ADVANCED ENERGY®

A POWERFUL ADVANTAGE™

Navigator® II Match Network

User Manual

November 2012 57023932-00B

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WARNING :

Read this entire manual and all other publications pertaining to the work to be performed before you install, operate, or maintain this equipment. Practice all plant and product safety instructions and precautions. Failure to follow instructions can cause personal injury and/or property damage. If the equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired. All personnel who work with or who are exposed to this equipment must take precautions to protect themselves against serious or possibly fatal bodily injury.

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Safety and Product Compliance Guidelines

A NOTE ON THE MANUAL

This manual is a generic document that covers many Navigator II match network models. This manual does not contain model-specific information, such as detailed specifications. You should, therefore, use this manual in combination with the Advanced Energy product specification for your particular model. If you do not have a copy of the relevant product specification, please contact AE.

RELATED DOCUMENTATION

This manual contains installation, operation, and troubleshooting information for the Navigator II family of products. For specifications of an individual unit as well as information about the features that are installed on that unit, see the specifications document that was included with the unit. Both this user manual and a specifications document are shipped on a CD with the unit.

This manual refers to the Virtual Front Panel (VFP) software, which ships with some Navigator II match networks. Virtual Front Panel software allows you to control and monitor the Navigator II 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.

NAVIGATOR II PRODUCT IDENTIFICATION NUMBER (PIN)

The Navigator II product line offers a variety of features that differ from unit to unit. This manual covers most of these features, not all of which are available in any individual unit. You can easily distinguish some features by looking at the unit. In other cases, if you cannot tell whether a unit has a given feature, see the specifications document that came with the unit or look at the unit Product Identification Number (PIN). The specifications document is on the user documentation CD for the unit.

Each Navigator II match network has a Product Identification Number (PIN), which identifies the configuration and features of the unit. The PIN is set at the factory.

To obtain your PIN, you can:

- Call AE Global Services with your 315XXXX-XXX unit part number
- Issue AE Bus command **221** at the **Host** port

The PIN is a 31-digit number. Each digit, or position, can identify a unit option. The PIN digits go from left to right. The following shows the PIN positions:

`0 1 2 3 4 5 6 7 8 9 10 11 12` and so on.

Use Table 1-1 to identify options on your unit:

1. Find the position in the PIN using the left column.
2. Identify the unit option using the right-most column.

Table 1-1. PIN description

PIN Position	Feature	Options and Descriptions
0	Reserved	
1	Match type, Match network 1	0—No capacitor for this frequency 1—Fixed match 2—Digital switched single capacitor 3—Digital switched dual capacitor 4—Single capacitor 5—Dual capacitor using the phase/mag tuning algorithm 6—Dual capacitor using the model-based tuning algorithm 7—Single capacitor with a single variable capacitor (SVC)
2	Match type, Match network 2	Same description as for PIN digit 1
3	Reserved	
4	Auxiliary capacitor for Match network 1	0—No capacitor 1—Splitter capacitor (automatically tunable) 2—Auxiliary capacitor 3—Termination capacitor (automatically tunable)
5	Auxiliary capacitor for Match network 2	Same description as for digit 4

Table 1-1. PIN description (Continued)

PIN Position	Feature	Options and Descriptions
6	Auxiliary capacitor for Match network 3	Same description as for digit 4
7	Measurement features	0—No measurement sensors 1—Standard measurement only, no pulse detection or frequency detection 2—Pulse detection 3—Frequency detection 4—Pulse detection and frequency detection
8	Input measurement sensor	0—No input sensor 1—Input sensor included for each tunable RF input
9	Output measurement sensor	0—No output sensors 1—Z'Scan II output sensor 2—Dual output sensor, full featured 3—Single output sensor 4—Dual output V/I sensor, voltage and current measurements only
10	Auxiliary measurement sensor	0—No auxiliary measurement sensor 1—One auxiliary measurement sensor 2—Two auxiliary measurement sensors
11	Serial ports	1 and 3—**Host** port only 2 and 4—**Host** and **Service** ports
12	**Ethernet** port	0—No **Ethernet** port 1—**Ethernet** port included
13	Optional interface ports in expansion slot 1	0—No interface ports in expansion slot 1 1—**PROFIBUS** port 2—**DeviceNet** port 3—DC bias monitor All other values—Customer-specific communication cards
14	Optional interface ports in expansion slot 2	Same description as for PIN digit 13
15	Reserved	
16	Reserved	

Table 1-1. PIN description (Continued)

PIN Position	Feature	Options and Descriptions
17	CPU module	2—This PIN position will always be set to 2
18	Reserved	
19	Motor encoders	0—No motor encoders installed 1—Motor encoders included
20	Cooling fans	0—No cooling fans installed All other values—Fans installed
21	Auxiliary board	0 = None 1 = DC Bias daughter board 2 = Analog I/O daughter board
22 through 30	Reserved	

IMPORTANT SAFETY INFORMATION

To ensure safe installation and operation of the Advanced Energy Navigator II 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

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.

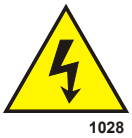
Rules for Safe Installation and Operation

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

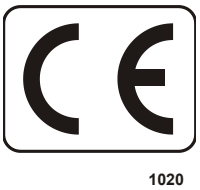
The following labels may appear on your unit:



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

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.
- 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 non ISM-band products only, use shielded cable for the power supply connector and ground the cable shield.
- Required pollution degree of the final installation varies by model. For model-specific information, see the product specification for your unit.

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. The following table lists the hardware interlocks and limiting conditions associated with the Navigator II match network that signal an incomplete installation sequence or potentially unsafe condition.

Interlock options vary by model. Not all the interlock options shown in the table are available on all models.

When an interlock relay is opened due to a software generated fault or an interlock switch is opened as the result of a user action (for example, removing a cover), the interlock string opens. Under normal installation, the interlock should be installed in series with the RF generator so that RF power will be shut off when the match opens the interlock. The match will close the interlock when the fault clears. If AE generators are used, the RF power will not come back on until the system commands the RF off then on again.

If an interlock switch opens, it will be reported as an interlock fault. If multiple interlock switches are open, each must be cleared before the interlock fault clears.

The maximum interlock response time is 50 ms.

Table 1-2. Match network interlock

Mechanism	Detection Method	Resolution
Interlock switch		
Removable panel switches	The switch opens whenever any of the removable panels on the unit are opened.	Replace the panel.
RF input cable connector switch	The switch opens when the RF input cable is not properly connected.	Ensure that the RF input cable is properly connected.
RF input cable cover switch	The switch opens when the RF input cable cover is not properly installed.	Ensure that the cables are properly connected and the RF input cable cover is properly installed.
Mounting surface switch	The switch opens if the Navigator match network is not mounted properly.	Ensure that the match is properly mounted.
Overtemperature switch Air-cooled units	The thermistor switch opens when there is a lack or loss of air flow.	When this fault occurs, the interlock string opens. After the unit cools, the fault switch will reset. Refer to troubleshooting section for information on addressing an overtemperature condition.
Overtemperature switch Water-cooled units	The thermistor sensor monitors water inlet temperature and opens the interlock when maximum specified temperature is exceeded.	When this fault occurs, the interlock string opens. The interlock will not close until the unit has cooled. Ensure that the unit's cooling specifications have been met. Refer to troubleshooting section for information on addressing an overtemperature condition.
Interlock relay		
Power supply functionality	The relay opens when the unit detects a lack or loss of power.	When this fault occurs, the interlock relay opens. Ensure that the unit is plugged in and that the input power meets specifications.

Table 1-2. Match network interlock (Continued)

Mechanism	Detection Method	Resolution
Fan speed monitor functionality	If the fan speed falls below a threshold limit, the relay opens.	When this fault occurs, the interlock relay opens. Ensure that there isn't a foreign object sticking through the unit's air vent that might be obstructing the fan. Contact AE Global Services.
Output overcurrent condition functionality	The relay opens.	When this fault occurs, the interlock relay opens. Ensure the unit does not exceed the specified maximum current. ☞ **Important** Water cooled units: The Navigator match network is rated for extremely high current and therefore cannot be internally protected against lack of water flow if the interlock is not connected to the generator.
Output overvoltage condition functionality	The relay opens.	When this fault occurs, the interlock relay opens. Check system configuration and also whether the plasma is lit. If the problem persists, contact AE Global Services.
Safe operating area (SOA) functionality	The relay opens when the power level measured is out of the safe operating area. This can occur in an overvoltage or overcurrent condition.	When this fault occurs, the interlock relay opens. Reduce power to the safe operating area shown in the unit specification. This fault resets at the next RF on.

Interlock Circuit

For models with the **User** port, the interlock connection appears on that port. The interlock connection appears on the **Host** port for models without the **User** connector.

On some models, the interlock connection may also appear on **Interlock** port.

Under normal operation, the relay or switch completes the circuit. If a fault occurs, the relay or switch opens, interrupting the flow of current. To recover from a fault, first determine the source of the fault. Then correct the fault condition (see the preceding table.)

The following graphic illustrates a typical interlock circuit. The actual circuit varies by model. The circuit may include a thermal switch, a variety of mechanical switches, and a relay that responds to various sensed conditions.

An open interlock will not shut off RF power unless the interlock circuit is properly connected to the generator.

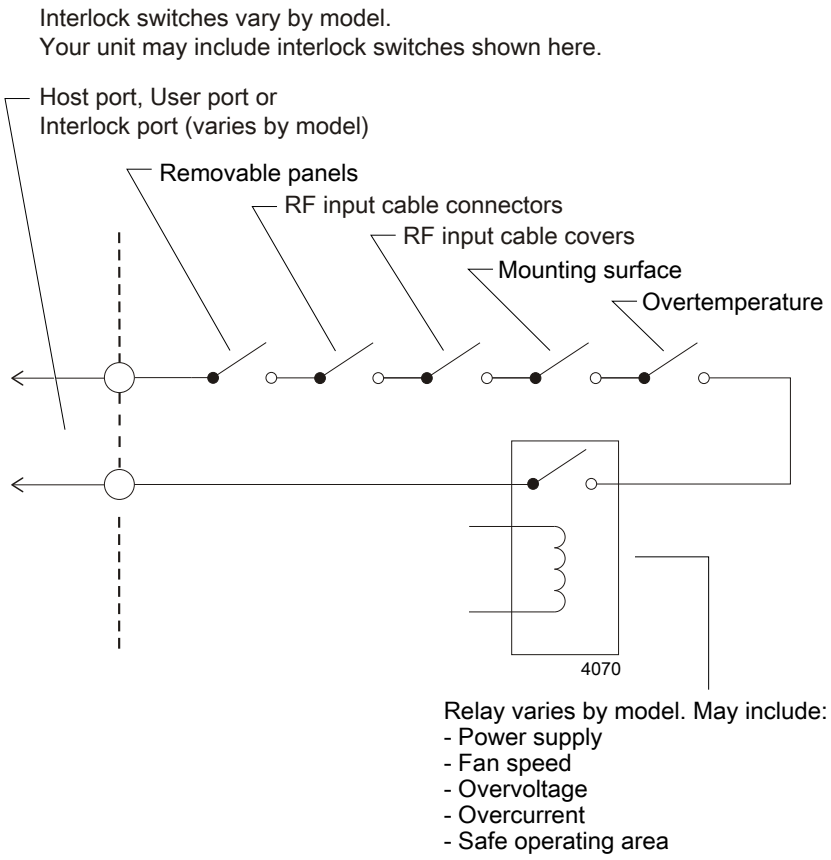


Figure 1-1. *Interlock circuit*

Product Overview

PRODUCT DESCRIPTION

The Navigator II match network represents a cornerstone in match development, providing rapid, accurate, and reliable impedance matching across a defined load range. This microprocessor-controlled match network automatically tunes, or matches, the complex impedance of a plasma to a desired impedance at the match input (default is 50-ohm resistive). Dual match units provide impedance matching for two 50-ohm generators, one at each frequency. The Navigator II 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 following control modes may be available on the Navigator II match network. For information on the control modes available with a specific unit see the product specification for that model.

- Automatic tune mode
- Host control mode

  Allows manual control of capacitor position through the following ports:

  - **Host**
  - **PROFIBUS**
  - **DeviceNet**
  - **Ethernet**
- User control mode

  Allows manual control of capacitor position through the **User** port (not available on all units).
- DeviceNet set point mode

Measurement System

The Navigator II measurement system can include optional input, output, and auxiliary measurement sensors. All measurement sensors take voltage and/or current readings. Some sensors can also take impedance, power, phase or gamma, voltage, and current readings.

Your unit can be equipped with any of the following measurement sensors:

- Z'Scan II output sensor

  This sensor is mounted at the output of the unit. The Z'Scan II sensor is capable of pulse detection and/or frequency detection at the unit fundamental frequencies. At a lower level of accuracy, this sensor is also capable of measuring up to the third harmonic of each fundamental frequency as well as three user-definable frequencies. Measurements available include frequency (if frequency detection is enabled), phase, power, resistance, reactance, RMS voltage, and RMS current.

- Dual output sensors

  These sensors are mounted at the outputs of a dual output unit. Dual output sensors are capable of pulse detection and/or frequency detection at the unit fundamental frequency. Measurements available include frequency (if frequency detection is enabled), phase, power, resistance, reactance, RMS voltage, and RMS current. Some dual output sensors measure only the frequency (if enabled), RMS voltage, and RMS current.

- Single output sensor

  This sensor is mounted at the output of the unit. Single output sensors are capable of pulse detection and/or frequency detection at the unit fundamental frequency. Measurements available include frequency (if frequency detection is enabled), phase, power, resistance, reactance, RMS voltage, and RMS current.

- Input sensor

  This sensor is mounted at the input of automatic tuning units. Input sensors are capable of pulse detection and/or frequency detection at the unit fundamental frequency. Measurements available include frequency (if frequency detection is enabled), gamma, delivered power, resistance, reactance, RMS voltage, and RMS current.

- Auxiliary sensor

  Two auxiliary ports are available to process a customer-supplied input. The auxiliary inputs can measure up to two factory-defined frequencies, and can be scaled according to the customer request. Only RF signals less than 5 V_{peak} can be accommodated at these inputs.

A Navigator II match network can include up to four sensors (the dual output sensor counts as two of the four). For example, a single frequency unit that includes one input sensor and could include any of the following combination of additional sensors:

- One Z'Scan II output sensor plus up to two auxiliary sensors
- One single output sensor plus up to two auxiliary sensors
- One dual output sensor (with primary and secondary sensors) plus zero or one auxiliary sensor
- Up to two auxiliary sensors

Depending on the unit, the input, output, and auxiliary sensors are either variable or fixed frequency:

- Variable frequency sensors let you set the specific frequency within the limits set at the factory.
- Fixed frequency sensors are calibrated at the fundamental frequency at the factory.

Frequency detection (some units) applies to all measurement sensors. If your unit includes frequency detection, you can enable/disable the feature.

Pulse detection (some units) applies to all measurement sensors on the unit. Units configured with pulse detection tolerate pulsing from the generator, and will tune to a user-defined pulsed waveform. Pulse detection is enabled at the factory.

To determine if your unit has the option, refer to the unit PIN ("Navigator II Product Identification Number (PIN)") or to the unit specifications document. Both this user manual and a specifications document are shipped on a CD with the unit.

Capacitors

The Navigator II unit can include one or more of the following capacitor options:

- Dual capacitor match network

  The tunable input is associated with two capacitors: load and tune. These capacitors can be configured to tune using either capacitor percentage positions (vacuum capacitors tunable from 0% through 100% using either customer-specified positions or an automatic tuning algorithm) or capacitor step positions (switched capacitors tunable with up to eight switch banks specified by the customer).

- Single capacitor match network

  The tunable input is associated with one capacitor. These capacitors can be configured to tune using either capacitor percentage positions (vacuum capacitors tunable from 0% through 100% using either customer-specified positions or an automatic tuning algorithm) or capacitor step positions (switched capacitors tunable with up to eight switch banks specified by the customer).

- Fixed capacitor match network.

  The capacitor tuning is set at the factory and is not customer-tunable.

- Auxiliary capacitors.

  The Navigator II product can include customer-specified auxiliary capacitors.

Each match network or auxiliary capacitor is associated with a factory-calibrated frequency. The unit specification will define which frequency is assigned to each match network or auxiliary capacitor.

Related Links

• "Navigator II Product Identification Number (PIN)" on page 1-1

THEORY OF OPERATION

Block Diagram

The following illustration is a block diagram describing the theory of operation of a typical Navigator II match network. This illustration includes blocks for optional functions not included in all models. The illustration is followed by information describing each of the unit's major operational sections.

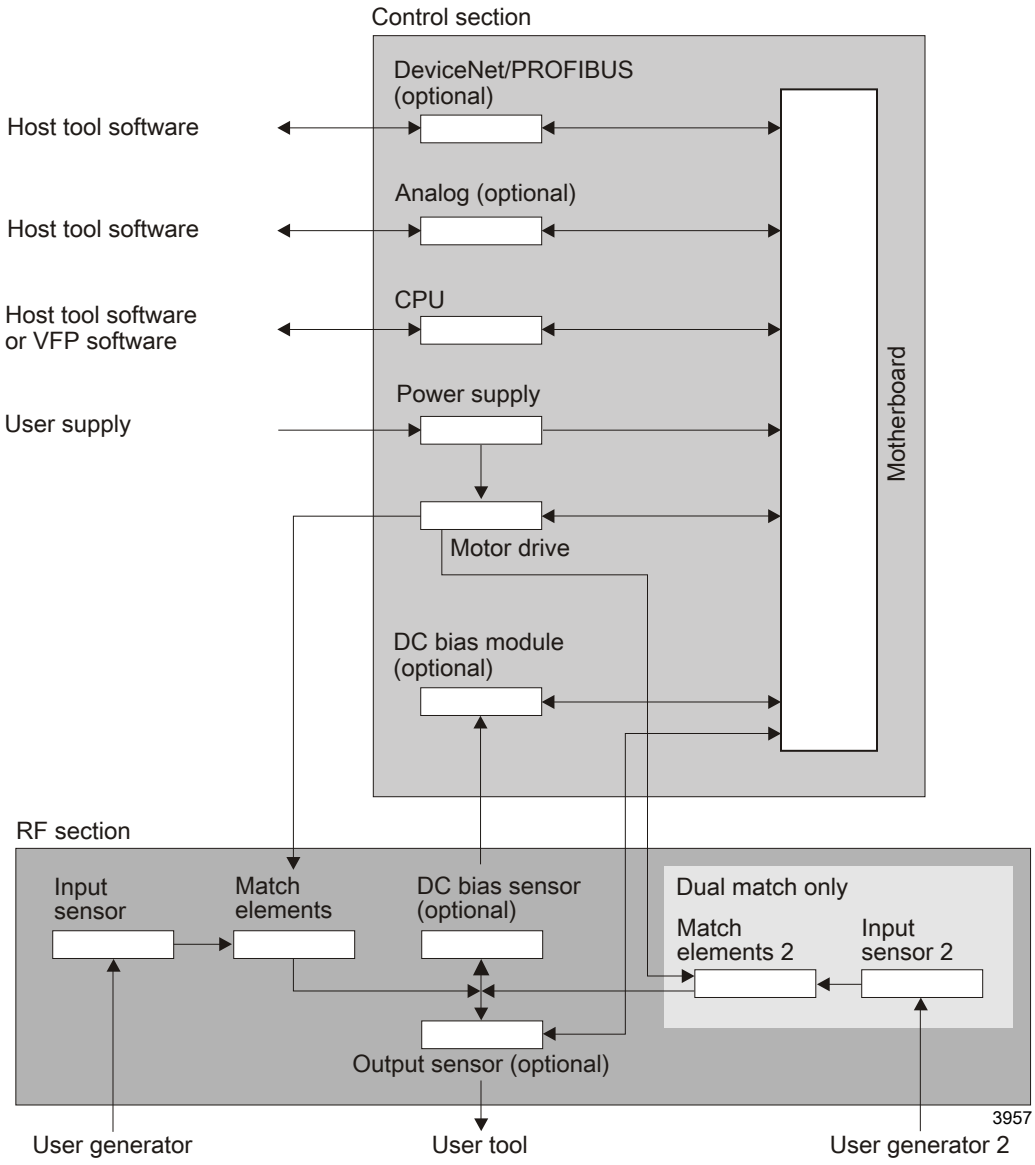


Figure 2-1. Navigator II match network block diagram

RF Section

The RF section of the Navigator II match network includes the following components:

- Input sensors
- Output sensors (on some models)
- Match (tuning) elements
- Optional output instrumentation

Table 2-1. RF section components

Component	Description
Input sensor	The input sensor samples the voltage and current, which is sent to the receiver in the electronics module. The module processes the voltage and current, and then calculates resistance, reactance, and delivered power. These calculated parameters are used to direct the tuning of the match.
Output sensor	The output sensor is mounted in-line with the Navigator II RF output. Not all units include an output sensor. Possible Navigator II output sensors: • Z'Scan II output sensor: Samples the voltage and current, which is sent to the receiver in the Z'Scan II electronics module. The electronics module processes the voltage and current, and then calculates the phase, resistance, reactance, and delivered power. • Dual output sensor: Senses the primary and secondary currents in the user tool and sends these values to the mother board. • Single output sensor: Senses the current in the user tool and sends this value to the mother board. See the measurement section for additional information.
Auxiliary sensor	Auxiliary sensors (on some models) are customer-specific.
Match (tuning) elements	The match elements consist of fixed and variable reactive elements depending on the match topology. Match topology varies from model to model.
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
Motherboard	The motherboard serves as the communication backplane for the match control system. It facilitates communication between the different control section modules and sensors.
CPU module	The CPU module contains the microprocessor that executes the control firmware for the match. This microprocessor performs the match network algorithm that calculates the electrical characteristics of the match input and determines how to control the variable tuning elements to convert the impedance to 50 Ω. The CPU module also supplies information to and receives commands from the user's system through a host interface (**Host** or **Service**).
DeviceNet / PROFIBUS module	The DeviceNet / PROFIBUS module provides an interface to supply information to and receive commands from the system controller through a DeviceNet or PROFIBUS interface. Not all units have a DeviceNet or PROFIBUS interface.
Analog or user module	The analog user module provides an interface to supply information to and receive commands from the system controller through an analog user interface. Not all units have this feature.
Motor drive module	The motor drive module contains the circuitry to control 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 CPU module and communicated to the motor drive module through a serial interface.
DC bias module	The DC bias module receives a scaled DC voltage from the DC bias sensor in the RF section and converts the voltage to a digital word with an analog to digital converter.
Power supply	The power supply converts the user-supplied +24 VDC to the required voltages for the control system components.

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

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

Communication Controls

AE BUS INTERFACE (HOST PORT AND SERVICE PORT)

The Navigator II unit provides a serial communications interface through both the **Host** and **Service** ports. This interface allows the Navigator II unit to interface with a host computer using the AE Bus protocol.

The Navigator II product includes the following AE Bus interfaces:

- **Host** port

  Most Navigator II match networks include the **Host** port. When included, this is the primary interface when using AE Bus commands.

- **Service** port

  Some Navigator II match networks include the **Service** port in addition to the **Host** port. When included, the **Service** port is used primarily for AE service personnel.

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 Port" on page 3-1
- "Service Port" on page 3-3
- "AE Bus Transmission Parameters" on page 3-4
- "AE Bus Interface DIP Switches" on page 3-4
- "AE Bus Protocol" on page 3-7
- "Creating an Ideal Communications Transaction" on page 3-9
- "AE Bus Commands" on page 3-12

Host Port

The serial **Host** port connector is a 9-pin, female, shielded, subminiature-D connector.

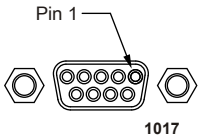


*Figure 3-1. **Host** port connector*

HOST PORT PIN DESCRIPTIONS

*Table 3-1. **Host** port pin descriptions*

Signal Pin	Name	Description
1	Reserved	Reserved for future use
2	*RS-232 TXD.D*	RS-232 transmit data to the host
3	*RS-232 RXD.D*	RS-232 receive data from the host
4	• For models that include the **Service** port: *INTERLOCK* • For all other models: Reserved	• For models that include the **Service** port: Interlock • For all other models: Reserved for future use
5	*COM.D*	Data common
6	• Models that do not include the **Service** port: *RS-485 -* • Models with both the **Host** and **Service** ports: Reserved	• Models that do not include the **Service** port: RS-485 TX/RX (-) transmit/ receive data • Models with both the **Host** and **Service** ports: Reserved for future use
7	• For models that do not include the **Service** port: *RS-485 +* • Models with both the **Host** and **Service** ports: Reserved	• For models that do not include the **Service** port: RS-485 TX/RX (+) transmit/ receive data • Models with both the **Host** and **Service** ports: Reserved for future use

*Table 3-1. **Host** port pin descriptions (Continued)*

Signal Pin	Name	Description
8	• For models that include the **Service** port: *INTERLOCK RETURN* • For all other models: Reserved	• For models that include the **Service** port: Interlock return • For all other models: Reserved for future use
9	Reserved	Reserved for future use

Service Port

The serial **Service** port connector is a 9-pin, female, shielded, subminiature-D connector.

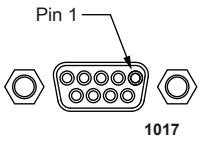


*Figure 3-2. **Service** port connector*

SERVICE PORT PIN DESCRIPTIONS

*Table 3-2. **Service** port pin descriptions*

Signal Pin	Name	Description
1	Reserved	Reserved for future use
2	*RS-232 TXD.D*	RS-232 transmit data to the host
3	*RS-232 RXD.D*	RS-232 receive data from the host
4	Reserved	Reserved for future use
5	*COM.D*	Data common
6	*RS-485 -*	RS-485 TX/RX (-) transmit/ receive data
7	*RS-485 +*	RS-485 TX/RX (+) transmit/ receive data
8	Reserved	Reserved for future use
9	Reserved	Reserved for future use

AE Bus Transmission Parameters

The communications capability of the AE Bus interface is limited to the following parameters:

- RS-232 or RS-485 transmission standard
- Baud rates:
  - 9600
  - 19,200
  - 57,600
  - 115,200
- Navigator II 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 Navigator II unit is factory set at 0.75 seconds (that is, no more than 0.75 seconds can elapse between bytes, or the unit will reset and begin searching for a new message packet). Use command **40** to change this value.

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

To set the baud rate, address, and communication mode:

- If the unit includes only a **Host** port, set the **Host** port parameters with the DIP switch adjacent to the port.
- If the unit includes both a **Host** port and a **Service** port:
  - Set the **Host** port parameters with AE Bus command **69** via the **Service** port.
  - Set the **Service** port parameters with the DIP switch adjacent to the port.

AE Bus Interface DIP Switches

DIP SWITCH AND SWITCH SETTINGS

The AE Bus DIP switch (typically labeled **Config**) is used to set transmission parameters for the AE Bus interface as follows:

- Units with only the **Host** port: The DIP switch is adjacent to the **Host** port, and sets the transmission parameters for the **Host** port.

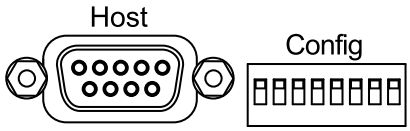


*Figure 3-3. DIP switch — units with only the **Host** port*

- Units with a **Service** port: The DIP switch is adjacent to the **Service** port, and sets the transmission parameters for the **Service** port.

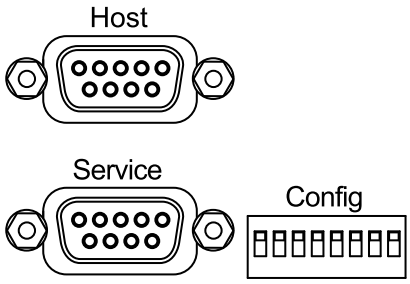


*Figure 3-4. DIP switch — units with both the **Host** and **Service** ports*

Use the DIP switch to set the unit AE Bus address, the baud rate, and the communication mode for the AE Bus interface that is adjacent to the DIP switch.

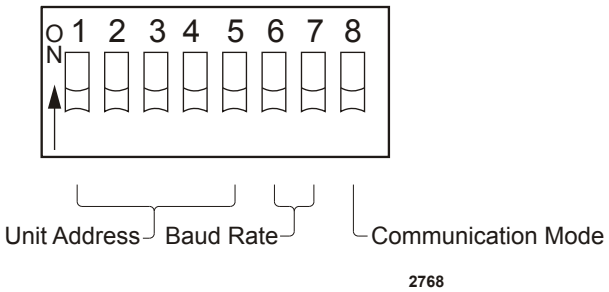


Figure 3-5. Slide DIP switch

The DIP switch contains eight individual switches. Setting a switch to the “on” position means sliding the switch toward the numbers on the DIP, and setting a switch to the “off” position means sliding it away from the numbers.

SWITCHES

The first five switches (1 to 5) specify the address of the unit, which a host computer must include in the message packet it sends.

The next two switches (6 and 7) specify the AE Bus port’s baud rate. Switch 8 sets communication mode, either RS-232 or RS-485.

SETTING THE BAUD RATE

Table 3-3. DIP switch settings for variable baud rate, switches 6 and 7

Baud	Switch 6	Switch 7
9600	on	on
19,200	on	off
57,600	off	on
115,200	off	off

SETTING THE COMMUNICATION MODE

Table 3-4. DIP switch settings for communication mode, switch 8

Switch Position	Communication Mode
On	RS-232
Off	RS-485

SETTING THE UNIT AE BUS ADDRESS

Table 3-5. AE Bus address settings

Address	Switch 1	Switch 2	Switch 3	Switch 4	Switch 5
0	Don't assign this address to a unit; it is the AE Bus broadcast address—all AE Bus units receive a message sent to this address by the host, but will not reply. If you set the address to 0, the unit automatically re-assigns the address to 1				
1	on	on	on	on	off
2	on	on	on	off	on
3	on	on	on	off	off
4	on	on	off	on	on
5	on	on	off	on	off
6	on	on	off	off	on
7	on	on	off	off	off
8	on	off	on	on	on
9	on	off	on	on	off
10	on	off	on	off	on
11	on	off	on	off	off
12	on	off	off	on	on
13	on	off	off	on	off

Table 3-5. AE Bus address settings (Continued)

Address	Switch 1	Switch 2	Switch 3	Switch 4	Switch 5
14	on	off	off	off	on
15	on	off	off	off	off
16	off	on	on	on	on
17	off	on	on	on	off
18	off	on	on	off	on
19	off	on	on	off	off
20	off	on	off	on	on
21	off	on	off	on	off
22	off	on	off	off	on
23	off	on	off	off	off
24	off	off	on	on	on
25	off	off	on	on	off
26	off	off	on	off	on
27	off	off	on	off	off
28	off	off	off	on	on
29	off	off	off	on	off
30	off	off	off	off	on
31	off	off	off	off	off

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 Navigator II 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 3-6 shows the organization of these fields in the AE Bus message packet. The subsequent paragraphs describe each field in detail.

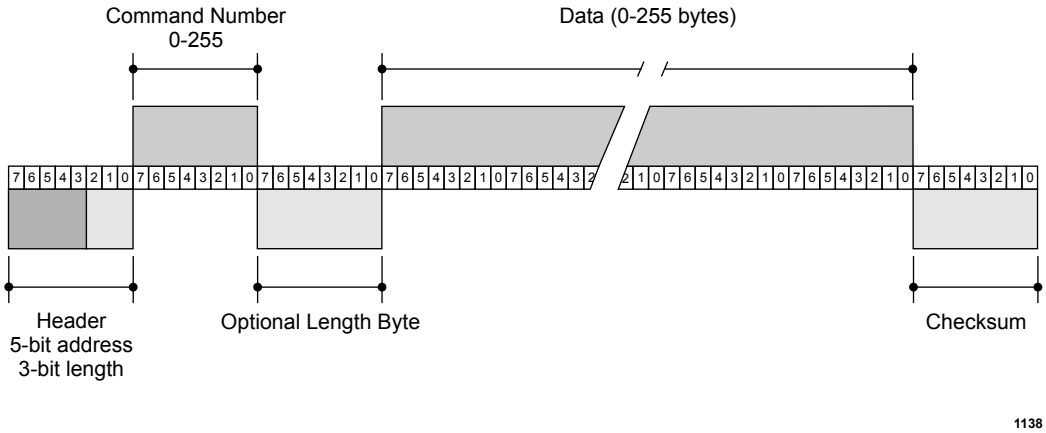


Figure 3-6. *Graphic representation of a message packet*

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 Navigator II unit, for example). If the packet is going to the host, the address specifies the packet origin (from the Navigator II 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 Navigator II 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.

Note: 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 Navigator II 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 Navigator II unit expects zero to six data bytes. However, if the value in the Header field is 7 (07h), the Navigator II 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 3-6.

Table 3-6. 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 3-7 illustrates the steps in an ideal communications transaction between a host computer and the Navigator II unit.

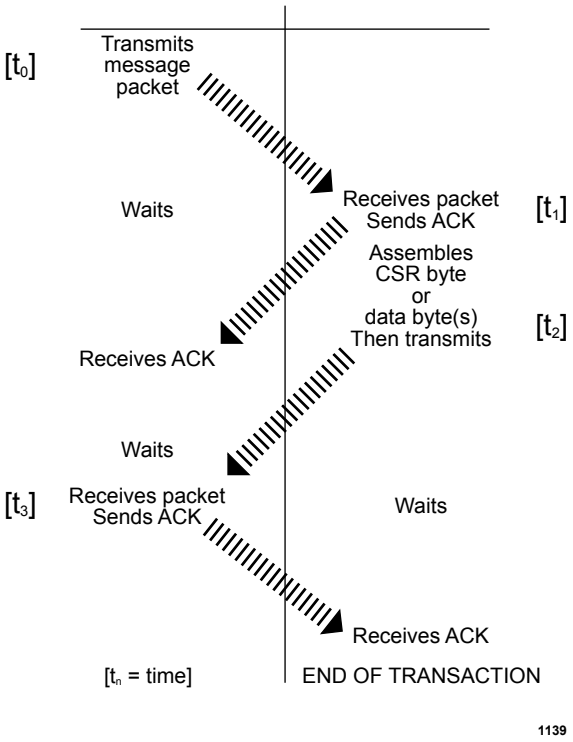


Figure 3-7. AE Bus communications transaction

T_0: HOST TRANSMITS MESSAGE PACKET

The host computer sends a message packet to the Navigator II 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

T_1: UNIT VERIFIES HOST TRANSMISSION PACKET

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

- If the address does not match, the Navigator II unit does not respond to the host computer; the Navigator II 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 Navigator II unit sends a negative acknowledgment (NAK), hexadecimal 15h, to the host computer.
- If the address matches and the message is intact, the Navigator II unit sends an acknowledgment (ACK), hexadecimal 06h, to the host computer.

If the Navigator II 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 Navigator II 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.

T_2: UNIT TRANSMITS RESPONSE TO HOST

The Navigator II 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.

T_3: HOST ACKNOWLEDGES UNIT RESPONSE

If the Navigator II unit receives an ACK from the host computer, it returns to the normal waiting state. If the Navigator II unit receives a NAK from the host computer, the unit retransmits the response packet. The Navigator II unit continues to retransmit in response to NAK transmissions until the host computer stops the cycle. If the Navigator II unit receives no response, it assumes an ACK and returns to the waiting state.

AE BUS COMMUNICATIONS TRANSACTION EXAMPLE

Figure 3-8 illustrates the steps in an example communications transaction between a host computer and the Navigator II unit.

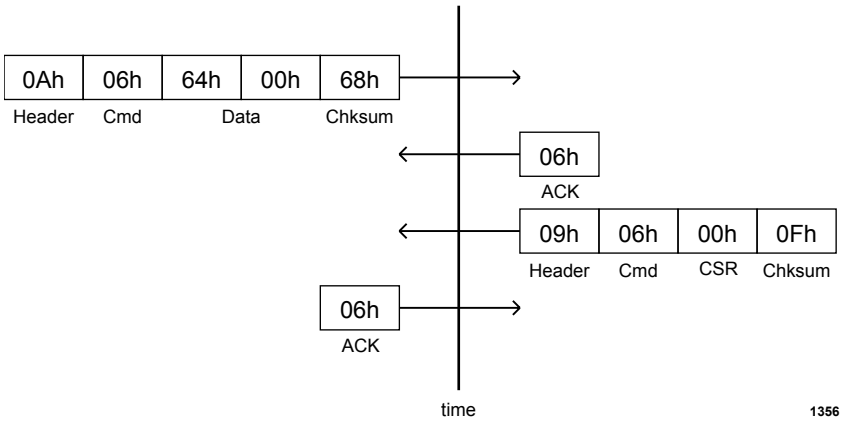


Figure 3-8. Communications transaction example

AE Bus Commands

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

NAVIGATOR MATCH NETWORK (LEGACY) COMMAND CHANGES

The Navigator II product's AE Bus command set uses many of the same commands that were used in the legacy Navigator product's AE Bus command set. Table 3-7 lists the legacy commands and summarizes the changes. Refer to "AE Bus Command Set" on page 3-16 for the full list of AE Bus commands, the updated descriptions, and the number of bytes sent/received.

Table 3-7. *Legacy command changes*

Legacy Command Number	New Command Number	Description	Differences
71	78	Setup target impedance	• New command number • Added match selection
73	None	Setup Voltage/Current interlock fault level	Legacy command not supported
76	None	Setup fan hysteresis	Legacy command not supported
82	82	Setup autotune parameters	• Added match selection • Added a second tuning algorithm
84	84	Set capacitor limits	Added match selection
88	77	Setup input sensor	• New command number • New command sets frequency instead of power off limit/averaging, and also supports different sensors
90	92	Setup presets/trajectories	• New command number • Added match selection
91	91	Select preset	Added match selection

Table 3-7. Legacy command changes (Continued)

Legacy Command Number	New Command Number	Description	Differences
93	93	Select control mode	Added match selection
94	94	Activate presets	Added match selection
95	95	Set up auxiliary capacitor parameters	Byte definitions have changed
97	97	Select internal/external presets	Added match selection
98	98	Enable/disable motor movement	Added motor and match selection
100	100	Setup preset delays	• Added match selection • Changed number of valid presets
112	112	Move shunt/load motor	Added match selection
115	119	Reset faults	New command number
117	69	Set AE bus baud rate	• New command number • Byte definitions have changed
122	122	Move series/tune motor	Added match selection
125	125	Initialize capacitors	None
127	69	Set AE bus address	• New command number • Byte definitions have changed
128	128	Report match type	Number of bytes returned has changed
130	130	Report software part number	Added a selection byte
131	162	Report process status	• New command number • Added match selection • Bit definitions have changed
132	132	Report FPGA revision	Byte definitions have changed
135	135	Report motor movement status	• Added match selection • Byte definitions have changed

Table 3-7. Legacy command changes (Continued)

Legacy Command Number	New Command Number	Description	Differences
141	148	Report target impedance	• New command number; Added match selection
143	None	Report Voltage/Current interlock fault level	Legacy command not supported
146	None	Report fan hysteresis	Legacy command not supported
152	152	Report autotuning parameters	• Added match selection • Added a second tuning algorithm
154	154	Report capacitor limits	Added match selection
158	None	Report 3x sensor setup	Legacy command not supported
160	160	Report presets/trajectories	Added match selection
161	161	Report selected preset	Added match selection
163	163	Report active control mode	Added match selection
164	164	Report preset activation status	Added match selection
165	165	Report auxiliary capacitor parameters	Byte definitions have changed
166	None	Report cap range	Legacy command not supported
167	167	Report internal/external preset select status	Added match selection
168	168	Report motor disabled status	Added match selection
169	221	Report PIN for match	• New command number • PIN definition has changed
170	170	Report preset/trajectory delays	• Added match selection • Changed number of valid presets
180	180	Report capacitor positions	Added match selection
181	None	Report encoder positions	Legacy command not supported

Table 3-7. Legacy command changes (Continued)

Legacy Command Number	New Command Number	Description	Differences
184	None	Report specified capacitor positions, FPGA vs. processor	Legacy command not supported
185	185	Report sensor calculated data	• Added match selection • Current command reports only input sensor information
186	248 sub command 10	Report RF peak and DC bias	• New command number • Current command reports only DC bias; legacy command reported RF peak and DC bias
187	None	Report high current	Legacy command not supported
198	198	Report software version	None
231	231	Report serial number	Format has changed
254	223	Report faults	• New command number • Format has changed

AE BUS COMMAND STATUS RESPONSE (CSR) CODES

When the Navigator II unit receives a command requesting a change in unit operation (command numbers 1 through 127), or when the Navigator II 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.

Not all models use all of the following CSR codes.

Table 3-8. AE 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.	
1	Control mode is incorrect.

Table 3-8. AE command status response (CSR) codes (Continued)

Code	Meaning
2	RF output is on.
4	Parameter is out of its acceptable range.
7	One or more faults are active.
9	Data byte count is incorrect
12	Feature is not available.
30	EEPROM read/write error.
35	Host control mode is inactive.
37	Selected preset is invalid.
40	Invalid control mode parameters were received.
47	Motor movement disabled.
48	Motors are already moving.
50	Motor movement failed.
53	24 V supply is low.
54	Match network selection is incorrect.
56	Internal host command failed.
57	Load motor is already moving.
58	Tune motor is already moving.
61	Processor busy with other tasks.
63	Flash mode is active.
99	Command is not implemented.

AE BUS COMMAND SET

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

- Commands **1** through **127** request a change to the Navigator II 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.

Not all models support all commands. Model-specific commands are noted in the command table.

☞ **Important**
To determine if your unit has the option, refer to the unit product specification.

Table 3-9. AE Bus commands

Command	Description	Data Bytes Sent	Data Bytes Returned
7 **Restore Factory Defaults**	Restores the unit to the original factory settings for all non-volatile RAM settings, even if you use the Virtual Front Panel software. After restoring factory values, the command resets the microprocessor. Send 2 bytes (16-bit value) = Always send 0	2	1 (CSR only)
40 **set host port time-out (NV)**	Sets the time-out value for the AE Bus interface, which is the amount of time allowed between bytes received. Set the value in units of 10 ms. The allowable range of values is 2 to 500 (20 ms to 5.00 s). The default is 75 (750 ms). Each AE Bus interface has its own unique time-out value that can only be set when this command is received through that port. Send 2 bytes (16-bit value) = The time-out value Read back with command **140**.	2	1 (CSR only)

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
69 **set serial port address and baud rate (NV)**	Sets the AE Bus address, baud rate, and RS-485 communication mode for the **Host** port on units that include both a **Host** port and a **Service** port. If your unit includes only a **Host** port, then use the DIP switches to configure the port. You can set the **Host** port parameters from the following ports: • **Service** port (if the unit includes a **Service** port) • **Ethernet** port (if unit includes an **Ethernet** port) The default values for these **Host** port parameters are: • AE Bus address = 2 • Baud rate = 19200 ☞ **Important** The Navigator II match network does not support the AE Bus broadcast mode. Therefore, if you set the AE Bus address to 0, the Navigator II match network will default to an address of 1. Send 4 bytes (four 8-bit values): • Byte 0 = Always send 1 • Byte 1 = AE Bus address; valid values are 1 through 31 • Byte 2 = Baud rate: ◦ 0 = 2400 baud ◦ 1 = 4800 baud ◦ 2 = 9600 baud ◦ 3 = 19200 baud ◦ 4 = 38400 baud ◦ 5 = 57600 baud ◦ 6 = 115200 baud • Byte 3 = Always send 0 (reserved) Read back with command **212**.	4	1 (CSR only)

Table 3-9. AE Bus commands (Continued)

<table>
<tr><th>Command</th><th>Description</th><th>Data Bytes Sent</th><th>Data Bytes Returned</th></tr>
<tr><td>70
set real-time clock</td><td>Sets the real time clock on the CPU module to the specified time and date . The data transmitted must be encoded in BCD (Binary Coded Decimal) format.
For example, to set the seconds to 48, the data value transmitted must be 0x48. The real time clock features automatic leap year compensation for years up to 2100.
Send 7 bytes (8-bit values):
• Byte 0 = Seconds (range: 0 to 59)
• Byte 1 = Minutes (range: 0 to 59)
• Byte 2 = Hours (range: 0 to 23)
• Byte 3 = Day of week (range: 1 to 7, 1= Sunday, ..., 7 = Saturday)
• Byte 4 = Date (range: 1 to 31)
• Byte 5 = Month (range: 1 to 12)
• Byte 6 = Year (range: 00 to 99)
Read back with command 215.</td><td>7</td><td>1
(CSR only)</td></tr>
<tr><td>71
set system control (subcommands) (NV)
Ethernet only</td><td>Available for units with Ethernet. This command allows you to send the secondary commands listed in the following rows.
<table>
<tr><th>Byte 0=</th><th>Subcommand</th></tr>
<tr><td>0</td><td>Set IP address</td></tr>
<tr><td>1</td><td>Set default gateway</td></tr>
<tr><td>2</td><td>Set subnet mask</td></tr>
<tr><td>5</td><td>Set DHCP client enable</td></tr>
<tr><td>200</td><td>Set domain name</td></tr>
<tr><td>202</td><td>Set DNS server IP address</td></tr>
<tr><td>203</td><td>Set DNS configuration</td></tr>
</table>
Read back with command 204.</td><td>Varies</td><td>Varies</td></tr>
</table>

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
71 **set IP address (NV)** (subcommand 0) Ethernet only	Available for units with Ethernet. Sets the unit network IP address, which is stored in nonvolatile memory and is restored each time the unit is powered on. Send 5 bytes: • Byte 0 = 0 (subcommand number) • Byte 1 through Byte 4 (32 bits, LSB first) = IP address For example, if your IP address is 192.168.0.1 you will send: ◦ Byte 1 = 1 ◦ Byte 2 = 0 ◦ Byte 3 = 168 ◦ Byte 4 = 192 See also command **71**, subcommands 1 and 2. Read back with command **204**.	5	1 (CSR only)
71 **set default gateway (NV)** (subcommand 1) Ethernet only	Available for units with Ethernet. Sets the unit network default gateway address, which is stored in nonvolatile memory and is restored each time the unit is powered on. Send 5 bytes: • Byte 0 = 1 (subcommand number) • Byte 1 through Byte 4 (32 bits, LSB first) = Default gateway address For example, to specify 192.168.0.254 you will send: ◦ Byte 1 = 254 ◦ Byte 2 = 0 ◦ Byte 3 = 168 ◦ Byte 4 = 192 See also command **71**, subcommands 9 and 2. Read back with command **204**.	5	1 (CSR only)

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
71 **set subnet mask (NV)** (subcommand 2) Ethernet only	Available for units with Ethernet. Sets the unit network subnet mask, which is stored in nonvolatile memory and is restored each time the unit is powered on. Send 5 bytes: • Byte 0 = 2 (subcommand number) • Byte 1 through Byte 4 (32 bits, LSB first) = Subnet mask For example, to specify 255.255.255.0 you will send: ◦ Byte 1 = 0 ◦ Byte 2 = 255 ◦ Byte 3 = 255 ◦ Byte 4 = 255 See also command **71**, subcommands 0 and 1. Read back with command **204**.	5	1 (CSR only)
71 **set DHCP client enable (NV)** (subcommand 5) Ethernet only	Available for units with Ethernet. Sets the unit network Dynamic Host Configuration Protocol (DHCP) client enable mode, which is stored in nonvolatile memory and is restored each time the unit is powered on. The default depends on the option and is set at the factory. • Byte 0 = 5 (subcommand number) • Byte 1 = DHCP enable/disable: ◦ 0 = Disable DHCP client mode ◦ 1 = Enable DHCP client mode	2	1 (CSR only)

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
71 **set domain name (NV)** (subcommand 200) Ethernet only	Available for units with Ethernet. Sets the unit network domain name, which is stored in nonvolatile memory and is restored each time the unit is powered on. Send up to 65 bytes: • Byte 0 = 200 (subcommand number) • Byte 1 through (length – 1) = Domain name The domain name can be up to 64 ASCII characters. Valid characters for the domain name are letters, digits, hyphens, and dots. The factory default value is NULL.	Varies	1 (CSR only)
71 **set DNS server IP address (NV)** (subcommand 202) Ethernet only	Available for units with Ethernet. Sets the DNS server IP address, which is stored in nonvolatile memory and is restored each time the unit is powered on. The DNS server IP address is sent LSB first (that is, byte 1 = the least significant octet of the DNS server IP address). This command is valid only if DHCP mode is disabled (see subcommand 5). The factory default value is equal to the value for the default gateway address (see subcommand 1). Send 5 bytes: • Byte 0 = 202 (subcommand number) • Bytes 1 through 4 = DNS server IP address	5	1 (CSR only)
71 **set DNS configuration (NV)** (subcommand 203) Ethernet only	Available for units with Ethernet. Sets the DNS configuration, which is stored in nonvolatile memory and is restored each time the unit is powered on. Send 3 bytes: • Byte 0 = 203 (subcommand number) • Bytes 1 and 2 = DNS configuration mode: ◦ 0 = Do not perform DNS server updates (factory default) ◦ 1 = Request the DHCP server to perform the updates	3	1 (CSR only)

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
77 **set sensor and measurement frequency**	Your unit may include one or more of the sensors controlled by this command. Selects the sensor nominal measurement frequency. Send 6 bytes: • Bytes 0 and 1 (16-bit value) = Sensor selection: ◦ 0 = Z'Scan II output sensor frequency (valid only if Z'Scan II is operating in the single frequency mode). Set the Z'Scan II measurement mode with command **118** sub 203. This command description also includes a description of the Z'Scan II measurement modes. ◦ 1 = Input sensor for Match network 1 ◦ 2 = Input sensor for Match network 2 ◦ 3 = Reserved ◦ 4 = Reserved ◦ 5 = Reserved ◦ 7 = Primary sensor for dual output sensor, or output sensor if your unit has a single output sensor ◦ 8 = Secondary sensor for dual output sensor • Bytes 2 through 5 (32-bit value) = Nominal measurement frequency in kHz. Range is 0 kHz to 200,000 kHz, in 1 kHz steps. Software will check for your unit calibrated frequency range. Read back with command **147**.	6	1 (CSR only)

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
78 **set impedance target**	Sets the target impedance to which the selected match network tunes. ☞ **Important** Setting a target impedance other than 50+j0 can cause stress on the RF generator that is connected to the match network. Ensure that the target impedance you select falls within the safe operational area of the RF generator that is connected to the Navigator II match network. Send 6 bytes: • Bytes 0 and 1 (16-bit value) = Match network selection: ◦ 1 = Match network 1 ◦ 2 = Match network 2 • Bytes 2 and 3 (16 bit signed integer) = The real part of the target impedance (r_target). Send a converted value (ohms * 20.48). For example, for 50 Ω send a value of 1024. The effective range is 25 Ω to 100 Ω. The converted range = 512 through 2048 (25 Ω * 20.48 through 100 Ω * 20.48). • Bytes 4 and 5 (16 bit signed integer) = The imaginary part of the target impedance (x_target). Send a converted value (ohms * 20.48). For example, for 50 Ω send a value of 1024. The effective range is -50 Ω to 50 Ω. The converted range = -1024 through 1024 (-50 Ω * 20.48 through +50 Ω * 20.48). Read back with command **148**.	6	1 (CSR only)
82 **autotune setup (NV)** Phase/Magnitude algorithm. If your unit uses the MBA	Sets up automatic tuning parameters for the selected match network using the phase/mag tuning algorithm. This command supports both phase/magnitude and model-based versions. The algorithm used for your unit is set at the factory.	29	1 (CSR only)

Table 3-9. AE Bus commands

Command	Description	Data Bytes Sent	Data Bytes Returned
algorithm, see the next row.	☞ **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 29 bytes, least significant byte first: • Bytes 0 and 1 (16-bit value) = Match network selection: ◦ 1 = Match network 1 ◦ 2 = Match network 2 • Bytes 2 and 3 (16-bit value) = Converted VSWR tuning stop value. Range = 1 to 32. • Bytes 4 and 5 (16-bit value) = Converted VSWR tuning start value. Range = 1 to 32. ☞ **Important** VSWR values must be converted before being sent. First, convert the VSWR value to a gamma value: gamma = (VSWR–1)/(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 6 through 9 = Reserved (default = 0) • Bytes 10 and 11 (16 bit value) = Maximum load percent capacitor position (in hundredths of a %) The automatic tuning algorithm uses this parameter (as well as those for bytes 14 through 17) to assist in capacitor movement control. • Bytes 12 and 13 = Reserved • Bytes 14 and 15 (16 bit value) = Maximum tune percent capacitor position (in hundredths of a %)		

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	• Bytes 16 and 17 (16 bit value) = Minimum tune percent capacitor position (in hundredths of a %) • Bytes 18 and 19 = Magnitude→load cross dependence coefficient (converted value, –1024 to 1024) ☞ **Important** 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. • Bytes 20 and 21 = Phase→load cross dependence coefficient (converted value, –1024 to 1024) • Bytes 22 and 23 = Magnitude→tune cross dependence coefficient (converted value, –1024 to 1024) • Bytes 24 and 25 = Phase→tune cross dependence coefficient (converted value, –1024 to 1024) • Byte 26 = Algorithm number (Send a value of 0 = VSWR tuning start/stop) • Byte 27 (8-bit value) = Hold load mode ◦ 0 = Turn off hold load mode ◦ 1 = Turn on hold load mode • Byte 28 (8-bit value) = Always send 0 to indicate no integration Read back with command **152**.		

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
82 **autotune setup** MBA algorithm. If your unit uses the phase/ magnitude algorithm, see the previous row.	Sets up automatic tuning parameters for the selected match network using the Model-Based Adaptive (MBA) algorithm. This command supports both phase/magnitude and model-based versions. The algorithm used for your unit is set at the factory. ☞ **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 20 bytes, least significant byte first: • Bytes 0 and 1 (16-bit value) = Match network selection: ◦ 1 = Match network 1 ◦ 2 = Match network 2 • Bytes 2 and 3 = Reserved • Bytes 4 through 7 (32-bit floating-point value) = VSWR tuning stop value. Range = >1 to <10.0. • Bytes 8 through 11 (32-bit floating-point value) = VSWR tuning start value. Range = >1 to <10.0. • Bytes 12 and 13 (16 bit value) = Maximum load capacitor step size (in hundredths of a %) The automatic tuning algorithm uses this parameter (as well as those for bytes 14 through 19) to assist in capacitor movement control. • Bytes 14 and 15 (16 bit value) = Maximum tune capacitor step size (in hundredths of a %) • Bytes 16 and 17 (16 bit value) = Target load capacitor position (in hundredths of a %) If a high VSWR is detected (> 5), the target load and target tune values are used. If these values are set to 0, target load and tune positions are never used. • Bytes 18 and 19 (16 bit value) = Target tune capacitor position (in hundredths of a %) Read back with command **152**.	20	1 (CSR only)

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
84 **capacitor limits (NV)**	Sets the minimum and maximum positions for the tune and load capacitors for the selected match network. The capacitor limits are used by the tuning algorithm. 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%). Send 10 bytes (four 16-bit values), least significant byte first: • Bytes 0 and 1 (16-bit value) = Match network selection: ◦ 1 = Match network 1 ◦ 2 = Match network 2 • Bytes 2 and 3 = Minimum load position (hundredths of a %) • Bytes 4 and 5 = Minimum tune position (hundredths of a %) • Bytes 6 and 7 = Maximum load position (hundredths of a %) • Bytes 8 and 9 = Maximum tune position (hundredths of a %) Read back with command **154**.	10	1 (CSR only)
91 **set active preset (NV)**	Sets the active preset for the selected match network. Send 4 bytes: • Bytes 0 and 1 (16-bit value) = Match network selection: ◦ 1 = Match network 1 ◦ 2 = Match network 2 • Bytes 2 and 3 (16-bit value) = Desired preset (1 through 10). For related settings, see commands **92**, **94**, **97**, and **100**. Read back with command **161**.	4	1 (CSR only)

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
92 **set up presets and trajectories (NV)**	Sets an initial preset position and, if desired, corresponding trajectory points for the selected match network. The number of data bytes depends on the number of trajectory positions. To set the initial position only, send 8 bytes. Send 4 additional bytes for each trajectory position (up to three). 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%). Send required bytes: • Bytes 0 and 1 (16-bit value) = Match network selection: ◦ 1 = Match network 1 ◦ 2 = Match network 2 • Byte 2 (8-bit value) = The preset to set (1 through 10) • Byte 3 (8-bit value) = Number of trajectories pairs in the packet (0, 1, 2, or 3) • Bytes 4 and 5 (16-bit value) = Initial position for the load capacitor • Bytes 6 and 7 (16-bit value) = Initial position for the tune capacitor • Bytes 8 and 9 (16-bit value) = First trajectory position on load capacitor • Bytes 10 and 11 (16-bit value) = First trajectory position on tune capacitor • Bytes 12 and 13 (16-bit value) = Second trajectory position on load capacitor • Bytes 14 and 15 (16-bit value) = Second trajectory position on tune capacitor • Bytes 16 and 17 (16-bit value) = Third trajectory position on load capacitor • Bytes 18 and 19 (16-bit value) = Third trajectory position on tune capacitor	8, 12, 16, or 20	1 (CSR only)

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	For related settings, see commands **91**, **94**, **97**, and **100**. Read back with command **160**.		
93 **set control mode (NV)**	Sets the control mode for the selected match network. Available control modes depends on your unit. Send 4 bytes: • Bytes 0 and 1 (16-bit value) = Match network selection: ◦ 1 = Match network 1 ◦ 2 = Match network 2 • Bytes 2 and 3 (16-bit value) = Control mode: ◦ 0 = User control mode A manual tuning mode that is controlled with the **User** port. ◦ 1 = Automatic tune mode ◦ 2 = Host control mode A manual tuning mode that is controlled through one of the following ports: ▪ **Host** ▪ **DeviceNet** ▪ **Ethernet** Read back with command **163**.	4	1 (CSR only)

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
94 **enable/disable presets (NV)**	Enables/disables the active preset for the selected match network. If you enable presets and the unit is in automatic tune 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 4 bytes: • Bytes 0 and 1 (16-bit value) = Match network selection: ◦ 1 = Match network 1 ◦ 2 = Match network 2 • Bytes 2 and 3 (16-bit value) = Enable or disable presets: ◦ 0 = Disable ◦ 1 = Enable For related settings, see commands, **91**, **97**, and **100**. Read back with command **164**.	4	1 (CSR only)
95 **set up auxiliary cap parameter**	This command is valid for units with an auxiliary capacitor. The parameters that are valid for you unit depend on the unit's auxiliary capacitor. ☞ **Important** If you send parameter 10 there will be an additional length byte (length=13). If you send any other parameter there will not be an additional length byte. The number of bytes to send varies depending on the parameter selected in byte 0: • Byte 0 = Auxiliary capacitor parameter selection: ◦ 0 = Move auxiliary capacitor position by % of total capacitor range. To select this, send 2 additional bytes:	varies	1 (CSR only)

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	▪ Bytes 1 and 2 (16-bit value) = Auxiliary capacitor position in hundredths of percent of the total range of potential capacitor movement. The valid range is 0 to 10000 (0% to 100%). ◦ 1 = Restricted ◦ 2 = Set auxiliary capacitor minimum and maximum positional data. If this is selected, then send 4 additional bytes: ▪ Bytes 1 and 2 (16-bit value) = Minimum auxiliary capacitor position in hundredths of percent of the total range of potential capacitor movement. The valid range is 0 to 10000 (0% to 100%). ▪ Bytes 3 and 4 (16-bit value) = Maximum auxiliary capacitor position in hundredths of percent of the total range of potential capacitor movement. The valid range is 0 to 10000 (0% to 100%). ◦ 3 = Set the target control parameter. If this is selected, then send 2 additional bytes: ▪ Bytes 1 and 2 (16-bit value) = One of the following, depending on the function of the auxiliary capacitor: Target current ratio (I^1/I^2) in thousandths. See your unit specification for the maximum target ratio. Target current in hundredths of amps. ◦ 4 = Restricted ◦ 5 = Set the auxiliary capacitor initial preset data. Default is no initial preset. If this is selected, then send 3 additional bytes: ▪ Byte 1 (8-bit value) = Preset selection (valid values are 1 through 4) ▪ Bytes 2 and 3 (16-bit value) = Initial auxiliary capacitor position in hundredths of percent of the total range of potential		

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	capacitor movement. The valid range is 0 to 10000 (0% to 100%). ◦ 6 = Restricted ◦ 7 = Set up auxiliary capacitor active preset selection. If this is selected, then send 1 additional byte: ▪ Byte 1 (8-bit value) = Active preset selection (valid values = 1 through 4) ◦ 8 = Enable/disable automatic tune mode for the auxiliary capacitor. If this is selected, then send 1 additional byte: ▪ Byte 1 (8-bit value) = 0 = Disable automatic tuning 1 = Enable automatic tuning ◦ 9 = Enable/disable auxiliary capacitor presets. If this is selected, then send 1 additional byte: ▪ Byte 1 (8-bit value) = 0 = Disable presets 1 = Enable presets active ◦ 10 = Set the auxiliary capacitor automatic tuning parameters. If this is selected, then send 12 additional bytes: ▪ Bytes 1 and 2 (16-bit value) = Motor movement period (unsigned integer value in ms) ▪ Bytes 3 and 4 (16-bit value) = Automatic tuning ratio error, or gain (integer value) ▪ Bytes 5 and 6 (16-bit value) = Maximum step in hundredths of percent of the total range of potential capacitor movement. The valid range is 0 to 10000 (0% to 100%). ▪ Bytes 7 and 8 (16-bit value) = Error. The value depends on the function of your auxiliary capacitor:		

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	Current ratio error in thousandths of a percent Deviance between the current reading and the set point in hundredths of an amp ▪ Bytes 9 through 12 = Reserved ◦ 13 = Set the over voltage trip level (valid for units with a splitter auxiliary capacitor). If this is selected, then send 2 additional bytes: ▪ Bytes 1 and 2 (16-bit value) = Over voltage limit (integer value in volts, valid values = 0 through 10,000) ◦ 15 = Move auxiliary capacitor position by % of impedance range, based on total impedance range of the match. If this is selected, then send 2 additional bytes: ▪ Bytes 1 and 2 (16-bit value) = Percentage of impedance range in hundredths of a % of the total impedance range ◦ 16 = Reserved ◦ 17 = Set the resonant point (valid for units with a current control termination capacitor). If this is selected, then send 2 data additional bytes: ▪ Bytes 1 and 2 (16-bit value) = Capacitor position in hundredths of a % ◦ 18 = Select the interface that you will use to control the auxiliary capacitor. If this is selected, then send 1 additional data byte: ▪ Byte 1 = Control interface selection: 0 = User control interface (some units) 2 = Host control interface Read back with command **165**.		

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
97 **select internal/ external presets (NV)**	This command is valid for units with the **User** port. Sets either internal or external presets for the selected match network. Send 4 bytes: • Bytes 0 and 1 (16-bit value) = Match network selection: ◦ 1 = Match network 1 ◦ 2 = Match network 2 • Bytes 2 and 3 (16-bit value) = Preset type: ◦ 0 = Internal (default) ◦ 1 = External (available only on units with a **User** port) For related settings, see commands **92**, **91**, **94**, and **100**. Read back with command **167**.	4	1 (CSR only)

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
98 **disable/enable motor movement**	Disables or enables motor movement for the selected stepper motor. Send 4 bytes: • Byte 0 and 1 (16-bit value) = Motor select (valid range 0 through 5): ◦ 0 = All motors in the unit ◦ 1 = Motor for Match network 1 tune capacitor ◦ 2 = Motor for Match network 2 tune capacitor If the unit is a single match unit and contains an auxiliary capacitor, this selects the motor for the auxiliary capacitor. ◦ 3 = Motor for Match network 1 load capacitor ◦ 4 = Motor for Match network 2 load capacitor ◦ 5 = If the unit is a dual match unit and contains an auxiliary capacitor, this selects the motor for the auxiliary capacitor • Byte 2 and 3 (16-bit value) = Enable/disable motor movement: ◦ 0 = Enable ◦ 1 = Disable Read back with command **168**.	4	1 (CSR only)

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
100 **set preset/ trajectory delays (NV)**	Sets the initial and trajectory delays for the specified preset in the selected match network. ☞ **Important** The second trajectory delay may not exist without the first trajectory delay. The third trajectory delay may not exist without the first and second trajectory delays. Send 8, 10, 12, or 14 bytes, depending on the number of trajectory delays: • Bytes 0 and 1 (16-bit value) = Match network selection: ◦ 1 = Match network 1 ◦ 2 = Match network 2 • Byte 2 (8-bit value) = The preset number (1 through 10) • Byte 3 (8-bit value) = Number of trajectory delays included in the packet: ◦ 0 = Initial preset delay only ◦ 1 = First trajectory delay ◦ 2 = First and second trajectory delays ◦ 3 = First, second, and third trajectory delays • Bytes 4 and 5 = Reserved • Byte 6 and 7 (16-bit value) = Initial preset delay All delays are set in hundredths of seconds. 0 disables the delay. Range = 1 to 250 (10 ms to 2.5 s). Values apply to load and tune capacitors. • Byte 8 and 9 (16-bit value) = First trajectory delay • Bytes 10 and 11 (16-bit value) = Second trajectory delay • Bytes 12 and 13 (16-bit value) = Third trajectory delay For related settings, see commands **90**, **91**, **94**, and **97**. Read back with command **170**.	8, 10, 12, or 14	1 (CSR only)

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
108 **set digital switched capacitor position**	Available for units with digital switched capacitors. This command is valid if the unit is in host or user control mode. Set the switch positions for the specified switch bank. The valid range varies by option. The unit can have 1 or 2 switch banks. Each switch bank has up to eight switches. Sending a value of all ones will move the capacitor to the maximum position. The base-10 value sent will be converted to a binary value that indicates on/off for the selected switch bank. For example, in an eight-switch bank: • A value of 255 sets all eight switches and will move the capacitor to the maximum position • A value of 5 (000101) will turn on switches 1 and 3 Send 6 bytes: • Bytes 0 and 1 (16-bit value) = Match network selection: ◦ 1 = Match network 1 ◦ 2 = Match network 2 • Bytes 2 and 3 (16-bit value) = Switch bank (1 or 2), to select the capacitor: ◦ If the unit is a single capacitor unit, send a value of 1. ◦ If the unit is a dual capacitor unit, this parameter is used to select the load or the tune capacitor. See the product specification to determine how the switch bank is assigned. • Bytes 4 and 5 (16-bit value) = Switch positions (base 10 value range varies by unit) Read back with command **208**.	6	1 (CSR only)

Table 3-9. AE Bus commands (Continued)

<table>
<tr><th>Command</th><th>Description</th><th>Data Bytes Sent</th><th>Data Bytes Returned</th></tr>
<tr><td>112
move load capacitor position</td><td>Moves the load capacitor to the specified position for the selected match network.
Send 4 bytes:
Bytes 0 and 1 (16-bit value) = Match network selection:
1 = Match network 1
2 = Match network 2
Bytes 2 and 3 (16-bit value) = Load capacitor position 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.</td><td>4</td><td>1
(CSR only)</td></tr>
<tr><td>118
set measurement (subcommands)</td><td>Your unit may not have all the features in this list. If you issue a command for a feature that your unit does not have, the unit returns CSR 12, Feature is not available on this unit.
This command allows you to set measurement parameters. For each command, the value sent in the first data byte identifies the subcommand that is being sent.
<table>
<tr><th>Bytes 0 and 1</th><th>Subcommand</th></tr>
<tr><td>28</td><td>Set custom measurement equation coefficients</td></tr>
<tr><td>46</td><td>Open/close output relay</td></tr>
<tr><td>203</td><td>Set Z'Scan II output sensor measurement mode</td></tr>
<tr><td>204</td><td>Enable/disable measurement system frequency detection</td></tr>
<tr><td>205</td><td>Set the Z'Scan II output sensor spectrum frequency</td></tr>
<tr><td>208</td><td>Set pulsing parameters</td></tr>
<tr><td>209</td><td>Set pulse detection parameters</td></tr>
</table>
Read back with command 248.</td><td>Varies</td><td>1
(CSR only)</td></tr>
</table>

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
118 **Set custom measurement equation coefficients** (subcommand 28)	Use this command if your unit supports custom measurements. Sets the coefficients that are used to calculate custom measurements (for example, DC bias output signal). These values can be used in customer-specified equations. All of the coefficient values are 4-byte floating point values. Send 22 bytes: • Bytes 0 and 1 (16-bit value) = 28 (subcommand number) • Bytes 2 through 5 = Coefficient A • Bytes 6 through 9 = Coefficient B • Bytes 10 through 13 = Coefficient C • Bytes 14 through 17 = Coefficient D • Bytes 18 through 21 = Coefficient E Read back with command **248**, subcommand 28.	22	1 (CSR only)
118 **Open/close output relay** (subcommand 46)	This command opens and closes a switch on the user card. Available on units with the **User** port that supports a controllable relay switch. See the unit specification for details. Send 4 bytes: • Bytes 0 and 1 (16-bit value) = 46 (subcommand number) • Bytes 2 and 3 (16-bit value) = Open/close output relay: ◦ 0 = Close the output relay ◦ 1 = Open the output relay Read back with command **248**, subcommand 46.	4	1 (CSR only)
118 **set Z'Scan II measurement mode** (subcommand 203)	For units equipped with the Z'Scan II output sensor. Sets the measurement mode for the Z'Scan II output sensor. Send 4 bytes:	4	1 (CSR only)

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	• Bytes 0 and 1 (16-bit value) = 203 (subcommand number) • Bytes 2 and 3 (16-bit value) = Set the Z'Scan II output sensor measurement mode (ignored if unit does not have a Z'Scan II output sensor): ◦ 0 = Leave the Z'Scan II output sensor at its current mode (that is, do not change the Z'Scan II output sensor mode). ◦ 1 = Single frequency—Take measurements at one fundamental frequency. ◦ 2 = Full spectrum—Cycle through all non-zero spectrum frequencies to set the frequency and take measurements. This mode runs all the impedance calculations. ◦ 6 = Fundamental frequency—Take measurements at each of the non-zero fundamental frequencies. Read back with command **248**, subcommand 203.		
118 **enable/disable measurement system frequency detection** (subcommand 204)	This command is valid for units with frequency detection capability. Enables/disables the measurement system frequency detection, and applies to all measurement sensors in the unit. When frequency detection is enabled, the unit searches for the measurement frequency within a window determined by the frequency specification, then locks on to and measures the frequency. Send 4 bytes: • Bytes 0 and 1 (16-bit value) = 204 (subcommand number) • Bytes 2 and 3 (16-bit value) = ◦ 0 = Disable frequency detection ◦ 1 = Enable frequency detection Read back with command **248**, subcommand 204.	4	1 (CSR only)
118 **set Z'Scan II measurement frequencies**	For units equipped with the Z'Scan II output sensor. Use this command to set frequencies when in Z'Scan II fundamental or full spectrum mode. Use command **77** to set the frequency for single measurement mode.	12	1 (CSR only)

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
(subcommand 205)	Set the Z'Scan II measurement mode with command **118**, subcommand 203. If your unit includes frequency detection, the Z'Scan II measurement system will use these frequencies to more quickly find the actual, measured frequency. • When used in fundamental mode: Set up to three fundamental frequencies using indexes 0, 3, and 6. Send 0 for all unused indexes. • When used in full spectrum mode: Set up to three fundamental frequencies and associated harmonic frequencies at which you want Z'Scan II output sensor to take measurements. You can also set up to 3 customer-defined frequencies to measure in addition to the fundamental frequencies. When the frequency index 0 is set, then values for indexes 1 and 2 are also valid, all others are ignored. When index 3 is set, then values for indexes 4 and 5 are also valid. When index 6 is set, then values for indexes 7 and 8 are also valid. When index 0, 3, and 6 are set, then all index values are valid. Send 12 bytes: • Bytes 0 and 1 (16-bit value) = 205 (subcommand number) • Bytes 2 and 3 (16-bit value) = Frequency index. The following values select the associated frequency: ◦ 0 = Fundamental frequency 1 ◦ 1 = Fundamental frequency 1, harmonic 2 ◦ 2 = Fundamental frequency 1, harmonic 3 ◦ 3 = Fundamental frequency 2 ◦ 4 = Fundamental frequency 2, harmonic 2 ◦ 5 = Fundamental frequency 2, harmonic 3 ◦ 6 = Fundamental frequency 3 ◦ 7 = Fundamental frequency 3, harmonic 2 ◦ 8 = Fundamental frequency 3, harmonic 3		

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	◦ 9 = Frequency (customer-defined) ◦ 10 = Frequency (customer-defined) ◦ 11 = Frequency (customer-defined) • Bytes 4 and 5 (16-bit value) = Always send 0 • Bytes 6 and 7 (16-bit value) = Always send 0 • Bytes 8 through 11 (32-bit value) = The nominal measurement frequency in kHz. The range of valid values is 0 to 200,000. Software will check for the unit calibrated frequency range. If you send a value of 0, the Z'Scan II output sensor will not take measurements for the specified index. Read back with command **248**, subcommand 205.		
118 **set pulsing parameters** (subcommand 208)	Available on units with pulse detection. Use this command to specify to the minimum pulsing duty cycle and minimum pulse frequency expected on the generator. The information provided should account for all generators connected to the match. The proper settings will maximize the performance of the measurement system. Send 8 bytes (four 16-bit values): • Bytes 0 and 1 = 208 (subcommand number) • Bytes 2 and 3 = A value of zero • Bytes 4 and 5 = The minimum pulsing duty cycle (in %) for the generator(s) connected to the unit (valid range = 1 through 100 percent) • Bytes 6 and 7 = The minimum pulse frequency (in Hz) for the generator(s) connected to the unit (minimum value = 10 Hz)	8	1 (CSR only)

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
118 **set pulse detection parameters** (subcommand 209)	Available on units with pulse detection. Sets the information needed to detect a valid pulse. Send 8 bytes (four 16-bit values): • Bytes 0 and 1 = 209 (subcommand number) • Bytes 2 and 3 = Fundamental frequency (valid range = 1, 2) The match/frequency for which you are setting the pulse detection parameters. On a single match unit, always send 1. On a dual match unit, you can set pulse detection parameters for either fundamental frequency 1 or 2. • Bytes 4 and 5 = Power averaging threshold for the voltage (V) channel (valid range = 0 through 65535) A unit-specific default is set at the factory. • Bytes 6 and 7 = Power averaging threshold for the current (I) channel (valid range = 0 through 65535) A unit-specific default is set at the factory. • Bytes 8 and 9 = Early pulse blanking (prior discard). Sets the time period to discard the signal after it reaches the V and I thresholds. Valid range = 0 µs through 65535 µs. • Bytes 10 and 11 = Late pulse blanking (future discard). Sets the time period to discard before the signal falls below the V and I thresholds. Valid range = 0 µs through 65535 µs. Set the time period to stop sampling the signal. All data from this time through RF off will be discarded. Read back with command **248**, subcommand 209.	12	1 (CSR only)
119 **Clear latched faults**	Clears the latched faults.	0	1 (CSR only)

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
122 **move tune capacitor position**	Moves the tune capacitor to the specified position for the selected match network. Send 4 bytes: • Bytes 0 and 1 (16-bit value) = Match network selection: ◦ 1 = Match network 1 ◦ 2 = Match network 2 • Bytes 2 and 3 (16-bit value) = Tune capacitor position 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**.	4	1 (CSR only)
124 **set capacitor motors to new positions**	Moves the selected load/tune capacitor motors to the specified position. Send 6 bytes: • Bytes 0 and 1 (16-bit value) = Motor pair selection: ◦ 1 = Load/tune motor pair for Match network 1 ◦ 2 = Load/tune motor pair for Match network 2 • Bytes 2 and 3 (16-bit value) = Load capacitor position in hundredths of percent of the total range of potential capacitor movement. The valid range is 0 to 10000 (0% to 100%). • Bytes 4 and 5 (16-bit value) = Tune capacitor position in hundredths of percent of the total range of potential capacitor movement. The valid range is 0 to 10000 (0% to 100%). This command performs the same function as commands **112** and **122**.	6	1 (CSR only)
125 **initialize capacitors**	Moves all capacitors to their minimum positions.	0	1 (CSR only)

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
128 **report match type**	Reports the match network type. Returns 6 bytes (ASCII format) representing the following: • NAV II	0	6
130 **report software number**	Reports the software part number. Send 1 byte (optional). If sent with zero transmit data bytes, the main processor application firmware part number is reported: • 0 = Requests main processor application firmware part number (default) • 3 = Requests bootloader firmware part number • 4 = Requests PROFIBUS or DeviceNet application firmware part number • 5 = Requests PROFIBUS or DeviceNet bootloader firmware part number • 6 = PROFIBUS or DeviceNet FPGA firmware part number • 10 = Requests motor control board application part number • 11 = Requests motor control board FPGA part number • 12 = Requests motor control board bootloader firmware part number Returns 7 bytes (ASCII format) representing a seven-digit software part number (for example, 7431005). See also command **198**.	1	7
132 **report FPGA firmware revision**	Returns the FPGA code revision as a three-element ASCII string, one letter and two numeric digits: • Byte 0 = ASCII revision level letter • Bytes 1 and 2 = ASCII revision level numerals	0	3

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
135 **report motor movement status**	Reports status of stepper motor movement. Send 2 bytes = Always send 0 Returns 2 bytes = Motor movement status: • Byte 0 (8-bit): ◦ 0 = Match network 1: Tune motor is moving ◦ 1 = Match network 1: Load motor is moving ◦ 2 = Match network 2: Tune motor is moving. On units with an auxiliary capacitor, the auxiliary capacitor motor is moving. ◦ 3 = Match network 2: Load motor is moving ◦ 4 through 7 = Reserved • Byte 1 (8-bit) = Reserved	2	2
140 **report host port time-out value (NV)**	Reports the time-out value on the AE Bus interface. This value represents the maximum time allowed between bytes received in units of 10 ms. The allowable range of values is from 2 to 500, representing 20 ms to 5.00 s. Each AE Bus interface has its own unique time-out value that can be reported only when this command is received through that port. Returns 2 bytes (16-bit value) = Time-out value Set with command **40**.	0	2

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
147 **report measurement frequency**	Your unit may include one or more of the sensors reported by this command. Reports the measurement frequency given in 1 kHz steps, from 0 kHz to 200,000 kHz. Send 2 bytes: • Bytes 0 and 1 (16-bit value) = Sensor selection: ◦ 0 = Z'Scan II output sensor frequency (operating in the single frequency mode) ◦ 1 = Input sensor for Match network 1 ◦ 2 = Input sensor for Match network 2 ◦ 4 = Reserved ◦ 5 = Reserved ◦ 7 = Primary sensor for dual output sensor, or output sensor if your unit has a single output sensor ◦ 8 = Secondary sensor for dual output sensor Returns 4 bytes (32-bit value) = Nominal measurement frequency in kHz Set with command **77**.	2	4

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
148 **report target impedance**	Reports the real and imaginary components of the target impedance for the selected match network. Send 2 bytes to select the match network: • Bytes 0 and 1 (16-bit value) = Match network selection: ◦ 1 = Match network 1 ◦ 2 = Match network 2 Returns 6 bytes (three 16-bit values), least significant byte first: • Bytes 0 and 1 = Match network selection: ◦ 1 = Match network 1 ◦ 2 = Match network 2 • Bytes 2 and 3 = Reports the real part of the target impedance (r_target). Reports a converted value (ohms * 20.48). For example, for 50 Ω the command returns a value of 1024. The effective range is 25 Ω to 100 Ω. • Bytes 4 and 5 = Reports the imaginary part of the target impedance (x_target). Reports a converted value (ohms * 20.48). For example, for 50 Ω the command returns a value of 1024. The effective range is -50 Ω to 50 Ω. Set with command **78**.	2	6
152 **report autotune setup (NV)** Phase/magnitude algorithm. See next row if your unit supports the MBA algorithm.	Reports the automatic tuning parameters for the selected match network when using the phase/mag tuning algorithm. Send 2 bytes to select the match network and the type of values to report: • Byte 0 (8-bit value) = Match network selection: ◦ 1 = Match network 1 ◦ 2 = Match network 2 • Byte 1 (8-bit value) = Value type: ◦ 0 = Current values ◦ 1 = Recommended (default) values	2	29

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	Returns 29 bytes, least significant byte first: • Byte 0 = Match network selection: ◦ 1 = Match network 1 ◦ 2 = Match network 2 • Byte 1 = Value type: ◦ 0 = Current values ◦ 1 = Recommended (default) values • Bytes 2 and 3 (16-bit value) = Converted VSWR tuning stop value (1 to 32) • Bytes 4 and 5 (16-bit value) = Converted VSWR tuning start value (1 to 32) 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: First, calculate gamma: $\sqrt{2/1024} = 0.044194$ Second, calculate VSWR: $1.09247 = \frac{1 + 0.044194}{1 - 0.044194}$ • Bytes 6 through 9 = Reserved (default = 0) • Bytes 10 and 11 (16-bit value) = Maximum load percent capacitor position (in hundredths of a %) The automatic tuning algorithm uses this parameter (as well as those for bytes 14 through 17) to assist in capacitor movement control. • Bytes 12 and 13 = Reserved • Bytes 14 and 15 (16-bit value) = Maximum tune percent capacitor position (in hundredths of a %) • Bytes 16 and 17 (16-bit value) = Minimum tune percent capacitor position (in hundredths of a %)		

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	• Bytes 18 and 19 = Magnitude→load cross dependence coefficient (converted value, –1024 to 1024) 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 20 and 21 = Phase→load cross dependence coefficient (converted value, –1024 to 1024) • Bytes 22 and 23 = Magnitude→tune cross dependence coefficient (converted value, –1024 to 1024) • Bytes 24 and 25 = Phase→tune cross dependence coefficient (converted value, –1024 to 1024) • Byte 26 = Algorithm number (Returns a value of 0 = VSWR tuning start/stop) • Byte 27 (8-bit value) = Hold load mode on/off: ◦ 0 = Turn off hold load mode ◦ 1 = Turn on hold load mode • Byte 28 (8-bit value) = Always 0 to indicate no integration Set with command **82**.		
152 **report autotune setup (NV)** MBA algorithm. See previous row for phase/ magnitude algorithm.	Reports the automatic tuning parameters for the selected match network when using the Model-Based Adaptive (MBA) tuning algorithm. Send 4 bytes: • Bytes 0 and 1 (16-bit value) = Match network selection: ◦ 1 = Match network 1 ◦ 2 = Match network 2 • Bytes 2 and 3 (16-bit value) = 3 (model-based adaptive algorithm) Returns 20 bytes, least significant byte first:	4	20

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	• Bytes 0 and 1 (16-bit value) = Match network selection: ◦ 1 = Match network 1 ◦ 2 = Match network 2 • Bytes 2 and 3 (16 bit value) = 3 • Bytes 4 through 7 (32-bit floating-point value) = VSWR tuning stop value. Range = 1 to 32. • Bytes 8 through 11 (32-bit floating-point value) = VSWR tuning start value. Range = 1 to 32. • Bytes 12 and 13 (16 bit value) = Maximum load capacitor step size (in hundredths of a %) The automatic tuning algorithm uses this parameter (as well as those for bytes 14 through 19) to assist in capacitor movement control. • Bytes 14 and 15 (16 bit value) = Maximum tune capacitor step size (in hundredths of a %) • Bytes 16 and 17 (16 bit value) = Target load capacitor position (in hundredths of a %) If a high VSWR is detected (> 5), the target load (bytes 16 and 17) and target tune (bytes 18 and 19) values are used. If these values are set to 0, target load and tune positions are never used. • Bytes 18 and 19 (16 bit value) = Target tune capacitor position (in hundredths of a %) Set with command **82**.		

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
154 **report capacitor limits (NV)**	Reports the minimum and maximum positions for the tune and load capacitors (which are used by the tuning algorithm) for the selected match network. Send 2 bytes to select the match network: • Bytes 0 and 1 (16-bit value) = Match network selection: ◦ 1 = Match network 1 ◦ 2 = Match network 2 Returns 10 bytes (five 16-bit values), least significant byte first: • Bytes 0 and 1 = Match network selection: ◦ 1 = Match network 1 ◦ 2 = Match network 2 • Bytes 2 and 3 = Minimum load percent capacitor position (in hundredths of a %) • Bytes 4 and 5 = Minimum tune percent capacitor position (in hundredths of a %) • Bytes 6 and 7 = Maximum load percent capacitor position (in hundredths of a %) • Bytes 8 and 9 = Maximum tune percent capacitor position (in hundredths of a %) Set with command **84**.	2	10
160 **report presets/ trajectories (NV)**	Reports one of up to ten initial preset positions and, if used, corresponding trajectory points for the selected match network. Send 3 bytes: • Bytes 0 and 1 (16-bit value) = Match network selection: ◦ 1 = Match network 1 ◦ 2 = Match network 2 • Byte 2 (8-bit value) = Desired preset (possible values are 1 through 10) Returns 8, 12, 16, or 20 bytes, depending on the number of established trajectory positions:	3	8, 12, 16, or 20

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	☞ **Important** Capacitor positions are reported in hundredths of percent of potential capacitor position (1000 = 10%). • Bytes 0 and 1 (16-bit value) = Match network selection: ◦ 1 = Match network 1 ◦ 2 = Match network 2 • Byte 2 (8-bit value) = The requested preset (possible values are 1 through 10) • Byte 3 (8-bit value) = Number of trajectory pairs included in the packet (0, 1, 2, or 3) • Bytes 4 and 5 (16-bit value) = Initial position for the load capacitor • Bytes 6 and 7 (16-bit value) = Initial position for the tune capacitor Bytes 8 through 19 may or may not be included. Byte 3 will indicate how many, if any, of these trajectory pairs will be included within the return packet. • Bytes 8 and 9 (16-bit value) = First trajectory position on load capacitor • Bytes 10 and 11 (16-bit value) = First trajectory position on tune capacitor • Bytes 12 and 13 (16-bit value) = Second trajectory position on load capacitor • Bytes 14 and 15 (16-bit value) = Second trajectory position on tune capacitor • Bytes 16 and 17 (16-bit value) = Third trajectory position on load capacitor • Bytes 18 and 19 (16-bit value) = Third trajectory position on tune capacitor For related readbacks, see commands **161**, **164**, **167**, and **170**. Set with command **92**.		

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
161 **report selected preset (NV)**	Reports the preset/trajectory set that is currently selected for the match network identified in the send bytes. Send 2 bytes (16-bit value): • Bytes 0 and 1 = Match network selection: ◦ 1 = Match network 1 ◦ 2 = Match network 2 Returns 4 bytes (two 16-bit values): • Bytes 0 and 1 = Match network selection: ◦ 1 = Match network 1 ◦ 2 = Match network 2 • Bytes 2 and 3 = Selected preset (1 through 10) For related readbacks, see commands **160**, **164**, **167**, and **170**. Set with command **91**.	2	4

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
162 **report process status**	Reports the process status for the match networks. If your unit is a single match, the bits for Match network 1 apply. If your unit is a dual match, the bits for Match network 1 and Match network 2 apply. If your unit is a triple match, all the bits described here apply. Returns 4 bytes (bit flags). When a bit is set, it indicates that associated status is true: Byte 0: • Bit 0 = Match network 1: Output is on • Bit 1 = Match network 1: Output is tuned • Bit 2 = Match network 2: Output is on • Bit 3 = Match network 2: Output is tuned • Bits 4 and 5 = Reserved • Bit 6 = Match network 1: Presets are active • Bit 7 = Match network 1: External presets are selected (available only on units with the **User** port) Byte 1: • Bit 0 = Low 24 V supply is detected • Bit 1 = Overtemperature is detected • Bit 2 = Interlock open • Bit 3 = Fan fault • Bit 4 = Match network 1: In automatic tune mode • Bit 5 = Match network 1: In host control mode • Bit 6 = Match network 2: In automatic tune mode • Bit 7 = Match network 2: In host control mode Byte 2: • Bit 0 = Auxiliary capacitor: Output is tuned • Bit 1 = Auxiliary capacitor: In automatic tune mode • Bit 2 = Auxiliary capacitor: Presets are active • Bits 3 and 4 = Reserved	0	4

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	• Bit 5 = Match network 1: In user control mode • Bit 6 = Match network 2: In user control mode • Bit 7 = Reserved Byte 3: • Bit 0 = One or more active or latched faults exists Use command **223** to report the list of current faults. • Bit 1 = One or more active warnings exist • Bit 2 = A motor failed to initialize • Bit 3 = Match network 2 presets are active • Bit 4 = Match network 2 external presets are selected (available only on units with the **User** port) • Bit 5 = Voltage over limit fault • Bits 6 and 7 = Reserved		
163 **report control mode (NV)**	Reports the control mode for the selected match network. Send 2 bytes (16-bit value): • Bytes 0 and 1 = Match network selection: ◦ 1 = Match network 1 ◦ 2 = Match network 2 Returns 4 bytes (two 16-bit values): • Bytes 0 and 1 = Match network selection: ◦ 1 = Match network 1 ◦ 2 = Match network 2 • Bytes 2 and 3 = Control mode: ◦ 0 = User control mode ◦ 1 = Automatic tune mode ◦ 2 = Host control mode Set with command **93**.	2	4

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
164 **report preset status (NV)**	Reports whether the currently active preset is enabled or disabled for the selected match network. Send 2 bytes (16-bit value): • Bytes 0 and 1 = Match network selection: ◦ 1 = Match network 1 ◦ 2 = Match network 2 Returns 4 bytes (two 16-bit values): • Bytes 0 and 1 = Match network selection: ◦ 1 = Match network 1 ◦ 2 = Match network 2 • Bytes 2 and 3 = Preset status: ◦ 1 = Enabled ◦ 0 = Disabled Set with command **94**. For related readbacks, see commands **160**, **161**, **167**, and **170**.	2	4
165 **report auxiliary capacitor parameter**	This command is valid for units with an auxiliary capacitor. The parameters that are valid for you unit depend on the unit's auxiliary capacitor. ☞ **Important** If you send parameter 10 there will be an additional length byte (length=13). If you send any other parameter there will not be an additional length byte. Send 2 bytes: • Byte 0 (8-bit value) = Auxiliary capacitor parameter selection: ◦ 0 = Report auxiliary capacitor position in % of total capacitor range ◦ 1 = Reserved ◦ 2 = Report auxiliary capacitor minimum and maximum positional data ◦ 3 = Report target control parameters	2	Varies

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	◦ 4 = Reserved ◦ 5 = Report auxiliary capacitor initial preset data ◦ 6= Reserved ◦ 7 = Report auxiliary capacitor active preset ◦ 8 = Report auxiliary capacitor automatic tune mode setting ◦ 9 = Report auxiliary capacitor preset enabled or disabled ◦ 10 = Report auxiliary capacitor automatic tuning parameters ◦ 11 and 12 = Reserved ◦ 13 = Report over voltage trip level ◦ 14 = Report auxiliary capacitor encoder positional data ◦ 15 = Report auxiliary capacitor position in % of impedance range, based on total impedance range of the match ◦ 16 = Reserved ◦ 17 = Report resonant point ◦ 18 = Report auxiliary capacitor control interface ◦ 19 = Reserved ◦ 20 = Report the calculated current ratio and measured currents ◦ 21 = Report auxiliary capacitor last encoder variance (difference between encoder count and firmware count) ◦ 22 = Report auxiliary capacitor measured voltage • Byte 1 = ◦ When Byte 0 = 5, sent the preset number desired (1 through 4)		

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	◦ For all other values of byte 0, do not send byte 1 Returns a variable number of bytes. Byte 0 is always returned and is an echo of the input parameter. The number of additional bytes (1 through 12) returned depends on the input parameter: • Byte 0 (8-bit value) = Auxiliary capacitor parameter selection: ◦ 0 = Report auxiliary capacitor position. If this is selected, then ▪ Bytes 1 and 2 (16-bit value) = Auxiliary capacitor position in hundredths of a % ◦ 1 = Reserved ◦ 2 = Report auxiliary capacitor minimum and maximum positional data. If this is selected, then: ▪ Bytes 1 and 2 (16-bit value) = Minimum auxiliary capacitor position in hundredths of a % ▪ Bytes 3 and 4 (16-bit value) = Maximum auxiliary capacitor position in hundredths of a % ◦ 3 = Report target control parameter. If this is selected, then: ▪ Bytes 1 and 2 (16-bit value) = The value returned depends on the function of your auxiliary capacitor: Target current ratio in thousandths Target current in hundredths of an amp ◦ 5 = Report auxiliary capacitor initial preset data. If this is selected, then: ▪ Byte 1 (8-bit value) = Preset selection (valid values are 1 through 4) ▪ Bytes 2 and 3 (16-bit value) = Initial auxiliary capacitor position in hundredths of a %		

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	◦ 7 = Report auxiliary capacitor active preset selection. If this is selected, then: ▪ Byte 1 (8-bit value) = Active preset selection (valid values = 1 through 4) ◦ 8 = Report auxiliary capacitor automatic tune mode setting. If this is selected, then: ▪ Byte 1 (8-bit value) = 1 = Automatic tuning enabled 2 = Automatic tuning disabled ◦ 9 = Report auxiliary capacitor preset enabled or disabled. If this is selected, then: ▪ Byte 1 (8-bit value) = 0 = Presets disabled 1 = Presets enabled (active) ◦ 10 = Report auxiliary capacitor automatic tuning parameters. If this is selected, then: ▪ Bytes 1 and 2 (16-bit unsigned integer value) = Timer (in ms) ▪ Bytes 3 and 4 (16-bit integer value) = Gain ▪ Bytes 5 and 6 (16-bit unsigned integer value) = Maximum step (in hundredths of a %) ▪ Bytes 7 and 8 (16-bit value) = Error. The value returned depends on the function of your auxiliary capacitor: Current error in thousandths Error tolerance in hundredths of an amp ▪ Bytes 9 through 12 (32-bit value) = Reserved ◦ 13 = Report over voltage trip level (valid for units with a splitter auxiliary capacitor). If this is selected, then: ▪ Bytes 1 and 2 (16-bit value) = Over voltage limit (in volts, valid values = 0 through 10,000)		

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	◦ 14 = Report auxiliary capacitor encoder positional data. If this is selected, then: ▪ Bytes 1 and 2 (16-bit value) = Auxiliary capacitor encoder position in hundredths of a % ◦ 15 = Report auxiliary capacitor position in impedance range. If this is selected, then: ▪ Bytes 1 and 2 = Percentage of impedance range in hundredths of a % ◦ Report resonant point (valid for units with a current control termination capacitor). If this is selected, then: ▪ Bytes 1 and 2 = Capacitor position in hundredths of a % ◦ 18 = Report the interface that is controlling the auxiliary capacitor. If this is selected, then: ▪ 0 = User interface control ▪ 2 = Host interface control ◦ 20 = Report the calculated current ratio and calculated currents. If this is selected, then: ▪ Bytes 1 and 2 (16-bit value) = Calculated current ratio in thousands ▪ Bytes 3 and 4 (16-bit value) = Current one (in 10 mA) ▪ Bytes 5 and 6 (16-bit value) = Current two (in 10 mA) ◦ 21 = Report auxiliary capacitor last encoder positional deviation. If this is selected, then: ▪ Bytes 1 and 2 (16-bit value) = Auxiliary capacitor encoder deviation (in number of motor steps) ◦ 22 = Report output sensor measured voltage. If this is selected, then: ▪ Bytes 1 and 2 (16-bit value) = Voltage one ▪ Bytes 3 and 4 (16-bit value) = Voltage two Set with command **95**.		

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
167 **report internal/ external preset select status (NV)**	Reports whether the selected match network is set to use either internal or external presets. Send 2 bytes (16-bit value): • Bytes 0 and 1 = Match network selection: ◦ 1 = Match network 1 ◦ 2 = Match network 2 Returns 4 bytes (two 16-bit values): • Bytes 0 and 1 = Match network selection: ◦ 1 = Match network 1 ◦ 2 = Match network 2 • Bytes 2 and 3 = Preset select status: ◦ 0 = Internal ◦ 1 = External Set with command **97**. For related readbacks, see commands **160**, **161**, **164**, and **170**.	2	4

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
168 **report motor status**	Reports whether motor movement is enabled or disabled. Send 2 bytes (16-bit value): • Bytes 0 and 1 = Select the motor (allowable values are 1 through 5): ◦ 1 = Motor for Match network 1 tune capacitor ◦ 2 = Motor for Match network 2 tune capacitor. If the unit is a single match and contains an auxiliary capacitor, this selects the motor for the auxiliary capacitor. ◦ 3 = Motor for Match network 1 load capacitor. ◦ 4 = Motor for Match network 2 load capacitor ◦ 5 = If the unit is a dual match and contains an auxiliary capacitor, this selects the motor for the auxiliary capacitor. Returns 4 bytes (two 16-bit values): • Bytes 0 and 1 = Selected motor (1 through 5) • Bytes 2 and 3 = Report motor status: ◦ 0 = Motor movement enabled ◦ 1 = Motor movement disabled Set with command **98**.	2	4

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
170 **report presets/ trajectory delays (NV)**	Reports any one of the initial preset delays and its associated trajectory delays for the selected match network. All delays are reported in hundredths of seconds (for example, 250 = 2.5 s). Send 3 bytes: • Bytes 0 and 1 = Match network selection: ◦ 1 = Match network 1 ◦ 2 = Match network 2 • Byte 2 = Preset selection (1 through 10 are valid values) Returns 8, 10, 12, or 14 bytes depending on the number of trajectories associated with the preset (16-bit values unless otherwise noted): • Bytes 0 and 1 = Match network selection: ◦ 1 = Match network 1 ◦ 2 = Match network 2 • Byte 2 (8-bit value) = Preset selection (1 through 10 are valid values) • Byte 3 (8-bit value) = Number of trajectories included in the packet (0 through 3, 0 indicates no trajectories set) • Bytes 4 and 5 = Reserved • Byte 6 and 7 = Initial preset delay • Byte 8 and 9 = First trajectory delay • Byte 10 and 11 = Second trajectory delay • Byte 12 and 13 = Third trajectory delay Set with command **100**. For related readbacks, see commands **160**, **161**, **164**, and **167**.	3	8, 10, 12, or 14

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
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. Send 2 bytes (16-bit value): • Bytes 0 and 1 = Motor pair selection: ◦ 1 = Load/tune motor pair for Match network 1 ◦ 2 = Load/tune motor pair for Match network 2 Returns 6 bytes (three 16-bit values): • Bytes 0 and 1 = Motor pair selection: ◦ 1 = Load/tune motor pair for Match network 1 ◦ 2 = Load/tune motor pair for Match network 2 • Bytes 2 and 3 = Load capacitor position • Bytes 4 and 5 = Tune capacitor position Set with command **124**.	2	6

Table 3-9. 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 on the selected match network. Send 4 bytes (two 16-bit values): • Bytes 0 and 1 = Match network selection: ◦ 1 = Match network 1 ◦ 2 = Match network 2 • Bytes 2 and 3 = Sensor selection. Always send 0 to select the input sensor. Returns 12 bytes (six 16-bit values): • Bytes 0 and 1 = Match network selection: ◦ 1 = Match network 1 ◦ 2 = Match network 2 • Bytes 2 and 3 = Sensor selection. Always returns 0 = input sensor. • Bytes 4 and 5 = R (converted). This and the next value are converted. Two versions of the conversion equation: ◦ Ω = (readback value * 50)/1024 ◦ Readback value = (Ω * 1024)/50 • Bytes 6 and 7 = X (converted—see equation for bytes 4 and 5) • Bytes 8 and 9 = Gamma (converted). The readback value is converted. Two versions of the conversion equation: ◦ Gamma = square root of ((readback value)/ 1024)) ◦ Readback value = ((gamma * gamma) * 1024)) • Bytes 10 and 11 = Power in watts	4	12

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
198 **report software version**	Reports the software version number string for either the main processor application code or the FPGA code. Send 0 or 1 byte. Send 1 byte to select either the main processor application code or the FPGA code. If you send 0 bytes, the command will report the main processor application code. • Byte 0 (8-bit value) = Code revision selection: ◦ 0 = Main processor application code revision ◦ 1 or 2 = FPGA code revision ◦ 4 = Bootloader firmware code revision ◦ 6 = DeviceNet/PROFIBUS firmware code revision ◦ 7 = DeviceNet/PROFIBUS bootloader firmware code revision ◦ 8 = DeviceNet/PROFIBUS FPGA firmware part number ◦ 10 = Motor control board application code revision ◦ 11 = Motor control board FPGA code revision ◦ 12 = Motor control board bootloader firmware code revision Returns 3 bytes: • Byte 0 (8-bit value) = ASCII revision level letter • Bytes 1 and 2 (16-bit value) = ASCII revision level numerals See also command **130**.	0 or 1	3

Table 3-9. AE Bus commands (Continued)

<table>
<tr><th>Command</th><th>Description</th><th>Data Bytes Sent</th><th>Data Bytes Returned</th></tr>
<tr><td>204
report system control (subcommands)
Ethernet only</td><td>This command reports the system control information listed in the following rows.
<table>
<tr><th>Byte 0</th><th>Subcommand</th></tr>
<tr><td>0</td><td>Report IP address</td></tr>
<tr><td>1</td><td>Report default gateway</td></tr>
<tr><td>2</td><td>Report subnet mask</td></tr>
<tr><td>3</td><td>Report MAC ID</td></tr>
<tr><td>5</td><td>Report DHCP client enable</td></tr>
<tr><td>92</td><td>Report warning or fault description</td></tr>
<tr><td>200</td><td>Report domain name</td></tr>
<tr><td>202</td><td>Report DNS server IP address</td></tr>
<tr><td>203</td><td>Report DNS configuration</td></tr>
</table>
Set with command 71.</td><td>Varies</td><td>Varies</td></tr>
<tr><td>204
report IP address
(subcommand 0)
Ethernet only</td><td>Reports the unit network IP address, which is stored in nonvolatile memory and is restored each time the unit is powered on. The IP Address is reported LSB first: Byte 0 = Least significant octet of the address.
Send 1 byte:
• Byte 0 = 0 (subcommand number)
Returns 4 bytes:
• Bytes 0 through 3 (32 bits) = IP address
Set with command 71.</td><td>1</td><td>4</td></tr>
</table>

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
204 **report default gateway** (subcommand 1) Ethernet only	Reports the unit network default gateway address, which is stored in nonvolatile memory and is restored each time the unit is powered on. The default gateway address is sent LSB first: Byte 0 = Least significant octet of the address. Send 1 byte: • Byte 0 = 1 (subcommand number) Returns 4 bytes: • Bytes 0 through 3 (32 bits) = Default gateway address Set with command **71**.	1	4
204 **report subnet mask** (subcommand 2) Ethernet only	Reports the unit network subnet mask, which is stored in nonvolatile memory and is restored each time the unit is powered on. The subnet mask is sent LSB first: Byte 0 = Least significant octet of the subnet mask. Send 1 byte: • Byte 0 = 2 (subcommand number) Returns 4 bytes: • Bytes 0 through 3 (32 bits) = Subnet mask Set with command **71**.	1	4
204 **report Mac ID** (subcommand 3) Ethernet only	Reports the MAC ID, which is stored in nonvolatile memory and is restored each time the unit is powered on. The MAC ID is sent LSB first: Byte 0 = Least significant octet of the MAC ID. Send 1 byte: • Byte 0 = 3 (subcommand number) Returns 6 bytes: • Bytes 0 through 5 (48 bits) = Mac ID Set with command **71**.	1	6

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
204 **report DHCP client enable** (subcommand 5) Ethernet only	Reports the unit network DHCP client enable mode. The DHCP enable mode is stored in non-volatile memory and is restored each time the unit is powered on. Send 1 byte: • Byte 0 = 5 (subcommand number) Returns 1 byte: • Byte 0 = DHCP enable mode: ◦ 0 = Disabled ◦ 1 = Enabled	1	1
204 **report warning or fault description** (subcommand 92) Ethernet only	Reports the specified warning or fault description. Send 4 bytes: • Byte 0 = 92 (subcommand number) • Byte 1 = Description type: ◦ 1 or 3 = Fault ◦ 2 or 4 = Warning • Bytes 2 and 3 = Fault or warning code If you send a description type value of 1 or 2, the command returns a variable number of bytes, up to 250 (ASCII characters) containing the fault description. These data bytes are the exact length of the description string up to 250 characters and are not NULL terminated. If you send a description type value of 3 or 4, the command returns exactly 80 bytes of ASCII characters. If the description string is less than 80 characters, the remainder of the response packet is padded with NULL characters. If the description string is more than 80 characters, the string is truncated to fit into the packet and will not be NULL terminated. If the description string is exactly 80 characters, the response packet will not be NULL terminated.	4	Varies

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
204 **report domain name** (subcommand 200) Ethernet only	Reports the unit network domain name. Send 1 byte: • Byte 0 = 200 (subcommand number) Returns up to 64 bytes: • Bytes 0 through (length – 1) = Domain name The length of the domain name is up to 64 ASCII characters.	1	Varies
204 **report DNS server IP address** (subcommand 202) Ethernet only	Reports the DNS server IP address, LSB first. Send 1 byte: • Byte 0 = 202 (subcommand number) Returns 4 bytes: • Bytes 0 through 3 = DNS server IP address, LSB first	1	4
204 **report DNS configuration** (subcommand 203) Ethernet only	Reports the DNS configuration for updates. Send 1 byte: • Byte 0 = 203 (subcommand number) Returns 2 bytes: • Bytes 0 through 1 = DNS configuration update mode: ◦ 0 = DNS server updates disabled—client will not perform DNS updates ◦ 1 = DNS server updates enabled—client will perform DNS updates	1	2

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
208 **report digital switch capacitor position**	This command is valid for units with digital switching capability. Returns the switch position for the selected switch. Send 4 bytes: • Bytes 0 and 1 (16-bit value) = Match network selection: ◦ 1 = Match network 1 ◦ 2 = Match network 2 • Bytes 2 and 3 (16-bit value) = Switch selection (1 or 2) Returns 2 bytes (16-bit value) = Switch position Set with command **108**.	4	2

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
212 **report serial port address and baud rate**	Reports the AE Bus address, baud rate, and, if available, the RS-485 mode for system serial ports: • **Host** port • **Service** port (if the unit includes a **Service** port You can issue this command from the following ports: • **Host** port • **Service** port (if the unit includes a **Service** port) • **Ethernet** port (if unit includes an **Ethernet** port) The AE Bus broadcast mode is not supported, therefore if the AE Bus address is set to 0, the unit will report the default address of 1. Send 1 byte: • Byte 0 = Serial port selection: ◦ 1 = **Host** port ◦ 2 = **Service** port (if the unit includes a **Service** port) Returns 3 bytes: • Byte 0 = AE Bus address (valid values: 0-31) • Byte 1 = Baud rate: ◦ 0 = 2400 ◦ 1 = 4800 ◦ 2 = 9600 ◦ 3 = 19200 ◦ 4 = 38400 ◦ 5 = 57600 ◦ 6 = 115200 • Byte 2 = RS-485 mode (valid values are: 0 = Off, 1 = On) Set with command **69**.	1	3

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
215 **report real-time clock**	Reports the real time clock on the CPU module to the time/date specified. The data received is encoded in BCD (Binary Coded Decimal) format. For example: if the value for seconds is 48, the value returned is 0x48. The real time clock features automatic leap year compensation for years up to 2100. Returns 7 bytes: • Byte 0 (8-bit value) = Seconds (range: 0 to 59) • Byte 1 (8-bit value) = Minutes (range: 0 to 59) • Byte 2 (8-bit value) = Hours (range: 0 to 23) • Byte 3 (8-bit value) = Day of week (range: 1 to 7, 1= Sunday, ..., 7 = Saturday) • Byte 4 (8-bit value) = Day (range: 1 to 31) • Byte 5 (8-bit value) = Month (range: 1 to 12) • Byte 6 (8-bit value) = Year (range: 00 to 99) Set with command **70**.	0	7

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
219 **report condensed match snapshot**	Returns a snapshot of data that is identical to the data reported by the individual commands. The command returns only the data that is applicable to the unit. If the unit does not include the feature, the command returns a 0. Send 0 or 2 bytes: • Bytes 0 and 1 = Send 0 (Optional. The command reports the same data whether or not the data bytes are sent.) Returns 88 bytes: • Bytes 0 through 3 (32-bit value) = Status bytes (see command **162**) • Bytes 4 and 5 (16-bit value) = Match network 1 load capacitor position (see command **180**) • Bytes 6 and 7 (16-bit value) = Match network 1 tune capacitor position (see command **180**) • Bytes 8 and 9 (16-bit value) = Match network 1 input sensor R (see command **185**) • Bytes 10 and 11 (16-bit value) = Match network 1 input sensor X (see command **185**) • Bytes 12 and 13 (16-bit value) = Match network 2 load capacitor position (see command **180**) • Bytes 14 and 15 (16-bit value) = Match network 2 tune capacitor position (see command **180**) • Bytes 16 and 17 (16-bit value) = Match network 2 input sensor R (see command **185**) • Bytes 18 and 19 (16-bit value) = Match network 2 input sensor X (see command **185**) • Bytes 20 and 21 (16-bit value) = RF peak, if available • Bytes 22 and 23 (16-bit value) = DC bias, if available • Bytes 24 and 25 (16-bit value) = Current sensor, if available • Bytes 26 and 27 (16-bit value) = V_{rf}	0 or 2	88

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	• Bytes 28 and 29 (16-bit value) = Auxiliary capacitor position (see command **165**) • Bytes 30 and 31 (16-bit value) = Auxiliary capacitor current reading on the primary sensor (see command **165**) • Bytes 32 and 33 (16-bit value) = Auxiliary capacitor current reading on the secondary sensor (see command **165**) • Bytes 34 and 35 (16-bit value) = Auxiliary capacitor current ratio (see command **165**) • Bytes 36 and 37 (16-bit value) = Auxiliary capacitor voltage reading on the primary sensor (or voltage reading on the output sensor if your unit has a single output sensor) (see command **165**) • Bytes 38 and 39 (16-bit value) = Auxiliary capacitor voltage reading on the secondary sensor (see command **165**) • Bytes 40 through 43 (32-bit value) = Z'Scan II, sensor 1, frequency 1, R (see command **248**, subcommand 206) *Note:* Not all units include a Z'Scan II output sensor. If the unit does not have a Z'Scan II output sensor, then Bytes 40 through 87 = Reserved. If the unit has a Z'Scan II output sensor, then Bytes 40 through 87 are defined as described here. • Bytes 44 through 47 (32-bit value) = Z'Scan II, sensor 1, frequency 1, X (see command **248**, subcommand 206) • Bytes 48 through 51 (32-bit value) = Z'Scan II, sensor 1, frequency 1, Voltage (see command **248**, subcommand 206) • Bytes 52 through 55 (32-bit value) = Z'Scan II, sensor 1, frequency 1, Current (see command **248**, subcommand 206) • Bytes 56 through 59 (32-bit value) = Z'Scan II, sensor 1, frequency 1, Phase (see command **248**, subcommand 206)		

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	• Bytes 60 through 63 (32-bit value) = Z'Scan II, sensor 1, frequency 1, Power delivered (see command **248**, subcommand 206) • Bytes 64 through 67 (32-bit value) = Z'Scan II, sensor 1, frequency 2, R (see command **248**, subcommand 206) • Bytes 68 through 71 (32-bit value) = Z'Scan II, sensor 1, frequency 2, X (see command **248**, subcommand 206) • Bytes 72 through 75 (32-bit value) = Z'Scan II, sensor 1, frequency 2, voltage (see command **248**, subcommand 206) • Bytes 76 through 79 (32-bit value) = Z'Scan II, sensor 1, frequency 2, current (see command **248**, subcommand 206) • Bytes 80 through 83 (32-bit value) = Z'Scan II, sensor 1, frequency 2, phase (see command **248**, subcommand 206) • Bytes 84 through 87 (32-bit value) = Z'Scan II, sensor 1, frequency 2, power delivered (see command **248**, subcommand 206)		
221 **report PIN number (NV)**	Reports the PIN number for the Navigator II match network. To interpret the unit PIN, see "Navigator II Product Identification Number (PIN)" on page 1-1. Returns 32 bytes = Null-terminated ASCII string representing the PIN number	0	32

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
223 **report fault code list**	Reports a list of all active or latched faults or active warnings that exist within the Navigator II match network. Send 1 byte to select faults or warnings (8-bit value): • 1 = Report active faults • 2 = Report active warnings If there are no active faults or warnings, returns 1 byte (8-bit value) with a CSR value of 0. If there are faults or warnings in the unit, returns a number of bytes equal to 2 times the number of faults (16-bit values). Each 16-bit value indicates a fault or warning codes. The fault and warning codes are described in troubleshooting.	1	Varies

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
231 **report manufacture data**	Returns a non-terminated ASCII string that represents the manufacture data requested. Send 1 byte: • Byte 0 (8-bit value): ◦ 0 = Requests the serial number of the unit ◦ 1 = Requests the AE part number for the unit ◦ 2 = Requests the customer number for the unit ◦ 3 = Requests the date of manufacture ◦ 4 = Requests the shipment date ◦ 5 = Requests the last service date Returns a variable number of data bytes (non-terminated ASCII string) that contains the requested data: • 0 = If this is selected, then the command returns bytes 0 through 3 (unsigned long integer value, LSB first) representing the serial number of the unit. • 1 = If this is selected, then the command returns bytes 0 through 11 (twelve 8-bit ASCII characters) representing the unit part number. • 2 = If this is selected, then the command returns bytes 0 through 15 (sixteen 8-bit ASCII characters) representing the customer number. • 3 = If this is selected, then the command returns bytes 0 through 11 (twelve 8-bit ASCII characters) representing the date of manufacture. • 4 = If this is selected, then the command returns bytes 0 through 11 (twelve 8-bit ASCII characters) representing the shipment date. • 5 = If this is selected, then the command returns bytes 0 through 11 (twelve 8-bit ASCII characters) representing the last service date.	1	Varies
242 **report service log data**	A sector is a snapshot of service data at a particular time (history log). It is a circular queue, where the active sector is the last sector that was written.	12	Varies

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	You can find out the active sector with command **251**. You can request data from a particular sector with command **252**. The service log data depends on the unit. Not all these values are applicable on all units. The length and data you send depends on whether you are requesting data for a match network or an auxiliary capacitor. To request data for a match network, send 12 bytes: • Bytes 0 and 1 (16 bits) = Match network selection: ◦ 1 = Match network 1 ◦ 2 = Match network 2 • Bytes 2 and 3 (16 bits) = Sector selection (0 through 49, –1 = active sector) • Byte 4 through Byte 7 (32 bits) = Set the associated bit to select data to be returned. For each bit described below, the data type shown indicates the number of bytes returned with the data. ◦ 0x00000001 = Echo back the bits selected in bytes 4 through 7 (long) ◦ 0x00000002 = Echo back the bits selected in bytes 8 through 11 (long) ◦ 0x00000004 = Specified sector number or the active sector (byte) ◦ 0x00000008 = Number of writes to sector (long) ◦ 0x00000010 = Load shaft revolution count (long) ◦ 0x00000020 = Tune shaft revolution count (long) ◦ 0x00000040 = Load shaft reversal count (integer) ◦ 0x00000080 = Load shaft reversal 10k count (10k reversals) (long)		

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	◦ 0x00000100 = Tune shaft reversal count (integer) ◦ 0x00000200 = Tune shaft reversal 10k count (10k reversals) (long) ◦ 0x00000400 = Automatic tuning starts count (long) ◦ 0x00000800 = Successful tune count (long) ◦ 0x00001000 = RF ON events count (long) ◦ 0x00002000 = AC power-on cycles count (integer) ◦ 0x00004000 = AC On hours (hours) (integer) ◦ 0x00008000 = RF On hours (hours) (integer) ◦ 0x00010000 = Capacitor initialization count (integer) ◦ 0x00020000 = Time to tune (long) ◦ 0x00040000 = Maximum power when tuned, measured on input (automatic tuning) (watts) (integer) ◦ 0x00080000 = Safe operating area margin (hundredths of a %) (integer) ◦ 0x00100000 = Associated Load position (hundredths of a %) (integer) ◦ 0x00200000 = Associated Tune position (hundredths of a %) (integer) ◦ 0x00400000 = Load shaft maximum stroke, the range of how much the cap moved (hundredths of a %) (integer) ◦ 0x00800000 = Tune shaft maximum stroke, the range of how much the cap moved (hundredths of a %) (integer) ◦ 0x01000000 = Fan fault count (long) ◦ 0x02000000 = Low supply 24 V fault count (long) ◦ 0x04000000 = SOA power limit fault count (long)		

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	◦ 0x08000000 = SOA voltage limit fault count (long) ◦ 0x10000000 = SOA current limit fault count (long) ◦ 0x20000000 through 0x80000000 = Reserved • Byte 8 through Byte 11 (32 bits) = Set the associated bit to select data to be returned. For each bit described below, the data type shown indicates the number of bytes returned with the data: ◦ 0x00000001 = Load encoder fault count (long) ◦ 0x00000002 = Load encoder delta step count (integer) ◦ 0x00000004 = Tune encoder fault count (long) ◦ 0x00000008 = Tune encoder delta step count (integer) ◦ 0x00000010 to 0x80000000 = Reserved To request data for an auxiliary capacitor, send 6 bytes: • Bytes 0 and 1 (16 bits) = Sector selection (0 through 49, –1 = active sector) • Bytes 2 through 5 (32 bits) = Set the associated bit to select data to be returned. For each bit described below, the data type shown indicates the number of bytes returned with the data: ◦ 0x00000001 = Echo back the bits selected in bytes 2 through 5 (long) ◦ 0x00000002 = Specified sector number or the active sector (byte) ◦ 0x00000004 = Number of writes to sector (long) ◦ 0x00000008 = Auxiliary capacitor encoder fault count (long) ◦ 0x00000010 = Auxiliary capacitor encoder delta step count (number of steps) (integer)		

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	◦ 0x00000020 = Auxiliary capacitor shaft revolution count (long) ◦ 0x00000040 = Auxiliary capacitor shaft reversal count (integer) ◦ 0x00000080 = Auxiliary capacitor shaft reversal 10k count (long) ◦ 0x00000100 = Associated auxiliary capacitor position (hundredths of a %) (integer) ◦ 0x00000200 = Associated auxiliary capacitor shaft maximum stroke (hundredths of a %) (integer) ◦ 0x00000400 = Overvoltage limit fault count (long) ◦ 0x00000800 to 0x80000000 = Reserved Returns the information requested in a variable number of bytes, depending on the data you requested.		

Table 3-9. AE Bus commands (Continued)

<table>
<tr><th>Command</th><th>Description</th><th>Data Bytes Sent</th><th>Data Bytes Returned</th></tr>
<tr><td>248
report measurement parameters (subcommands)</td><td>Not all subcommands are available on all units.
This command allows you to read back parameters for several optional measurement parameters. If you issue a command for a feature that your unit does not have, the unit returns CSR 12, Feature is not available on this unit.
The value sent in the first 2 bytes identifies the subcommand that is being sent. Other send and return bytes vary by subcommand.
<table>
<tr><th>Bytes 0 and 1</th><th>Subcommand</th></tr>
<tr><td>10</td><td>Report DC bias</td></tr>
<tr><td>28</td><td>Report custom measurement equation coefficients</td></tr>
<tr><td>29</td><td>Report V_{rf}</td></tr>
<tr><td>46</td><td>Report output relay open/closed state</td></tr>
<tr><td>48</td><td>Report interlock state</td></tr>
<tr><td>200</td><td>Report temperature</td></tr>
<tr><td>201</td><td>Report input/output sensor data</td></tr>
<tr><td>202</td><td>Report auxiliary voltage and current sensor data</td></tr>
<tr><td>203</td><td>Report Z'Scan II output sensor measurement mode</td></tr>
<tr><td>204</td><td>Report measurement system frequency detection enable/disable</td></tr>
<tr><td>205</td><td>Report the Z'Scan II output sensor spectrum frequency</td></tr>
<tr><td>206</td><td>Report Z'Scan II output sensor spectrum frequency data</td></tr>
<tr><td>207</td><td>Report Z'Scan II output sensor detected frequency</td></tr>
<tr><td>208</td><td>Report pulsing parameters</td></tr>
<tr><td>209</td><td>Report pulse detection parameters</td></tr>
</table>
Set with command 118.</td><td>Varies</td><td>Varies</td></tr>
</table>

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
248 **report DC bias** (subcommand 10)	Supported on units with DC bias capability. Reports the DC bias. Send 2 bytes: • Bytes 0 and 1 (16-bit value) = 10 (subcommand number) Returns 2 bytes: • Bytes 0 through 1 (24-byte integer) = DC bias in volts	2	2
248 **report custom measurement equation coefficients** (subcommand 28)	This command is valid for units that support custom measurements. Reports the coefficients that are used to calculate measurements in customer-specified equations (for example, DC bias output signal). All of the coefficient values are 4-byte floating point values. Send 2 bytes: • Bytes 0 and 1 (16-bit value) = 28 (subcommand number) Returns 20 bytes: • Bytes 0 through 3 = Coefficient A • Bytes 4 through 7 = Coefficient B • Bytes 8 through 11 = Coefficient C • Bytes 12 through 15 = Coefficient D • Bytes 16 through 19 = Coefficient E Set with command **118**, subcommand 28.	2	20

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
248 **report custom calculation** (subcommand 29)	This command is valid for units with custom calculations. Reports the value calculated from a custom equation based on the coefficients and a custom formula. Send 2 bytes: • Bytes 0 and 1 (16-bit value) = 29 (subcommand number) Returns 4 bytes: • Bytes 0 through 3 (4-byte floating-point value) = Value from the custom calculation	2	4
248 **Report output relay open/ closed state** (subcommand 46)	This command reports whether the **User** port relay switch is open or closed. Available on units with the **User** port that supports a controllable relay switch. Send 2 bytes: • Bytes 0 and 1 (16-bit value) = 46 (subcommand number) Returns 2 bytes: • Bytes 0 and 1 (16-bit value) = Open/close output relay: ◦ 0 = Output relay is open ◦ 1 = Output relay is closed Set with command **118**, subcommand 46.	2	2

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
248 **Report interlock state** (subcommand 48)	Reports the interlock state on all listed components. Send 2 data bytes (16-bit values): • Bytes 0 and 1 = 48 (subcommand number) Returns 2 data bytes: • Byte 0 (8-bit value) = The interlock state. 1 indicates that some element of the interlock chain is open. 0 indicates that the interlock is closed. The following shows which bit corresponds to each unit component reporting the interlock state (not all components are available on all units): ◦ Bit 0 = Reserved ◦ Bit 1 = **Host** port (units that include a **Service** port) ◦ Bit 2 = Mechanical devices, including a removable panel switch, RF input cable connector, RF input cable cover, mounting surface, and overtemperature. ◦ Bit 3 = Expansion slot 1 (for example, a **User** port) ◦ Bit 4 = Expansion slot 2 (for example, a **User** port) ◦ Bit 5 = Firmware-controlled relay, including SOA, fan speed fault, low 24 voltage power supply, output overcurrent, and output overvoltage ◦ Bit 6 = Fuse ◦ Bit 7 = Reserved • Byte 1 (8-bit value) = Reserved	2	2

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
248 **report temperature** (subcommand 200)	Reports the temperature if a temperature sensor is connected. Send 4 bytes: • Bytes 0 and 1 (16-bit value) = 200 (subcommand number) • Bytes 2 and 3 (16-bit value) = Sensor selection: ◦ 0 = External temperature in sensor—valid for units with either a Z'Scan II or a dual output sensor. Both of these output sensors include a temperature sensor. ◦ 1 = Measurement board temperature—valid for all units Returns 2 bytes: • Bytes 0 and 1 (16-bit value) = Temperature in tenths of a degree Celsius	4	2

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
248 **report input/ output sensor data** (subcommand 201)	Your unit may include one or more of the sensors reported by this command. Reports the measurement data for all input and output sensors except the Z'Scan II and auxiliary measurement sensors. Send 4 bytes: • Bytes 0 and 1 (16-bit value) = 201 (subcommand number) • Bytes 2 and 3 (16-bit value) = Select sensor: ◦ 1 = Input sensor for Match network 1 ◦ 2 = Input sensor for Match network 2 ◦ 7 = Primary sensor of the dual output sensor (or the output sensor if your unit has a single output sensor) ◦ 8 = Secondary sensor of the dual output sensor Returns 28 bytes (4-byte floating-point format) for the specified sensor: • Bytes 0 through 3 = Frequency (in Hz) If the unit includes frequency detection, this is the detected frequency. If the unit does not include frequency detection, this is the frequency set in command **77**. • Bytes 4 through 7 = ◦ For input sensors: Gamma (the reflection coefficient) ◦ For output sensors: Phase • Bytes 8 through 11 = Delivered Power (Watts) • Bytes 12 through 15 = Resistance (R) • Bytes 16 through 19 = Reactance (X) • Bytes 20 through 23 = Voltage (rms) • Bytes 24 through 27 = Current (rms) See command **248**, subcommand 202 for reporting auxiliary sensor data. See command **248**, subcommand 206 for reporting Z'Scan II output sensor data.	4	28

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
248 **report auxiliary sensor data** (subcommand 202)	Available for units with either the auxiliary current sensor or the auxiliary voltage sensor. Reports the sensor data on the auxiliary capacitor. Refer to the unit specification for the scaling. Send 4 bytes: • Bytes 0 and 1 (16-bit value) = 202 (subcommand number) • Bytes 2 and 3 (16-bit value) = Select auxiliary sensor ◦ 4 = Auxiliary sensor 1 ◦ 5 = Auxiliary sensor 2 Returns 16 bytes (4-byte floating-point format) for the specified auxiliary sensor. The frequency reported here is the same as the frequency reported in command **147**: • Bytes 0 through 3 = Measured frequency (Hz), frequency 1 • Bytes 4 through 7 = Voltage (V_{rms}) or current (A_{rms}), depending on unit configuration (frequency 1) • Bytes 8 through 11 = Measured frequency (Hz), frequency 2 • Bytes 12 through 15 = Voltage (V_{rms}) or current (A_{rms}), depending on unit configuration (frequency 2) See command **248** subcommands 201 and 206 for reporting measurement data for other sensors.	4	16
248 **report Z'Scan II measurement mode** (subcommand 203)	For units equipped with the Z'Scan II output sensor. Report the measurement mode for the Z'Scan II output sensor. Send 4 bytes: • Bytes 0 and 1 (16-bit value) = 203 (subcommand number) • Bytes 2 and 3 (16-bit value) = 0 Returns 2 bytes:	4	2

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	• Bytes 0 and 1 (16-bit value) = Measurement mode for Z'Scan II output sensor: ◦ 1 = Single frequency—Report measurements at one fundamental frequency. ◦ 2 = Full spectrum—Report measurements at each of the non-zero spectrum frequencies. This mode runs all the impedance calculations. ◦ 6 = Fundamental frequency—Report measurements at each of the non-zero fundamental frequencies. See related readback commands: command **248**, subcommands 205, 206, 207. Set with command **118**, subcommand 203.		
248 **report measurement system frequency detection enable/disable** (subcommand 204)	Reports whether measurement system frequency detection is enabled or disabled. Send 2 bytes: • Bytes 0 and 1 (16-bit value) = 204 (subcommand number) Returns 2 bytes: • Bytes 0 and 1 (16-bit value) = ◦ 0 = Frequency detection disabled ◦ 1 = Frequency detection enabled Set with command **118**, subcommand 204.	2	2
248 **report Z'Scan II spectrum frequency** (subcommand 205)	For units equipped with the Z'Scan II output sensor operating in either fundamental or full spectrum mode. If the unit is in single measurement mode, use command **147** to report the sensor frequency. Reports the Z'Scan II output sensor frequency for the selected index (echo of the value set in command **118** subcommand 205). To request the detected frequency (units with frequency detection enabled) instead of reporting the values set in command **118** subcommand 205, see command **248**, subcommand 207. Send 4 bytes:	4	4

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	• Bytes 0 and 1 (16-bit value) = 205 (subcommand number) • Bytes 2 and 3 (16-bit value) = Spectrum frequency index; the following index values reflect the associated frequency: ◦ 0 = Fundamental frequency 1 ◦ 1 = Fundamental frequency 1, harmonic 2 ◦ 2 = Fundamental frequency 1, harmonic 3 ◦ 3 = Fundamental frequency 2 ◦ 4 = Fundamental frequency 2, harmonic 2 ◦ 5 = Fundamental frequency 2, harmonic 3 ◦ 6 = Fundamental frequency 3 ◦ 7 = Fundamental frequency 3, harmonic 2 ◦ 8 = Fundamental frequency 3, harmonic 3 ◦ 9 = Frequency (customer defined) ◦ 10 = Frequency (customer defined) ◦ 11 = Frequency (customer defined) Returns 4 bytes: • Bytes 0 through 3 (4-byte integer format) = Nominal measurement frequency in kHz (0 through 200,000 for the selected frequency index) See related readback commands: command **248**, subcommands 203, 206, 207. These values are set with command **118**, subcommand 205.		

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
248 **report Z'Scan II spectrum frequency data** (subcommand 206)	For units equipped with the Z'Scan II output sensor. Reports the listed data for the selected spectrum frequency on the Z'Scan II output sensor. When the unit is in single measurement mode, always use index 0. All returned data are in 4-byte floating point format. Send 4 bytes: • Bytes 0 and 1 (16-bit value) = 206 (subcommand number) • Bytes 2 and 3 (16-bit value) = Full spectrum index selection: ◦ 1 = Frequency indexes 0 through 5 ◦ 2 = Frequency indexes 6 through 11 Returns a variable number of bytes, depending on which measurement mode is active and which set of indexes is selected. For the details of what is returned for each measurement mode, see "Details for report Z'Scan II spectrum frequency data (command 248, subcommand 206)" on page 3-100. See related readback commands: command **248**, subcommands 203, 205, 207.	4	Varies
248 **report Z'Scan II output sensor detected frequency** (subcommand 207)	For units equipped with the Z'Scan II output sensor. If frequency detection is enabled, report Z'Scan II output sensor frequency that is detected and locked onto by the Z'Scan II output sensor. All returned data is frequency in kHz, in 4-byte integer format. The detected frequency reported in this command may differ from the values reported with command **248**, subcommand 205. If frequency detection is not enabled, then this command reports the value set in command **118**, subcommand 205. Send 4 bytes: • Bytes 0 and 1 (16-bit value) = 207 (subcommand number)	4	4

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	• Bytes 2 and 3 (16-bit value) = Detected frequency index (0 through 11) ◦ 0 = Fundamental frequency 1 Send 0 if using the Z'Scan II sensor is in single measurement mode. ◦ 1 = Fundamental frequency 1, harmonic 2 ◦ 2 = Fundamental frequency 1, harmonic 3 ◦ 3 = Fundamental frequency 2 ◦ 4 = Fundamental frequency 2, harmonic 2 ◦ 5 = Fundamental frequency 2, harmonic 3 ◦ 6 = Fundamental frequency 3 ◦ 7 = Fundamental frequency 3, harmonic 2 ◦ 8 = Fundamental frequency 3, harmonic 3 ◦ 9 = Frequency (customer defined) ◦ 10 = Frequency (customer defined) ◦ 11 = Frequency (customer defined) Returns 4 bytes: • Bytes 0 through 3 (32-bit value) = Detected frequency in kHz (0 through 200,000) for the given index. See related readback commands: command **248**, subcommands 203, 205, 206.		

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
248 **report pulsing parameters** (subcommand 208)	Available for units with pulse detection. Reports the minimum pulsing duty cycle and minimum pulsing frequency expected from the generator. Send 4 bytes: • Bytes 0 and 1 (16-bit value) = 208 (subcommand number) • Bytes 2 and 3 (16-bit value) = Always send 0 Returns 4 bytes: • Bytes 0 through 1 (16-bit value) = The minimum pulsing duty cycle (in %) for the connected generator(s). • Bytes 2 through 3 (16-bit value) = The minimum pulsing frequency (in Hz) for the connected generator(s). Set with command **118**, subcommand 208.	4	4
248 **Report pulse detection parameters** (subcommand 209)	Available on units with pulse detection. Reports the information needed to detect a valid pulse. Send 4 data bytes (two 16-bit values): • Bytes 0 and 1 = 209 (subcommand number) • Bytes 2 and 3 = Fundamental frequency (valid range = 1, 2) Returns 8 bytes (eight 16-bit values): • Bytes 0 and 1 = Power averaging threshold for the voltage (V) channel (valid range = 0 through 65535) • Bytes 2 and 3 = Power averaging threshold for the current (I) channel (valid range = 0 through 65535) • Bytes 4 and 5 = Early pulse blanking (prior discard) (valid range = 0 µs through 65535 µs) • Bytes 6 and 7 = Late pulse blanking (future discard) (valid range = 0 µs through 65535 µs) Set with command **118**, subcommand 209.	4	8

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
251 **report active service log sector**	Reports the active service log sector. A sector is a snapshot of service data at a particular time (history log). It is a circular queue, where the active sector is the last sector that was written. See related commands **242** and **252**. Send 2 bytes (16 bits) to select the match network: • 1 = Match network 1 • 2 = Match network 2 Returns 4 bytes: • Bytes 0 and 1 = Select match network: ◦ 1 = Match network 1 ◦ 2 = Match network 2 • Bytes 2 and 3 = Report the service log sector that is active (values are 0 through 9)	2	4
252 **report service log sector's data**	Report the service log sector data for a particular sector on a specified match network. To report the sector that is active, use command **251**. To report all service log data, use command **242**. A sector is a snapshot of service data at a particular time (history log). It is a circular queue, where the active sector is the last sector that was written. Send 4 bytes: • Bytes 0 and 1 (16-bit value) = Select match network or auxiliary capacitor: ◦ 1 = Match network 1 data ◦ 2 = Match network 2 data ◦ 3 = Reserved ◦ 4 = Auxiliary capacitor data • Bytes 2 and 3 = Select the service log sector (values are -1, 0 through 49; -1 will return the sector data from the currently active sector) If you selected one of the match networks (byte 0 and 1 = 1 or 2), then the command returns the information shown below in the section labeled Match Data. If you selected the auxiliary capacitor data (byte 0 and 1 = 4)	4	124 or 40

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	then the command returns the information sown in the section labeled Auxiliary Capacitor Data. Match Network Data (bytes 0 and 1 = 1 or 2). Returns 124 bytes: • Bytes 0 through 3 = Selected sector number • Bytes 4 through 7 = Number of writes to sector • Bytes 8 through 11 = Load revolutions • Bytes 12 through 15 = Tune revolutions • Bytes 16 through 19 = Load reversals • Bytes 20 through 23 = Number of load reversals in 10 thousands (1 = 10,000) • Bytes 24 through 27 = Tune reversals • Bytes 28 through 31 = Number of tune reversals in 10 thousands (1 = 10,000) • Bytes 32 through 35 = Automatic tuning starts • Bytes 36 through 39 = Successful tunes • Bytes 40 through 43 = Output on events • Bytes 44 through 47 = Unit on events • Bytes 48 through 51 = Unit on hours • Bytes 52 through 55 = Output on hours • Bytes 56 through 59 = Capacitor initializations • Bytes 60 through 63 = Time to tune (milliseconds) • Bytes 64 through 67 = Maximum power at tune • Bytes 68 through 71= SOA margin • Bytes 72 through 75 = Associated load capacitor position • Bytes 76 through 79 = Associated tune capacitor position • Bytes 80 through 83 = Load capacitor maximum stroke • Bytes 84 through 87 = Tune capacitor maximum stroke		

Table 3-9. AE Bus commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	• Bytes 88 through 91= Low supply 24 V faults • Bytes 92 through 95 = Fan faults • Bytes 96 through 99 = SOA power faults • Bytes 100 through 103 = SOA voltage faults • Bytes 104 through 107 = SOA current faults • Bytes 108 through 111 = Load capacitor encoder warnings • Bytes 112 through 115 = Load capacitor encoder last variance (difference between encoder count and firmware count) • Bytes 116 through 119 = Tune capacitor encoder warnings • Bytes 120 through 123 = Tune capacitor encoder last variance (difference between encoder count and firmware count) Auxiliary Capacitor Data (bytes 0 and 1 = 4). Returns 40 bytes: • Bytes 0 through 3 = Sector number • Bytes 4 through 7 = Number of writes to sector • Bytes 8 through 11 = Auxiliary capacitor encoder warnings • Bytes 12 through 15 = Auxiliary capacitor encoder last variance (difference between encoder count and firmware count) • Bytes 16 through 19 = Auxiliary capacitor revolutions • Bytes 20 through 23 = Auxiliary capacitor reversals • Bytes 24 through 27 = Number of auxiliary capacitor reversals in 10 thousands (1 = 10,000) • Bytes 28 through 31 = Associated auxiliary capacitor position • Bytes 32 through 35 = Auxiliary capacitor maximum stroke • Bytes 36 through 39 = Overvoltage faults		

Details for report Z'Scan II spectrum frequency data (command 248, subcommand 206)

Table 3-10. *Details for report Z'Scan II spectrum frequency data (command 248, subcommand 206)*

Z'Scan II Output Sensor Measurement Mode	Number of Data Bytes Returned	Details of Return Data Bytes
Single Frequency Mode	28	Returns 28 bytes, which contain the following information for the fundamental frequency at index 0 (all values are 4-byte floating point values): • First 4-byte value = Reserved • Second 4-byte value = Phase • Third 4-byte value = Delivered power in Watts • Fourth 4-byte value = R (resistance) in Ohms • Fifth 4-byte value = X (reactance) in Ohms • Sixth 4-byte value = V_{RMS} in Volts • Seventh 4-byte value = I_{RMS} in Amps
Full Spectrum Mode	168	For each of the specified frequencies, the unit returns 28 bytes. The first 28 bytes contains information for the frequency at index 0 or 6 (selected with the full spectrum selection, bytes 2 and 3 of command **248**, subcommand 206). The second 28 bytes contains information for the frequency at index 1 or 7, and so on. Each set of 28 bytes contains the following information for the frequency at that index (all values are 4-byte floating point values): • First 4-byte value = Reserved • Second 4-byte value = Phase • Third 4-byte value = Delivered power in Watts • Fourth 4-byte value = R (resistance) in Ohms • Fifth 4-byte value = X (reactance) in Ohms • Sixth 4-byte value = V_{RMS} in Volts • Seventh 4-byte value = I_{RMS} in Amps

Table 3-10. Details for report Z'Scan II spectrum frequency data (command 248, subcommand 206) (Continued)

Z'Scan II Output Sensor Measurement Mode	Number of Data Bytes Returned	Details of Return Data Bytes
Fundamental Frequency Mode	84	The first 28 bytes contains information for the frequency at index 0. The second 28 bytes contains information for the frequency at index 3. The third 28 bytes contains information for the frequency at index 6. Each set of 28 bytes contains the following information for the frequency at that index (all values are 4-byte floating point values): • First 4-byte value = Reserved • Second 4-byte value = Phase • Third 4-byte value = Delivered power in Watts • Fourth 4-byte value = R (resistance) in Ohms • Fifth 4-byte value = X (reactance) in Ohms • Sixth 4-byte value = V_{RMS} in Volts • Seventh 4-byte value = I_{RMS} in Amps

PROFIBUS INTERFACE

Some models of the Navigator II match network include a **PROFIBUS** port on the unit. To determine whether a unit has this interface, you can check for a **PROFIBUS** port on the unit itself.

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

Related Links

- "PROFIBUS Connector" on page 3-102
- "PROFIBUS Port Pin and Signal Descriptions" on page 3-102
- "PROFIBUS Cabling and Termination" on page 3-102
- "AE PROFIBUS Protocol" on page 3-103
- "AE PROFIBUS Protocol" on page 3-103
- "PROFIBUS Commands" on page 3-108

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.

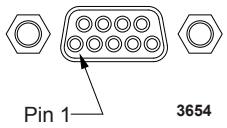


Figure 3-9. PROFIBUS port connector

PROFIBUS Port Pin and Signal Descriptions

Table 3-11. 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
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 3-12. Baud rate and cable lengths

Baud Rate	Length
1.5 M	200 meters

Table 3-12. Baud rate and cable lengths (Continued)

Baud Rate	Length
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.

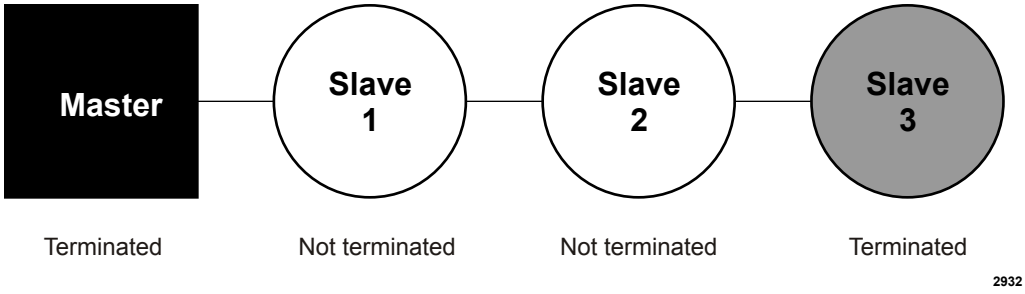


Figure 3-10. Example of a segment

AE PROFIBUS Protocol

The **PROFIBUS** port provides an interface that lets you communicate with the Navigator II 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 Navigator II 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).

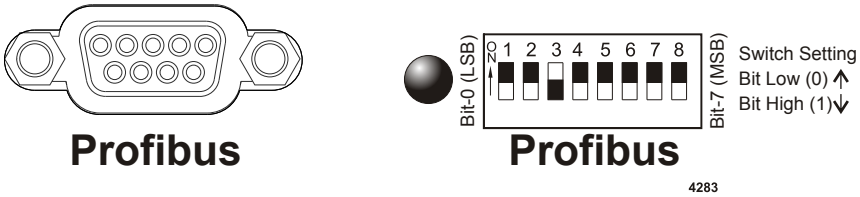


*Figure 3-11. **PROFIBUS** port, LED, and DIP switch*

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 Navigator II 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 Navigator II 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 Navigator II 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 Navigator II unit. Data inconsistency most often results in inappropriate value changes at the Navigator II 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 Navigator II 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 Navigator II unit can respond. This situation can cause the Navigator II 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 Navigator II 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 3-13. 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 Navigator II unit supplies a 14-byte upload packet. This table defines the bytes contained in the upload packet.

Table 3-14. 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
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 Navigator II unit:

Table 3-15. 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 Navigator II 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 has an active fault • Bit 1 = Overtemperature condition • Bit 2 = Interlock fault • Bits 3 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 Navigator II unit in response to a PROFIBUS command as well as the PROFIBUS commands for the Navigator II unit.

Not all models use all of the following CSR codes and commands. Model-specific commands are noted in the command table.

PROFIBUS COMMAND STATUS RESPONSE (CSR) CODES

When the Navigator II unit receives a command requesting a change in unit operation (command numbers 1 through 127), or when the Navigator II 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.

Not all models use all of the following CSR codes.

Table 3-16. AE 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.	
1	Control mode is incorrect.
2	RF output is on.
4	Parameter is out of its acceptable range.
7	One or more faults are active.
9	Data byte count is incorrect
12	Feature is not available.
30	EEPROM read/write error.
35	Host control mode is inactive.
37	Selected preset is invalid.
40	Invalid control mode parameters were received.
47	Motor movement disabled.
48	Motors are already moving.
50	Motor movement failed.
53	24 V supply is low.
54	Match network selection is incorrect.
56	Internal host command failed.
57	Load motor is already moving.
58	Tune motor is already moving.
61	Processor busy with other tasks.
63	Flash mode is active.

Table 3-16. AE command status response (CSR) codes (Continued)

Code	Meaning
99	Command is not implemented.

PROFIBUS COMMAND SET

The PROFIBUS interface has two types of commands:

- Commands **1** through **127** request a change to the Navigator II 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.

☞ **Important**
Not all models use all of the following commands. Model-specific commands are noted in the command table.

Table 3-17. PROFIBUS commands

Command	Description	Data Bytes Sent	Data Bytes Returned
0 **Null**	Reserved. If sent, this command performs no action.	0	1
7 **Restore Factory Defaults**	Restores the unit to the original factory settings for all non-volatile RAM settings, even if you use the Virtual Front Panel software. After restoring factory values, the command resets the microprocessor. Send 2 bytes (16-bit value) = Always send 0	2	1 (CSR only)
77 **set measurement frequency for Z'Scan II sensor in single mode**	Selects the nominal measurement frequency for the Z'Scan II output sensor (some units) in single measurement mode. Send 3 bytes: • Bytes 0 through 3 (24-bit value) = Nominal measurement frequency in kHz. Range is 0 kHz to 200,000 kHz, in 1 kHz steps. Read back with command **147**.	3	1 (CSR only)

Table 3-17. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
78 **set impedance target**	Sets the target impedance to which the selected match network tunes. ☞ **Important** Setting a target impedance other than 50+j0 can cause stress on the RF generator that is connected to the match network. Ensure that the target impedance you select falls within the safe operational area of the RF generator that is connected to the Navigator II match network. Send 3 bytes: • Byte 0 (8-bit value) = Match network and parameter selection: ◦ Bits 0 through 3 = Real or Imaginary parameter selection ▪ 0 = Select real part (r_target) ▪ 1 = Select imaginary part (x_target) ◦ Bits 4 and 5 = Match network selection ▪ 1 = Match network 1 ▪ 2 = Match network 2 ◦ Bits 6 and 7 = Always send 0 • Bytes 1 and 2 (16-bit value) = Real part (r_target) or imaginary part (x_target) of the target impedance. Send a converted value (ohms * 20.48). For example, for 50 Ω send a value of 1024. ◦ The effective range of the real part is 25 Ω to 100 Ω. The converted range = 512 through 2048 (25 Ω * 20.48 through 100 Ω * 20.48). ◦ The effective range of the imaginary part is -50 Ω to 50 Ω. The converted range = -1024 through 1024 (-50 Ω * 20.48 through +50 Ω * 20.48). Read back with command **148**.	3	1 (CSR only)
82 **autotune setup**	Sets up automatic tuning parameters for the selected match network. This command supports both a phase/magnitude and a model-based algorithm.	3	1 (CSR only)

Table 3-17. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	☞ **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 = Select the match network and the autotune parameter. ◦ Bits 0 through 3 = Autotune parameter: ▪ 0 = Converted VSWR tuning stop value (range = 1 to 32) Parameters 0 and 1, send a converted VSWR value. ☞ **Important** VSWR values must be converted before being sent. First, convert the VSWR value to a gamma value: gamma = (VSWR–1)/(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. ▪ 1 = Converted VSWR tuning start value (range = 1 to 32) ▪ 2 and 3 = Reserved ▪ 4 = Maximum load percent capacitor position (in hundredths of a %) ▪ 5 = Reserved ▪ 6 = Maximum tune percent capacitor position (in hundredths of a %)		

Table 3-17. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	Capacitor position values for parameters 6 and 7: Value in hundredths of a %. The automatic tuning algorithm uses these parameters to assist in capacitor movement control. ▪ 7 = Minimum tune percent capacitor position (in hundredths of a %) ▪ 8 = Magnitude→load cross dependence coefficient (converted value, –1024 to 1024) Cross dependence coefficient values for parameters 8 through 11: These values 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 value, –1024 to 1024) ▪ 10 = Magnitude→tune cross dependence coefficient (converted value, –1024 to 1024) ▪ 11 = Phase→tune cross dependence coefficient (converted value, –1024 to 1024) ▪ 12 = Algorithm number (Send a value of 0 = VSWR tuning start/stop) ▪ 13 = Hold load mode: 0 = Turn off hold load mode 1 = Turn on hold load mode ▪ 14 = Always 0 to indicate no integration ◦ Bits 4 and 5 = Match network selection ▪ 1 = Match network 1 ▪ 2 = Match network 2 ◦ Bits 6 and 7 = Always send 0 • Bytes 1 and 2 = Value for the parameter sent in byte 0 Read back with command **152**.		

Table 3-17. PROFIBUS 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 for the selected match network. The capacitor limits are used by the tuning algorithm. 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%). Send 3 bytes, least significant byte first: • Byte 0 = Selection byte: ◦ Bits 0 through 3: Use to select the capacitor and whether the value is the minimum or maximum position: ▪ 0 = Minimum load position (hundredths of a %) ▪ 1 = Minimum tune position (hundredths of a %) ▪ 2 = Maximum load position (hundredths of a %) ▪ 3 = Maximum tune position (hundredths of a %) ◦ Bits 4 and 5 = Match network selection ▪ 1 = Match network 1 ▪ 2 = Match network 2 ◦ Bits 6 and 7 = Always send 0 • Bytes 1 and 2 (16-bit value) = The value (in hundredths of a %) for the capacitor position specified in byte 0. Valid range is 0 to 10000. Read back with command **154**.	3	1 (CSR only)

Table 3-17. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
91 **set active preset (NV)**	Sets the active preset for the selected match network. Send 3 bytes: • Byte 0 (8-bit value) = Match network selection: ◦ Bits 0 through 3: Always send 0 ◦ Bits 4 and 5 = Match network selection: ▪ 1 = Match network 1 ▪ 2 = Match network 2 ◦ Bits 6 and 7 = Always send 0 • Bytes 1 and 2 (16-bit value) = Desired preset (1 through 10) For related settings, see commands **92**, **94**, **97**, and **100**. Read back with command **161**.	3	1 (CSR only)
92 **set up presets and trajectories (NV)**	Sets an initial preset position and, if desired, corresponding trajectory points for the selected match network. Capacitor positions are set in hundredths of percent of potential capacitor position (1000 = 10%). Send command **92** multiple times to set presets and trajectories. Send the commands in the following sequence to make sure the match network performs as intended: • Set the match network selection each time you send the command. • Set the preset before specifying the initial load or tune position. • Set the trajectory count before specifying the trajectories. ☞ **Important** Failure to send the command in this order will result in unspecified behavior. 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. Send 3 bytes:	3	1 (CSR only)

Table 3-17. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	• Byte 0 (8-bit value) = Select the match and the desired parameter: ◦ Bits 0 through 3: Preset parameter selection. Use this to specify the value you will send in bytes 1 and 2: ▪ 0 = Preset select (1 through 10) ▪ 1 = Trajectory count (0 through 3) ▪ 2 = Initial load capacitor position for active preset (hundredths of a %) ▪ 3 = Initial tune capacitor position for active preset (hundredths of a %) ▪ 4 = First load trajectory position for active preset (hundredths of a %) ▪ 5 = First tune trajectory position for active preset (hundredths of a %) ▪ 6 = Second load trajectory position for active preset (hundredths of a %) ▪ 7 = Second tune trajectory position for active preset (hundredths of a %) ▪ 8 = Third load trajectory position for active preset (hundredths of a %) ▪ 9 = Third tune trajectory position for active preset (hundredths of a %) ◦ Bits 4 and 5 = Match network selection: ▪ 1 = Match network 1 ▪ 2 = Match network 2 ◦ Bits 6 and 7 = Always send 0 • Bytes 1 and 2 (16-bit value) = The value for the parameter sent in byte 0. For related settings, see commands **91**, **94**, **97**, and **100**. Read back with command **160**.		

Table 3-17. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
93 **set control mode (NV)**	Sets the control mode for the selected match network. Send 3 bytes: • Byte 0 = (8-bit value) = Match network selection: ◦ Bits 0 through 3: Always send 0 ◦ Bits 4 and 5 = Match network selection: ▪ 1 = Match network 1 ▪ 2 = Match network 2 ◦ Bits 6 and 7 = Always send 0 • Bytes 1 and 2 (16-bit value) = Control mode: ◦ 0 = User control mode A manual tuning mode controlled with the User. ◦ 1 = Automatic tune mode ◦ 2 = Host control mode A manual tuning mode that is controlled through one of the following ports: ▪ **Host** ▪ **PROFIBUS** ▪ **DeviceNet** ▪ **Ethernet** Read back with command **163**.	3	1 (CSR only)

Table 3-17. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
94 **enable/disable presets (NV)**	Enables/disables the active preset for the selected match network. If you enable presets and the unit is in automatic tune 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 3 bytes: • Byte 0 (8-bit value) = Match network selection ◦ Bits 0 through 3 = Always send 0 ◦ Bits 4 and 5 = Match network selection: ▪ 1 = Match network 1 ▪ 2 = Match network 2 ◦ Bits 6 and 7 = Always send 0 • Bytes 1 and 2 (16-bit value) = Enable or disable presets: ◦ 0 = Disable ◦ 1 = Enable For related settings, see commands, **91**, **97**, and **100**. Read back with command **164**.	3	1 (CSR only)

Table 3-17. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
97 **select internal/ external presets (NV)**	This command is valid for units with the **User** port. Sets either internal or external presets for the selected match network. Send 3 bytes: • Byte 0 = Match network selection: ◦ Bits 0 through 3 = Always send 0 ◦ Bits 4 and 5 = Match network selection: ▪ 1 = Match network 1 ▪ 2 = Match network 2 ◦ Bits 6 and 7 = Always send 0 • Bytes 1 and 2 (16-bit value) = Preset type: ◦ 0= Internal ◦ 1= External (available only on units with a **User** port) For related settings, see commands **92**, **91**, **94**, and **100**. Read back with command **167**.	3	1 (CSR only)

Table 3-17. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
98 **disable/enable motor movement**	Disables or enables motor movement for the selected stepper motor. Send 2 bytes: • Byte 0 (8-bit value) = Motor select (valid range 0 through 5): ◦ 0 = All motors in the unit ◦ 1 = Motor for Match network 1 tune capacitor ◦ 2 = Motor for Match network 2 tune capacitor If the unit is a single match unit and contains an auxiliary capacitor, this selects the motor for the auxiliary capacitor. ◦ 3 = Motor for Match network 1 load capacitor ◦ 4 = Motor for Match network 2 load capacitor ◦ 5 = If the unit is a dual match unit and contains an auxiliary capacitor, this selects the motor for the auxiliary capacitor • Byte 1 (8-bit value) = Enable/disable motor movement: ◦ 0 = Enable ◦ 1 = Disable Read back with command **168**.	2	1 (CSR only)
100 **set preset/ trajectory delays (NV)**	Sets the initial preset delay and trajectory delays for the specified preset in the selected match network. You need to send a sequence of this command: First, send the preset select number to establish which preset to set up. Additional commands to set the number of trajectories, preset delay, or trajectory delays will be applied to the selected preset. Continue this sequence for up to 10 presets. ☞ **Important** The second trajectory delay may not exist without the first trajectory delay. The third trajectory delay may not exist without the first and second trajectory delays. Send 2 bytes:	2	1 (CSR only)

Table 3-17. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	• Byte 0 (8-bit value) = Match network and preset delay parameter selection: ◦ Bits 0 through 3 = Preset delay parameter selection. Use this to specify the value you will send in bytes 1 and 2: ▪ 0 = Preset select ▪ 1 = Trajectory count ▪ 2 = Reserved ▪ 3 = Initial preset delay All delays are set in hundredths of seconds. 0 disables the delay. Range = 1 to 250 (10 ms to 2.5 s). Values apply to load and tune capacitors. ▪ 4 = First trajectory delay ▪ 5 = Second trajectory delay ▪ 6 = Third trajectory delay ◦ Bits 4 and 5 = Match network selection ▪ 1 = Match network 1 ▪ 2 = Match network 2 ◦ Bits 6 and 7 = Always send 0 • Bytes 1 and 2 (16-bit value) = The value for the parameter sent in byte 0: ◦ Preset number = Possible values are 1 through 10 ◦ Number of trajectories to set = Possible values are 0 through 3 (0 indicates no trajectories) ◦ Preset or trajectory delay = Delay in hundredths of seconds (Range = 1 to 250 (10 ms to 2.5 s). 0 disables the delay.) For related settings, see commands **90**, **91**, **94**, and **97**. Read back with command **170**.		

Table 3-17. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
112 **move load capacitor position**	Moves the load capacitor to the specified position for the selected match network. Send 3 bytes: • Byte 0 (8-bit value) = Match network selection: ◦ Bits 0 through 3 = Always send 0 ◦ Bits 4 and 5 = Match network selection ▪ 1 = Match network 1 ▪ 2 = Match network 2 ◦ Bits 6 and 7 = Always send 0 • Bytes 1 and 2 (16-bit value) = Load capacitor position 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**.	3	1 (CSR only)
118 **set pulsing parameters** (subcommand 208)	Available on units with pulse detection. Use this command to specify to the minimum pulsing duty cycle and minimum pulse frequency expected on the generator. The information provided should account for all generators connected to the match. The proper settings will maximize the performance of the measurement system. Send 8 bytes (four 16-bit values): • Bytes 0 and 1 = 208 (subcommand number) • Bytes 2 and 3 = A value of zero • Bytes 4 and 5 = The minimum pulsing duty cycle (in %) for the generator(s) connected to the unit (valid range = 1 through 100 percent) • Bytes 6 and 7 = The minimum pulse frequency (in Hz) for the generator(s) connected to the unit (minimum value = 10 Hz)	8	1 (CSR only)

Table 3-17. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
118 **set pulse detection parameters** (subcommand 209)	Available on units with pulse detection. Sets the information needed to detect a valid pulse. Send 8 bytes (four 16-bit values): • Bytes 0 and 1 = 209 (subcommand number) • Bytes 2 and 3 = Fundamental frequency (valid range = 1, 2) The match/frequency for which you are setting the pulse detection parameters. On a single match unit, always send 1. On a dual match unit, you can set pulse detection parameters for either fundamental frequency 1 or 2. • Bytes 4 and 5 = Power averaging threshold for the voltage (V) channel (valid range = 0 through 65535) A unit-specific default is set at the factory. • Bytes 6 and 7 = Power averaging threshold for the current (I) channel (valid range = 0 through 65535) A unit-specific default is set at the factory. • Bytes 8 and 9 = Early pulse blanking (prior discard). Sets the time period to discard the signal after it reaches the V and I thresholds. Valid range = 0 µs through 65535 µs. • Bytes 10 and 11 = Late pulse blanking (future discard). Sets the time period to discard before the signal falls below the V and I thresholds. Valid range = 0 µs through 65535 µs. Set the time period to stop sampling the signal. All data from this time through RF off will be discarded. Read back with command **248**, subcommand 209.	12	1 (CSR only)
119 **Clear latched faults**	Clears the latched faults.	0	1 (CSR only)

Table 3-17. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
122 **move tune capacitor position**	Moves the tune capacitor to the specified position for the selected match network. Send 3 bytes: • Byte 0 (8-bit value) = Select the match network and the desired parameter: ◦ Bits 0 through 3 = Always send 0 ◦ Bits 4 and 5 = Match network selection: ▪ 1 = Match network 1 ▪ 2 = Match network 2 ◦ Bits 6 and 7 = Always send 0 • Bytes 1 and (16-bit value) = Tune capacitor position 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**.	3	1 (CSR only)
125 **initialize capacitors**	Moves all capacitors to their minimum positions.	0	1 (CSR only)
128 **report match type**	Reports the match network type. Returns 5 bytes (ASCII format) representing the following: • NAV II	0	5

Table 3-17. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
130 **report software number**	Reports the software part number. Send 1 byte (optional). If sent with zero transmit data bytes, the main processor application firmware part number is reported: • 0 = Requests main processor application firmware part number (default) • 3 = Requests bootloader firmware part number • 4 = Requests PROFIBUS or DeviceNet application firmware part number • 5 = Requests PROFIBUS or DeviceNet bootloader firmware part number • 6 = PROFIBUS or DeviceNet FPGA firmware part number • 10 = Requests motor control board application part number • 11 = Requests motor control board FPGA part number • 12 = Requests motor control board bootloader firmware part number Returns 5 bytes (ASCII format) representing the last 5 characters of the software part number. See also command **198**.	1	5
132 **report FPGA firmware revision**	Returns the FPGA code revision as a three-element ASCII string, one letter and two numeric digits: • Byte 0 = ASCII revision level letter • Bytes 1 and 2 = ASCII revision level numerals	0	3

Table 3-17. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
135 **report motor movement status**	Reports status of stepper motor movement. Send 2 bytes = Always send 0 Returns 2 bytes = Motor movement status: • Byte 0 (8-bit): ◦ 0 = Match network 1: Tune motor is moving ◦ 1 = Match network 1: Load motor is moving ◦ 2 = Match network 2: Tune motor is moving. On units with an auxiliary capacitor, the auxiliary capacitor motor is moving. ◦ 3 = Match network 2: Load motor is moving ◦ 4 through 7 = Reserved • Byte 1 (8-bit) = Reserved	2	2
147 **report measurement frequency**	Your unit may include one or more of the sensors reported by this command. Reports the measurement frequency given in 1 kHz steps, from 0 kHz to 200,000 kHz. Send 2 bytes: • Bytes 0 and 1 (16-bit value) = Sensor selection: ◦ 0 = Z'Scan II output sensor frequency (operating in the single frequency mode) ◦ 1 = Input sensor for Match network 1 ◦ 2 = Input sensor for Match network 2 ◦ 4 = Reserved ◦ 5 = Reserved ◦ 7 = Primary sensor for dual output sensor, or output sensor if your unit has a single output sensor ◦ 8 = Secondary sensor for dual output sensor Returns 4 bytes (32-bit value) = Nominal measurement frequency in kHz Set with command **77**.	2	4

Table 3-17. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
148 **Report target impedance**	Reports the real and imaginary components of the target impedance for the selected match network. Send 1 byte to select the match network: • Byte 0 (8-bit value) = ◦ Bits 0 through 3 = Always send 0 ◦ Bits 4 and 5 = Match network selection: ▪ 1 = Match network 1 ▪ 2 = Match network 2 ◦ Bits 6 and 7 = Always send 0 Returns 5 bytes (one 8-bit and two 16-bit values), least significant byte first: • Byte 0 = The match network for the parameter being returned (see send byte 0) • Bytes 1 and 2 = The real part of the target impedance (r_target). Reports a converted value (ohms * 20.48). For example, for 50 Ω the command returns a value of 1024. The effective range is 25 Ω to 100 Ω. • Bytes 3 and 4 = The imaginary part of the target impedance (x_target). Reports a converted value (ohms * 20.48). For example, for 50 Ω the command returns a value of 1024. The effective range is - 50 Ω to 50 Ω. Set with command **78**	1	5
152 **report autotune setup (NV)**	Reports the automatic tuning parameters for the selected match network. Send 1 byte to select the match network and the requested tuning parameter: • Byte 0 (8-bit value) = Select the match network and tuning parameter: ◦ Bits 0 through 3 = Tuning parameter selection: ▪ 0 = Converted VSWR tuning stop value ▪ 1 = Converted VSWR tuning start value ▪ 2 and 3 = Reserved	1	3

Table 3-17. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	▪ 4 = Maximum load percent capacitor position ▪ 5 = Reserved ▪ 6 = Maximum tune percent capacitor position ▪ 7 = Minimum tune percent capacitor position ▪ 8 = Magnitude→load cross dependence coefficient (converted) ▪ 9 = Phase→load cross dependence coefficient (converted) ▪ 10 = Magnitude→tune cross dependence coefficient (converted) ▪ 11 = Phase→tune cross dependence coefficient (converted) ▪ 12 = Send a value of 0 = VSWR tuning start/stop ▪ 13 = Hold load mode ▪ 14 = Integrated value of gamma, which determines whether automatic tuning should start again ◦ Bits 4 and 5 = Match network selection: ▪ 1 = Match network 1 ▪ 2 = Match network 2 ◦ Bits 6 and 7 = Always send 0 Returns 3 bytes (three 8-bit values), least significant byte first: • Byte 0 = The match network and parameter being returned (see send byte 0) • Bytes 1 and 2 = Value for the selected parameter ◦ Capacitor positions = Reported in hundredths of a % The automatic tuning algorithm uses these parameters to assist in capacitor movement control.		

Table 3-17. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	◦ VSWR values = converted VSWR values. 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: First, calculate gamma: $\sqrt{2/1024} = 0.044194$ Second, calculate VSWR: $1.09247 = \frac{1 + 0.044194}{1 - 0.044194}$ ◦ Cross dependence coefficients = These values 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. ◦ Algorithm number = 0 for VSWR tuning start/ stop ◦ Integrated value of gamma = Always 0 to indicate no integration Set with command **82**.		

Table 3-17. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
154 **report capacitor limits (NV)**	Reports the minimum and maximum positions for the tune and load capacitors (which are used by the tuning algorithm) for the selected match network. Send 1 byte to select the match network: • Byte 0 (8-bit value) = Select the match network and tuning range parameter: ◦ Bits 0 through 3 = Tuning range parameter selection: ▪ 0 = Minimum load percent capacitor position (in hundredths of a %) ▪ 1 = Minimum tune percent capacitor position (in hundredths of a %) ▪ 2 = Maximum load percent capacitor position (in hundredths of a %) ▪ 3 = Maximum tune percent capacitor position (in hundredths of a %) ◦ Bits 4 and 5 = Match network selection: ▪ 1 = Match network 1 ▪ 2 = Match network 2 ◦ Bits 6 and 7 = Always send 0 Returns 3 bytes (three 16-bit values), least significant byte first: • Byte 0 = The match network and parameter being returned (see send byte 0) • Bytes 1 and 2 (16-bit value) = The tuning range in hundredths of a % Set with command **84**.	1	3
160 **report presets/ trajectories (NV)**	Reports one of up to ten initial preset positions and, if used, corresponding trajectory points for the selected match network. Send the command multiple times to read all presets and trajectories. Send 2 bytes: • Byte 0 (8-bit value) = Select the match network and preset parameter:	2	5

Table 3-17. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	◦ Bits 0 through 3 = Select the preset value you want returned: ▪ 0 = Return the preset number most recently set in command **92**) ▪ 1 = Trajectory count ▪ 2 = Initial position for the load capacitor ▪ 3 = Initial position for the tune capacitor ▪ 4 = First trajectory position on load capacitor ▪ 5 = First trajectory position on tune capacitor ▪ 6 = Second trajectory position on load capacitor ▪ 7 = Second trajectory position on tune capacitor ▪ 8 = Third trajectory position on load capacitor ▪ 9 = Third trajectory position on tune capacitor ◦ Bits 4 and 5 = Match network selection: ▪ 1 = Match network 1 ▪ 2 = Match network 2 ◦ Bits 6 and 7 = Always send 0 • Byte 1 (8-bit value) = Preset number of the trajectory and capacitor values you want reported (1 through 10). If you sent 0 in bits 0 through 3 of byte 0, then this value is ignored. Returns 5 bytes: ☞ **Important** Capacitor positions are reported in hundredths of percent of potential capacitor position (1000 = 10%). • Byte 0 (8-bit value) = The match network and parameter being returned (see send byte 0) • Bytes 1 and 2 (16-bit value) = Preset number requested (possible values are 1 through 10)		

Table 3-17. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	• Bytes 3 and 4 (16-bit value) = Value of the requested parameter. The value depends on the parameter requested: ◦ Preset = Value of the preset number set in command 92 ◦ Trajectory = Possible values are 1 through 3 ◦ Capacitor positions = Value, in hundredths of percent of potential capacitor position, of the requested parameter. For related readbacks, see commands **161**, **164**, **167**, and **170**. Set with command **92**.		
161 **report selected preset (NV)**	Reports the preset/trajectory set that is currently selected for the match network identified in the send bytes. Send 1 byte to select the match network: • Byte 0 (8-bit value) = Select the match network: ◦ Bits 0 through 3 = Always send 0 ◦ Bits 4 and 5 = Match network selection: ▪ 1 = Match network 1 ▪ 2 = Match network 2 ◦ Bits 6 and 7 = Always send 0 Returns 3 bytes (three 16-bit values), least significant byte first: • Byte 0 = The match network for the preset being returned (see send byte 0) • Bytes 1 and 2 (16-bit value) = The active preset (1 through 10 for the selected match network) For related readbacks, see commands **160**, **164**, **167**, and **170**. Set with command **91**.	1	3
162 **report process status**	Reports the process status for the match networks. If your unit is a single match, the bits for Match network 1 apply. If your unit is a dual match, the bits for Match network 1 and Match network 2 apply. If your unit is a triple match, all the bits described here apply.	0	4

Table 3-17. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	Returns 4 bytes (bit flags). When a bit is set, it indicates that associated status is true: Byte 0: • Bit 0 = Match network 1: Output is on • Bit 1 = Match network 1: Output is tuned • Bit 2 = Match network 2: Output is on • Bit 3 = Match network 2: Output is tuned • Bits 4 and 5 = Reserved • Bit 6 = Match network 1: Presets are active • Bit 7 = Match network 1: External presets are selected (available only on units with the **User** port) Byte 1: • Bit 0 = Low 24 V supply is detected • Bit 1 = Overtemperature is detected • Bit 2 = Interlock open • Bit 3 = Fan fault • Bit 4 = Match network 1: In automatic tune mode • Bit 5 = Match network 1: In host control mode • Bit 6 = Match network 2: In automatic tune mode • Bit 7 = Match network 2: In host control mode Byte 2: • Bit 0 = Auxiliary capacitor: Output is tuned • Bit 1 = Auxiliary capacitor: In automatic tune mode • Bit 2 = Auxiliary capacitor: Presets are active • Bits 3 and 4 = Reserved • Bit 5 = Match network 1: In user control mode • Bit 6 = Match network 2: In user control mode • Bit 7 = Reserved Byte 3:		

Table 3-17. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	• Bit 0 = One or more active or latched faults exists Use command **223** to report the list of current faults. • Bit 1 = One or more active warnings exist • Bit 2 = A motor failed to initialize • Bit 3 = Match network 2 presets are active • Bit 4 = Match network 2 external presets are selected (available only on units with the **User** port) • Bit 5 = Voltage over limit fault • Bits 6 and 7 = Reserved		
163 **report control mode (NV)**	Reports the control mode for the selected match network. Send 3 bytes to select the match network: • Byte 0 (8-bit value) = Select the match network: ◦ Bits 0 through 3 = Always send 0 ◦ Bits 4 and 5 = Match network selection: ▪ 1 = Match network 1 ▪ 2 = Match network 2 ◦ Bits 6 and 7 = Always send 0 Returns 3 bytes (three 16-bit values), least significant byte first: • Byte 0 = The match network for the control mode being returned (see send byte 0) • Bytes 1 and 2 (16-bit value) = Control mode: ◦ 0 = User control mode ◦ 1 = Automatic tune mode ◦ 2 = Host control mode Set with command **93**.	1	3

Table 3-17. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
164 **report preset status (NV)**	Reports whether the currently active preset is enabled or disabled for the selected match network. Send 1 byte to select the match network. • Byte 0 (8-bit value) = Match network selection: ◦ Bits 0 through 3 = Always send 0 ◦ Bits 4 and 5 = Match network selection: ▪ 1 = Match network 1 ▪ 2 = Match network 2 ◦ Bits 6 and 7 = Always send 0 Returns 3 bytes (three 16-bit values), least significant byte first: • Byte 0 = The match network for the preset status being returned (see send byte 0) • Bytes 1 and 2 (16-bit value) = Preset status: ◦ 1 = Enabled ◦ 0 = Disabled For related readbacks, see commands **160**, **161**, **167**, and **170**. Set with command **94**.	1	3

Table 3-17. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
167 **report internal/ external preset select status (NV)**	Reports whether the selected match network is set to use either internal or external presets. Send 1 byte to select the match network: • Byte 0 (8-bit value) = Select the match network: ◦ Bits 0 through 3 = Always send 0 ◦ Bits 4 and 5 = Match network selection ▪ 1 = Match network 1 ▪ 2 = Match network 2 ◦ Bits 6 and 7 = Always send 0 Returns 3 bytes (three 16-bit values), least significant byte first: • Byte 0 = The match network selected (see send byte 0) • Bytes 1 and 2 (16-bit value) = Preset select status ◦ 0 = Internal ◦ 1 = External For related readbacks, see commands **160**, **161**, **164**, and **170**. Set with command **97**.	1	3

Table 3-17. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
168 **report motor status**	Reports whether motor movement is enabled or disabled. Send 1 byte (8-bit value): • Byte 0 = Select the motor (allowable values are 1 through 5): ◦ 1 = Motor for Match network 1 tune capacitor ◦ 2 = Motor for Match network 2 tune capacitor. If the unit is a single match and contains an auxiliary capacitor, this selects the motor for the auxiliary capacitor. ◦ 3 = Motor for Match network 1 load capacitor. ◦ 4 = Motor for Match network 2 load capacitor ◦ 5 = If the unit is a dual match and contains an auxiliary capacitor, this selects the motor for the auxiliary capacitor. Returns 3 bytes (three 8-bit values), least significant byte first: • Byte 0 = Selected motor (1 through 5) • Bytes 1 and 2 = Report motor status: ◦ 0 = Motor movement enabled ◦ 1 = Motor movement disabled Set with command **98**.	1	3
170 **report presets/ trajectory delays (NV)**	Reports any one of the initial preset delays and its associated trajectory delays for the selected match network. All delays are reported in hundredths of seconds (for example, 250 = 2.5 s). A delay of 0 indicates the delay is disabled. Send 2 bytes to select the match network. • Byte 0 (8-bit value) = Select the match network and the desired parameter: ◦ Bits 0 through 3 = Parameter to read: ▪ 0 = Return the preset most recently set in command **100** ▪ 1 = Number of trajectories defined	2	5

Table 3-17. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	▪ 2 = Reserved ▪ 3 = Initial preset delay ▪ 4 = First trajectory delay ▪ 5 = Second trajectory delay ▪ 6 = Third trajectory delay ◦ Bits 4 and 5 = Match network selection: ▪ 1 = Match network 1 ▪ 2 = Match network 2 ◦ Bits 6 and 7 = Always send 0 • Byte 1 (8-bit value) = Preset number of the preset delay you want reported (1 through 10). If you sent 0 in bits 0 through 3 of byte 0 (report preset most recently set), then this value is ignored. Returns 5 bytes (one 8-bit and two 16-bit values), least significant byte first: • Byte 0 = The match network and parameter being returned (see send byte 0) • Bytes 1 and 2 (16-bit value) = Preset number requested (see send byte 1) • Bytes 3 and 4 (16-bit value) = Value of the requested parameter. The value depends on the parameter requested: ◦ Preset = Value of the preset number set in command **100** ◦ Number of trajectories = Possible values are 1 through 3 ◦ Trajectory delays = Value, in hundredths of seconds, of the requested parameter. For related readbacks, see commands **160**, **161**, **164**, and **167**. Set with command **100**.		

Table 3-17. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
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. Send 1 byte to select the motor pair: • Byte 0 (8-bit value) = Select byte. Use this to select the motor pair: ◦ Bits 0 through 3 = Always send 0 ◦ Bits 4 and 5 = Motor pair selection ▪ 1 = Load/tune motor pair for Match network 1 ▪ 2 = Load/tune motor pair for Match network 2 ◦ Bits 6 and 7 = Always send 0 Returns 5 bytes (one 8-bit and two 16-bit values), least significant byte first: • Byte 0 = The motor pair selected (see send byte 0) • Bytes 1 and 2 (16-bit value) = Load capacitor position • Bytes 3 and 4 (16-bit value) = Tune capacitor position Set with command **124**.	1	5
185 **report sensors calculated data**	Calculates r, x, gamma, and power for the specified sensor on the selected match network. Send 2 bytes: • Byte 0 (8-bit value) = Select the match network and calculation value: ◦ Bits 0 through 3 = Calculation value selection: ▪ 0 = R and X impedance ▪ 1 = Gamma and power ◦ Bits 4 and 5 = Match network selection: ▪ 1 = Match network 1 ▪ 2 = Match network 2	2	5

Table 3-17. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
	◦ Bits 6 and 7 = Always send 0 • Byte 1 (8-bit value) = Sensor selection. Always send 0 to select the input sensor. Returns 5 bytes (one 8-bit and two 16-bit values), least significant byte first: • Byte 0 = The match network and calculation value being returned (see send byte 0 for the values) The content of bytes 1 through 4 depend on the requested calculation values in byte 0, bits 0 through 3: • If you set send byte 0 bits 0 through 3 = 0 (r and x impedance): ◦ Bytes 1 and 2 (16-bit value) = R (converted). This and the next value are converted. Two versions of the conversion equation: ▪ Ω = (readback value * 50)/1024 ▪ Readback value = (Ω * 1024)/50 ◦ Bytes 3 and 4 (16-bit value) = X (converted—see equation for bytes 1 and 2) • If you set send byte 0 bits 0 through 3 = 1 (gamma and power): ◦ Bytes 1 and 2 (16-bit value) = Gamma (converted). The readback value is converted. Two versions of the conversion equation: ▪ Gamma = square root of ((readback value)/1024) ▪ Readback value = ((gamma * gamma) * 1024) ◦ Bytes 3 and 4 (16-bit value) = Power in watts		

Table 3-17. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
198 **report software version**	Reports the software version number string for either the main processor application code or the FPGA code. Send 0 or 1 byte. Send 1 byte to select either the main processor application code or the FPGA code. If you send 0 bytes, the command will report the main processor application code. Send 1 byte to select either the main processor application code or the FPGA code. • Byte 0 (8-bit value) = Code revision selection: ◦ 0 = Main processor application code revision ◦ 1 or 2 = FPGA code revision ◦ 4 = Bootloader firmware code revision ◦ 6 = DeviceNet/PROFIBUS firmware code revision ◦ 7 = DeviceNet/PROFIBUS bootloader firmware code revision ◦ 8 = DeviceNet/PROFIBUS FPGA firmware part number ◦ 10 = Motor control board application code revision ◦ 11 = Motor control board FPGA code revision ◦ 12 = Motor control board bootloader firmware code revision Returns 3 bytes: • Byte 0 (8-bit value) = ASCII revision level letter • Bytes 1 and 2 (16-bit value) = ASCII revision level numerals See also command **130**.	1	3

Table 3-17. PROFIBUS commands (Continued)

Command	Description	Data Bytes Sent	Data Bytes Returned
208 **report digital switch capacitor position**	This command is valid for units with digital switching capability. Returns the switch position for the selected switch. Send 4 bytes: • Bytes 0 and 1 (16-bit value) = Match network selection: ◦ 1 = Match network 1 ◦ 2 = Match network 2 • Bytes 2 and 3 (16-bit value) = Switch selection (1 or 2) Returns 2 bytes (16-bit value) = Switch position Set with command **108**.	4	2
231 **report unit serial number**	Returns a non-terminated ASCII string that represents the serial number of the unit. Returns 4 bytes (32-bit value) = The unit serial number (LSB first)	4	0
248 **report DC bias** (subcommand 10)	Supported on units with DC bias capability. Reports the DC bias. Send 2 bytes: • Bytes 0 and 1 (16-bit value) = 10 (subcommand number) Returns 2 bytes: • Bytes 0 through 1 (24-byte integer) = DC bias in volts	2	2

DEVICENET™ INTERFACE

The DeviceNet system enables basic control of the Navigator II unit through a 5-pin **DeviceNet** port. The Navigator II unit operates as a GROUP 2 slave device on an established DeviceNet network in accordance with the Open DeviceNet Vendor Association (ODVA) DeviceNet specification (revision 2.0 or later). For questions specific to the DeviceNet system or for a copy of the DeviceNet specification,

consult either a DeviceNet network administrator or visit the ODVA web site at http://www.odva.org, where members can download the specification.

For additional information on the DeviceNet interface for your unit, you can request the AE DeviceNet interface specification from AE Global Services.

DeviceNet Port

The **DeviceNet** port is a round, five-pin, male micro connector.

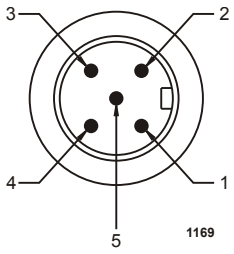


Figure 3-12. DeviceNet port

DeviceNet Port Pin Descriptions

Table 3-18. DeviceNet port pin descriptions

Pin Number	Pin Name
1	Drain
2	V+
3	V-
4	CAN_H
5	CAN_L

DeviceNet Control Panel

The DeviceNet control panel includes two LEDs that allow you to monitor DeviceNet communications and three rotary switches that allow you to set communication parameters.

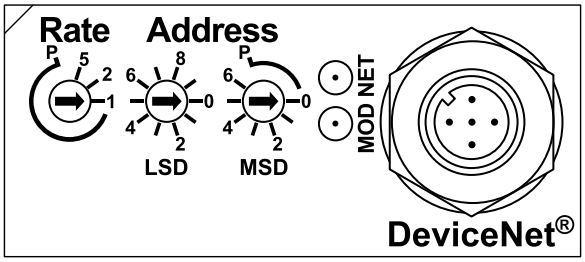


Figure 3-13. DeviceNet control panel

DEVICENET CONTROL PANEL LEDS

The DeviceNet control panel features two bicolor LEDs (light-emitting diodes). One LED is labeled **MOD** and indicates module status. The other LED is labeled **NET** and indicates network status.

DeviceNet Module Status (MOD) LED

The **MOD** bicolor (amber/green) LED provides device status, such as whether the device has power and is operating properly.

Table 3-19. DeviceNet module status (MOD) LED

LED Status	Indication	Unit Status
Off	No power	Unit is not receiving power.
Green (steady)	Operational	Unit is operating normally.
Green (flashing)	Standby	Unit requires maintenance because the configuration is missing, incomplete, or incorrect.
Amber (steady)	Unrecoverable fault	Unit has experienced a fault from which it cannot recover; you may need to cycle power.
Amber/Green (flashing)	Device self testing	Unit is running self diagnostics.

☞ **Important**

For further information on indicator flash rates, refer to the current DeviceNet specification (available to ODVA members from the ODVA web site at http://www.odva.org).

☞ **Important**

For further information about module status indications during power-up, refer to the current DeviceNet specification.

Network Status (NET) LED

The **NET** bicolor (amber/green) LED is the network status LED and indicates the status of the communication link.

LED Status	Indication	Unit Status
Off	No power	Unit is not online because • Unit has not completed the Dup_MAC_ID test • Unit is not receiving power (check the **MOD** LED)
Green (steady)	Link okay	Unit is online and allocated to the master.
Green (flashing)	Online, not connected	Unit is online but has no connections in its existing state because • Unit has not established connections to other nodes • Unit is not allocated to the master
Amber (flashing)	Connection time-out, critical link failure	One or more I/O connections are in the timed-out state.
Amber (steady)	Critical link failure	Communication has failed (that is, the unit has detected an error that has made it incapable of communicating on the network). If you have a unit configured with two DeviceNet cards, the cause of this failure may be: • The two DeviceNet cards are not set to the same data rate as the network • The two DeviceNet cards have the same node address

☞ **Important**
For further information on indicator flash rates, refer to the current DeviceNet specification (available to ODVA members from the ODVA web site at: http://www.odva.org).

CONTROL PANEL ROTARY SWITCHES

The DeviceNet control panel features three rotary switches to set the network address and communication data rate. Each time the DeviceNet interface is energized, the DeviceNet master reads the switch settings.

Data Rate Rotary Switch

Use the **DATA RATE** switch to select a communication baud rate:

- 0 = 125 kbits per second
- 1 = 250 kbits per second

- 2 = 500 kbits per second

The default is 500 kbits per second. A switch setting in the **P** or **PGM** region allows the DeviceNet master to set the baud rate for the unit.

Node Address Rotary Switches

Use the **NODE ADDRESS** rotary switches, **MSD** (most significant digit) and **LSD** (least significant digit), to select the DeviceNet network address (MAC ID). MAC IDs 0 through 63 are valid. Use the **MSD** switch to select the MAC ID's most significant digit; use the **LSD** switch to select the MAC ID's least significant digit. Switch settings greater than 63 (or in the **P** or **PGM** region of the **MSD** switch) allow you to set the MAC ID through the DeviceNet master.

USER PORT

The **User** port is included on some models of the Navigator II match network. When present, this port provides analog and digital signals for controlling and monitoring the unit. To determine whether a unit has this interface, you can check for a **User** port on the unit itself.

The **User** port is a shielded, subminiature-D connector. The number of pins on the connector varies by model. Analog signals on this port typically have a range from -10 V to +10 V, with the actual range varying by model. All digital output signals are 0 V to 24 V, open collector signals with separate return lines referenced to ground. All digital input signals must be driven high. The threshold for a logical high varies by model. For detailed **User** port signal information, see the product specification for your model.

The cable that connects the Navigator II match network **User** port to the system controller must be a shielded I/O cable. Shielded twisted-pair wiring is optional. Keep the cable length as short as possible to minimize signal losses. 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 Navigator II match network must be tied to a local earth ground through an adequately sized copper grounding strap.

ETHERNET INTERFACE

The Navigator II unit provides an Ethernet communications interface that allows the unit to communicate with a host computer. The interface consists of an RJ45 port (labeled **Ethernet** on your unit) and the AE TCP protocol, which uses function code (FC) 100.

Ethernet Connector and Indicators

You can control the Navigator II unit through a network using an Ethernet Modbus/TCP connection. This connection is mounted directly on the CPU module.

Important

The Navigator II unit supports a Modbus/TCP connection to port 502. For more information about the Modbus/TCP protocol, visit the Modbus Users Web Site at: www.modbus.org.

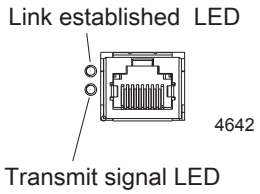


Figure 3-14. Ethernet connector and indicators

The two LEDs next to the Ethernet connector communicate when the unit is transmitting data and if the Ethernet link has been established.

- The Transmit Signal (yellow) LED lights and flashes when the unit is actively transmitting. The LED is off (not lit) when no data is being transmitted.
- The Link Established (green) LED is on (is lit and steady) when the Ethernet link has been established with the unit. The LED is off when no link has been established with the unit.

Ethernet Port Pin and Signal Descriptions

Table 3-20. Ethernet port pin and signal descriptions

Signal Pin	Pin Name	Description
1	*TX*+	Transmit data +
2	*TX*–	Transmit data –
3	*RX*+	Receive data +
4	Unassigned	Not connected
5	Unassigned	Not connected
6	*RX*–	Receive data –
7	Unassigned	Not connected
8	Unassigned	Not connected

AE TCP Protocol (FC100)

The AE TCP protocol is a method for communicating with an AE product using a network connection. It uses Modbus/TCP as a transport for AE Bus commands. The power supply acts as a server while the host or tool program communicating with the unit acts as a client. The power supply listens for requests for TCP connections on registered port 502. Port 502 is assigned to Modbus/TCP protocol. The power supply can support up to six simultaneous TCP connections.

Modbus user-defined function code FC100 encapsulates AE Bus commands and data into Modbus/TCP packets. FC100 functions according to the Modbus/TCP standard (go to http://www.modbus.org for more information). You can use FC100 to run all common commands.

ESTABLISHING A CONNECTION

To establish a TCP connection, the host or tool program (client) connects to TCP port 502. If the number of already established connections exceeds the predefined limit for the given equipment, the connection is rejected.

Once the connection is established, the client may perform multiple transactions consisting of the following two steps:

1. The client sends a request containing an AE Bus command to be executed by the Navigator II unit (server).
2. The server executes the AE Bus command and returns a packet containing the unit's reply to the command (CSR and data).

☞ **Important**

For optimum performance, keep the TCP connection open during continuous operation. Opening and closing a connection for each command transaction will result in poor communication performance.

DATA ENCODING

Each Modbus/TCP message packet consists of two sections: A Modbus Application Protocol (MBAP) header and a protocol data unit (PDU).

The MBAP header contains the following information:

- Transaction ID (2 bytes)
- Protocol ID (2 bytes)
- Length (2 bytes)
- Unit ID (1 byte)

Following the MBAP header, the PDU consists of the following information:

- Function code (1 byte)
- Command number (1 byte)

- Command status response (CSR; 1 byte) All commands and responses include a CSR byte.
- Data length (2 bytes).
- Data bytes (as many as 248).

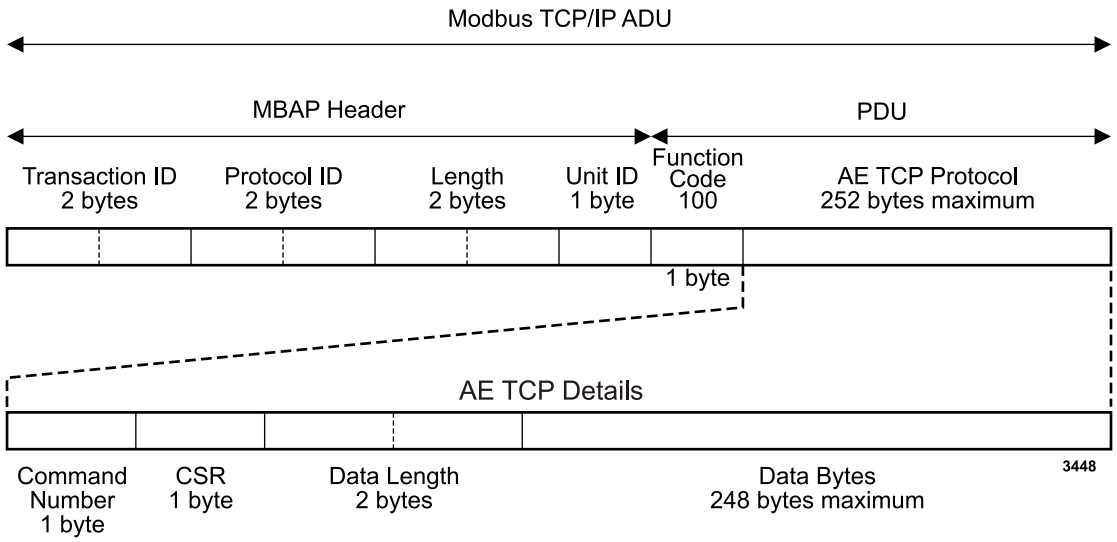


Figure 3-15. Data encoding for AE TCP using FC100

The Modbus/TCP protocol uses big endian (most significant byte first) architecture. The AE TCP portion of each packet uses little endian (least significant byte first) architecture.

To remain compliant with Modbus/TCP protocol, the PDU size must be no larger than 253 bytes.

Using AE FC100

FC100 allows you to send any Navigator II AE Bus command through the Ethernet interface, providing complete control of the system.

FC100 SEND PACKET FORMAT

Table 3-21. Format for FC100 send packet

Byte Numbers	Purpose	Value To Send
MBAP		
0 and 1	Transaction ID	Not used (value is copied into reply)

Table 3-21. Format for FC100 send packet (Continued)

Byte Numbers	Purpose	Value To Send
2 and 3	Protocol ID	0
4 and 5	Number of bytes following	Count of bytes in packet (starting with byte 6)
6	Unit ID	Address of unit. • Unit ID ◦ 1 = Normal operation ◦ 2 to 255 = Reserved
PDU		
7	Function code	100 = 0x64
8	AE command number	AE Bus command number
9	CSR	Send packets do not use the CSR byte; it may be set to 0.
10 and 11	Data length	Number of AE TCP data bytes in the packet
12 and up	Data bytes	Data bytes contained in the command packet. ☞ **Important** All bytes in the PDU (byte 8 to end of packet) are in little endian order (least significant bytes first).

FC100 RESPONSE PACKET

Table 3-22. Format for FC100 response packet

Byte Numbers	Purpose	Value To Send
MBAP		
0 and 1	Transaction ID	Not used (value is copied from send packet)
2 and 3	Protocol ID	0
4 and 5	Number of bytes following	Count of bytes in packet (starting with byte 6)

Table 3-22. Format for FC100 response packet (Continued)

Byte Numbers	Purpose	Value To Send
6	Unit ID	Identity of unit: • Unit ID ◦ 1 = Normal operation ◦ 2 to 255 = Reserved
PDU		
7	Function code (100)	0x64
8	AE command number	AE Bus command number
9	CSR	CSR byte (always returned):
10 and 11	Data length	Total number of data bytes in the packet
12 and up	Data bytes	Data bytes contained in the command packet ☞ **Important** All bytes in the PDU (byte 8 to end of packet) are in little endian order (least significant bytes first).

FC100 ERROR PACKETS

If the communication from host to power supply encounters no problems, the power supply sends CSR 0 (command accepted). If something goes wrong in the communication to the power supply, you receive one of these two notifications:

- Modbus/TCP error packet: The Modbus/TCP protocol issues an exception error packet
- CSR packet: The Navigator II unit replies to commands with a CSR packet.

Table 3-23. Format for FC100 Modbus/TCP exception error packet

Byte Numbers	Purpose	Response Value
0 and 1	Transaction ID	Not used (value is copied from send packet)
2 and 3	Protocol ID	0
4 and 5	Number of bytes following	Count of bytes in packet (starting with byte 6)
6	Unit ID	Unit identifier
7	Function code	228 = 0xE4

Table 3-23. Format for FC100 Modbus/TCP exception error packet (Continued)

Byte Numbers	Purpose	Response Value
8	Exception code	One of many available exception codes

Table 3-24. Format for FC100 CSR packet

Byte Numbers	Purpose	Response Value
0 and 1	Transaction ID	Not used (value is copied from send packet)
2 and 3	Protocol ID	0
4 and 5	Number of bytes following	Count of bytes in packet (starting with byte 6)
6	Unit ID	Unit identifier
7	Function code	100 = 0x64
8	Command	AE Bus command number
9	CSR	One of many CSR codes
10 and 11	Data length	0

FC100 EXAMPLE

Refer to the following information for an example that illustrates using AE Bus command 14 to read back power, voltage, and current from the power supply using the AE TCP connection with FC100.

Table 3-25. Packet format for command 112 send

Byte Numbers	Send Value	Purpose
0 and 1	0x00, 0x00	Transaction ID (any value, increment each time a command is sent)
2 and 3	0x00, 0x00	Protocol ID
4 and 5	0x00, 0x0A	Number of bytes following (count of bytes in packet starting with byte 6)
6	0x01	Unit ID
7	0x64	Function code (100 = 0x64)
8	0x70	AE Bus command number = 112
9	0x00	CSR = Reserved

10 and 11	0x04, 0x00	Data length = 1 End of packet—no data bytes exist in this command.
12 and 13	0x01, 0x00	Command data: 1 = Match network frequency 1
14 and 15	0xE8, 0x03	Load capacitor position = 10%

This table illustrates the response packet for command 112.

Table 3-26. Packet format for command 112 response

Byte Numbers	Send Value	Purpose
0 and 1	0x00, 0x00	Transaction ID (echo of transaction sent)
2 and 3	0x00, 0x00	Protocol ID
4 and 5	0x00, 0x06	Number of bytes following (count of bytes in packet starting with byte 6)
6	0x01	Unit ID
7	0x64	Function code (100 = 0x64)
8	0x70	AE Bus command number = 112
9	0x00	AE command status response = CSR value
10 and 11	0x00, 0x00	Number of data bytes in response

Installation, Setup, and Operation

PREPARING TO INSTALL THE UNIT

Spacing Requirements

The unit spacing requirements vary by model. For model-specific information, see the product specifications for your unit.

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.

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 Navigator II match network is either air or water cooled, depending on the model. Ensure that all cooling specifications are met. Also, for air-cooled models,

ensure that exhausted air does not circulate back into the unit and affect input air flow.

In water-cooled systems, the cooling system contains copper, silver, and brass parts. Using water or coolant that contains materials that are corrosive to copper, silver, and brass may damage the cooling system and void the warranty.

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 Navigator II 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 Navigator II Match Network

Mount the Navigator II match network using the following guidelines:

- Mount the match network as close as possible to the vacuum chamber, leaving room to access all connectors. Unit dimensions vary by model. For model-specific information, see the product specifications for your unit.
- Ensure the unit will remain within the specified operating temperatures.
- Mounting points vary by model. For model-specific information, see the product specifications for your unit.
- Ensure that exhausted air does not circulate back into the unit and affect input air flow.

- Ensure that the tool is cool before mounting.

> **CAUTION:**
> Do not mount on hot tool; excessive temperatures can cause components to overheat and fail.

- Ensure that all removable panels are closed and secure.

Connecting RF Output

RF output connections vary by unit. For model-specific information, see the product specifications for your unit.

To Ground the Unit

> **WARNING:**
> Do not attempt to turn on power until the Navigator II 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.

- 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 typical connectors for a Navigator II match network. Your unit may not have all of the illustrated connectors. The power connector also varies by model. For model-specific information, see the product specifications for your unit.

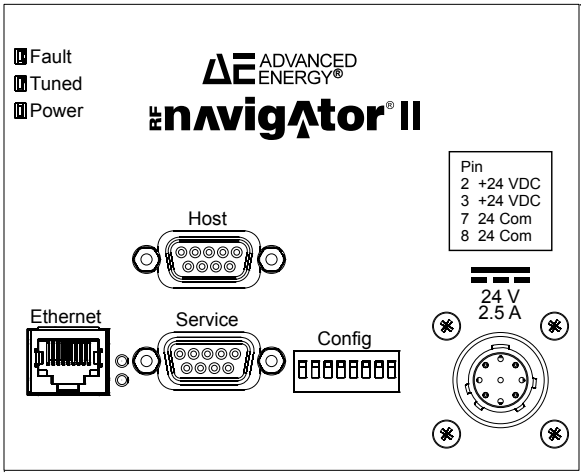


Figure 4-1. *Example Navigator II match network connectors*

To Connect the Water Line

Some units are water cooled. For model-specific information, see the product specifications for your unit.

The cooling system contains copper, silver, and brass parts. Using water or coolant that contains materials that are corrosive to copper, silver, and brass may damage the cooling system and void the warranty.

1. Install the user-supplied water line to the marked inlet and outlet connectors.

> **CAUTION:**
> **When fastening the water hose, be sure the bulkhead does not rotate; this could cause internal damage to the unit.**

2. Leak-check the water connections.

Power Supply Connection

The power supply connection varies by model. For model-specific information, see the product specifications for your unit. For products with a 24 VDC power supply, the following general recommendations apply.

24 VDC POWER SUPPLY RECOMMENDATIONS

AE recommends the use of universal power supplies (85 VAC – 264 VAC to 24 VDC) with the Navigator II 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 Navigator II 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.

To determine which table applies for your unit, see the input power maximum current electrical specification for your unit.

Table 4-1. *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′)

Table 4-2. *Wire recommendations for 24 VDC power supply (5 amp draw)*

Wire Gauge	Wire Run Length (5 Amp Draw)
24	1.8 m (6′)
22	3.0 m (10′)
20	4.3 m (14′)
18	7.3 m (24′)
16	11.9 m (39′)
14	19.2 m (63′)

Table 4-3. Wire recommendations for 24 VDC power supply (7 amp draw)

Wire Gauge	Wire Run Length (7 Amp Draw)
24	1.4 m (4.5′)
22	2.1 m (7′)
20	3.0 m (10′)
18	5.2 m (17′)
16	8.5 m (28′)
14	13.7 m (45′)

Connecting RF Input

The RF input connector for the Navigator II match network varies by model. For information about the input connector on a specific unit, see the specifications for that unit.

Connect the RF input using the guidelines shown in this table. Some models may have additional installation requirements.

Table 4-4. RF input installation guidelines

Category	Guidelines
Connector	Varies with model
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 1-6

• “Match Network Interlocks” on page 1-7

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 Navigator II Match Network for the First Time

1. Power on the unit.
2. For water-cooled models, ensure that water is flowing at or above the specified minimum value. For air-cooled models, ensure that the cooling fan is operating. Fans are not installed on all units (see the product specification).
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. The interlock opens while the motors initialize; you can monitor the interlocks on the generator if the unit is connected to the generator.
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. Ensure the interlocks close after initialization.

   If the interlocks remain open, refer to the interlock information for the unit.
7. For first-time use, verify that the Navigator II 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 Navigator II 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.

8. 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 ≤1% reflected power within a defined forward power level.

9. Check for plasma. If you encounter any of the problems noted here, see the Navigator II 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

10. 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.

11. 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 Navigator II 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

- "LED Indicators" on page 4-9
- "Navigator II Control Modes" on page 4-9
- "Measurement System Operation" on page 4-11
- "Presets" on page 4-20
- "Adjusting Tuning Parameters" on page 4-21
- "Default (Typical) Tuning Parameters" on page 4-27
- "Solid State Digital Switched Capacitors" on page 4-27
- "Splitter, Termination, and Auxiliary Capacitor Operation" on page 4-28
- "Maintenance" on page 4-29

LED INDICATORS

The LED indicators (most units) on the Navigator II match network provide basic status information about the match network's operation, as described in the following table. For the list of unit-specific LEDs, see the unit specification.

Table 4-5. LED indicators

LED Name	LED Color	Description of States
Power	Green	When lit, this LED indicates that the match network is receiving DC input. When not lit, this LED indicates that the match network is not receiving DC power.
Tuned	Green	When lit, this LED indicates that the match network is currently tuned. When not lit, this LED indicates that the match network is not currently tuned.
Fault	Amber	When lit, this LED indicates that one or more faults are active or latched. Use the troubleshooting information to manage these conditions. When not lit, this LED indicates that no faults are active or latched.

Related Links

- "Troubleshooting Guide" on page 5-1

NAVIGATOR II CONTROL MODES

The Navigator II 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 Navigator II match network internally controls the impedance matching functions.

Related Links

- "Automatic Tune Mode" on page 4-10
- "Host Control Mode" on page 4-10
- "User Control Mode" on page 4-11
- "Splitter, Termination, and Auxiliary Capacitor Operation" on page 4-28
- "Z'Scan II Output Sensor Operation" on page 4-13

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 Navigator II 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 Navigator II 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 Navigator II 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 Navigator II 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
- **User** port
- **DeviceNet** port

☞ **Important**
Only one preset is available when running exclusively with DeviceNet.

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
- **DeviceNet** port

When the Navigator II 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 **User** port. In user control mode, the automatic tune feature is disabled and capacitor position is controlled through the **User** interface port on the match network. You can set the unit to user control mode through AE Bus command **93**.

Note: User control mode is sometimes referred to as manual mode.

MEASUREMENT SYSTEM OPERATION

The Navigator II measurement system can include optional input, output, and auxiliary measurement sensors. All measurement sensors take voltage and/or current readings. Some sensors can also take impedance, power, phase or gamma, voltage, and current readings.

To determine if your unit has the option, refer to the unit product specification.

Using AE Bus commands or Virtual Front Panel software, you can set parameters and monitor input and output sensor data. To set and monitor the measurement data, you need to consider all of the following measurement system pieces:

- Data you want to measure
- Calibrated and fundamental frequencies
- Input and output sensors
- Frequency detection
- Pulse detection

Related Links

- "Setting and Monitoring Measurement System Data" on page 4-12
- "Z'Scan II Output Sensor Operation" on page 4-13
- "Input Sensor, Dual Output Sensor, and Single Output Sensor Operation" on page 4-15
- "Auxiliary Sensor Operation" on page 4-15
- "Frequency Detection and Calibrated Frequencies" on page 4-16
- "Pulse Detection" on page 4-16
- "Measurement System AE Bus Commands Summary" on page 4-18
- "Navigator II Product Identification Number (PIN)" on page 1-1

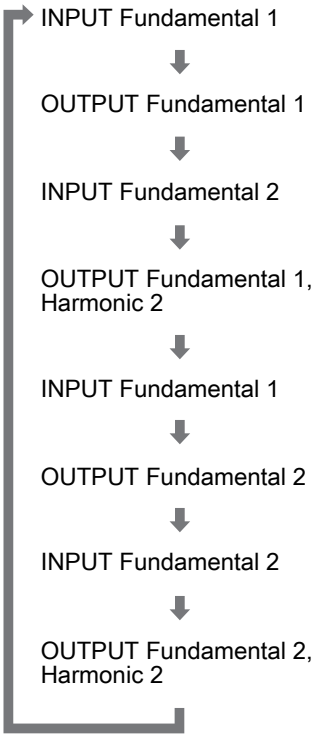
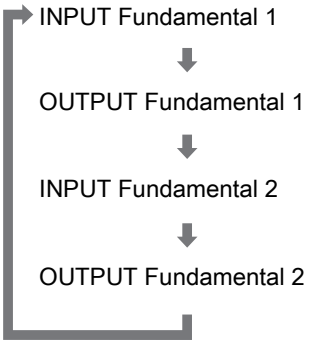
Setting and Monitoring Measurement System Data

The Navigator II continuously scans through all sensors at the requested frequencies as follows:

- Alternates between input and output sensors
- Cycles through each defined frequency in the sensors
- Scans with the following frequency:
  - Input sensors—Each input measurement is at most 3 scans old
  - Output sensor—Each output is measured every (2 * *Num_Frequencies_Defined*) scans
- The scan time is affected by:
  - Number of input sensors
  - Z'Scan II output sensor measurement mode and number of frequencies defined
  - Pulsing

  Frequency detection does not affect the measurement scanning time.

For example, if you have two input sensors and a Z'Scan II output sensor, the measurement system will update the measured values in the cyclic order shown below. These illustrations compare the measurements in full spectrum and fundamental measurement modes.

Full spectrum measurement mode with: • Two fundamental frequencies • One harmonic on each defined frequency	Fundamental measurement mode with: • Two fundamental frequencies
	

Z'Scan® II Output Sensor Operation

The Navigator II match network may include a Z'Scan II output sensor. To determine if your unit has the option, refer to the unit product specification.

The Z'Scan II output sensor is capable of being a full spectrum, full featured output sensor which can take measurements anywhere along the spectrum of 0 MHz to 200 MHz. This sensor collects output voltage, current, and phase data. The Z'Scan II system uses this data to calculate the resistance, reactance, and delivered power. The calibrated frequencies for your unit are in the unit specification.

Using the Z'Scan II output sensor, you can specify any frequency across the entire spectrum:

- If frequency detection is enabled, the sensor will detect the frequency within the calibrated range. When in Z'Scan II full spectrum measurement mode, the measurement system also calculates the 2nd and 3rd harmonic based on the detected fundamental frequency. Measurement data will be taken at each of these frequencies.

- If frequency detection is disabled, the Z'Scan II output sensor allows you to measure at any frequency along the full spectrum (0 MHz through 200 MHz). Measurement data will be taken at the specified frequencies.
- Frequencies that are calibrated at the factory will be measured with guaranteed accuracy.

The Z'Scan II RF sensor system provides user-selectable measurement modes:

- Single frequency mode—In this mode, a single, user-selectable frequency is continuously measured. Use this mode for single frequency Navigator II match networks to see the characteristics of only a single RF frequency; typically the Navigator II match network operational frequency. You can use this mode to explore different frequencies, one at a time.
- Fundamental frequency mode—In this mode, up to three user-selectable frequencies are used to take measurements. The Z'Scan II sensor system will alternate rapidly between measurements of these frequencies. You can use this mode for the following:
  - For dual frequency units, to measure the characteristics of the RF at each operational frequency of the match. This is the typical measurement mode to use for a dual frequency match network.
  - For single frequency units, if you want to measure the interactions of another RF frequency on the tool at the output of the match network.
- Full spectrum mode—In this mode, you can specify up to 12 frequencies at which to gather measurement data:
  - Up to three user-selectable fundamental frequencies.
  - Based on each fundamental frequency specified, the Z'Scan II sensor system determines the proper measurement frequencies for the second and third harmonics.
  - Up to three additional frequencies that do not need to be associated with fundamentals.

  During operation in this mode, the Z'Scan II rapidly cycles through measurements at each of the resultant frequencies. Use this mode to characterize the frequency content present in a plasma excited by two different RF frequencies.

Use the following AE Bus commands or the Virtual Front Panel software to set and report Z'Scan II output sensor parameters:

- To set the measurement mode, use command **118** subcommand 203
- To set the measurement frequency:
  - Use command **77** to set a single frequency for use in single measurement mode (report this frequency with command **147**)
  - Use command **118** subcommand 205 to set all the frequencies for use in full spectrum or fundamental mode (report these frequencies with command **248** subcommand 205)

- To report the detected frequency (if the unit is enabled for frequency detection) use command **248** subcommand 207 (single mode always uses index 0)
- To report the measured data use command **248** subcommand 206 (single mode always uses index 0)

Input Sensor, Dual Output Sensor, and Single Output Sensor Operation

The Navigator II match network may include one or more input or output sensors. To determine if your unit has the option, refer to the unit product specification.

The input and output measurement sensors take voltage and/or current readings. On some units the sensor can also take impedance, power, phase or gamma, voltage, and current readings.

Use the following AE Bus commands or the Virtual Front Panel software to set and report input and output sensor parameters:

- To set the measurement frequency, use command **77**
- To report the customer-specified frequency, use command **147**
- To report the detected frequency (if the unit is enabled for frequency detection) and the measured data use command **248** subcommand 201

Auxiliary Sensor Operation

The Navigator II match network may include one or more auxiliary sensors. To determine if your unit has the option, refer to the unit product specification.

Auxiliary sensors can measure voltage and/or current readings at up to two frequencies.

If the unit includes both a Z'Scan II output sensor and an auxiliary sensor, the auxiliary sensor frequencies are set to the Z'Scan II sensor frequencies as follows:

- Z'Scan II output sensor must be set to either fundamental or full spectrum mode
- If the auxiliary sensor is a single frequency sensor, it uses fundamental frequency 1 from the Z'Scan II frequency settings
- If the auxiliary sensor is a dual frequency sensor, it uses fundamental frequencies 1 and 2 from the Z'Scan II frequency settings

If the unit does not have a Z'Scan II sensor, the auxiliary sensor will use the frequencies calibrated at the factory.

To report auxiliary sensor detected frequency (if the unit is enabled for frequency detection) and the measurement data, use the Virtual Front Panel software or AE Bus command **248** subcommand 202.

Frequency Detection and Calibrated Frequencies

Frequency detection is available on some units. Calibrated frequencies are unit dependent. To determine if your unit has the option, refer to the unit product specification.

Navigator II match networks include one or more fundamental frequencies calibrated at the factory. The calibrated frequencies will typically include the input sensor calibrated fundamentals. Depending on the unit, a calibrated frequency is either a specific frequency or a frequency range.

If frequency detection is enabled at the factory, it can also be enabled/disabled by the customer as needed. Frequency detection (when enabled) applies to all measurement sensors on the Navigator II.

When frequency detection is enabled, the unit searches for the measurement frequency within a window determined by the frequency specification, then locks on to and measures the frequency.

To enable or disable frequency detection, use the Virtual Front Panel software or AE Bus command **118** subcommand 204.

Pulse Detection

Pulse detection (some units) applies to all measurement sensors on the Navigator II. To determine if your unit has the option, refer to the unit product specification.

Units configured with pulse detection can tolerate pulsing from the generator, and tune to a pulsed waveform. With pulsed RF input, the Navigator II electronics allow the tuning algorithm to react only during the on-time of RF pulse. Properly setting the pulsing parameters will result in minimal reflected power. Pulsing parameters include:

- Minimum duty cycle
- Minimum pulse frequency
- Voltage and current thresholds
- Time period to blank (ignore) at the beginning and end of the signal

Additional pulsing specifications are in the unit specification.

The minimum duty cycle and minimum pulse frequency affect the measurement system response time. The more accurately these parameters are set, the better the measurement scanning performance. Before attempting to tune, the system will wait for a maximum time, as calculated with the following equation:

MaximumTuneWaitTime (s) = (*#input_sensors* * (*output_sensors* +1) + *#auxiliary_sensors*) * *max_sensor_measurement_time*)

- *#input_sensors* = The number of input sensors on the unit
- *output_sensors* =

  - 0 if the unit does not include any output sensors
  - 1 if the unit includes any output sensors
- *#auxiliary_sensors* = The number of auxiliary sensors on the unit
- *max_sensor_measurement_time = minimum_pulse_duty_cycle (%) / minimum_pulse_frequency (Hz)*

  minimum_pulse_duty_cycle (%) and *minimum_pulse_frequency (Hz)* are set with AE Bus commands. The measurement system sets *max_sensor_measurement_time* to 0.14 s (140 ms) or the user-set *max_sensor_measurement_time*, whichever is less.

For example, if you have one input sensor and one output sensor:

- If the *max_sensor_measurement_time* = 100 ms, then the measurement system will use the user-set value of 100 ms: (1 * 2) * 100 ms = 200 ms maximum wait time for RF on detection.
- If the *max_sensor_measurement_time* = 150 ms, then the measurement system will use the maximum value of 140 ms: (1 * 2) * 140 ms = 280 ms maximum wait time for RF on detection.

The minimum sensor measurement time is shown in the unit specification as the measurement response time.

Power averaging thresholds and blanking periods are used together to determine the valid pulsing period.

- Power averaging thresholds determine the current and voltage channel noise floor. The thresholds are set at the factory based on the noise level of the analog-to-digital converter for your unit. You typically will not need to adjust the power averaging thresholds.
- Blanking periods specify the signal transition time to ignore.

If you find that you need to adjust the thresholds, use AE Bus command **118**, subcommand 209 as follows:

1. Set the generator to the lowest expected power.
2. Set both the current and voltage thresholds high enough that RF is no longer recognized by the match (100 is typically sufficient).
3. Reduce the level of either of the power averaging thresholds (voltage or current channel).
4. Continue reducing until the match recognizes RF on. This is the value to use for this channel.
5. Once you have determined this value for one channel, set the value back to high, and repeat for the other channel (voltage or current).

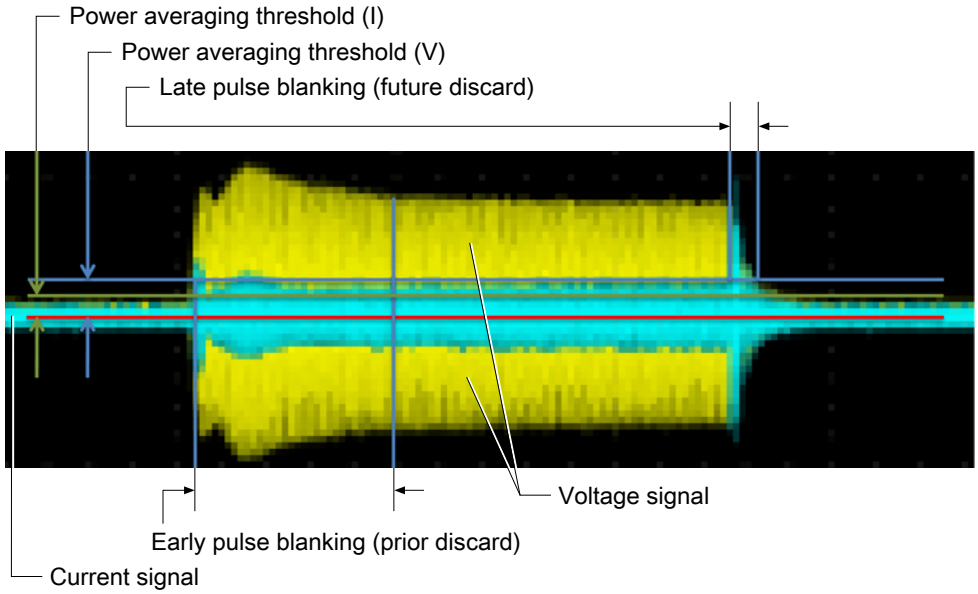
Once the power averaging thresholds are set, set the early and late pulse blanking periods. To do so, you will need an oscilloscope.

1. On the generator, turn on RF in continuous wave (CW) mode.

2. Use an oscilloscope to capture the current and voltage signals.
3. On the generator, turn on RF in pulsing mode.
4. Compare the pulsed signal to the CW signal, and determine the portion of the waveform to measure. Once you determine the valid signal period, you can identify the signal transition times to discard:
   - Early pulse (prior) blanking period
   - Late pulse (future) blanking period

   You will supply these times (in µs) to AE Bus command **118**, subcommand 209.

   For example:



To set the pulsing parameters, use the Virtual Front Panel software or AE Bus command **118** subcommands 208 and 209. Read back with command **248**, subcommands 208 and 209.

Measurement System AE Bus Commands Summary

Table 4-6. Measurement system AE Bus command summary

Task	Sensor				
	Input	Dual Output and Single Output	Z'Scan II Single Mode	Z'Scan II Full Spectrum and Fundamental Mode	Auxiliary
Set the frequency	**77**	**77**	**77**	**118** subcommand 205	Command currently not available for this sensor
Report the customer-specified frequency	**147**	**147**	**147**	**248** subcommand 205	Command currently not available for this sensor
Report the detected frequency (if frequency detection is enabled)	**248** subcommand 201	**248** subcommand 201	**248** subcommand 207 (always uses index 0)	**248** subcommand 207	**248** subcommand 202
Report measured data	**185** and **248** subcommand 201	**248** subcommand 201 (dual or single output sensor) or command **185** (single output sensor)	**248** subcommand 206 (always uses index 0)	**248** subcommand 206	**248** subcommand 202
Set and report measurement mode	This sensor does not include measurement modes	This sensor does not include measurement modes	Set: **118** subcommand 203 Report: **248** subcommand 203	Set: **118** subcommand 203 Report: **248** subcommand 203	This sensor does not include measurement modes
Set and report pulsing parameters	Set: **118** subcommands 208, 209 Report: **248** subcommands 208, 209				
Enable or disable frequency detection	Set: **118** subcommand 204 Report: **248** subcommand 204				

PRESETS

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. For a Navigator II match network that has the **User** port, there are two types of presets, external and internal. Units without the **User** port only provide internal presets. 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 4-7. Source of capacitor position when RF turns off

Preset Type	Automatic Mode	Host Control Mode	User Control Mode
Internal presets	Nonvolatile RAM	Not applicable	Not applicable
External presets	Analog interface	Host command (system or Virtual Front Panel software)	User interface
No presets	Last position	Last position	Not applicable

External Presets

External presets are presets set through the **User** port signals. Not all units include the **User** port and not all units with the **User** port allow you to set external presets. To determine if your unit has the option, refer to the unit product specification.

External presets do not allow you to set trajectories.

Internal Presets

The Navigator II match network can store up to ten 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 91 to select the active preset.
  - Use command 92 to set internal presets and trajectories.

  - Use command 94 to enable or disable presets.
  - Use command 97 to select internal or external presets.
  - Use command 100 to set preset and trajectory delays.
- **PROFIBUS** port (see command descriptions under the previous item)

Enabling and Disabling Presets

If you enable presets and the Navigator II 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 Navigator II 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 Navigator II 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 Navigator II match network for specific applications.

Navigator II match network capacitors can be moved by two different methods:

- Percentages of the capacitor range of movement

- Based on discrete switch positions

This section applies to units whose capacitors move based on percentage of the capacitor range of movement.

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.

The Navigator II match network offers the following tuning algorithms (set at the factory):

- Model-Based Adaptive (MBA)

  The MBA algorithm is based on a model of the match, independent of the load, which makes the tuning algorithm maximally efficient for each specific unit.

- Phase/Mag

  The Phase/Mag tuning algorithm is offered for backwards compatibility.

To determine if your unit has the option, refer to the unit product specification.

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

Related Links

- “Model-Based Adaptive (MBA) Tuning Parameters” on page 4-22
- “Phase/Mag Tuning Parameters” on page 4-25
- “Solid State Digital Switched Capacitors” on page 4-27
- “Navigator II Product Identification Number (PIN)” on page 1-1

Model-Based Adaptive (MBA) Tuning Parameters

The model-based adaptive (MBA) tuning algorithm is the default Navigator II tuning algorithm. It is faster and easier to use than the tuning algorithm used in older Navigator units. The MBA algorithm is based on a model of the match, independent of the load, which makes the tuning algorithm maximally efficient for each specific unit.

The MBA tuning algorithm uses the following parameters to tune the match:

- Capacitor limits (expressed as a percentage of the capacitor’s potential range of movement)

- VSWR Start/Stop
- Maximum load and tune capacitor step size (expressed as percentage as of the total range of capacitor movement)
- Target load and tune capacitor position (expressed as a percentage that defines the desired capacitor position)

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 Navigator II 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.

VSWR START AND STOP

These are the only parameters you will typically set for the MBA tuning algorithm.

☞ **Important**
For the MBA tuning algorithm, VSWR is true floating point and no conversion is needed. The phase/mag tuning algorithm used for older Navigator units required a conversion.

The VSWR start and stop settings are the values at which the Navigator II match network will start and stop automatic tuning.

The start/stop tuning values define the range over which the Navigator II match network considers the load to be tuned by setting the levels at which the unit will start and stop tuning. The MBA algorithm quickly tunes to the stop value and will not make adjustments in the tuning until the start value is encountered. The stop value must be set lower than the start value for the match network to operate correctly.

- The stop value sets the level at or below which the match is tuned (and at or below which it stops tuning).
- The start value sets the level above which the match starts tuning.

MAXIMUM STEP SIZE

The maximum load step size (in percent of capacitor movement) is the maximum distance that the load capacitor will move between VSWR measurements.

The maximum tune step size (in percent of capacitor movement) is the maximum distance that the tune capacitor will move between VSWR measurements.

Starting from the default values, the algorithm will automatically adjust the step size to best tune to the target. Do not change the parameter defaults unless you have one of the following situations:

- You have a high VSWR starting point
- When tuning, you overshoot the target VSWR

If you specify the maximum step size, the automatic tuning algorithm uses it to assist in capacitor movement control by limiting the maximum size of the movement step for each iteration of the calculation. The recommendation is to set it no greater than 15% to 20%. A higher step size value results in a larger movement. Optimizing the maximum step size can prevent wide oscillations in some setups where the tuning map is very steep.

TARGET POSITION

The target load position (in percent of capacitor movement) specifies a target point for the load capacitor within the VSWR < 5 tuning area.

The target tune position (in percent of capacitor movement) specifies a target point for the load capacitor within the VSWR < 5 tuning area.

Setting the target position is useful only if you know the approximate position of the capacitors at the final tuning point within VSWR < 5.

If you set the target position parameters, the capacitors will move in maximum step increments directly towards the target load and target tune positions as long as VSWR > 5. As soon as VSWR < 5, the MBA algorithm will become active and it will drive the capacitors to their final tuned position. You can disable this feature by setting both target load and tune values to 0.

USING PRESETS AND TRAJECTORIES WITH THE MBA TUNING ALGORITHM

As with the phase/mag algorithm, presets define the position that the capacitors move to when RF is turned off. Then, when RF turns on, the capacitors start from the preset positions. If a trajectory is defined, the capacitors will move through the trajectory points/delays before turning the process over to the automatic tuning algorithm.

When using the MBA algorithm, presets and trajectories are useful for igniting the load. However, additional presets and/or trajectories may increase the tuning time. Typically you will specify one initial preset which will be used at RF on to ignite the load, but will not use additional presets/trajectories to improve tuning performance because the MBA algorithm efficiently tunes to the VSWR start/stop range.

TYPICAL MBA SEQUENCE

Before automatic tuning, set a preset to ignite the load (optional) and set VSWR start and stop. If your installation requires you to constrain the algorithm, set a target load/tune percent and a maximum step size. A typical sequence might include the following steps:

1. Set the unit to automatic tuning mode.
2. If presets are enabled, capacitors move to the preset to allow ignition of the load.
3. Turn RF on.
4. The tuning algorithm tunes the match network as follows:
   - If you did not set the maximum step and target position parameters (recommended for most installations), the MBA tuning algorithm automatically tunes the match network per the assigned VSWR start and stop values.
   - If you set the maximum step and target position parameters, capacitors move directly towards the target percentage as long as VSWR > 5. When VSWR < 5, the MBA tuning algorithm takes over and drives the capacitors to their final tuned positions.

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 Navigator II 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 Navigator II match network will start and stop automatic tuning.

The start/stop tuning values define the range over which the Navigator II 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 Navigator II match network uses the magnitude and phase error values to control the load and tune capacitor movements.

In automatic tune mode, the Navigator II 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.

DEFAULT (TYPICAL) TUNING PARAMETERS

These parameters vary by model. For model-specific information, see the product specification for your unit. You can also read back the tuning parameter settings using AE Bus command **152**.

SOLID STATE DIGITAL SWITCHED CAPACITORS

Navigator II match network capacitors can be moved by two different methods:

- Percentages of the capacitor range of movement
- Based on discrete switch positions

This section applies to units whose capacitors move based on discrete switch positions.

On digital switched units, the capacitor moves based on discrete switch positions rather than percentages of the capacitor range of movement. For these units, the capacitor does not have a tuning algorithm; instead, the capacitor position is controlled by specifying the position. The unit must be in host or user control mode.

Capacitor movements are based on switch positions defined at the factory. For units that support digital switching capacitors, the unit specification will define the number of switch banks, specify which capacitor each bank switches, the number of switches available, and the switch positions.

AE Bus command **108** controls the capacitor.

If your unit uses a **User** port to control the capacitor, see the unit specification for the **User** port information.

Related Links

- “Adjusting Tuning Parameters” on page 4-21
- “Navigator II Product Identification Number (PIN)” on page 1-1

SPLITTER, TERMINATION, AND AUXILIARY CAPACITOR OPERATION

Some Navigator II units include one of the following types of auxiliary capacitors that can be automatically tuned:

- Splitter capacitor, which controls the current ratio between two outputs
- Termination capacitor, which filters a frequency on the output

Some Navigator II units include an auxiliary capacitor that can not be automatically tuned.

To determine if your unit has the option, refer to the unit product specification.

As with the tune and load capacitors, the tunable auxiliary capacitor can be controlled as follows:

- Automatic tuning or manual control

  This capacitor can be automatically tuned, or you can disable the automatic tuning and control the capacitor using either the user (some units) or host interface. Auxiliary capacitor control mode is set and controlled separately from the tune/load capacitor tuning. You can change the auxiliary capacitor control mode at any time.

- Automatic tuning parameters

  You can set a variety of parameters that affect how the capacitor tunes.

- Presets

  The Navigator II match network can store up to four preset positions for the auxiliary capacitor (one preset can be active). These presets define positions to which the capacitor can move when RF power is turned off. Using presets, you can enable fast tuning once RF is turned back on and automatic tune mode takes over. Presets for the capacitor are available only in auxiliary capacitor automatic tune mode when the preset function is enabled.

  If you enable auxiliary capacitor presets and the match is in auxiliary capacitor automatic tune mode, the active preset takes effect at the next RF-off event. If RF is already off, the auxiliary capacitor moves to the preset position when you enable the presets.

  Important
  If you disable presets, no preset position is applied, and the auxiliary capacitor remains in its current position when RF is turned off.

The non-tunable auxiliary capacitor customer-defined position is set at the factory. You can change the position of the capacitor, but you cannot use presets or automatic tuning.

On units that have an auxiliary capacitor, you can use either the Virtual Front Panel software or with AE Bus command **95** to set capacitor tuning parameters.

Splitter Capacitor Operation

The splitter capacitor (some units) is an automatically-tunable capacitor that controls the current ratio between the two outputs on dual output units. Sensors measure RF output current from these two outputs, which are designed to be terminated with two inductors from the source.

Termination Capacitor Operation

A termination capacitor (some units) is an automatically-tunable capacitor that acts as a filter for a specific frequency on the load. Termination capacitors are sometimes called trap capacitors.

These capacitors are customer-specified and are typically controlled using a **User** port. If your unit uses a **User** port to control the capacitor, see the unit specification for the **User** port information.

Auxiliary Capacitor Operation

The auxiliary capacitor (some units) can act as either a splitter capacitor or a termination capacitor. This capacitor is customer-specified and controlled, and has no automatic tuning associated with it. See the unit specification for information.

MAINTENANCE

Consumable Parts

Some parts in the Navigator II are consumable and may wear out over time. For a current list of consumable and wear components in the Navigator II 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 Navigator II match network as described in the instructions.
2. Connect the Navigator II match network to the supply voltage.

   Is the **Power** LED lit?
   - If yes, go to the next step.
   - If no, see "To Troubleshoot Input Voltage" on page 5-3.
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 5-3.

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 yes, see "Apparent Capacitor Malfunction" on page 5-3.
5. Is the plasma in the chamber lit?
   - If yes, go to the next step.
   - If no, see "Plasma Does Not Ignite" on page 5-5.
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 5-6.
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 5-6.
   - If no, go to the next step.
8. Does the match network have an overtemperature condition? (Not all units report this condition.)

   If you have Virtual Front Panel software, you will see a fault reported on the screen. For information on checking fault conditions, see the Virtual Front Panel software manual. If you do not have Virtual Front Panel software and are working with an air-cooled unit, check to make sure that the fans are rotating. Fans that are not rotating may indicate an overtemperature condition.
   - If yes, "Troubleshooting an Overtemperature Condition " on page 5-7 .
   - If no, go to the next step.
9. Does the match network have an overvoltage, overcurrent, or SOA condition?

   If you have Virtual Front Panel software, you will see a fault reported on the screen. For information on checking fault conditions, see the Virtual Front Panel software manual.
   - If yes, "Troubleshooting an Overvoltage, Overcurrent, or SOACondition" on page 5-4.
   - If no, go to the next step.
10. Does the Navigator II 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 5-8.

11. Are you having trouble with presets? Is the tuning time slower than desired?
    - If yes, see “To Troubleshoot Preset Problems” on page 5-8.
    - If no, go to the next step.
12. 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 Navigator II 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 Navigator II 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 5-3
- “Troubleshooting Incorrect Navigator II Control Modes” on page 5-4
- “To Troubleshoot Low RF Input Power” on page 5-4
- “Troubleshooting an Overvoltage, Overcurrent, or SOACondition” on page 5-4
- “To Troubleshoot an Internal Failure” on page 5-5

To Troubleshoot Input Voltage

1. Ensure that the input voltage to the Navigator II 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 Navigator II Control Modes

Advanced Energy recommends that you operate the Navigator II 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**
  - **DeviceNet**
  - **Ethernet**
- User control mode

  Allows manual control of capacitor position through the **User** port (not available on all units).

TO TROUBLESHOOT INCORRECT NAVIGATOR II 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 Navigator II 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 Navigator II match network for the threshold.

Troubleshooting an Overvoltage, Overcurrent, or SOACondition

Too much power or excessive current through the Navigator II match network can cause an overvoltage, overcurrent, or SOA condition. When one of these conditions occurs, RF power may turn off, and one of the connecting straps may darken in color. Also, if you have Virtual Front Panel software, you may see a fault reported on the

screen. Check the power, voltage, and current through the match network to ensure that they are within specified ratings.

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 for error codes. See "Troubleshooting Using Error Codes" on page 5-11.
2. 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 Navigator II match network and the chamber
- Poor grounding
- The impedance of the chamber is outside of the Navigator II 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

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 Navigator II 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 Navigator II 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 Navigator II match network and the chamber.

Related Links

• “To Troubleshoot Poor RF Connections” on page 5-5

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.

TROUBLESHOOTING AN OVERTEMPERATURE CONDITION

When an overtemperature condition occurs, the Navigator II match network opens the interlock. If you have Virtual Front Panel software, you will see a fault reported on the screen. For information on checking fault conditions, see the Virtual Front Panel software manual. After the unit cools, it will reset. Several factors can cause an overtemperature condition:

- Too much power or excessive current through the match network—Check the power and current through the match to ensure that they are within specified current and power ratings.
- Incorrect installation—If the Navigator II match network is downstream (in terms of the cooling water) from the generator, place the Navigator II match network upstream from the generator. Ensure that the match network is not mounted in an excessive temperature environment. Also, check for proper installation clearance.
- Water temperature is too high—Reduce inlet water temperature.
- Lack of water flow—Turn off RF power and wait for the unit to cool If the unit does not automatically reset after it cools, ensure that the water line is unobstructed.

  ⚠ **CAUTION:**
  Wait for the Overtemp fault on the Virtual Front Panel screen to clear before reapplying water.

- Incorrect air flow—Check that the air flow is unobstructed and below the specified input temperature. Listen to make sure that the fan(s) are operating.

TO TROUBLESHOOT COMMUNICATION PROBLEMS

Virtual Front Panel software indicates when the Navigator II 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 Navigator II match network are the same. This can be set by either the DIP switch or AE bus command **69**, depending on the unit.
- 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 Navigator II 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

• “Default (Typical) Tuning Parameters” on page 4-27

VERIFYING MATCH NETWORK BASIC FUNCTION

Required Tools and Software:

- Computer running AE Navigator II Virtual Front Panel software. Virtual Front Panel software allows you to control and monitor the Navigator II match network from a personal computer. The software is shipped on a CD-ROM with some Navigator II units. If you need a copy of the Virtual Front Panel software CD-ROM, contact AE.

- Serial interface cable to connect the Navigator II match network to the computer
- 24 V, 6 A DC power supply (to provide power to the Navigator II match network)
- Navigator II match network power cable
- Capacitance meter that can measure < 100 pF with at least three digits resolution. AE recommends the B&K mode 890 meter or equivalent.

  ☞ **Important**

  Using a network analyzer may give you different results than those discussed here.

Understanding the Procedure

⚠ **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.

The procedure in this section allows you to verify the basic function of the Navigator II match network by verifying that the following are functional:

- RS-232 communications
- Power supply
- Control card
- Interlock
- Load and tune power train

This procedure does not test the tuning algorithm, the input sensor, or PROFIBUS or DeviceNet communications.

These procedures should be performed on a work bench. The Navigator II match network needs to be off the tool to perform these procedures.

To Verify Match Network Basic Function

1. To verify interlock connection:
   a. Connect the DC power cable from the power supply to the power connector on the Navigator II match network, then supply power to the match network.
   b. Verify that the external supply is providing 24 VDC.
   c. You should hear normal match initialization sounds.
   d. Verify continuity at the appropriate power connector pins as described in the product specification.

e. If there is no connection, ensure that the microswitches at the RF input and RF output are mechanically closed.

f. If there is still no connection, see "Match Network Interlocks" for other possible causes.

2. Disconnect and lockout/tagout the RF input and output cables if they are connected to the Navigator II match network.

3. Connect the serial interface cable between the computer and the **Host** connector on the Navigator II match network.

4. In the Navigator II Virtual Front Panel software, connect to the Navigator II unit.

   For instructions on making this connection, see the Virtual Front Panel software help system. If you are not able to make this connection:

   ◦ Ensure that you are using an RS-232 serial cable, not a terminal configured cable.

   ◦ Ensure that the serial cable is connected to the **Host** connector on the Navigator II match network.

5. Using Virtual Front Panel software, check whether there are active faults in the Navigator II match network. If there are active faults, resolve those faults before continuing with this procedure.

   An interlock warning means that the customer tool is not suppling the voltage to the interlock string. An interlock fault indicates that the voltage is supplied to the interlock string but that the match's interlock string is open somewhere (for example, the RF connector, cover switch, or over-temperature).

6. Using Virtual Front Panel software, set the Navigator II operating mode to host control mode.

7. Connect the test leads of the capacitance meter between the RF input center pin and the Navigator II match network chassis.

   The polarity of the leads does not matter.

   ☞ **Important**
   The test leads must remain in the same position as you take measurements. If either lead shifts, you will need to re-take the measurements.

8. Use Virtual Front Panel software to set both the load and tune capacitors to 0%, then set or record the minimum measured capacitance reading:

   ◦ If you are using the recommended B&K 890 meter, press the **Rel** button to set a zero reference level.

   ◦ If you are using another meter, record the measured value.

9. Use Virtual Front Panel software to set the load capacitor to 100% then write down the measured capacitance reading.

   Compare this reading to that of a known good unit, if available. Compare these values to the values in the product specification.

10. Using the two measured values and the following equation, calculate the expected measured capacitance reading if you set the load capacitor to 50%.

    If you set a zero reference level for a B&K 890 meter as described earlier in the procedure, the calculated value is simply 50% of the value at 100%. If you used an alternate meter, use the following equation:

    [(100% reading - 0% reading) / 2] + 0% reading = expected reading at 50%

    For example, if the 0% reading was 80 and the 100% reading was 340:
    [(340-80) / 2] +80 = 210

    You can use percentages other than 50% if desired. The relationship to position and capacitance is linear.

11. Use Virtual Front Panel software to set the load capacitor to 50%.

    This reading should be approximately ±3 pF of the expected reading calculated in the previous step. If the value is outside of this range, contact AE Global Services. If it is within this range, continue this procedure.

12. Reconnect the test leads of the capacitance meter between the RF input center pin and the output strap.

    The polarity of the leads does not matter.

    ☞ **Important**
    The test leads must remain in the same position as you take measurements. If either lead shifts, you will need to re-take the measurements.

13. Use Virtual Front Panel software to set both capacitors back to 0%.
14. Repeat step 10 through step 12, this time moving the tune capacitor instead of the load capacitor.
15. If moving both capacitors produced readings that were in the expected range, then you have verified that the capacitors are moving to specified values.

    If these steps did not produce readings in the expected range, contact AE Global Services.

16. Return the Navigator II match network to automatic tuning mode before reinstalling the unit on the tool.

TROUBLESHOOTING USING ERROR CODES

Accessing Error Codes

You can access error codes in two ways:

- You can use serial communication (the **Host** or **Service** port) to request a report of active warning or fault error codes (command **223**). Once you have received a list of active errors, see the error code table to look up these error codes and troubleshoot the associated faults or warnings.
- You can use the Navigator II Virtual Front Panel software program to look up active error codes. Use the help system that came with the Virtual Front Panel software if you have trouble finding the list of active error codes. Once you have the list of active error codes, see the error code table to look up these error codes and troubleshoot the associated faults or warnings.

Virtual Front Panel software allows you to control and monitor your Navigator II unit using a personal computer via serial communication. If you did not purchase the Virtual Front Panel software with your unit and would like a copy of the program, contact AE Global Services.

Fault and Warning Types and Clearing Faults

The unit can report one or more types of fault or warning:

- Fatal Faults–These faults can occur at initialization or after running. You can try to clear the fault by cycling power to the unit. If the fault persists, contact AE Global Services.
- Latching Faults–When these faults occur, they remain latched until the RF ON is detected. If the cause of the fault has not cleared, the fault does not clear.
- Non-Latching Faults–Faults that are self-clearing.
  - Fault occurs when RF is OFF: A fault is non-latching only if the fault occurs while RF is OFF. If the fault condition clears, the fault self-clears; however, if the cause of the fault has not cleared, the fault does not clear.
  - Fault occurs when RF is ON: If output was ON when the fault occurred, the interlock is opened if the condition could damage the match and the fault latches. The fault is cleared when RF ON is detected.
- Non-Latching Warnings – Warnings self-clear when the condition that caused the warning clears. If a warning occurs while RF is ON, no further action is performed by the match network.

Error Code Table

Use the following tables to troubleshoot error and warning codes received from communication ports.

Table 5-1. Error codes

Error Code	Problem Description	Suggested Action
17 **Ethernet Stack Runtime Fault**	Fatal fault	Cycle power to the unit. If the fault persists, contact AE Global Services.
18 **Ethernet Initialization Fault**	Fatal fault	Contact AE Global Services.
19 **EEPROM CRC Fault**	Latching fault	Contact AE Global Services.
20 **Hardware Initialization Fault**	Fatal fault	Contact AE Global Services.
21 **RTOS Initialization Fault**	Fatal fault	Contact AE Global Services.
22 **EEPROM Initialization Fault**	Latching fault	Contact AE Global Services.
23 **A-D Converter Initialization Fault**	Fatal fault	Contact AE Global Services.
24 **Invalid Pin Number Fault**	Latching fault	Contact AE Global Services.
25 **Unexpected Error Fault**	Fatal fault	Cycle power to the unit. If the fault persists, contact AE Global Services.
26 **RTOS Runtime Fault**	Fatal fault	Cycle power to the unit. If the fault persists, contact AE Global Services.
27 **User Card Configuration Fault**	Fatal fault	Contact AE Global Services.
28 **NOVRAM Fixed Store Fault**	Latching fault	Contact AE Global Services.
29 **NOVRAM Free Store Fault**	Latching fault	Contact AE Global Services.
30 **Interlock Open Fault**	Non-latching fault • An interlock is open.	Verify interlock. If the fault persists, contact AE Global Services.

Table 5-1. Error codes (Continued)

Error Code	Problem Description	Suggested Action
31 **Over Temperature Fault**	Latching fault	• Ensure that power and current are within specified ratings. • Ensure that water temperature and water flow are within specifications. • Ensure that nothing is blocking the fan. If the fault persists, contact AE Global Services.
32 **Ambient Air Temperature Fault**	Non-latching fault	Ensure that nothing is blocking the fan. If the fault persists, contact AE Global Services.
33 **Over Voltage Fault**	Latching fault	Contact AE Global Services.
34 **Fan 1 Speed Fault**	Latching fault • Fan RPM speed is lower than specification	Ensure that nothing is blocking the fan. If the fault persists, contact AE Global Services.
35 **Fan 2 Speed Fault**	Latching fault • Fan RPM speed is lower than specification	Ensure that nothing is blocking the fan. If the fault persists, contact AE Global Services.
38 **Fan 3 Speed Fault**	Latching fault • Fan RPM speed is lower than specification	Ensure that nothing is blocking the fan. If the fault persists, contact AE Global Services.
39 **Fan 4 Speed Fault**	Latching fault • Fan RPM speed is lower than specification	Ensure that nothing is blocking the fan. If the fault persists, contact AE Global Services.
65 **A-D Converter RF-Peak/ DC-Bias Initialization Fault**	Latching fault	Contact AE Global Services.
66 **Motor Initialization Fault**	Latching fault	Cycle power to the unit. If the fault persists, contact AE Global Services.

Table 5-1. Error codes (Continued)

Error Code	Problem Description	Suggested Action
67 **Motor Already Moving Fault**	Non-latching fault	Re-initialize motors. If the fault persists, contact AE Global Services.
77 **Measurement Board Temperature Fault**	Fatal fault	Ensure that nothing is blocking the fan or the vents. If the fault persists, contact AE Global Services.
79 **Low 24 V Supply Fault**	Fatal fault	Cycle power to the unit. If the fault persists, contact AE Global Services.
82 **Communication Card Configuration Fault**	Latching fault	If the fault persists, contact AE Global Services.
83 **Unable To Tune Fault, Match 1**	Non-latching fault	Try different presets. Check tuning parameters. If the fault persists, contact AE Global Services.
84 **Unable To Tune Fault, Match 2**	Non-latching fault	Try different presets. Check tuning parameters. If the fault persists, contact AE Global Services.
85 **Unable To Tune Fault, Match 3**	Non-latching fault	Try different presets. Check tuning parameters. If the fault persists, contact AE Global Services.
87 **Safe Operating Area Match 1 Exceeded Fault**	Latching fault	If the fault persists, contact AE Global Services.
88 **Safe Operating Area Match 2 Exceeded Fault**	Latching fault	If the fault persists, contact AE Global Services.
89 **Safe Operating Area Match 3 Exceeded Fault**	Latching fault	If the fault persists, contact AE Global Services.
90 **Safe Operating Area Voltage Exceeded Fault**	Latching fault	If the fault persists, contact AE Global Services.

Table 5-1. Error codes (Continued)

Error Code	Problem Description	Suggested Action
91 **Safe Operating Area Current Exceeded Fault**	Latching fault	If the fault persists, contact AE Global Services.
130 **Motor Control Board Hardware Initialization Fault**	Latching fault	Contact AE Global Services.
131 **Motor Control Board RTOS Initialization Fault**	Latching fault	Contact AE Global Services.
132 **Motor Control Board EEPROM Initialization Fault**	Latching fault	Contact AE Global Services.
133 **Motor Control Board Invalid PIN Fault**	Latching fault	Contact AE Global Services.
134 **Motor Control Board RTOS Runtime Fault**	Fatal fault	Cycle power to the unit. If the fault persists, contact AE Global Services.
135 **Motor Control Board Message Queue Overflow Fault**	Fatal fault	Cycle power to the unit. If the fault persists, contact AE Global Services.
300 **EEPROM CRC Fault – Motherboard**	Latching fault	Contact AE Global Services.
301 **EEPROM CRC Fault – Communication Slot** (units with PROFIBUS or DeviceNet)	Latching fault	Contact AE Global Services.
302 **EEPROM CRC Fault – User Card**	Latching fault	Contact AE Global Services.
303 **EEPROM CRC Fault – Measurement**	Latching fault	Contact AE Global Services.

Table 5-1. Error codes (Continued)

Error Code	Problem Description	Suggested Action
304 **EEPROM CRC Fault – Main Processor**	Latching fault	Contact AE Global Services.
306 **EEPROM CRC Fault – Diagnostic**	Latching fault	Contact AE Global Services.
307 **EEPROM CRC Fault – Data Log**	Latching fault	Contact AE Global Services.
308 **EEPROM CRC Fault – Communication Slot CPU**	Latching fault	If the fault persists, contact AE Global Services.
309 **EEPROM CRC Fault – Z'Scan II**	Latching fault	If the fault persists, contact AE Global Services.
310 **EEPROM CRC Fault – Match 1 Measurement**	Latching fault	If the fault persists, contact AE Global Services.
311 **EEPROM CRC Fault – Match 2 Measurement**	Latching fault	If the fault persists, contact AE Global Services.
312 **EEPROM CRC Fault – Match 3 Measurement**	Latching fault	If the fault persists, contact AE Global Services.
314 **EEPROM CRC Fault – Auxiliary Capacitor Measurement**	Latching fault	If the fault persists, contact AE Global Services.
325 **EEPROM Initialization Fault – Motherboard**	Latching fault	Contact AE Global Services.
326 **EEPROM Initialization Fault – Communication Slot**	Latching fault	Contact AE Global Services.
327 **EEPROM Initialization Fault – User Card**	Latching fault	Contact AE Global Services.

Table 5-1. Error codes (Continued)

Error Code	Problem Description	Suggested Action
328 **EEPROM Initialization Fault – Measurement**	Latching fault	Contact AE Global Services.
329 **EEPROM Initialization Fault – Main Processor**	Latching fault	Contact AE Global Services.
331 **EEPROM Initialization Fault – Diagnostic**	Latching fault	Contact AE Global Services.
332 **EEPROM Initialization Fault – Data Log**	Latching fault	Contact AE Global Services.
333 **EEPROM Initialization Fault – Communication Slot CPU**	Latching fault	Contact AE Global Services.
334 **EEPROM Initialization Fault – Z'Scan II**	Latching fault	Contact AE Global Services.
335 **EEPROM Initialization Fault – Match 1 Measurement**	Latching fault	Contact AE Global Services.
336 **EEPROM Initialization Fault – Match 2 Measurement**	Latching fault	Contact AE Global Services.
337 **EEPROM Initialization Fault – Match 3 Measurement**	Latching fault	Contact AE Global Services.
339 **EEPROM Initialization Fault – Auxiliary Capacitor Measurement**	Latching fault	Contact AE Global Services.

Table 5-1. Error codes (Continued)

Error Code	Problem Description	Suggested Action
350 **Serial Port Baud Rate Fault – Secondary**	Latching fault	Ensure that the host port parameters are set per the specification. If the fault persists, contact AE Global Services.
351 **Serial Port RS-485 Configuration Fault – Secondary**	Latching fault	Ensure that the host port parameters are set per the specification. If the fault persists, contact AE Global Services.
352 **Serial Port Open Fault**	Latching fault	If the fault persists, contact AE Global Services.
353 **Serial Port Baud Rate Fault**	Latching fault	Ensure that the host port parameters are set per the specification. If the fault persists, contact AE Global Services.
354 **Serial Port Data Format Fault**	Latching fault	Contact AE Global Services.
355 **Serial Port RS-485 Configuration Fault**	Latching fault	Ensure that the host port parameters are set per the specification. If the fault persists, contact AE Global Services.
356 **AE Interface Hardware Initialization Fault**	Latching fault	Contact AE Global Services.
357 **CPU Module I2C Controller Fault**	Fatal fault	Cycle power to the unit. If the fault persists, contact AE Global Services.
358 **CPU Module SPI Controller Fault**	Fatal fault	Cycle power to the unit. If the fault persists, contact AE Global Services.
359 **CPU Module Real Time Clock Fault**	Fatal fault	Cycle power to the unit. If the fault persists, contact AE Global Services.

Table 5-1. Error codes (Continued)

Error Code	Problem Description	Suggested Action
360 **CPU Module Hardware Timer Fault**	Fatal fault	Cycle power to the unit. If the fault persists, contact AE Global Services.
361 **Data bus Master Hardware Initialization Fault**	Latching fault	Contact AE Global Services.
363 **Flash Data bus Master Hardware Initialization Fault**	Latching fault	Cycle power to the unit. If the fault persists, contact AE Global Services.
365 **Measurement Module Initialization Fault**	Latching fault	Contact AE Global Services.
366 **Communication Card Master Interface Fault**	Latching fault	Cycle power to the unit. If the fault persists, contact AE Global Services.
367 **Serial Port (secondary) Initialization Fault**	Latching fault	Ensure that the host port parameters are set per the specification. If the fault persists, contact AE Global Services.
368 **Ethernet Port Initialization Fault**	Latching fault	Ensure that the host port parameters are set per the specification. If the fault persists, contact AE Global Services.
371 **Expansion Slot 1 Initialization Fault**	Latching fault	Cycle power to the unit. If the fault persists, contact AE Global Services.
373 **Expansion Slot 2 Initialization Fault**	Latching fault	Cycle power to the unit. If the fault persists, contact AE Global Services.
377 **Power Fail Interrupt Fault**	Fatal fault	Cycle power to the unit. If the fault persists, contact AE Global Services.
378 **External Bus Interrupt Fault**	Fatal fault	Cycle power to the unit. If the fault persists, contact AE Global Services.

Table 5-1. Error codes (Continued)

Error Code	Problem Description	Suggested Action
379 **Low Level Initialization Fault**	Latching fault	Contact AE Global Services.
380 **External Bus Wait States Fault**	Latching fault	Contact AE Global Services.
381 **CPU Module Initialization Fault**	Latching fault	Contact AE Global Services.
382 **Engine Module Initialization Fault**	Latching fault	Contact AE Global Services.
383 **Auxiliary Cap Module Initialization Fault**	Latching fault	Contact AE Global Services.
386 **Serial Port Initialization (primary) Fault**	Latching fault	Contact AE Global Services.
387 **Internal FPGA Initialization Fault**	Latching fault	Contact AE Global Services.
390 **Modbus RS-485 Serial Port Open Fault**	Fatal fault	Cycle power to the unit. If the fault persists, contact AE Global Services.
391 **Tuner Module Initialization Fault**	Latching fault	Contact AE Global Services.
401 **AE Interface Communication Fault**	Non-latching fault	Cycle power to the unit. If the fault persists, contact AE Global Services.
402 **DeviceNet Power Failure**	Non-latching fault	Take these actions: • Check the DeviceNet power source. Make sure the DeviceNet cable connectors are secure. If the fault persists, contact AE Global Services.

Table 5-1. Error codes (Continued)

Error Code	Problem Description	Suggested Action
403 **DeviceNet Network Failure**	Non-latching fault	Take these actions: • Check the DeviceNet network integrity. If the fault persists, contact AE Global Services.
404 **PROFIBUS Master Released Slave Fault**	Latching fault • PROFIBUS master released slave	Take these actions: 1. Have the master reestablish communications with the slave to recover the slave from the off state 2. Send a master reset to clear the error. If the fault persists, contact AE Global Services.
405 **PROFIBUS Watchdog Timeout Fault**	Latching fault • PROFIBUS watchdog expired	Take these actions: 1. Verify serial cable is connected. 2. Have the master reestablish communications and send a master reset to clear the error. If the fault persists, contact AE Global Services.
406 **PROFIBUS MAC Reset Fault**	Latching fault	If the fault persists, contact AE Global Services.
407 **PROFIBUS Buffer Overflow Fault**	Latching fault • PROFIBUS memory buffer overflow	Take this action: • Increase the time between packets being sent to the unit via the PROFIBUS Master. If the fault persists, contact AE Global Services.

Table 5-1. Error codes (Continued)

Error Code	Problem Description	Suggested Action
998 **Flash Mode Failure**	Latching fault • Unit failed to go into flash mode	Cycle power to the unit. If the fault persists, contact AE Global Services.
999 **Flash Mode Active**	Latching fault • Unit is in flash mode	Cycle power to the unit. If the fault persists, contact AE Global Services.
1001 **Message Queue Overflow fault**	Fatal fault Serial communication hardware problem	Cycle power to the unit. If the fault persists, contact AE Global Services.
1002 **Network Configuration Fault**	Latching fault Serial communication hardware problem	Review the network configuration parameters. If the fault persists, contact AE Global Services.
1003 **UART Queue Overflow Fault**	Fatal fault	Cycle power to the unit. If the fault persists, contact AE Global Services.
1004 **AE Bus Master Message Queue Overflow**	Fatal fault	Cycle power to the unit. If the fault persists, contact AE Global Services.
1005 **AE Bus Master Communication Fault**	Fatal fault	Cycle power to the unit. If the fault persists, contact AE Global Services.
1006 **AE Bus Master Command Fault**	Fatal fault If this error is reported, the stepper motors will not be moving and you will see additional errors.	Cycle power to the unit. If the fault persists, contact AE Global Services.

Table 5-2. Warning codes

Warning Code	Problem Description	Suggested Action
34 **Fan 1 low speed warning**	Warning	Ensure that nothing is blocking the fan.
35 **Fan 2 low speed warning**	Warning	Ensure that nothing is blocking the fan.
36 **Fan 3 low speed warning**	Warning	Ensure that nothing is blocking the fan.

Table 5-2. Warning codes (Continued)

Warning Code	Problem Description	Suggested Action
37 **Fan 4 low speed warning**	Warning	Ensure that nothing is blocking the fan.
55 **Tool disconnected warning**	Warning	Ensure that the tool is properly connected to the match.
56 **Ethernet DHCP problem warning**	Warning	1. Make sure the Ethernet parameters are set correctly. 2. Make sure the unit is properly connected to the Ethernet network. 3. If you still receive this warning, contact your IT representative.
57 **Ethernet DNS problem warning**	Warning	1. Make sure the Ethernet parameters are set correctly. 2. Make sure the unit is properly connected to the Ethernet network. 3. If you still receive this warning, contact your IT representative.
74 **Safe operating area limit match 1 warning**	Warning	Make sure your operating environment fits within the unit specifications.
75 **Safe operating area limit match 2 warning**	Warning	Make sure your operating environment fits within the unit specifications.
76 **Safe operating area limit match 3 warning**	Warning	Make sure your operating environment fits within the unit specifications.
81 **Motor 0 position warning**	Warning	Re-initialize the motor.
82 **Motor 1 position warning**	Warning	Re-initialize the motor.

Table 5-2. Warning codes (Continued)

Warning Code	Problem Description	Suggested Action
83 **Motor 2 position warning**	Warning	Re-initialize the motor.
84 **Motor 3 position warning**	Warning	Re-initialize the motor.
85 **Motor 0 correction warning**	Warning	Re-initialize the motor.
86 **Motor 1 correction warning**	Warning	Re-initialize the motor.
87 **Motor 2 correction warning**	Warning	Re-initialize the motor.
88 **Motor 3 correction warning**	Warning	Re-initialize the motor.

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 5-3. 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

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