TELEDYNE LECROY
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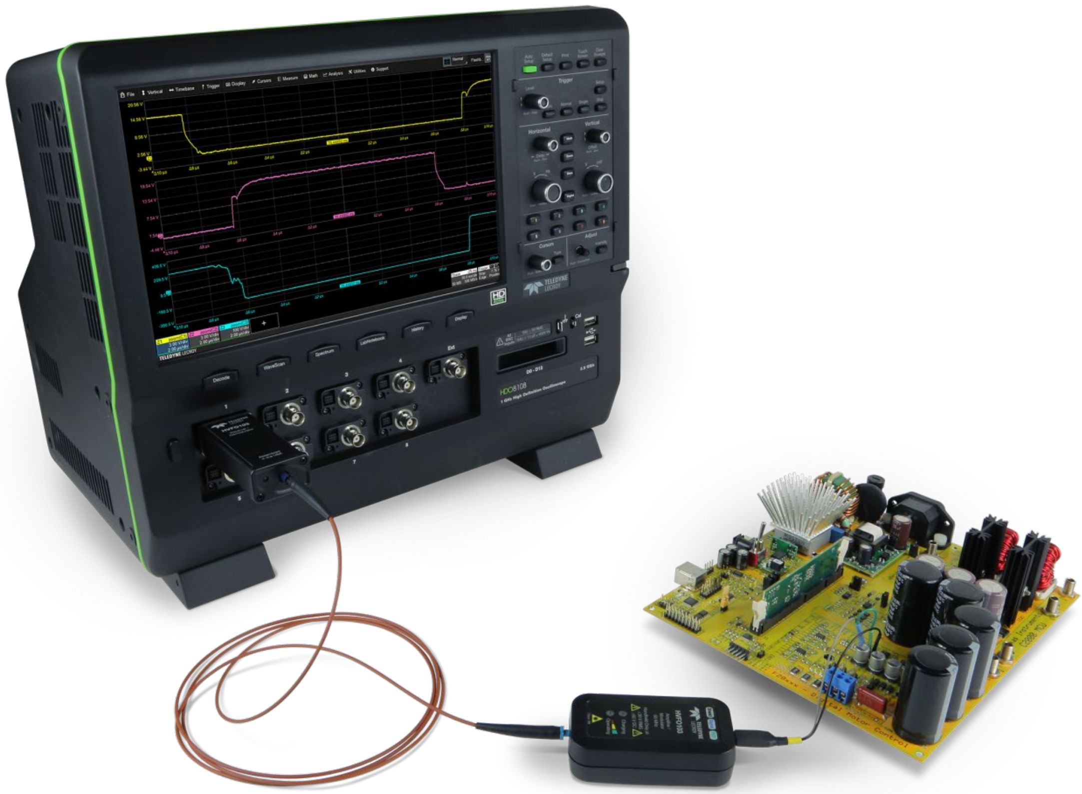

Operator's Manual

HVFO103

High-Voltage

Fiber Optically Isolated Probe

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January, 2019

HVFO103 High-Voltage Fiber Optically Isolated Probe Operator's Manual

929785-00 Rev A
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Contents

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.

	WARNING, 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.**

General Precautions

To avoid personal injury or damage to your equipment:

Use only as specified. The probe is intended to be used only with compatible Teledyne LeCroy instruments. Using the probe and/or the equipment it is connected to in a manner other than specified may impair the protection mechanisms.

Do not overload; observe all ratings. Do not connect the probe to any circuit that exceeds the 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. Substituting other accessories than those specified in this manual may create an electrical hazard.

Connect and disconnect properly. Connect the probe to the measurement instrument before connecting to the circuit being measured. Avoid excessive bending that can damage cables.

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

Do not use the probe for measurements on Mains circuits. This probe does not have a CAT rating for use on these types of circuits.

Except for gain accuracy adjustment, do not remove the probe's casing. Touching exposed connections may result in electric shock.

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

Keep product surfaces clean and dry.

Handle with care. Probe tips are sharp and may cause injury if not handled properly.

Do not operate with suspected failures. Before each use, inspect the probe and accessories for damage such as tears or other defects in the body, cable jacket, etc. If any part is damaged, cease operation immediately and sequester the probe from inadvertent use.

High Voltage Precautions

To avoid injury or death due to electric shock or burn:

Do not handle probe tips, leads or any part of the amplifier/modulating transmitter at any time if DC bus voltages are >60 V. The probe is not rated for hand-held use above 60 V. If there is any question as to whether >60 V voltages are present in the circuit, use caution and DO NOT touch these components.

Always ensure that, when not hand-held, the amplifier/modulating transmitter and attached tip are positioned to maintain adequate spacing between these two components and earth ground. Some of the probe components float at the common-mode voltage and some do not. The spacing requirements depend on the common-mode voltage present in the test setup.

Safety Ratings for Accessories

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. See definitions on p.33.

Safe Operating Environment

Temperature, Operating	0° C to 50° 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) 45% RH above 30 C
Relative Humidity, Non-operating	5% to 95% RH (Non-Condensing) 75% RH above 30 C 45% RH above 40 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 61010-031:2015. See definitions on p.33.

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.

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Introduction

The HVFO103 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. Furthermore, it mitigates the need to rely on dangerous test setups that require floating the oscilloscope and probe.

Key Features

- 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
- 60 MHz bandwidth
- 2% DC and low-frequency gain accuracy
- ProBus interface with automatic scaling
- Auto Zero capabilities

Method of Operation

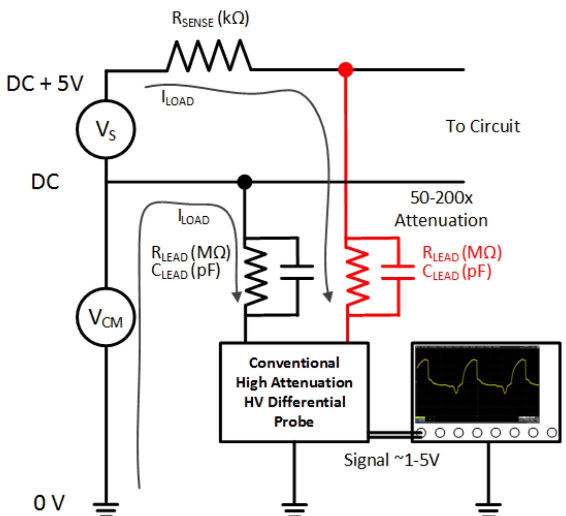
The low-attenuation tip makes a three-wire (Signal, Reference, and Shield) electrical connection to the device under test (DUT). The Signal connection wire is coaxial and attaches to the high side of the signal measurement. The Reference wire and Shield wires are non-coaxial and attach to the low side 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.

Probe Design Compared to a Differential Probe

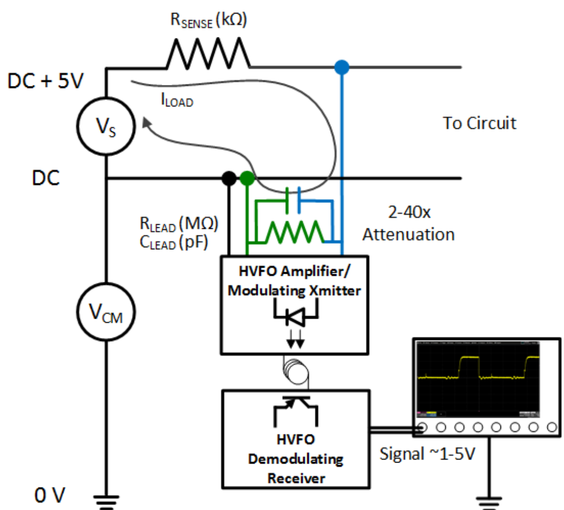
When properly used in its intended application, the HVFO103 will achieve much better results than a conventional, high-attenuation HV differential probe due to the dramatically different probe design.



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_S 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 >> 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.32) 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).

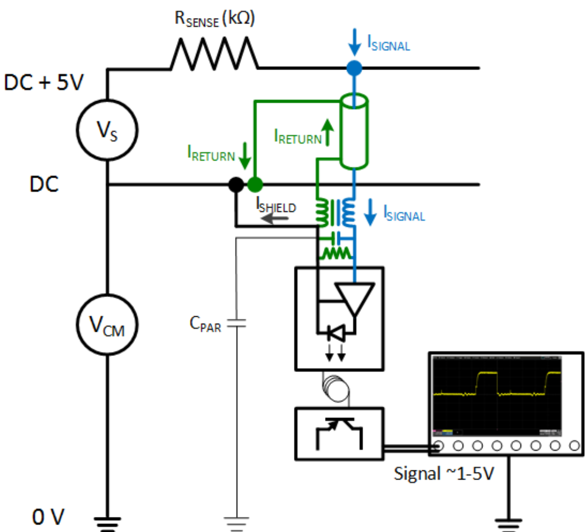
- The V_{CM} has no impact on the loading of the circuit, since the $R_{LEAD} >> R_{SENSE}$.
- The small C_{LEAD} requires minimal charging current, since the voltage V_S is very low (volts, not hundreds of volts or kilovolts).
- The tip attenuation is very low, so the signal is not being highly attenuated 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 HVFO103 will show much improvement on a very low voltage DC bus (~20 V) 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 ≥ 5 k V_{AC} class equipment, the advantages of the HVFO will be obvious, in most cases.

Effect of Tip Design on Current Paths



The HVFO103 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 HVFO103, 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 HVFO103.

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

The HVFO103 probe is compatible with a wide range of Teledyne LeCroy oscilloscopes equipped with the ProBus interface. Visit teledynelecroy.com/oscilloscope to confirm compatibility with your oscilloscope model.

In general, Teledyne LeCroy 12-bit High Resolution Oscilloscopes (HRO) and High Definition Oscilloscopes (HDO) provide the most offset capability over the widest range of V/div settings (see p.21 for maximum offset calculations).

Note: HVFO103 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

The 10X tip requires a more recent version of firmware than do the others.

64-bit MAUI oscilloscope	8.3.x.x or higher
64-bit MAUI oscilloscope with 10x Tip	8.7.0.5 or higher
32-bit MAUI oscilloscope	8.1.2.x or higher
32-bit MAUI oscilloscope with 10x Tip	N/A

HVFO Probe System

HVFO103

The parts shown below are delivered standard with the HVFO103 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. It is recharged through the same USB Micro-B interface used to connect the tip. A spare transmitter may be purchased separately so that one can be charged while the other is in use.

The VersaLink (V-pin) 400/430um **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; 2- 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/). Satisfactory optical transmission has been tested using cables up to 25 meters (longer lengths may work as well).

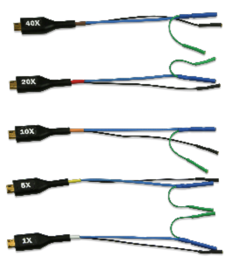
The **demodulating receiver** utilizes the ProBus interface to communicate tip attenuation value and proper voltage scaling to the oscilloscope. With the ProBus interface, the HVFO probe becomes an integral part of the measuring instrument. Power is provided to the receiver through the signal interface, 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.

Optional Accessories

These items may be purchased separately as accessories to the probe.

Description	Part Number	Quantity
Additional 1-meter fiber optic cable	HVFO-1M-FIBER	1
2-meter fiber optic cable	HVFO-2M-FIBER	1
6-meter fiber optic cable	HVFO-6M-FIBER	1
Additional Amplifier/Modulating Transmitter	HVFO10x-XMITTER	1

Optional 1-meter, 2-meter, and 6-meter fiber optic cables

HVFO103 Probe Specifications

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

Specifications

Bandwidth (typical, probe+oscilloscope)	60 MHz
Risetime 10-90% (typical)	7.5 ns
DC Gain Accuracy (warranted)	+/- 2 %
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

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	50 mV/div – 1 V/div
5x tip	250 mV/div – 5 V/div
10x tip	500 mV/div – 10 V/div
20x tip	1 V/div – 20 V/div
40x tip	2 V/div – 40 V/div

Amplifier/Modulating Transmitter Battery

Charging Interface	USB Micro-B
Typical Life	> 6 hours
Recharge Time	
Oscilloscope USB port	3 hours
USB charger	1.5 hours
Cycle Life	> 500 cycles*

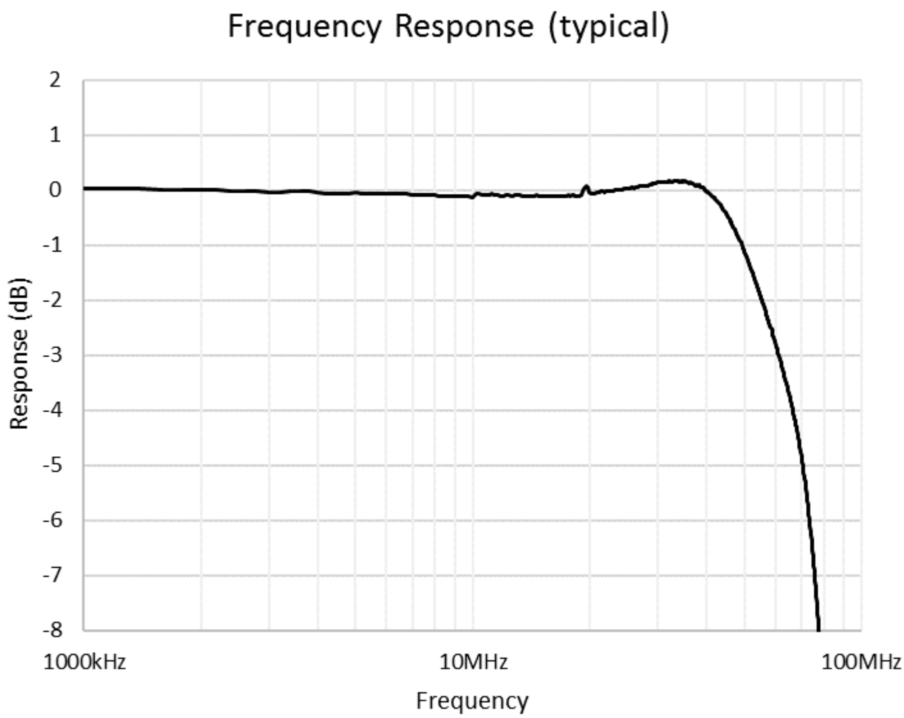
* For battery life > 5.5 hours.

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 HVFO103 using any attenuating tip is shown below:

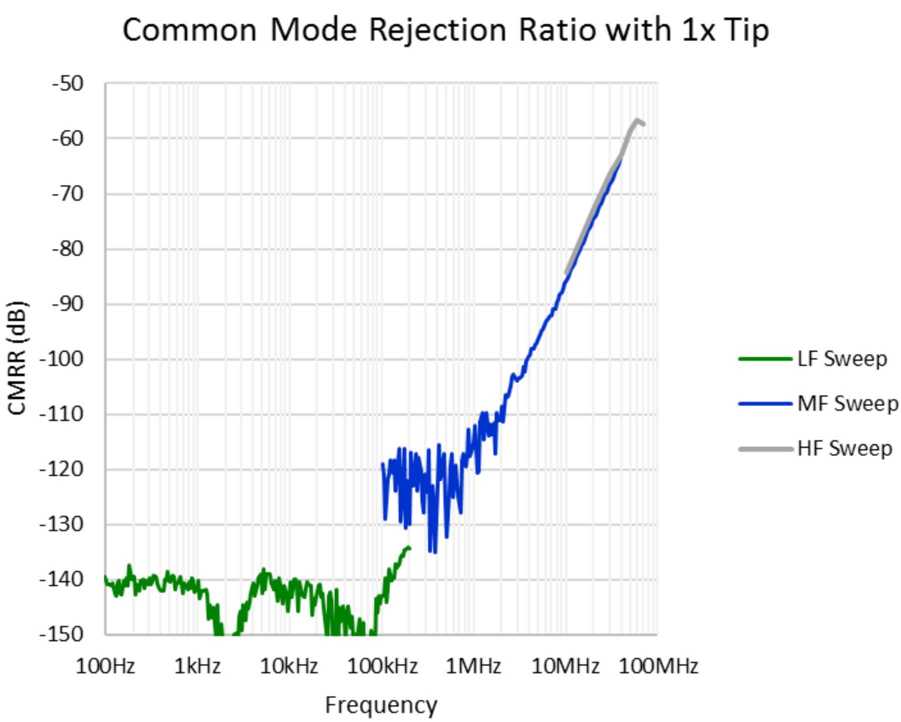


Common Mode Rejection Ratio

The performance shown in the graph below is typical performance with the 1x tip connected to the HVFO103 and the black Reference and blue Signal leads twisted together.

- The Green line (LF Sweep) was measured with a low-bandwidth, high-voltage generator.
- The Blue line (MF Sweep) was measured with a frequency response analyzer.
- The Gray line (HF Sweep) was measured with an external generator.

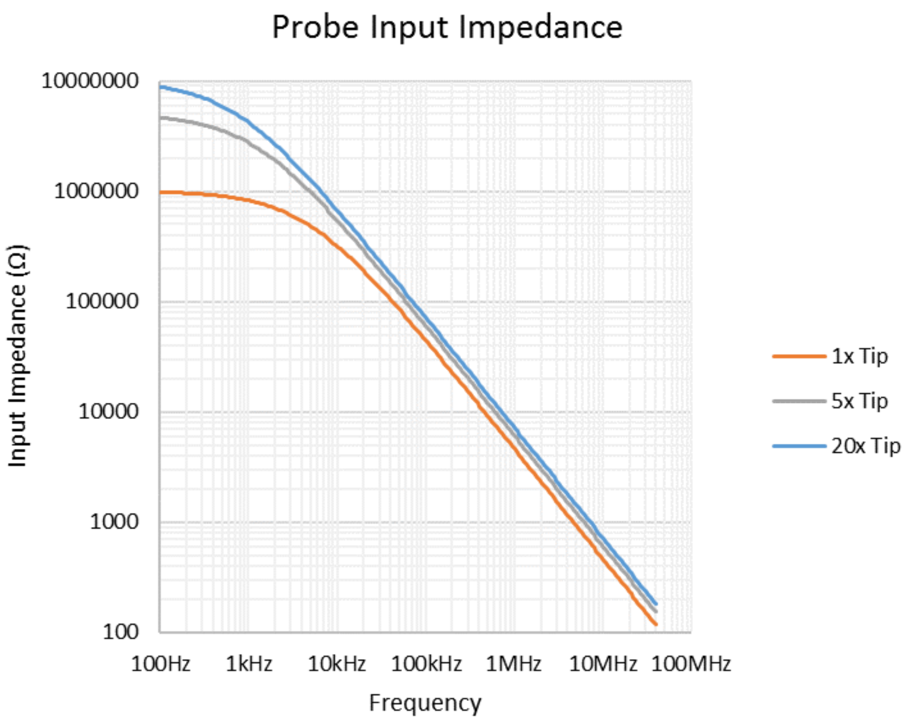
The discontinuity between the green line and blue line at 100-300 kHz is due to the noise floor limitation of the frequency response analyzer.



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 $20\log_{10}(5/1)$ = 14dB 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 Mohm // 23 pF.



Operation

Note: Probe operation requires the correct oscilloscope firmware, see p.9. To check the installed version, choose Utilities > Utilities Setup > Status from the oscilloscope menu bar.

Assembling the Probe

To ready the HVFO probe for use:

1. Remove the protective covers from the fiber optic cable.
2. Connect one end of the fiber optic cable to the demodulating receiver. This requires a small amount of force. You will hear a "click" when it is inserted.
3. Connect the other end of the fiber optic cable to the transmitter.

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

4. Connect the tip to the USB Micro-B interface on the transmitter.

   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. When the HVFO103 is consuming battery power, the LED will flash on both the transmitter and the receiver/demodulator.

Connecting to the Test Circuit

WARNING: The HVFO103 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

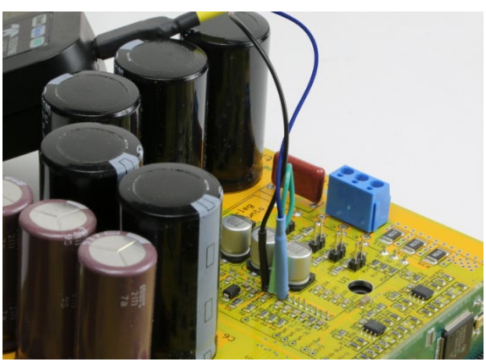
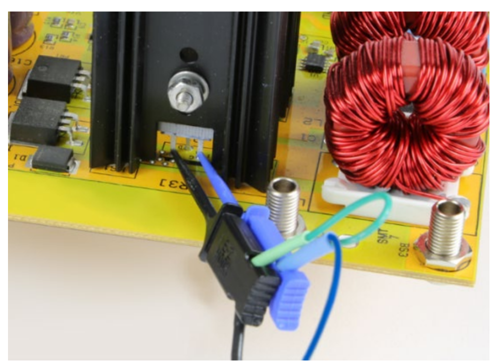
For accurate measurements, connect all three inputs at the probe tip to the test circuit:

1. Connect the blue Signal lead to the voltage that is to be measured, ensuring that the attenuating tip used has sufficient input dynamic range to measure the signal (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. 22AWG wires or 0.100" pitch pin headers work well with the tip socket.

   Alternately, the micro-grippers may also be used to connect to the test circuit (right). The micro-gripper has provisions for 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 measurement potential will damage the DUT and/or HVFO 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.

Optimizing Performance

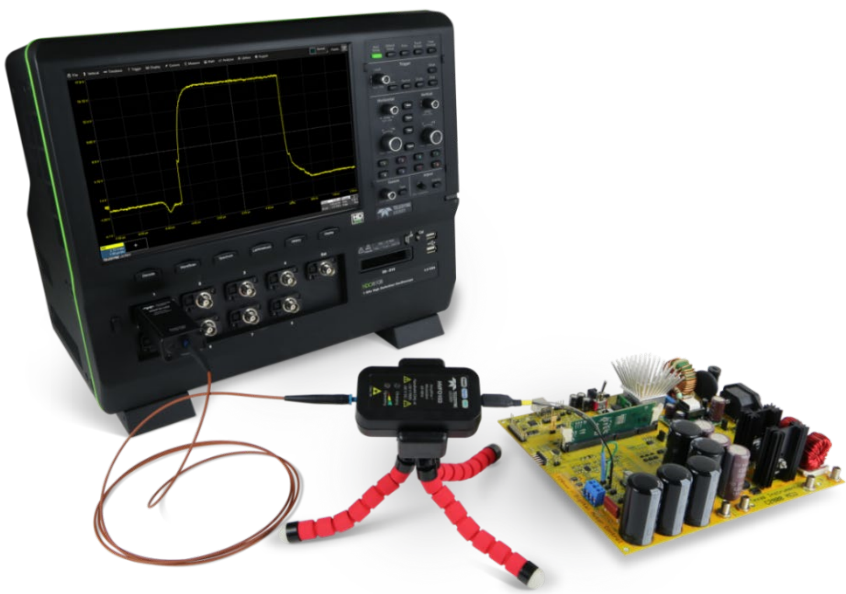
To maintain the probe's high performance capability, exercise care when connecting the probe. Increasing the parasitic capacitance or inductance in the input paths may introduce a "ring" or slow the rise time of fast signals.

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 MΩ. The oscilloscope probe control functions are activated, and the C*n*HVFO103 dialog appears behind the C*n* dialog of the probe input channel.

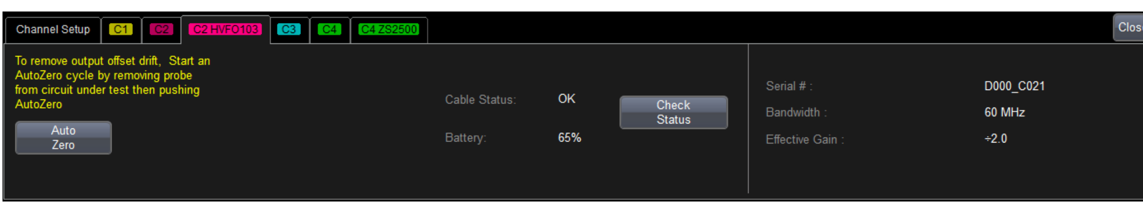
Once a tip is connected to the transmitter, the oscilloscope will set the proper probe attenuation according to the information received from the tip. A colored LED will blink on both the transmitter and the demodulating receiver, keyed to the state of the HVFO battery. Progress from green to yellow 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.21).

Operating with an Oscilloscope

When the entire HVFO103, 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 HVFO103 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 ÷2, while a 20x tip will have a total attenuation of 40x and effective gain is ÷40.



HVFO103 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 its life and should be replaced.

Battery indicates the remaining battery life. 100% is roughly equivalent to 6 hours of life.

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: $\text{Oscilloscope Front End V/Div} = (\text{Probe and Oscilloscope})\ \text{V/Div} \div \text{Total Probe Attenuation}$

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 HVFO103 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

The battery is recharged through the same USB Micro-B interface that connects the tip during operation. This is to ensure safety of the operator and other equipment as it precludes charging while the probe is operating (and floating above ground).

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. To recharge the battery, either:

- Use the USB to USB Micro-B charging cable (supplied) to connect the transmitter to a USB port on the oscilloscope or another computer.
- Use a USB charger (not supplied) and connect to power.

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

CAUTION: If you plug into the USB port of a powered down computer or oscilloscope, the battery will not charge, it will keep discharging ("operating" light is lit). Make sure the computer or oscilloscope is plugged in and powered on.

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 three hours if connected to the oscilloscope (or PC), or one and a half hours if using a USB charger.

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

Performance Verification

HVFO103 probes are shipped from Teledyne LeCroy are tested as a system (transmitter with demodulating receiver) and adjusted to meet the DC Gain Accuracy specification. This procedure can be used to verify the warranted performance of an HVFO103, or to test and calibrate an HVFO103 system where a different transmitter or receiver has been introduced. Test results can be recorded on a photocopy of the HVFO103 Test Record provided in this manual.

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.

Note: Operating the probe requires firmware version 8.3.x.x or higher. To confirm the version, choose Utilities > Utilities Setup from the oscilloscope menu bar, then open the Status tab.

Required Test Equipment

The following equipment (or its equivalent) is required for performance verification of the HVFO103 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, HDO8000, MDA800
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, 50Ω, 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 C1HVFO103 tab appears behind the C1 setup dialog. This confirms that the probe is sensed.
2. Open the C1HVFO103 dialog and touch **Auto Zero**, then **OK**.
3. Confirm that the message "Performing AutoZero on HVFO103...." is displayed in the message bar, and that no error messages are displayed.

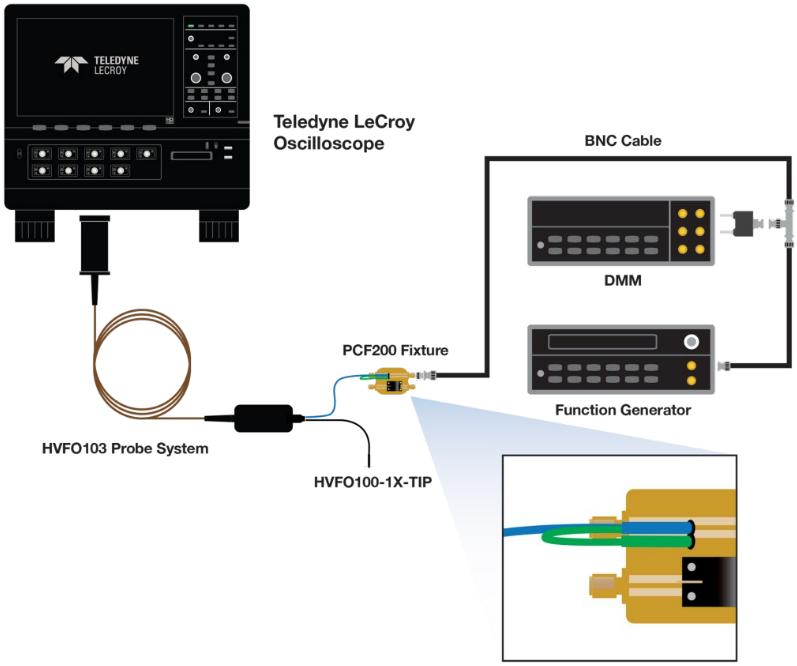
Before You Begin

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 HVFO103-1X-TIP 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 $V_{PK\text{-}PK}$.
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 ± 1 mV_{RMS}).
7. Record the ampl(C1) measurement on the test record.
8. Calculate the gain accuracy (%) using the equation:

$$(Step\ 7\ value - 1.0) * 100$$

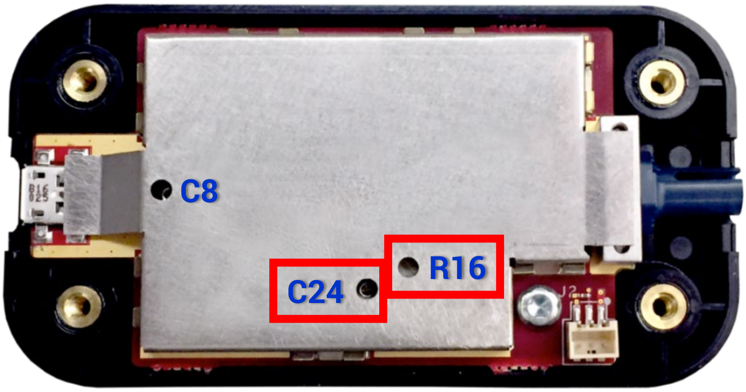
9. Record the gain accuracy on the test record.

Adjust Gain Accuracy

If the HVFO103 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 (ampl 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 C24 so that the ampl of C1 is maximized.
4. Carefully adjust the resistor R16 so that the ampl of C1 is equal to 1.00 ± 0.010 V.

Note: Do not adjust C8.



HVFO103 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	HVFO103 Measured Voltage	V_{PK-PK}	
8	Gain Error (< ± 2.00%)		%

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 HVFO103 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 field replaceable. See the instructions provided with the replacement battery.

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.26.

Service Strategy

The HVFO103 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.

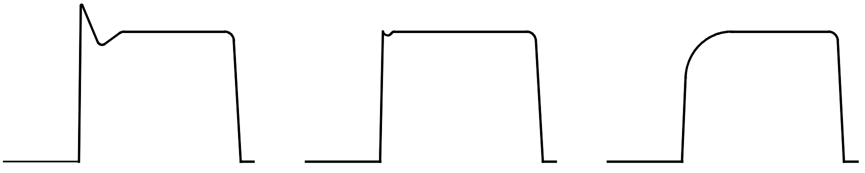
CAUTION: Refer all servicing to qualified personnel. A defective probe under warranty will be replaced with a factory refurbished probe.

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

Returning a Product for Service

Contact your regional 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 device.
2. Pack the product in its case, surrounded by the original packing material (or equivalent). Do not include the manual.
3. Label the case with a tag containing:
   - The RMA
   - Name and address of the owner
   - Product model and serial number
   - Description of failure or requisite service
4. Pack the product case in a cardboard shipping box with adequate padding to avoid damage in transit.
5. 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
6. If returning a product to a different country:
   - Mark the shipment as a "Return of US manufactured goods for warranty repair/recalibration."
   - If there is a cost for the service, list the cost in the Value column and the original purchase price "For insurance purposes only."
   - Be very specific about the reason for shipment. Duties may have to be paid on the value of the service.

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

Technical Support

Live Support

Registered users can contact their local Teledyne LeCroy service center at the number listed on our website. You can also request Technical Support via the website at:

teledynelecroy.com/support/techhelp

Resources

Teledyne LeCroy publishes a free Technical Library on its website. Manuals, tutorials, application notes, white papers, and videos are available to help you get the most out of your Teledyne LeCroy products. Visit:

teledynelecroy.com/support/techlib

Service Centers

For a complete list of offices by country, including our sales and distribution partners, visit:

teledynelecroy.com/support/contact

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

Sales and Service:
Ph: 800-553-2769 / 845-425-2000
FAX: 845-578-5985
contact.corp@teledynelecroy.com

Support:
Ph: 800-553-2769
customersupport@teledynelecroy.com

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_{RMS}/60 V_{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.

IEC/EN 61010-031:2015 Definitions

Measurement Category III (CAT III) applies to test and measuring circuits connected to the distribution part of the building's low-voltage mains installation.

Measurement Category II (CAT II) applies to test and measuring circuits connected directly to utilization points (socket outlets and similar points) of the low-voltage mains installation.

No Rated Measurement Category applies to other circuits that are not directly connected to the mains supply.

Pollution Degree 2 refers to an operating environment where normally only dry, non-conductive pollution occurs. Conductivity caused by temporary condensation should be expected.

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, b) improper connection to incompatible equipment, or c) 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 product. 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

Teledyne LeCroy certifies compliance to the following standards as of the date of publication. For the current certifications, see the EC Declaration of Conformity shipped with your product.

EMC Compliance

EC Declaration of Conformity - EMC

The HVFO probe meets the intent of EC Directive 2014/30/EU for Electromagnetic Compatibility. Compliance was demonstrated to the following specifications as listed in the Official Journal of the European Communities:

IEC/EN 61326-1:2013 EMC requirements for electrical equipment for measurement, control, and laboratory use [1]

Electromagnetic Emissions:

IEC/EN 55011/A1:2010 Radiated and Conducted Emissions Group 1 Class A [2] [3]

Electromagnetic Immunity:

IEC/EN 61000-4-2:2009 Electrostatic Discharge, 4 kV contact, 8 kV air, 4 kV vertical/horizontal coupling planes [4]

IEC/EN 61000-4-3/A2:2010 RF Radiated Electromagnetic Field, 3 V/m, 80-1000 MHz; 3 V/m, 1400 MHz - 2 GHz; 1 V/m, 2 GHz - 2.7 GHz

1 To ensure compliance with the applicable EMC standards, use high quality shielded interface cables.

2 This product is intended for use in nonresidential areas only. Use in residential areas may cause electromagnetic interference.

3 Emissions which exceed the levels required by this standard may occur when the probe is connected to a test object.

4 Meets Performance Criteria “B” limits of the respective standard: during the disturbance, product undergoes a temporary degradation or loss of function or performance which is self-recoverable.

European Contact:*

Teledyne LeCroy Europe GmbH
Im Breitspiel 11c
D-69126 Heidelberg
Germany
Tel: (49) 6221 82700

Australia & New Zealand Declaration of Conformity - EMC

The probe complies with the EMC provision of the Radio Communications Act per the following standards, in accordance with requirements imposed by the Australian Communication and Media Authority (ACMA):

AS/NZS CISPR 11:2009/A1:2010, IEC 55011:2009/A1:2010 Radiated and Conducted Emissions, Group 1, Class A.

Australia / New Zealand Contacts:*

RS Components Pty Ltd.
Suite 326 The Parade West
Kent Town, South Australia 5067

RS Components Ltd.
Units 30 & 31 Warehouse World
761 Great South Road
Penrose, Auckland, New Zealand

* Visit teledynelecroy.com/support/contact for the latest contact information.

Safety Compliance

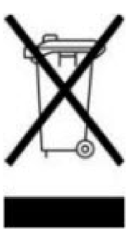
EC Declaration of Conformity – Low Voltage

The probe meets the intent of EC Directive 2014/35/EU for Product Safety. Compliance was demonstrated to the following specifications as listed in the Official Journal of the European Communities:

IEC/EN 61010-031:2015 Safety requirements for electrical equipment for measurement, control and laboratory use – Part 031: Safety requirements for handheld probe assemblies for electrical measurement and test.

Environmental Compliance

End-Of-Life Handling



The probe is marked with this symbol to indicate that it complies with the applicable European Union requirements to Directives 2012/19/EU and 2013/56/EU on Waste Electrical and Electronic Equipment (WEEE) and Batteries.

The probe is subject to disposal and recycling regulations that vary by country and region. Many countries prohibit the disposal of waste electronic equipment in standard waste receptacles. For more information about proper disposal and recycling of your Teledyne LeCroy product, visit teledynelecroy.com/recycle.

Restriction of Hazardous Substances (RoHS)

The product and its accessories conform to the 2011/65/EU RoHS2 Directive.

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TELEDYNE LECROY
Everywhereyoulook™

700 Chestnut Ridge Road
Chestnut Ridge, NY 10977
USA

teledynelecroy.com