Performance Verification

This procedure can be used to verify the warranted characteristics of the AP033 Active Differential Probe.

The recommended calibration interval for the model AP033 Active Differential Probe is one year. The complete performance verification procedure should be performed as the first step of annual calibration. You can record test results on a photocopy of the Test Record provided in the Appendix at the end of this manual.

You can do the performance verification without removing the instrument covers, exposing yourself to hazardous voltages. Adjustment should only be attempted if a parameter measured in the Performance Verification Procedure is outside of the specified limits.

Adjustment should only be performed by qualified personnel. The Adjustment Procedure is contained in the AP033 Active Differential Probe Service Manual.

TEST EQUIPMENT REQUIRED

Table 3 lists the test equipment and accessories (or their equivalents) that are required for performance verification of the AP033 Active Differential 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 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.

TABLE 3
List of Required Equipment

Description	Minimum Requirements	Test Equipment Examples
Wide Band Oscilloscope [1]	Minimum **1 GHz bandwidth** 2 mV to 5 V scale factors ProBus interface equipped **2% vertical accuracy**	LeCroy Wavepro 950
Digital Multimeter	**DC: 0.1% accuracy** **AC: 0.2% accuracy** to measure 200 mV and 2 V rms @ 1 kHz 5½ digit resolution	Agilent Technologies 34401A Fluke 8842A-09 Keithley 2001
Function Generator	Sine Wave and Square Wave output waveforms 20 V_{p-p} into 1 MΩ 70 Hz to 10 MHz frequency range	Agilent Technologies 33120A,. Stanford Research Model DS340
Leveled Sine Wave Generator[2]	**Relative output level accurate to 3% flatness from 50 to 500 MHz and 50 kHz.** Output adjustable to 2 V_{p-p}	Tegam SG504 with TM series mainframe A high frequency sine wave generator calibrated using semi-automated software leveled with a power meter may be substituted.
Terminator, in-line, BNC	50 Ω ±2% coaxial termination	Pomona 4119-50
Terminator, precision, BNC	50 Ω ±0.2%	LeCroy TERM-CF01
Attenuator, BNC	50 Ω ±2%, ÷10 (20 dB)	Pomona 4108-20dB
Attenuator, BNC	50 Ω ± 2%, ÷2 (6 dB),	Pomona 4108-6dB
BNC coaxial cable (2 required)	male-male BNC, 50 Ω, 36 in.	Pomona 5697-36
Calibration Fixture	ProBus Extension Cable	LeCroy PROBUS-CF01
Calibration Fixture	AP033/AP034 Calibration Fixture	LeCroy AP03x-CF01
Banana Plug adapter	BNC female-to-banana plug	Pomona 1269

Notes

[1] If a LeCroy ProBus equipped oscilloscope is not available, you may use an alternate oscilloscope that meets the other minimum specifications listed, and the model ADPPS power supply, to perform the performance verification procedure. The input termination of the alternate oscilloscope must be set to 50 Ω, the offset or position must remain at center screen, and the high frequency adjustments must be performed with the ADPPS connected directly to the input of the oscilloscope.

[2] The high frequency sine wave generator must be calibrated for leveled output amplitude. In lieu of the SG504 leveled sine wave generator, you may use a standard generator by calibrating the output amplitude using a power meter and a software routine to store the table of leveling correction factors. To avoid errors resulting from standing wave reflections, the AP03X-CF01 Calibration Fixture should be attached directly to the output of the generator with suitable adapters. If physical constraints require you to use an additional cable, use the minimum length possible (6 in. or less). If a cable is required, it is essential that system calibration occurred with the cable installed.

PRELIMINARY PROCEDURE

1. Connect the AP033 Active Differential Probe to the female end of the ProBus Extension Cable. Connect the male end of the ProBus extension cable to Channel 1 of the oscilloscope.
2. Turn the oscilloscope on and allow at least a 30-minutes warm-up time for the AP033 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 in the Appendix at the end of this manual), and fill in the necessary data.

The warranted characteristics of the AP033 Active Differential Probe are valid at any temperature within the Environmental Characteristics listed in the Specifications. However, some of the other test equipment used to verify the performance may have environmental limitations required to meet the accuracy needed for the procedure. Make sure that the ambient conditions meet the requirements of all the test instruments used in this procedure.

PROCEDURE

Note

The operation of the controls of the AP033 may differ depending on which version of software is loaded in the LeCroy oscilloscope. In version 8.1.0 and higher, the offset controls on the front panel of the probe are disabled. The AP033 Offset is controlled by the ***OFFSET*** *knob in the oscilloscope CHANNEL section. In software versions 7.6.0 to 8.0.x, probe offset is controlled through one of the menu knobs while the "Coupling" menu is displayed.*

In versions 7.8.0 and higher, you have the option of selecting manual or automatic gain control. The oscilloscope defaults to AUTOMATIC mode. This procedure is best performed with the oscilloscope set to MANUAL gain control. Gain control can be selected in the "Coupling" menu for the channel to which the probe is connected.

You can find out the software version by pushing ***SHOW STATUS****, then selecting the* ***SYSTEM*** *menu option.*

A. Check Gain Accuracy

1. From the oscilloscope display, select the channel that the AP033 is connected to (channel 1), then select the "Coupling" menu. Set the **AP033 Atten/Gain** to **Manual**, the **Probe Gain** to **X1**, and the **Probe Atten** to **/1**. (**/1** is the same as **÷1**)

2. If necessary, set the probe offset to 0.000 V by rotating the OFFSET knob in the CHANNEL section of the oscilloscope or with the **Offset** knob in the “Coupling” menu (older software versions).
3. Using a BNC female-to-female adapter, 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.
4. Connect one end of a second BNC cable to the output of the Function Generator. Attach the BNC to dual male banana plug adapter to the free end of the second BNC cable. Insert the banana plugs of the adapter into the input terminals of the Digital Multimeter (DMM).
5. Set the DMM to measure AC Volts.
6. Set the mode of the Function Generator to Sine Wave; the frequency to approximately 1 kHz; and the output amplitude to approximately 200 mV, as measured by the DMM.
7. Record the measured amplitude to 100 µV resolution in the Test Record.
8. Unplug the output cable from the DMM. Remove the BNC to banana plug adapter from the end of the cable.
9. Autobalance the AP033 by pressing the **AUTOBALANCE** menu button located in the “Coupling” menu.
10. Carefully align the four pins that correspond to the **Differential Drive No Termination** portion of the AP03x-CF01 Calibration Fixture with the input receptacles in the AP033 probe head. Press the probe into the fixture to fully engage the pins.
11. Connect the banana plugs of the precision terminator to the input of the digital multimeter (DMM).
12. Connect the free end of the output cable from the Function Generator to the **Differential Drive No Termination** connector of the AP033/AP034 Calibration Fixture.
13. After the DMM reading has stabilized, record the measured output amplitude to 100 µV resolution in the Test Record.

14. Divide the measured output voltage recorded in step A-13 by the sine wave generator output voltage (probe input voltage) from step A-7. Subtract 1.0 from the ratio and multiply the result by 100 to get the error in percent.

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

15. Record the answer to two significant places (±x.xx%) on line A-15 in the Test Record.
16. Verify that the X1 gain error is less than ±2%.
17. In the oscilloscope's "Coupling" menu, change the **Probe Atten** to **/10** and the **Probe Gain** to **X10**.
18. After the DMM reading has stabilized, record the measured output amplitude to 100 µV resolution in the Test Record.
19. Divide the measured output voltage recorded in step A-18 by the sine wave generator output voltage (probe input voltage) from step A-7. Subtract 1.0 from the ratio and multiply the result by 100 to get the error in percent.

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

20. Record the answer to two significant places (±x.xx%) on line A-20 in the Test Record.
21. Verify that the X10 gain error is less than ±2%.
22. Divide the Sine Wave Generator output voltage recorded in step A-7 by 10. Record the result as "Expected Probe Output Voltage" in the Test Record.
23. In the oscilloscope's "Coupling" menu, return the **Probe Gain** to **X1**. Leave the **Probe Atten** set to **/10**.
24. After the DMM reading has stabilized, record the measured output amplitude to 10 µV resolution in the Test Record.
25. Calculate the error by dividing the measured output voltage recorded in step A-24 by the expected output voltage

recorded in step A-22. Subtract 1.0 from this ratio and multiply by 100 to get the error in percent.

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

26. Record the calculated error to two decimal places (±x.xx%) as '÷10 Gain Error' in the Test Record.
27. Verify that the ÷10 gain error is less than ±2%.
28. Disconnect both BNC cables from the test setup.

B. Check High Frequency Common Mode Rejection Ratio (CMRR)

Note

Common Mode Rejection Ratio (CMRR) is defined as the Differential Mode Gain divided by the Common Mode Gain (normalized inverse of the Common Mode response). At higher frequencies where the bandwidth of the amplifier begins to attenuate the differential mode signal, both the differential mode gain and common mode gain must be measured to derive the CMRR.

1. Disconnect the ProBus Extension cable from the AP033 Active Differential Probe and the oscilloscope. Reconnect the AP033 directly to the Channel 1 input of the oscilloscope.
2. Carefully move the AP033 probe head from the **Differential Drive No Termination** connector of the AP033/AP034 Calibration Fixture to the **Differential Drive 50 ohm Termination** connector. Make sure that the probe is fully engaged in the fixture.
3. In the oscilloscope Channel 1 COUPLING menu, set **Coupling** to **DC 1MΩ**, **Global BWL** to **Off**, AP033 Atten/Gain to **Manual**, Probe Atten to **/1**, and Probe Gain to **X1**. Autobalance the AP033 by pressing the **AUTOBALANCE** menu button twice. Set the oscilloscope trigger mode to **AUTO**.

4. If necessary, center the trace with the Probe Offset (channel OFFSET knob).
5. Connect the output of the leveled sine wave generator to the **Differential Drive 50 ohm Termination** connector of the AP033/AP034 Calibration Fixture. If using a model SG504 generator, insert a ÷2 50Ω BNC attenuator between the generator output and the test fixture input.
6. Set the leveled sine wave generator frequency to 50 kHz, and the amplitude to approximately 300 mV_{p-p}. When using a model SG504 generator, set the output to 0.6V pk-pk at the output which will correspond to 300 mV at the output of the ÷2 attenuator.
7. Set the oscilloscope vertical scale factor to 50 mV/div and the horizontal scale factor to 10 µsec/div. Set the Trigger source to Channel 1. Adjust the trigger level for a stable display. Turn on Math Channel A. Press **MATH SETUP**, then **REDEFINE A**. Set the A Math type to **Average**, Avg Type to **Continuous**, with **1:15** weighting, of channel 1. Turn off the trace 1 display.
8. Adjust the output amplitude of the leveled sine wave generator for a display of exactly 6 divisions (300 mV) peak to peak.
9. Change the leveled sine wave generator frequency to 250 MHz, taking care not to change the output amplitude.
10. Change the oscilloscope horizontal scale to 1 ns/div. In the **SETUP TIMEBASE** menu, select **RIS Sampling**. If necessary, turn the channel 1 display back on and adjust the trigger for a stable trace. Once a stable trace has been achieved, turn off the channel 1 trace to only display the averaged waveform.
11. Measure the peak-to-peak output amplitude of the AP033. Record the reading to two-digit resolution (xx0 mV) as 'Probe Output Voltage at 250 MHz' in the Test Record.
12. Divide the measured output amplitude recorded in step B-11 by 300 mV. Record the answer to two-digit resolution (0.xx) in the Test Record. This is the 'Differential Mode Gain at 250 MHz'.

13. Move the leveled sine wave generator output cable from the **Differential Drive 50 ohm Termination** connector of the AP033/AP034 Calibration Fixture to the channel 2 input of the oscilloscope.
14. Carefully move the AP033 probe head from the **Differential Drive 50 ohm Termination** connector of the AP033/AP034 Calibration Fixture to the **Common Mode Drive 50 ohm Termination** connector. Make sure the probe is fully engaged in the fixture.
15. Set the oscilloscope to display channel 2, channel 2 vertical scale to 0.5 Volt/div, channel 2 input coupling to DC50Ω, and trigger source to channel 2. If necessary, adjust the trigger level for a stable display.
16. Set the sine wave generator output amplitude to exactly 2 V_{p-p}. (4 divisions on the oscilloscope).
17. Remove the leveled sine wave generator output cable from the oscilloscope and reconnect it to the **Common Mode Drive 50 ohm Termination** input connector of the AP033/AP034 Calibration Fixture.
18. Set the oscilloscope to display Math channel A (Averaged AP033 Output), and trigger source to channel 1.
19. Increase the channel 1 vertical sensitivity as needed to view the signal.
20. Measure the peak to peak amplitude of the averaged waveform. This is the common mode signal.

Note

*The amplitude of the Common Mode signal should be relatively small. If the output waveform appears to be a 1-Volt square wave, verify that the **Common Mode Drive 50 ohm Termination** connector of the AP033/AP034 Calibration Fixture is being used, and not the **Differential Drive 50 ohm Termination** connector.*

21. Record the Common Mode signal amplitude to two-digit resolution (xx0 mV) in the Test Record as ‘Common Mode Signal at 250 MHz’.

22. Calculate the Common Mode Gain by dividing the Common Mode signal recorded in step B-21 (in mV) by 2,000 mV.

23. Record the result to two significant places as ‘Common Mode Gain at 250 MHz’ in the Test Record. (Keep all of the leading zeros or use scientific notation.)

24. Calculate the Common Mode Rejection Ratio (CMRR) at 200 MHz by dividing the Differential Mode Gain at 250 MHz as recorded in step B-12 by the Common Mode Gain recorded in step B-23.

25. Record the result as ‘Common Mode Rejection Ratio at 250 MHz’ in the Test Record.

26. Verify that the CMRR at 250 MHz is greater than 5:1 (14 dB).

27. Disconnect the output and frequency reference cables from the leveled sine wave generator.

C. Check Low Frequency CMRR

Note

The attenuation of the AP033 Active Differential Probe below 10 MHz is so insignificant that the Differential Mode Gain can be assumed to be unity (1.0).

1. Carefully move the AP033 probe head from the **Common Mode Drive 50 ohm Termination** connector of the AP033/AP034 Calibration Fixture to the **Common Mode Drive No Termination** connector. Make sure the probe is fully engaged in the fixture.

Note

Because greater amplitudes are required to measure the higher CMRR specifications at low frequencies, the Function Generator will be used in place of *the leveled sine wave generator for the low frequency CMRR test.*

2. Set the oscilloscope to display channel 2, channel 2 input coupling to DC1MΩ, channel 2 vertical scale to 1 Volt/div, horizontal scale to 5 ms/div, trigger source to channel 2. Set the BW limiting on channels 1 and 2 to 25 MHz.
3. In the oscilloscope Channel 1 COUPLING menu, verify the settings: Coupling to **DC 1MΩ**, Global BWL to **Off**, AP033 Atten/Gain to **Manual**, Probe Atten to **/1**, and Probe Gain to **X1**.
4. Attach a BNC cable from the output of the Function Generator to the BNC T adapter. Attach the BNC T adapter on the output connector of the Function Generator. Connect a BNC cable from one end of the BNC T adapter to channel 2 of the oscilloscope. Connect a second BNC cable from the remaining end of the BNC T adapter to the Common Mode Drive No Termination input connector of the AP033/AP034 Calibration Fixture.

Caution

*Make sure that you use the **Common Mode Drive No Termination** connection. Prolonged application of the power levels used in the low frequency common mode test may damage the termination resistance in either 50 ohm Termination input of the AP033/AP034 calibration fixture.*

5. Set the sine wave generator frequency to 70 Hz, output amplitude to 8 $V_{p\text{-}p}$, (eight divisions on the oscilloscope). If necessary, adjust the trigger level for a stable display.
6. Set the oscilloscope to display channel 1, but leave the trigger source set to channel 2. Set the vertical scale of channel 1 to 2 mV/div. Create a math waveform on channel A defined as the Average of channel 1. Set the average factor as necessary to reduce noise. Turn off the waveform display of all channels except Math A waveform.

7. Increase the zoom of Math waveform A as needed to measure the peak-to-peak amplitude. This is the common mode signal.
8. Record the displayed ‘Common Mode Signal at 70 Hz’ to two-digit resolution (0.xx mV) in the Test Record.
9. Calculate the Common Mode Rejection Ratio (CMRR) at 70 Hz by dividing 8,000 mV by the measured Common Mode Signal recorded in step C-8 (direct reciprocal of the Common Mode Gain). Record the result to two-digit resolution (xx,000 : 1) in the Test Record.
10. Verify that the Common Mode Rejection Ratio at 70 Hz is greater than 3,160:1 (70 dB).
11. Set the oscilloscope to display channel 2. Change the horizontal scale factor to 0.5 µs/division. Set the BWL on channels 1 and 2 to **200 MHz**.
12. Change the frequency of the Function Generator to 1 MHz.
13. Adjust the trigger level as necessary for a stable display. Adjust the Function Generator amplitude as needed to maintain 8.0V pk-pk as measured on channel 2.
14. Turn off the oscilloscope channel 2 display; turn on the display of channel 1 and Math waveform A (averaged channel 1). Adjust the scale factor of channel 1 and the Zoom of Math A as necessary to accurately measure the amplitude of the averaged waveform.
15. Record the displayed ‘Common Mode Signal at 1 MHz’ to two-digit resolution in the Test Record.
16. Calculate the Common Mode Rejection Ratio (CMRR) at 1 MHz by dividing 8,000 mV by the measured Common Mode Signal recorded in step C-22. Record the result in the Test Record.
17. Verify that the Common Mode Rejection Ratio at 1 MHz is greater than 1,000:1 (60 dB).
18. Remove all cables and test fixtures from the AP033 probe.

This concludes the Performance Verification of the AP033. Complete and file the results recorded in the AP033 Performance

Verification Test Record as required by your quality procedures. Apply a suitable calibration label to the AP033 housing as required.

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