Active Probes

Active Probes for the LeCroy Analog Oscilloscopes

Typically a passive probe's impedance, principally input capacitance, decreases as the applied frequency increases. This limits the use passive probes in certain applications. One solution is the use of active probes which have lower input capacitance and extend high impedance capabilities to full scope frequency bandwidth. LeCroy Analog oscilloscopes have Active Probe connections on the front panel for easy access and, FET Probe Offset controls are a standard feature.

PROBING:

The probe is used to provide a convenient, reliable and repeatable method of coupling the Device Under Test (hereafter DUT) to the oscilloscope. The probe is used to minimize measurement error due to loading, poor shielding and limited frequency bandwidth.

Consider the problems that arise when a wire is connected directly from a DUT to the input terminal of an oscilloscope:

1) Susceptible to interference, and noise

2) Limited frequency bandwidth

3) Large loading effect on DUT

The first problem can be remedied by the use of coaxial cable or shielded wire. However, this does not resolve problems 2 or 3.

The second problem, the frequency bandwidth is limited, as a result of the inductance and stray capacitance of the wire. Use of a 10:1 probe will reduce such effects.

The third problem, the large loading effect, is due to the poor impedance match between the DUT and oscilloscope. This can be minimized by the use of the appropriate probe.

In any measurement a certain degree of measurement error and uncertainty arises from the DUT and, measurement instruments. The instrumentation accuracy and measurement technique constitutes a large portion of the error. The unwanted interaction of the DUT and the measurement system causes any measurement made to have a degree of uncertainty.

The key point for oscilloscope measurements is probing. When measuring a circuit, a small amount of energy is taken out through the probe, this is known as “loading”; the smaller the amount of energy taken out, the smaller the influence on the circuit under test. It is necessary to consider the influence of the probe on the circuit under test.

It is common to perform measurements using the probes supplied with the oscilloscope when purchased. However, other types of probes are available for specific applications such as low impedance, low capacitance or high voltage probes.

Consider the connection of oscilloscope input and DUT via shielded wire vs. 10:1 probe.

<u>10:1 Probe:</u>
1.5 meter and input capacitance of 15pF

<u>Shielded wire:</u>
1.5 meter and total capacitance of 150pF (assuming 100pF/m)

<u>Oscilloscope:</u>
Input capacitance 30pF

<u>Wire and Scope combination:</u>
150pF+30pF = 180pF (added in parallel). The large capacitance will adversely affect measurement accuracy and response time.

<u>Probe and Scope combination:</u>
Approximately 15pF (added in series). Amplitude will be attenuated by 1/10, but the DUT will be only minimally loaded by the connection.

BANDWIDTH (f_{Bw}):

The purpose of a probe is to provide a satisfactory impedance match between the oscilloscope and the DUT. Probes have frequency bandwidth limitations, which can be calculated from the following:

$$f_{bw} = \frac{1}{2pR_s(C_s + C_o)}$$

where:

f_{Bw} = 3dB cutoff frequency

R_s = Source resistance

C_s = Source capacitance

C_o = O'scope capacitance

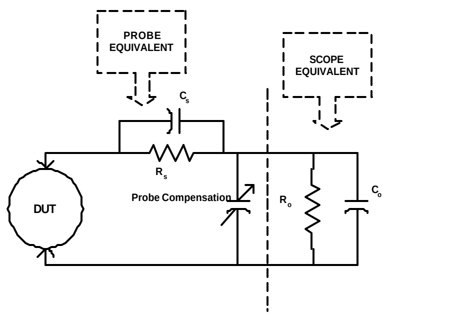

Figure 1: Equivalent Circuit

For example, consider a DUT with circuit impedance of 510Ω. If a 15pF probe is connected to the DUT what is the frequency bandwidth for this configuration?

Simplified from above:

$$f_{bw} = \frac{1}{(6.28)(510)(15E-12)}$$

$$= 20.8\text{Mhz}$$

Therefore, any measurements of frequencies above 20.8Mhz are reduced due to limited bandwidth.

LOADING EFFECT:

It does not seem obvious that the connection of an ordinary 10:1 probe to a DUT would have a large loading effect on the DUT. The normal resistance of a 10:1 probe is 10MΩ and a 15pF capacitance. This is true when considering the DC operation of the DUT. However, as the measured signal frequency of the DUT increases the probe impedance decreases.

Consider the effect of a 1Mhz signal on the impedance of a 10:1 probe. Assume the relationship of frequency and capacative reactance is:

$$X_c = \frac{1}{2pfc}$$

$$X_c = \frac{1}{(6.28)(1E+6)(15E-12)}$$

Approximately 10.6kΩ

Now consider the effects of a 10Mhz signal using the same 10:1 probe.

$$X_c = \frac{1}{(6.28)(1E+7)(15E-12)}$$

Approximately 1kΩ

In these examples it becomes apparent that a 15pF capacitance will change the impedance value of the probe as the measured frequency changes. The result in RC time constant change may cause undesired changes in pulse rise/fall times and cause signal delays in the DUT which can result in unstable operation. Some examples of circuits in which this might be cause for serious concern are high-speed logic circuits.

F.E.T. PROBE:

The Field Effect Transistor (F.E.T.) probe is composed of a wide band buffer amplifier that has a low input capacitance (≤3pF typical) in comparison with a common passive probe (15pF typical) and high input impedance. The reduction in input capacitance is intended to reduce the probe influence on the DUT. It is important to remember F.E.T. probes have some special limitations. First, F.E.T. probes require an external source of power for operation. Second, F.E.T. probes have limited voltage range and may require external attenuation for large voltage measurements.

GROUND LEAD:

It is necessary to consider the effects of ground lead connections made to a DUT. When signals of greater than 10MHz are measured the amplitude is affected by the connection of the ground lead. This is of particular importance when measuring high-speed signals such as emitter coupled logic (ECL). In such cases it is necessary to minimize the length of the ground lead connection so as to minimize the effect of stray inductance, which adversely effects bandwidth of the probe connection. This can be ac-

Probe	*f_{Bw}*	*Input R*	*Input C*	*Max Input*
10:1 Passive	400MHz	10MΩ	15 pF	600V
F.E.T.	1GHz	1MΩ	2 pF	100V
Low Impedance	3GHz	500Ω	0.7 pF	16V

complished by using the short bayonet clip on probe tip ground attachment in place of the alligator clip ground.

The input impedance vs. frequency characteristics of the above probes demonstrates the input impedance of the common 10:1 and 1:1 probes become lower than the FET probe when the input frequency is greater 10kHz. The input impedance of the common 1:1, 10:1 and FET probes decreases < low impedance probe for frequencies > 10 MHz. The low impedance probe is generally usable up to 1GHz.

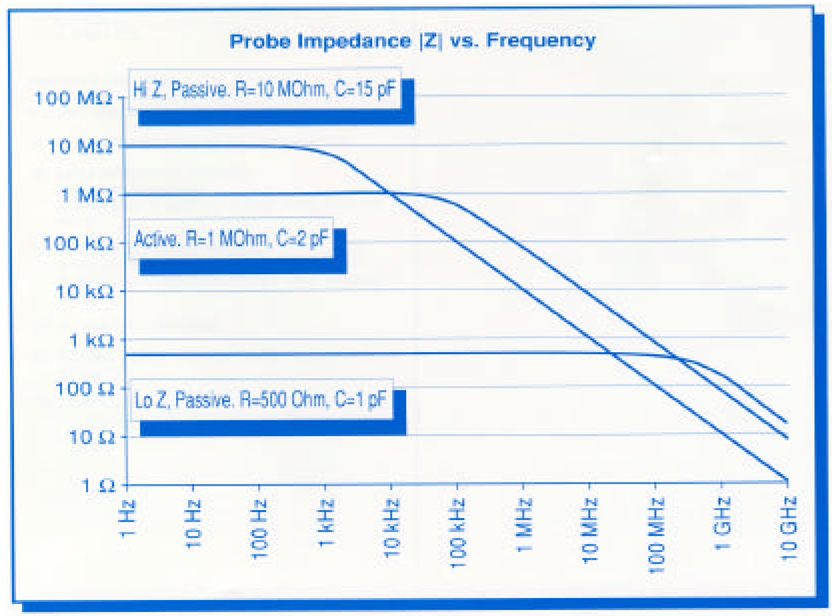

Figure 2: Passive Vs Active Probe impedance derating curves

PROBE MODEL	SPF-5A	SPF-4A
SPEC f_{BW}	DC-1GHz, -3dB	DC-800MHz, -3dB
ATTENUATION	10:1 +/-2.5%	10:1 +/-2.5%
WEIGHT	~180 g	~180 g
LENGTH	~1.5m	~1.5m
PROBE TIP I/P R	1MΩ +/-5%	1MΩ +/-5%
PROBE TIP I/P C	1.9pF	2.15pF
OVERSHOOT	< +/-10%	< +/-10%
RINGING	< +/-4%	< +/-4%
OFFSET O/P VOLTAGE	<15mV	<15mV
MAX I/P VOLTAGE (Frequency derated)	+/-100V	+/-100V
DYNAMIC RANGE	+/-7.0V	+/-7.0V
DC OFFSET RANGE	+/-20V	+/-20V
O/P RESISTANCE	50 Ohms +/-1%	50 Ohms +/-1%
POWER SUPPLY REQUIREMENTS	+12V to +15V at 74mA	+12V to +15V at 74mA
(Standard on LA314, LA314H and LA354)	-12V to –15V at 74mA	-12V to -15V at 74mA
GUARANTEED PERFORMANCE ENVIROMENT	+5C to +35C at 45% to 85% RH	+5C to +35C at 45% to 85% RH
OPERATING ENVIROMENT	-10C to +55C @ 40% to 90% RH	-10C to +55C @ 40% to 90% RH
STORAGE ENVIROMENT	-20C to +70C	-20C to +70C

Table 2: SFP-4A and SFP-5A Active Probe Specifications

The LA314, 314H and 354 oscilloscopes are configured for use of active FET probes as a standard feature.

Standard active probe features provided with LeCroy analog oscilloscope features are:

a) Two front panel FET power and control connections
b) Dual FET probe DC Offset, Per Cent vertical display control
c) Input coupling selection

The use of active FET probes extends the probe tip frequency bandwidth to exploit the full capability of the oscilloscope.

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