MODEL 3945

170Hz to 25.6MHz
Dual Low-Pass
Programmable Butterworth Filter

Operating Manual

KROHN-HITE CORPORATION

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Model 3945

170Hz to 25.6MHz
Dual Low-Pass Butterworth
IEEE-488 Programmable Filter

Operating Manual

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Model 3945 Filter

SECTION 1
GENERAL DESCRIPTION

1.1 INTRODUCTION

The Model 3945, Figure 1, programmable Butterworth/Bessel filter provides one Butterworth channel of low-pass, tunable over the range from 170Hz to 25.6MHz; and two independent Butterworth or Bessel channels of low-pass, high-pass, by-pas or one channel of band-pass or band-reject, tunable over the range form 3Hz to 2MHz.

The 3945 has been specifically designed for applications requiring high frequency band-pass filtering. The high cutoff may be set to any frequency between 170Hz and 10MHz, and low cutoff to any frequency between 3Hz and 2MHz.

Input gain is useful to users wanting to increase the amplitude of the signal and improve the signal-to-noise ratio before filtering.

Channels 1.1 and 1.2 furnish Bessel or Butterworth transfer functions can be programmed to operate as two low-pass, two high-pass, one band-pass or one-band reject filter with gains up to 40dB per channel.

The filter is controlled by the front panel keyboard or over the IEEE-488 bus. Provided are LED displays and indicators for input and output gain, cutoff frequency, channel selection, overload (channel 2.1 only) and remote operation. Non-volatile, battery-backed, CMOS memory permits storing and recalling of 99 selectable groups of front panel settings. Storing and recalling group settings is accomplished with a single command. Self-testing of the digital circuitry occurs upon power-up.

1.2 SPECIFICATIONS

1.2.1 Function

Channel 1.1 and 1.2: Two independent channels of low-pass, high-pass or bypass; one channel of band-pass or band-reject.

Channel 2.1: One low-pass filter channel or amplified bypass.

1.2.2 Channels 1.1 AND 1.2

1.2.2.1 Filter Characteristics

Type: 4-pole Butterworth (maximally flat) or Bessel (linear phase).

Attenuation Slope: 24dB/octave per channel.

Tunable Frequency Range (fc): 3Hz to 2MHz.

Frequency Resolution: 1Hz from 3Hz to 1kHz; 10Hz to 2kHz; 100Hz to 100kHz; 1kHz to 1MHz; 10kHz to 2MHz.

Cutoff Frequency Accuracy (fc): ±2% or least significant digit (which ever is grate) 20Hz to 500kHz; ±5% to 2MHz.

Relative Gain at fc: Butterworth, -3dB; Bessel, -7.58dB.

Bandwidth: dc to fc, dc coupled; 0.2Hz to fc, ac coupled (low-pass); fc to 10MHz (high-pass).

Passband Response (0dB, Input/Output gain): ±0.5dB to 2MHz.

Stopband Attentuation: -100dB to 1MHz; -75dB at 10MHz; -55dB at 30MHz; -50dB at 50MHz; -40dB to 100MHz.

Harmonic Distortion: -80dB at 1kHz at Vrms.

Noise (referred to input): <200mV with 2MHz bandwidth detector.

Input:

Pre-Filter Gain: 0dB or 20dB; ±0.2dB.

Coupling: ac or dc.

Impedance: 1 megohm in parallel with 100pf.

Maximum Signal (at 0dB gain): ±4.5V peak at fc <1MHz; ±4V peak at 2MHz.

Maximum DC Blocking Voltage: ±200V in ac coupled mode.

Output:

Post-Filter Gain: 0dB or 20dB; ±0.2dB.

Impedance: 50ohms

Maximum Voltage: ±6.5V peak into > 500 ohms; ±1.3V peak into > 50 ohms.

Maximum Current: ±25mA.

DC Level: Adjustable to Zero.

DC Stability: ±0.5mV/°C typical; ±1mV/°C max.

1.2.3 Channel 2.1

1.2.3.1 Filter Characteristics

Filter Type: 4-Pole, Butterworth, low-pass.

Attenuation: 24dB/Octave.

Tunable Frequency Range: 170Hz to 25.6MHz.

Frequency Resolution: 10Hz from 170Hz to 2.56Hz; 100Hz from 2.6kHz to 25.6kHz; 1kHz from 26kHz to 256kHz; 10kHz from 260kHz to 2.56MHz; 100kHz from 2.6MHz to 25.6MHz.

Cutoff Frequency Accuracy: ±2% to 2.56MHz, ±5% to 25.6MHz.

Passband Response: ±0.2dB up to 256MHz, ±0.5dB to 25.6MHz.

Stopband Attenuation: 100dB to 1MHz; 80dB at 10MHz; 70dB at 30MHz; 30dB at 50MHz; 50dB to 100MHz.

Input/Output Coupling: AC or DC. AC coupling cutoff is approximately 16Hz at the input and 10Hz at the output with a 50W termination. Note that the internal 50 ohms input termination is before the AC coupling.

Noise Spectral Density (10kHz to 100MHz referred to input): Below –128dBm/Hz into 50 ohms. This translates into a wideband noise power or voltage for a 30MHz BW of below –53dB or 500mVrms referred to input.

Harmonic Distortion (1Vrms sinewave): >-60dB below signal up to 100kHz (0.1%). All harmonics below 50dB to 1mHz; below 40dB above 1MHz.

Spurious Signals: Below –80dBm to 65MHz; below –75dBm to 100MHz. Referred to input represented in voltage form: 22mV and 40mV respectively.

DC Stability: ±0.5mV/°C referred to input.

Input:

Pre-Filter Gain: 0dB, +10dB, +20dB; ±0.1dB.

Impedance: Selectable 1M ohms or 50 ohms, ±2%, shunted by 65pF.

Maximum Signal: ±1.5V peak with 0dB input gain, reduced in proportion to input gain selected.

Maximum Input Without Damage: 12Vrms with input terminator OFF, 7Vrms with input terminator ON.

Maximum DC Blocking Voltage: 200V. Note that the internal input termination is before the AC coupling and can only tolerate 7Vrms when ON.

Output:

Post-Filter Gain: 0dB, +6dB, +20dB, +26dB; ±0.1dB.

Impedance: 50 ohms, ±2%.

Maximum Signal: ±3V peak open circuit; ±1.5V peak into 50 ohms.

DC Level: Adjustable to Zero.

1.2.4 Amplifier Mode Characteristics (Channel 2.1 only)

Bandwidth: >50MHz.

Input and Output: Same as Channel 2.1 Filter Characteristics.

Rise and Fall Time: <7ns with 0dB input gain 6dB output gain; <10ns with +20 input or output gain. <5% ringing or overshoot.

1.2.5 High Frequency Band-Pass Operation

Connecting the output of channel 1.1 or 1.2 (set to high-pass) to the input of channel 2.1 (set to low-pass, 50 ohm input impedance, 6dB output gain), provides a band-pass filter with 0dB insertion loss and the low-cutoff adjustable between 3Hz and 2MHz, and the high-cutoff adjustable between 170Hz and 0mHz. At high-cutoff settings above 10mHz, the passband response will deteriorate.

1.2.6 General

Frequency: Keypad entry or increment, decrement keys.

Memory: 99 selectable groups; memory is non-volatile battery-backed CMOS.

Overload Modes (Channel 2.1 only): Three selectable modes; non-latching, that monitors all channels and displays the first channel to have an overload; latching, that maintains the overload display until it is cleared; and no indications.

Overload Indicators (Channel 2.1 only): LEDS for input and output. Gain display flashes when overload occurs on displayed channel.

Self-Test Diagnostics: MPU checks unit upon power-up. Display indicates failure mode.

Displays: 7 segment, green, LED; 0.3” high.

Remote Programming: IEEE-488/1978 GPIB interface. Subsets: SH1, AH1, T6, L4, SR1, RL1, PP1, DC1, DT0, C0, E1.

Operating Temperature: 0°C to 50°C.

Isolation to Chassis: ±200Vdc.

Storage Temperature: -20°C to 70°C.

Input/Output Connectors: BNC, front and rear.

Power Requirements: 90-132/180-264 volts ac, 50Hz-400Hz, 35 watts.

Dimensions: 3 ½” (9cm) high, 8 ½” (21.8cm) wide, 18” (46.2cm) deep.

Weights: 12 lbs. (5.4kg) net; 14 lbs (6.3kg) shipping.

Accessories: 6 foot, 3 terminal line cord; operating and maintenance manual.

1.2.7 Options

Rack Mount Kit: Part No. RK-37, permits installation of the Model 3945 into a standard 19” rack spacing.

Specifications apply at 25°C ±10°C.

Specifications subject to change without notice.

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Section 2

OPERATION

2.1 INTRODUCTION

The Model 3945 three channel filter covering the frequency range from 3Hz to 2MHz (channels 1.1 and 1.2) and 170Hz to 25.6MHz (channel 2.1). All filter parameters are programmable via the front panel keyboard controls or remotely over the IEEE-488 (GPIB) bus.

The filter has five modes of operation: high-pass, low-pass, band-pass, band-reject, gain (channel 2.1 only) and bypass (channels 1.1 and 1.2 only).

2.2 TURN-ON PROCEDURE

The Model 3945's line voltage range has been preset for either 115V or 230V operation. To change this setting, remove the bottom cover to expose the line switch. Be sure to change the fuse to the proper rating for the line switch setting selected.

Make certain the POWER switch on the front panel is off.

Plug the line cord into the unit, then the ac outlet.

If the Model 3945 is to be programmed remotely, connect the bus cable to the rear panel connector of the unit.

After reading the Self-Test feature, described next, turn on the Model 3945.

2.3 SELF TEST

When the Model 3945 is turned on, the microprocessor performs a self-test routine whereby the entire RAM and ROM operation is verified. During the test, the front panel LEDs and DISPLAYS will light sequentially. If there is a malfunction on the microprocessor board, such as a defective RAM or ROM, the sequence will stop and the word "bad" will appear in the DISPLAY followed by a number 1, 2 or 3. Refer to Section 6, Maintenance, to find which RAM or ROM is defective.

When the self-test program is complete, the Model 3945 will return to the last set-up prior to turning the unit off. The Model 3945 is now ready to operate.

2.4 FRONT PANEL CONTROLS AND DISPLAY

2.4.1 Data Keys and Display

Data entry keyboard controls [0] to [9] and [.] set the numeric value of the parameter selected. To enter 1.5kHz, press the [1][.][5] keys and the parameter key [KILO] and [FREQ]. The cutoff frequency will be indicated in the DISPLAY.

2.4.2 Parameter and Control Keys

[KILO]	When pressed, multiplies the numeric value of the keyboard entry by 103.
auto [MEGA]	When pressed, multiplies the numeric value of the keyboard by 106.
[FREQ]	When pressed, enters and/or displays frequency in Hertz.
[TYPE]	When pressed, DISPLAY will indicate the filter type in the selected channel, “bu.” (Butterworth), “bES.” (Bessel) for channels 1.1 and 1.2; and “bu.” only for channel 2.1. When pressed again, the type will change to the next type (i.e. “bu.” to “bES.”). There will be no change for channel 2.1. When in band-pass or band-reject mode (channels 1.1 and 1.2 only), the type will be changed on each channel simultaneously.
[MODE]	When pressed, DISPLAY indicates the mode of operation for the channel displayed. For channels 1.1 and 1.2, the DISPLAY will indicate “bYP.” for bypass, “L.P.” for low-pass, “h.P.” for high-pass, “b.P.” for band-pass and “b.r.” for band-reject. Channel 2.1 will indicate “L.P.” or gAin” (Amplifier mode). When pressed again, the MODE will change to the next in the order explained above.
[RECLL]	When preceded by a number, it will recall the entire instrument set-up from the memory location selected. When first pressed, the DISPLAY indicates the number of the next memory location to be recalled. For example, the DISPLAY will indicate the following: “n=09”. Pressing the [RECLL] key again will recall the entire instrument set-up of from the next memory location. When pressed to indicate the next memory location to be recalled only, pressing the [CE] (clear entry key) will restore the DISPLAY to the cutoff frequency setting.
[ALL CH]	When frequency, input/output gain, type, mode or coupling are entered or changed, the LED in the [ALLCH] key is lit, the new setting will be entered in all channels of the filter (channels 1.1 and 1.2 only).
[SHIFT]	The [SHIFT] key in conjunction with other keys (keys with red lettering under them) provide additional filter characteristics, and permits front panel entry of the type of GPIB line termination and address.

Store	When [SHIFT][RECLL] is first pressed, the DISPLAY indicates that the number of the next memory location available. For example, the DISPLAY will indicate the following: "n = 09". Pressing [RECLL] again will store the entire instrument set-up into that memory location. If another memory location is desired, enter that location on the keyboard and then press [SHIFT][RECLL]. When [SHIFT][RECLL] is preceded by a number (0-98), the filter will store the entire instrument set-up into the memory location selected. The maximum number of memory groups is 99. When [SHIFT][RECLL] is pressed to indicate the next memory location only, pressing the clear entry key [CE] will restore the DISPLAY to the cutoff frequency setting.
AC/DC *Coupling*	Pressing the [SHIFT] key followed by the [TYPE] key will display the input coupling, indicating "AC" or "dC", and will alternate between the two when in the low-pass, band-reject, amplifier and bypass modes. High-pass and band-pass modes (channels 1.1 and 1.2 only) will indicate "AC" only.
GPIB *Address*	When the [SHIFT] key followed by the [MEGA] key are pressed, the DISPLAY will indicate the existing GPIB address setting. To select a different address setting, enter the address number in the data keys from [0] to [30] and press the [SHIFT] and [MEGA] keys (see Section 3.2.1 for GPIB addressing information).
GPIB *Line Termination*	When the [SHIFT] key followed by the [ALL CH] key are pressed, the DISPLAY will indicate the existing GPIB Line Termination Code sequence. To select a different one, enter a number from [0] to [4] and press [SHIFT] [ALL CH] keys (see Section 3.2.1 for line termination information).
Software *Version*	When the [SHIFT] key followed by the [KILO] key are pressed, the DISPLAY will indicate the software version installed (i.e. 3.5).

2.4.3 Channel Selection

The up [D] control key below the CHANNEL display cycles through the channel settings. When held, channels will cycle through all channels continuously.

2.4.4 Cutoff Frequency

Data entry keyboard controls [0] to [9] and [.] set the numeric value of the cutoff frequency desired. To select 1.5kHz, press the [1][.][5] data keys and parameter keys [KILO] and [FREQ]. The cutoff frequency for the channel selected will be indicated in Hertz on the four digit DISPLAY. The KILO and FREQ keys will be lit. Also see 2.4.7.

2.4.5 Input Gain (Pre-Filter)

Up [D] and down [Ñ] INPUT GAIN SET controls increase or decrease the input amplifier by 20dB for channels 1.1 and 1.2 and from 0dB to 20dB in 10dB steps for channel 2.1. The two digit DISPLAY will indicate the gain selected.

2.4.6 Output Gain (Post Filter)

Up [D] and down [Ñ] OUTPUT GAIN SET controls increase or decrease the output amplifier by 20dB for channels 1.1 and 1.2, and to either 0dB, 6dB, 20dB or 26dB on channel 2.1. The two digit DISPLAY will indicate the gain selected.

2.4.7 Digit Select/Increment and Decrement

When the [SHIFT] key is pressed, followed by either the [D] or the [Ñ] keys under FREQ beside the INPUT BNC connectors, the DISPLAY will intensify either the least or the most significant digit. Pressing the [D] or [Ñ] keys will then increment or decrement the intensified desired digit.

Pressing [SHIFT] and either [D] or the [Ñ] keys again will intensify the next digit in the DISPLAY. The [D] key will move the intensified digit to the left and the [Ñ] will move the intensified digit to the right (direction is labeled in red to the left of keys).

Input Ohms

When the [SHIFT] key is pressed, followed by either [D] or [Ñ] key under the Input Gain display, the Cutoff Frequency display will indicate the present Input Ohms setting, either “50” for 50 ohms or “Hi” for 1M ohms. Pressing the [SHIFT] key and either [D] or [Ñ] key again, will toggle the setting.

Key Click Feature On/Off

When the [SHIFT] key is pressed, followed by the [D] key under the CHANNEL display, the key click feature will either toggle on or off.

2.5 REAR PANEL CONTROLS AND CONNECTORS

2.5.1 Introduction

Model 3945 rear panel consists of the following: three input and output BNC connectors, dc level adjustments, a fuse holder, GPIB bus connector, front connector switches for Channel 2.1 and an ac receptacle.

2.5.2 Front Connector Selector Switch

For optimum performance when using the rear connectors, the switches on the rear near the connectors should be in the OFF position. This will disconnect the cabling from the front panel connectors.

2.5.3 BNC Connectors

There are three input and output BNC connectors. Each connector (1.1, 1.2 and 2.1) is an independent filter channel. In the band-pass and band-reject modes, the input and output connectors are configured as in paragraphs 2.6.2.1 through 2.6.2.3.

2.5.4 DC Level Adj

Proper procedure for adjusting input and output dc levels can be found in the Calibration section of this manual.

2.5.5 Power

Receptacle: Standard 3 pin.

Fuse: 3/8 amp slow-blow for 120V operation; 3/16 amp slow-blow for 230V operation. To change this setting, refer to Section 2.2.

2.5.6 GPIB Connector

Standard IEEE-488 interface. Subsets are SH1, AH1, T6, L4, SR1, RL1, PP1, DC1, DT0, C0 and E1.

2.6 FILTER OPERATION

2.6.1 Introduction

The Model 3945 is a Multichannel filter with three channels that can function independently. Each channel can operate in either the low-pass mode or high-pass mode and provide 24dB/octave attenuation, or channels 1.1 and 1.2 can be set to the same mode and connected in series, externally, to obtain 48dB/octave attenuation. The interconnection of two channels, by front panel data key entry, will provide band-pass or band-reject (null) operation and no external connections are needed.

2.6.2 Variable Band-Pass and Band-Reject Operation

2.6.2.1 Band-Pass

Variable band-pass response is obtained by applying the input signal to channel 1.1. With the Channel Display on 1.1, set the filter to the band-pass mode by pressing the [MODE] key until “b.P.” appears in the DISPLAY. Enter the desired low-cutoff (high-pass) frequency, then set the filter to channel 1.2 and enter the desired high-cutoff (low-pass) frequency. The band-pass response will appear at the output BNC connector of channel 1.1 simultaneously.

2.6.2.2 High Frequency Band-Pass

When a high frequency band-pass response above 2MHz is desired, the Model 3945 can be configured by connecting, externally, the output of channel 1.1 or 1.2 (set to high-pass) to the input channel 2.1 (set to low-pass, 50 ohm input impedance and 6dB output gain for 0dB insertion loss).

This provides a band-pass filter that has a low cutoff (high-pass) that is adjustable between 3Hz to 2MHz and a high cutoff (low-pass) that is adjustable between 170Hz and 10MHz.

Note: At high cutoff settings above 10MHz, 3945 passband response will deteriorate.

2.6.2.3 Band-Reject

Variable band-reject response is obtained by applying the signal to channel 1.1. With the Channel Display on 1.1, set the filter to the band-reject mode by pressing the [MODE] key until “b.r.” appears in the display. Enter the desired low-cutoff (low-pass) frequency into channel 1.1, then set the filter to channel 1.2 and enter the desired high-cutoff (high-pass) frequency. A null can be obtained by setting the low cutoff frequency to approximately 0.58 of the desired null frequency, the high cutoff frequency to approximately 1.7 of the null frequency. Fine tuning of both cutoff frequencies can be accomplished by varying the cutoff frequency using the increment/decrement feature of the DIGIT SELECT described in paragraph 2.4.7. The resolution of the Model 3945 will limit the extent of the null.

2.6.3 Amplitude Response

Each Channel 1.1 and Channel 1.2 of the Model 3945 can operate in either the low-pass or high-pass mode at 24dB/octave attenuation and provide either maximally flat (Butterworth) amplitude response or linear response (Bessel) operation. Comparative amplitude response characteristics are shown in Figure 2.1A and 2.1B.

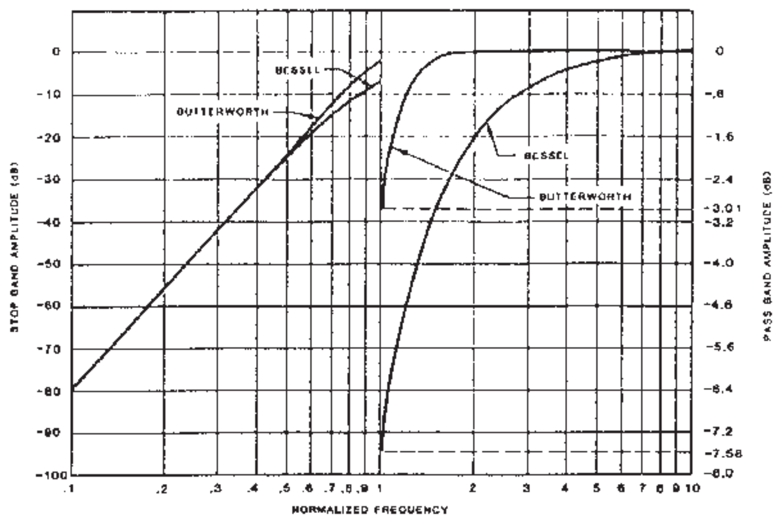

Figure 2.1A High-Pass Amplitude Response

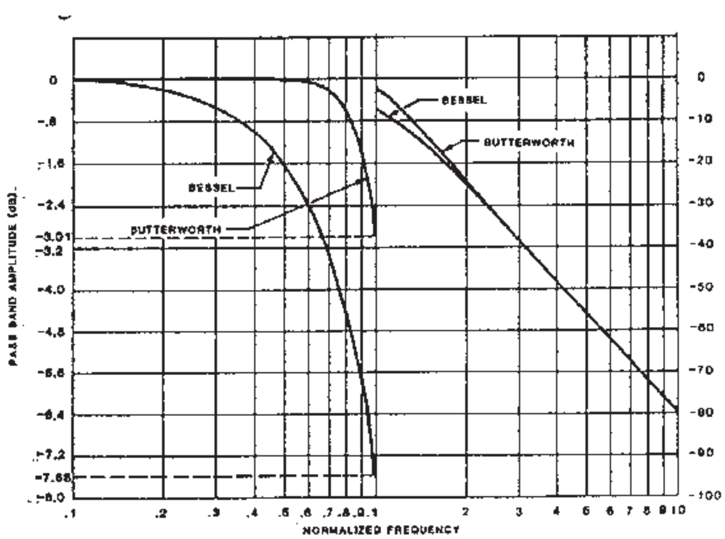

Figure 2.1B Low-Pass Amplitude Response

2.6.4 Phase Response

Phase characteristics of the Model 3945 are shown in Figure 2.2. It provides output phase relative to the input with the filter operating in the low-pass mode with Butterworth and Bessel response.

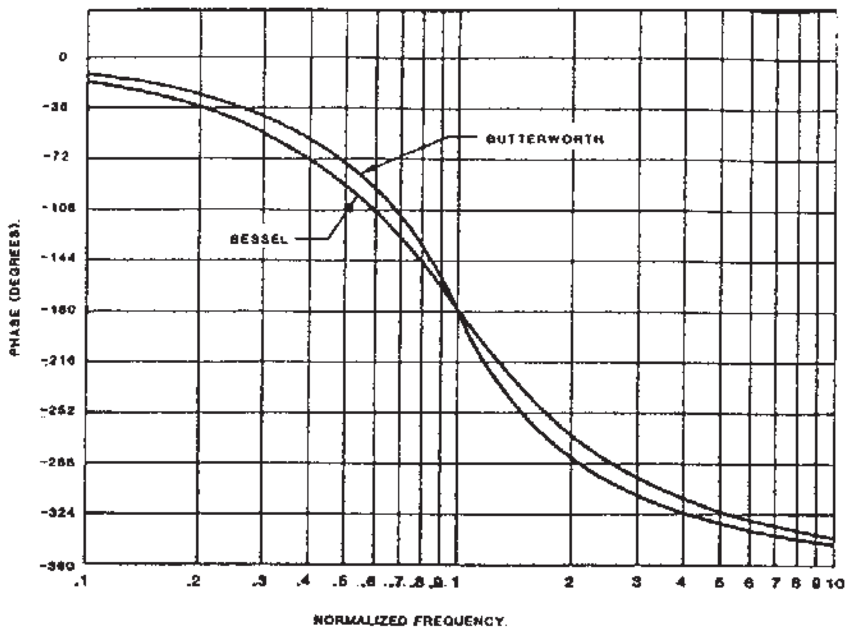

Figure 2.2 Phase Response

2.6.5 Group Delay

Group delay, shown in Figure 2.3, is defined as the derivative of radian phase with respect to radian frequency, which is the slop of the phase curve. A flat group delay is considered a linear phase response which corresponds to a constant slope of the phase curve. With linear phase response the distortion of complex data signals will be minimized because their various frequency components, due to a constant time delay, will not shift relative phase.

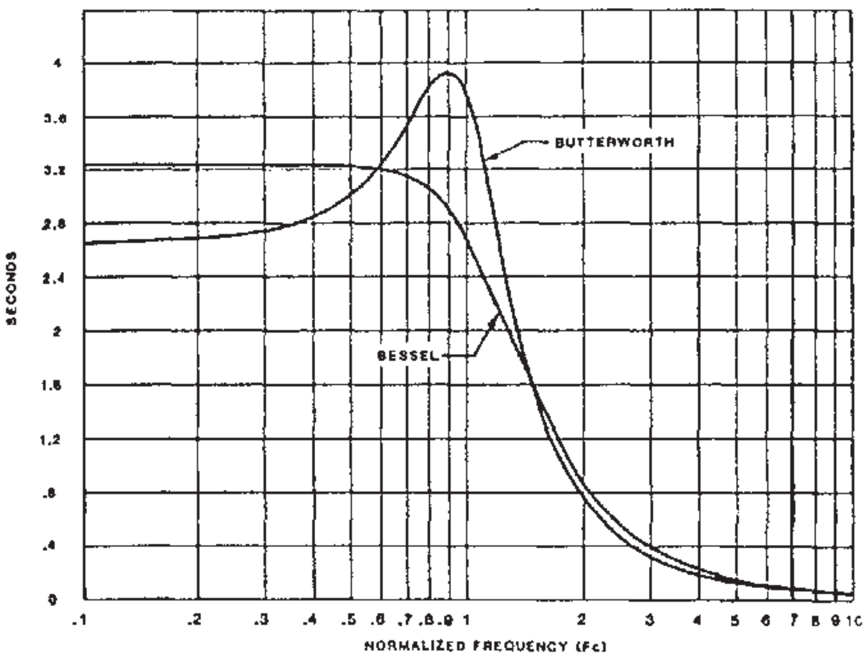

Figure 2.3 Group Delay

In numeric terms, the zero frequency phase slope is –149.7°/Hz for Butterworth and –183.4°/Hz for Bessel, when normalized for a cutoff frequency of 1Hz. This will be 2p times greater in °/Hz for a cutoff of 1 radian/sec or –940.7°/Hz and –1152.4°/Hz respectively. Dividing by 360 converts °/Hz to radians/radians-per-sec yields a group delay time of 2.61s for Butterworth and 3.20s for Bessel.

2.6.6 Transient Response

The normalized response for a unit step voltage applied to the input of the Model 3945 operating in the low-pass mode with both Butterworth and Bessel response is shown in Figure 2.4.

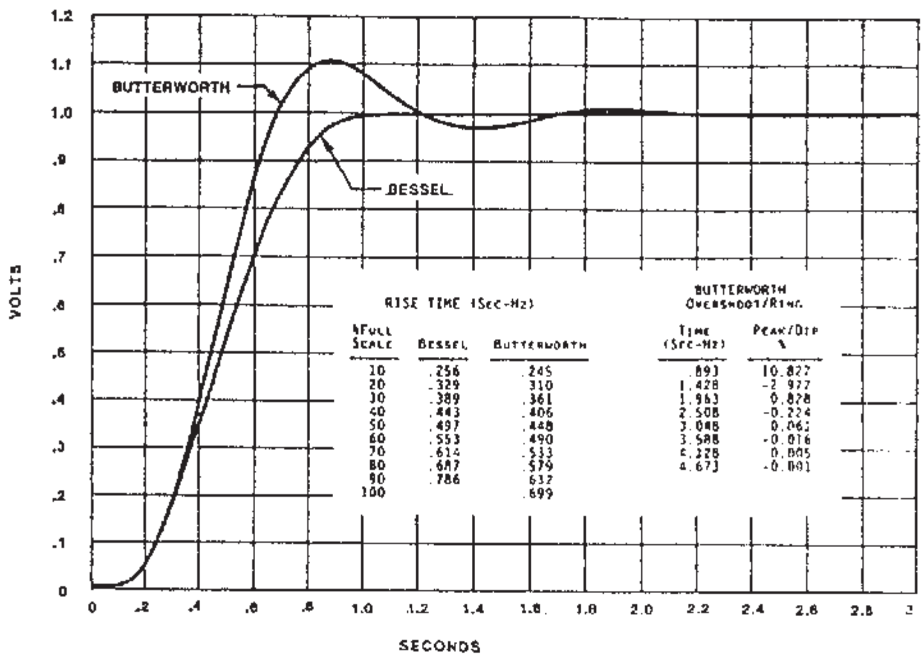

Figure 2.4 Transient Response

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SECTION 3

IEEE-488 STD (GPIB) PROGRAMMING

3.1 INTRODUCTION

The Model 3945 remote programming interface accepts both ASCII data command and IEEE-488 standard commands (ATN true) for control of the unit.

In presenting the information required to program the Model 3945 via the IEEE-488 STD bus, this manual presupposes a user knowledge of both ASCII data and IEEE-488 bus commands.

3.2 PRELIMINARY PROGRAMMING INFORMATION

3.2.1 GPIB Primary Bus Address

The GPIB primary address and software line-termination-character-sequence (LTCS) selection is set via the front panel keyboard as listed in Tables 3.1 and 3.2. These two parameters are stored in non-volatile memory and will be remembered indefinitely, even when the power to the unit is removed. They do not need to be reentered each time the unit is turned on.

The LTCS affects the GPIB in the TALKER mode only (data output from the 3945 to the GPIB). After the printable characters have been sent, non-printable characters, such as carriage return (CR) and line feed (LF), are often required to achieve the desired results in various computers. Table 3.2 lists the various key sequences with the LTCS it selects.

SETTING AND DISPLAYING THE GPIB PRIMARY ADDRESS		
Function		**Keyboard Entry**
a.	To set a primary address from 0 to 30	[x][SHIFT][MEGA]
b.	To display the primary address	[SHIFT][MEGA]

LINE-TERMINATION-CHARACTER-SEQUENCE		
Line-Termination Character-Sequence		Keyboard Entry
a.	None (EOI only)	[0][SHIFT] [ALL CH]
b.	Carriage return (with EOI)	[1][SHIFT] [ALL CH]
c.	Line Feed (with EOI)	[2][SHIFT] [ALLCH]
d.	Carriage return followed by line feed (with EOI)	[3][SHIFT] [ALL CH]
e.	Line feed followed by carriage return (with EOI)	[4][SHIFT] [ALL CH]
f.	Display present LTCS	[SHIFT] [ALL CH]

3.2.2 IEEE-488 Bus Interface Programming Connector

The rear panel programming connector, labeled “IEEE-488 PORT” (Figure 3.1), is the standard bus interface connector as specified in the IEEE-488 STD.

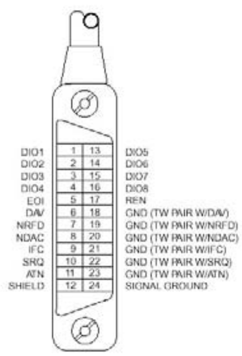

Figure 3.1 Rear Panel GPIB Conenctor

3.3 ASCII DATA COMMANDS

3.3.1 Format

The Model 3945 employs free-format software commands, allowing the user to program a specific function in several different ways. See Section 3.3.3.

3.3.2 Types of Data Commands

a) Commands fall into two types: Those involving numeric parameters and those that do not.
Commands which involve numeric data contain (3) types of fields:

1) Numeric: Numeric fields may be floating point or scientific notion.
1 = 1.0
1.0 = 1.0
2.7E3 = 2.7 X 10^3
-2E3 = -2 X 10^3
2E-3 = 2 X 10^3

2) Multiplier: “KILO”, “MEGA”.

3) Parameter: Parameter (frequency, gain, channel, etc.) is included in Section 3.3.3.

b) Delimiters which may separate commands are the following: (; : / \ .)

c) Two consecutive character strings (i.e. parameter and multiplier) must have a space between them or they will be treated as one string.

d) The Model 3945 uses an internal 32 character buffer for command processing. A line may be composed of multiple commands, separated by delimiters mentioned above. No commands are executed until the line is terminated with a line feed ASCII character (Hex0A) or carriage return (Hex0D) or by sending the end-or-identify (EOI) command with the last character.

3.3.3 Table of ASCII Commands

In this Section, there are characters that are underlined and characters that are **NOT** underlined. The characters that are underlined **MUST** be sent for the command to be recognized properly. Any additional characters may be sent once all the underlined letters are sent. Commands are case sensitive; upper case characters **MUST** be used.

MODEL 3945 GPIB COMMANDS		
Command Desired	Allowable Character String	
Input Gain	IG IU ID	set input gain increase input gain (up) decrease input gain (down)
Frequency	F H K ME	frequency frequency (Hz) kilo (10^3 multiplier) Mega (10^6 multiplier)
Channel	CH CU CD	set channel next channel (up) previous channel (down)
Output Gain	OG OU OD	set output gain increase output gain (up) decrease output gain (down)
Type Channels 1.1 and 1.2	TY1 TY2	Butterworth Bessel
Type Channel 2.1	TY1	Butterworth
Mode Channels 1.1 and 1.2	M1 M2 M3 M4 M5	Low-Pass High-Pass Band-Pass Band-Reject By-Pass
Mode Channel 2.1	M1 M2	Low-Pass Amplified By-Pass
Coupling	AC D	ac coupled dc coupled
Store	ST	store
Recall	R	recall
All Channel	AL	all channel mode
Channel 1.1 and 1.2	B	NOT all channel mode
Misc.	CE OV Q SRQON SRQOF TE U V	clear entry overflow (1, 2, 3) reports board model number(s) GPIB service request on GPIB service request off Input terminate (50 ohms Ch. 2.1 only) Input Unterminate (1M ohm Ch. 2.1 only) reports model number and software version

3.3.4 Examples

3.3.4.1 Example 1

To set all channels to 10dB input gain, 2kHz, 0dB output gain: AL;10IG;2K;0OG

NOTE: It is only necessary to send those parameters that change, all others remain unaffected.

3.3.4.2 Example 2

To change frequency to 150Hz:

150H
or 150bHZ=

or 150F

or .15K

or F150

or H150

or HZ150

or K0.15

or 1.5E2HZ

or F1.5E2

or etc.

b represents a space

3.3.4.3 Example 3

To read back the settings of channel 2.2 (see Section 3.5.1):

Data sent to filter: CH2.2

Data received from filter=: 10b2.000E + 3b02.2b00bAC*

Interpretation: 10dB input gain

2kHz cutoff frequency
channel #2.2
0dB output gain
ac coupled
all channel mode (indicated by the "*")

3.4 IEEE-488 STANDARD COMMANDS

These commands are sent with ATN true as described in the standard.

3.4.1 Multi-Line Messages

IEEE-488 Command	Mnemonic	Result
My listen address	MLA	Enables unit to receive data.
Unlisten	UNL	Disables unit from receiving data.
My talk Address	MTA	Designates unit to send data.
Untalk	UNT	Disables unit from sending data.
Local-lockout	LLO	Disables return-to-local key [CE key] on front panel such that when in remote mode, keyboard can not be activated by pressing a front panel key.
Go-to-local	GTL	Puts unit in local control mode such that front panel keyboard is activated.

Device clear	DCL	When the device clear command is sent, the following parameters are changed regardless of their existing settings: Input Gain: 0dB Output Gain: 0dB Response: Butterworth Mode: Low-Pass Cutoff Frequency: 100kHz All Channel Mode: Off Overload Mode: 2 Coupling: AC Clears current settings for all channels. It does not clear set-ups stored with [STORE] key. It does not change interface bus parameters and flags, such as: addresses, SRQ on/off, parallel poll bit selected, etc.
Selected device clear	SDC	Performs same function as device clear (DCL) except only if unit is addressed.

DISCUSSION (See Section 2.8 and Figure 10 of the IEEE-488 Interface Standard): Note that there are 4 possible states; local, remote, local-with-lockout and remote-with-lockout. Front panel control is considered to be local while control forthe system controller is considered to be remote. Selection of the local or local-with-lockout and remote and remote-with-lockout is done in several ways. When the unit is addressed to talk (MTA) or listen (MLA), it will enter into remote. When go-to-local (GTL) is sent, it enters into local mode or local-with-lockout mode.

Also, if lockout mode is noti involked by the controller (local lockout command LLO), pressing the [CE] key when the remote led is on will return control to the keyboard.

NOTE: The lockout mode is not related to whether control is local or remote, only whether control can be returned to local by the [CE] key.

Lockout mode (local-with-lockout or remote-with-lockout versus remote and local) is controlled by the controller. Sending the local lockout command (LLO) selects the local-with-lockout and remote-with-lockout pair versus remote and local without lockout out. Lockout can only be cancelled by the controller, placing the remote enabled line false.

3.4.1.1 Polling Commands

The IEEE standard provides two methods of determining the status of the devices in the system; namely serial poll and parallel poll. The parallel poll produces up to 8 bits of status from up to 8 different units simultaneously. A parallel poll is very fast but provides limited information. The serial poll provides 7 bits of status from one unit at a time.

3.4.1.2 Parallel Polling

The model 3940/3944 provides for software configuring of which bit and with which polarity the unit should respond. This bit is "true" when an error condition exists. ("ERR" displayed on the panel). Configuring needs to be done only once or anytime the software desires to change the configuration. The commands related to parallel poll are as follows:

For sample sequences, see section 6.5.4 of the IEEE-488 standard.

IEEE-488 Command	**Mneonic**	**Result**
Configure	PPC	Places unit into a state where it expects parallel poll enable and disable commands to establish which bits should be set or selected in response to a parallel poll.
Unconfigure	PPU	Removes unit from PPC state (UNL does the same, but also unlistens device).
Enable	PPE	When unit is in PPC state, it indicates which bit and which polarity the device should respond. Hex codes 60-67 selects bits 0-7 respectively to be set to 0 for a true error response. Since logic 0 is HI on open collector lines, this provides a logical "OR" of al units designated to respond with a given line. Hex codes 68-6F selects bits 0-7 respectively to be set to 1 for a true (error) response. This can provide logical NAND of all units designated to respond, with a given line.
wrap default Disable	PPD	Clears any configuration previously entered. This is valid only when unit is in PPC state.

Example: If the Model 3940/3944 to be configures is unit #5, and we want it to respond with a “1” when an error exits:

IEEE-488 Command	Result
MLA 5	Addresses unit to be configured.
PPC	Places unit into parallel poll configured mode.
PPE 8	Configures bit #0 (Lo 3 bits of command) to respond with a “1” (8’s bit) when an error exits.
UNL	Unlistens unit.

For additional sample sequences, see Section 6.5.4 of the Standard.

3.4.1.3 Service Request and Serial Polling

The IEEE-488 standard provides serial polling as a method of determining which unit caused a service request. When serial poll enable (SPE) is sent, the system enters into serial poll state. When a unit is addressed to talk, a single status byte will be sent. The hex 40 bit in this byte is true if that unit is requesting service. The remaining bits are used to provide status information. The Model 3940/3944 service request capability is enabled or disabled with the SRQON and SRQOFF commands (see Section 3.3.3). The unit turns on with service request disabled. This is an extension of the standard.

IEEE-488 Command	Mnemonic	Result
Enable	SPE	Unit enters serial poll when a unit is addressed to talk. It will send one status byte in which the hex 40 bit is true if the unit is requesting service.
Disable	SPD	Unit exists serial poll state.

3.4.1.4 Serial Responses

The chart below lists the error numbers, in decimal notation, resulting a command error either from the bus or not from the bus.

The serial responses are:

1. No error: 0.
2. Error (error numbers in decimal notation); See the chart below.

Note: that if SRQ is “ON” and the command which caused the error came from the bus, not the front panel, then the 64 bits will be set in the serial poll response, indicating that this unit requires service.

Error #	Description
1	Input gain too high or too low.
2	Frequency too high.
3	Frequency too low.
4	Channel # too high.
5	Channel # too low.
6	Output gain too high or too low.
7	Store page # too high.
8	Recall page # too high.
9	Type # invalid.
10	Mode # invalid.

3.4.2 Uniline Messages

IEEE-488 Command	Mnemonic	Result
End	END	Sent with last byte of data. A line of data may either be terminated by a line feed character or by this command.
Identify	IDY	This command, issued by the controller, causes a parallel, response which was previously configured by the PPC, PPD, PPE and PPU commands.
Request service	RQS	Generated in response to an error when a command came from the bus, and service request is enabled by the SRQON command.
Remote enable	REN	When true, allows the 3940/3944 to respond to remote messages. When this line goes false, the unit will go to local-with-lockout state, activating the front panel.
Interface clear	IFC	Un-addresses all units and clears all special states.

3.5 TALKER FORMAT

The Talker Software allows an IEEE-488 (GPIB) controller to interrogate the Model 3940/3944 and read back over the bus it’s settings (gain, frequency, etc.).

Four different types of data can be sent over the bus: Normally parameter information is returned unless an “OS”, “Q” or “V” command is sent to the unit.

3.5.1 Parameter Information Format

1. Two (2) digits of input gain.

1a. space

2. Four (4) digits plus decimal of frequency or other alpha.

3. If frequency is displayed:

   E+0 if both kilo and mega LEDs are off.

   E+3 if kilo LED is on.

   E+6 if mega LED is on.

   otherwise 3 spaces.

3a. space

4. Two (2) digits, a decimal and one digit of channel #

4a. space

5. Two (2) digits of output gain.

5a. space

6. “AC” if ac coupled

   “DC” if dc coupled

7. “*” if all channel mode, otherwise a space (see Section 3.3.4.3 for example)

3.5.2 Model Number and Software Version Format

After sending the “V” commands, the next line of data read from the Model 3940/3944 will be as follows:

KROHN-HITE 3940 or 3944, V3.5

The version number will reflect the revision level of the firmware in the instrument.

This data is returned only once per command; after that is returns to talking what the front panel display is showing.

3.6 PROGRAMMING EXAMPLES

The following are programming examples in Microsoftâ Quick Basicä and Borland Turbo C.

3.6.1 Example 1 – Microsoft Quick Basic

```
' Microsoft Quick Basicä program for the Krohn-Hite Model 39XX
'
' * Enter this program from DOS by typing:  QB 39XX /LQBIB.QLB
'        (the /L switch means tells Quick Basic to load a library)
'
' *  Set the instrument to GPIB address 1:
'        Press 1 [SECOND FUNCTION] [MEGA]
'
' * Set the instrument for no carriage return or line feed (EOI only):
' Press 0 [SECOND FUNCTION] [ALL CHAN]
'
____  Initialized National Instruments Interface Board _____
'
' $INCLUDE: 'QBDECL.BAS'
 CLS
 CALL IBFIND("GPIB0", BRD0%): ¢intialize access to the board
 CALL IBFIND("DIV1", D39XX%): ¢init access to the instrument, assumes addr 1!
 CALL IBTMO(D39XX%, 10):  ' set timeout at 300mS
'
' ____________ Send/receive the data ____________
'
' Set to 500 Hz (500Hz), 0dB input gain (0IG), 0db output gain (00G),
' DC coupled, re-display the frequency (F) so it will be read over the bus.
'
 CALL IBWRT(D39XX%, "500HZ;0IG;0OG;DC;F"):  IF IBSTA% <0 THEN GOT0 gpiberr

' allocate a buffer (define a string long enough to hold the response)
' and read the meter

 Buf$ = SPACE$(40):  CALL IBRD(D39XX%, Buf$):  IF IBSTA% <0 THEN GOTO gpiberr

' Shorten buffer to the # of characters actually received and print it

Buf$ = LEFT$(Buf$, IBCNT%)
PRINT "Read:  "; Buf$

Send UNLISTEN(?), UNTALK(_) so the bus will be in an idle state

 CALL IBCMD(BRD0%, "?_"):  IF IBSTA% <0 THEN GOTO gpiberr

'
' Set to 333 Hz, 20dB input gain (20IG), 20dB output gain (20OG), AC coupled,
' and again display frequency in the main display window.

 CALL IBWRT(D39XX%, "333HZ;20IG;20OG;AC;F"):  IF IBSTA% <0 THEN GO TO gpiberr
 Buf$ = SPACE$(40):  CALL IBRD(D39XX%, Buf$):  IF IBSTA% <0 THEN GO TO GPIBERR
 Buf$ = LEFT$(Buf$, IBCNT%)
```

```
  PRINT "Read:  "; Buf$
  CALL IBCMD(BRD0%, "?_"):  IF IBSTA% <0 THEN GOTO gpiberr

'
'____________ Cleanup and End ____________
'

cleanup:

  CALL IBONL(BRD0%, 0):  'Release the board file handle
  CALL IBONL(D39XX%, 0):  'Release the instrument file handle

END

GPIBERR:

  PRINT "IBSTA%="; HEX$(IBSTA%); ", IBERR%="; IBERR%:  GOTO cleanup
```

3.6.2 Example 2 – Borland Turbo C

```
/*
*       Borland Turbo C Example Program for the Krohn-Hite Model 39XX multichannel
*       filter using the NI-488
*       Should work with Microsoft C also.
*/
*/================================================================
*
*       This sample program sends and receives data from a Krohn-Hite model 39XX
*          In the Borland IDE, place "MCIB.OBJ" in your project list
*

*       Set the instrument to GPIB address 1:
*       Press [1] [SECOND FUNCTION] [MEGA]
*       Set the instrument for no carriage return or line feed (EOI only):
*       Press [0] [SECOND FUNCTION] [ALL CHAN]
*
*       This program assumes the name of the device at address 1 hasn't been
*       changed in IBCONFIG (it's still called DEV1, which is the default).
*       The status variables IBSTA, IBERR, and IBCNT are defined in DECL.H.
*       Each bit of IBSTA and each value of IBERR are defined in DECL.H as
*       a mnemonic constant for easy recognition in application programs.  In
*       this example, these mnemonic definitions are logically ANDed with the
*       variable IBSTA to determine if a particular bit has been set.  The mnemonic
*       definitions are equated with the variable IBERR to determine the error
*       code.
*
*       The function GPIBERR is called when a NI-488 function fails.  The
*       error message is printed along with the status variables IBSTA, IBERR,
*       and IBCNT.

*       The NI-488 function IBONL is called from the main body of the program or
*       from the function GPIBERR.  When the second parameter of the function
```

```
*       IBONL is zero, the software and hardware are disabled.
*       Execution of this program is terminated after the call to the function
*       IBONL to disable the software and hardware.
*
*       The function EXIT is used to terminate this program within the function
*       GPIBERR.  The exit status is set to 1 to indicate an error has occurred.
*

*/==================================================================

*/

#include <stdio.h>
#include <stdib.h>
#include <string.h>

/*      DECL.H contains constants, declarations, and function prototypes. */

#include "decl.h"
#define DEVNUM "devl" /* Set instrument to GPIB address 1 */

/ *      GPIBERR is an error function that is called when a NI-488 function fails. */
void gpiberr(char *msg);

char            rd[255];                        /* read data buffer */
int             GpibDev, GpibBoard;             * device handles */

void main() {

        printf("\nSending data to the Krohn-Hite model 39xx…\n");
        printf("\n");

/ *
*       Assign a unique identifier (a 'handle') to the K-H 39XX and store it in the
*       variable GpibDev.  If BpibDev is less than zero, call GPIBERR with an error
*       message.
*/

        GpibDev = ibfind (DEVNUM);
        if (GpibDev ,0) gpiberr("ibfind Error");

/ *
*       Assign a handle to the GPIB board so we can use IBCMD to send board
*       level commands such as UNL and UNT.
*/

        GpibBoard = ibfind ("gpib0");
        if (GpibBoard <0) gpiberr("ibfind Error");

/*

*       Clear the K-H 39XX to its default state.  The settings vary depending on the
*       type of board in each channel.  These settings are listed in the GPIB
```

```
*       section of the manual for each filter board (not the 39XX manual).
*       If the error bit ERR is set in IBSTA, call GPIBERR with an error message.
*/

        ibclr (GpibDev);
        if (ibsta & ERR) gpiberr(“ibclr’Error”);

/ *
*       Write a string out to the K-H 39XX.
*       If the error bit ERR is set in IBSTA, call GPIBERR with an error message.
*/

        Ibwrt (GpibDev, “500HZ;0IG; 0OG;DC;F”,18L);  /* the ‘F’ displays the frequency so when*/
        if (ibsta & ERR) gpiberr (“ibwrt Error”); /* we read the unit we’ll see the freq */

/ *
*       Read the K-H 39XX.  If the error bit ERR is set in IBSTA, call GPIBERR with
*       an error message.
*/

        ibrd (GpibDev, rd, 30L);
        if (ibsta & ERR) gpiberr (“ibrd Error”);

        /*  Append the null character to mark the end of the data*/
        rd[ibcnt] = ‘\0’; /* do this BEFORE calling ibcmd because ibcnt will be */
        printf(“Read:  %s\n”, rd);              /* changed by any  ‘ib’ calls.  */


        ibcmd(GpibBoard,”?_”,2L);       /*  send unt, unl */
        if (ibsta & ERR) gpiberr(“ibcmd Error”);

/ *
*       Change the K-H 39XX setting
*/

    ibwrt (GpibDev), “333HZ;20IG;20OG;AC;F”, 20L); /* the ‘F’ displays the frequency so when */
    if (ibsta & ERR) gpiberr(“ibwrt Error”);  /* we read the unit we’ll see the freq */

/*
*       Read the K-H 39XX again like before.
*/
        ibrd (GpibDev,rd,30L);
        if (ibsta & ERR) gpiberr(“ibrd Error”);

        rd[ibcnt] = ‘\0’;
        printf(“Read:  %s\n”, rd);

        ibcmd(GpibBoard,”?_”,2L); /* send unt, unl */
        if (ibsta & ERR) gpiberr(“ibcmd Error”);

/*      Call the ibonl function to disable the hardware and software. */
```

```
    ibonl (GpibDev, 0); /* Release the device handle */
    ibonl (GpibBoard, 0); /* Release the board handle */

    exit(0); /* exit with no error */

} /* main */

/*===============================================================

*                         Function GPIBERR
*       This function will notify you that a NI-488 function failed by
*       printing an error message.  The status variable IBSTA will also be
*       printed in hexadecimal along with the mnemonic meaning of the bit position.
*       The status variable IBERR will be printed in decimal along with the
*       mnemonic meaning of the decimal value.  The status variable IBCNT will
*       be printed in decimal.
*
*       The NI-488 function IBONL is called to disable the hardware and software.
*
*       The EXIT function will terminate this program.
*================================================================
*/

void gpiberr(char *msg)  {
    Unsigned int I;

    /*    Table of ibsta (interface board status word) bit positions and
          corresponding messages  */
   statis struct { in bit; char *msg;} ibstaMsg [16]=
      {    {ERR,  " ERR"},
          {TIMO,  " TIMO"},

          {END,  " END"},
          {SRQI,  "SRQI"},
          {RQS,  "RQD"},
          {SPOLL,  "SPOLL"},
          {EVENT,  "  EVENT"},
          {CMPL,  " CMPL"},
          {LOK,  " LOK"},
          {REM,  " REM"},
          {CIC,  "  CIC"},
          {ATN,  " ATN"},
          {TACS,  " TACS"},
          {LACS,  " LACS"},
          {DTAS,  " DTAS"},
          {DCAS,  " DCAS"} };

/*      Table of iberr error messages */
static struct { int val; char *msg;} iberrMsg[15]=
```

```
{       { EDVR, " EDVR <DOS Error>\n"],
        { ECIC, " ECIC <Not CIC>\n"},
        { ENOL;. " ENOL <No Listener>\n"},
        { EADR, " EADR <Address error>\n"},
        { EARG, " EARG <Invalid argument>\n"},
        { ESAC, " ESAC <Not Sys Ctrlr>\n"},
        { EABO, " EABO <Op. aborted>n"},
        { ENEB, " ENEB <No GPIB board>\n"},
        { EOIP, " EOIP <Async I/O in prg>\n"},
        { ECAP, " ECAP <No capability>\n"},
        { EFSO, " EFSO <File sys> error>\n"},
        { EBUS, " EBUS <Command error>\n"},
        { ESTB, " ESTB <Status bye lost>\n"},
        { ESRQ, " ESRQ <SRQ stuck on >\n"},
        { ETAB, " ETAB <Table Overflow>\n"};

printf ("%s\n:, msg); /* Print the application supplied context message. */

/*
*       The ibsta variable provides the primary information about the cause o
*       the error:  print it's value and mnemonic for each bit set.
*/

printf ("ibsta = &H%X  <", ibsta);
for (i=0;  i<=15; i++)
        {  if (ibsta & ibstaMsg[i].bit)  printf  ("%s",ibstaMsg[i].msg);  };
printf ("  .\n");

/*
*       Print the iberr value and interpertation
*/

printf ("iberr = %d, iberr);
for (i=0; i<=14; i++)
  { if (iberr==iberrMsg[i].val)  printf ("%s", iberrMsg[i].msg); };

/*
*       Print ibcnt in decimal
*/

printf ("ibcnt = %d\n", ibcnt);
printf ("\n)'

/*      put the board and device offline */

ibonl (GpibDev, 0); /* Release the device handle (/
ibonl (GpibBoard, 0); /* Release the board handle */

exit (1); /* exit the status=1 to indicate error */
}
```

3.6.3 Example 3 – National Instruments IBIC

Preperation:

Your c:\config.sys file must have the following line in it:

device=c:\488\gpib.com

After you add this line, you must re-boot (reset) your computer for the driver to be loaded. For purposes of this demo, set the Krohn-Hite Model 3940/3944 to GPIB address 1:

Press 1 [SECOND FUNCTION][MEGA]

Set the talker to only send EOI:

Press 1 [SECOND FUNCTION][ALL CHAN}

Prompt	Command You Type	Comments
C:\488>	ibic	From the DOS command line, enter the IBIC program.
	ibfind gpib0	Initialize the program to access the board.
gpib0.	ibfind dev1	Initialize the program to access the device at GPIB address 1.
dev1	ibwrt "5.1K"	Set the unit to 5.1kHz.
dev1	ibrd 50	Read the unit (50 characters is adequate).
dev1	set gpib0	The ibrd command does not unaddress the unit; it must be done manually: select the board so you can do a board level command.
gpib0	ibcmd "?_"	Send "unlisten (UNL)" which is "?" and "untalk (UNT)" which is "_" (underscore).
dev1	ibwrt "AL;0IG;0OG;1TY;1MO;DC"	Set: all channel mode (AL), 0dB input gain (0IG), 0dB output gain (0OG), type 1 (Butterworth), mode 1 (low-pass), DC coupling.
dev1	ibwrt "B;CH1;1K;CH2;2K;CH3;5K"	Set: all channel mode off (B), channel 1 to 1kHz cutoff, channel 2 5o 2kHz cutoff and channel 3 to 5kHz.
dev1	e	Exit IBIC
c:\488>		

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Section 4

INCOMING ACCEPTANCE

4.1 CHANNELS 1.1 AND 1.2

4.1.1 Introduction

The following procedure should be used to verify that channels 1.1 and 1.2 of the Model 3945 filter are operating within specifications. These chaecks may be used for incoming acceptance and periodic performance checks. Test must be made with all covers inplace and operating for a minimum of a half hour to reach thermal equilibrium. Before testing, follow the initial set-up and operating procedure in Section 2.

4.1.2 Required Test Equipment

The equipment below is required to perform the tests in this section.

a. Low Distortion RC Oscilaltor: Krohn-Hite Model 4402B or equivalent.
b. RC Oscilaltor: 10Hz to 10MHz, frequency response of <0.025dB from 10Hz to 500kHz. Krohn-Hite Model 4200B or 4300B or equivalent.
c. AC Voltmeter: capable of measuring 100uV to 10Vrms, 10MHz bandwidth, Fluke Model 8920A or equivalent.
d. Frequency Counter.
e. Distortion Analyzer: Krohn-Hite Model 6900B or equivalent.

4.1.3 Procedure

4.1.3.1 Low-Pass/High-Pass Response

Channels 1.1 and 1.2 can be either low-pass, high-pass or by-pass modes; or one channelin the band-pass or band-reject modes. Either Butterworth (maximally flat) or Bessel (linear phase) responses is selctable. This procedure can be used to check either channel.

Set the filter cutoff frequency to 1kHz in the low-pass mode "L.P.", with Butterworth response "bu." and with 0dB input and output gain.

Apply 1Vrms at 100Hz to the input channel under test.

Note: *These settings can be entered into both channels simultaneously by pressing the [ALL CHAN] key (so its LED is on) prior to entering the above settings. When this LED is off, these settings will only be entered into the channel indicated in the CHANNEL display.*

Monitor the output of the filter channel under test with an ac voltmeter referenced to 0dB. Set the oscillator frequency to 1kHz.

The output voltage should be approximately -3dB.
Set the frequency to 2kHz.
The output voltage should be approximately -24dB.
Set the filter to Bessel response 'bES" and repeat the above.
The output voltage should be approximately -7.6dB and -25.4dB respectively.

Set the filter cutoff frequency to 1kHz in the high-pass "h.P." with Butterworth response and with 0dB input and output gain.
Apply 1Vrms at 10kHz to the input of the filter channel under test.
Monitor the output with an ac voltmeter referenced to 0dB.
Set the oscillator frequency to 1kHz.
The output voltage should be approximately -3dB.
Set the frequency of the oscillator to 500Hz.
The output voltage should be approximately -24dB.
Set the filter response to Bessel and repeat the above.
The output voltage should be approximtely -7.6dB and 25.4dB respectively.

In the by-pass mode "bYp." the input is connected directly to the output.
Monitor the input and output to verify this operation.

4.1.3.2 Cutoff Frequency Accuracy

Connect the oscillator at 1Vrms at 50Hz to the input of the channel under test.
Set the filter to Butterworth response.
Set the filter cutoff frequency to 1kHz in the low-pass mode with 0dB input and output gain.

Monitor the output of the filter with a freuqncy counter and an ac voltmeter referenced to 0dB.
Set the oscillator to 1kHz and adjust the frequency so the output voltage is -3dB.
The oscillator frequency should be within ±2% of the cutoff frequency of 1kHz.

Repeat the above with a cutoff frequency of 100kHz, 500kHz and 1MHz.
Tolerance should be within ±2% at 100kHz and 500kHz, and ±5% at 1MHz.

Connect the oscillator at 1Vrms at 20kHz to the filter input under test.
Set the filter to a cutoff frequency of 1kHz in the high-pass mode with 0dB input and output gain.

Monitor the output of the filter with a frequency counter and ac voltmeter referenced to 0dB.
Set the oscillator to 1kHz and adjust its frequency so the output voltage is -3dB.
The oscillator frequency should be within ±2% of the cutoff frequency of 1kHz.

Repeat the above with a cutoff frequency of 100kHz, 500kHz and 1MHz.
Tolerance should be within ±2% at 100kHz and 500kHz, and ±5% at 1MHz.

4.1.3.3 Band-Pass/Band-Reject Response

Variable band-pass response shown in Figure 4.1, is obtained by applying the input signal to channel 1.1 input. Set the CHANNEL display to channel 1.1. Set the filter to band-pass mode "b.P.". In the band-pass mode it is necessary that the [ALL CHAN] LED is off.

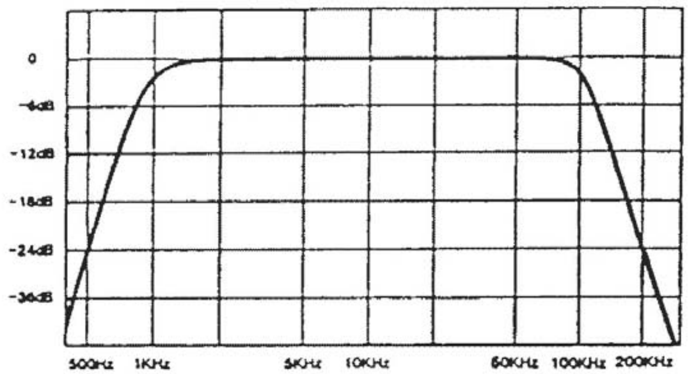


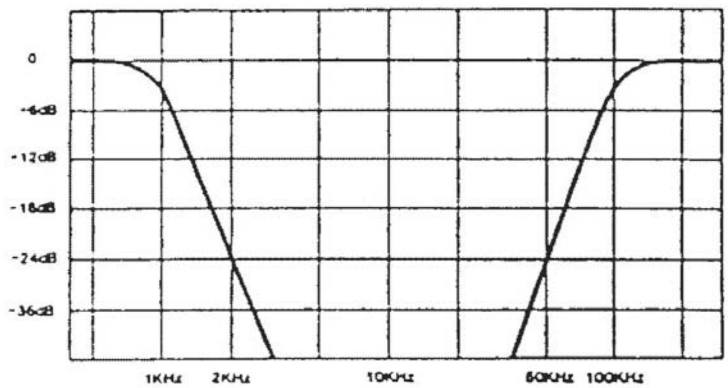
Figure 4.1 Band-Pass Response

Set the filter to Butterworth response and apply 1Vrms at 10kHz to the input of channel 1.1.
Set the filter to a low cutoff frequency of 1kHz.
Set the filter to channel 1.2.
Set the filter to a high cutoff frequency of 100kHz.

Monitor the output of channel 1.1 with an ac voltmeter referenced to 0dB.
Set the oscillator frequency to 1kHz and 100kHz.
The output voltage should be approximately -3dB at these frequencies.
Set the oscillator frequencies to 500Hz and 200kHz.
The output voltage should be approximimtely -24dB at these frequencies.

Variable band-reject response, shown in Figure 4.2, is obtained by applying the input signal to channel 1.1 input.
Set the CHANNEL display to 1.1.
Set the filter to band-reject mode "b.r." and Butterworth response.
Apply 1Vrms at 100Hz to the input of channel 1.1 and set the filter low cutoff to 1kHz.
Set the filter to channel 1.2 and the high cutoff frequency to 100kHz.
In the band-reject mode, it is necessary that[ALL CHAN] is off.

Monitor the output of channel 1.1 with an ac voltmeter referenced to 0dB.
Set the oscillator frequency to 1kHz and 100kHz.
The output voltage should be approximately -3dB at these frequencies.
Set the oscillator frequencies to 2kHz and 50kHz.
The output voltage should be -24dB at these frequencies.



Figute 4.2 Band-Reject Response

4.1.3.4 Stopband Attenuation

Accurate stopband attenuation measurements require some simple precautions because of low level signals. The filter should be shielded with top and bottom covers in place. BNC cables ONLY should be used between oscillator, volatmeter and filter, and no other instruments should be connceted.

Connect the oscilaltor at 3Vrms at 20kHz to channel 1.1. input of the filter.
Set the filter to a cutoff frequency of 1kHz with 0dB input and output gain.
Connect channel 1.1 output of the filter through a 6kHz passive high-pass filter as shown in Figure 4.3 to the ac voltmeter.
Set the filter to the low-pass mode.
The filter output should be <-80dB (300uVrms).

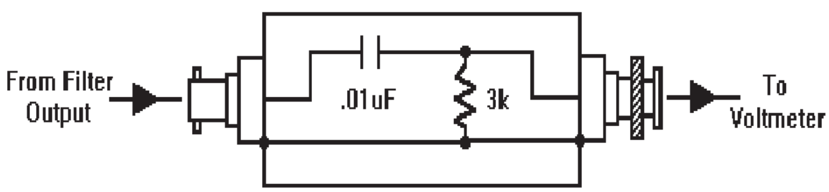


Figure 4.3 High-Pass Filter

4.1.3.5 Pre-Filter and Post Filter Gain Accuracy

Set the filter to a cutoff frequency of 1kHz in the low-pass mode with 0dB input and output gain.
Apply 50mVrms at 100Hz to the channel 2.1 input.

Monitor the output of the filter with an ac voltmeter referenced to 0dB.
Set the filter CHANNEL dispay to 2.1.
Set the input gain to 20dB.
The output of the filter should be a sinewave and 20dB, ±0.2dB.
Set the input gain to 0dB and the output gain to 20dB.
The output of the filter should be a sinewave and 20dB, ±0.2dB.

4.1.3.6 Noise Check

Short the input of the filter and set the input and output gain to 0dB.
Set the filter to the low-pass mode, Butterworth response and a cutoff frequency of 2MHz.
Connect the output of the filter using a shielded BNC cable in series with a 2MHz low-pass filter, shown in Figure 4.4, to the ac voltmeter.
Voltmeter reading should be <200uV.

NOTE: *The 2MHz filter should be inserted into a shielded enclosure (Pomona Model 3231 or equivalent) and connected directly to the voltmeter. Nothing else should be connected to the filter and the voltmeter.*

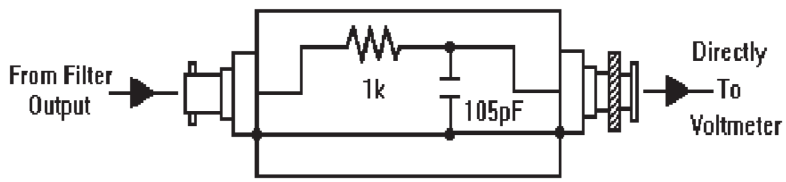


Figure 4.4 2MHz Low-Pass Filter

4.2 CHANNEL 2.1

4.2.1 Introduction

The following procedures may be used for incoming acceptance and periodic preformance checks for channel 2.1 of the Model 3945. Test must be made with all covers in place and operating for a minimum of one half hour to reach operating temperature.

CAUTION: *If the distortion is excessive, verify that the distortion of the oscilaltor being used is less than 0.005%.*

4.2.2 Required Test Equipment

The test equipment below is required to performa the following tests:

a. DC Voltmeter (DVM): capable of measuring 1mV to 20V, Fluke 8000 or equivalent.
b. AC RMS Voltmeter: capable of measuring 100uV to 10Vrms and a useful bandwidth to 25MHz, Fluke Model 8920A or equivalent.
c. Squarewave Source: 2Vp-p squarewave with a rise and fall time <5ns with <5% overshoot or ring, HP8012B or equivalent.
d. Low Distortion Sinewave Signal Source: <0.05% distortion to100kHz, 0.1% to 1MHz, Krohn-Hite Model 4200B/4300B or equivalent.
e. Distortion Analyzer: capable of measuring distortion to 1MHz, Krohn-Hite Model 6900B or equivalent.
f. Sinewave Signal Source: covering frequency range of 1MHz to 100MHz, Tektronix Model 191 or equivalent.
g. Spectrum Analyzer: HP Model 141T with RF section 8553B and IF section 8552B or equivalent.
h. Oscilloscope: 100MHz bandwidth, Tektronix Model 2245A or equivalent.

4.2.3 Initial Settings and Procedure

Input Ohms: 50
Input Gain: 0dB
Input Coupling: DC
Cutoff Frequency: 10MHz
Output Gain: 0dB
Overload Mode: 2
Filter Mode: Low-Pass

NOTE: *Good "high frequency techniques" should be used at all times, which includes the use of good quality 50 ohm cabling for signal connections to and from the filter.*

4.2.4 DC Output Level

Connect the DVM set for DC operation to the filter output.
Measure the DC level for all input and output gain settings.
Should be <±10mVdc.

4.2.5 Gain Accuracy

Disconnect the DVM and connect the Fluke 8920A to the filter output.
Connect a 0.1Vrms, 1kHz signal to the input of channel 2.1

NOTE: *The filter input is set for 50 ohms and will terminate a 50 ohm source producing a factor of 2 less in amplitude.*

Set the filter output gain to 0dB.
Set the Fluke 8920A for ac referenced to 0dB.
Check each input and output gain setting by switching each one up from 0dB independently. All dB readings should be within 0.1dB of the filter gain setting.

4.2.6 Distortion

Disconnect the Fluke 8920A from the filter output.
Set the filter for 0dB input gain and 6dB output gain.
Set the signal source for 1Vrms, 1kHz, sinewave and connect to the filter channel 2.1 input.

Connect the distortion analyzer to the filter channel 2.1 output. through 50 ohm cable terminated at the analyzer end.
Measure the distortion at the following frequencies: 1kHz, 100kHz, 1MHz.

Readings should be <0.1% at 1kHz and 100kHz.
Reading should be <0.3% at 1MHz.

If necessary, verify that the signal source's distortion is below the above readings by measuring it separately.

4.2.7 Squarewave Rise and Fall Times

Disconnect the distortion anlyzer and signal source from the filter.
Set the filter to the GAIN mode.
Set the filter input gain to 0dB and output gain to 6dB.
Set the filter input ohms to 50.
Set the filter coupling to AC.

Connect the input using a 50 ohm cable to the squarewave source set for 2Vp-p, 2.5MHz, squarewave.
Connect the filter output to an oscilloscope with a 50 ohm cable terminated at the scope end.
Observe on the scope that the overshoot and ringing is <5%.
Measure the rise and fall time from 10% and 90% waveform points.
should be <7ns.

Set the squarewave source for 0.2Vp-p.
Check the output waveform first with 20dB input gain and then 26dB output gain for <5% overshoot and ringing, and <10ns rise and fall time.

4.2.8 Frequency Calibration

Set the filter for the initial settings at the beginning of this section.
Connect the filter input via a 50 ohm cable to a 1Vrms, 1kHz, sinewave signal source.
Connect the Fluke 8920a to the output of the filter with a 50 ohm cable.
Set the Fluke for relative dB operation.

Set the filter for a cutoff frequency of 1kHz and Gain mode.
Zero reference the Fluke.
Set the filter for Low-Pass mode (L.P.) and measure the drop in dB on the output.
Should be within -2.67dB to -3.37dB for a ±2% calibration range.

Set the sinewave generator and filter cutoff to the following frequencies and zero referencing the Fluke in the filter gain mode.
Measure the drop in gain on the output of the filter when switching the filter to the Low-Pass mode.

Frequency	dB at Cutoff Range	% Error Spec
1kHz	-2.67dB to -3.37dB	±2%
10kHz		
100kHz		
1MHz		
10MHz	-2.21dB to -3.94dB	±5%

4.2.9 Wideband Noise

Set the filter for 25.6MHz, LP mode, 0dB input gain and 26dB output gain.
Disconnect the sinewave signal from the filter input.
With the Fluke connected to the output via a 50 ohm terminated cable, measure the wideband noise present.

Wideband noise should be <5mV which translates into 500uV referenced to the input, since the net gain from the filter input to the meter is 20dB.

4.2.10 Stopband Attenuation

NOTE: *This test uses a spectrum analyzer to detect the rejected signal. Most spectrum analyzers have a maximum signal amplitude without damage limit. Care should be taken that this signal level limit is not exceeded. A simple precaution would be to use a 50 ohm in line 20dB attenuator at the analyzer input. It is also advisable to set all the equipment before connecting the analyzer.*

Set the filter to the initial settings at the beginning of this section.

Set the filter coupling to AC, cutoff frequency to 10kHz and mode to gain.
Set the Tektronix 191 signal generator for 1MHz, 3Vp-p into 50 ohms.

Connect the Tektronix 191 to the filter input.
Set the spectrum analyzer to measure the 3Vp-p, 1MHz signal into a 50 ohm termination at the filter output and connect ther filter output to the analyzer.
Adjust the analyzer for 0dB, referencing level at the 1MHz signal.

Set the filter for Low-Pass mode.
The measured amount of 1MHz signal should be down 100dB.
Set the signal generator for 10MHz.
The measured amount of 10MHz signal should be down 80dB.
Set the signal generator for 30MHz.
The measured amount of 10MHz signal should be down 70dB.

NOTE: *Zero referencing of the spectrum analyzer at 100MHz must be done by connecting the signal generator to the spectrum analyzer input.*

Set the signal generator for 100Mhz.
The measured amount of 100MHz signal should be down 50dB.

End of Procedure.