

User Manual

HVF0108

High-Voltage

Fiber Optically Isolated Probe

HVF0108 High-Voltage Fiber Optically Isolated Probe User Manual

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Safety

Follow these instructions to keep the probe operating in a correct and safe condition. Observe generally accepted safety procedures in addition to the precautions specified here. **The overall safety of any system incorporating this accessory is the responsibility of the system owner.**

Symbols

These symbols appear on the probe and accessories or in this manual to alert you to important safety considerations.

	DANGER, HIGH VOLTAGE. Risk of electric shock or burn.
	CAUTION of damage to probe or instrument, or WARNING of hazard to health. Attend to the accompanying information to protect against personal injury or damage. Do not proceed until conditions are fully understood and met.
	ESD CAUTION. Risk of Electrostatic Discharge (ESD) that can damage the probe or instrument if anti-static measures are not taken.
	Laser Safety WARNING.

Terms

The terms *isolated* and *electrically floating* are used to indicate measurements where there is no direct conduction path to earth ground.



General Safety Precautions

To avoid personal injury or damage to your equipment:

For use only by trained personnel. Not for use in households or by children.

Use only as specified. Using the probe and/or the equipment it is connected to in a manner other than specified may impair the protection mechanisms.

Before use, test the probe with a known source to ensure it is operating correctly.

Do not overload; observe all terminal ratings. Do not connect the probe to any circuit that exceeds the CAT, voltage or current ratings of the oscilloscope terminal, probe or probe-accessory combination.

Use only accessories compatible with the probe. Use only accessories that are rated for the application. Using accessories other than those shipped with the probe may create an electrical hazard.

Connect and disconnect properly. Connect the probe to the oscilloscope before connecting to the circuit being measured.

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Keep the probe body and output cable away from the circuits being measured. Only tips are intended for contact with electrical sources.

Do not excessively bend cables. Avoid tight radius bends, crushing, crimping, twisting or otherwise stressing the cables.

Do not remove the probe's casing. Touching exposed connections may result in electric shock.

Do not disassemble the probe body or remove inside parts. Refer all service to Teledyne LeCroy personnel.

Use only indoors and within the operational environment listed. Do not use in wet or explosive atmospheres.

Keep product surfaces clean and dry.

Do not use with damaged cables. Before each use, inspect cables for damage to the protective insulation.

Do not operate with suspected failures. Before each use, inspect the probe and accessories. If any part is damaged, cease operation immediately and sequester the probe from inadvertent use.



High Voltage Safety

The probe is not rated for hand-held use above 60 V_{DC} /30 V_{rms}. Do not handle probe tips, leads or any part of the transmitter at any time if there is any possibility >60 V_{DC} is present in the circuit. The plastic case of the transmitter and tip cable do not provide safe isolation.

Do not connect tip leads to an energized circuit. Always de-energize the circuit-under-test before installing or removing tip leads.

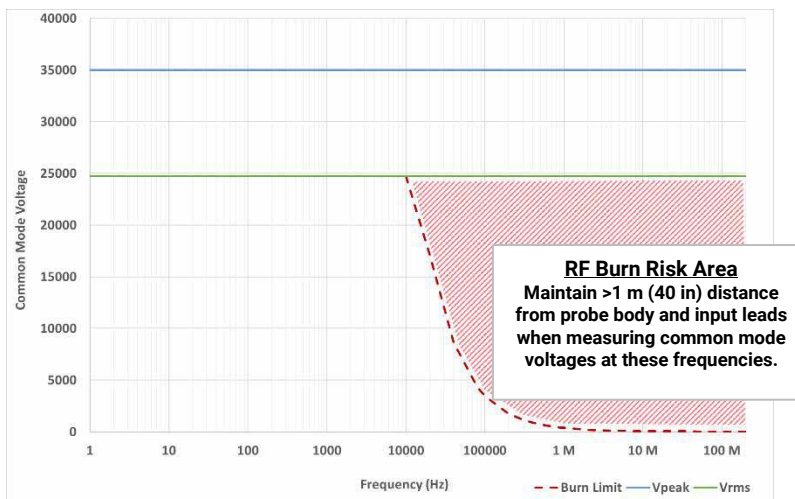
Beware when using with high-voltage or high-frequency signals. Read the manual thoroughly before use to understand how the probe and accessories are derated depending on use.



Clearance Requirements

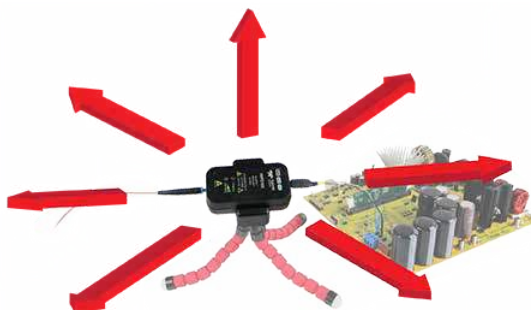
The unique common mode voltage range of the probe system allows it to be used in the presence of high-frequency/high-voltage common mode signals, but it is important to observe all precautions while using it.

WARNING: RF burns or electric shock can occur when using the HVF0108. The plastic case of the probe head and tip shields do not provide safe isolation from hazardous common mode voltages. Do not access the probe while measuring signals in the RF burn risk area.



Maximum safe handling limits for common mode voltages between the probe body and tip leads with respect to earth ground

WARNING: Maintain 1 m (~40 in) safe clearance of the probe transmitter and tip in all directions when connected to an energized circuit. Place the oscilloscope and any equipment you need to access at least 1 m away from the circuit and transmitter.





Laser Safety

LASER RADIATION
DO NOT EXPOSE USERS OF TELESCOPIC OPTICS

CLASS 1M LASER PRODUCT

WARNING: The HVFO108 probe contains laser sources, exposing which may cause laser burns. Do not remove any covers from the transmitter or receiver, or otherwise attempt to disassemble the probe.

Using controls, adjustments or procedures other than those specified in the product manual may result in hazardous radiation exposure.

The probe uses optical fibers within a single cable between the transmitter and receiver. Therefore, standard optical fiber handling practices are required. **Avoid tight radius bends, crushing, crimping, twisting or otherwise stressing the fiber-optic cable.**

Minimum cable radius bend is 65 mm; avoid making loops smaller than 4 in (10.2 cm).

Before each use, inspect the cable for damage such as tears and other defects.



Battery Precautions

To avoid personal injury or property damage due to explosion or fire, follow all warnings listed in [Appendix A: Battery Safety and Handling](#).

Safety Derating for Accessories

The measurement terminals of the probe as well as all accessories are to be used only for measurements on circuits not directly connected to the mains.



WARNING: The probe and its accessories are not rated for measurements within Measurement Categories (CAT) II, III or IV. The Measurement Category is the lower of the Measurement Categories of the probe or accessory. **Do not exceed the CAT, voltage or current rating of the lowest rated individual component.**

Accessory	Part Number	CAT Rating*	Max. Input Voltage Probe & Accessory (input to ground)
1x Attenuating Tip	HVFO100-1X-TIP-U	No Rated Measurement Category	±1 V (DC + Peak AC) (5 V maximum non-destruct)
5x Attenuating Tip	HVFO100-5X-TIP-U	No Rated Measurement Category	± 5 V (DC + Peak AC) (25 V maximum non-destruct)
10x Attenuating Tip	HVFO100-10X-TIP-U	No Rated Measurement Category	± 10 V (DC + Peak AC) (50 V maximum non-destruct)
20x Attenuating Tip	HVFO100-20X-TIP-U	No Rated Measurement Category	± 20 V (DC + Peak AC) (100 V maximum non-destruct)
40x Attenuating Tip	HVFO100-40X-TIP-U	No Rated Measurement Category	± 40 V (DC + Peak AC) (100 V maximum non-destruct)

* Per IEC/EN 61010-031:2015 definitions, No Rated Measurement Category applies to other circuits that are not directly connected to the mains supply.

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Safe Operating Environment

Temperature, Operating	10 °C to 40 °C
Temperature, Charging	0 °C to 40 °C
Temperature, Non-operating	20 °C to 70 °C
Relative Humidity, Operating	5% to 80% RH (non-condensing) up to 30 °C decreasing linearly to 45% RH at 50 °C
Relative Humidity, Non-operating	5% to 95% RH (non-condensing) 80% RH above 30 °C 45% RH above 50 °C
Altitude, Operating	3000 m (9842 ft.) maximum
Altitude, Non-Operating	10,000 m (32,807 ft.) maximum
Usage	Indoor Use Only
Pollution Degree	2. Per IEC/EN 61010-1:2010, this is an operating environment where normally only dry, non-conductive pollution occurs. Conductivity caused by temporary condensation should be expected.



The SAC-01 case and packaging materials shipped with the probe may not be suitable for certain ESD sensitive areas, such as EPAs (ESD Protected Areas). If this is a concern for your application, please take the necessary steps required for your test environment.

Introduction

The HVF0108 High Voltage Fiber Optically Isolated probe is an affordable, optimally designed probe for measurement of small signals floating on an HV bus in power electronics designs, or for EMC, EFT, ESD, and RF immunity testing sensor monitoring. It far surpasses the measurement capabilities and signal fidelity of conventional high-attenuation, high-voltage differential probes and acquisition systems that rely on galvanic channel-channel and channel-ground high-voltage isolation.

Key Features

- 150 MHz bandwidth
- 35 kV common-mode voltage rating (fiber optic isolation)
- Signal voltage measurement range from +/-1 V to +/-40 V with selectable tips
- Superior noise and rejection:
 - >100 dB common mode rejection ratio (CMRR)
 - Low loop inductance
 - Low attenuation
- Gain accuracy of 2.5% typical, 4% guaranteed
- ProBus interface with automatic scaling
- Auto Zero capabilities

Method of Operation

The low-attenuation tip makes a three-wire (Signal, Reference, and Shield) electrical connection to the device under test (DUT). The Signal connection wire is coaxial and attaches to the high side of the signal measurement. The Reference wire and Shield wires are non-coaxial and attach to the low side of the signal measurement. The Reference wire carries the signal return current, while the Shield wire carries the current that is associated with the stray parasitic capacitances.

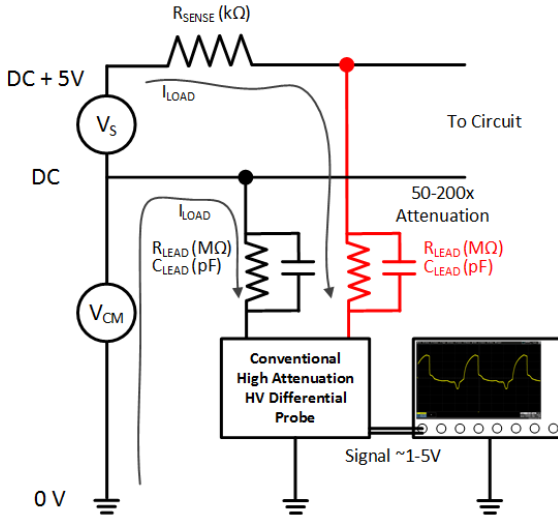
The output of the tip is input to the transmitter where an integrated, low-noise electrical amplifier amplifies the attenuated signal, which is then frequency modulated in optical form for transmission across the fiber optic cable. A subcarrier to the main modulation signal carries tip identifying information so that attenuation and voltage scaling can be communicated to the oscilloscope.

The receiver demodulates the fiber optic signal to an electrical signal for input to the oscilloscope. The subcarrier tip attenuation information is communicated through the oscilloscope ProBus interface for proper voltage scaling.

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Probe Design Compared to a Differential Probe

When properly used in its intended application, the HVFO108 will achieve much better results than a conventional, high-attenuation HV differential probe due to the dramatically different probe design.



Consider the case where a conventional, high-attenuation HV differential probe is connected in-circuit to measure a small signal floating on a HV DC bus (left).

The differential leads are connected across a sense resistor at a voltage V_S that is floating above ground by the DC bus common-mode (V_{CM}) voltage. The probe must use high attenuation to reduce the measured voltage ($V_{CM}+V_S$) to a low enough level to use safely with an oscilloscope.

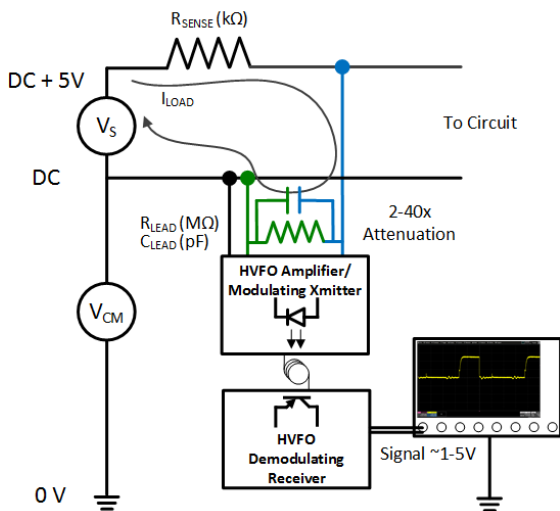
The two input leads are connected across the low voltage V_S , but due to the probe construction, these leads are actually measuring V_{CM} and ($V_{CM}+V_S$), and the difference between them is V_S .

The high V_{CM} value (typically 500 to 1000 V_{DC}) results in large current flows (based on the proportion of R_{LEAD} to R_{SENSE}) when R_{LEAD} is not $\gg R_{SENSE}$. These large current flows may load the circuit and inhibit proper DUT operation.

The input lead capacitance C_{LEAD} has a very high voltage (either V_{CM} or $V_{CM}+V_S$), which will result in a large capacitive charging current that will further load the DUT and likely affect the fidelity of the measured signal. These limitations are inherent in this design.

The high attenuation requires that the oscilloscope be operated in a very high sensitivity (small V/div) setting, which results in higher gain and more noise on the signal—often enough to make the measurement nearly unusable.

Since the probe is connected to ground, the common mode rejection ratio (CMRR, p.33) of the differential amplifier in the probe must be very good or else signal noise and interference will not be rejected and will add to measurement noise. High enough CMRR is difficult and costly to accomplish, since it requires very precise matching of the + and - probe input leads and excellent amplifier design.



Now, consider the advantages of the HVFO design in a circuit where the HVFO tip wires are connected only across V_S (left).

The V_{CM} has no impact on the loading of the circuit, since the $R_{LEAD} \gg R_{SENSE}$.

The small C_{LEAD} requires minimal charging current, since the voltage V_S is very low (volts, not hundreds of volts or kilovolts).

The tip attenuation is very low, so the signal is not being highly attenuated and then highly amplified by oscilloscope, which would result in higher noise.

The CMRR can easily be made very high, since there is no requirement to identically match a differential lead pair, and the high CMRR performance is inherent in the fiber

optic isolation from ground.

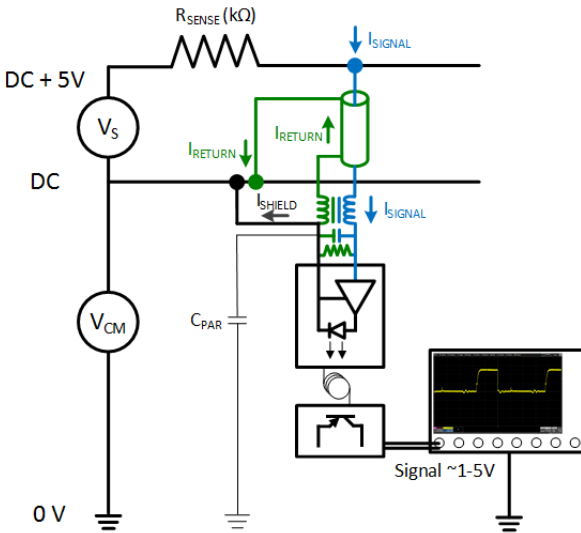
In the example above, the HVFO will perform better than a conventional, high-attenuation HV differential probe when some or all of the following are true:

- Common mode voltages (V_{CM}) are higher $-170V_{DC}$ or more.
- DUT impedance is lower.
- Signal rise times are faster (within the limitation of the probe bandwidth).
- Switched energy is higher.

It is unlikely that the HVFO108 will show much improvement on a very low voltage DC bus ($\sim 20V$) floating signal unless the rise time is very fast. However, with typical 120/240 V_{AC} supplied equipment (340-500 V_{DC} bus voltage), 600 V_{AC} class equipment (1000 V_{DC} bus voltage), or $\geq 5kV_{AC}$ class equipment, the advantages of the HVFO will be obvious, in most cases.

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Effect of Tip Design on Current Paths



The HVFO108 three-wire tip provides optimal measurement results by separating the signal return currents from the currents associated with the probe stray parasitic capacitance. This reduces the noise measured in the system and improves the CMRR performance of the probe.

The image at left shows how the tip construction affects the current paths.

The blue Signal wire conducts the Signal current, which follows a return path through the green Reference wire.

The green Reference wire is connected to the Signal coaxial outer conductor close to the Signal connection. This ensures that the Signal and Return currents are equal and opposite through the common-mode choke

(i.e., $I_{RETURN} = -I_{SIGNAL}$).

The black Shield wire connects to the same in-circuit location as the Reference wire, and then electrically connects to the tip at the internal shield of the transmitter. The current flowing through the Shield wire will drive the reference voltage for the single-ended amplifier, including the effects of any parasitic capacitance.

The HVFO108, by design, is not a differential probe, so the Signal and Reference wires are imbalanced in impedance. By using separate Reference (signal return) and Shield wires to carry currents, the probe segregates these currents to overcome any impact of impedance imbalance between the Signal and Reference wires. If only the Signal and Reference wires were connected (and not the Shield wire), the probe response at DC and high frequency would be unaffected, but the CMRR would be degraded. If only the Signal and Shield wires were connected (and not the Reference wire), the probe response at DC would be unaffected, but the high-frequency response would be degraded, and CMRR may also be degraded.



CAUTION: The Reference and the Shield wires are electrically connected inside the tip. Failure to connect them to the same measurement potential will damage the DUT and/or the HVFO108.

The common-mode capacitance (C_{PAR} in the drawing) is ~ 7 pF. This value is highly dependent on the probe position and could be larger if the transmitter is positioned close to the DUT ground. Note that the HVFO uses a dual-reference lead (as described earlier) that separates the common-mode current from the signal return current. This greatly reduces the effect of the ground current due to the common-mode capacitance and results in CMRR performance that is much better than would otherwise be expected for an ~ 7 pF common-mode capacitance.

Compatibility

Use only with compatible Teledyne LeCroy instruments running Windows 10 and 64-bit MAUI[®] firmware, v.9.2.x.x or higher. For a current list of compatible instruments, visit:

teledynelecroy.com/probes/high-voltage-fiber-optically-isolated-probes

In general, Teledyne LeCroy 12-bit High Definition Oscilloscopes (HDO) provide the most offset capability over the widest range of V/div settings.

Note: HVFO108 is not compatible with WaveSurfer Xs oscilloscopes, which only run up to 32-bit XstreamDSO 7.2.0.5. Contact Service for available oscilloscope upgrades.

Required Firmware Versions

Correct operation of the HVFO108 probe requires that the oscilloscope be installed with MAUI firmware version 9.2.x.x. or higher.

HVFO Probe System

HVFO108 Probe

The parts shown below are delivered standard with the HVFO108 in a soft carrying case.



The **amplifier/modulating transmitter** is a frequency modulating optical transmitter integrated with a high-performance electrical amplifier. The transmitter is battery-powered, so there is no direct connection from the floating DUT, providing HV isolation between the device under test (DUT) and the grounded oscilloscope. The battery is recharged through the same USB Micro-B interface used to connect the tip.

The **VersaLink (V-pin) 400/430 μm fiber optic cable assembly** has low loss and excellent transmission characteristics, helping to optimize the battery life of the transmitter. If the attenuation in the fiber optic cable is too high, or the cable is damaged and

not transmitting properly, the probe will provide a warning to the user. A 1-meter cable is supplied; additional 1- or 6-meter cables are available as optional accessories. The cable utilizes an Avago VersaLink connector, enabling it to be interchanged with low cost, off-the-shelf fiber optic cables. Cables longer than 6 meters may be sourced directly from the manufacturer (Industrial Fiber Optics, <http://www.i-fiberoptics.com/>), although HVFO108 accuracy specifications apply only to the cables shipped in the original box.

Note: If using a cable obtained from another vendor, perform the Performance Verification procedure and calibration (p.26) with the new cable connected prior to operating the probe.

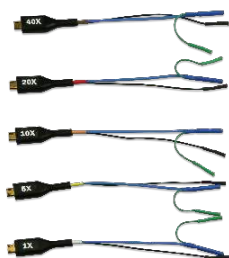
The **demodulating receiver** utilizes the ProBus interface to communicate tip attenuation value and proper voltage scaling to the oscilloscope. With the ProBus interface, the HVFO probe becomes an integral part of the measuring instrument. Power is provided to the receiver through the signal interface, so there is no need for a separate power supply or batteries.

Also included are a **USB-A – USB Micro-B cable** and **E-Z Micro-Grippers** (1 set of 3).

Attenuating Tips (one required)

Attenuating tips are sold separately from the probe itself, but at least one tip is required for proper functioning. Tips can be stored in a compartment in the soft carrying case.

Description	Part Number	Quantity
1x (+/-1 V) attenuating tip	HVFO100-1X-TIP-U	1
5x (+/-5 V) attenuating tip	HVFO100-5X-TIP-U	1
10x (+/-10 V) attenuating tip	HVFO100-10X-TIP-U	1
20x (+/-20 V) attenuating tip	HVFO100-20X-TIP-U	1
40x (+/-40 V) attenuating tip	HVFO100-40X-TIP-U	1



The **attenuating tip** makes a three-wire connection to the DUT, while the other end of the tip connects to the USB Micro-B input on the transmitter. Each tip communicates identifying information to the transmitter. The fixed attenuation determines the maximum voltage level that can be measured. All tips are interchangeable with any HVFO transmitter and do not require specialized calibration with a specific HVFO probe. The E-Z Micro-Grippers may be used with any of the tips.

Note: Tip selection is important to optimize for best noise performance. Using a tip with a wider dynamic voltage range than necessary will result in more noise.

HVFO108 Probe Specifications

For the current specifications, see the product datasheet at teledynelecroy.com. Specifications are subject to change without notice.

Performance

Bandwidth (probe + oscilloscope)	150 MHz typical
Risetime 10-90%	3.3 ns typical
Gain Accuracy	± 2.5% typical, 4% guaranteed
CMRR (typical, 1x tip attached)	140 dB @ 100 Hz 120 dB @ 100 Hz - 1 MHz 85 dB @ 1 - 10 MHz 60 dB @ 10 - 60 MHz 35 dB @ 150 MHz

Electrical Characteristics

Input Dynamic Voltage Range	
1x tip	± 1 V
5x tip	± 5 V
10x tip	± 10 V
20x tip	± 20 V
40x tip	± 40 V
Max. Common Mode Voltage (from either input to ground)	± 35 kV (DC + peak AC)
Max. Input Voltage to Earth (from either input to ground)	± 35 kV (DC + peak AC)
Max. Safe Input Voltage	30 V _{RMS} / 60 V _{DC} (hand-held)
Max. Non-destruct Voltage	Lower of 5X dynamic range or 100 V
Noise (probe only)	
1x tip	7 mVrms
5x tip	35 mVrms
10x tip	70 mVrms
20x tip	140 mVrms
40x tip	280 mVrms



WARNING: The probe is not intended for hand-held use above 60 V_{DC}. Always maintain adequate spacing between floating probe components and earth ground when measuring at high voltage in a stationary test setup.

Vertical Sensitivity

1x tip	10 mV/div – 1 V/div
5x tip	50 mV/div – 5 V/div
10x tip	100 mV/div – 10 V/div
20x tip	200 mV/div – 20 V/div
40x tip	400 mV/div – 40 V/div

Amplifier/Modulating Transmitter Battery

Charging Interface	USB Micro-B
Typical Life	> 6 hours
Recharge Time	
Oscilloscope USB port	5 hours
USB charger	2.5 hours
Cycle Life	> 500 cycles*

* For battery life > 5.5 hours.

Dimensions

Amplifier/Modulating Transmitter

Width	48 mm (1.89 in.)
Length	
Body only	90.2 mm (3.55 in.)
With leads attached	245 mm (9.65 in.)
Height	
Without feet	25 mm (0.98 in.)
With feet	27.5 mm (1.08 in.)

Attenuating Tips

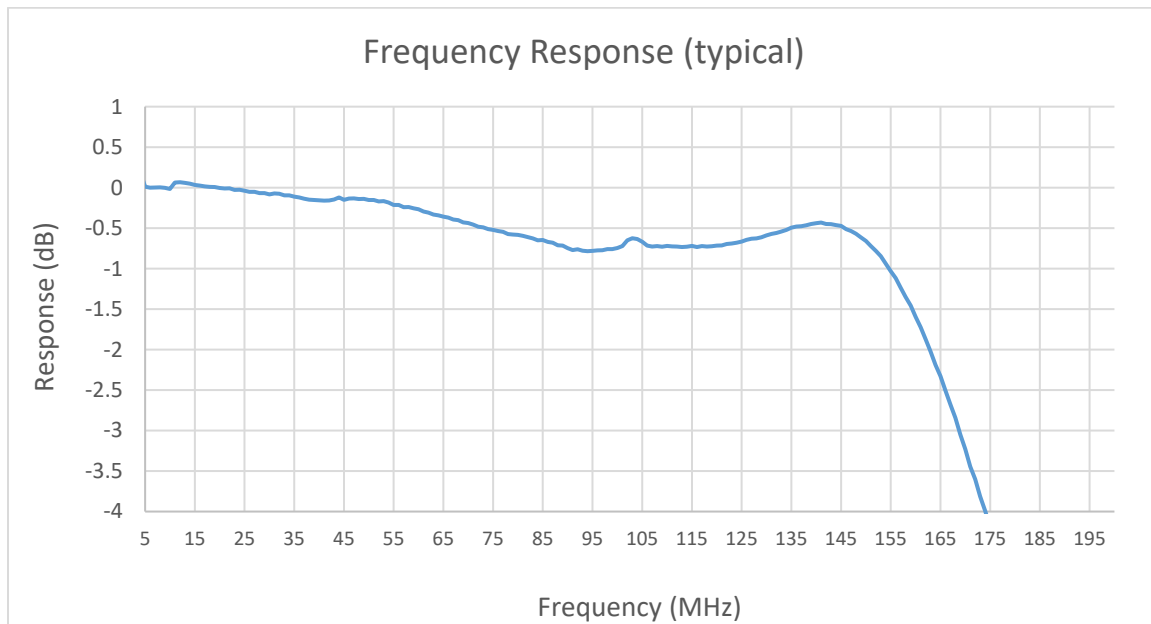
Insulated Socket Diameter	3 mm (0.12 in.)
Length Green REF Wire	8 cm (3.15 in.)
Overall Length	16 cm (6.3 in.)

Demodulating Receiver

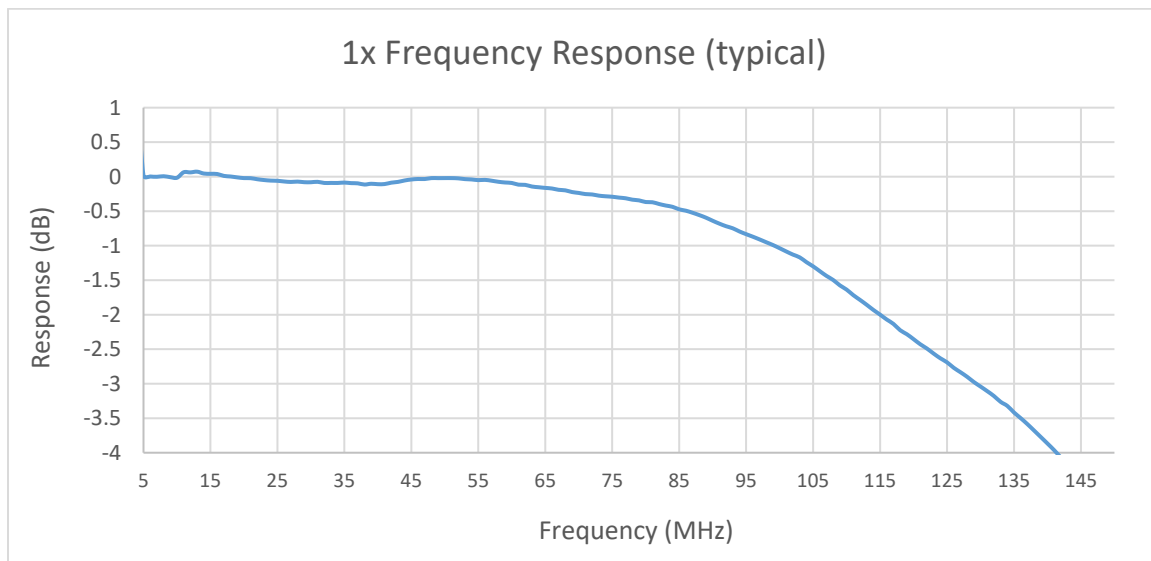
Width	39 mm (1.54 in.)
Length	95.9 mm (3.77 in.)
Height	23.6 mm (0.93 in.)

Bandwidth

Typical bandwidth of the HVFO108 using the 5x, 10x, 20x and 40x tips, averaged:



Typical bandwidth of the HVFO108 using the 1x attenuating tip:

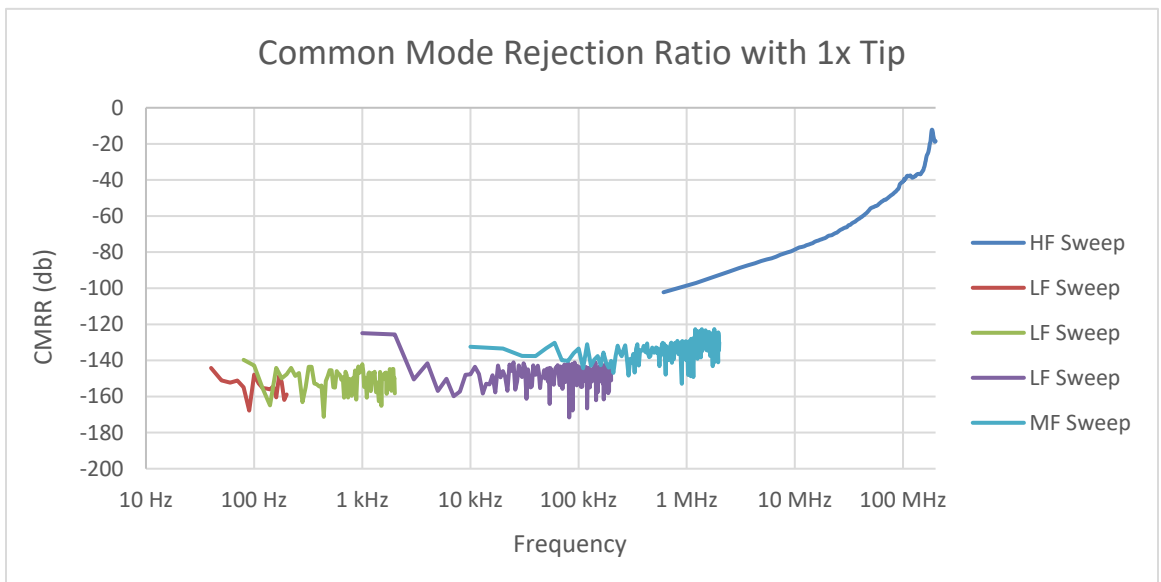


Common Mode Rejection Ratio

The performance shown in the graph below is typical performance with the 1x tip connected to the HVF0108 and the black Reference and blue Signal leads twisted together.

- The (LF Sweep) was measured with a low-bandwidth, high-voltage generator.
- The (MF Sweep) was measured with a dual stage low-bandwidth, high-voltage generator.
- The (HF Sweep) was measured with an external generator.

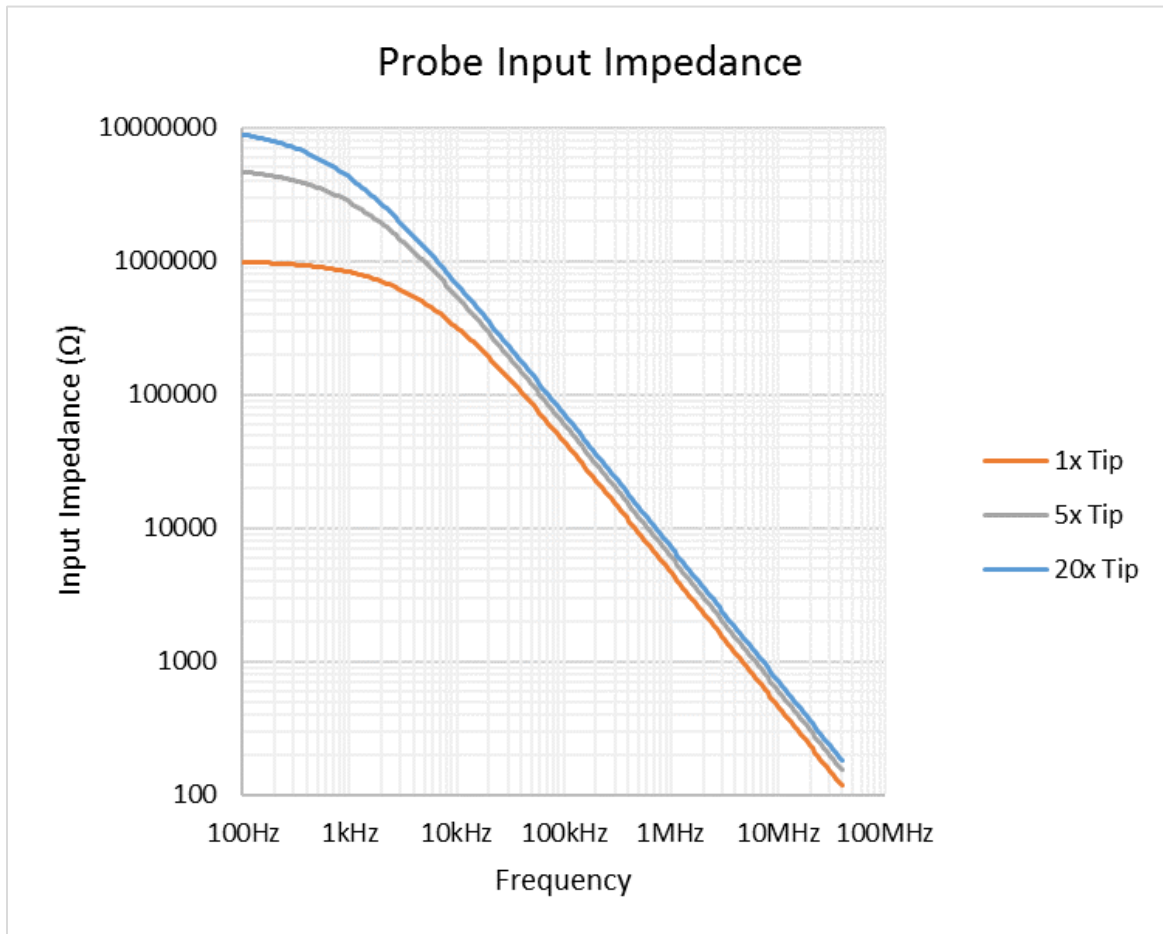
All discontinuities are due to a combination of noise floor limitations of the measurement device and amplification capabilities of the generators.



CMRR for the 5x, 20x and 40x tips can be expected to scale proportional to the tip attenuation ratios. For instance, for a 5x tip, the CMRR will be $20\log_{10}(5/1) = 14\text{dB}$ less than shown above (i.e., ~126 dB instead of 140 dB from 100 Hz to 100 kHz).

Input Impedance

Typical input impedance for the tips is described in the plot below. Input impedance for the 40X tip is the same as for the 20X tip. Input impedance for the 10X tip is $8\text{ M}\Omega // 23\text{ pF}$.



Operation

Note: Operating the probe requires firmware version 9.2.x.x or higher. To confirm the version, choose Utilities > Utilities Setup from the oscilloscope menu bar, then open the Status tab.

Assembling the Probe

To ready the HVFO probe for use:

1. Remove the protective covers from the fiber optic cable.
2. Connect the fiber optic cable to the receiver and transmitter. This requires a small amount of force. You will hear a “click” when it is inserted.



CAUTION: The minimum bend radius of the fiber optic cable is 65 mm.

3. Connect the tip to the USB Micro-B interface on the transmitter.
4. Press the demodulating receiver box onto the oscilloscope ProBus interface



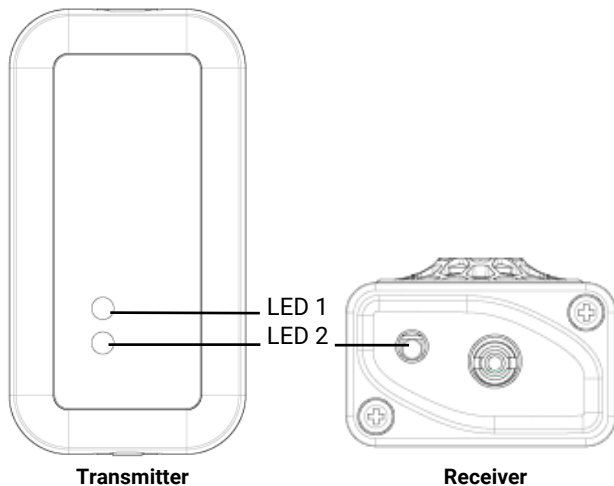
CAUTION: As soon as the tip is connected, it will turn on the transmitter and begin to consume power from the built-in battery, so do not leave it connected unless the probe is in use.







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LED Indicators

When the HVFO108 is consuming battery power, the LEDs will flash on both the transmitter and the receiver.



LED 1	Indicates
 Steady Amber	Battery Charging
LED 2	Indicates
Steady or flashing:  Green  Amber  Red	Operational/Battery Status See the CHnHVFO108 Probe dialog for battery status and operational state.

Connecting to the Test Circuit



WARNING: The HVF0108 uses fiber-optic isolation to permit the transmitter to float above ground without damaging the oscilloscope or harming the operator. **DO NOT touch the transmitter or leads while connected to a live circuit.** These components are only rated $30 V_{RMS}/60 V_{DC}$ for hand-held use, and serious harm will result if you touch them while they are floating above ground.

Connecting the Tips

For accurate measurements, connect all three inputs at the probe tip to the test circuit:

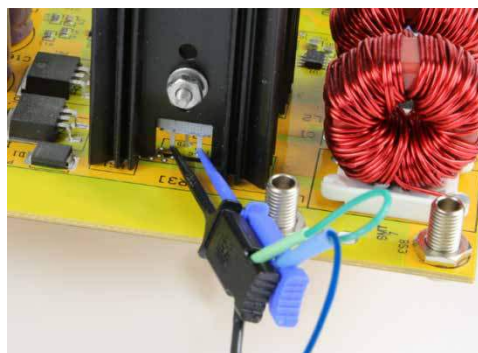
1. Connect the blue Signal lead to the signal that is to be measured, ensuring that the attenuating tip used has sufficient input dynamic range to measure the voltage (V_S) but not so much dynamic range that the measurement is noisier than desired.
2. Connect the green Reference and black Shield leads to the floating board reference (V_{CM}).

The example below left shows the tip lead sockets connected to a short stub on the circuit board. Tip lead sockets fit well onto 22AWG wires or 0.100" pitch pin headers.

Alternately, the micro-grippers may also be used to connect to the test circuit (right). The micro-grippers provide two connections, so the green Reference and black Shield leads may be connected to one micro-gripper.



CAUTION: The Reference and Shield wires are electrically connected inside the tip. Failure to connect them to the same potential will damage the DUT and/or probe.



Properly connected tip when using stubs (left) or micro-grippers (right)

Positive voltages applied to the Signal input relative to the Reference and Shield inputs will deflect the oscilloscope trace toward the top of the screen.

HVFO108 High-Voltage Fiber Optically Isolated Probe

Optimizing Performance

To maintain the probe's high-performance capability, exercise care when connecting the probe. Increasing the parasitic capacitance or inductance in the input paths may introduce a “ring” or slow the rise time of fast signals.

Don't add length to the leads. Input leads that form a large loop area will pick up any radiated electromagnetic field that passes through the loop and may induce noise into the probe inputs.

Twist together the blue Signal and the black Shield wires to reduce loop inductance and to achieve optimum CMRR performance.

For best CMRR performance, directly connect the tip socket to a short stub or wire connected to the circuit. Only use a micro-gripper if absolutely necessary, or if you can demonstrate that it performs acceptably well.

If parasitic common-mode capacitance is expected to be high, use a non-conductive platform (not supplied) to hold the probe body above the DUT, as this will improve CMRR due to less parasitic common-mode capacitance. These types of platforms are commonly available for use with digital cameras and can be repurposed for this application. Ensure that whatever is used is appropriate for the common-mode voltages present in the circuit.



Probe elevated above DUT

Connecting to the Test Instrument

Connect the assembled probe to the test instrument by pushing the demodulating receiver body onto the oscilloscope's ProBus input. The instrument will recognize the connected probe and set the oscilloscope input termination to 1 M Ω . The oscilloscope probe control functions are activated, and the CnHVFO108 dialog appears behind the Cn dialog of the probe input channel.

Once a tip is connected to the transmitter, the oscilloscope will set the proper probe attenuation according to the information received from the tip. A colored LED will blink on both the transmitter and the demodulating receiver, keyed to the state of the HVFO battery. Progress from green to yellow to red indicates the approximate remaining charge.

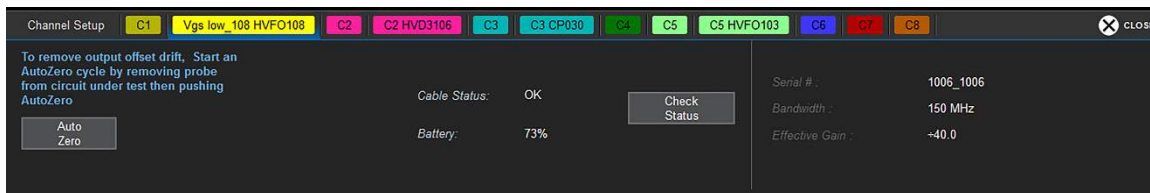
For accurate measurements, connect the probe to the oscilloscope and allow it to warm up for at least 20 minutes before taking any measurements. Perform Auto Zero prior to taking measurements (see p.24).

Note: When a probe with tip is first connected to the oscilloscope, you will see a sine wave oscillate up to 40 khz on top of any actual signal for 7 seconds, whether or not the probe is connected to a DUT. This is an artifact of the phase lock loop locking the amplifier receiver to the transmitter. If connected to a DUT, the DUT is safe and will not see this signal.

Operating with an Oscilloscope

When the entire HVFO108, including the attenuating tip, is connected to a Teledyne LeCroy oscilloscope, the displayed scale factor and measurement values are adjusted to account for the effective gain of the probe. The probe's bandwidth, effective gain, cable status, and battery status are all shown on the Probe dialog.

Note: The effective gain shown is simply the reciprocal of total attenuation. Total attenuation is a combination of the HVFO108 tip attenuation (1x, 5x, 20x, etc.) and the amplifier attenuation (a fixed value of 2x). Thus, a 1x attenuating tip will have a total attenuation of 2x and effective gain is $\div 2$, while a 20x tip will have a total attenuation of 40x and effective gain is $\div 40$.



HVFO108 Probe dialog

Cable Status and Battery

Cable Status indicates the general quality of the fiber optic cable. If "Poor" is indicated, the cable is near the end of life and should be replaced.

Battery indicates the remaining battery life. 100% is roughly equivalent to 6 hours. LEDs on the transmitter and receiver body also indicate when the battery requires recharging.

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Cable Status and Battery are updated whenever the probe dialog is opened. If you wish to update them after the dialog has been opened, touch the Check Status button.

Probe Volts/Div and Attenuation

The front panel Volts/Div knob controls the oscilloscope's scale factor. When the probe is connected, the oscilloscope voltage per division settings will be limited to a minimum sensitivity setting based on the attached tip.

Offset

Offset allows you to remove a DC bias voltage from the input signal while maintaining DC coupling. This ensures that the probe will never be overdriven while a signal is displayed on screen and prevents inaccurate measurements. Keep in mind that the HVFO design already removes the common mode voltage from the measurement, so large offsets will not typically be required for most measurements.

The total usable offset of the system is a function of three values: oscilloscope V/div setting, oscilloscope offset at that V/div setting, and total probe attenuation (tip plus transmitter). Find the oscilloscope front-end V/div (Vertical Scale) setting with the probe connected. This may be calculated as: *Oscilloscope Front End V/Div = (Probe and Oscilloscope) V/Div ÷ Total Probe Attenuation*

Once the oscilloscope V/div value is known, you can find the maximum offset available at that V/div setting either by consulting the oscilloscope specifications or by selecting to Use Max Offset with the oscilloscope set to that V/div.

Bandwidth Limiting

Probe bandwidth limit may be switched from Off (maximum bandwidth) to 20 MHz on the input Channel (Cn) dialog.

Auto Zero

Auto Zero corrects for DC offset drifts that naturally occur from thermal effects in the amplifier. The HVFO probe incorporates Auto Zero capability to remove the DC offset from the probe's amplifier output to improve the measurement accuracy.

Auto Zero is invoked manually from the HVFO108 dialog that appears when the probe is connected to the oscilloscope. Always perform Auto Zero after the probe is warmed up (recommended warm-up is 20 minutes). Depending on the measurement accuracy desired and/or changes in ambient temperature, it may be necessary to perform Auto Zero more often. If the probe is disconnected from the oscilloscope and reconnected, repeat Auto Zero after a suitable warm-up time.



CAUTION: Disconnect the probe from the circuit before Auto Zero, or else any DC component that is part of the Signal to be measured will be zeroed out.

Recharging the Amplifier/Modulating Transmitter Battery

An LED indicator on the transmitter body indicates when the battery requires recharging. Battery Status is also indicated on the Probe dialog, which shows the approximate percentage of battery remaining. The battery is recharged through the same USB Micro-B interface that connects the tip during operation to ensure safety of the operator and other equipment, as it precludes charging while the probe is operating (and floating above ground).

To recharge the battery:

1. Remove the tip.
2. Insert the charging cable into the Micro-B port on the transmitter.
3. Connecting the cable to a USB port on the oscilloscope, a PC or a USB charger.

Ambient temperature during charging should be between 0° and 40° C (which is lower than the operating range of the probe).



CAUTION: Recharge temperature is lower than the operating range of the probe.

The LED will flash while the battery is recharging. If the battery is completely depleted, it may take a few minutes for the "charging" light to turn on. Recharge time is approximately five hours if connected to the oscilloscope (or PC), or two and a half hours if using a USB charger.



CAUTION: Make sure the power source is plugged in and powered on or the battery will continue discharging.

Once the unit is done charging, unplug from the USB charging system.



Amplifier recharging from oscilloscope USB port.

Performance Verification

HVFO108 probes shipped from Teledyne LeCroy are tested as a system (transmitter with demodulating receiver) and adjusted to meet the Gain Accuracy specification. This procedure can be used to verify the warranted performance of an HVFO108, or to test and calibrate an HVFO108 system where a different transmitter or receiver has been introduced. Test results can be recorded on a photocopy of the HVFO108 Test Record in this manual.

Note: Repeat this procedure whenever a probe component is changed (e.g., new cable). Components purchased from Teledyne Lecroy should meet all performance specifications.

Some of the 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 his procedure.

Required Test Equipment

The following equipment (or its equivalent) is required for performance verification of the HVFO108 probe. As input/output connector types vary on different brands of instruments, additional adapters or cables may be required.

Description	Minimum Requirements	Example Equipment
Oscilloscope	ProBus interface equipped 12-bit resolution	Teledyne LeCroy HDO4000, HDO6000, WaveRunner 8000 HD
Digital Multimeter (DMM)	DC: 0.1% accuracy AC: 0.1% accuracy 5.5 digit resolution	Keysight Technologies 34401A Fluke 8842A-09
Function Generator	Square Wave output amplitude adjustable to 1.0 Vp-p (0.5 Vrms) into 50 Ω at 100 Hz	Teledyne LeCroy WaveStation 3082 Keysight Technologies 33120A Stanford Research Model DS340
BNC Coaxial Cable (2)	Male to Male, 50 Ω , 36"	Pomona 2249-C-36 Pomona 5697-36
BNC Tee Connector	Male to Dual Female	Pomona 3285
Banana Plug Adapter	Female BNC to Dual Banana Plug	Pomona 1269
BNC to SMA adapter	BNC (f) to SMA (f)	Pomona 4291 Amphenol RF 242123
Probe Calibration Fixture	SMA to square pin adapter	Teledyne LeCroy PCF200
SMA Termination	50 Ω	Pomona 72975 Amphenol RF 132360

Functional Check

The functional check will verify the basic operation of the probe functions. It is recommended to perform the functional check prior to the performance verification procedure.

1. Connect the demodulating receiver to the C1 input. Verify that the C1HVFO108 tab appears behind the C1 setup dialog. This confirms that the probe is sensed.
2. Open the C1HVFO108 dialog and touch **Auto Zero**, then **OK**.
3. Confirm that the message "Performing AutoZero on HVFO108..." is displayed in the message bar, and that no error messages are displayed.

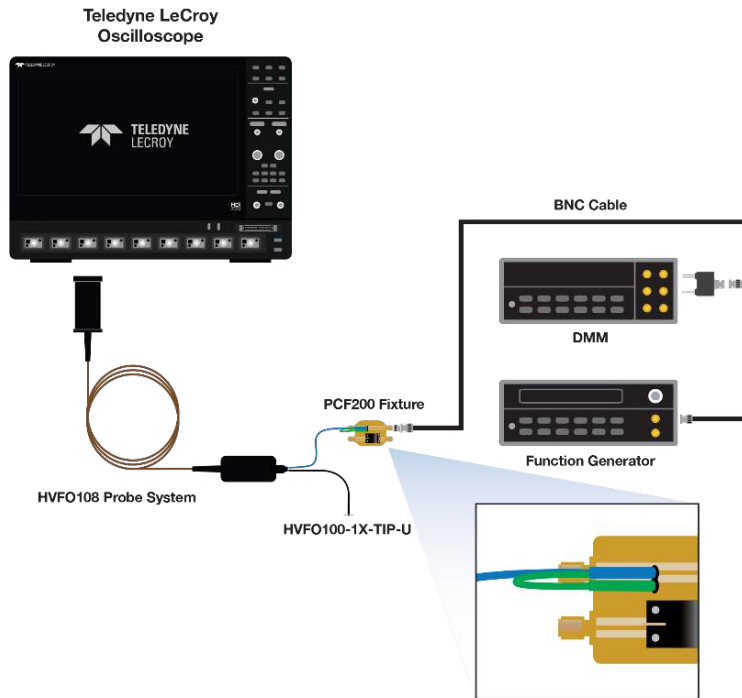
Before You Begin

1. With the demodulating receiver connected to C1, allow at least 30 minutes warm up.
2. Turn on the other test equipment and allow these to warm up for the time recommended by the manufacturer.
3. Connect the transmitter to the demodulating receiver. Connect the HVFO100-1X-TIP-U to the input of the transmitter to power up. Allow at least another 20 minutes for the transmitter to warm up.

Note: If using a tip other than the 1x, multiply the values in the procedure by the appropriate scale factor.

4. While the instruments are reaching operating temperature, make a photocopy of the Performance Verification Test Record and fill in the necessary data.

Performance Verification Test Setup



Check Gain Accuracy

1. Connect the probe system and test equipment as shown in the diagram above. Use the C1 input for the probe.
2. Set the DMM to measure V_{AC} .
3. Set the function generator to output a square wave of 100 Hz amplitude of $1.0 V_{PK-PK}$.
4. Set the oscilloscope Timebase to 10 mS/div and C1 Vertical Scale to 200 mV/div.
5. Turn on measurements. Set oscilloscope P1 to measure the amplitude (ampl) of C1.
6. Adjust the generator output voltage so that the voltage measured on the DMM is as close to $500 mV_{RMS}$ as possible (this should be $500 \pm 1 mV_{RMS}$).
7. Record the $ampl(C1)$ measurement on the test record.
8. Calculate the gain accuracy (%) using the equation: $(Step\ 7\ value - 1.0) * 100$
9. Record the gain accuracy on the test record.

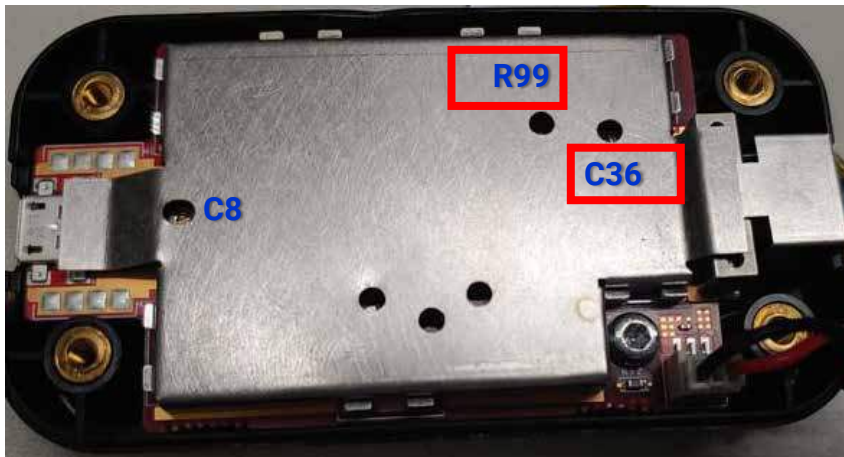
Adjust Gain Accuracy

If the HVF0108 system does not meet the accuracy specification, the transmitter can be adjusted to more precisely match the characteristics of the specific demodulating receiver.

1. Keeping the equipment connected as in the 'Check Gain Accuracy' section, open the transmitter by removing the sticky rubber feet and screws that hold together the housing top and bottom.
2. On the oscilloscope, set the math trace F1 to be the Trend of measurement P1 (amplitude of C1). This will enable you to see small variations in the amplitude so that the adjustments can be more precise.
3. Carefully adjust the capacitor C36 so that the ampl of C1 is maximized.
4. Carefully adjust the resistor R99 so that the ampl of C1 is equal to 1.00 ± 0.010 V.

Note: Do not adjust C8.

5. Repeat Steps 3 and 4 at least once, since the two adjustments can affect one another.



HVFO108 Performance Verification Test Record

Receiver Serial Number: _____

Amplifier Serial Number: _____

Asset/Tracking Number: _____

Date: _____

Technician: _____

Equipment	Model	Serial Number	Calibration Due Date
Digital Multimeter			
Oscilloscope			
Function Generator*			N/A

* The function generator is used for making relative measurements. The output of the generator is measured with a DMM or oscilloscope. Thus, the generator is not required to be calibrated.

Gain Accuracy

Step	Description	Intermediate Data	Test Result
7	HVFO108 Measured Voltage	V_{PK-PK}	
8	Gain Error ($< \pm 4\%$)		%

Permission is granted to photocopy this page to record the results of the Performance Verification procedure. File the completed record as required by applicable internal quality procedures.

Results recorded under "Test Result" are the actual specification limit check. The test limits are included in each step. Record other measurements and intermediate calculations that support the limit check under "Intermediate Data".

Care and Maintenance

Cleaning the Probe Body

Clean only the exterior surfaces of the device using a soft cloth or swab dampened with water or 75% isopropyl alcohol solution. Do not use harsh chemicals or abrasive cleansers. Dry the probe and accessories thoroughly before making any voltage measurements.



CAUTION: The HVF0108 probe is not waterproof. Under no circumstances submerge the probe in liquid or allow moisture to penetrate it.

Cleaning the Optical Ports

Keep the fiber optic ports clear of dust. If required, they can be cleaned by applying low pressure dry air. Do not insert anything into the ports except fiber optic cable or apply solvents to them.

Cleaning the Fiber Optic Cable

The fiber optic cable connectors should only be cleaned with solvents and wipes/swaps appropriate for optical fiber, such as Sticklers Fiber Optic Cleaner or similar (<https://sticklers.microcare.com/products/product/sticklers-fiber-optic-cleaner/>).

Replacing the Transmitter Battery

The transmitter battery is not field replaceable. Return the probe to Teledyne LeCroy service if the battery malfunctions. See Appendix A: Battery Safety and Handling for indicators of failure.

Calibration Interval

The recommended calibration interval is one year. A performance verification procedure is included in this manual. The complete performance verification should be performed as the first step of annual calibration. If necessary, the transmitter can be adjusted to better match the characteristics of the demodulating receiver, see p.29.

Service Strategy

The HVF0108 probe utilizes fine-pitch surface mount devices. Apart from replacing the battery, it is impractical to attempt repair in the field. Defective probes must be returned to a Teledyne LeCroy service facility for diagnosis and exchange.



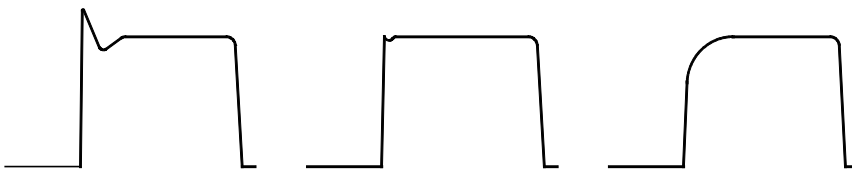
CAUTION: Refer all servicing to qualified personnel. A defective probe under warranty will be replaced with a factory refurbished probe.

Probes not under warranty can be exchanged for a factory refurbished probe for a modest fee. Replacement probes are factory repaired, inspected, and calibrated to the same standards as a new product. You must return the defective probe in order to receive credit for the probe core.

Attenuating Tip Compensation

Tips are compensated at the factory and should not require compensation during normal use. However, there are cases where accuracy may be affected, such as after using a tip with a different amplifier than that with which it was initially calibrated. Follow these steps to compensate 5X, 10X, 20X and 40X attenuating tips. 1X attenuating tips do not need compensation.

1. Connect the tip to a 1 kHz square wave signal.
 - 5X attenuating tips may be connected to the Cal Out hook on the oscilloscope.
 - 10X, 20X and 40X attenuating tips should be connected to a function generator with a good square wave.
2. Adjust the trimmer located on the back of the Micro-B connector until you achieve a flat-topped square wave, as shown in the center image below.



Over-compensated, correct, and under-compensated waveforms

Reference

Common Mode Rejection Ratio

The ideal amplifier would sense and amplify only the desired voltage component and reject the entire common mode voltage (V_{CM}) component. Typically, this is best done with a differential amplifier, but real differential amplifiers are not perfect, and a small portion of the V_{CM} component appears at the output.

Common Mode Rejection Ratio (CMRR) is the measure of how much the amplifier rejects the common mode voltage component. It is most often used to describe the performance of a differential probe/amplifier and in that case 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 (e.g., 10,000:1) or implicitly in dB (e.g., 80 dB). Higher numbers indicate greater rejection (better performance).

In a differential probe/amplifier, the first order term determining the CMRR is the relative gain matching between the + and – input paths. High CMRR values are obtained by precisely matching the input attenuators in a differential amplifier. The matching includes the DC attenuation and the capacitance which determines the AC attenuation. As the frequency of the common mode component increases, the effects of stray parasitic capacitance and inductance in determining the AC component become more pronounced. In a conventional high attenuation HV differential probe used to measure a small signal floating on a high common mode voltage, the differential mode gain must be very high, and the input path matching must be very precise, limiting how good the CMRR performance can practically be for high common mode voltages.

In the HVFO, the amplifier is single-ended. This is possible since the amplifier is floating and the signal return path is not to oscilloscope ground. The requirement for precisely matched impedances between two input leads does not have to be met in order to achieve high CMRR. Additional techniques are used to separate signal return currents from currents caused by stray parasitic capacitances, as a result making it easier to achieve high CMRR at high frequencies.

The CMRR becomes smaller as the frequency increases. Therefore, the CMRR is usually specified in a graph of CMRR versus common mode frequency. The common mode frequency in these graphs 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. This makes it very difficult to represent actual performance in CMRR-vs-frequency graphs. The practical purpose of such graphs is to compare the relative common mode rejection performance between different probes and amplifiers.

Common Mode Range

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 (if the probe is so rated) can result in unpredictable measurements or damage to the probe, DUT, oscilloscope or operator. Safety standards are typically used to specify the maximum common mode voltage that the probe may be safely used at, with different ratings based on whether the probe is designed to be used to measure mains voltages (and if so, how close to low impedance utility supply the measurement can be made) and if the probe is designed to be hand-held.

Most hand-held probes with high common mode voltage safety ratings are large and bulky (for obvious reasons) and impractical to use on dense, compact power electronics circuits. More recently, safety standards have recognized this reality and created new measurement categories for probes used in test and measurement applications and not connected to the mains. However, probes like the HVFO defy measurement categorization. The HVFO uses a fiber optic cable to optically isolate the amplifier from the grounded measurement instrument, and is not designed to be hand-held at common mode voltages $> 30 V_{\text{RMS}}/60 V_{\text{DC}}$. The practical common mode range in this case when not hand-held is simply the expected dielectric withstand rating of the fiber optic cable connection between the transmitter and demodulating receiver. Realistically, this is much, much greater than typical test voltages in 600 V class power electronics applications, and can range into the tens of kilovolts. User should follow appropriate safety guidelines when using the HVFO with these levels of common mode voltages.

Returning a Product for Service

Contact your local Teledyne LeCroy service center for calibration or other service. If the product cannot be serviced on location, the service center will give you a Return Material Authorization (RMA) code and instruct you where to ship the product. All products returned to the factory must have an RMA.

Return shipments must be prepaid. Teledyne LeCroy cannot accept COD or Collect shipments. We recommend air freighting. Insure the item you're returning for at least the replacement cost.

1. Remove all accessories from the probe.
2. Pack the probe in its case. If possible, include all tips. Do not include the manual.
3. Pack the case in its original shipping box, or an equivalent carton with adequate padding to avoid damage in transit.
4. Mark the outside of the box with the shipping address given to you by Teledyne LeCroy. Be sure to add the following:
ATTN:<RMA code assigned by Teledyne LeCroy>
FRAGILE
5. **If returning a probe to a different country:** contact Teledyne LeCroy Service for instructions on completing your import/export documents.

Extended warranty, calibration and upgrade plans are available for purchase. Contact your Teledyne LeCroy sales representative to purchase a service plan.

Technical Support

For a complete list of offices by country, including our sales & distribution partners, visit: teledynelecroy.com/support/contact

Teledyne LeCroy
700 Chestnut Ridge Road
Chestnut Ridge, NY, 10977, USA

US Service and Support:

Ph: 800-553-2769 / 845-425-2000
FAX: 845-578-5985
support@teledynelecroy.com

HVFO108 High-Voltage Fiber Optically Isolated Probe

Warranty

THE WARRANTY BELOW REPLACES ALL OTHER WARRANTIES, EXPRESSED OR IMPLIED, INCLUDING BUT NOT LIMITED TO ANY IMPLIED WARRANTY OF MERCHANTABILITY, FITNESS, OR ADEQUACY FOR ANY PARTICULAR PURPOSE OR USE. TELEDYNE LECROY SHALL NOT BE LIABLE FOR ANY SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES, WHETHER IN CONTRACT OR OTHERWISE. THE CUSTOMER IS RESPONSIBLE FOR THE TRANSPORTATION AND INSURANCE CHARGES FOR THE RETURN OF PRODUCTS TO THE SERVICE FACILITY. TELEDYNE LECROY WILL RETURN ALL PRODUCTS UNDER WARRANTY WITH TRANSPORT PREPAID.

The product is warranted for normal use and operation, within specifications, for a period of one year from shipment. Teledyne LeCroy will either repair or, at our option, replace any product returned to one of our authorized service centers within this period. However, in order to do this we must first examine the product and find that it is defective due to workmanship or materials and not due to misuse, neglect, accident, or abnormal conditions or operation.

Teledyne LeCroy shall not be responsible for any defect, damage, or failure caused by any of the following: a) attempted repairs or installations by personnel other than Teledyne LeCroy representatives, or b) improper connection to incompatible equipment, or c) for any damage or malfunction caused by the use of non-Teledyne LeCroy supplies. Furthermore, Teledyne LeCroy shall not be obligated to service a product that has been modified or integrated where the modification or integration increases the task duration or difficulty of servicing the oscilloscope. Spare and replacement parts, and repairs, all have a 90-day warranty.

Products not made by Teledyne LeCroy are covered solely by the warranty of the original equipment manufacturer.

Certifications

For the full list of current certifications, see the EC Declaration of Conformity shipped with your product. The HVFO108 conforms to the following safety standards:

IEC/EN 61010-1:2010 - Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use – Part 1: General Requirements

IEC/EN 60825-1. Safety of Laser Products-Part 1: Equipment Classification and Requirements - Edition 3 (2014)

US 21CFR Part 1010 Performance Standard for Electronic Products: General

US 21CFR Part 1040 Performance Standards for Light-Emitting Products



The HVFO108 complies with the applicable European Union requirements to Directives 2012/19/EU and 2006/66/EC on Waste Electrical and Electronic Equipment (WEEE) and Batteries. For more information about proper disposal and recycling of your Teledyne LeCroy product, visit teledynelecroy.com/recycle.

Unless otherwise specified, all materials and processes are compliant with RoHS Directive 2011/65/EU in its entirety, inclusive of any further amendments or modifications of said Directive.

Appendix A: Battery Safety and Handling

The HVF0108 amplifier/transmitter incorporates a Lithium Polymer battery. The battery pack should have enough protection for an ICP cell from the specification of its electrical, mechanical and environmental characteristics, provided you always follow the instructions below when using the probe.



DANGER: Using the HVF0108 probe other than according to the UL1642 safety requirements listed here may cause electrical bursts, fire, smoke or severe performance failure making it unsafe for use.

- (1) **Do not disassemble or modify the probe body.** The battery has a safety function and protection circuit to avoid danger of electrical fire. The ICP cell is packaged in aluminum laminated plastic film which can be easily damaged by sharp instruments such as pins, needles, edge of devices like nickel tabs, etc. If the film is seriously damaged, electrolyte leakage or short-circuit between positive and negative tabs, etc., could occur.
- (2) **Do not incinerate or heat the probe.** Do not use or leave it near fire, stove or heated surfaces (more than 130 °C). Doing so can melt the battery insulator, damage the safety function, or ignite electrolytes. If the polymer separator is melted, an internal short-circuit can occur in individual cells.
- (3) **Do not place the probe in a microwave or a high-pressure container.** Heat can damage the battery's protective mechanisms.
- (4) **Do not use the probe near fire or other heat sources.** If liquid leaks from the battery, or you smell noxious fumes, remove the battery from nearby heat sources immediately.
- (5) **Do not use the probe near static electricity.** Static electricity of more than 100 V can damage the battery's internal protection mechanisms.
- (6) **Do not expose the probe to direct ultrasonic wave power or solder near the battery.** Soldering near the battery may melt and damage components such as separator and insulator.
- (7) **Do not drive nails or sharp objects into the probe, strike it with a hammer or other object, or step on it.** A deformed or broken battery can short-circuit.
- (8) **Do not throw the probe or cause excessive impact.** ICP batteries can be damaged by strong mechanical shock causing wire breakage, short-circuits inside the cell, leakage of electrolytes, etc. If the battery's protective mechanisms are broken, the battery will be charged at an abnormal voltage or current, and an abnormal chemical reaction can occur.
- (9) **Charge the amplifier/battery only as specified.** Charging it in an unspecified manner (e.g., under high temperature over the regulated value, excessive high voltage or current over the regulated value, or remodeled with the PCM failed or disassembled) may cause it to be overcharged or an abnormal chemical reaction to occur in the cells.
- (10) **Do not charge the amplifier/battery from a wall socket or car cigarette charger.** Excessive

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voltage can damage the battery's protective mechanisms.



CAUTION

- (1) Read the manual before using the probe. Keep the manual handy where using the probe.
- (2) Read the charging instructions before charging the battery.
- (3) If the probe is rusted, smells bad, or otherwise appears to be damaged before first time use, do not use it. Return it to the vendor.

hvfo108-user-manual-eng_02aug22.pdf
August, 2022



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