Treetop Circuits

Owner's Manual for LC-2 Active Probe System

Version 1

Overview

This system provides the high input impedance associated with active probes, but has design features which provide an unusually rugged and versatile probe with a wide range of capabilities.

The probe is always used with one of four detachable attenuator tips. These provide an attenuation of 10:1 or 100:1 from probe tip to instrument, and a choice of AC or DC coupling. Using an attenuator tip reduces the input capacitance, and provides current limiting to protect the amplifier if an excessive voltage is accidentally applied.

Fig. 1: Probe body with 10:1 Dc-coupled tip and ground lead attached.

The main probe body contains an amplifier and matching circuit to drive the 50-ohm cable connecting it to the instrument; it also contains power conditioning circuitry, which in turn is driven by a 15-volt universal power converter. (*Fig. 1 and 2*).

In many cases, it is necessary to observe a small AC signal which is superimposed on a large DC voltage. The AC-coupled tips are used for this. The AC coupling provided on many oscilloscopes will be ineffective, because the DC voltage must be blocked before it reaches the amplifier.

The probe is designed to work with a 50-ohm load, which typically is provided by the instrument itself. In many oscilloscopes, the input impedance is much higher than this, as mentioned above. In this case, a 50-ohm through-terminator must be used at the instrument input.

The Probe Kit (*Fig. 2*)

The probe system is normally supplied in a kit, consisting of:

1. The probe body, with flexible 50 inch (1.3 m)coaxial cable and power conductors.
2. A universal power converter, which provides operating power for the probe circuitry. The converter is suitable for worldwide application. One input connector for the region in which the probe will be used is included. Input connectors for other regions are available. Use of other supplies is not recommended.
3. A set of four attenuator tips providing 10:1 and 100:1 attenuation, with DC and AC coupling. An adjusting tool is included.
4. Two ground leads of different lengths, and an extra clip so the user can make up custom ground leads.
5. A slip-on shield for use if stray coupling occurs.

Fig. 2: The probe kit, as supplied. A slip-on aluminum shield (not shown) is also included. The power converter is shown with a North American mains connector. Connectors for other regions are available.

Using the Probe System

!! Never attempt to use the probe without an attenuator tip. Damage can result !!

!! Remember that you may be in contact with instrument ground when using a probe. Make sure that circuit ground and instrument ground are connected together independent of the probe ground connection !!

We recommend that you read the section on Probe Basics at some point. You may wish to do this now before proceeding further.

Familiarize yourself with the operating limits in the Specifications section. Note that there is a large difference between the operating limits and the "damage" limits, so the probe will survive unintended contact with out-of-range voltages in most cases.

Connect the converter to the probe power connector. Connect the power converter to the mains.

Select one of the tips and screw it firmly onto the probe body. Remember that the voltage at the instrument will be attenuated by 10:1 or 100:1 (20 or 40 dB) depending on the tip selected. It is best to use an AC-coupled tip unless you need to preserve DC or low-frequency signal components.

Check the maximum voltage rating of the instrument input. Under extreme overload conditions, the probe can produce up to 1.7 volts DC or 1.7 volts peak AC (+15 dBm) into a 50-ohm load. If this exceeds the instrument rating, it is ***strongly recommended*** that you use a suitable DC blocking capacitor and/or attenuator at the instrument input.

Connect the probe to the instrument input; remember to use the terminator if the instrument has a high-impedance input.

Operation from this point on is straightforward. The probe body will feel warm; this is normal. With the probe tip not connected to a signal source, you may notice an increased tendency to pick up local electrical noise. This is normal; due to its very high impedance, an active probe is inherently sensitive to electric fields when not connected to a source.

Shielding

The attenuator tips use an open style of construction to minimize capacitance to ground. In nearly all circumstances, this causes no problems. However, particularly when a 100:1 tip is used, high-level signals present on nearby circuitry may couple into the circuitry in the tip. In such cases, the slip-on shield can be used.

Grounding

In addition to reducing loading on the circuit, an active probe makes it easier to avoid grounding problems. This is because the ground return current is about 10 times less than in the case of a typical 10:1 passive probe.

Improper ground connections are probably the biggest single source of problems in probing high-frequency circuits. The subject is often ignored because of its apparent simplicity; in reality, it is anything but simple. While the use of an active probe reduces the problem significantly, an understanding of the issues remains important.

The problem exists because the signal transmitted from the probe to the instrument is the voltage between the probe tip and the probe body, which is fine if the probe body remains at circuit ground potential. But in practice, the probe body will generally be connected to circuit ground through a short ground lead, which has an effective inductance of the order of nanohenries. The ground return current, which is inversely related to the probe input impedance, flows through this ground-lead impedance, thus creating a voltage difference between the probe body and circuit ground. In addition, at high frequencies, the ground lead may resonate with the probe input capacitance, or transmission-line effects may appear in the ground lead.

Lowering the input capacitance reduces all these effects because the current in the ground lead is reduced by a similar factor.

To illustrate the importance of this, both traces in *Fig. 3* show the same rectangular pulse displayed on an oscilloscope with a 275 MHz bandwidth. The upper trace is produced by an active probe with a 10:1 tip, and the lower trace by a good-quality 10:1 passive probe. Both probe tips are connected together to the same pulse source, and the probe bodies are grounded through similar leads about four inches(100 mm) long. The oscilloscope settings are 10 nS/major division and 0.5 volt/major division.

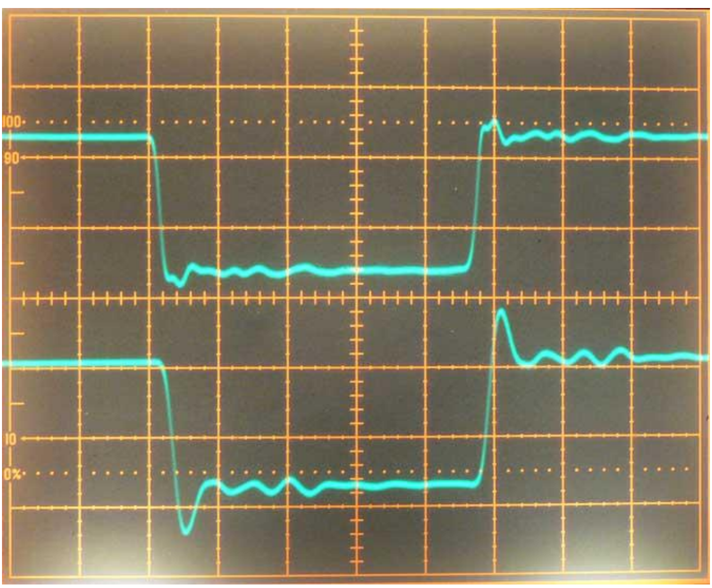

Fig. 3: Improvement in transient response due to reduced ground return current (upper trace). Horizontal scale is 10 ns per major division.

Attenuator Tips and Calibration

The probe is always used with one of the attenuator tips. These reduce the effective input capacitance of the probe, and protect the amplifier from damage due to high voltages. Since 10:1 and 100:1 tips are provided, the available range of input voltages is increased.

The DC tips act as resistive dividers for signals from DC to about 40 kHz; at higher frequencies, they act as capacitive dividers.

In the AC probes, all coupling is through the trimmer capacitor, which acts together with the other capacitances to form a voltage divider. Response drops off below about 7 kHz with the 10:1 AC tip and 700 Hz with the 100:1 AC tip, falling to zero at DC.

The trimmer capacitors are factory-set before the probe kit is shipped. The adjustments are not affected by instrument input characteristics, and the trimmers are unlikely to need frequent readjustment. That said, the adjustments should be checked periodically. Also, they depend on the input capacitance of the individual probe, so they should be checked if a replacement tip is purchased or a tip is used with another probe.

There are many ways to verify correct operation and adjust the trimmers. Two methods are described here.

When the probe is used with an oscilloscope, it is convenient to use the square-wave calibration signal which is available at the front panel of most oscilloscopes. The signal is suitable if the amplitude is between 300 millivolts and 10 volts p-p, the risetime is one microsecond or less, and the frequency is less than 10 kHz.

Typical pulse responses for correctly and incorrectly adjusted tips are shown in *Figs. 4 to 7*.

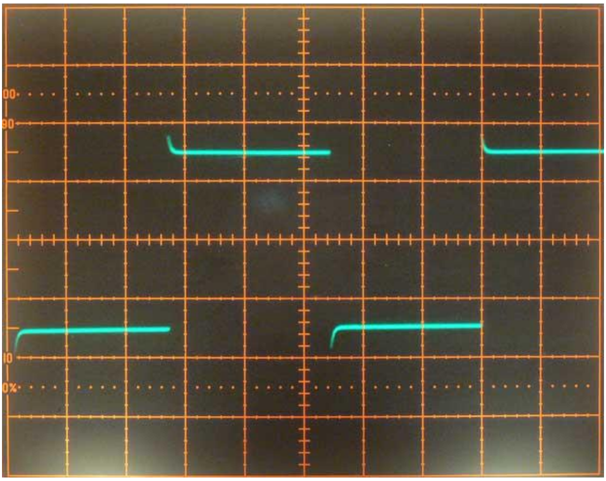

Fig. 4: DC-coupled tip. Trimmer capacitance too high, causing high frequencies to be accentuated. Horizontal scale is 200 microseconds per major division.

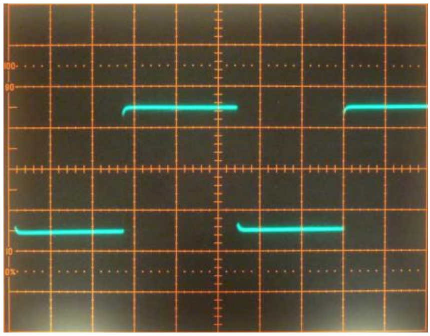

Fig. 5: DC-coupled tip. Trimmer capacitance too low, causing high frequencies to be attenuated. Horizontal scale is 200 microseconds per major division.

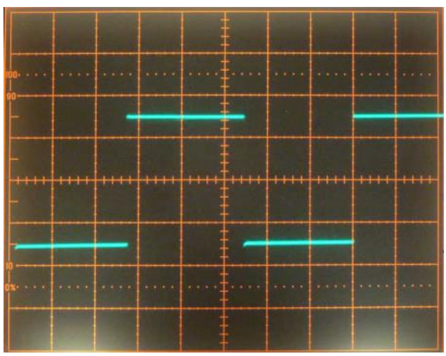

Fig.6: DC-coupled tip. Trimmer capacitance is correct. Frequency response is flat, and pulses will be displayed correctly. Horizontal scale is 200 microseconds per major division.

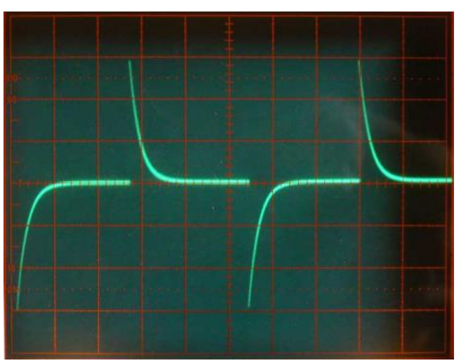

Fig. 7: A 300 millivolt rectangular wave viewed using a 10:1 AC-coupled tip. Scales are 10mVand 200 microseconds per major division. When the trimmer is set correctly, the peaks will be 3 divisions above and below the center line.

Alternatively, a sinusoid of known amplitude can be used. Any frequency between 500kHz and 100 MHz is suitable. This is available from the calibrator in many spectrum analyzers. Compared to a direct connection from source to instrument, the signal should be down 20 dB with a 10x tip or 40 dB with a 100x tip. Remember that such sources are normally specified in RMS volts, so if such a source is used in conjunction with an oscilloscope the p-p voltage will be 2.828 times the given value.

In all cases, remember that the calibrator may require a specific load (often 50 ohms) to produce the rated voltage. At low frequencies a discrete resistor may be used. At higher frequencies a through-terminator is recommended because it avoids the reactive effects of component leads, and the terminator output can be probed directly.

Probe Basics

A probe's function is to transfer the signal at the probe tip accurately to the measuring instrument. It should present the circuit being tested with as high an impedance as possible to minimize the loading effect of the probe on the circuit.

In most situations, passive probes are perfectly adequate and there is no need to resort to active probes, which are invariably more expensive than their passive counterparts and are subject to other limitations. But there are situations in which an active probe is needed. A brief overview of the limitations of passive and active probes, and the reasons for these limitations, may be helpful, as follows:

With a passive probe, our ability to achieve a high impedance at the probe tip is limited by the input impedance of the instrument and by the properties of the cable between the probe and the instrument.

Most spectrum analyzers, network analyzers, and high-frequency oscilloscopes have 50-ohm coaxial inputs. If a 50-ohm cable is connected to such an input, the other end of the cable will always present a 50-ohm resistive load, regardless of cable length. A 1:1 passive probe can be constructed by simply attaching small clips or equivalent to the end of the cable, and connecting them to the circuit under test. However, in most cases, applying a 50 ohm load to the circuit in this manner will alter circuit operation to the point where the results are meaningless, and damage to the circuit and/or the instrument may result, so this arrangement is seldom used.

A more practical approach is to incorporate a suitable resistor in the probe body, so that the voltage is divided between the resistor and the 50-ohm input of the cable (*Fig. 8*). With a 450 ohm resistor, the circuit sees a 500 ohm load, and there is a 10:1 attenuation of the voltage. If a higher impedance is needed, a 4950 ohm resistor will present a 5000 ohm load to the circuit, but there will be a 100:1 attenuation of the signal. Both of these arrangements are commonly used.

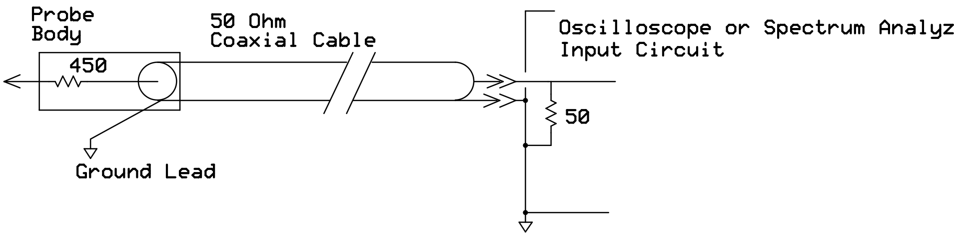

Fig. 8: A 10:1 probe used with a 50-ohm instrument.

Some instruments, such as oscilloscopes with bandwidths up to a few hundred megaHertz, have a higher input impedance, typically one megohm in parallel with a capacitance of 10 – 20 pF. At frequencies up to a few megahertz, simple 1:1 probes can be used; the probe simply provides a direct connection to the instrument via a coaxial cable. Since the capacitance between the inner conductor and sheath of the cable appears in parallel with the input of the instrument, the cable typically has a very thin inner conductor to minimize this capacitance. Such probes are useful at low frequencies, but as frequency increases the capacitance may affect the circuit being tested. Also, the attainable characteristic impedance of the cable is of the order of a few hundred ohms, so it is seriously mismatched. At frequencies exceeding a few megahertz, reflections will affect the readings, and may also affect circuit operation.

For these reasons, the most widely used probe for such instruments is probably the 10:1 passive probe. The probe body contains a 9-megohm resistor in parallel with a small capacitor; this capacitor has a value of 1/9th of the total capacitance of the instrument and the cable (*Fig. 9*). The voltage divides between this combination and the combination of the instrument and cable capacitances. From DC to middle audio frequencies, this arrangement acts as a 10:1 resistive divider. As frequency increases, it transitions smoothly to a capacitive divider. At still higher frequencies, reflections in the cable have to be eliminated, so a small box containing a complex array of passive components is typically incorporated with the connector to provide a termination for the cable. Unfortunately, the terminated cable presents a significant resistive load, so at these frequencies, the actual impedance seen at the probe tip bears little resemblance to the nominal impedance (10 megohms in parallel with 10 or so pF) of the probe, and a resistive load of the order of hundreds of ohms is present.

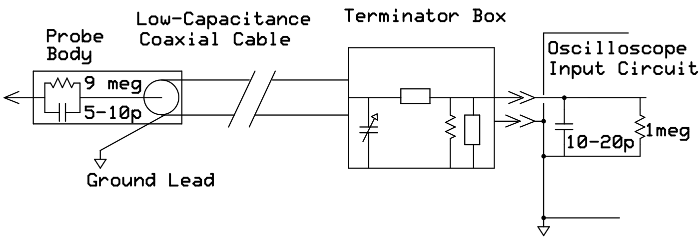

Fig. 9: A 10:1 passive probe used with a typical high-impedance oscilloscope input. The termination box generally contains more components than shown here.

In an active probe, a small amplifier with a very high input impedance and a wide bandwidth is built into the probe body. The amplifier also has the ability to produce significant output current to drive the coaxial cable leading to the instrument. An active probe has an essentially capacitive input impedance over a very wide frequency range. The input capacitance is a few picofarads or even less.

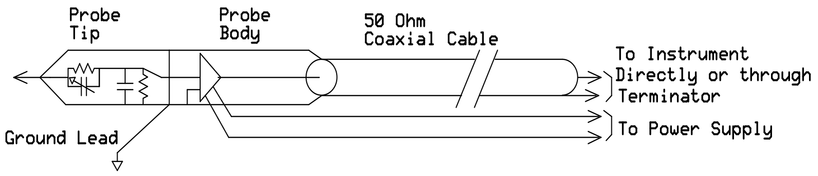

Fig. 10: A simplified diagram of the Treetop Circuits LC-2 probe.

An active probe is inevitably more expensive than a passive probe, and requires a power supply. Its ability to handle high signal levels is limited by the available output swing of the amplifier, and decreases as the frequency increases due to slew-rate limiting in the amplifier.

Unless a DC reference must be preserved (as when observing digital signals), it is generally better to use an AC-coupled tip.

Because these factors must be kept constantly in mind, most users will stick with passive probes for most work. That said, active probes can extend significantly the effective capabilities of the instruments with which they are used.

Specifications

Attenuation (from probe tip to 50 ohm load), trimmers set according to procedure

With DC-coupled tip:
10:1 +/- 5% at DC, flat within+/- 3 dB to 1 GHz.
100:1 +/- 5% at DC, flat within+/- 3 dB to 600 MHz.

With AC-coupled tip:
10:1 tip – Flat within +/- 3 dB from 7 kHz to 1 GHz
100: 1 tip – Flat within +/- 3 dB from 700 Hz to 600 MHz

The probe is usable well beyond the stated frequency ranges, but must be calibrated against a known signal.

Input impedance (measured at 100 MHz)
With 10:1 DC-coupled tip: 10 megohms in parallel with 1.1 pF

With 100:1 DC-coupled tip: 10 megohms in parallel with 0.9 pF

With 10:1 AC-coupled tip: 1.1pF

With 100:1 AC-coupled tip: 0.9pF

Power Requirements:

100 – 240 VAC, 50 – 60 Hz, 3 watts., when equipped with appropriate mains connector

Maximum Applied Voltage at Tip:

200 volts (DC plus peak AC). **Beyond this level, damage may occur.**

Noise (at instrument)

Above 50 kHz : -155 dBm/Hz, or 69 microvolts RMS in 300 MHz.
At 1 kHz : -135 dBm/Hz
Noise referred to tip will be 20 or 40 dB higher for 10:1 and 100:1 tips respectively.

Measurement Limits (referred to probe tip) see *Figs. 11 to 13.*

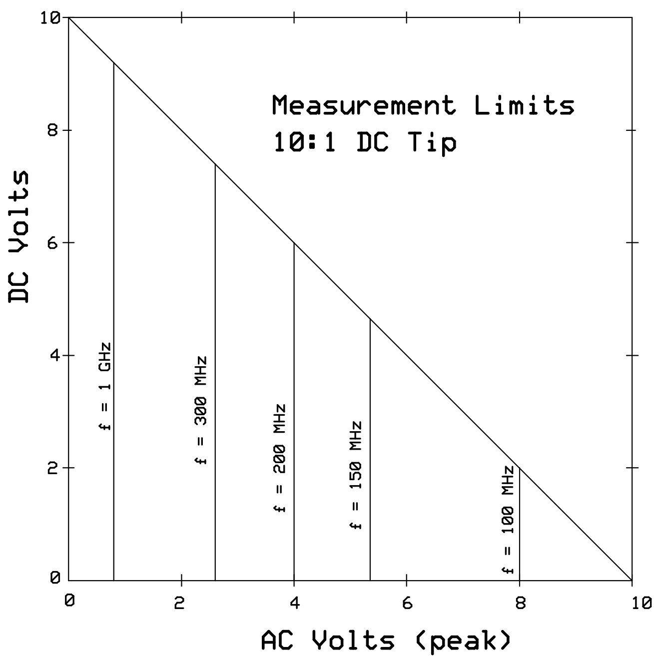

Fig. 11: Measurement limits for combined AC and DC signals with 10:1 DC-coupled tip. Locate the point on the graph representing the DC and peak AC voltages. If it is below the sloping line and left of the vertical line for the frequency, the signal is within limits.

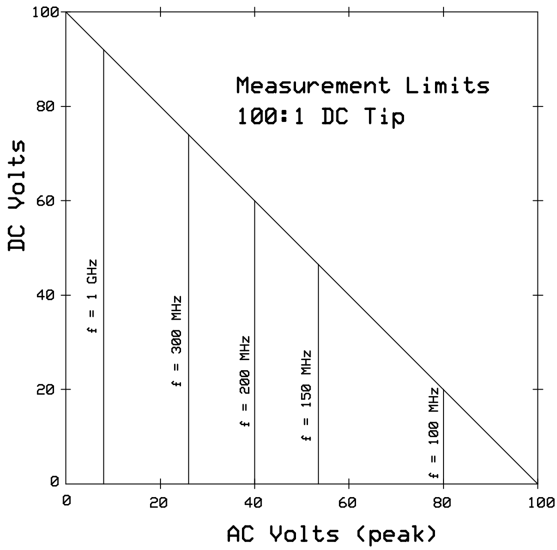

Fig. 12: The same as Fig. 11, but for a 100:1 DC-coupled tip.

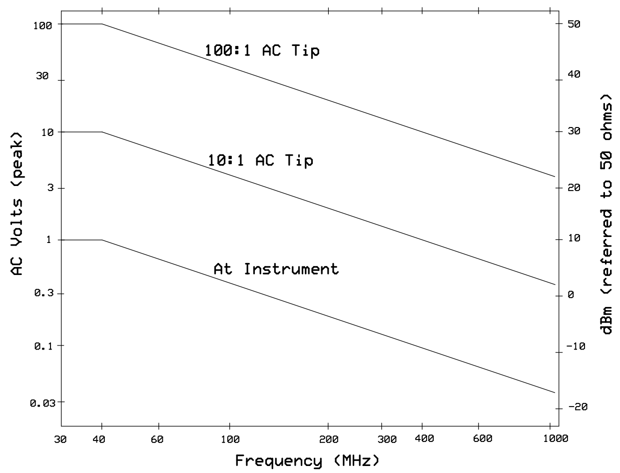

Fig. 13: Maximum signal levels using AC-coupled tips. The dBm scale on the right is convenient when using the probe with a spectrum or network analyzer.

Warranty

If you are not satisfied with the product for any reason, you can ship it back to us at your expense. Provided that it is shipped within 30 days of purchase, and we receive it in good condition, we will refund the amount you paid us – that is, full purchase price plus shipping one way.

If the product fails in normal use within one year from date of purchase, return it to us at your expense. We will repair or replace it (our option) at no charge and ship it back to you at no charge. We will not be responsible for damage caused by electrical overload, mechanical abuse, or other events beyond our control, including (but not limited to) power surges and lightning hits.

After the one-year warranty period, repairs due to failures in the probe or accessories will be carried out for a flat fee of $45 U.S. plus shipping both ways. We will also perform repairs needed for other reasons such as normal wear or mishap for this fee, but extra charges may apply to heavily damaged units. In this case, we will contact you before proceeding.

If you ship the unit, it must be packed in a manner equivalent to the original packaging, to protect against damage due to mechanical shock and electrostatic discharge. Be advised that Customs services in most countries, including Canada, require proper documentation. The requirements are generally straightforward, but must be observed if lengthy delays are to be avoided

Our liability is limited to the above; we are not responsible for damage caused to other equipment due to malfunction of this product, or for other losses caused by its malfunction.

Treetop Circuits
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