for your application, thereby speeding up the tuning process. The following table shows the source of capacitor positioning when RF turns off, depending on the control mode and preset source that are set in the unit.

Table 5-6. Source of capacitor position when RF turns off

Preset Type	Automatic Mode	Host Control Mode
Internal presets	Nonvolatile RAM	Not applicable
No presets	Last position	Last position

Internal Presets

The Navio match network can store up to four sets of preset capacitor positions and trajectories in nonvolatile memory. Each of these sets of “internal” presets include initial positions for both the tune and load capacitors and, if desired, trajectories of up to three successive positions for both capacitors. You can also set delays for the initial preset position and each trajectory, which allows you, for example, to delay tuning while the plasma ignites. You set internal presets through the following ports or through AE’s Virtual Front Panel (VFP) software or other host tool software.

- **Host port**
 - Use command 90 to set internal presets and trajectories.
 - Use command 91 to select the active preset.
 - Use command 94 to enable or disable presets.
 - Use command 100 to set preset and trajectory delays.
- **PROFIBUS port** or (see command descriptions under the previous item)

Enabling and Disabling Presets

If you enable presets and the Navio match network is in automatic tuning mode, the active preset takes effect at the next RF-off event. If RF is already off, the capacitors move to the preset positions when you enable presets.

If you disable presets, no preset positions will be applied, and the capacitors remain in their current positions when RF is turned off. To enable or disable presets, see command 94.

Determining Appropriate Preset and Trajectory Positions

Appropriate preset values vary widely from application to application, depending on operating variables such as the type of application gas, the amount of pressure in the chamber, and the configuration of the chamber. You can use this process to help determine appropriate preset positions.

1. In an experimental chamber, turn on RF power at the expected power level.
2. Allow the Navio match network to tune in automatic tune mode

- If the plasma ignites, adjust the capacitor positions only slightly to find the optimum positions.
 - If the plasma fails to ignite, experiment to find a position where the plasma will ignite; then make small adjustments from that point to find the optimum positions
3. In addition, you may need to adjust the trajectories so the plasma will not extinguish as the Navio match network begins to tune. Trajectories ensure that the plasma remains lit, and they allow you to move the capacitors along an optimal path from the preset point to a known tune point.

ADJUSTING TUNING PARAMETERS

With the Advanced Energy Virtual Front Panel software or other host tool software, you can modify the tuning parameters to optimize the Navio match network for specific applications.

Tuning parameters and tuning algorithms are used when the unit is in automatic tune mode. Automatic tune mode is available on units where the capacitor is controlled by specifying a percentage of capacitor range of movement.

Improperly selecting parameters may cause the unit to attempt, but fail, to tune, and thereby cause power fluctuation to the chamber. These conditions are characterized by unstable plasma glow or flickering plasma.



CAUTION:

Changing the tuning parameters can affect tuning success and tuning speed.

AE Bus command **84** sets the capacitor limits. All other values are set with AE Bus command **82**.

Related Links

- [“Phase/Mag Tuning Parameters” on page 5-34](#)

Phase/Mag Tuning Parameters

The Phase/Mag tuning algorithm uses the following parameters to tune the match:

- Capacitor automatic tuning limits
- Tuning start and stop parameters
- Maximum load and tune percent
- Minimum tune percent

CAPACITOR AUTOMATIC TUNING LIMITS

The capacitor limits define the range over which the capacitors move in automatic tuning mode by setting minimum and maximum capacitor positions. These positions are set as percentages of the capacitor's potential range of movement. The Navio match network uses these values in the automatic tuning algorithms.



Important

Capacitor limits do not change the preset or trajectory positions that capacitors can move to, nor do they limit the movement of the capacitors in host and user control modes.

TUNING START AND STOP PARAMETERS

You can set the VSWR values at which the Navio match network will start and stop automatic tuning.

The start/stop tuning values define the range over which the Navio match network considers the load to be tuned by setting the levels at which the unit will start and stop tuning. The stop value must be set lower than the start value for the match network to operate correctly.

- The stop value sets level at which the match is tuned (and at which it stops tuning). This value depends on the required minimum reflected power.
- The start value sets the level at which the match starts tuning. This value depends on the required maximum reflected power.

MAXIMUM LOAD PERCENT

The maximum load percent is the maximum distance that the load capacitor will move between VSWR measurements. Changing this parameter changes the load capacitor's sensitivity to the error values described in [“Magnitude and Phase Calculated Error Values”](#).



Important

Increasing the maximum load percent will make the match network tune faster, but the unit could become unstable.

MAXIMUM TUNE PERCENT

The maximum tune percent is the maximum distance that the tune capacitor will move between VSWR measurements. Changing this parameter changes the tune capacitor's sensitivity to the error values described in [“Magnitude and Phase Calculated Error Values”](#).

MINIMUM TUNE PERCENT

The minimum tune percent sets the lower limit for the maximum tune distance to avoid unreasonable adjustments of the tune capacitor's position.

MAGNITUDE AND PHASE CALCULATED ERROR VALUES

The magnitude→load, phase→load, magnitude→tune, and phase→tune parameters define how the Navio match network uses the magnitude and phase error values to control the load and tune capacitor movements.

In automatic tune mode, the Navio match network senses the initial load impedance and calculates the electrical characteristics of that impedance, including magnitude and phase error. The match network uses these two values to calculate the direction and magnitude of the load and tune capacitors to convert the impedance to 50 ohms. In simple terms, the value of the phase error directs movement of the tune capacitor, and the value of the magnitude error directs movement of the load capacitor. In reality, however, some interaction or cross talk in these relationships can improve trajectories and create faster, more reliable tuning (that is, phase directing load movement and magnitude directing tune movement). These parameters are process-dependent and will be set differently to maximize the tuning speed and repeatability for each application, but they are factory set to default values that will work in most applications. Contact AE Global Services for additional information on these parameters.

HOLD LOAD

The hold load option is for inductively coupled plasma (ICP) applications. When hold load is enabled, only the tune capacitor moves between the time that RF power is turned on and when the phase error signal changes sign. After RF is on and the phase error signal has changed sign, both capacitors automatically begin operating in normal tuning operation.

TYPICAL TUNING PARAMETERS

The Navio matching networks are shipped from the factory with default tuning parameters. You can set and read back the tuning parameters using the AE Bus commands.



Important

Always document your custom parameter settings prior to sending the unit to AE for service.

The following table lists typical tuning parameter settings for the Navio match network. Use the AE Bus read back commands to report your unit's parameter settings.

Table 5-7. Typical tuning parameters

Parameter	Typical Setting
Control mode	Automatic tune mode
VSWR (tuning) start/stop limits	VSWR start: 1.19  Important Decreasing the VSWR start value increases the wear on the mechanical vacuum capacitors and may result in the need for earlier capacitor replacement. Contact AE if a lower VSWR start value is required. VSWR stop: 1.06
Capacitor range settings	Tune: Minimum 0%, maximum 100% Load: Minimum 0%, maximum 100%
Step Limits	Tune: Minimum 0.5%, Maximum 10% Load: Maximum 10%
Magnitude and phase gain settings	Magnitude load: 0.8 Magnitude tune: -0.2 Phase load: 0.2 Phase tune: 0.8
Presets	Load: 80% Tune: 60% Tune/load presets: On
Hold load	False
Sample integration	3
Input sensor power off	• 1 kW units: 15 W • 3 kW units: 25 W • 5 kW units: 35 W
Input sensor average	4

SET UP THE MATCH FOR THE LOAD

The ability of the Navio match network to properly match your load will be determined by two major match components:

- The variable capacitors

The range of the variable capacitors is determined by the Navio match network model you purchased. Motors drive the variable capacitors to match the load.

- The number of turns on load and tune coils

You can adjust the tune range of your unit by changing the load or tune coil. If you require a different tune or load coil, contact AE Global Services.

Selecting the Correct Tune Coil

The Navio match network is equipped with a tune coil and a load coil. The transformation step is determined primarily by the tune coil; accomplished by the tune capacitor in series with the coil. To compensate and correct the phase for optimum matching quality, a load capacitor and coil are also used. The tuning elements interact, and are used together to obtain the best possible match

The following guidelines will help to determine the optimum component values for a particular load system:

- The match network should be configured to allow matching with the tune capacitor set between 20% and 80% of its capacitance range to avoid extreme RF stress. Always try to achieve a tuning position with both capacitors in the range of 20% to 80%.
- If the tune capacitor is at the upper end of its tuning range (greater than 80%), you can select a tune coil with more turns for more inductance.
- If the tune capacitor is at the lower end of its tuning range (less than 20%), you can select a tune coil with fewer turns for less inductance.

For specific recommendations, contact AE Global Services.

Selecting the Correct Load Coil

The other device in the match network that affects the range of the match capability is the load capacitor. Depending upon the load resistance (the real part of the load impedance) this load capacitor needs to be more or less capacitive. A small coil at the input of the Navio match network enables the effective value of the load capacitor to be increased to several times its actual value.

By changing the load coil, you can adjust the match range for the size of the load. The more coils that are active between the tap and the load capacitor, the higher the resulting capacitance. The ideal number of turns on the load coil depends on the real part of the load impedance. For example, lower load impedance requires more capacitance of load capacitor, which requires a load coil with more active turns (more turns means more inductance).

MAINTENANCE

Consumable Parts

Some parts in the Navio are consumable and may wear out over time. For a current list of consumable and wear components in the Navio as well as for estimated lifetimes and recommended refurbishment schedules, please contact AE Global Services.

Periodic Vacuum Capacitor Re-lubrication

All automatic load matching networks can develop an area on the vacuum capacitors nearly devoid of lubricating grease or oil during normal use in certain applications. This is a phenomenon caused by repetitively using a small portion of the entire capacitor travel. A result of this repetitive use is that the lubricating grease or oil is pushed to the outer ends of the lead thread screw which could result in premature wear or, if severe enough, early capacitor failures.

To reduce the likelihood of premature wear, AE recommends following the vacuum capacitor manufacturer's recommendation to periodically cycle the capacitor position from end to end to re-distribute the lubricating grease or oil. The recommended preventative maintenance period is 20,000 capacitor cycles as a minimum to 50,000 capacitor cycles as a maximum.

Additionally, migration of the lubricating grease or oil can occur during transport or extended storage, depending on the capacitor orientation, as a result of gravity. In addition to the above preventive maintenance cycle, AE recommends that the capacitor position be cycled from end to end upon installation or initialization to prevent the potential binding or premature wear that can occur as a result of this migration.

Troubleshooting and Global Services

Before calling AE Global Services, perform recommended checks and troubleshooting procedures. If you are still unable to resolve the issue and resume normal operation after following these checks and procedures, contact AE Global Services.

TROUBLESHOOTING GUIDE

**DANGER:**

RISK OF DEATH OR BODILY INJURY. Disconnect and lockout/tagout all sources of input power before working on this unit or anything connected to it.

Use the following questions to help troubleshoot problems with the unit.

1. Did you install the match network according to the installation instructions in this manual?
 - If yes, go to the next step.
 - If no, reinstall the Navio match network as described in the instructions.
2. Connect the Navio match network to the supply voltage.
3. Listen for the capacitors to turn.

The length of the initialization will vary, depending on the location of the capacitors when the unit receives power.

Did you hear the capacitors turn and then stop?

- If yes, go to the next step.
 - If no, see [“Apparent Capacitor Malfunction”](#) on page 6-2 .
4. With the RF input cable from the generator to the match network connected, turn on the RF generator to at least 10% of rated match network power. Is the generator showing high reflected power?
 - If no, go to the next step.
 - If no, see [“Apparent Capacitor Malfunction”](#) on page 6-2 .
 5. Is the plasma in the chamber lit?

- If yes, go to the next step.
 - If no, see [“Plasma Does Not Ignite”](#) on page 6-4.
6. Does the reflected power go to less than 5 W or 1% of set point (whichever is greater)?
- If yes, go to the next step.
 - If no, see [“Troubleshooting an Impedance Matching Problem”](#) on page 6-5.
7. Is the plasma unstable? That is, when you look through the viewing port on the chamber, does the plasma appear to flicker or to brighten then dim?
- If yes, see [“To Troubleshoot Unstable Plasma”](#) on page 6-6.
 - If no, go to the next step.
8. Does the Navio match network communicate with the host computer?
- If you are using Virtual Front Panel software, the software indicates when the unit is communicating properly with the computer. For information on monitoring communication, see the Virtual Front Panel software manual.
- If the match is communicating with the host computer, go to the next step.
 - If the match is not communicating with the host computer, see [“To Troubleshoot Communication Problems”](#) on page 6-6.
9. Are you having trouble with presets? Is the tuning time slower than desired?
- If yes, see [“To Troubleshoot Preset Problems”](#) on page 6-7.
 - If no, go to the next step.
10. If this procedure did not solve your problem, please contact AE Global Services.

APPARENT CAPACITOR MALFUNCTION

Several types of operational problems can cause an apparent capacitor malfunction:

- The Navio match network is receiving no or incorrect DC power or input voltage
- The unit is set for an incorrect control mode
- The RF input power is too low
- The source supply overpowers the match outside of its ratings
- Incorrect parameters are set for the unit—AE ships the Navio match network with parameters that satisfy most tuning requirements. However, you may adjust the programmed parameters to optimize them for your specific application using Virtual Front Panel software or other host software.

- Tuning start/stop is set incorrectly

Apparent capacitor problems can also be caused by an internal failure in the unit.

Related Links

- [“To Troubleshoot Input Voltage” on page 6-3](#)
- [“Troubleshooting Incorrect Navio Control Modes” on page 6-3](#)
- [“To Troubleshoot Low RF Input Power” on page 6-4](#)
- [“To Troubleshoot Unstable Plasma” on page 6-6](#)
- [“To Troubleshoot an Internal Failure” on page 6-4](#)

To Troubleshoot Input Voltage

1. Ensure that the input voltage to the Navio match network is within specifications.
2. Ensure that the input connector is connected to the correct pins.
3. Once you have verified that you have the correct input voltage and connection, disconnect the input voltage and reconnect it.

The capacitors should initialize.

Troubleshooting Incorrect Navio Control Modes

Advanced Energy recommends that you operate the Navio in automatic tune mode. The match network can operate in the following modes:

- Automatic tune mode
- Host control mode

Allows manual control of capacitor position through the following ports:

- **Host**
- **PROFIBUS**

- User control mode

Allows manual control of capacitor position through the **Analog I/O** port (not available on all units).

TO TROUBLESHOOT INCORRECT NAVIO CONTROL MODES

- Ensure that the correct mode is set for the desired operation. You can check the control mode using Virtual Front Panel software or host port command **163**. You can set the control mode using Virtual Front Panel software or host port command **93**.

To Troubleshoot Low RF Input Power

- The Navio match network has a low threshold for the RF input power that must be met and maintained before the unit will begin tuning in automatic tune mode. Check the RF input from the generator to see if it is above this threshold.

See the electrical specifications for the Navio match network for the threshold.

To Troubleshoot an Internal Failure

Internal failures could be due to wear, capacitor mechanical problems, or a failure in the motor driver or stepper motors.

1. Check to see if the stepper motor is moving. If not, contact AE Global Services.

PLASMA DOES NOT IGNITE

Several factors could cause the plasma to fail to ignite:

- Incorrect process parameters—Check your process parameters
- Poor RF connections between the Navio match network and the chamber
- Poor grounding
- The impedance of the chamber is outside of the Navio match network range—If this is a new installation or a new application, the chamber impedance may be outside the range of the match network. Contact AE Global Services.
- Generator set point may be inaccurate—Check the generator set point

Related Links

- [“To Troubleshoot Poor RF Connections” on page 6-4](#)
- [“To Troubleshoot Poor Grounding” on page 6-5](#)

To Troubleshoot Poor RF Connections

Make the following checks of the RF connections:

- Inspect the RF connections between the unit and the feed through for loose connections.
- Check for oxidation or corrosion at the connections.
- Check the RF feed-through for correct impedance readings.
- Inspect the cathode for shorts.
- Ensure that ground connections are adequate and secure.

- Ensure that there is adequate shielding around the RF connections.

To Troubleshoot Poor Grounding

Make the following checks of the RF connections:

- Inspect the chamber ground for a low impedance path.
- Inspect the RF return from the match network to the chamber for a low RF impedance path.

TROUBLESHOOTING AN IMPEDANCE MATCHING PROBLEM

If the Navio match network cannot tune to less than 5 W or 1% of set point (whichever is greater), but the plasma ignites and the capacitors can move, the unit could be out of the proper impedance matching range. In this situation, make the following checks.

- Ensure that your process parameters are correct.
- Check for arcing (visually and audibly). If you detect arcing, contact AE Global Services.
- Through Virtual Front Panel software, check to see what the capacitor positions are when they stop moving.
 - If one or more of the capacitors are at the end of their travel limits, then the impedance of the plasma is out of range. Contact AE Global Services.
 - If the capacitors' positions are not at the travel limits, then check the tuning parameters. If incorrect, they can affect the operation of the match network.
- Be sure you are operating within the tuning range for the Navio match network. Advanced Energy recommends validating target impedance data. Initial sets of critical observations can help you avoid or troubleshoot process impedance problems in the future.
- Troubleshoot the RF connections between the Navio match network and the chamber.

Related Links

- [“To Troubleshoot Poor RF Connections” on page 6-4](#)

TO TROUBLESHOOT UNSTABLE PLASMA

Unstable plasma may appear to brighten and dim, or the forward power and reflected power may fluctuate. In this situation, make the following checks.

- Check to make sure that you have proper hysteresis settings.
 - The typical Stop VSWR setting is 1.06. Incrementally increase the Stop VSWR to see if the problem stops.



Important

Setting the Stop VSWR setting to 1.00 will run the motors continuously, thereby severely shortening match lifetime.

- The Start VSWR setting must be greater than the Stop VSWR setting.

You can make these settings through Virtual Front Panel software or through AE Bus command **82**.

- Check the power supply and ensure that input is within specifications
- Check for visible damage to the cables, and check the continuity of the cables for opens or shorts.

If necessary, replace the coaxial cable or connector. If there is excessive noise, be sure to properly shield the cables.

TO TROUBLESHOOT COMMUNICATION PROBLEMS

Virtual Front Panel software indicates when the Navio match network is communicating properly with the computer. You can use Virtual Front Panel software to check whether the unit is communicating. For information on monitoring communication with Virtual Front Panel software, see the Virtual Front Panel software manual.

Use the following checks to troubleshoot communication problems.

- Verify that the unit is connected to the correct communication port on the PC.
- Check the baud rate.
- Ensure the address used by the host computer and the AE bus address set in the Navio match network are the same. You can set the address using AE bus command **127**.
- Verify that the data packet has been set up correctly.
- Make sure you are using the recommended AE Bus handshaking protocol.

TO TROUBLESHOOT PRESET PROBLEMS

- If the Navio match network does not tune or has nonrepeatable tune characteristics, check to ensure that the tuning parameters are still correct. You can check tuning parameters using Virtual Front Panel software or the host port.

Related Links

- [“Typical Tuning Parameters” on page 5-36](#)

AE GLOBAL SERVICES

Please contact AE Global Services if you have questions or problems that cannot be resolved by working through the provided troubleshooting. When you call Global Services, make sure to have the unit serial number and part number. These numbers are available on unit labels.

Table 6-1. AE Global Services 24 X 7 contact information

Office	Contact
AE, World Headquarters 1625 Sharp Point Drive Fort Collins, CO 80525 USA  Important For returns and repairs, please call Global Services to get the correct shipping address.	Phone (24 hrs/day, 7 days/week): 800.446.9167 or 970.221.0108 Fax (M–F, 7:00 am – 5:30 pm MST): 970.407.5981 Email: (We will respond to email by the next business day.) technical.support@aei.com For Sekidenko thermal product support, contact by email: thermalapplications@aei.com
If you would prefer to contact a local or regional sales or service office, visit the Advanced Energy web site for current contact information: • http://www.advanced-energy.com	

RETURNING UNITS FOR REPAIR

Before returning any product for repair and/or adjustment, first follow all troubleshooting procedures. After following troubleshooting procedures, if your unit is unable to resume normal operation, contact AE Global Services and discuss the problem with a representative. Be prepared to give them the model number and serial number of the unit as well as the reason for the proposed return. This consultation call will allow Global Services to determine if the unit must actually be returned for the problem to be corrected. Such technical consultation is always available at no charge.

Setting Capacitor Position

Before returning the unit to AE for service, return the capacitors to minimum positions (0%). Doing so will accomplish the following:

- Reduce the likelihood of shipping damage to the vacuum capacitors
- Help ensure that the unit will be received in the best condition possible so that AE can troubleshoot and service the original customer problem

Tune Ranges

FINDING THE TUNING RANGE FOR YOUR UNIT

Each frequency supports multiple tune ranges. Within a frequency, the tune range depends on the internal coils. The tune range number is indicated by the first digit in the part number option (-Txx).



Important

The tune ranges shown in this manual are approximate. To obtain the specific tune range and safe operating area for your unit, please contact AE Global Services.

Click on the part number in [Table 7-1](#) to see to the nominal tune range.

The unit power (*P* in the part number) does not affect the tune range within the frequency. However, a combination of unit frequency and power determines the maximum RF input power limits for the unit. For maximum RF input power limits for your unit, please contact AE Global Services.

[Figure 7-1](#) shows how to interpret certain specifications based on the part number.

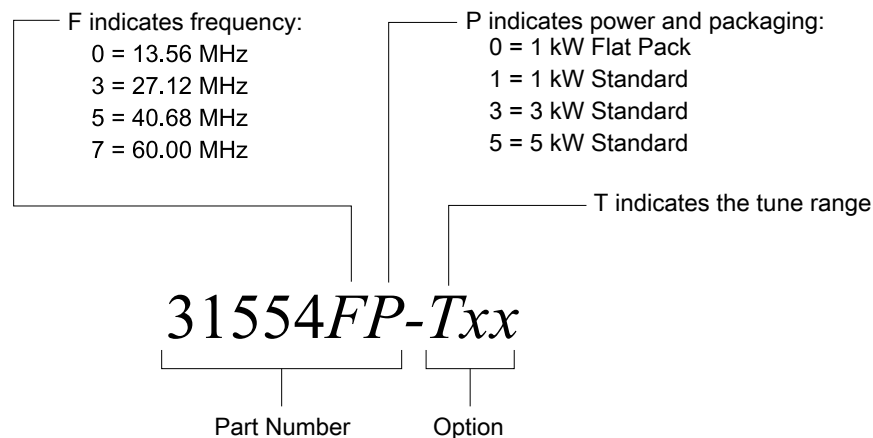


Figure 7-1. Unit part number and option description



Important

The serial tag on the unit includes the part number and option.

Table 7-1. Tune range selection

Unit Frequency	Tune Range			
	0	1	2	3
13.56 MHz	315540P-0xx, 3155403-300, 3155401-300	315540P-1xx	315540P-2xx	315540P-3xx
27.12 MHz	315543P-0xx	315543P-1xx	Not available for this frequency.	Not available for this frequency.
40.68 MHz	315545P-0xx	315545P-1xx	Not available for this frequency.	Not available for this frequency.
60.00 MHz	315547P-0xx	315547P-1xx	Not available for this frequency.	Not available for this frequency.

7-3

13.56 MHz Tuning Range 1 (315540P-1xx)

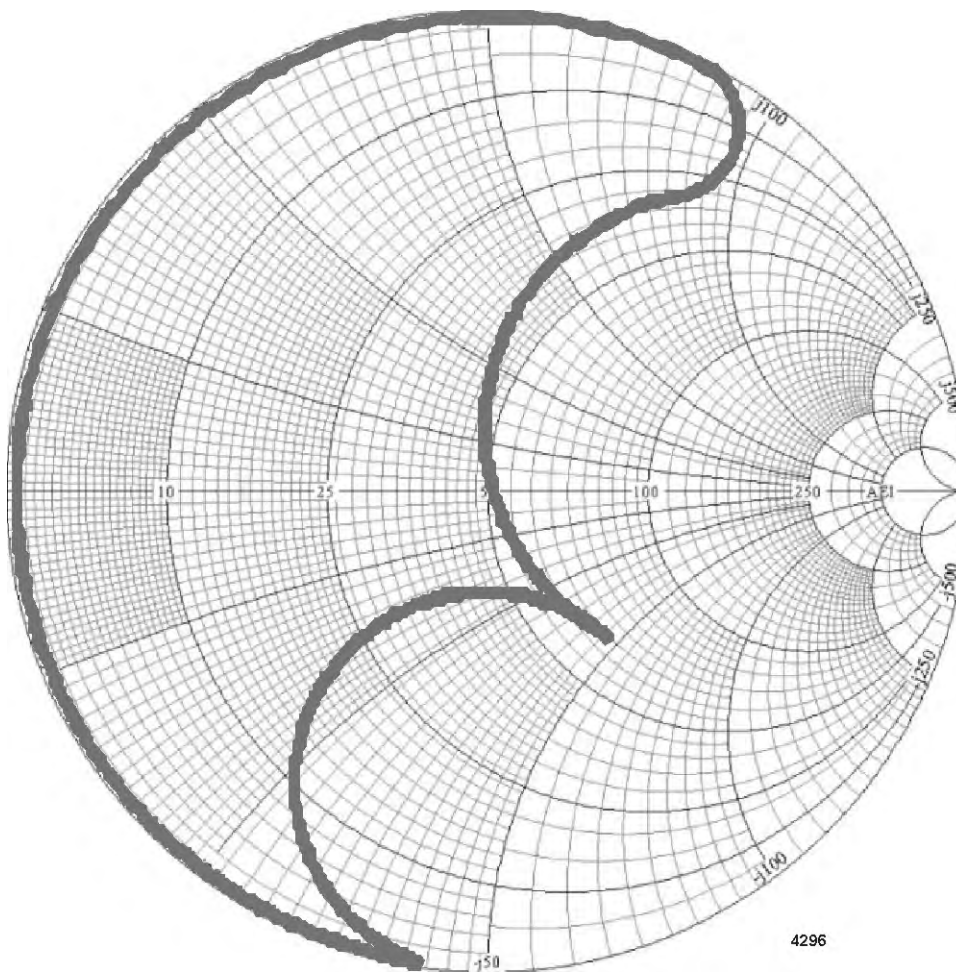


Figure 7-3. 13.56 MHz Tuning range, Smith chart (315540P-1xx)

13.56 MHz Tuning Range 2 (315540P-2xx)

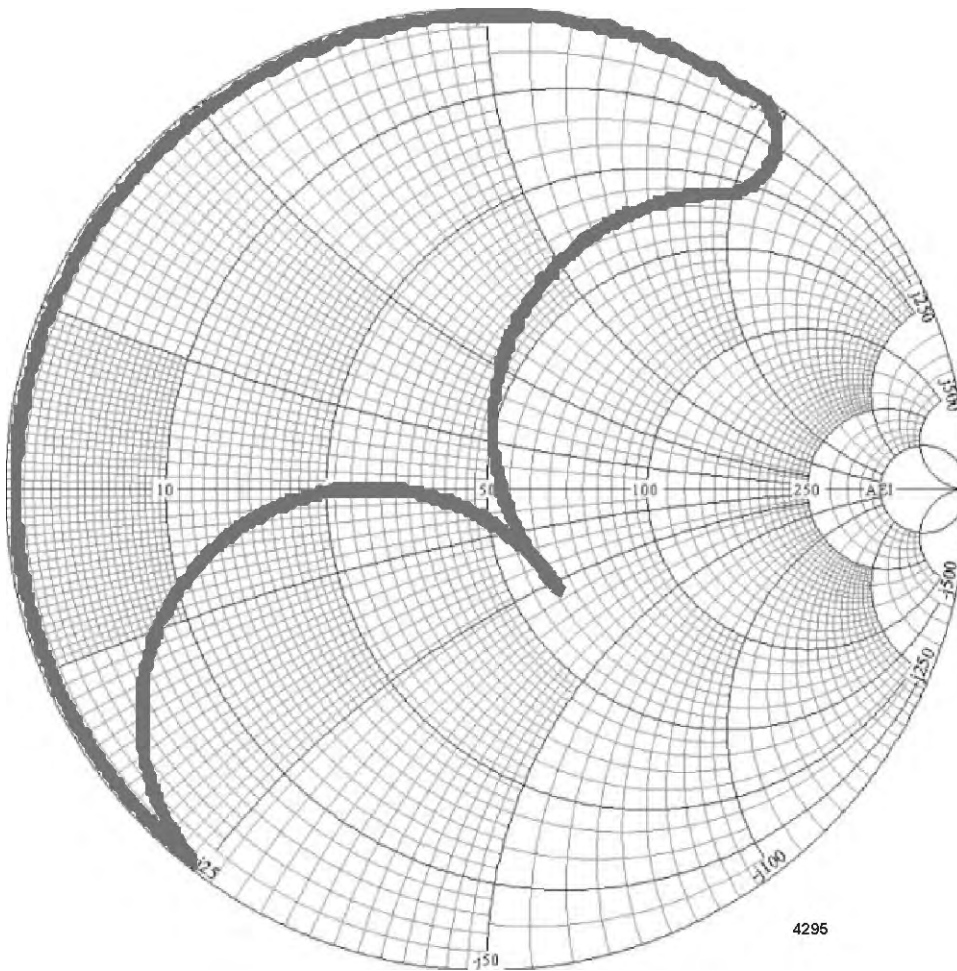


Figure 7-4. 13.56 MHz Tuning range, Smith chart (315540P-2xx)

13.56 MHz Tuning Range 3 (315540P-3xx)

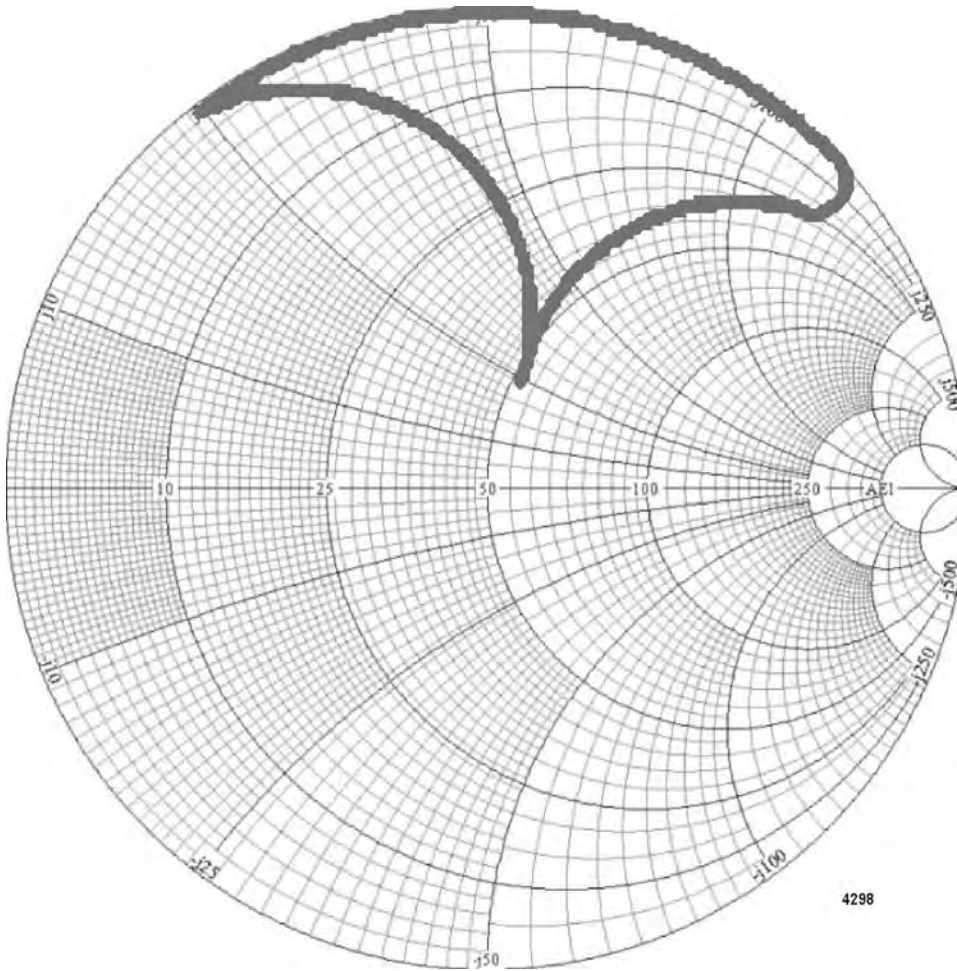


Figure 7-5. 13.56 MHz Tuning range, Smith chart (315540P-3xx)

TUNING RANGES FOR 40.68 MHZ UNITS (315545P-XXX)

40.68 MHz Tuning Range 0 (315545P-0xx)

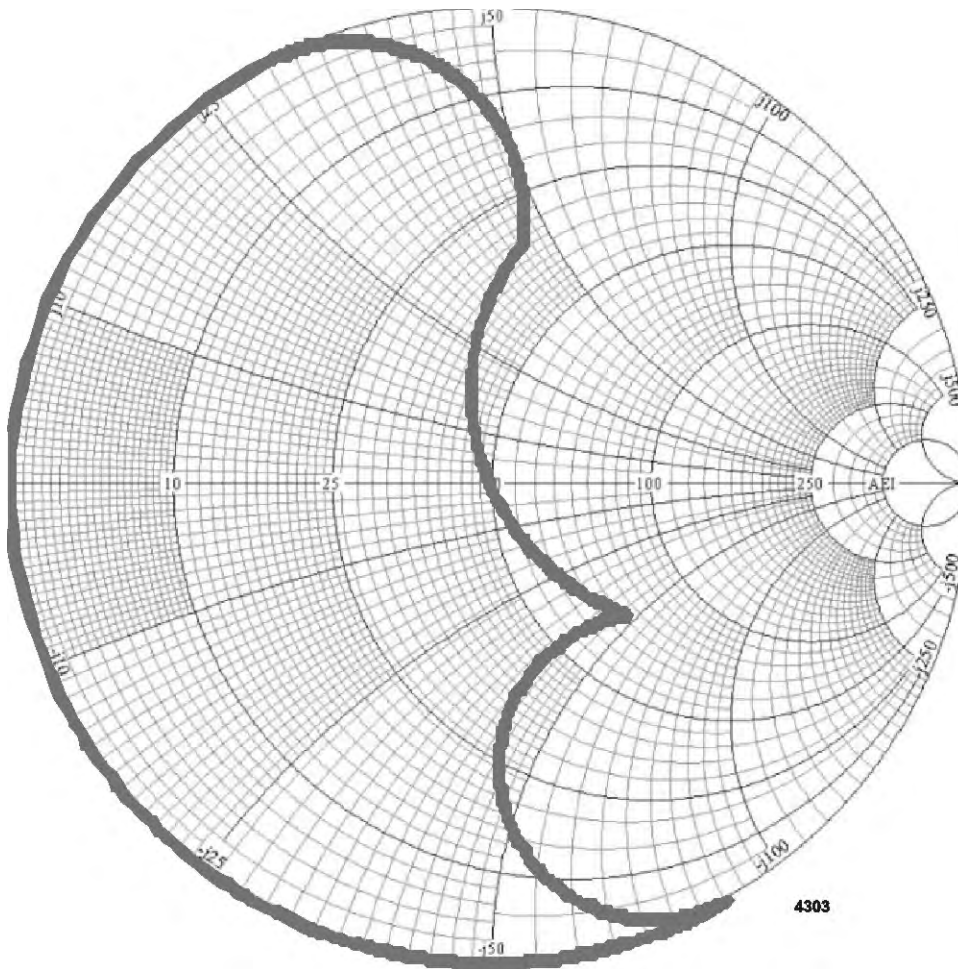


Figure 7-8. 40.68 MHz Tuning range 0, Smith chart (315545P-0xx)

TUNING RANGES FOR 60.00 MHZ UNITS (315547P-XXX)

60.00 MHz Tuning Range 0 (315547P-0xx)

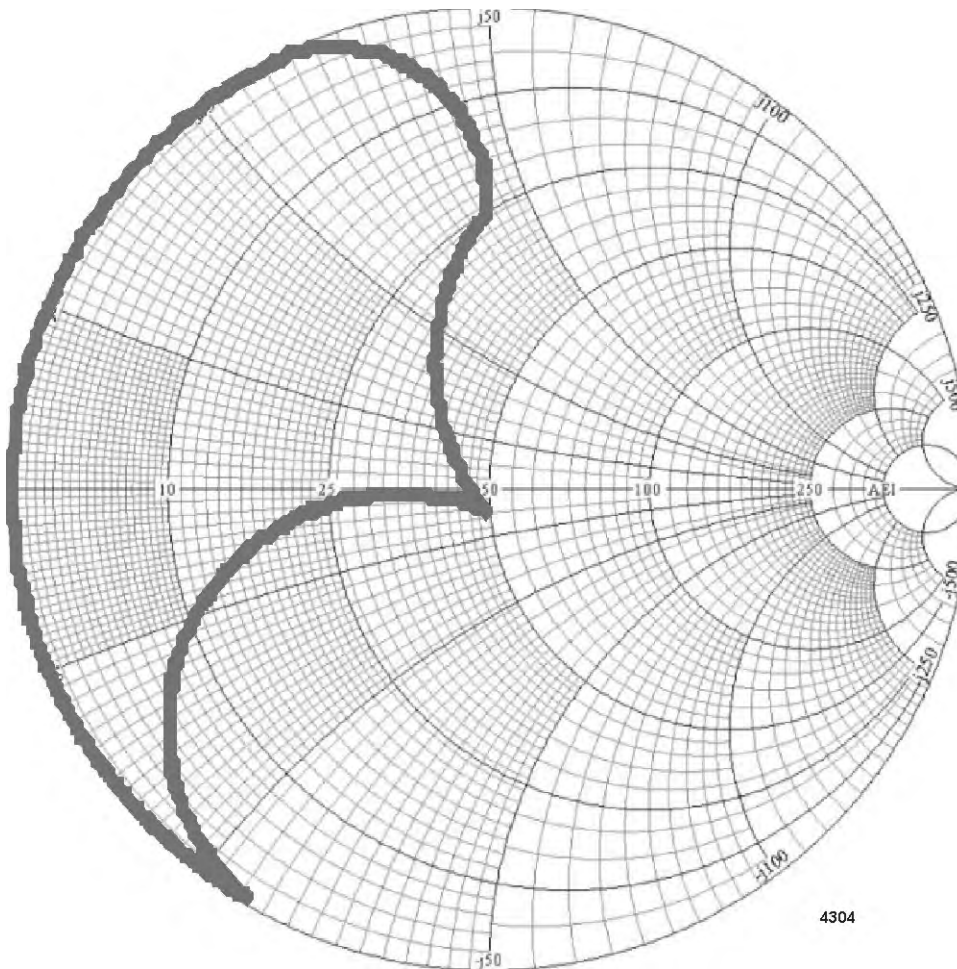


Figure 7-10. 60.00 MHz Tuning range 0, Smith chart (315547P-0xx)

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