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# **Instruction Manual**

## **LeCroy AP033**

### **Active Differential Probe**

DECEMBER, 2010

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# LeCroy

## Warranty

LeCroy warrants this oscilloscope accessory for normal use and operation within specifications for a period of one year from the date of shipment. Calibration after a yearly interval is recommended to ensure performance to specification. Spare parts, replacement parts and repairs are warranted for 30 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.

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# Overview

## DESCRIPTION

The AP033 is a wide band differential active probe. The probe features low noise, low input capacitance, high common mode rejection, and FET-buffered inputs in the probe head. User selectable attenuation and offset give the probe flexibility to measure a large range of signal amplitudes. Plug-on attenuator and AC coupling accessories further extend the application range. Interconnect accessories included allow connection to surface mount and through-hole components with minimal signal degradation. The input receptacles in the probe head are compatible with standard 0.025 in. (0.635 mm) square pins. This provides a convenient low cost method of creating device characterization test fixtures.

The probe is powered directly from a LeCroy oscilloscope through the ProBus® interface. The ProBus interface also allows local control of the probe through the oscilloscope user interface and remote control through the interface buses, (GPIB, RS-232). The optional ADPPS power supply allows the AP033 to be used with other instruments such as spectrum analyzers, network analyzers, and oscilloscopes without ProBus interface.

## APPLICATIONS

The AP033 is ideal for acquiring high speed differential signals such as those found in disk drive read channels, differential LAN, video, etc. It can also be used with spectrum analyzers to acquire signals in some RF systems (for example, balanced IF mixers in hand held cellular telephones). The high impedance characteristics of both inputs allow the probe to be used as a FET probe to make single-ended measurements in digital systems without introducing a ground loop, as a conventional FET probe would.





## 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 should be followed 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.*

The following symbol may appear on the product:



### **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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## Safety Information

### OPERATOR SAFETY

The probe is intended to be used only with instruments that are connected to earth ground through the input BNC connector. When you are using it with the ADPPS Power Supply Adapter, make sure that the adapter is connected to a BNC connector that is grounded by the test instrument before you connect the probe inputs to the test circuit.

Do not use in wet or explosive atmospheres. Remove any contamination from the probe housing before you connect the probe inputs to any circuit. Make sure that the surface of the probe head is completely dry before connecting the inputs.

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

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

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## Operation



### Caution

*The input circuits in the AP033 incorporate components that protect the probe from damage resulting from electrostatic discharge (ESD). Keep in mind that this is an active probe, and it should be handled carefully to avoid damage. When using the AP033, you are advised to take precautions against potential instrument damage due to ESD.*

### CONNECTING THE PROBE TO THE TEST INSTRUMENT

When using the probe with a LeCroy Oscilloscope equipped with ProBus, attach the probe output connector to the oscilloscope input connector. The oscilloscope will recognize the probe, set the oscilloscope input termination to 50  $\Omega$ , and activate the probe control functions in the user interface.

To use the AP033 probe with instrumentation not equipped with a ProBus interface, it is necessary to use the Active Differential Probe Power Supply (ADPPS). Attach the ADPPS connector to the probe output connector. The output connector of the ADPPS is a standard male BNC which can be directly connected to the test instrument. If necessary, the output of the ADPPS can be interconnected with a 50  $\Omega$  coaxial cable. To minimize the effects of skin loss, this cable should be 1 m or less in length. The AP033 is designed to drive a 50- $\Omega$  load. The gain will be uncalibrated if the output is not correctly terminated. When using the AP033 with an instrument that has a high input impedance, place a 50- $\Omega$  BNC in-line terminator on the instrument input before attaching the ADPPS.

### CONNECTING THE PROBE TO THE TEST CIRCUIT

Two inputs and a ground connection are available at the probe tip to connect the probe to a circuit under test. For accurate measurements, both the + and - inputs must always be connected to the test circuit. The ground connection is optional.



## AP033 Active Probe

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Positive voltages applied to the + input relative to the – input will deflect the oscilloscope trace toward the top of the screen.

To maintain the high performance capability of the probe in measurement applications, be careful when connecting the probe to the test circuit. Increasing the parasitic capacitance or inductance in the input paths may introduce a “ring,” or slow down the rise time of fast signals. To minimize these effects, use the shortest length possible when connecting the probe to the circuit under test. Input leads that form a large loop area (even shielded coaxial cables) will pick up any radiated electromagnetic field that passes through the loop, and may introduce noise into the probe inputs. Because this signal will appear as a differential mode signal, the probe’s common mode rejection will not remove it. This effect can be greatly reduced by using short interconnection leads, and twisting them together to minimize the loop area.

High common mode rejection requires precise matching of the relative gain or attenuation in the + and – input signal paths. Mismatches in additional parasitic capacitance, inductance, delay and source impedance difference between the + and – signal paths will lower the common mode rejection ratio. Therefore it is desirable to use the same length and type of wire and connectors for both input connections. When possible, try to connect the inputs to points in the circuit with approximately the same source impedance.

If you desire AC coupling, install the AC coupling accessory on the probe tip before connecting it to the test circuit. The low frequency cut off (-3 dB point) of the AC coupler is approximately 16 Hz.

If the voltage in the test circuit requires more than  $\pm 10$  attenuation, add the external  $\pm 10$  attenuator to the probe tip. If you are using both the external attenuator and AC coupler, install the attenuator on the probe tip first, and then install the AC coupler on the attenuator input.

In addition to being compatible with the lead set included, the probe input connectors will mate with standard 0.025 in. (0.635 mm) square pins in any rotational orientation. To avoid damaging the input connectors, do not attempt to insert

connectors or wires with a diameter larger than 0.036 in. (0.91 mm). Avoid rotating square pins after they are inserted into the input connectors.

The accessories included simplify the task of connecting the probe to the test circuit:

- Use the small (0.5 mm) mini-clips with the flexible lead set when probing fine pitch surface mount IC leads.
- You can use the larger (0.8 mm) mini-clips to probe through-hole leaded components.
- You can use the offset round pins for hand-held probing applications. Reposition the pins by rotating them to obtain the required spacing.

## PROBE INPUT LOADING

Attaching any probe to a test circuit will add some loading. In most applications, the high impedance of the AP033 imparts an insignificant load to the test circuit. However, at very high frequencies, the capacitive reactance of the probe's input capacitance may load the circuit enough to affect the accuracy of the measurement. The equivalence model of the probe input circuits is shown in Figure 1.

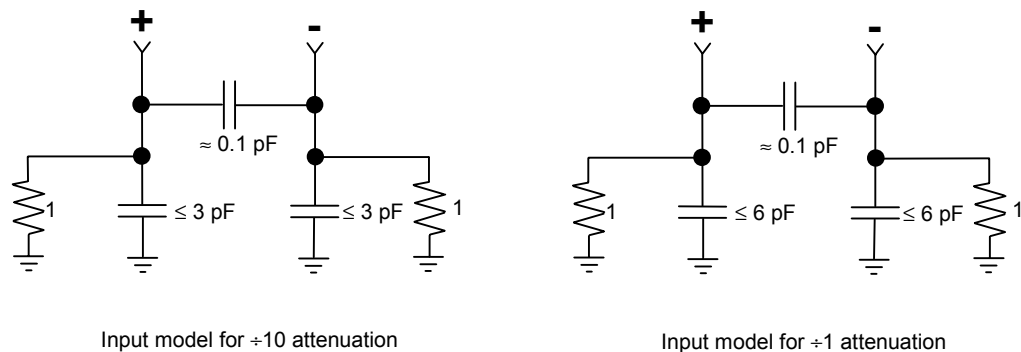


Figure 1. AP033 Equivalent Input Model



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### GROUNDING THE PROBE

You can use the single lead and one of the larger (0.8 mm) mini-clips to ground the probe to the test circuit. Insert the pin end of the lead into the receptacle marked:  $\perp$

#### **Note**

*Do not use the attenuator encoding receptacle (unmarked socket near the “-” input) to ground the probe. Connection to the encoding receptacle will not provide adequate grounding and may result in an incorrect effective gain indication.*

In many cases it is not necessary to ground the probe to the circuit under test. However, if the test circuit is isolated from earth ground, it is usually necessary to connect the probe ground to a point in the circuit. Grounding test circuits that are referenced to earth ground may improve the fidelity of high frequency components in the waveforms. The potential for improvement with grounding will vary depending on the common mode source impedance. However, connecting the probe ground to a circuit that is referenced to earth ground can create a ground loop that may add noise to low amplitude signals. The rejection of high frequency common mode signals is improved when the probe head is not grounded.

The best recommendation for connecting or not connecting the probe ground is to try both configurations and select the one that performs the best.

#### **Note**

*The AP033 transmits the measured signal differentially through the probe cable. This essentially eliminates signal degradation from ground loop effects within the probe. However, creating a ground loop may introduce signal distortions in the test circuit itself, or in any coaxial cable between the ADPPS power supply and the test instrument.*

## SELECTING THE PROPER RANGE

The AP033 has two independent controls that set the common mode range and equivalent volts/division. The probe gain can be set to x1 or x10. The gain control (GAIN) only affects the differential mode range of the probe. A separate input attenuation control (ATTEN) sets the probe input attenuator to either  $\div 1$  or  $\div 10$ . See Figure 2.

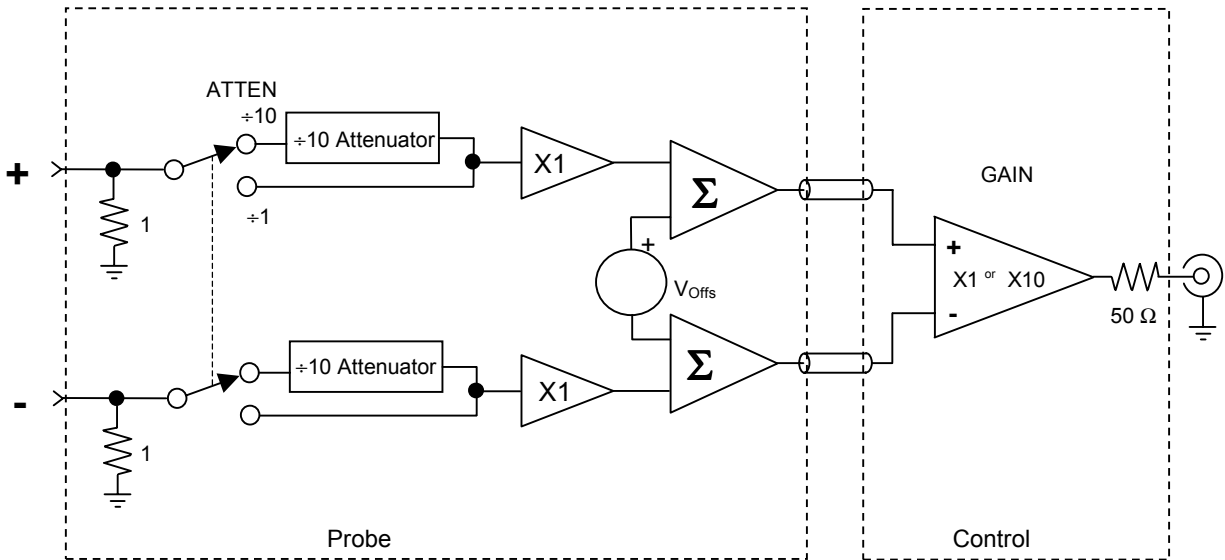


Figure 2. AP033 Block Diagram

The attenuator is located at the probe input and, therefore, affects both the differential mode and common mode ranges. (Refer to the Reference Section for definitions of Common Mode and Differential Mode.) By using the plug-on attenuator, you can extend the attenuation range to  $\div 100$ . The maximum ranges are given in Table 1.





## AP033 Active Probe

Table 1. AP033 Dynamic ranges and input capacitance at different attenuator settings

	<b>÷1 Attenuation</b>	<b>÷10 Attenuation</b>	<b>÷100 Attenuation</b>
Common Mode Range	±4.2 V	±42 V	±42 V
Differential Mode Range with x1 Gain*	±400 mV	±4 V	±40 V
Differential Mode Range with x10 Gain*	±40 mV	±400 mV	±4 V
Input Capacitance, each side to ground	6.0 pF	3.0 pF	1.9 pF
Input Capacitance each side to ground, with AC Coupler	7.3 pF	4.3 pF	3.2 pF

\*Offset moves the center point of this range.

When you are using a differential probe or amplifier, be careful not to exceed the common mode range. Because the common mode signal is rejected by the probe, and not displayed, changes in the amplitude of the common mode component are not apparent. Exceeding the common mode range may introduce distortion into the AP033 output. To reduce the possibility of errors caused by exceeding the common mode range, the probe monitors the input voltage. If the common mode range is exceeded when the ÷1 input attenuator is selected, the probe will automatically switch to the ÷10 attenuator. If the voltage on either input exceeds 55 volts, both the ÷1 and ÷10 attenuator lights will alternately flash to alert the user to the over-range condition.

There are two combinations which result in x1 effective gain. A ÷10 attenuation with x10 gain results in higher common mode range and lower input capacitance, but it increases the noise referred to the input. Conversely, ÷1 attenuation with x1 gain reduces the noise at the expense of less common mode range and greater input capacitance.

Circuitry in the probe decodes the effective gain of the probe based on the settings of the gain, internal attenuation and the presence of the external attenuator. The resulting effective gain is displayed on the probe front panel.

## OPERATION WITH LECROY OSCILLOSCOPES

When the AP033 probe is connected to a LeCroy oscilloscope equipped with the ProBus interface, the displayed scale factor and measurement values will be adjusted to account for the effective gain of the probe.

When the AP033 probe is first connected to the oscilloscope, the following message will appear: "WARNING: Probe offset buttons are locked". This is to alert the user that offset control must be made through the oscilloscope, rather than through the buttons located on the probe. It does not indicate a failure in the probe or oscilloscope.

With oscilloscope software versions 7.6.0 and higher, the probe gain, internal attenuation, and offset can be conveniently controlled through the oscilloscope's user interface. The common mode range is also displayed. Manual control through the oscilloscope user interface can be found in the **COUPLING** menu of the channel to which the probe is connected. The appearance and functionality of the control menu has changed with incremental versions of the oscilloscope software. Refer to the section titled "Oscilloscope Software Compatibility" for additional information.

With software versions 8.1.0 and higher, there are two modes of gain control: Auto and Manual. The oscilloscope defaults to Auto mode when the probe is first attached. In Auto mode, the **VOLTS/DIV** knob controls the oscilloscope's scale factor, AP033 gain, and AP033 attenuation to give the full available dynamic range: 200  $\mu\text{V}/\text{div}$  to 1  $\text{V}/\text{div}$  (without external attenuator), or 2  $\text{mV}/\text{div}$  to 10  $\text{V}/\text{div}$  (with external  $\pm 10$  attenuator installed). Some of the transitions in scale factor will result in a change of the attenuation in the AP033 probe. The common mode range, input capacitance, and noise level of the probe will change with the probe attenuator setting. For Volts/Div settings which can be produced with more than one combination of probe gain and attenuation settings, Auto mode selects the combination which results in greater common mode range and lower input capacitance.

In some situations, you may wish to select probe settings optimized for the lowest noise performance with lower common mode range. Likewise, you may require that the probe not



## AP033 Active Probe

change input capacitance, noise, or common mode range as you change the VOLTS/DIV setting. These requirements can be met by setting the probe to Manual gain control mode. When set to Manual mode, the dynamic range of the **VOLTS/DIV** knob is limited to the scale factors that can be obtained without changing the AP033 gain or attenuation. Thus in Manual gain control mode, only the scale factor of the oscilloscope will be changed. In this mode, dedicated menu boxes are displayed for Probe Attenuation and Probe Gain. (Refer to Figure 3). The available values that appear in the Probe Atten menu box will change depending on the presence of the external attenuator. When the external  $\div 10$  attenuator is not installed,  $\div 10$  and  $\div 1$  will be displayed. With the external  $\div 10$  attenuator, only  $\times 100$  will be displayed.

In software versions 8.1.0 and higher, the channel OFFSET knob will control the probe offset, rather than the offset at the oscilloscope input. The OFFSET buttons on the probe body are disabled.

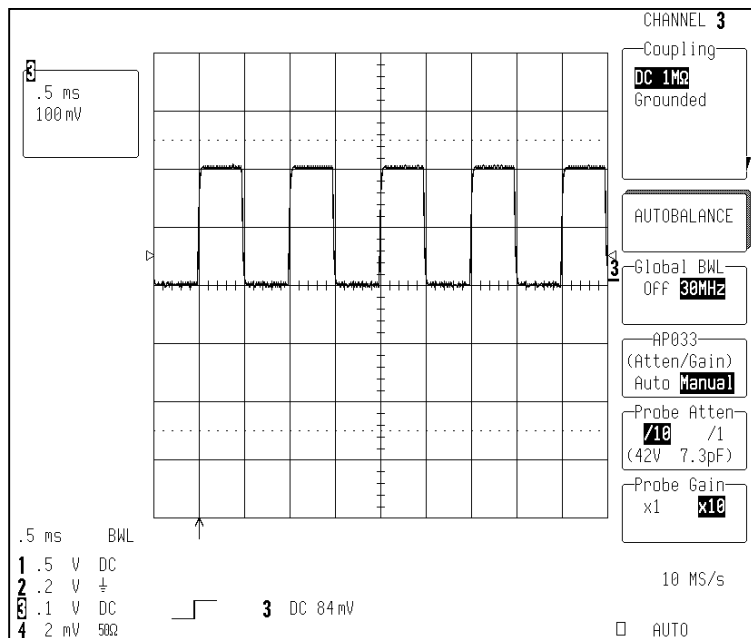


Figure 3. AP033 Probe Control Menu with V8.1.0 Software

The Coupling Menu refers to the probe input. The common mode dynamic range (CMDR) for the selected probe gain and attenuation settings are displayed in the Probe Attenuation menu. In some versions of software, the input capacitance from each input to ground is also displayed.

When using the AP033 with the ADPPS power supply on oscilloscopes without a ProBus interface, use Table 2 to select the desired effective volts per division scaling.

Table 2. Recommended AP033 and Oscilloscope settings to obtain desired equivalent Volts/Division

Equivalent Scale Factor	Oscilloscope Scale Factor	AP033 Attenuation	AP033 Gain	Common Mode Range	Differential Mode Range	Maximum Offset	Input Noise (nV/√Hz)
100 μV/Div	1 mV/Div	÷1	X10	±4.2 V	±40 mV	±400 mV	6
200 μV/Div	2 mV/Div	÷1	X10	±4.2 V	±40 mV	±400 mV	6
500 μV/Div	5 mV/Div	÷1	X10	±4.2 V	±40 mV	±400 mV	6
1 mV/Div	10 mV/Div	÷1	X10	±4.2 V	±40 mV	±400 mV	6
2 mV/Div	20 mV/Div	÷1	X10	±4.2 V	±40 mV	±400 mV	6
5 mV/Div	50 mV/Div	÷1	X10	±4.2 V	±40 mV	±400 mV	6
10 mV/Div	100 mV/Div	÷1	X10	±4.2 V	±40 mV	±400 mV	6
20 mV/Div	20 mV/Div	÷10	X10	±42 V	±400 mV	±4 V	60
50 mV/Div	50 mV/Div	÷10	X10	±42 V	±400 mV	±4 V	60
100 mV/Div	100 mV/Div	÷10	X10	±42 V	±400 mV	±4 V	60
200 mV/Div	20 mV/Div	÷10	X1	±42 V	±4 V	±4 V	115
500 mV/Div	50 mV/Div	÷10	X1	±42 V	±4 V	±4 V	115
1 V/Div	100 mV/Div	÷10	X1	±42 V	±4 V	±4 V	115
2 V/Div	20 mV/Div	÷100 <sup>1</sup>	X1	±42 V	±40 V	±40 V	1150
5 V/Div	50 mV/Div	÷100 <sup>1</sup>	X1	±42 V	±40 V	±40 V	1150
10 V/Div	100 mV/Div	÷100 <sup>1</sup>	X1	±42 V	±40 V	±40 V	1150

<sup>1</sup>÷100 attenuation obtained using the external ÷10 attenuator. The probe is automatically set to ÷10 internally when the external attenuator is installed. The internal ÷1 attenuator cannot be selected when the external ÷10 attenuator is installed.



## ADDING OFFSET

The AP033 has true differential offset capability. This allows you to remove a DC bias voltage from the differential input signal while maintaining DC coupling. By using probe offset rather than the “position” control on the oscilloscope, the full dynamic range of the probe remains centered around the offset level.

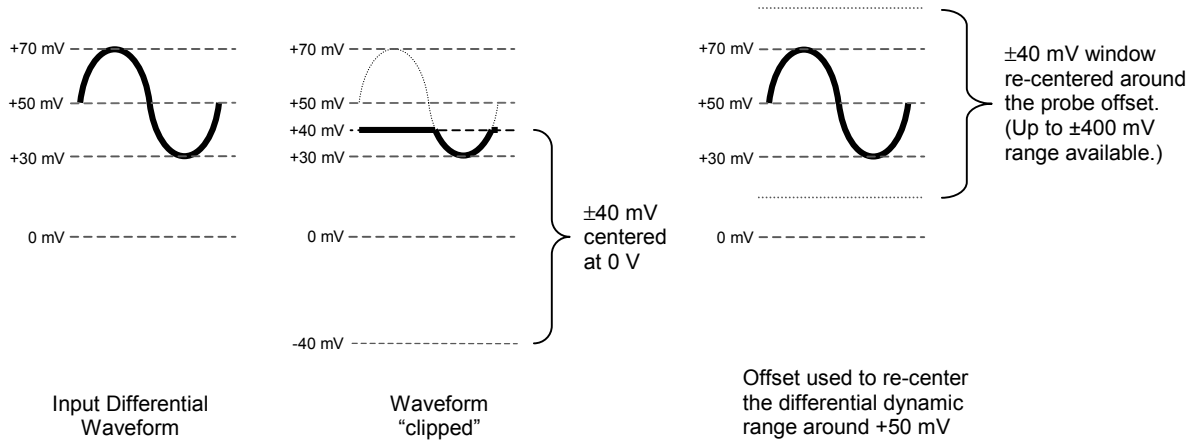


Figure 4. Effect of Differential Offset

When the AP033 is used with a LeCroy oscilloscope equipped with a ProBus interface and software versions 7.6.0 to 8.0.0, the probe offset must be controlled through either the Probe Offset menu selection in the COUPLING screen, or the buttons on the probe body. The channel OFFSET control does not change the probe offset and, therefore, should not be used.

When used with the ADPPS Power Supply on instruments that lack ProBus support, offset can be controlled with the buttons on the front panel. The offset can be returned to zero at any time by briefly pressing the  $\uparrow$  and  $\downarrow$  OFFSET buttons at the same time. Pressing and holding the  $\uparrow$  and  $\downarrow$  OFFSET buttons for more than two seconds will initiate an Autobalance cycle.

### AUTOBALANCE

The AP033 incorporates an Autobalance function to remove the DC offset from the output. Autobalance must be invoked by you. When power is first applied, the probe will return to the internal values resulting from the last Autobalance cycle. For Autobalance to function properly, all signals must be removed from the input.

After several minutes of warm up, or when the probe is exposed to a large shift in ambient temperature, some DC offset drift may occur from thermal effects in the amplifier circuitry. To initiate an Autobalance cycle, remove the probe from the test circuit and select **AUTOBALANCE** from the oscilloscope's **COUPLING** menu for the channel the probe is connected to. If the probe is being used with the ADPPS power supply, remove the input signal, and push and hold both the **OFFSET** buttons for two seconds. The AP033 output must be terminated into 50  $\Omega$  for successful Autobalance.

Upon successful completion of the Autobalance cycle, all four of the **EFFECTIVE GAIN** indicators will be briefly illuminated. If an input signal is present during auto balancing and the routine fails, the **EFFECTIVE GAIN** indicators will not illuminate. The probe will then revert to the offset values that resulted from the last successful completion of the Autobalance cycle. In many situations, this will be adequate to make routine measurements.



## DESIGNING TEST FIXTURES FOR THE AP033 PROBE

Often it is desirable to connect the probe directly to user-fabricated test fixtures, such as those used for semiconductor characterization. To facilitate use with custom test fixtures, the input receptacles of the AP033 probe are compatible with commercially available 0.025 in. (0.635 mm) square pins. The receptacles do not require a specific rotational alignment for the square pin. The dimensions listed below can be used as a layout guide for a test fixture circuit board. The recommended insertion depth of the pins is 0.100 in. (2.5 mm) to 0.200 in. (5.0 mm).

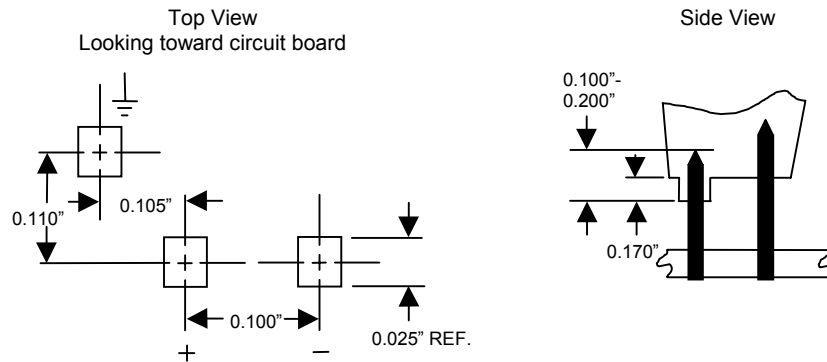


Figure 5. Layout dimensions for test fixtures

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# Reference Information

### DIFFERENTIAL MODE AND COMMON MODE

Differential probes amplify the voltage difference that appears between the + and – inputs. This voltage is referred to as the Differential Mode or Normal Mode voltage. The voltage component that is referenced to earth ground, and is identical on both inputs, is rejected by the amplifier. This voltage is referred to as the Common Mode voltage, because it is common to both inputs. The common mode voltage can be expressed as:

$$V_{CM} = \frac{V_{+Input} + V_{-Input}}{2}$$

### DIFFERENTIAL MODE RANGE AND COMMON MODE RANGE

The Differential Mode Range is the maximum signal that can be applied between the + and – inputs without overloading the probe amplifier, resulting in “clipping” or distortion of the waveform measured by the oscilloscope.

The Common Mode Range is the maximum voltage with respect to earth ground that can be applied to either input. Exceeding the common mode range can result in unpredictable results. Because the Common Mode signal is normally rejected and is not displayed on the oscilloscope, you need to be careful to avoid accidentally exceeding the common mode range.



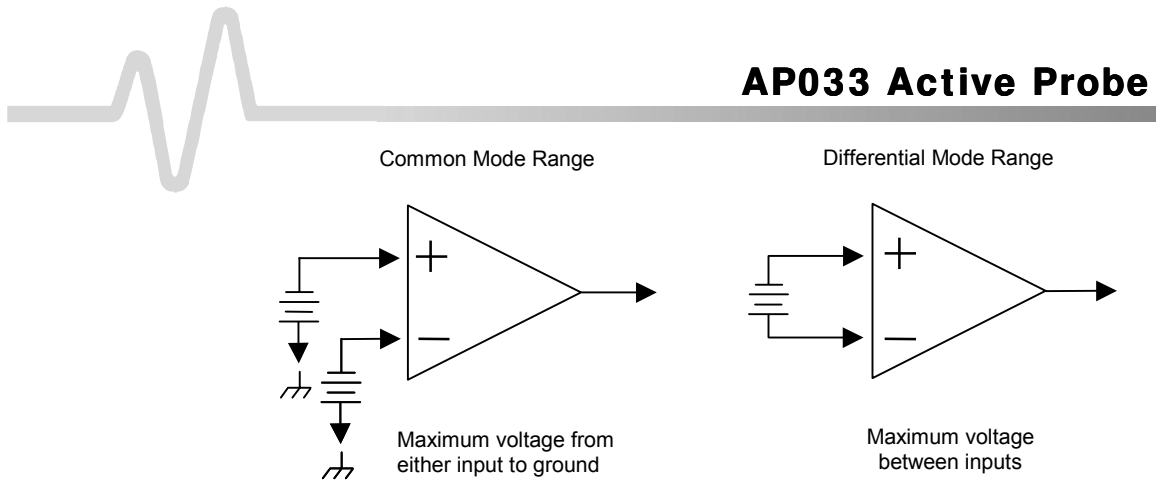


Figure 6. Common Mode and Differential Mode Range

## COMMON MODE REJECTION RATIO

The ideal differential probe or differential amplifier would amplify only the differential mode voltage component and reject all of the common mode voltage component. Real differential probes and amplifiers are less than ideal, so a small portion of the common mode voltage component appears in the output. Common Mode Rejection Ratio (CMRR) is the measure of how effectively the probe or amplifier rejects the common mode voltage component. CMRR is equal to the differential mode gain (or normal gain) divided by the common mode gain. Common mode gain is equal to the output voltage divided by the input voltage when both inputs are driven by only the common mode signal. CMRR can be expressed as a ratio (for example, 10,000:1) or implicitly in dB (for example, 80 dB). Higher numbers indicate greater rejection (better performance).

The first order term that determines the CMRR is the relative gain matching between the + and - input paths. To obtain high CMRR values, the input attenuators in a differential probe are precisely matched to each other. The matching includes the DC attenuation as well as the capacitance that determines the AC attenuation. As the frequency of the common mode components increases, the effects of stray parasitic capacitance and inductance in determining the AC attenuation become more pronounced. The CMRR becomes smaller as the frequency increases. Hence, CMRR is usually specified as a plot versus common mode frequency.

## Reference Information

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The common mode frequency in these plots is assumed to be sinusoidal. In real life applications, the common mode signal is seldom a pure sine wave. Signals with pulse wave shapes contain frequency components much higher than the repetition rate may suggest. As such, it is very difficult to predict actual performance in the application for CMRR versus frequency graphs. The practical application of these graphs is to compare the relative common mode rejection performance between different probes or amplifiers.

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