AKL-PT5 7 GHz Passive Probe Operator Manual

Antikernel Labs

November 13, 2022

Contents

1 Overview

1.1 Manufacturer

Antikernel Labs
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1.2 Warranty

Antikernel Labs warrants this probe to meet published specifications during ordinary laboratory use and operation for a period of one (1) year from date of shipment and will repair or replace, at its sole option, any defective product. This warranty covers manufacturing and assembly defects only. Damage caused by negligence, misuse, accident, unapproved alterations, or exceeding published operating limits is specifically not covered. The tip resistor, ground lead, and mounting wire are consumable and are expected to degrade over time from repeated soldering, desoldering, and flexing; damage from ordinary wear and tear is not covered.

Antikernel Labs's maximum liability under this warranty is limited to the replacement value of the probe. Antikernel Labs will not be liable for any direct, indirect, special, exemplary, or consequential damages (including, but not limited to, procurement of substitute goods or services, loss of use, data, or profits; or business interruption) arising in any way out of the use of this probe, even if advised of the possibility of such damage.

1.3 Open Hardware

The most up-to-date design files for this probe may be found on GitHub under the 3-clause BSD license, including:

- KiCAD schematic
- KiCAD board layout
- Board fabrication notes including stackup and impedance
- Sonnet field solver models

The current location of design files as of this writing is: `https://www.github.com/azonenberg/starshipraider/`, under the AKL-PT5 subdirectories.

1.4 Regulatory Compliance

This probe is RoHS compliant. Exemption 6(c), lead in copper alloys, applies to the brass connector bodies. All other components of the probe and cable, including solder, are lead free.

2 Safety Information

To avoid personal injury, damage to the probe, or damage to the attached instrument, it is important to understand and follow the warnings and specification limits in this document.

- Only personnel familiar with the safe use and operation of electronic test equipment should use this probe.
- Do not connect the ground terminal of this probe to any voltage other than earth ground.
- Do not exceed operating limits in the specifications section of this document.
- The soldermask on this probe is *not* rated for insulation against hazardous voltages, and conductive elements are exposed at the tip and connector. Do not use this probe on any circuits which may contain voltages exceeding 30 Vrms, or the touch-safe voltage limit in your organization's standard operating procedures if this is lower.
- Do not operate in damp or wet conditions, or under temperature/humidity extremes in which condensation is likely.
- Do not operate this probe in a flammable or explosive atmosphere.
- Wear eye protection and ensure good ventilation when soldering.
- The SMPM connector center terminal is made from beryllium copper (BeCu) alloy. While exposure to beryllium is expected to be insignificant during ordinary use of this product as the BeCu is in solid form and covered by gold plating, hazardous dust could potentially be generated if the contact material is ground or abraded.

  CA PROP 65 WARNING: This product can expose you to beryllium, which is known to the State of California to cause cancer.

3 Theory of Operation

Tha AKL-PT5 probe is a *transmission line probe* and works very differently from high-impedance passive or active probes many engineers are familiar with. It is intended primarily for probing relatively low impedance (50Ω), high bandwidth digital signals, which ordinarily require expensive active probes to properly examine.

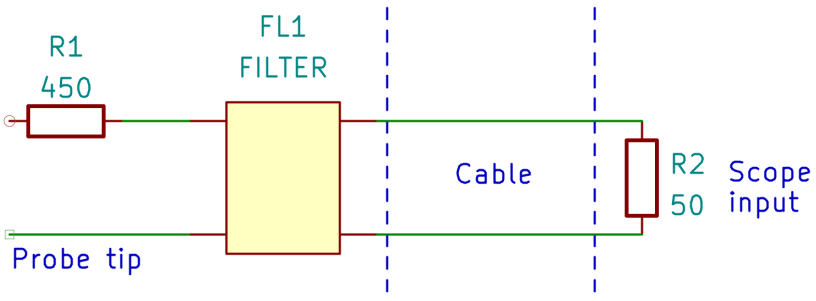

Figure 1: Simplified probe schematic

The signal is split off from the DUT at the point of contact and travels through a 450Ω resistor at the probe tip. A distributed element filter applies a low-pass response to compensate for parasitic capacitance of the tip resistor, which would otherwise create undesired peaking. It then travels on 50Ω transmission line through a SMPM connector and coaxial cable to the oscilloscope, which terminates the signal with 50Ω to ground.

The tip resistor and termination form a 10:1 voltage divider, so the oscilloscope sees the incident signal attenuated by a factor of 10 (-20 dB). *Note that a* 50Ω *termination at the instrument is required. This probe cannot be used with lower-cost oscilloscopes that only have* $1M\Omega$ *terminations.*

The tip resistor and scope-side termination in series present a total loading of 500Ω on the DUT. While this is a significantly lower DC impedance than conventional probes, the resistive input stage has extremely flat frequency characteristics with much less capacitance than conventional passive probes. This means that the impedance of the probe remains comparatively constant across the entire operating range, rather than greatly decreasing at higher frequencies.

4 Usage Instructions

Proper soldering and desoldering technique is crucial to getting the best performance and lifetime from your probe.

4.1 Probe Coupling

Transmission line probes such as the AKL-PT5 have significantly higher DC loading than a the common $10M\Omega$ passive R-C divider probe, and may interact poorly with pull-up/pull-down resistors or level shifters with automatic direction sensing. Consider AC coupling (using an industry standard SMA inner DC block before the scope input), or use of a different type of probe for these applications.

4.2 Test Point Design

The probe tip leads are flexible and can mate with signal and ground contacts at arbitrary spacing from 0 to 8mm. The natural spacing of signal and ground contacts, requiring the least amount of bending of the leads, is 2.0 mm.

Avoid placing test points in confined spaces between components or in other difficult-to-reach locations. The probe PCB is nominally 5.6 mm wide so a minimum width of 6.0 mm is suggested for a free fit allowing for PCB routing tolerances. Sufficient clearance around the signal and ground contacts for hand soldering must be provided, taking into account the location of the probe PCB itself.

4.3 Placing and Securing

4.3.1 Site Selection and Optimal Placement

Determine which side of the test point you intend for the probe to approach from and ensure a good ground point is easily reachable, removing solder mask if necessary.

If your probe is configured with the ground lead on the wrong side[1] of the signal contact, desolder it and reattach it to the opposite footprint.

The probe should approach the test point from a fairly steep angle: a 45 to 60 degree angle from horizontal usually works well. This minimizes coupling between the tip leads/resistor and signals or ground planes on the DUT, which can introduce crosstalk to measurements or degrade bandwidth. Avoid placing the probe body or leads parallel to the board whenever possible.

4.3.2 Mounting the Probe Head

The probe leads are fragile and not intended to be load bearing. When working with any solder-in probe, it is critical to provide a firm mechanical attachment *before* soldering the tip. Securing a probe operating at microwave frequencies, such as the AKL-PT5, requires additional care to avoid degrading the performance of the system.

The AKL-PT5 contains an integrated mounting fixture consisting of an 0.5 inch (12.7 mm) square FR4 “foot" and a 2.1 inch (55 mm) length of 20 AWG (0.81mm) insulated solid copper wire, attached to each other and the probe head with SAC305 solder. To mount the probe, begin by selecting a suitable location for the mounting foot, typically about 1 inch (25 mm) from the test point. The upper surfaces of ICs or connectors are often good locations for the foot, as seen in Fig. 2.

[1]For convenience, the AKL-PT5 is available with one of two ground lead placements from the factory, to the left (AKL-PT5L) or right (AKL-PT5R) of the signal contact as seen with the SMPM connector facing upward. The PCB is identical for both SKUs, and a probe can be easily swapped between configurations in the field with a soldering iron.

Select a piece of double-sided tape and attach one side of the tape to the underside of the mounting foot. The AKL-PT5 ships with sample quantities of two different types of tape: a clear acrylic elastomer and a white polyurethane foam. For information on ordering additional tape, see the Ordering Information section.

Both tapes may be removed from the probe and DUT without damage or leaving residue if appropriate care is exercised, however the white foam tape provides significantly greater holding force when attached to typical PCB materials. It is typically used for longer term, semi-permanent measurements; the clear tape has a weaker adhesive and may be preferable for shorter term use when the probe is expected to be frequently repositioned.

Hold the foot in place and place the probe head close to the test point to check the fit. Adjust the mount as needed so that the leads are floating a short distance (roughly the thickness of the probe PCB) above the test point, accounting for the thickness of the mounting tape.

Remove the liner from the tape and secure the foot to the desired location.

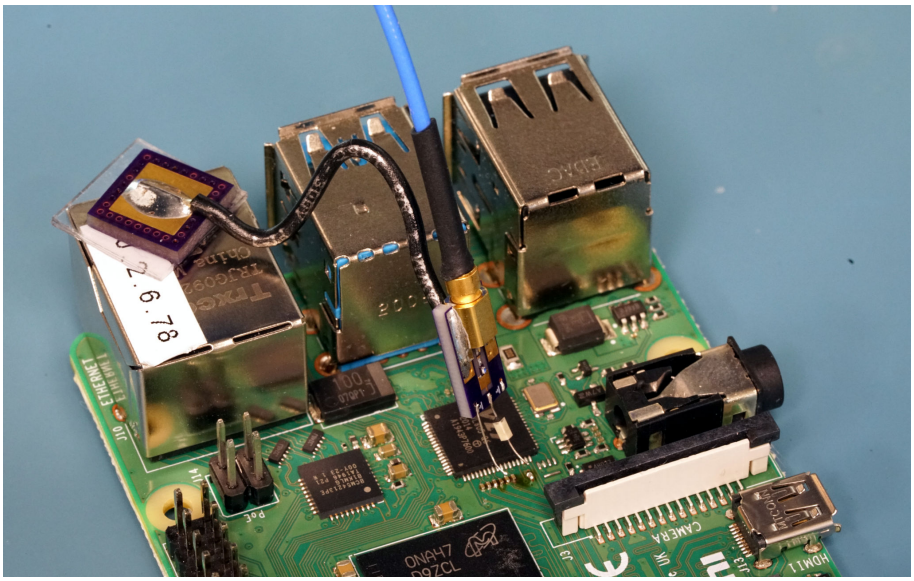

Figure 2: AKL-PT5 probe mounted to DUT with double-sided adhesive square and ready to solder. Note placement of mounting foot on connector.

4.3.3 Attaching and Securing the Cable

Once you are satisfied with the placement, if the probe head and cable are not already attached, connect the SMPM cable to the probe head by grasping the cable connector and probe PCB firmly and pressing the connectors straight into each other, as shown in Fig. 3. You may hear or feel a slight click when the connector seats fully, but this may not be noticeable in every case.

Make sure to hold the probe by the edges to avoid exerting force on the leads. Do not twist or rotate the connectors during or after mating.

CAUTION: DO NOT attempt to mate or unmate the SMPM connector once the probe is soldered to the DUT. This is very likely to result in the probe moving enough to damage the test point, probe, or both. Always mate the connector prior to soldering, and desolder the probe prior to unmating.

The coaxial cable attached to the probe should also be secured to prevent applying excessive force to the probe body, as the mounting wire is too flexible to resist a significant tug on the cable without the probe head moving. Any method providing adequate mechanical

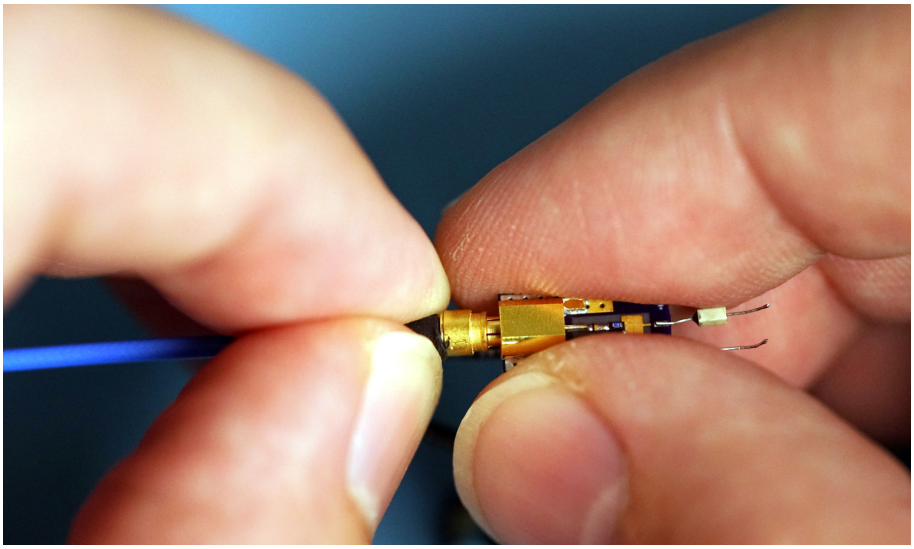

Figure 3: Connecting the probe and cable.

support while respecting the minimum bend radius of the cable (0.1 inch / 2.54 mm) may be used.

For a small DUT it may be necessary to either loop the cable back over the board before taping it down (see example setup using polyimide tape in Fig. 4) or tape both the DUT and cable to the bench. Leave sufficient slack at the probe end of the cable to allow motion during soldering, and to act as a strain relief in case the main length of the cable is accidentally bumped or tugged.

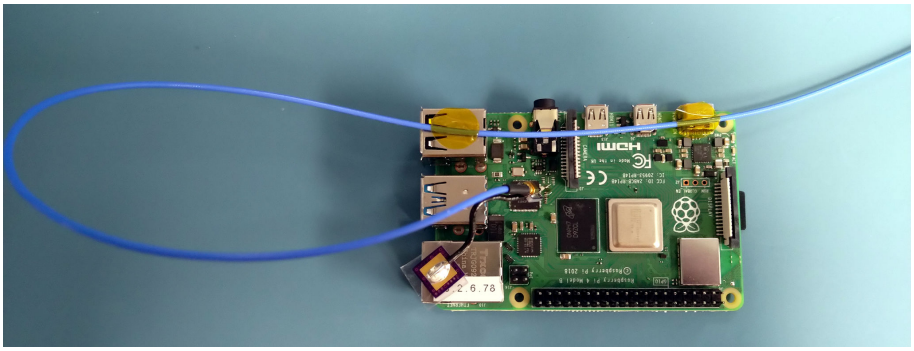

Figure 4: Securing cable to DUT with polyimide tape

4.4 Soldering

Once the mounting foot is secured to the DUT and the mounting wire is bent correctly, the signal and ground leads should be floating just above the test point. Use tweezers to pre-bend the signal and ground leads so that the tips are correctly spaced for your test points. The probe body should be roughly centered between the signal and ground points so that both leads bend approximately the same amount. The goal is for the springiness of the mounting wire to hold the leads under very slight tension once soldered - just enough to keep them taut, but not enough to place significant force on the solder joints.

Remove soldermask from the signal and ground test points with a scraper if necessary, and tin the points with a fine point soldering iron.

Apply a small amount of flux to the ground test point. Manipulate the probe body with one hand while holding the soldering iron in the other. Gently move the probe body to press

the ground lead against the tinned test point, then melt the solder to form the joint. Do not tug directly on the ground lead with tweezers as this places significant stress on it.

Ensure the solder solidifies fully before letting go of the probe. (Soldering the ground point before the signal point helps reduce mechanical stresses on the DUT signal traces, which are typically smaller and less mechanically robust than large ground planes or bypass capacitor pads.)

Apply flux to the signal test point, then use tweezers to position the signal lead against the tinned test point and solder it. Inspect the joints as necessary. Remove excess flux after soldering using isopropyl alcohol on a lint-free swab.

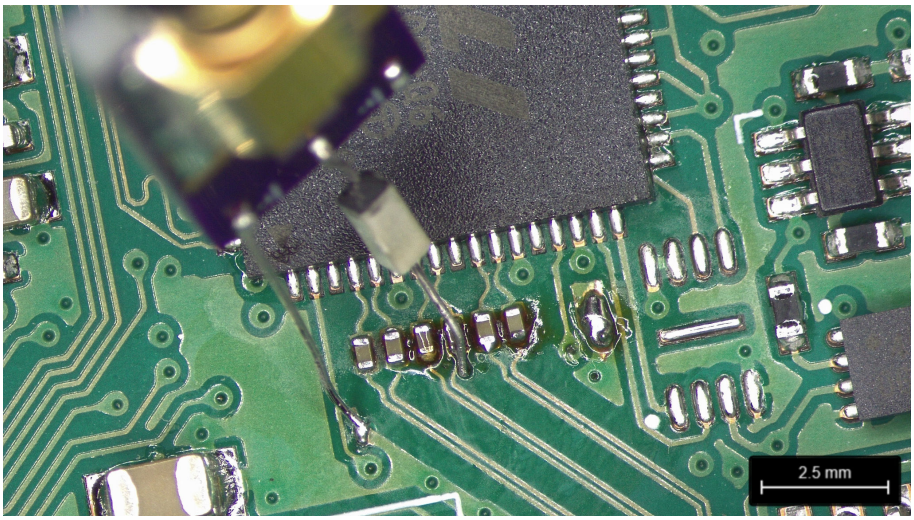

Figure 5: AKL-PT5 tip soldered to test point

4.5 Desoldering

Use a soldering iron to melt the solder on the signal contact, then gently nudge the probe tip wire to one side with tweezers. Desolder the ground lead after the signal lead is free of the DUT, holding the probe body or mounting wire with your other hand to prevent it from moving suddenly as the solder melts.

Remove any excess solder from the tip leads and test points with desoldering braid.

After desoldering is complete, gently peel the mounting foot off the DUT and discard the used adhesive pad. The clear tape's adhesive has a lower peel strength and should not require any special techniques to remove; the white tape is significantly stronger and requires more effort to remove. It may be necessary to apply some prying force at a corner of the foot-to-tape joint with a spudger or similar tool. Once the probe is free of the tape, the tape on the DUT should come free easily by peeling from one corner, without leaving behind any residue on the probe or DUT.

To unmate the cable from the probe, grasp the probe head by the edges between two fingers with one hand while holding the SMPM connector of the cable between two fingers of the other hand and pull them apart with a slight rocking motion. Do not apply any force to the coaxial cable or heat shrink tubing as these are not designed to handle significant tensile loads. You may be able to get a better grip on the cable connector by using your fingernails to pull the front face of the connector away from the probe (Fig. 6)

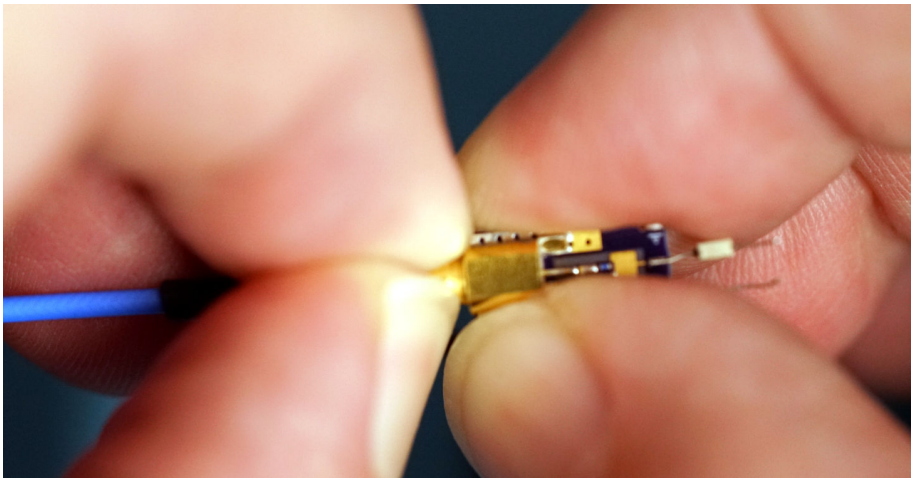

Figure 6: Disconnecting SMPM connector. Note placement of fingernail. TODO: re-shoot with better focus.

4.6 Maintenance and Repair

4.6.1 Replacing the Mounting Wire

The mounting wire is considered to be a consumable and is expected to eventually fail from repeated bending over the lifetime of the probe. The mounting wire may be easily replaced with a new piece of wire by hand soldering when this happens, or if a longer, shorter, stiffer, or more flexible mount is preferred. The factory-supplied mounting wire is a 2.1 inch (55 mm) length of 20 AWG (0.81mm) insulated solid copper.

The solder joint connecting the mounting wire to the underside of the probe head is covered by a peelable blue polyurethane mask (Dymax E-MAX 906-B or similar) to reduce the risk of accidentally short-circuiting the DUT. This mask may be easily peeled away with tweezers to enable desoldering of the mounting wire. Once a new mounting wire is installed, flux residue should be removed and the solder joint re-covered with an insulative material. Electrical tape, polyimide tape, or a similar peelable maskant are all acceptable for this purpose.

4.6.2 Replacing the Tip Resistor or Ground Lead

The tip resistor and ground lead are expected to fail over time from repeated bending and soldering cycles. The ground lead may also need to be moved from one side to the other in order to fit a particular DUT.

TODO: talk about details of parts and procedure

4.7 Cleaning and Storage

To avoid attracting dust or corroding the tip contacts, when the probe is being stored it is best to remove flux residue from the tip area. This may be done with isopropyl alcohol and a lint-free swab, or any other industry-standard flux remover suitable for the flux in question.

The SMA connector on the supplied cable is gaged before shipment to ensure the pin and dielectric position are within tolerance, however it is good practice to gage the connector periodically to detect any gradual misalignments as the connector wears.

The probe should be stored in the provided foam-lined cardboard box when not in use to protect the fragile tip contacts from mechanical damage. The foam and cardboard are static dissipative to ensure ESD safety and prevent charges from building up on the probe which could damage surrounding equipment, however the probe itself has no active components and is relatively insensitive to ESD.

4.8 Cables

The AKL-PT5 must be connected to the host instrument via a 50Ω coaxial cable terminated with a SMPM female connector at the probe side. Highly flexible cabling, such as 0.047" / 1.19mm micro coax, is preferred for mechanical reasons despite having higher loss than larger cables: thicker flexible cables are much stiffer and springier, and unless perfectly straight are likely to apply significant forces to the solder joints.

The stock cable supplied with the probe kit is Koaxis part number AO10-KF047-RO10-36.00-MC-TD, and comes with individually serialized S-parameters for de-embedding. Longer or shorter cables using the same KF047 cable stock, or using a connector other than SMA at the instrument end, may be ordered directly from Koaxis if required for your application.

For specialized applications requiring very low loss, consider use of hand formable cables. Although they have limited lifetime, their relative lack of springiness once bent allows thicker cabling to be used without applying excessive force to the probe.

The cable should be taped to a lab bench or the DUT as shown in Fig. 4, or otherwise secured to prevent transferring any force into the probe.

5 Mechanical Specifications

Description	Typ	Units
Mass (probe head and mounting foot)	xx	g
Height (probe head)	xx	mm
Length (probe head PCB)	10.2	mm
Length (probe head and tip resistor)	xx	mm
Width	5.3	mm

6 Electrical Specifications

Values in this section are typical / limit values. For measured values from a specific probe, please consult your calibration certificate.

6.1 Absolute Maximum Ratings

Exceeding these limits may result in permanent damage to the probe. Ratings in this section are stress ratings only and normal operation at these limits is not implied.

Parameter	Description	Limit	Units
T_{amin}	Minimum temperature	0	$°C$
T_{amax}	Maximum temperature	95	$°C$
I_{max}	Maximum sustained current	xx	mA
V_{maxT}	Maximum sustained tip voltage	xx	$Vrms$
V_{maxV}	Maximum instantaneous tip voltage	xx	$Vrms$

ENGINEERING NOTE: The sustained current/voltage limits are thermally limited and based on the 50 mW power rating of the 200Ω tip resistors. Brief pulses or low duty cycle waveforms whose average power does not exceed these limits *may* be possible to probe safely with the AKL-PT5 as long as tip voltage does not exceed the instantaneous voltage limit at any time, however Antikernel Labs has not performed any testing of the probe under pulsed load conditions. Use of the probe with instantaneous power levels exceeding the thermal limits will void the warranty and customer assumes all risk of harm to personnel and equipment resulting from such usage.

6.2 Recommended Operating Conditions

While the probe will not be damaged by exposure to conditions outside the values in this section (but below the “Absolute Maximum Ratings" limits), tolerances may be temporarily exceeded.

Parameter	Description	Limit	Units
T_{min}	Minimum temperature	15	°C
T_{max}	Maximum temperature	45	°C

6.3 DC Characteristics

Parameter	Description	Min	Typ	Max	Units
G_{dc}	Gain across 50Ω load[2]		0.094		V/V
R_{gnd}	Signal path resistance from SMPM to tip	xx	xx	xx	Ω
R_{sig}	Ground path resistance from SMPM tip	xx	xx	xx	Ω
TCR	Temperature coefficient of resistance			±100	ppm / °C

[2] Assuming ideal 50Ω termination at instrument

6.4 AC Characteristics

Data in this section is based on characterization in a 50Ω environment, with cable and fixture effects de-embedded, unless otherwise stated.

Parameter	Description	Min	Typ	Max	Units
S_{11o}	S_{11} across open circuit from DC - 6 GHz	xx	xx	xx	dB
S_{21}	S_{21} from DC - 6 GHz	xx	xx	xx	dB
BW	-3 dB bandwidth	8.0	8.5		GHz
BW_{nodbed}	-3 dB bandwidth including cable losses		4		GHz
$Rise_{90}$	Rise time (10-90 %)		xx	xx	ps
$Rise_{80}$	Rise time (20-80 %)		xx	xx	ps
Tpd	Propagation delay		xx		ps

7 Performance Graphs

7.1 Insertion Loss

Figure 7: S_{21} range of probes across 50Ω termination

7.2 Group Delay

Figure 8: Group delay variation of probes

7.3 Return Loss

Figure 9: Variation in S_{11} of probes across 50Ω load

Figure 10: Variation in S_{11} of probes across open circuit

7.4 Step Response

Figure 11: Typical response of AKL-PT5 to fast rising edge (200ps/div)

8 Performance Data

If you requested full characterization at the time of your order, test measurements are available at https://www.antikernel.net/downloads/AKL-PT5/caldata/ and searching for your probe's serial number. All measurements are de-embedded to the SMPM connector or probe tip, as applicable.

The following S-parameter data files are provided:

- probe.s2p - probe across 50Ω load with cable de-embedded
- cable.s2p - the provided cable
- system.s2p - probe across 50Ω load including cable effects

Touchstone port 1 is connected to the DUT side of the probe and port 2 (if applicable) is connected to the instrument side.

9 Ordering Information

9.1 Probe

The standard AKL-PT5 kit includes the probe head, mounting foot, serialized SMA to SMPM cable with S-parameters, and a starter pack of double-sided mounting tape.

Probe heads may also be purchased with no accessories (other than the mounting foot) for use with existing cables.

Item	Supplier	Part number
Probe kit, left hand ground	Antikernel Labs	AKL-PT5L-KIT
Probe kit, right hand ground	Antikernel Labs	AKL-PT5R-KIT
Probe head only, left hand ground	Antikernel Labs	AKL-PT5L-HEAD
Probe head only, right hand ground	Antikernel Labs	AKL-PT5R-HEAD

9.2 Cable

The cable supplied in the AKL-PT5 accessory kit is 36 inches in length, SMA straight plug (m) to SMPM straight plug (f), and made from Koaxis KF047 0.047" coaxial cable. Cables are individually serialized and include S-parameters to 26.5 GHz.

For specialized applications, cables of other lengths or with different scope-side connectors may be ordered directly from Koaxis. Antikernel Labs recommends using only KF047 cable or equivalent highly flexible micro coax with the AKL-PT5 to avoid placing excessive mechanical forces on the probe head or solder joints.

Item	Supplier	Part number
Standard cable	Koaxis	AO10-KF047-RO10-36.00-MC-TD

9.3 Consumables

Item	Supplier	Part number
Mounting tape, clear rubber	Scotch	MMR103B
Mounting tape, white polyurethane foam	McMaster-Carr	76535A21
Mounting wire (25 ft spool)	Remington Industries	20UL1007SLDBLA25
Tip resistor [3]	Antikernel Labs	AKL-PT5-RESISTOR
Ground lead [4]	Antikernel Labs	AKL-PT5-GROUND

[3] Vishay Dale part number HML01450RFKE05, trimmed to 7.5 mm overall length by Antikernel Labs

[4] 0.188 mm (approximately 33 AWG) x 7.5mm tin-plated nickel wire