Instruction Manual

LeCroy AP022 Active Probe

Revision B — December 1999

Warranty

LeCroy warrants this oscilloscope accessory for normal use and operation within specifications for a period of three years from the date of shipment. Calibration after each 12 month interval is recommended to ensure performance to specification. Spare parts, replacement parts and repairs are warranted for 90 days. The instrument's firmware has been thoroughly tested and thought to be functional, but is supplied without warranty of any kind covering detailed performance.

In exercising its warranty, LeCroy will repair or at its option, replace any assembly returned within its warranty period to the Customer Service Department or an authorized service center. However, this will be done only if the product is determined by LeCroy's examination to be defective due to workmanship or materials, and the defect is not caused by misuse, neglect, accident, abnormal conditions of operation, or damage resulting from attempted repair or modifications by a non-authorized service facility.

The customer will be responsible for the transportation and insurance charges for the return of products to the service facility. LeCroy will return all products under warranty with transportation prepaid.

This warranty replaces all other warranties, expressed or implied, including but not limited to any implied warranty of merchantability, fitness, or adequacy for any particular purposes or use. LeCroy shall not be liable for any special, incidental, or consequential damages, whether in contract or otherwise.

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AP022-IM-E Rev B 1299

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Overview

FEATURES

The LeCroy AP022 is an active probe specifically designed for high frequency voltage measurements, to be interfaced with LeCroy oscilloscopes. Its features include:

- Bandwidth: 2.5 GHz
- Input capacitance ~0.6 pF
- Input resistance 100 kΩ
- ÷10 attenuation
- Dynamic range: ±5 V peak ac
- Variable dc offset ±12 V

CONVENTIONS USED IN THIS MANUAL

The following conventions may appear in this manual:

Note

A Note contains general information relating to the use of the product.

Caution

A Caution contains information that you should follow to avoid possible damage to the instrument or the device under test.

WARNING

A Warning alerts you to potential injury to yourself. Failing to adhere to the statement in a WARNING message could result in bodily injury.

⚠ **Read First: Safety Information**

The corresponding information in the manual is denoted with the same symbol.

CAT I Overvoltage Installation Category per EN 61010-1

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⚠ Specifications

NOMINAL CHARACTERISTICS

Nominal characteristics are parameters and attributes that are guaranteed by design, but do not have associated tolerances.

Configuration:	Single ended
Type:	Passive attenuator followed by active gain stage in probe tip
Attenuation:	÷10
Oscilloscope interface:	Compatible with LeCroy ProBus interface
Dynamic Range:	± 5 V, see Figure 2
Offset range:	±12 V
⚠ Maximum input:	See Chapter 3, Figure 2

WARRANTED CHARACTERISTICS

Warranted characteristics are parameters with guaranteed performance. Tests are provided in the Performance Verification Procedure for all warranted specifications.

DC accuracy:	±0.5%
Output zero:	±4 mV (referred to input)
Offset accuracy:	±1%, ±4 mV (referred to input)

TYPICAL CHARACTERISTICS

Typical characteristics are parameters that do not have guaranteed performance. Tests for typical characteristics are not provided in the Performance Verification Procedure.

Bandwidth: (-3 dB, probe only)	>2.5 GHz
Rise time:	<140 ps
Input capacitance:	0.6 pF
DC Input resistance:	100 kΩ, ± 1%

ENVIRONMENTALCHARACTERISTICS

Environmental characteristics are tested to specification MIL-PRF-28800F modified Class 3. Refer to this specification if performance verification of environmental characteristics is required.

Temperature:	0 to 50 °C Operating -40 to 75 °C storage
Relative Humidity:	Up to 90% (non-condensing) (0 to 40 ºC) Up to 70% (non-condensing) (40 to 50 ºC)
Altitude:	2000 m (operating) 12 000 m (storage)

PHYSICAL CHARACTERISTICS

Probe head diameter:	19.05 mm (0.75 inches)
Cable length:	1700 mm (66.93 inches)
Weight (probe only):	0.16 kg (5.64 oz)

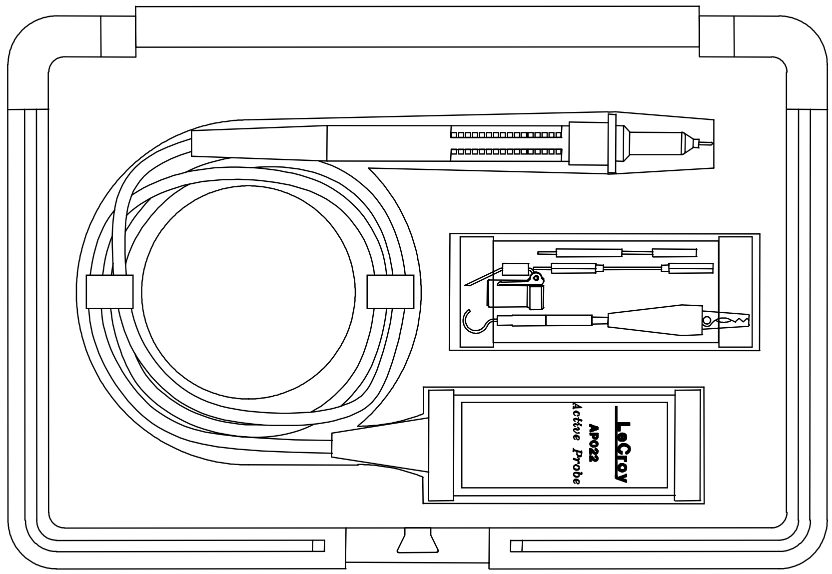

Figure 1. AP022 Active Probe and Accessories in Protective Case

COMPLIANCES

EC Declaration of Conformity Conforms to EMC Directive 89/336/EEC for electromagnetic emission and immunity requirements, and Low Voltage Directive 73/23/EEC for product safety.

Emissions: EN 55011:1997, Class B

Immunity: EN 50082–1:1997

Safety: EN 61010–1:1993
42.4 V, CAT I, Pollution Degree 1

⚠ **Operator Safety**

The probe is intended to be used only with instruments that are connected to earth ground through the input BNC connector. Do not use in wet or explosive atmospheres. Refer to the Usage and Maintenance Information.

Cleaning

The exterior of the probe and cable should only be cleaned with a soft cloth moistened with water or isopropyl alcohol. The use of abrasive agents, strong detergents, or other solvents may damage the probe.

Usage and Maintenance

Use of the probe or the instrument it is connected to in a manner other than that specified may impair the protection mechanisms.

To guarantee accurate performance, the probe should be calibrated every 12 months. Avoid exposing the probe to mechanical shock and excessive bending of the cable.

Do not use the probe if any part is damaged. All maintenance should be referred to qualified service personnel.

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Operation

Note

While the AP022 has some protection against the adverse effects of electrostatic discharge (ESD), bear in mind that this is an active probe, and must be handled carefully to avoid damage. When working with the AP022, take the usual precautions against potential instrument damage due to ESD.

CONNECTING THE PROBE

You should connect the probe to the oscilloscope before connecting it to the test circuit. The AP022 is compatible with LeCroy oscilloscopes that have the ProBus interface. The ProBus interface can be identified by the distinctive input connector system that mates with the probe. Any regular channel input, or the external trigger input, may be used. **DO NOT connect the probe to the calibrator output connector.**

To attach the probe, insert the rectangular housing onto the mating input connector of the desired channel of the oscilloscope. You can safely connect or disconnect the probe from the oscilloscope with power ON or OFF. The ProBus interface will provide the correct power to the probe, and communicate the necessary control and scale factor information.

Note

The AP022 is intended to be used only with a LeCroy oscilloscope equipped with the ProBus interface. While the use of the ADPPS ProBus power supply adapter will correctly power the probe, a lack of control communication will result in the probe offset being programmed to a random value.

BASIC SETTINGS

Operating Range

The operating and maximum input ranges of the probe are shown in Figure 2. Signals to be measured should lie within the operating region to ensure accuracy of measurements. Offset can be used to re-center the operating range at a point other than ground.

Input voltages greater than the Maximum Non-Destruct Range may damage the probe.

Note

If the input exceeds –14 V relative to the selected offset value, the probe will enter a protection mode, folding back the output to approximately –0.8 V. Return the probe to normal operation by restoring its input to a voltage within the specified operating range.

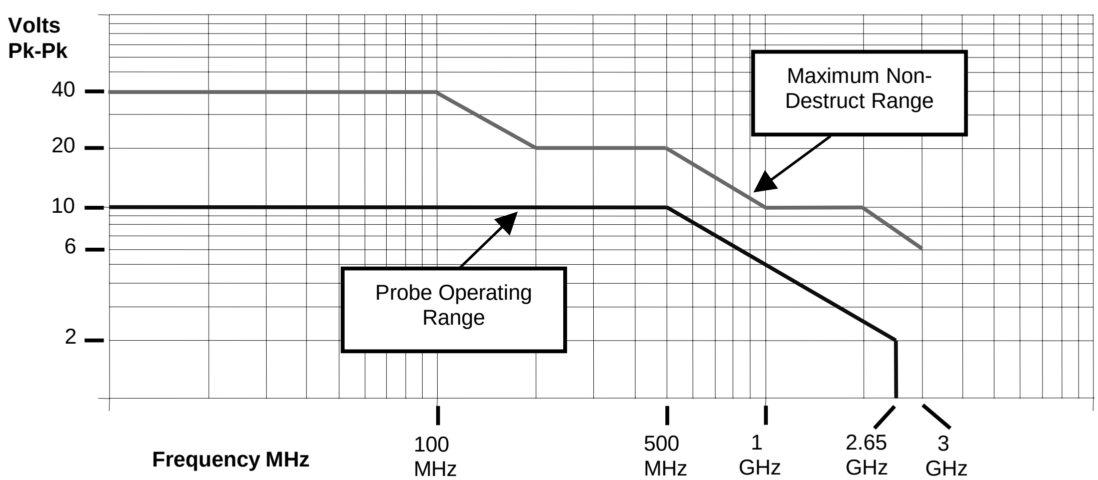

Figure 2. AP022 Operating and Maximum Input Ranges

Probe Offset Adjustment

➢ Set the dc offset to place the steady state signal in the middle of the vertical scale.

The dynamic range of the probe is ±5 V, centered around the selected offset value. Through the use of dc offset, up to ±12 Vdc of offset bias can be applied to the probe. You can adjust the probe offset by selecting the channel to which the probe is connected, and rotating the OFFSET knob in the CHANNEL section of the front panel. The offset voltage is displayed above the graticule on the oscilloscope screen for a few seconds after a change is made. The OFFSET knob only controls the probe offset for channels on which the AP022 is installed. The channel offset remains at 0.0 V.

MEASUREMENT ACCURACY

In order to accurately measure input signals the following factors must be considered:

- Resistive loading
- Capacitive loading
- Ground inductance
- Probe bandwidth

RESISTIVE LOADING

➢ Higher input resistance reduces the load on the circuit being measured, resulting in more accurate measurements at any frequency.

The probe adds a resistance to ground to the circuit being probed. This can act on the source impedance of the circuit, forming a voltage divider that will change the measured voltage. The percentage error introduced is calculated as follows:

$$\%\ error = [R_{source}/(R_{source} + R_{probe})] \times 100$$

To reduce the error due to resistive loading, R_{probe} should be as high as possible in relation to R_{source}.

Example:

A voltage source of resistance 10 kΩ is being measured by a probe whose input resistance is 100 kΩ. What error will be introduced into the measurement as a result of the probe input resistance?

Answer:

$$\% \text{ error} = [R_{source}/(R_{source} + R_{probe})] \times 100$$
$$= [10K/(10K+100K)] \times 100$$
$$= 9.09\%$$

CAPACITIVE LOADING

➢ Lower input capacitance results in more accurate high frequency measurements.

Capacitance is one of the most important parameters affecting high frequency measurements. The input capacitance of the probe causes its input impedance to decrease with increasing frequency, affecting measured signal rise time and shifting event time. The lower the input impedance, the more inaccuracy introduced into a measurement. For higher frequency signals, probes with lower input capacitance are required in order to conduct accurate timing and rise time measurements.

Figure 3 shows a comparison of input impedance vs. frequency for two probes:

(a) LeCroy PP05 passive probe, with the following input characteristics:

- Input resistance = 10 MΩ
- Input capacitance = 11 pF

(b) LeCroy AP022 active probe, with the following input characteristics:

- Input resistance = 100 kΩ
- Input capacitance = 0.6 pF

At lower frequencies (150 kHz and below) the PP05 has higher input impedance. However, at frequencies above 200 kHz the AP022 has higher input impedance.

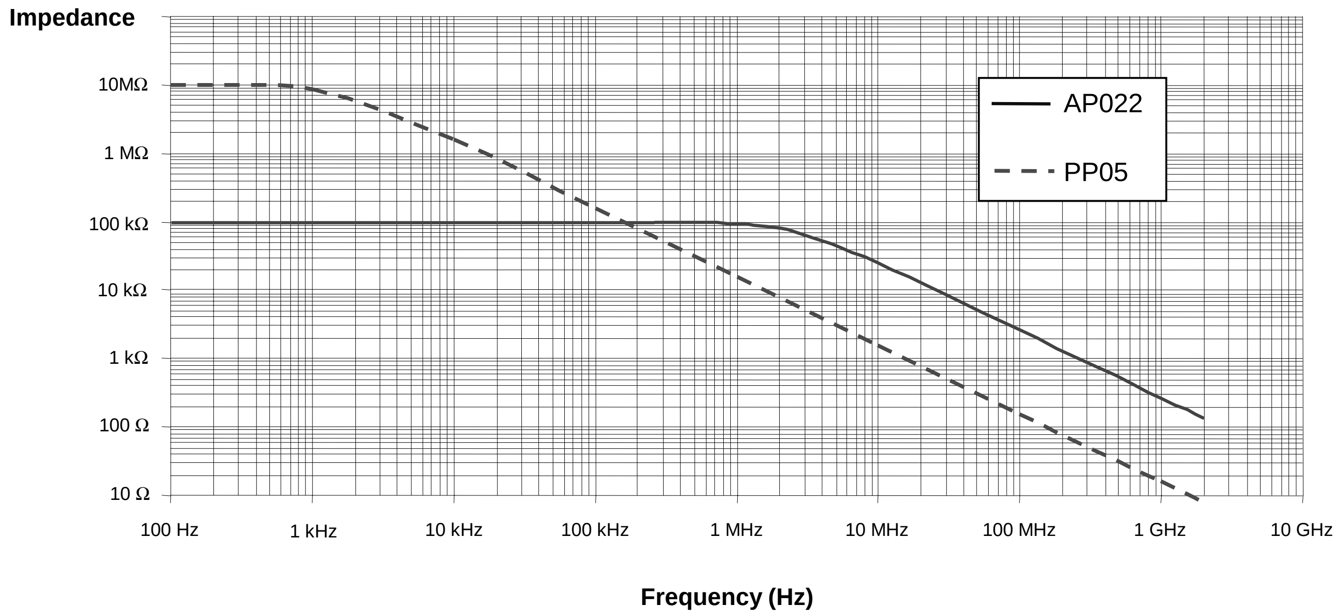

Figure 3. Probe Impedance Versus Frequency

- When making digital timing measurements, do not mix probe types.

If two probes of different types are used to measure relative pulse timing Δt (such as for "set up and hold" measurements) each probe will affect differently the timing of the pulse being measured, and the resulting difference Δt will be inaccurate. Parameters such as input capacitance, ground lead length, and probe cable length determine the propagation delay of the measured signal.

In the case of absolute timing measurements, altering the measured delay and rise time can be significant.

GROUND INDUCTANCE

- Short ground leads result in more accurate high frequency measurements.

Inductance of the ground return lead, when combined with probe input capacitance, results in LC series resonance, causing difficulty in high frequency measurements. This resonance causes overshoot and ringing on pulse edges that are seen on the oscilloscope display. Furthermore, attaching accessories to the probe input can add to the effect by increasing the magnitude of the parasitic capacitance and inductance. For signals with frequency content above 100 MHz, which is often the case in modern digital systems, a surprisingly short length of additional ground lead or input lead can produce a large amount of ringing. Therefore, it is very important to keep the probe input and ground leads as short as possible. In active probes with low input capacitance, the tendency to ring can also be reduced by adding a small resistive loss in the ground path.

To minimize the effects of probe resonance, the resonant frequency of the probe should be greater than the frequency content of the signal being measured.

The resonant frequency of the probe input capacitance C and ground inductance L (L=25 nH per inch) is calculated as follows:

$$f_r = 1/ [2\pi(LC)^{1/2}] \ ,$$

while the bandwidth of the signal to be measured, BW_{signal} is calculated as follows:

$$BW_{signal} \text{ (MHz)} = 0.35/[\text{rise time (ns)}]$$

Example:

Calculate resonant frequency and predict whether overshoot and ringing will be present for a signal with a rise time of 400 ps when measured by two different probes:

- PP05, input capacitance = 11.0 pF
  ground length = 1/2 inch

- AP022, input capacitance = 0.6 pF
  ground length = 1 inch

PP05

The inductance of the ground return is calculated to be

$$L = (25\ \text{nH/inch})\ (1/2\ \text{inch})$$
$$= 12.5\ \text{nH}$$
$$= 12.5 \times 10^{-9}\ \text{H}$$

The probe's resonant frequency is calculated to be

$$f_r = 1/\ [2\pi\ (LC)^{1/2}]$$
$$= 1/[2^*\ (3.14)\ (12.5 \times 10^{-9}\ \text{H} * 11 \times 10^{-12}\ \text{F})^{1/2}]$$
$$= 0.5/[(3.14)(3.71\text{x}10^{-10})]$$
$$= 429.4\ \text{MHz.}$$

For a signal with a rise time of 400 ps,

$$BW_{signal} = 0.35/400 \times 10^{-12}\ \text{s}$$
$$= 875\ \text{MHz}$$

Since the probe resonant frequency is smaller than the signal bandwidth, there will be significant overshoot and ringing present on the oscilloscope display.

AP022

The inductance of the ground return is calculated to be:

$$L = (25\ \text{nH/inch})\ (1\ \text{inch})$$
$$= 25\ \text{nH}$$
$$= 25 \times 10^{-9}\ \text{H}$$

The probe's resonant frequency is calculated to be:

$$f_r = 1/\ [2\pi\ (LC)^{1/2}]$$
$$= 1/[2^*\ (3.14)\ (25 \times 10^{-9}\ \text{H} * 0.6 \times 10^{-12}\text{F})^{\ 1/2}]$$
$$= 0.5/[(3.14)(1.225 \times 10\text{-}^{10})]$$
$$= 1300\ \text{MHz}$$
$$= 1.30\ \text{GHz}$$

For a signal with rise time of 400 ps, BW_{signal} = 875 MHz

Here the probe resonant frequency is significantly larger than the signal bandwidth; hence, there will be a negligible amount of overshoot and ringing present on the oscilloscope display, even though the ground lead is twice as long as in the previous example. Figure 4 shows the actual measurements.

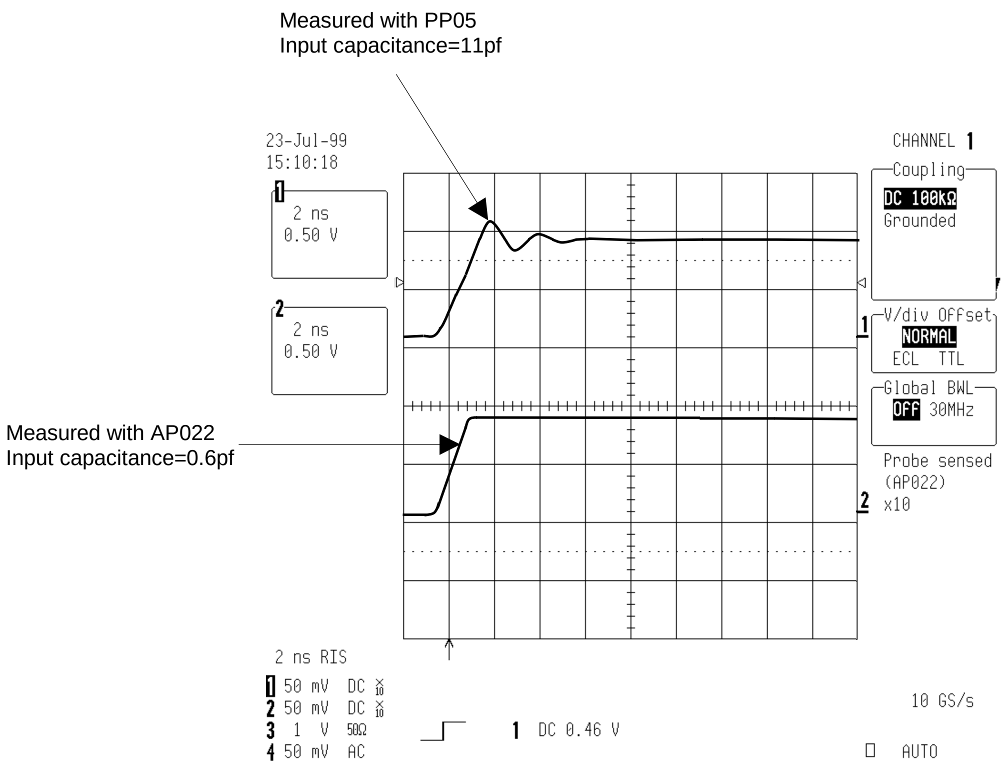

Figure 4 Probe Resonance Effects

PROBE BANDWIDTH

- To ensure that the measurement error is less than 6%, the probe bandwidth should be at least three times the value of the signal being measured.

As the bandwidth of the signal being measured approaches the bandwidth of the measurement system, there will be error introduced into the measurement. The probe bandwidth subtracts from the overall measurement system bandwidth. To keep measurement errors less than 6%, the system bandwidth, including the probe, must be at least three times that of the signal being measured.

Example:

A 1 ns signal is being measured by two probes, with

- Probe bandwidth 700 MHz
- Probe bandwidth 1.05 GHz

Compare the values of signal rise time measured by each probe.

Treating the probe as a single pole low pass filter, the measured rise time can be calculated by

$$Tr = [(tr_1)^2 + (tr_2)^2]^{1/2}$$

where tr_1 is the rise time of the probe, and tr_2 is the rise time of the signal.

(a) The rise time of the 700 MHz bandwidth probe can be calculated from

$$tr_1 = 0.35/\text{probe bandwidth}$$

$$= 0.35/700\ \text{MHz}$$

$$= 0.5\ \text{ns}$$

Therefore, the measured rise time will be

$$tr = (tr_1)^2 + (tr_2)^2]^{½}$$

$$= [(0.5\ \text{ns})^2 + (1.0\ \text{ns})^2]^{½}$$

$$= 1.12\ \text{ns}$$

which is in error by 12% from the actual value of 1.0 ns.

(b) The rise time of the 1.05 GHz bandwidth probe is

$$tr1 = 0.35/1.05\ \text{GHz} = 0.33\ \text{ns}$$

and so the measured rise time can be calculated as

$$tr = [(tr_1)^2 + (tr_2)^2]^{½} = [(0.33\ \text{ns})^2 + (1.0\ \text{ns})^2]^{½} = 1.054\ \text{ns}$$

which is in error from the actual value by only 5.4%.

Example: CMOS gate

With a fast CMOS gate as the device being measured, using the AP022 (100 kΩ, 0.6 pF) probe, we consider each of the four factors affecting measurement performance: resistive loading, capacitive loading, ground inductance, and probe bandwidth.

a. Resistive Loading

When the CMOS output is high (+5 V), the probe draws a current of 50 µA (I = 5 V/100 kΩ). The output impedance of the CMOS gate is 100 Ω, much less than the probe's input impedance. Hence, the voltage divider formed by the two will be insignificant, and will not affect the state of the gate.

b. Capacitive Loading

A CMOS gate typically has an input capacitance of 5 to 10 pF. Metal interconnects between CMOS gates typically introduce an additional 5 to 10 pF. Together the total capacitance of the circuit is 10 to 20 pF.

The additional capacitance of the AP022 probe (0.6 pF) is between 3% and 6% of the circuit capacitance, and will not significantly affect the circuit's time constant.

c. Ground Inductance

Using a short ground (length = 0.80”, L $\cong$ 20 nH) the probe’s resonant frequency will be

$$f_r = 1/[2\pi(LC)^{½}]$$

$$= 1/[2^* 3.14^* (20 \times 10^{-9} * 0.6 \times 10^{-12})^{½}]$$

$$= 1.45 \text{ GHz}$$

The CMOS gate rise time of ~1 ns translates to a bandwidth ($BW_{circuit}$) of

$$BW_{circuit} = 0.35/tr$$

$$= 350 \text{ MHz}$$

which is significantly less than one half of the probe’s resonant frequency. Therefore, little signal distortion due to probe resonance will be seen.

d. Bandwidth

If the bandwidth of the probe/oscilloscope combination is at least 3 times the signal bandwidth of the CMOS signals,

$$3^* BW_{circuit} = 3^* 350 \text{ MHz}$$

$$= 1.05 \text{ GHz}$$

This will be displayed on the oscilloscope in an accurate representation of the signal.

The AP022 probe has a bandwidth ≥2.5 GHz, while the bandwidth of a suitable oscilloscope is 1.5 GHz. The bandwidth of the probe-oscilloscope combination is approximately

$BW_{probe\text{-}oscilloscope} = 1.5$ GHz.

Hence, when used in combination with a high-bandwidth oscilloscope, no measurement error is to be expected due to probe bandwidth.

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Accessories

STANDARD ACCESSORIES

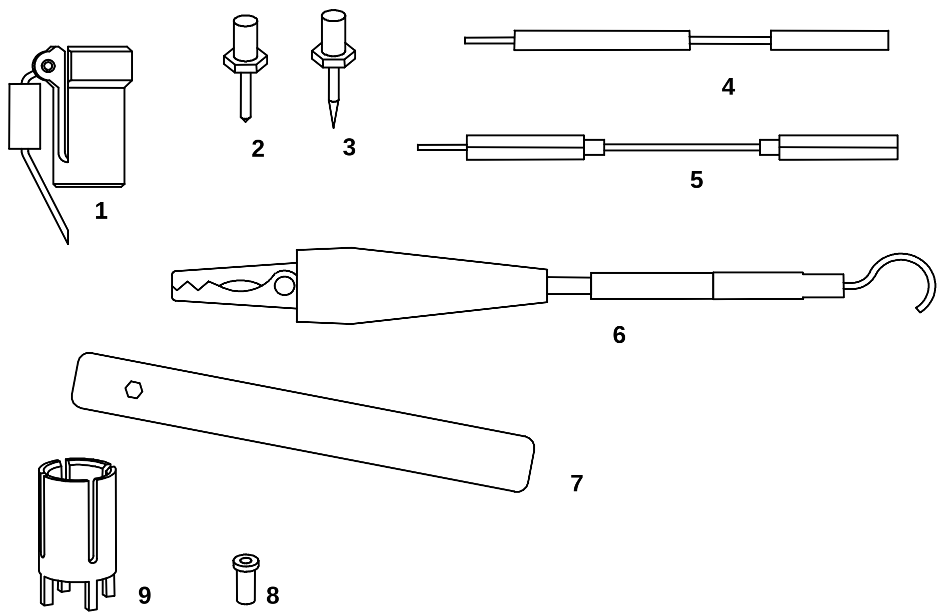

Figure 5. Standard Probe Accessories

1. Adjustable position ground
2. Probe replacement tip, 0.030 inch diameter
3. Sharp probe tip, 0.025 inch diameter
4. 200 Ω signal lead
5. 2-inch ground lead extension, attachable to adjustable position ground
6. 4-inch alligator ground lead, attachable to probe tip ground
7. Nut driver, 3/32 inch, for replacing probe tips
8. Single-contact socket
9. Probe ground socket

The standard probe replacement tip (labeled “2” in Figure 5) for general applications is made up of a material that will bend before breaking. The sharp probe tip (labeled “3” in Figure 6) is made of a harder material, and can be used to penetrate hard coatings.

Caution

Do not solder the probe tip into circuitry. Excessive heat can cause damage to the probe tip and to the circuitry inside the probe. If soldering is necessary, use the single contact socket and probe ground socket (8 and 9 in Figure 5).

Note

The probe socket is a direct fit to the shield of the AP022 probe. This socket (9), along with the single contact socket (8), is used in probing a PC board. The combination provides the shortest lead length for probing PC board circuits. See figure 6 for mounting details.

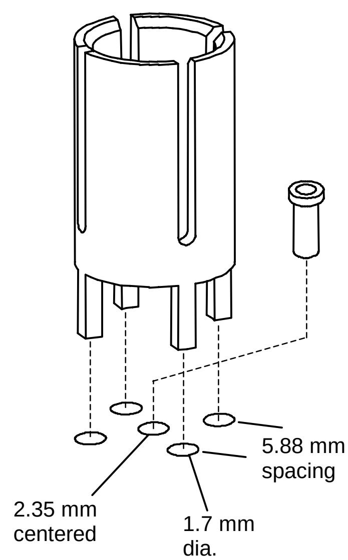

Figure 6. Probe Ground Socket and Single Contact Socket for PC Board Testing

OPTIONAL ACCESSORIES

The BNC-to-probe tip adapter, unterminated (see Figure 7), is available for use in performing probe gain verification and directly connecting the probe to BNC cables or accessories. This adapter is limited to low frequency applications as it is not terminated.

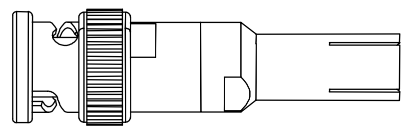

Figure 7. BNC-to-probe tip adapter

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Care and Maintenance

SERVICE STRATEGY

The AP022 uses a precision, laser trimmed hybrid microelectronic circuit, and is not field repairable. Defective probes must be returned to a LeCroy service facility for diagnosis and exchange. A defective probe under warranty will be replaced with a factory refurbished probe. A probe that is not under warranty can be exchanged for a factory refurbished probe. A modest fee is charged for this service. You must return the defective probe in order to receive credit for the probe core.

TROUBLESHOOTING

If the probe is not operating properly, the problem may be a defect in the probe, or a problem with the way in which the probe is being used. Several possible scenarios are described below.

A. Trace off of scale

This is typically caused by improper offset setting, or by an input signal that exceeds the probe dynamic range. Perform the following:

1. Change the offset of the active channel to which the probe is attached. Does the trace return to a value within the available dynamic range?
2. Remove the input signal from the probe and return the offset to zero. Does the trace return to approximately the center of the graticule?
3. Connect the probe input to the calibrator output signal. Is a waveform displayed with approximately the amplitude indicated by the calibrator setting?

4. Is a ProBus Power Supply Overload error message displayed? If so, remove all other ProBus accessories from the oscilloscope. Is the message still displayed? If so, remove the AP022. Is the message still displayed? If so, the oscilloscope should be returned for service.
5. If, after removing the AP022, the Power Supply Overload error message is not displayed, the problem may be either the probe or the oscilloscope. Repeat the test with a different ProBus accessory. If the message does not return with a different accessory, the AP022 may be defective and should be returned for service.

B. Incorrect frequency response

Possible causes are defective probe, oscilloscope, poor connections, or poor grounding. Try the following:

1. Verify that the BW limiting of the oscilloscope is not enabled.
2. Connect the probe to another oscilloscope. If the probe now measures properly, the problem is a defective oscilloscope.
3. If the probe behaves as if it is ac-coupled at high frequency, check for a loose probe tip.
4. Verify that there is a good ground connection between the probe head and the circuit under test.

C. DC Errors

Incorrect dc gain requires factory repair.

1. Incorrect input resistance may be due to a loose probe tip. If this is not the case, factory repair is necessary.
2. Incorrect offset is due to misadjusted offset zero.
3. With no signal input and no offset setting, the dc output of the probe should be within ±3 mV. If not, recalibration is necessary.

RETURNING A DEFECTIVE PROBE

The procedure for returning a defective probe to be exchanged, is as follows:

Contact your local LeCroy sales representative to find out where to return the product. All returned products should be identified by model and serial number. You should describe the defect or failure, and provide your name and contact number. In the case of products returned to the factory, a Return Authorization Number (RAN) should be used. The RAN can be established by contacting your nearest LeCroy office, or the New York Customer Care Center.

Return shipments should be made prepaid. LeCroy cannot accept COD or Collect Return shipments. We recommend air-freighting. It is important that the RAN be clearly shown on the outside of the shipping package for prompt forwarding to the appropriate LeCroy department.

1. Contact your local LeCroy sales or service representative to obtain a Return Authorization Number.
2. Remove all accessories from the probe, including all removable cables.
3. Pack the probe in its case, surrounded by the original packing material (or equivalent).
4. Label the case with a tag containing:
   - The RAN
   - Name and address of owner
   - Instrument model and serial number
   - Description of the failure mode
5. Package the probe case in a cardboard shipping box with adequate padding to avoid damage in transit.
6. Mark the outside of the box with the shipping address given to you by the LeCroy representative; be sure to add the following:
   - ATTN: <RAN assigned by the LeCroy representative>
   - FRAGILE
7. Insure the item for the replacement cost of the probe.
8. Ship the package to the appropriate address.

REPLACEABLE PARTS LIST

Part No.	Description
AP022-PROBE-FRU	AP022 Probe Assembly, Exchange
AP022-PK022	AP022 Accessory Kit
AP022-CKT-BD-ADP	Circuit Board Adapter Kit, consisting of:
	probe ground sockets (2)
	probe single contact sockets (5)
554425003	screws (2), M 2.5x6, self tapping
7093XXP53	Frame, Front ProBus
AP022-IM-E	Instruction Manual, AP022

OPTIONAL ACCESSORY

Part No.	Description
AP022-BNC-ADP	AP022 Probe Tip to BNC (m) Adapter, unterminated

Performance Verification

Performance verification can be completed without removing the instrument covers or exposing the user to hazardous voltages. Adjustment should only be attempted if a parameter measured in the Performance Verification Procedure is outside of the specification limits.

Note

Adjustment should be performed only by qualified personnel. A Performance Verification Test Record is provided at the end of this section. It may be photocopied and used to record the test results.

TEST EQUIPMENT REQUIRED

The following test equipment and accessories are required for performance verification of the AP022 active probe. This procedure has been developed to minimize the number of calibrated test instruments required.

Only the parameters listed in **boldface** in the “Minimum Requirements” column of the following table must be calibrated to the accuracy indicated.

Because the input and output connector types may vary on different brands and models of test instruments, additional adapters or cables may be required.

Description	Minimum Requirements	Examples
Digital Oscilloscope	ProBus interface	LeCroy LT344 LeCroy LC584
Digital Multimeter (DMM) with test probe leads	4.5 digit **0.1% Basic DC Accuracy** **0.1% basic AC Accuracy**	HP 34401A Fluke 8842A
Sine Wave Signal Generator	Output Amplitude 10 Vp-p into 1 MΩ at 70 Hz	HP 33120A Stanford Research DS340
BNC coaxial cable	Male-male BNC, 50 Ω, 36 in.	Pomona 2249-C-36
Power Supply	0–12 V, settable to 10 mV	HP E3611A
BNC Tee connector	Male-to-dual female, BNC	Pomona 3285
Terminator, precision, BNC	50 Ω, ±0.05%	LeCroy TERM-CF01
Banana Plug adapter (2 ea.)	BNC female-to-dual male banana plug	Pomona 1269
Probe Tip Adapter	AP022-to-male BNC Unterminated	LeCroy AP022-BNC-ADP
Calibration Fixture	ProBus Extender	LeCroy ProBus – CF01

PRELIMINARY PROCEDURE

1. Connect the AP022 Active Probe to the female ProBus end of the ProBus Extension Cable. Connect the other end of the ProBus Extension Cable to Channel 1 of the oscilloscope.
2. Allow at least 20 minutes warm-up time for the AP022 and test equipment before performing the Verification Procedure.
3. Turn on the other test equipment and allow these to warm up for the time recommended by the manufacturer.
4. While the instruments are reaching operating temperature, make a photocopy of the Performance Verification Test Record (located at the end of this section), and fill in the necessary data.

The warranted characteristics of the AP022 active probe are valid at any temperature within the Environmental Characteristics indicated in this manual. However, some of the other test equipment used to verify the performance may have environmental limitations required in order to meet the accuracy requirements for the procedure. Be sure that the ambient conditions meet the requirements of all the test instruments used in the procedure.

VERIFICATION PROCEDURES

A. Output Zero

1. Select the channel to which the Probe is connected. Display this channel. Set the oscilloscope sensitivity to 20 mV/division.
2. Disconnect the ProBus Extender from the oscilloscope. Verify that the Display Scale Factor changes from 20 mV/div to 2mV/div.
3. Reconnect the ProBus Extender to the oscilloscope. Leave the probe tip open so that it is not connected to any other device.
4. Connect one end of a BNC cable to the female BNC connector on the probe end of the ProBus Extension Cable.

Connect the Precision 50 Ω Terminator to the other end of the BNC cable, as in Figure 8.

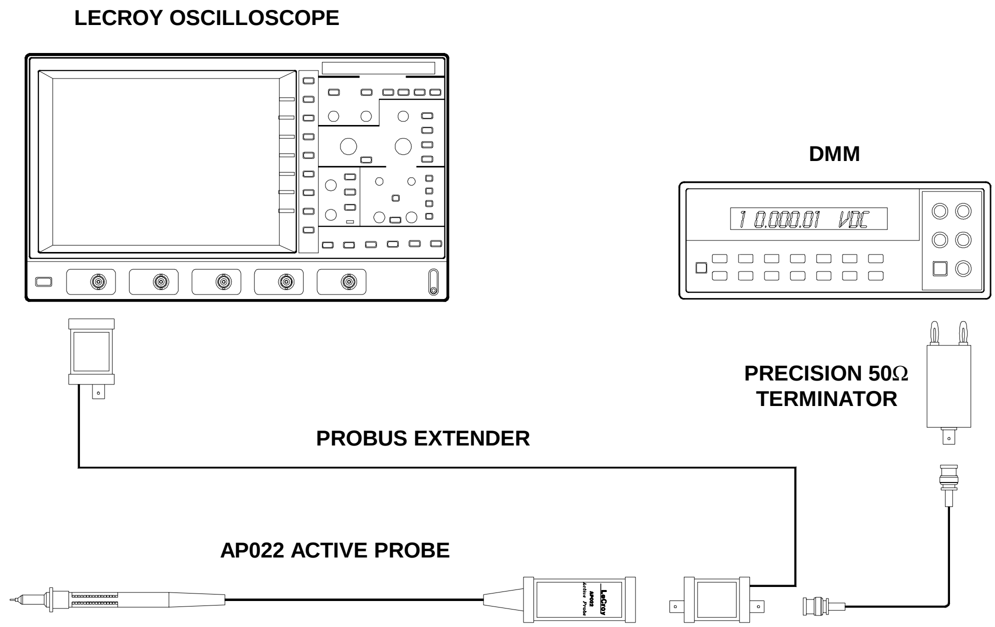

Figure 8. Test Setup for Verifying Output Zero.

5. Connect the banana plugs of the precision terminator to the input of the digital multimeter (DMM). Make sure the plug corresponding to the BNC shield (marked “Ground”) is connected to the **LO** or **COMMON** input of the DMM.
6. Set OFFSET on the oscilloscope to zero, as indicated by the on-screen display.
7. Set the DMM to read DC Volts on the most sensitive range.

8. Record the voltage measured on the DMM to 100 µV resolution as "Output Zero Voltage" in the Performance Verification test record.

9. Verify that the voltage indicated by the DMM is less than ±400 µV.

10. Leave the setup connections in place for the next section.

B. Offset Accuracy

1. Connect the Probe Tip adapter to a BNC tee adapter and a BNC-to-dual banana plug adapter, as shown in Figure 9.

Caution

Make sure that a non-terminated adapter is used. The power level used in this test would destroy the 50 Ω resistor in a terminated adapter.

2. Carefully insert the AP022 probe tip into the Probe Tip Adapter. Make sure the probe is fully seated into the adapter.

3. Set the power supply to approximately 0 volts.

4. Plug the dual banana plug adapter, with the probe attached, into the output terminals of the power supply. Make sure that the side of the banana plug corresponding to the probe and BNC ground is connected to the **positive** terminal of the power supply.

5. Attach a BNC cable to the unused port of the BNC tee. Attach a dual banana plug adapter to the other end of the cable and plug it into the DMM input, as shown in Figure 9. Make sure that the side of the banana plug corresponding to the BNC shield (marked "GROUND") is connected to the LOW or COMMON input of the DMM.

6. Adjust the power supply to an output of 10.0 V ±100 mV. Record the DMM reading, which should be a negative number, as "Power Supply Output Voltage" in the Performance Verification Test record. Record to 10 mV resolution.

7. To the “Power Supply Output Voltage” recorded in the previous step, add 10.00 V. (Do NOT adjust the power supply output.) Divide the resulting sum by 10. Record the answer to three significant figures in the Test Record, as “Expected Output Voltage.”

8. Remove the banana plug adapter from the DMM input and plug the 50 Ω terminator into the DMM input. Make sure that the display for channel 1 on the oscilloscope is turned on. Set the oscilloscope OFFSET knob to +10.00 V, as read on the oscilloscope display. Make sure that the side of the banana plug corresponding to the BNC shield (marked “Ground”) is connected to the LOW or COMMON input of the DMM.

9. Set the DMM to read DC Volts on the most sensitive range.

10. After the DMM has settled, record the reading to three significant digits of resolution, as “Measured Output Voltage” in the Test Record.

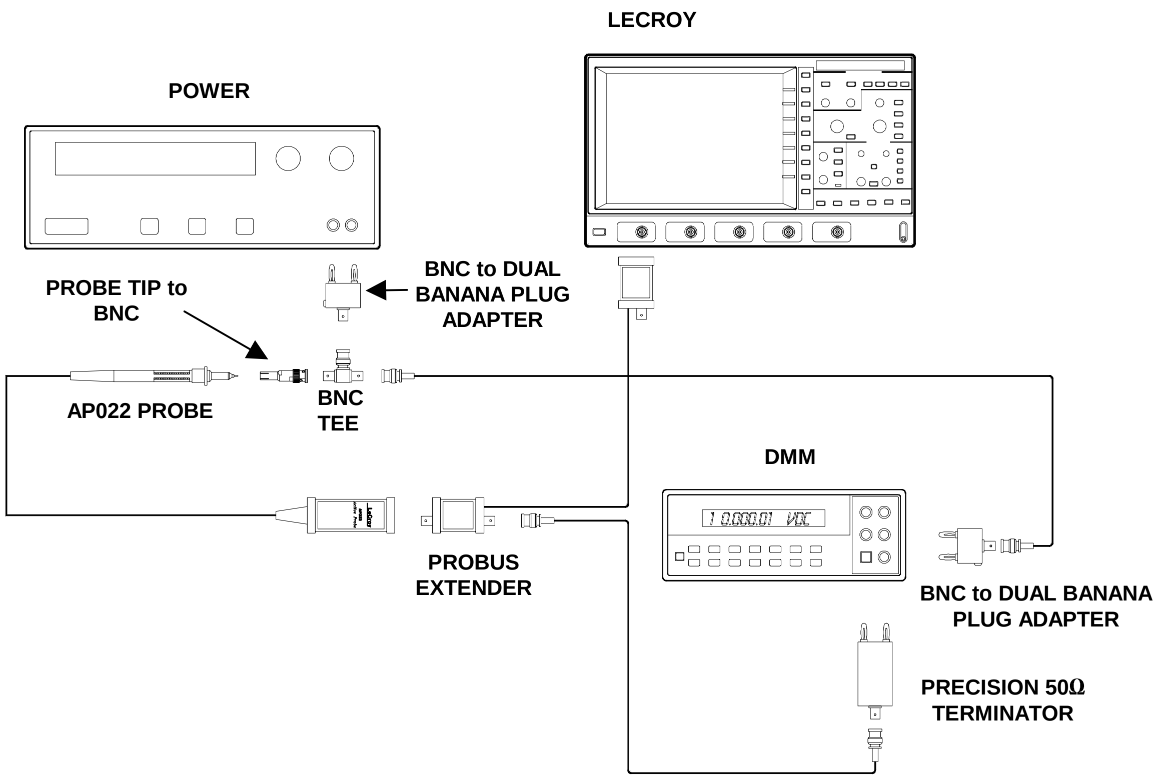

Figure 9. Test Setup for Verifying Offset Accuracy

11. Subtract the Measured Output Voltage, recorded in step B-10 from the Expected Output Voltage recorded in step B-7. Be sure to include the sign of each of the values in the calculation. Record the answer to three significant digits as “Offset Error Voltage” in the Test Record.

12. Verify that the Output Error Voltage is less than ±13.1 mV.

Note

The error term is derived from the Offset Accuracy specification of 1% + 1 mV. Using a 10.0-V offset setting, the maximum error would be 101 mV referred to the input, which becomes ±10.1 mV referred to the output (taking into account the ÷10 attenuation). Adding to the Output Zero specification of 3 mV, gives a final error limit of ±13.1mV.

13. Using the channel OFFSET knob on the oscilloscope, set the probe offset to 0 volts, as indicated in the on-screen display.
14. Remove the dual banana plug adapter with the AP022 probe tip from the power supply output terminals. Reverse the connector and install it in the terminals, with the plug corresponding to the probe (and BNC) ground connected to the **negative** or common output terminal.
15. Set the oscilloscope OFFSET knob to –10.00 V, as read on the oscilloscope display.
16. Subtract 10.00 from the measured power supply voltage recorded in step B-6. Divide the resulting difference by 10. Record the answer to three significant digits as “Expected Output Voltage” in the test record.
17. Record the DMM reading to three significant digits as “Measured Output Voltage” in the Test Record.
18. Subtract the Measured Output voltage recorded in step B-17 from the Expected Output Voltage recorded in step B-16. Be sure to include the signs of the values in the calculation. Record the answer, to three significant digits, as “Offset Error Voltage” in the Test Record. Verify that the output error is less than ±13.1 mV.
19. Return the oscilloscope offset to 0 V. Leave the setup connections for the next section.

C. DC Accuracy

Note

In order to eliminate the Output Zero error term, the DC Accuracy will be verified with a low frequency AC signal.

1. Disconnect the BNC tee at the power supply, from the dual banana plug-to-BNC adapter. Connect this tee to the output of the sine wave generator. Use a 50 Ω terminator if the sine wave generator requires such a load.
2. Set the DMM to read AC volts, and a range to measure 7 volts, if it does not have autoranging.
3. Set the mode of the signal generator to Sine Wave, the Frequency to 70 Hz, and the Output Amplitude to 7.0 V rms ±10 mV, as measured on the DMM.
4. Record the Generator Output Voltage to 1 mV resolution in the Performance Verification Test Record. Be careful not to alter the output amplitude after the reading is recorded.
5. Divide the reading recorded in step C-4 by 10 and record the result as “Expected Output Voltage, top range” to 100 μV resolution in the space provided in the Test Record.
6. Connect the banana plugs of the precision terminator to the input of the digital multimeter (DMM). Make sure the plug corresponding to the BNC shield (marked “Ground”) is connected to the **LOW** or **COMMON** input of the DMM.

Caution

Make sure that a non-terminated adapter is used. The power level used in this test would destroy the 50 Ω resistor in a terminated adapter.

7. After the DMM reading has stabilized, record in the Test Record the Measured Output Voltage, to 100 μV resolution.
8. Calculate the error by dividing the measured output voltage recorded in step C-7 by the expected top range output

voltage recorded in step C-5. Subtract 1 from this ratio and multiply by 100 to get the percentage error.

$$\%Error = \left(1 - \frac{Measured\ Output\ Voltage}{Expected\ Output\ Voltage} - 1\right) \times 100$$

9. Record the calculated error to two decimal places (±0.xx%) in the Test Record, as “Gain Error, top range”. Verify that the top range gain error is less than ±0.5%.
10. Unplug the precision terminator from the DMM. Keep the terminator attached to the BNC cable.
11. Insert the banana plug end of the BNC cable, from the BNC tee at the sine wave generator output, into the DMM input. Make sure that the side of the plug corresponding to the BNC shield (marked “Ground”) is connected to the **LOW** or **COMMON** input of the DMM.
12. Adjust the sine wave generator Output Amplitude to approximately 3.5 Vrms, as measured on the DMM.
13. Record the Generator Output Voltage to 1 mV resolution in the Test Record. Be careful not to alter the output amplitude after the reading is recorded.
14. Divide the reading recorded in step C-13 by 10, and record the result to 100 µV resolution as “Expected Output Voltage, mid-range” in the Test Record.
15. Remove the BNC-to-banana plug adapter from the DMM input. Plug the precision terminator into the DMM input. Make sure the plug corresponding to the BNC shield (marked “Ground”) is connected to the **LOW** or **COMMON** input of the DMM.
16. After the DMM reading has stabilized, record the Measured Output Voltage to 100 µV resolution in the Test Record.
17. Calculate the error by dividing the Measured Output Voltage recorded in step C-16 by the Expected Output Voltage, mid range recorded in step C-14. Subtract 1 from this ratio, and multiply by 100 to get the percentage error.

$$\%Error = \left(\frac{Measured\ Output\ Voltage}{Expected\ Output\ Voltage} - 1 \right) \times 100$$

18. Record the calculated error to two decimal places (±0.xx%), as “Gain Error, mid-range” in the Test Record.
19. Verify that the mid-range gain error is less than ±0.5%.

This completes the Performance Verification of the AP022. Complete and file the results recorded in the AP022 Performance Verification Test Record as required by your quality procedures. Apply suitable calibration label to the AP022 housing as required.

# # #

AP022 PERFORMANCE VERIFICATION TEST RECORD

This record can be used to record the results of measurements made during the performance verification of the AP022 Active Probe.

Photocopy this page and record the results on the copy. File the completed record as required by applicable internal quality procedures.

The section in the test record corresponds to the parameters tested in the performance verification procedure. The numbers preceding the individual data records correspond to the steps in the procedure that require the recording of data. Intermediate data used to arrive at the final specification check are to be recorded in the "Intermediate Data" column.

Results recorded in the column at the right are to be compared with the specification, which is indicated in parentheses to the left of the recorded number.

Permission is granted to reproduce these pages for the purpose of recording test results.

Model: ___________AP022__________

Serial Number: ____________________________

Asset or Tracking Number: ____________________________

Date: ____________________________

Technician: ____________________________

EQUIPMENT USED:

	MODEL	SERIAL NUMBER	CALIBRATION DUE DATE
DIGITAL MULTIMETER			

Notes: ____

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AP022 PERFORMANCE VERIFICATION TEST RECORD

Step	Description	Intermediate Data	Test Result
A-8	Output Zero Voltage (Test limit ≤ ±3 mVdc		________________mV
Offset Accuracy			
B-6	Power Supply Output Voltage	__________________V	
B-7	Expected Output Voltage	________________ mV	
B-10	Measured Output Voltage	________________ mV	
B-11	**Offset Error Voltage** (Test Limit ≤ ±13.1 mV)		________________mV
B-16	Expected Output Voltage	________________ mV	
B-17	Measured Output Voltage	________________ mV	
B-18	**Offset Error Voltage** (Test Limit ≤ ±13.1 mV)		________________mV
DC Accuracy			
C-5	Generator Output Voltage	__________________V	
C-6	Expected Output Voltage, top range	________________ mV	
C-10	Measured Output Voltage	________________ mV	
C-12	**Gain Error, top range** (Test Limit ≤ ±0.5%)		_________________%
C-13	Generator Output Voltage	__________________V	
C-14	Expected Output Voltage, mid range	________________ mV	
C-16	Measured Output Voltage	________________ mV	
C-17	**Gain Error, mid-range** (Test Limit ≤ ±0.5%)		_________________%

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Adjustment Procedure

INTRODUCTION

This procedure should only be performed if the instrument fails to meet the Performance Check tests for Output Zero or Offset Accuracy (steps A and B). Gain, which affects DC Accuracy, cannot be adjusted during routine calibration. Probes that fail DC Accuracy during performance verification (step C) must be returned to the factory for rework. If the probe cannot be adjusted to meet the Performance Verification Limits, repair may be necessary.

To ensure instrument accuracy, check the calibration of the AP022 every 2000 hours or every year if used infrequently. Before calibration, thoroughly clean and inspect the unit as outlined in the Maintenance section.

To ensure that the probe will meet published specifications over the entire temperature range, adjustment must be performed in a controlled ambient environment with temperature of 23 ±5 °C.

TEST EQUIPMENT REQUIRED

The following test equipment and accessories, or their equivalents, are required for complete calibration. Specifications given for the test equipment are the minimum necessary for accurate calibration. All test equipment is assumed to be correctly calibrated and operating within the listed specifications. Detailed operating instructions for the test equipment are not given in this procedure. Refer to the test equipment manual if more information is needed.

If alternate test equipment is substituted, control settings or calibration equipment setups may need to be altered.

Test Equipment and Accessories		
Description	**Minimum Requirements**	**Examples**
Digital Oscilloscope	ProBus interface	LeCroy LT344 LeCroy LC584
Digital Multimeter (DMM) with test probe leads	4.5 digit **0.1% Basic DC Accuracy** **0.1% basic AC Accuracy**	HP 34401A Fluke 8842A
BNC coaxial cable	Male-male BNC, 50 Ω, 36 in.	Pomona 2249-C-36
Power Supply	0–12 V, settable to 10 mV	HP E 3611A
Terminator, precision, BNC	50 Ω ±0.05%	LeCroy TERM-CF01
Banana Plug adapter, (2 required)	BNC female-to-dual male banana plug	Pomona 1269
Probe Tip Adapter	AP022-to-male BNC Unterminated	LeCroy AP022-BNC-ADP
Calibration Fixture	ProBus Extender	LeCroy ProBus – CF01

PRELIMINARY PROCEDURE

⚠ ***Caution***

Repair and adjustment should only be performed by a qualified service technician. Probe disassembly should only be attempted in a ESD protected work area. Exercise normal ESD control procedures when handling the probe circuit board.

- Remove the two screws that secure the plastic cover on the cable end of the ProBus interface housing. Gently pull on the probe cable to slide the circuit board assembly from the metal housing.
- Connect the AP022 Active Probe to the female end of the ProBus Extension Cable, being careful to line

up all six pins of the ProBus connector. Connect the male end of the ProBus extension cable to Channel 1 of the oscilloscope. (See Figure 8 in Performance Verification).

- Apply power to the oscilloscope and to the test equipment.
- Allow at least 30 minutes warm-up time for the AP022 and test equipment before starting the calibration procedure.

Note

Completion of each step in the Adjustment Procedure ensures that this instrument meets the electrical specifications. For best overall instrument performance when performing the adjustment procedure, make each adjustment to the exact setting, even when the adjustment is within the allowable calibration limits.

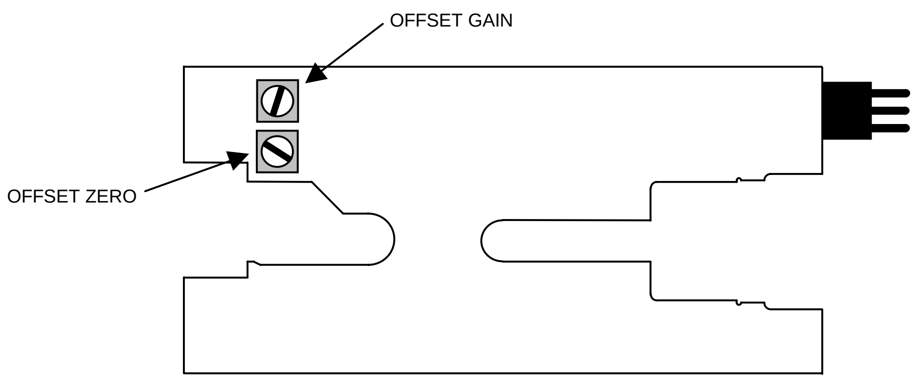

Figure 10. Adjustment Locations

ADJUSTMENT PROCEDURE

A. Adjust Offset Zero

1. Connect one end of a BNC cable to the probe end of the ProBus Extension Cable. Connect the Precision 50 Ω Terminator to the other end of the BNC cable, as shown in Figure 8.
2. Connect the banana plugs of the precision terminator to the input of the digital multimeter (DMM). Make sure that the plug corresponding to the BNC shield (marked “Ground”) is connected to the **LO** or **COMMON** input of the DMM.
3. Select the channel to which the probe and ProBus Extender is connected. Set OFFSET on the oscilloscope to zero, as indicated by on-screen display.
4. Set the DMM to read DC Volts on the most sensitive range.
5. Make sure that the probe tip input of the AP022 is open.
6. Adjust the **OFFSET** trimmer on the AP022 board until the DMM reads 0 V ±100 µV. (See Figure 10 for location)
7. Leave the setup connections in place for the next section.

B. Adjust Offset Gain

1. Connect the Probe Tip adapter to a BNC tee and a BNC-to-dual banana plug adapter, as shown in Figure 9 in the Performance Verification Procedure.

Caution

Make sure that a non-terminated adapter is used. The power level used in this test would destroy the 50 Ω resistor in a terminated adapter.

2. Carefully insert the AP022 probe tip into the Probe Tip Adapter. Make sure that the probe is fully seated in the adapter.
3. Set the power supply to approximately 0 volts.

4. Plug the dual banana plug adapter, with the probe attached, into the output terminals of the power supply. Make sure the side of the banana plug corresponding to the probe and BNC ground is connected to the negative, or common terminal of the power supply.
5. Attach a BNC cable to the unused port of the BNC tee. Attach a dual banana plug adapter to the other end of the cable and plug it in to the DMM input, as shown in Figure 9. Make sure that the side of the banana plug corresponding to the BNC shield (marked "GROUND") is connected to the LOW or COMMON input of the DMM.
6. Adjust the power supply to an output of 10.00 V ±10 mV. Record the DMM reading.
7. Remove the banana plug adapter from the DMM and plug the precision 50 Ω terminator into the DMM input. Make sure that the side of the banana plug corresponding to the BNC shield (marked "Ground") is connected to the LOW or COMMON input of the DMM.
8. Make sure that the display for channel 1 on the oscilloscope is turned on. Set the oscilloscope **OFFSET** knob to –10.00V, as read on the oscilloscope display.
9. Set the DMM to read DC Volts on the most sensitive range.
10. Subtract 10.0 V from the power supply output recorded in step B-6. Be sure to keep track of the sign of the result.
11. Adjust the **GAIN** trimmer on the AP022 board until the DMM reads the same voltage (±2 mV) as calculated in step B-10 above. Be sure the sign agrees.
12. Repeat steps A-3 through A-7 of the ADJUST OFFSET procedure (above).
13. Disconnect the probe from the ProBus extension cable and reinstall the circuit board in the probe case, being careful to align the ProBus interface connector with the opening on the other end of the case.

C. Verify Calibration

Use the Performance Verification procedure to ensure that the probe meets accuracy specifications. Apply a calibration seal, if required, in accordance with your quality process.

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