FREQUENCY DEVICES™, INC.

Model 9002

September 1999

Dual-Channel Programmable Filter Instrument

OPERATOR MANUAL

CE-Certified

25 Locust St, Haverhill, Massachusetts 01830 • Tel: 800/252-7074, 978/374-0761 • FAX: 978/521-1839
e-mail: sales@freqdev.com • Web Address: http://www.freqdev.com

25 Locust St, Haverhill, Massachusetts 01830 • Tel: 800/252-7074, 978/374-0761 • FAX: 978/521-1839
e-mail: sales@freqdev.com • Web Address: http://www.freqdev.com

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Preface

The Frequency Devices, Inc. Model 9002 is a Dual Channel, Programmable Lowpass or Highpass active, electronic filter. It represents state-of-the art filter modeling, utility, flexibility and ease of programming, either from the front panel or by a remote controller. Users can select from a total of four lowpass and two highpass filter models.

The system can be internally programmed for eight different filters in each channel. The unit operates over a wide range of frequencies and provides the finest resolution for a given input frequency. Filter types for each channel are specified at time of purchase. Remote operation of the Model 9002 is accomplished through a controller equipped with an IEEE-488 interface.

This manual contains installation, operation, programming and troubleshooting information about the Model 9002. Although operation of the Model 9002 is quite straightforward, you must read and understand the information in this manual before applying power or connecting any components or external devices.

Warranty information is given on the following page, Improper use of the instrument may void the warranty, so please use this manual as an instruction guide at all times.

We at Frequency Devices, Inc. are pleased that you have selected our product for your research and development applications. Should you have any questions or problems, do not hesitate to contact your local Frequency Devices, Inc. representative for prompt assistance.

Each section of this manual begins with a table of contents and a brief discussion. This will help you access the information you need as quickly as possible. The instruction and associated information for the Model 9002 are presented as follows:

Section 1 - Introduction
Contains general descriptive information about the Models 9002, including applications information.

Section 2 - Description
Provides physical and technical specifications and control details.

Section 3 - Installation
Provides step-by-step instructions for unpacking, installation and setup.

Section 4 - Front Panel Operations
Item-by-item presentation of local operation from the front panel.

Section 5 - Remote Control Operations
System programming and operating via a remote controller.

Appendices
The Appendices provide you with additional technical and reference information for advanced operations, as well as examples of remote operation programs.

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Warranty

The Model 9002 Instrument is warranted against defects in material and workmanship for a period of one (1) year from the date of shipment. During the warranty period, Frequency Devices Inc. will, at its option, repair or replace products that prove to be defective.

For warranty service or repair, all products must be returned to Frequency Devices Inc. after obtaining a return authorization (RA) number from the factory. Frequency Devices Inc. will pay the shipping charges from and to the Buyer, except for products returned to FDI from another country. In this case the Buyer shall be responsible for all shipping charges, duties, and taxes.

Limited Warranty

This warranty shall not apply to defects that are the results of improper use, unauthorized modification or repair, or improper installation or maintenance.

No other warranty is expressed or implied. Frequency Devices, Inc. specifically disclaims the implied warranties of merchantability and fitness for a particular purpose.

The remedies provided herein are the Buyer's sole and exclusive remedies. Frequency Devices Inc. shall not be liable for any direct, indirect, special, incidental, or consequential damages, whether based on contract, tort, or any other legal theory.

Certification

Frequency Devices Inc. certifies that this product met its published specification at the time of shipment from the factory. Frequency Devices, Inc. further certifies that its calibration measurements are traceable to the United States national Bureau of Standards, to the extent allowed by the bureau's calibration facility, and to the calibration facilities of other International Standards Organization member.

Repair

Frequency Devices, Inc. maintains a repair facility at its factory in Haverhill, Massachusetts which is available for both in-warranty and non-warranty repair. We suggest that you contact your local FDI representative before taking steps to return equipment for repair.

Return Authorization

All products being returned to Frequency Devices, Inc. must have a Return Authorization (RA) number. This number may be obtained by calling Frequency Devices, Inc. before returning the product.

The RA number should be clearly displayed on the outside of the package being returned and should be placed on all correspondence concerning the instrument.

Frequency Devices, Inc. may refuse to accept shipment and will not be responsible for shipping charges of product returned without an RA number.

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Section 1
Introduction

1.1 - Device Description

This system is intended for use as an electronic filter for applications in the Hertz to hundred of kiloHertz range. It can exhibit either highpass or lowpass characteristics and simulates any two of six possible mathematical configurations:

Lowpass:	Butterworth, Elliptic, Bessel, Constant Delay
Highpass:	Butterworth, Elliptic

The filter type in each channel is selected at time of purchase and is installed at the factory. If changing of the filter type is desired, contact your local FDI representative.

The two channels in the unit are entirely independent. They can by externally interconnected to create a bandpass filter with adjustable upper and lower cutoff points. The unit is voltage protected at the input up to 100 V and current limited at the output to 100 mA.

Each channel can be programmed to eight separate configurations, becoming eight distinct filters. The programming can be done at the front panel or via an IEEE-488 interface to a remote controller. The configurations are stored in nonvolatile memory for recall or change at any time.

1.2 - Applications

The Model 9002 filter can be used in any application where frequency filtration is required. A wide range of frequencies, input voltage ranges, and pre- and post-amplification stages enables these filters to interconnect with most laboratory equipment as well as standard audio and radio frequency test equipment. Since the filter characteristics can be precisely defined, the Model 9002 is an excellent development instrument for perfecting filter spectra in analytic, electronic, biomedical, and physics applications.

1.3 - System Interconnection

The Model 9002 may be considered to be two, independent electronic frequency filters with either highpass or lowpass properties. The channels may be cascaded to produce a bandpass filter. Use of the filter is the same as any R-L-C filter network, with the following exceptions:

1. Your signal source is not loaded by the filter.
2. The output has a fixed, 50 ohm resistive impedance.
3. Signal levels can be controlled at the input and output by means of built-in variable gain operational amplifiers.

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Section 1 Introduction

Connection of the filter with your system is straightforward; a typical setup is shown in Figure 1.1, below.

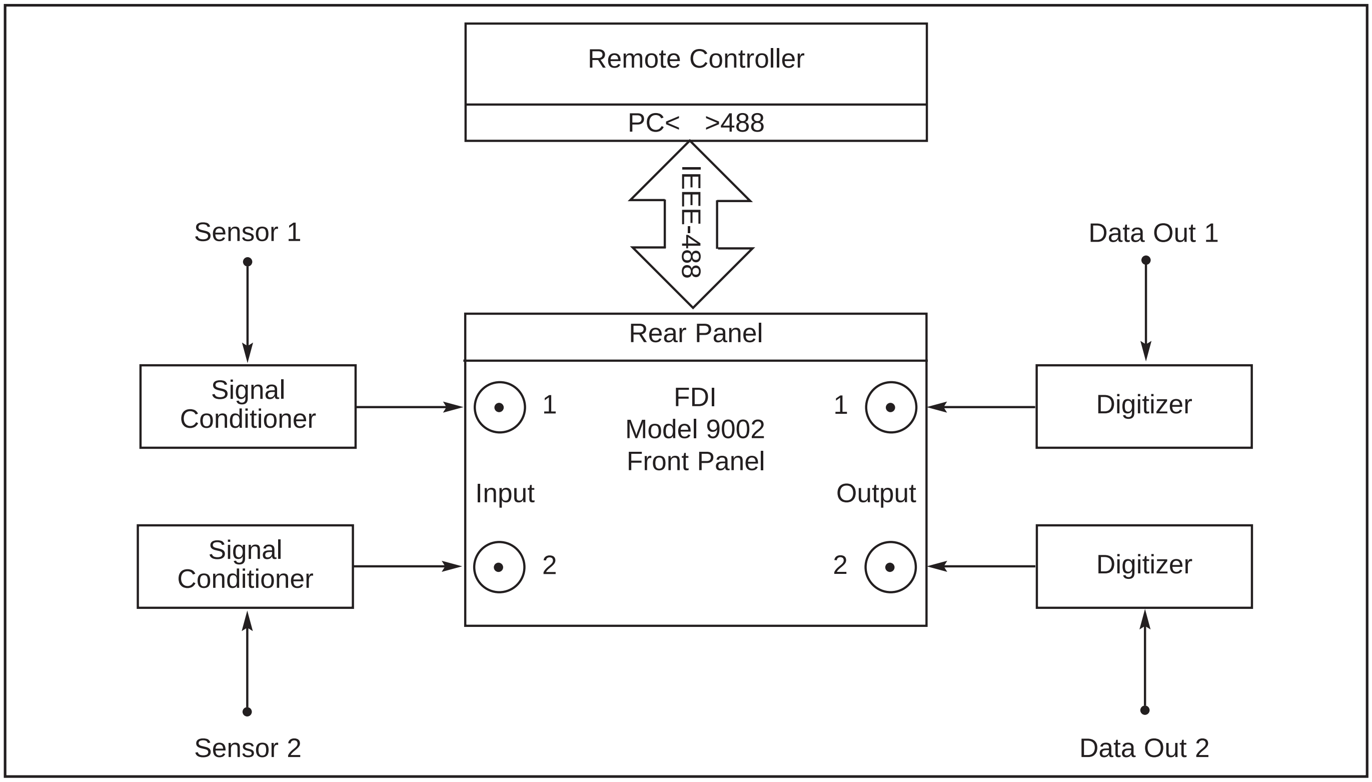

Figure 1.1 Model 9002 in a Typical Setup

When operating the filter with a remote controller, care must be taken to follow the programming rules presented in Section 5 of this manual. In the remote mode, the unit looks at the IEEE-488 bus for its operating commands. Control of the filters is switched to and from the front panel by depressing a single function key on the panel or by the appropriate controller commands.

Section 2
Instrument Description

2.1 - Front and Rear Panel Controls

Control and system I/O is accomplished on the front panel of the system. In the remote mode, control is transferred to an interconnected controller. Figures 2.1a and 2.1b show the front and rear panels, respectively.

Upper Figure 2.1a Front Panel Lower Figure 2.1b Rear Panel

2.2 - Input/Output Characteristics

The Model 9002 is contained in a single electronic chassis and is designed to interface directly with a remote controller fitted with an IEEE-488 interface card. Connection to the controller is via an IEEE connector on the rear panel as shown in Figure 2.1b. A standard IEEE connector with appropriate callouts is shown in Figure 2.2.

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Pin	Definition	Pin	Definition	Pin	Definition
1	D101	5	EOI	12	Shield-Chassis Ground
2	D102	17	REN	18	P/O Twisted Pair with Pin 6
3	D103	6	DAV	19	P/O Twisted Pair with Pin 7
4	D104	7	NRFD	20	P/O Twisted Pair with Pin 8
13	D105	8	NDAC	21	P/O Twisted Pair with Pin 9
14	D106	9	IFC	22	P/O Twisted Pair with Pin 10
15	D107	10	SRQ	23	P/O Twisted Pair with Pin 11
16	D108	11	ATN	24	Isolated Digital Ground

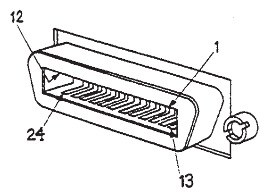

Figure 2.2 IEEE Connector Identification

The signals to be filtered are introduced to the Model 9002 via front and rear panel coaxial BNC connectors as seen in Figure 2.1a. Input impedance is one megohm resistive shunted by a fixed 47 picofarad capacitance. Signal inputs can be up to 20 volts p-p without clipping.

The filtered outputs are also supplied a BNCs on the front and rear panels. The output amplifiers are protected by current limiting resistors. Outputs take on the same AC or DC coupling as the inputs, though output signal levels can be independently adjusted.

Inputs are operator programmable by either single-ended or differential input, and may be either AC or DC coupled. The input is overload protected via diode clamping to the power supply.

Precise circuit configurations for both input and output are given in the Product Data Sheet (Appendix A).

2.3 - Filter Properties

The Model 9002 is configured with two standard filters that are specified at the time of ordering. These filters are chosen from the six models available, ten lowpass and five highpass. Table 2.1 lists the filter models available:

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Type Number	Characteristic
Lowpass	
LP00	8-pole Butterworth
LP01	8-pole, 6-zero elliptic 1.77
LP02	8-pole,Bessel
LP03	8-pole, 6-zero constant delay
LP05	8-pole, 6-zero elliptic (200 kHz)
LP06	4-pole Bessel
LP07	4-pole Butterworth
LP08	8-pole, Bessel (200 kHz)
LP09	8-pole, Butterworth (200 kHz)
LP10	8-pole, 6-zero constant delay (200 kHz)
Highpass	
HP00	8-pole Butterworth
HP01	8-pole, 6-zero elliptic1.77
HP05	8-pole, 6-zero elliptic (200 kHz)
HP07	4-pole Butterworth
HP09	8-pole, Butterworth (200 kHz)

Table 2.1 Electrical Characteristics of Filters

Each filter channel has eight programmable configurations which are stored in the system's nonvolatile memory. Any of the eight configurations may be modified and selected from the front panel or from the front panel or from the remote controller.

Filters may be bypassed by use of a front panel control. This replaces the filter with a unity gain amplifier; all other input and output setups of the configurations (gains, AC/DC, etc.) remain in the configuration path. Detailed characteristics of the filters are contained in the Product Data Sheet (Appendix A).

2.4 - Specifications

2.4.1 - Electrical

Line Voltage	100,120,220, 240 VAC
Power consumption	200 watts
Number of Channels	2
Configurations per channel	8

Frequency Range	Frequency Increment
0.1 Hz-102.4 Hz	0.1 Hz
103.0 Hz-1,024.0 Hz	1 Hz
1,030.0 Hz-10,240 Hz	10 Hz
10,300.0 Hz-102,400 Hz	100 Hz[1]

Pre-gain and Post-gain characteristics
- Amplifiers are non-inverting
- Gains are variable from 1x (0 db) to 13.75x (22.7 db)
- Gain increments are in steps of 0.05x
- Precision of gain ratios is ±.02x

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Input Impedance[2]	
Single ended	1 M Ωpar. with 47 pF to analog grd.
Differential	1 M Ωpar. with 47 pF to analog grd. on each side

Input Signal Level
± 10V peak for linear system operation
Protected to withstand 115 volts AC at input without damage

Common Mode Rejection
60 db typical, 50 db minimum, DC to 100 kHz

Common Mode Voltage range	Full signal swing (±-10V)
Output Characteristics	
Impedance	50 ohms, resistive[2]
Current maximum	±100 mA into a 50 ohm load
Offset Voltage	±2 mV, for 0 db Pre- and Post-gain

Filter Bypass mode
System maintains all characteristics of the chosen filter except the passband is flat with a small signal bandwidth of 1 mHz (-6 db) and full power bandwidth of 125 kHz.

2.4.2 - Physical

Height	3.5 in; 90 mm
Width	8.5 in; 216 mm
Depth	17 in; 432 mm
Mounting	Benchtop or 19 inch rack mount

2.4.3 - Environmental

Operating Temperatures	
Full specifications and resolution	20 to 30° C; 68 to 86° F
Reduced specifications	0 to +40° C; 32 to 104° F
Storage Temperature	-25 to +55° C; -13 to +131° F
Relative Humidity	95% max., without condensation
Altitude	Up to 15,000 feet; 4500 meters

[1] 10,400.0 Hz-204,800.0 Hz @ 200 Hz increments for 9002-200 kHz
[2] See the Product Data Sheet (Appendix A) for circuit details.

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Section 3
Installation and Setup

3.1 - Unpacking and Inspection

When Model 9002 is received, inspect the cartons for visible external damage. If there is obvious physical damage, we suggest that the carrier's agent be present during unpacking. Do not destroy the shipment container during opening so that it may be used for future shipment of the device.

After removing the Model 9002 from the shipping container, examine it for obvious physical damage such as dents, dislodged components or damaged connectors. If a component is damaged, notify the carrier and follow the instructions for damage claims.

Warning
DO NOT APPLY POWER TO DAMAGED COMPONENTS. INJURY OR FURTHER COMPONENT DAMAGE MAY OCCUR.

Inform your Frequency Devices, Inc. representative immediately with specific details about the actual extent of the damage. Your representative will assist in arranging for repair or replacement of the instrument.

3.2 - Packaging for Shipment

Keep the original shipping cartons. Frequency Devices, Inc. will not accept responsibility for damages in shipment nor shipping costs if the unit is returned to FDI in an unapproved carton.

Before returning a unit to FDI, you must obtain a Return Authorization (RA) number from FDI.

To pack the Model 9002 for shipment:

1. Tape a tag or letter to the unit identifying the owner and the service or repair to be made.
   Include the following information:
   - RA number
   - Model number
   - Serial numbers on the instrument

In any correspondence with us, identify the unit by these numbers.

2. Place the unit in the original carton or request a replacement carton from Frequency Devices, Inc. (no charge for units in warranty).
3. Secure the carton with strong tape.

4. For international shipments, or if an alternate shipping carton must be used, do the following:

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Wrap the unit in heavy plastic and place packing material around all sides of the instrument in a strong carton. Protect the front panel with extra cardboard strips. Seal the carton with strong tape.

5. Mark the shipping carton:

DELICATE ELECTRONIC INSTRUMENT. FRAGILE.

3.3 - Environmental Requirements

The Model 9002 operates as either a benchtop or rack mounted unit. When setting up the Model 9002, be sure it has sufficient space for proper ventilation. Ambient temperature and humidity should not exceed the values given in the specifications of Section 2.4.3.

3.4 - Line Voltage Selection

The unit can be set up to operate on 100, 120, 220 or 240 Volts AC, at 50 or 60 Hz. Units are shipped for 120 Volt operation unless otherwise specified at the time of purchase.

The system is delivered with a power line cord appropriate to the ordered voltage configuration. If you have received the improper line cord for your area, please contact your local FDI representative for assistance.

Caution
MAKE SURE THE REAR PANEL POWER INPUT CONNECTOR IS IN THE CORRECT POSITION AND THE CORRECT FUSE IS INSTALLED BEFORE APPLYING AC POWER.

See Figure 3.1

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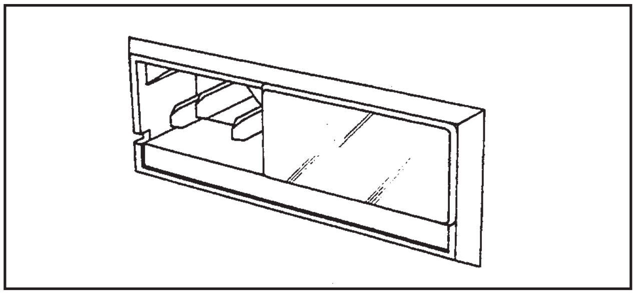
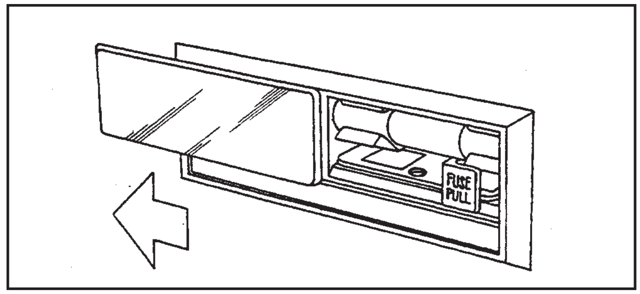
Section 3 Installation and Setup

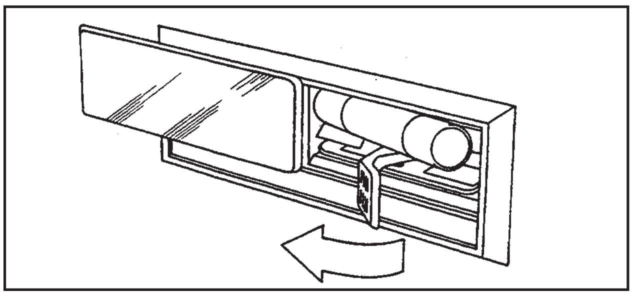
Reconfiguration of the system for a different voltage is accomplished as follows:



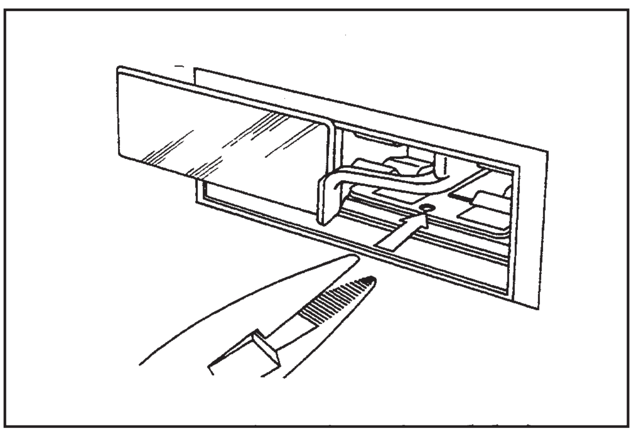
A. Remove the power cord.



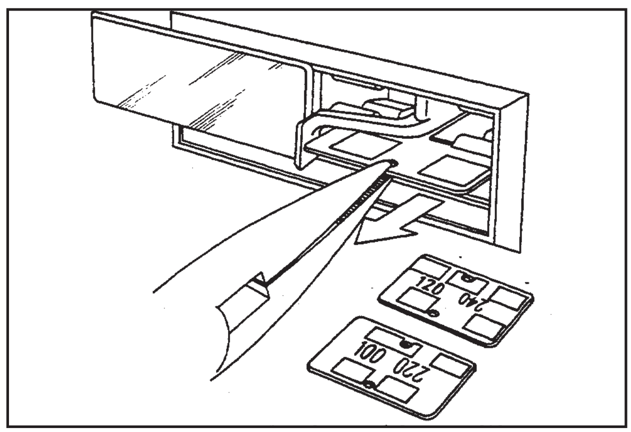
B. Slide the plastic door to the left.



C. Pull the fuse lever out and to the left; remove the fuse.



D. Grasp the voltage board, being careful no to damage plated pads.



E. Remove the board by pulling straight out.

F. Select voltage by rotating the board until the desired voltage is oriented at the top left side of the board.

Figure 3.1 Changing the Line Voltage

Reverse this procedure to reassemble the voltage connector.

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3.4.1 - System Grounds

The Model 9002 grounding system has been designed to allow maximum flexibility and noise immunity. There are three electrically isolated grounds brought out for connection to the external components.

Digital ground for connection to the remote controller is provided on the IEEE-488 interface connector.

Analog signal ground is brought out through a rear panel plastic banana plug and is internally connected to the unit's analog power supply. Analog ground provides a system ground reference for differential input configurations.

Effective grounding of signal lines and every chassis will greatly improve noise immunity and assure precise filter spectra. A discussion of noise and distortion that accompanies the Model 9002 filter process is found in the Product Data Sheet (Appendix A).

3.5 - Basic Setup

The Model 9002 may now be connected to the power source, to the remote controller (if remote is being used), and to the circuit to be filtered.

1. Connect the device being filtered to the input and output BNCs on the front or rear panel. Be sure that both input and output are hooked up to the same channel. If possible, connect a ground strap between the chassis of the device and the Model 9002 chassis.

2. For remote operation, connect the IEEE-488 interface from the remote controller to the connector provided on the rear panel of the Model 9002. If the controller is not already equipped with an IEEE-488 interface card, one must be installed. Refer to the computer or controller manufacturer's instructions for card installation.

3. Plug the unit into the power source.

4. You are now ready to learn and utilize the many features of your Model 9002 Dual Channel Programmable Filter. The following sections contain specific control, modification, and programming information. Please read these sections carefully before using the system.

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Section 4
Operation from the Front Panel

4.1 - Front Panel Description

In local operation the Model 9002 can be completely operated from the front panel. Remote control requires the writing of programs using codes and commands that are described in Section 5. The panel indicators and controls can be grouped into five categories:

Indicator LEDs	16 LEDs
Numeric keypad	0-9 plus associated keys
Function keys	10 keys
Input and Output connectors	1 input & 1 output per channel
Alphanumeric display	3-1/2 digits

4.2 - Indicator LEDs

Table 4.1 gives the name and active function of the 16 LEDs on the front panel.

Indicator Label	**Model 9002 Active Function**
SNG	Configured for single-ended Input
DIF	Configured for differential Input
AC	AC Input/Output Coupling
DC	DC Input/Output Coupling
BYP	Filter Bypass mode is selected
MEM	Displays present filter config.#
REM	Remote control operation is selected
CH1	Channel 1 selected for display
CH2	Channel 2 selected for display
PRE	Pre-filter gain is displayed
POST	Post-filter gain is displayed
KHZ	Frequency is displayed, kHz Scale
HZ	Frequency is displayed, Hz Scale
GAIN	Value of Pre- or Post-gain is displayed
CLIP 1	Channel 1 input is being clipped
CLIP 2	Channel 2 input is being clipped

Table 4.1 Explanation of LED Indicators

4.3 - Function Keys

There are 10 function keys for programming and reviewing the setup of the Model 9002. These are used in the process of setting up a channel in any of the eight programmable filter configurations, and in checking the status of the filter during use.
Most keys are inactivated when the control of the system is transferred to a remote controller. Table 4.2 and the discussion in the following section include the key functions and the situations in which they are active or inactive.

Key Label	Affect on Model 9002 Operation
CH1/CH2	Toggle: Programming and display between Ch. 1 & Ch. 2
FLTR MEM	Selects Filter Number (0-7) in both channels
FLTR TYPE	Display Filter Type for the active channel
REM CTL	Toggle: Remote or Local control
FREQ/GAIN	3-position Toggle: Freq., Pre-gain, or Post-gain
SNG/DIF	Toggle: Single-ended or Differential input
ACT/BYP	Toggle: Filter in-circuit or Bypassed
AC/DC	Toggle AC or DC I/O Coupling
HZ/KHZ	Toggle: HZ or KHZ for frequency multiplier for programming and display
CLR DSP	Clears the LED Display

Table 4.2 Explanation of Function Keys

The numerical keypad and the function keys ENT, ⇑, and ⇓, allow control of frequency, gain, filter configuration number, and remote IEEE address. The following are detailed instructions for using the functions keys and corresponding LEDs. Refer to Figure 4.1 for front panel location.

4.3.1 - Details of the function keys

Selection of particular function keys or selection of remote control from the controller (REM CTL) will deactivate certain keys. In the following description, the function key labels are shown in boxes on the left; the bracketed keys on the right are the active or inactive keys.

Figure 4.1 Front Panel

Section 4 Operation from the Front Panel

CH1 / CH2

[all active keys]

This functions key switches programming and display between Channel 1 and Channel 2. The selected channel is shown by illumination of the CH 1 and CH 2 indicator. CH1/CH2 does not change the configuration of a filter; it only shows the present configuration for the selected channel.

FLTR MEM

[active keys: keypad, ENT, ⇑/⇓ , CH1/CH2, CLR DSP FLTR MEM]

This key displays the present filter configuration number 0-7. The MEM indicator light will turn on. A configuration contains the following combination of user-programmable filter parameter.

- Pre- and Post-gain levels
- Corner Frequency
- Single-ended or Differential input
- Filter in-circuit or Bypassed
- AC or DC I/O Coupling

The filter configuration number can be changed in the range 0-7 on the numeric keypad or by using the ⇑/⇓ keys. The Model 9002 will not allow any number over 7 to be entered. The configuration number affects both Channel 1 and Channel 2. The CH1/CH2 key is used to display the configuration number in the selected channel. Thus, Channel 1 cannot be set to configuration number 0, and Channel 2 simultaneously set to configuration number 5. They will automatically be set to the same configuration number, although the setup of each configuration may be different for each channel.

Pressing FLTR MEM a second time will return the system to the previous control mode and update the instrument to the presently selected configuration.

FLTR TYPE

[active keys: CH1/CH2, FLTR TYPE]

Activation of this function causes the display of an alphanumeric, coded description of the type of filter in the selected channel. The types are selected from those in Table 4.3. The CH1/CH2 key may be used to display the filter type in the selected channel.

Type Number	Characteristic
Lowpass	
LP00	8-pole Butterworth
LP01	8-pole, 6-zero elliptic 1.77
LP02	8-pole,Bessel
LP03	8-pole, 6-zero constant delay
LP05	8-pole, 6-zero elliptic (200 kHz)
LP06	4-pole Bessel
LP07	4-pole Butterworth
LP08	8-pole, Bessel (200 kHz)
LP09	8-pole, Butterworth (200 kHz)
LP10	8-pole, 6-zero constant delay (200 kHz)
Highpass	
HP00	8-pole Butterworth
HP01	8-pole, 6-zero elliptic1.77
HP05	8-pole, 6-zero elliptic (200 kHz)
HP07	4-pole Butterworth
HP09	8-pole, Butterworth (200 kHz)

Table 4.3 Electrical Characteristics of Filters

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Pressing FLTR TYPE a second time will return the system to the previous mode.

REM CTL

[active keys: ⇑/⇓, CH1/CH2, FLTR TYPE, ENT, FLTR MEM, REM CTL,]

This function key allows the user to place the Model 9002 under the operation of the remote controller and displays the presently assigned address of the instrument. The address can be changed using the ⇑/⇓ keys. Only addresses 0-31 are valid. After entering the address, press the ENT key to transfer control to the remote controller. This will light the REM indicator.

Once the system is under remote control, the only active key is REM CTL. Depressing this key a second time at any stage of this procedure will return control of the Model 9002 to the front panel.

FREQ GAIN

[inactive key: HZ/KHZ]

This key steps the display through the three filter parameter states while turning on the appropriate LED indicator. The steps in sequence are:

Pre-filter gain
Post-filter gain
Filter Frequency

PRE-GAIN

[inactive key: HZ/KHZ]

The method for changing gain is the same for both Pre- and Post-gain.

The PRE and GAIN LEDs will be lighted. The display will show the Pre-gain setup for the presently selected channel and filter configuration number.

The gain has a range from 1.00-13.75 in incremental steps of 0.05. The numeric keypad or ⇑/⇓ keys are used to change the gain. The suggested method for gain change is as follows:

Enter the gain value on the keypad
Press ENT to store the data

The ⇑/⇓ keys store the gain on-line and the ENT key need not be pressed. These keys will increase or decrease gain by one increment, that is, 0.05. Gain will change as long as the key is depressed. The value displayed will automatically be stored in the present filter configuration number and selected channel. Pressing CH1/CH2 will display the Pre-gain of the selected channel.

Pressing the FREQ/GAIN key a second time will put the unit in the filter Post-gain setup.

POST-GAIN

[inactive key: HZ/KHZ]

The POST and GAIN LEDs will be lighted. The display shows the Post-filter gain of the selected channel and filter configuration number. Post-gain operation is the same as Pre-gain operation and CH1/CH2 will display the Post-gain of the selected channel.

Pressing FREQ/GAIN a third time will place the system in the filter-frequency setup.

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FREQUENCY

[all keys active]

The HZ or KHZ LED will be lit. The display will show the present corner frequency for the selected channel and filter configuration number.

The corner frequency can be chosen in the range of 0.1 Hz to 102.4 kHz. (See Table 4.4 for 200 kHz models). The numeric keypad or the ⇑/⇓ keys, in conjunction with the HZ/KHZ key, are used to change the frequency value.

When using the numeric keypad for CH1/CH2, FREQGAIN, or HZ/KHZ, ENT or any function key (excluding SNG/DIF, ACT/BYP, or AD/DC) may be depressed to store the data. The recommended sequence is:

Enter the new frequency
Select HZ or KHZ
Press the ENT key

The ⇑/⇓ keys store the data immediately and no other key depression is required. As above, the HZ/KHZ key selects the range of frequency to be displayed and entered. The frequency will increase or decrease by one increment in accordance with Table 4.4.

Frequency Range	Frequency Increment
0.1 Hz-102.4 Hz	0.1 Hz
103.0 Hz-1,024.0	1 Hz
1,030.0 Hz-10,240 Hz	10 Hz
10,300.0 Hz-102,400 Hz	100 Hz*
* 10,400.0 Hz-204,800.0 Hz	200 Hz (for 200 kHz models only)

Table 4.4 Frequency Ranges and Increments

Pressing CH1/CH2 will display the filter corner frequency of the selected channel. Any data displayed when using the ⇑/⇓ keys will be stored in the present filter configuration number and selected channel as the keys are being pressed.

SNG / DIF

[all keys active]

The function key toggles the selected channel between a single ended and differential input. Either the SNG or DIF LED will be lighted. The data will immediately be stored to the present filter configuration number and selected channel.

ACT / BYP

[all keys active]

This key toggles the selected channel between the filter in circuit mode (active) and the filter bypass mode (bypass). The BYP LED will be on for bypass and off for active. This data will immediately be stored to the present filter configuration number and selected channel.

AC / DC

[all keys active]

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The AC/DC function toggles the selected channel between AC and DC coupled input and output stages. The AC or DC LEDs will display which configuration is selected. This data will immediately be stored to the present filter configuration number and selected channel.

[all keys active]

HZ / KHZ

The HZ/KHZ function toggles the displayed frequency of the selected channel between Hz and kHz. The HZ or KHZ LEDs will display which configuration is selected. This data will immediately be stored to the present filter configuration number and selected channel.

[all keys active]

CLP / DSP

This function clears the display to provide a clean state for entering new data. No other aspect of the instrument is affected.

[all keys active]

CLIP1 / CLIP2

The CLIP1 and CLIP2 LEDs are controlled internally by the Model 9002. They are warning lights that indicate impending or actual amplitude clipping in the indicated filter channel and after each internal gain stage. The LEDs are continuously updated and monitor both positive and negative peak signals.

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Section 5
Remote Control Operation

5.1 - The Control Method

Remote control of the Model 9002 is conveyed on an IEEE-488 bus to the appropriately addressed filter system. Each Model 9002 system is assigned an address in the 0-31 range, as was discussed in Section 3.5

We recommend that you read and understand Section 4, Operation from the Front Panel, before attempting remote control of the system. Commands that duplicate front panel controls are not re-explained in this section.

An understanding of programming and use of the IEEE-488 interface bus structure is necessary for effective use of the remote mode of operation. Your computer or other remote controller must be outfitted with the appropriate IEEE-488 card to implement remote operation of the Model 9002.

As an assist, conversion tables from binary to decimal to hex are given in Appendix B. For ease of notation, all binary commands are stated in hex throughout this section. Hex commands are identified by the presence of a $ sign before the hex number.

5.2 - Programming Rules

The Model 9002 accepts only eight-bit binary data. Codes sent to control the Model 9002 will be referred to as programs. These programs must begin with the start code $11 and conclude with the end code $13. If either code is omitted, the Model 9002 will not accept the communicated program.

The maximum length of a program is 256 bytes including the start and end codes. Programs requiring more than 256 bytes of information must be sent as two consecutive programs with separate start and end codes.

Programming is accomplished by combining codes that simulate front panel controls (key-push commands) and keyboard inputted numbers, as well as single and multi-byte special command codes.

The Model 9002 can be set up to receive remote data by means of a front panel command or a remote command. At the front panel, you press the REM CTL function key. At the remote controller, send special codes $0F, Go to Remote Control. The front panel is inactive when the Model 9002 is in remote control.

A typical program for setup by remote command is:

Code	Function
$11	Start
$0F	Go to Remote Control
$13	End

The unit remote address can be set at the front panel or by using an IEEE-488 command. If the command is used to change the address, the display will not show this new address. However, the system will only listen to commands at the new address. This address will remain in effect until a new address is sent or the Model 9002 is returned to local control and the front panel address is active.

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5.2.1 - Listen/Talk Structure

Interactions between the Model 9002 and a remote controller should follow the command structure shown below:

Talk	Listen	
Talk	Listen	Controller sets up Model 9002 as a Listener
"	"	.
"	"	.
"	"	Controller sends Command data
"	"	.
"	"	.
"	"	Controller sets up Model 9002 as a Talker
"	"	.
"	"	.
"	"	Controller receives Model 9002 data

5.3 - Key-Push Commands

Key-push codes instruct the unit to perform as if commanded by the front panel thus allowing the remote controller to perform all functions available under local operation. Each Key-push codes is independent and instructs the Model 9002 to perform front panel functions, one step at at time.

Table 5.1 lists the hex codes for the front panel function keys. These keys are described in Section 4.3.

Note
Key-push codes that control a toggled function are indicated by an asterisk [*].
Care should be taken to empty these codes only when previous system status has been defined earlier in the program lest they inadvertently switch important functions ON or OFF.

Key	Code	Key	Code
CH1* CH2	$40	SNG* DIF	$50
FLTR TYPE	$41	ACT* DC	$51
FLTR TYPE	$42	AC* DC	$52
REM CTL	$43	HZ* KHZ	$53
FREQ* GAIN	$20	CLR DSP	$30

Table 5.1 Codes for Function Keys

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The numeric keyboard is remotely simulated by the command codes listed in Table 5.2.

Keypad	Code	Keypad	Code
0	$30	7	$37
1	$31	8	$38
2	$32	9	$39
3	$33	.	$3A
4	$34	ENT	$3B
5	$35	⇑	$3E
6	$36	⇓	$3D

Table 5.2 Codes for the Numeric Keypad

5.4 - Special Command Codes

Special codes allow the remote controller to perform functions not available or not necessary under local control. Some special codes consist of a command code and one or more data codes that further define the special code. Therefore, these codes may be made up of more than one byte.

Table 5.3 is a summary of these special codes.

Command Code	Function
$05	Abort to Local
$06	Set Filter
$0B	Go to Channel 1 or 2, Filter 0-7
$0C	Send back Channel Status
$0D	Send back Channel Definition
$0E	Send back Clip Status
$0F	Go to Remote Control

Table 5.3 Special Codes

Reference to Table B.3 in Appendix B, Decimal to Hex Conversion, may prove helpful in following the discussion in this section.

5.4.1 - Use of Special Codes $05, Abort to Local

Special code $05 is a one-byte instruction that returns the Model 9002 to local control. The REM CTL light is turned off and the selected channel and its filter configuration will be displayed. All other codes following $05 are ignored. For example:

Code	Function
$11	Start of Program
$05	Abort to Local
•	
•	Code here is ignored
$13	End of Program

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5.4.2 - Use of Special Codes $06, Set Filter

Special code $06 is a seven-byte instruction used to establish a filter configuration. It is composed of a command code ($06) followed by six hex codes that define the filter setup. The parameters to be programmed are listed in Table 5.4.

Programmed Parameters
Corner Frequency
Filter mode (active or bypass)
Input configuration (single-ended or differential)
Input and Output coupling (AC or DC)
Pre-gain
Post-gain

Table 5.4 Parameters Programmed with Code $06

Each byte in the $05 sequence performs a part of the setup function. The programming process involves the use of this special code to setup the sixteen filter configurations in the instrument.

5.4.2.1 - The Code $06 Command Setup

The setup of each byte in the $06 Command Code sequence is:

- Byte 1 is the command code and, therefore, is always $06.
- Byte 2 contains the channel number to be set up, which is defined as one of the following:

Channel	Code
CH1	$00
CH2	$01

- Byte 3 contains the filter configuration number to be set up, which is defined as one of the following:

Configuration	Code
CONFIG0	$00
CONFIG1	$01
CONFIG2	$02
CONFIG3	$03
CONFIG4	$04
CONFIG5	$05
CONFIG6	$06
CONFIG7	$07

Table 5.5 Filter Configuration Codes

- Bytes 4 to 7 define the setup of the selected channel number and filter configuration number. These bytes are mapped out in Table 5.6. Calculation of the correct values for this table is critical to understanding and implementing the remote control process.

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Byte #	D7	D6	D5	D4	D3	D2	D1	D0
4	F7	F6	F5	F4	F3	F2	F1	F0
5	ACT	DIF	DC	R2	R1	R0	F9	F8
6	PRE7	PRE6	PRE5	PRE4	PRE3	PRE2	PRE1	PRE0
7	PO7	PO6	PO5	PO4	PO3	PO2	PO1	PO0

Table 5.6 The $06 Command Setup List

- Byte 4 contains the least significant bits, F7-F0, of the frequency base, a term we will shortly define.

- Byte 5 sets up a number of key parameters:

ACT/BYP function Selection of SNG or DIF Choice of AC or DC coupling Frequency range R2-R0 2 MSBs, F9 & F8, of the base frequency

As Table 5.6 shows, ACT, DIF and DC are the high (1) setting. A low setting (0) stands for BYP, SNG, and AC.

- Byte 6 is the Pre-gain in binary code.

- Byte 7 is the Post-gain in binary code.

5.4.2.2 - Calculating Program Parameters

Programming the filters involves calculating certain specially defined numbers related to frequency and gain. These calculations are shown step-by-step in this section. Examples are shown with each step to aid your understanding of the process.

Desired Corner Frequency (DCF)

The Desired Corner Frequency is approximated in the instrument by the Programmed Corner Frequency (PCF). The PCF is composed of two components:

Range R
Frequency base F

These values are derived from the Desired Corner Frequency such that the following equation is true:

PCF = (F + 1) x R

R is the frequency range value .1, 1, 10, or 100 which, when divided into the Desired Corner Frequency, yields the largest possible number between 1 and 1024.

For example, let us calculate R for a Desired Corner Frequency of 10,638 Hz. Table 5.7 lists the results of dividing 10,638 by 0.1 1, 10, and 100.

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DFC	R		Base Result
10,638	0.1	=	106,380
10,638	1	=	10,638
10,638	10	=	1,063.8
10,638	100	=	106.38 Use this 100 range. (106.38 is the base result.)

Table 5.7 Calculation of R

Range 100 is selected because the Base Result (106.38) is the largest value of the four results in the range 1 to 1024. When the range has been determined, the binary digits (R2-R0) of the Table 5.6 are selected from Table 5.8 below. These become bits D4-D2 of byte 5.

R	R2	R1	R0
0.1	1	1	0
1	1	0	1
10	0	1	1
100	1	1	1

Table 5.8 Range Selection Table

In our example, R = 100, therefore:

R2	R1	R0
1	1	1

The frequency base F is calculated after R is known by rounding the base result of Table 5.7 to the nearest whole number and subtracting one (1). When the frequency base F has been determined, it must be converted to a 10-bit binary number and inserted into bytes 4 and 5, bits D7-D0 and D1-D0 of Table 5.6.

The base result of 106.38 in Table 5.7 rounds down to 106 resulting in a frequency base F of 106 - 1 = 105. A check of these results shows:

Programmed Corner Frequency = (F + 1) x R = (105 + 1) x 100
= 10,600 Hz = 10.6 kHz

This value is within the 100 Hz system resolution at the 10kHz level.

Conversion of the frequency base to a binary number is the next step. Using established methods, we find the following binary equivalent to 105 decimal.

F9	F8	F7	F6	F5	F4	F3	F2	F1	F0
0	0	0	1	1	0	1	0	0	1

These digits are for insertion in bytes 4 and 5, as defined by Table 5.6

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ACT/BYP Status
Binary bit 7 of byte 5, calling for the filter to be active or bypassed, is now selected and inserted in Table 5.6.

Status	ACT
Active	1
Bypass	0

SNG/DIF configuration
Binary bit 6 of byte 5, distinguishing between SNG and DIF configuration, is now selected and inserted in Table 5.6.

Input	DIF
Differential	1
Single-ended	0

I/O coupling
Binary bit 5 of byte 5, distinguishing between AC and DC coupling, is now selected and inserted in Table 5.6.

Coupling	DC
DC Coupling	1
AC Coupling	0

PRE- and POST-gain
The binary digits of byte 6, PRE7-PRE0, represent the Pre-gain. The digits PO7 -PO0, byte 7, represent the Post-gain. Both gains range from a factor of 1.00 to a factor of 13.75 in digitized increments of .05.

The decimal gain code is calculated by the following formula:

$$(\text{Gain} - 1) \times 20 = \text{Decimal gain code}$$

As the gain is incremented in steps of 0.05, the calculated decimal code should be rounded off to the nearest .05.

Decimal, hex, and binary gain code conversions are given in Table 5.9. Intermediate values are obtained by continuing the sequence.

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Gain Level	Dec		Hex		P7....P0 (bytes 6 & 7)
1	0	=	$00	=	00000000
1.05	1	=	$01	+	00000001
1.1	2	=	$02	=	00000010
1.15	3	=	$03	=	00000011
1.2	4	=	$04	=	00000100
1.25	5	=	$05	=	00000101
.					
.					
13.5	250	=	$FA	=	11111010
13.55	251	=	$FB	=	11111011
13.6	252	=	$FC	=	11111100
13.65	253	=	$FD	=	11111101
13.7	254	=	$FE	=	11111110
13.75	255	=	$FF	=	11111111

Table 5.9 Gain in Various Numerical Bases

Let us expand our example to call for a Pre-gain of 5.15 and a Post-gain of 12.1. Using the gain formula above, the following decimal codes are calculated:

(5.15 - 1) x 20	=	83	=	Decimal code for Pre-gain
(12.1 - 1) x 20	=	222	=	Decimal code for Post-gain

The conversions to binary and hex code are shown below.

PRE7	PRE6	PRE5	PRE4	PRE3	PRE2	PRE1	PRE0	
0	1	0	1	0	0	1	1	$=83_{10}=53_{16}$
PO7	PO6	PO5	PO4	PO3	PO2	PO1	PO0	
1	1	0	1	1	1	1	0	$=222_{10}=0E_{16}$

5.4.2.3 - Example of a Code $06 program

This exercise is a step-by-step example of the program calculations required for setup with a Special Code $06 program.

Sample Configuration

Channel	#1
Filter Configuration	#4
Desired Corner Frequency	100 Hz
Filter Mode	Active
Input Configuration	Single
Coupling	AC
Pre-gain	2.30
Post-gain	10.05

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Perform the following steps to calculate the Code $06 sequence for the sample configuration given above.

Step #	Action to be Taken
1	Get Byte 1
1a	Command Code = $06
2	Get Byte 2
2a	Get selected channel # code Channel selected = Ch. 1 Channel code = $00
3	Get Byte 3
3a	Get selected filter configuration # code Configuration selected = Config. 4 Configuration Code = $04
4	Get bytes 4 - 7 to set filter signal parameters
4a	Calculate range (R) and Base Result Base Result = DCF/R = for that R which yield the largest number between 1 and 1024 Desired Corner Frequency (DCF) = 100

Determining the Base Result for the Example

DCF	R	Base Result
100	0.1	1000; Select R - 0.1 & Base Result = 1000
100	0	100
100	10	10
100	100	1

Step #	Action to be Taken
4b	Get Range Code (R2-R0) for R = 0.1, R2 - R0 = 110, See Table 5.8
4c	Calculate Frequency Base (F) F = Base Result - 1 F = 1000 - 1 F = 999
4d	Get Frequency Base Code (F9 - F0) Convert F (Frequency Base) to a 10-bit binary 999 = 1111100111 = F9(MSB) - F0(LSB).
4e	Verify F & R results by calculating PCF (Programmed Corner Frequency) PCF = (F + 1) x R = (999 + 1) x 0.1 = 100 If PCF equals the DCF within the resolution for that range, then the results are correct.

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Step #	Action to be Taken
4f	Get ACT/BYP status code (ACT) Desired status = Active ACT bit = 1
4g	Get SNG/DIF configuration code (DIF) Desired Configuration = Single DIF bit = 0
4h	Get I/O coupling code (DC) Desired coupling = AC DC = 0
4i	Get decimal Pre-gain code Decimal gain code = (gain - 1) x 20 Desired Pre-gain code = 2.30 Decimal Pre-gain code = (2.30 - 1) x 20 Decimal Pre-gain code = 26
4j	Get Pre-gain code (PRE7 - PRE0) Convert decimal Pre-gain code to an 8 bit binary number 26 = 00011010 = PRE7(MSB) - PRE0(LSB)
4k	Get decimal Post-gain code Decimal gain code = (gain - 1) x 20 Desired Post-gain code = 10.05 Decimal Post-gain code = (10.05 - 1) x 20 Decimal Post-gain code = 181
4l	Get Post-gain code (PO7 - PO0) Convert decimal post-gain code to an 8-bit binary number 181 = 10110101 = PO7(MSB) - PO0(LSB)

Table 5.10 shows a summary of Step 4. Using the formulas for R, F, and Gain code given in the previous sections, we can calculate the binary numbers for this configuration that are to be inserted into the format of Table 5.6.

Function	Value	Binary	Table 5.6 Location
R	.1	110	R2 - R0
F	999	1111100111	F9 - F0
Status	Active	1	ACT
Input	Single	0	DIF
Coupling	AC	0	DC
Pre-gain	2.30gain⇒26code⇒	00011010	PRE7 - PRE0
Post-gain	10.05gain⇒181code⇒	10110101	PO7 - PO0

Table 5.10 Development of Codes for the Sample Configuration

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Table 5.10 translates into the following form of Table 5.6.

Byte	D7	D6	D5	D4	D3	D2	D1	D0	Hex
4	1	1	1	1	1	0	0	1	$E7
5	1	0	0	1	1	0	1	1	$9B
6	0	0	0	1	1	0	1	0	$1A
7	1	0	1	1	0	1	0	1	$B5

These codes can be developed into the following code sequence for the Model 9002. The hex codes become the programming codes transmitted via IEEE-488 to the Model 9002.

Code Sequence for Sample Configuration

Code	Function
$11	Start of Program
$06	Code 6, Set Filter
$00	Channel #1
$04	Filter Configuration #4
$E7	These bytes are the Filter Setup
$9B	for Freq, Range, Mode
$1A	Input, Coupling and
$B5	Pre- and Post-gain
$13	End of program

The front display and indicator lights will indicate that the data was sent by the Code $06 command.

5.4.3 - Code $0B - Go to Channel N, Filter M

Special Code $0B is a three byte instruction that allows the remote controller to select a filter configuration number and a channel number. The three bytes consist of:

- Byte 1 Command code ($0B)
- Byte 2 Defines channel number (1 or 2.). See Sec. 5.4.2.1
- Byte 3 Defines filter config. nun=number (0-7). See Sec. 5.4.2.1

Sending the $0B code will cause the front display and LEDs to indicate the selected channel number and filter configuration, and will update the instrument to the selected configuration.

An example of the use of the $0B code follows.

Code	**Description**
$11	Start of program
$0B	Code $0B, Go to Channel N, Filter M
$00	Channel #1 chosen
$02	Filter Configuration #2 chosen
$13	End of program

Command data subsequent to this sequence will be stored in Channel 1 and Filter configuration number 2.

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5.4.4 - Code $0C - Send Back Channel Status

Special Code $0C is a one-byte instruction that sets the system up to send back channel status data. The Model 9002 must be set up as a talker by the remote controller to send back the data. The Model 9002 will send 11 bytes of data representing the setup of Channels 1 and 2.

The data bytes sent back are:

- Byte 1 — Number of codes to be sent back (including byte 1)
- Byte 2 — Identification of special code sent = $0C
- Byte 3 — Present filter configuration number
- Byte 4-7 — Channel 1 status data as defined in bytes 4-7 of Code $06 command description, Table 5.5
- Bytes 8-11 — Channel 2 status data as defined in bytes 4-7 of Codes $06 command description, Table 5.5

A simple instructional program follows.

Code	Description
$11	Start of program
$0C	Code $0C, Send Back Channel Status
$13	End of program

As an example, suppose the following is the status of the channels:

Status Data	CH1	CH2
Filter config. No.	2	2
Frequency	100 Hz	20 kHz
Mode	Active	Active
Configuration	Differential	Single
Coupling	DC	AC
Pre-gain	1.00	1.35
Post-gain	5.00	13.75

The system will send back the following data bytes:

Byte #	Hex	Function
1	$0B	Number of data bytes being sent
2	$0C	Value of special code (To define the type of data being sent (i.e., Channel data = $0C)
3	$02	Filter Configuration number 2
4	$E7	Ch. 1 Data per Table 5.6, byte 4
5	$FB	Ch. 1 Data per Table 5.6, byte 5
6	$00	Ch. 1 Data per Table 5.6, byte 6
7	$50	Ch. 1 Data per Table 5.6, byte 7
8	$C7	Ch. 2 Data per Table 5.6, byte 4
9	$9C	Ch. 2 Data per Table 5.6, byte 5
10	$07	Ch. 2 Data per Table 5.6, byte 6
11	$FF	Ch. 2 Data per Table 5.6, byte 7

5.4.5 - Code $0D - Send Back Channel Definition

This is a one-byte instruction which sets the system up to send back filter type data in the related channel. The Model 9002 must be set up as a talker by the remote controller to send back the data. The data consists of four bytes which represent the filters of Channel 1 and 2.

- Byte 1 — # of codes being sent back
- Byte 2 — Identification of special code sent = $0D
- Byte 3 — Coded filter type in Channel 1
- Byte 4 — Coded filter type in Channel 2

There are three types of channel filter cards to be encoded for return transmission: Lowpass, Highpass and Special. The hex codes for the available low- and highpass filters are given in Table 5.11.

Filter Code	Characteristic
Lowpass	
$00	8-pole Butterworth
$01	8-pole 6 zero elliptic
$02	8-pole Bessel
$03	8-pole 6-zero constant delay
$05	8-pole, 6-zero, elliptic (200kHz)
$06	4-pole Bessel
$07	4-pole, Butterworth
$08	8-pole, Bessel (200kHz)
$09	8-pole, Butterworth (200kHz)
$0A	8-pole, 6-zero constant delay (200 kHz)
Highpass	
$10	8-pole Butterworth
$11	8-pole 6 zero elliptic
$15	8-pole, 6-zero elliptic (200kHz)
$17	4-pole, Butterworth
$19	8-pole, Butterworth (200kHz)

Table 5.11 Hex Codes of Filters

Bytes 3 and 4 will be sent back with the filter type data for Channels 1 and 2, respectively. The structure of bytes 3 and 4 is given below.

D7	D6	D5	D4	D3	D2	D1	D0
0	0	x	x	x	x	x	x

D7 and D6 will always be zero for this command codes.

If D5 = 1, the channel is a special filer (FL). D4-D0 are decoded into number between 0 and 31. Refer to the Product Data Sheet (Appendix A) for the code definitions.

If D5 = 0, then D4 = 0 for LP and D4 = 1 for HP. D3 - D0 are decoded into a number between 0 and 15.
In the following example, a program is sent to the Model 9002, and it then responds with a four-byte sequence of data. The program sent is:

Code	Function
$11	Start of Program
$0D	Codes $0D. Send back Channel Definition
$13	End of Program

If Channel 1 is an 8-pole, 6-zero lowpass Elliptic filter and Channel 2 is a highpass Butterworth filter, then the Model 9002 will send back the following data bytes as displayed in Table 5.12

Byte #	Hex	Description
Byte 1	$04	# of bytes being sent back
Byte 2	$0D	Identification of special code
Byte 3	$01	Channel 1 coded definition
Byte 4	$10	Channel 2 coded definition

Table 5.12 Channel Definition Data Sent Back

5.4.6 - Code $0E - Send Back Clip Status

Special Code $0E is a one-byte instruction which sets the Model 9002 up to send back signal clipping data. The Model 9002 must be set up as a talker by the remote controller to send back the data. It sends back three bytes of data which represent the clipping status of Channels 1 and 2.

Byte #	Hex		Description
Byte 1	$03		Number of codes being sent back
Byte 2	$0E		Identification of special code sent back
Byte 3			Clip status of Channel 1 and 2
	$00	=	Clipping in Channels 1 and 2
	$80	=	Clipping in Channels 2 only
	$40	=	Clipping in Channels 1 only
	$C0	=	No Clipping

Table 5.13 Clip Status Definition

A remote control sequence to request clipping data is:

Code	Function
$11	Start of Program
$0E	Codes $0E. Send back Channel Definition
$13	End of Program

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If Channel 1 is clipping and Channel 2 is not clipping, then the Model 9002 will send back the following data bytes:

- Byte 1 = $03 — # of bytes being sent back
- Byte 2 = $0E — Identification of special code
- Byte 3 = $40 — Channel 1 clipping only

5.4.7 - Code $0F - Go to Remote Control

Special code $0F is a 1-byte instruction which puts the Model 9002 into remote control at its present remote address. This sets up the Model 9002 as a listener and turns on the REM indicator light. An example of a program to enable this function is:

Code	Function
$11	Start of Program
$0F	Go to Remote Control
$13	End of Program

5.5 - Example of a Remote Control Program

In the following example, the Model 9002 is to be set up as shown in the boxed text below, and is then told to send back a series of status reports.

Channel #1, Filter Configuration #0	
Freq	50.4 Hz
Pre-gain	1.5 dB
Post-gain	13.55 dB
Coupling	DC
Input config.	Single ended
Filter mode	Bypass
Channel #1, Filter Configuration #1	
Freq	12.6 Hz

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Section 5 Remote Control Operation

The following program makes use of all the special codes and many of the front panel key pushes.

Code	Function
$11	Start of Program
$0F	Go to remote control
$06	Set filter
$00	Channel 1
$00	Filter configuration #0
$F7	Corner freq = 50.4 Hz
$39	Range 0, DC, Single, Bypass
$0A	Pre-gain = 1.5
$FB	Post-gain = 13.55
$0B	Go to channel N, filter M
$00	Channel 1
$01	Filter configuration #1
$3C	Clear display (CLR DSP) keypad push
$31	Keypad push 1
$32	Keypad push 2
$3A	Keypad push '.'
$36	Keypad push 6
$3B	Keypad push ENT
$0C	Send back channel status
$0D	Send back channel definition
$0E	Send back clip status
$05	Abort remote
$13	End of program

The Send back codes ($0C, $0D, and $0E) are included in the program to provide feedback of the correctness of the setup. When the program is finished and the Model 9002 is in local control, verify the filter configuration system by performing front panel key push commands.

For two additional examples of code sequences used to send and receive data from the Model 9002, refer to Appendix C.

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Appendix B
Binary/Decimal/Hex Review

When remotely programming the Model 9002, you must convert a decimal number to a 10-bit binary number and then convert it into a hex code. This review describes the formulas and procedures that are used to make such conversions.

B.1 - Decimal to Binary

A decimal number is converted to a binary number by using an algorithm which performs repeated division by two, and then multiplies the remainder by two to determine the value of the binary data bits.

Conversion of Decimal 999 to Binary 1111100111

Number 999	Decimal N	Remainder R	Value 2xR	Binary Bit
N/2=	499	0.5	1	D0
	249	0.5	1	D1
	124	0.5	1	D2
	62	0	0	D3
	31	0	0	D4
	15	0.5	1	D5
	7	0.5	1	D6
	3	0.5	1	D7
	1	0.5	1	D8
	0	0.5	1	D9

Therefore, the 10-bit binary equivalent to the decimal number 999 is:

D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
1	1	1	1	1	0	0	1	1	1

Conversion of Decimal 224 to Binary 0011100000

Number 224	Decimal N	Remainder R	Value 2xR	Binary Bit
N/2=	112	0	0	D0
	56	0	0	D1
	28	0	0	D2
	14	0	0	D3
	7	0	0	D4
	3	0.5	1	D5
	1	0.5	1	D6
	0	0.5	1	D7
	0	0	0	D8
	0	0	0	D9

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B.2 - Binary to Hex

Data input to the Model 9002 is a sequence of 8-bit binary bytes. For ease of presentation, this manual is written in 2-digit hex notation. What follows is a review of the relationship between binary and hex formats. The relationship between a 4-bit binary number and a 1-digit hex number is as follows:

4-Bit Binary	1-Digit Hex
0000	0
0001	1
0010	2
0011	3
0100	4
0101	5
0110	6
0111	7
1000	8
1001	9
1010	A
1011	B
1100	C
1101	D
1110	E
1111	F

Table B.1 Binary to Hex Conversion

Two digit hex notation represents (2-digit x 4-bit) 8-bit binary data. Therefore, in hex notation, an 8-bit byte is 2, 4-bit binary numbers side by side. The relationship between 8-bit binary and two digit hex is as follows:

8-Bit Binary	2-Digit Hex
0000 1111	0F
0001 1110	1E
0010 1101	2D
0011 1100	3C
0100 1011	4B
0101 1010	5A
0110 1001	69
0111 1000	78

Table B.2 Conversion of 8-Bit Binary to Hex

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B.3 - Decimal to Hex

Conversion from decimal to hex is shown in Table B.3. The process can be extended for larger decimal numbers.

Dec	Hex	Dec	Hex	Dec	Hex
01	$01	28	$1C	55	$37
02	$02	29	$1D	56	$38
03	$03	30	$1E	57	$39
04	$04	31	$1F	58	$3A
05	$05	32	$20	59	$3B
06	$06	33	$21	60	$3C
07	$07	34	$22	61	$3D
08	$08	35	$23	62	$3E
09	$09	36	$24	63	$3F
10	$0A	37	$25	64	$40
11	$0B	38	$26	65	$41
12	$0C	39	$27	66	$42
13	$0D	40	$28	67	$43
14	$0E	41	$29	68	$44
15	$0F	42	$2A	69	$45
16	$10	43	$2B	70	$46
17	$11	44	$2C	71	$47
18	$12	45	$2D	72	$48
19	$13	46	$2E	73	$49
20	$14	47	$2F	74	$4A
21	$15	48	$30	75	$4B
22	$16	49	$31	76	$4C
23	$17	50	$32	77	$4D
24	$18	51	$33	78	$4E
25	$19	52	$34	79	$4F
26	$1A	53	$35	80	$50
27	$1B	54	$36		

Table B.3 Decimal to Hex Conversion

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Appendix C
Remote Control Programs

The following programs are examples that can be used to send and receive data from the Model 9002. An IBM PC and a PC < >488 board manufactured by Capitol Equipment Corporation have been used for these examples. The programs were written in Microsoft Basic.

The PC < >488 will drive 15 devices with a total cable length of 20 meters or 2 meters times the number of devices, whichever is less. The PC < >488 consists of hardware that will fully implement the IEEE-488 standard.

In these programs, T$ contains 8-bit binary data to be sent over the bus to the Model 9002. The Model 9002 will not accept ASCII data. The data has been sent in decimal, not hex (the hex numbers have been converted to decimal).

The user has set the address of the Model 9002 to 0, and the system has been told to listen. MTA means MY TALK ADDRESS, which has told the PC that it is a talker.

Program 1

This program performs a Code $06, Set Filter, using the PC < >488 and the PC.

```
10      DEF SEG=&HC400; Define segment for PC board (memory address)
20      INITIALIZE=0; Subroutine offset for initialize
30              MY.ADDRESS%=21; IBM GPIB address
40      CONTROLLER%=0; System Control
50      CALL INITIALIZE (MY.ADDRESS%, CONTROLLER%); Initialize PC board
60      TRANSMIT=3; Subroutine offset for routine which sends data
70      T$="LISTEN 0 MTA DATA 17 06 00 00 247 57 10 351 19"
80      *Command data for 9002. Send a Code $06 to set up Ch1, Flt 0, F=50.4 Hz, DC, Single
90      *Bypass, Pre-gain = 1.5, Post-gain = 13.55
100     *Listen address = 0 (9002 has been set to 0) 9002 will listen only
110     *MTA = My Talk Address. The IBM has been addressed to talk
120     CALL TRANSMIT (T$, STATUS%) ;Send data to 9002
130     PRINT STATUS%; Indicates whether transfer went ok
140     *STATUS%=0, Transfer successful: STATUS%=8, Unsuccessful, timed-out
150     STOP
```


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Program 2

This program performs a Code $0C, Send Back Channel Status, using the PC < >488 and and IBM PC.

```
10   DIM INFO%(10); Array used to store data being sent by the 9002
20   DEF SEG=&HC400; Memory address of board
30   TRANSMIT=3: TARRAY=203; Two subroutine offset addresses
40   INITIALIZE=0; Subroutine offset address
50   MY.ADDRESS%=21; IBM address
60   LEVEL% =0; System control
70   CALL INITIALIZE (MY.ADDRESS%, LEVEL%); Initialize board
80   T$ =”LISTEN 0 MTA DATA 17 12 19” ; Command data sent to 9002
90   *A Code $0C is sent, which says send back the status of channels
100  *LISTEN at address 0=9002 address, MTA - my talk address IBM
110  CALL TRANSMIT (T$, STATUS%); Send data to 9002
120  CMD$=”UNL TALK 0 MLA”; UNL = Unlisten all addresses, TALK at address 0
130  *address 0 = 9002 address. MLA = my listen address IBM
140  CALL TRANSMIT (CMD$, STATUS%); Set Model 9002 up as a talker
150  SEGMENT%=-1; Default data segment address
160  COUNT%=11; # of data bytes being transmitted from 9002
170  R$=SPACE$(11); Set up space in the string to receive data
180  LENGTH%=0; Returns actual # of bytes received
190  OFS%=0; Offset portion of the memory address of the data
200  OFS=0; Variable to hold string address
210  STATUS%=0; Indicates whether transfer went ok
220  OFS% = VARPTR(R$); Get address of the data
230  DEF SEG; Set to default segment
240  OFS=PEEK (OFS%+1)=256*PEEK(OFS%+2); Get string address
250  IF OFS > 32767 THEN OFS=OFS-65536; Make address into a valid integer
260  DEF SEG=&HC400; Set to PC488 segment
270  OFS%=OFS; Store incoming data to this string address
280  CALL RARRAY (SEGMENT%,OFS%,COUNT%,LENGTH%,STATUS%);Receive binary data
290  *from the 9002 and store in string R$ located at address in OFS%
300  FOR I%=1 TO 11; Print data in ASCII format
310  PRINT ASC(MID$,I%,1)); Print data received to screen
320  NEXT
330  END
```

After the talk back Code $0C is sent, then the Model 9002 is told to talk and the IBM is told to listen. The data being sent from the Model 9002 is 8-bit binary data, no ASCII. Therefore, RARRAY had to be used.

This data is going to be received into a string variable. To do this, the string must first be set to the required length. Second, the address of the string must be obtained for use with an RARRAY call. The VARPTR function in BASIC returns the address of ‘String Descriptor’, which in turn, contains the address of the string.

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