Basic Communication Laboratory Manual

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CONTENTS

Chapter 1
THE OSCILLOSCOPE

1.1 Objectives

This experiment deals with basic and advanced time domain measurement, and. The purpose of the laboratory is to develop the skill needed to

use basic laboratory equipment, to characterize basic electronic circuits, which demonstrate the real capability and limitation

of time domain measurement. Upon completion of the experiment the student will:

- Understand the function of each main block of the oscilloscope.
- Making basic and advanced measurements with a oscilloscope.
- Know- the limitations of the oscilloscope.
- Possess the necessary tools to evaluate signals in time domain.

1.2 Prelab

1. Find the dc value (average value) and rms value of sawtooth signal as indicated in figure -1

2. Using Matlab, draw a graph of trianglewave, frequency 100k Hz, amplitude $1V_p$,in time domain and frequency domain (magnitude only), using the data calculate the THD and SINAD(dB) of the trianglewave. (see figure-2)

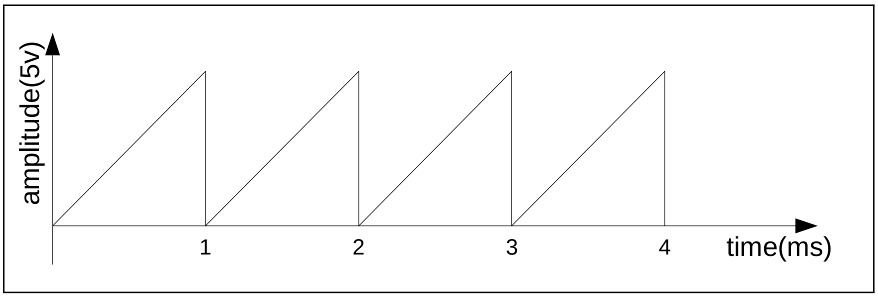

Figure 1 Problem-1 sawtooth signal

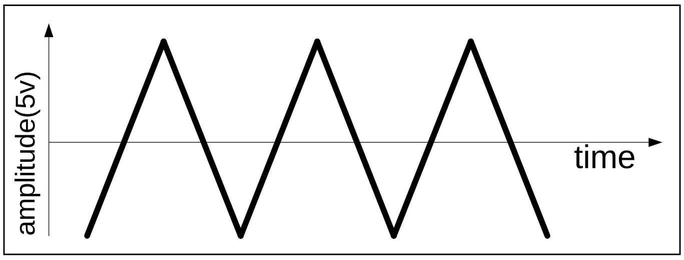

Figure 2 Problem-2 trianglewave

1.3 Background Theory- Analog Oscilloscope

In order to use an analog oscilloscope, you need to adjust three basic settings to accommodate an incoming signal:

* The time base- This sets the amount of time per division (usually written as time/div or sec/div) represented horizontally across the screen. The horizontal scale control on your oscilloscope lets you adjust the time base.

* The attenuation or amplification of the signal- The vertical scale control lets you adjust the amplitude of the signal before it is applied to the vertical deflection system.

* The triggering of the oscilloscope- This control lets you stabilize a repeating signal, as well as triggering on a single event.

1.4 Digital Oscilloscopes- Coupling and input section

Digital Oscilloscopes uses the same system as those in analog oscilloscopes; however, digital oscilloscopes contain additional data processing capability systems. (See Figure 2.) Digital oscilloscope collects data for the entire waveform and then displays the incoming signal.

When you attach a probe to a circuit, the vertical system coupled to the signal and adjusts the amplitude of the signal using attenuator or amplifier as necessary. Coupling means the way used to connect an electrical signal from one circuit to the another. in our case the coupling can be set to DC, AC or ground. DC coupling connect the signal directly to the vertical system and shows all of an input signal components (see Fig.-4). AC coupling connect the input signal through capacitor, therefore capacitor blocks the DC component of a signal (see Fig.-3), so that you see the waveform centered at zero volts.Next, the analog-to-digital converter (ADC) in the acquisition system samples the signal at discrete points in time and converts the signal's voltage at these points to digital values called sample points, and store the data at channel memory. The horizontal system's time base clock determines the rate of the A/D converter sample. The rate at which the clock "ticks" is called the sample rate, and is measured in samples per second. Sampling methods used usually fall into two types:

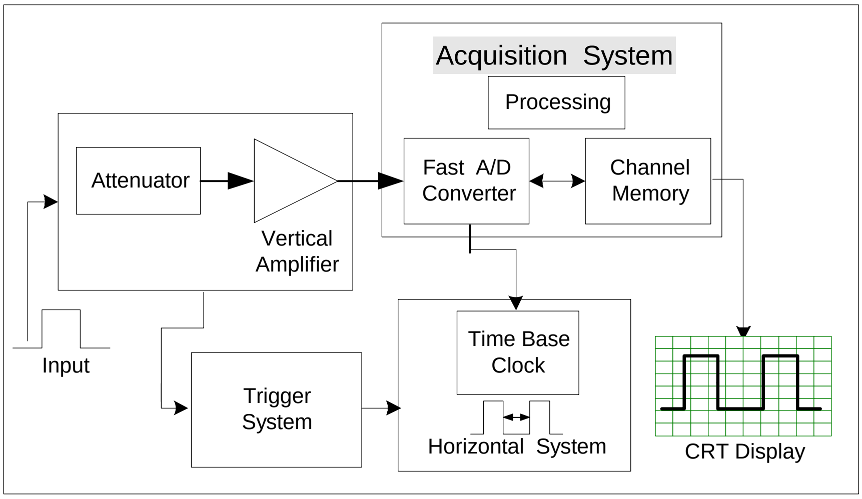

Figure 3 Major blocks of digital oscilloscope

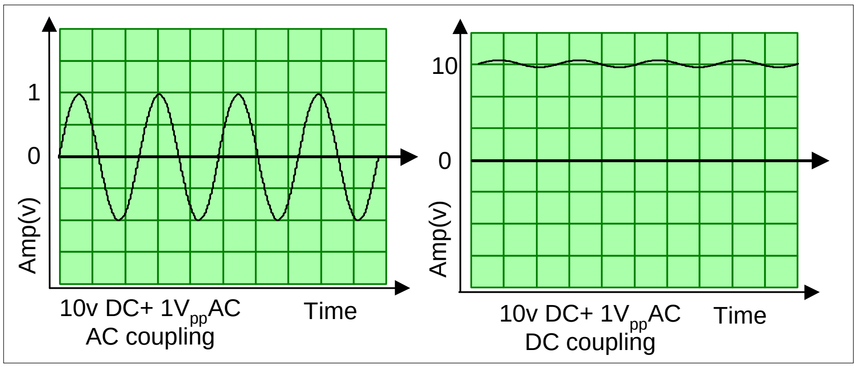

Figure 4 AC and Dc coupling of composite signal

* Real-time sampling.

* Equivalent time sampling.

The sample points from the A/D converter are stored in memory as waveform points. More than one sample point may make up one waveform point. Together, all the stored waveform points make up one waveform record. The number of waveform points used to make a waveform record is called the record length. The trigger system determines the start and stop points of the record. The display receives these record points after being stored in memory. Depending on the capabilities of your oscilloscope, additional processing of the sample points may take place, enhancing the display. Pre-trigger may be available, allowing you to see events before the trigger point. With a digital oscilloscope, you need to adjust these main control settings to take a measurement.

* The time base. This sets the amount of time represented by the width of the screen. The horizontal scale control (Time/Div) on the oscilloscope lets you adjust the time base.

* The attenuation or amplification of the input signal. The vertical scale control (Volt/Div) lets you adjust the amplitude of the signal before sending it to the Analog to Digital Converter.

* The triggering. This control (Trigger) mark the system, the process of the acquisition signal, stabilize a repeating signal, capture a single-shot signal,

* The acquisition mode and sampling method. These settings depend on the frequency and complexity of the signal you are trying to measure. Front panel controls let you adjust these settings.

1.5 Sampling Methods

The sampling method tells the oscilloscope how to collect sample points. At low frequencies a digital oscilloscope easily collects more than enough sample points to construct an accurate picture of the original signal. However, at higher frequencies (how high depends on the oscilloscope's maximum sample rate) the oscilloscope cannot collect enough samples. The digital oscilloscope can do two things:

* It can collect and build a picture of the waveform, over several period over time, as long as the signal is repetitive. (equivalent - time sampling mode).

* It can collect a few sample points of the signal in a single pass (about 10 points in real-time sampling mode) and then use interpolation. Interpolation is a processing algorithm to estimate the shape of the waveform looks like based on a sampled points.

1.6 Real-time Sampling with Interpolation

In real-time sampling mode, the oscilloscope collects as many samples as it determine to reconstruct the signal, depending

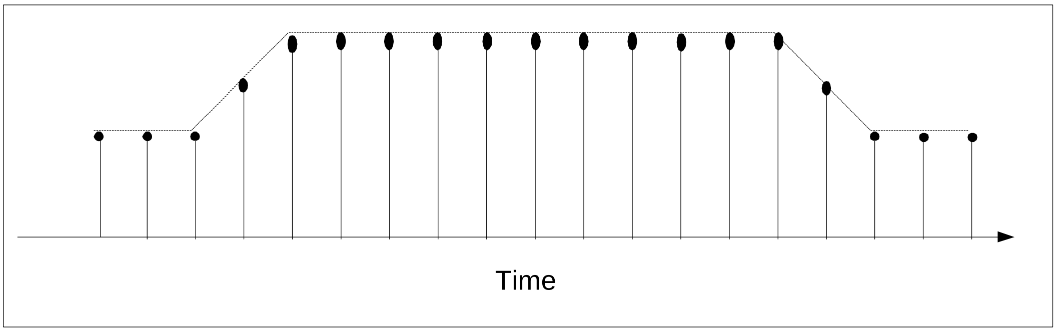

Figure 5 Real time sampling

on the duration shape and the amount of memory available for the channel (see Figure 5).For a single-shot or transient signals user must choose real time sampling mode. Interpolation is the way that the oscilloscope

use to "connects the dots." Linear interpolation connects sample points with straight lines, and sine interpolation connects

sample points with curves (see Figure 6).Digital oscilloscope use linear interpolation for pulses and sine interpolation for sinusoidal waves as a default.

1.7 Equivalent-time Sampling

Digital oscilloscope use equivalent-time sampling for a very fast repeating signal (when the time base scale is about 500 ns or faster). Equivalent-time sampling extends the useful frequency range of an oscilloscope. Equivalent-time sampling lets you construct a picture of a repetitive signal by capturing a little bit of information from each cycle (see Figure 7).

1.8 XY Display Mode

The normal display of the oscilloscope is volts versus time. The XY mode convert the display to a volt versus volts display. You can use various application such as volts versus current or another two physical relating phenomena using transducers. If you have two sinusoidal wave with the same frequency, but with arbitrary phase, one method of measuring phase shift is to use the XY mode. This involves in applying one signal into the horizontal system and another signal to vertical system. The waveform resulting from this arrangement, is called Lissajous pattern. From the shape of the Lissajous pattern, you can tell the phase difference between the two signals (see figure -8).

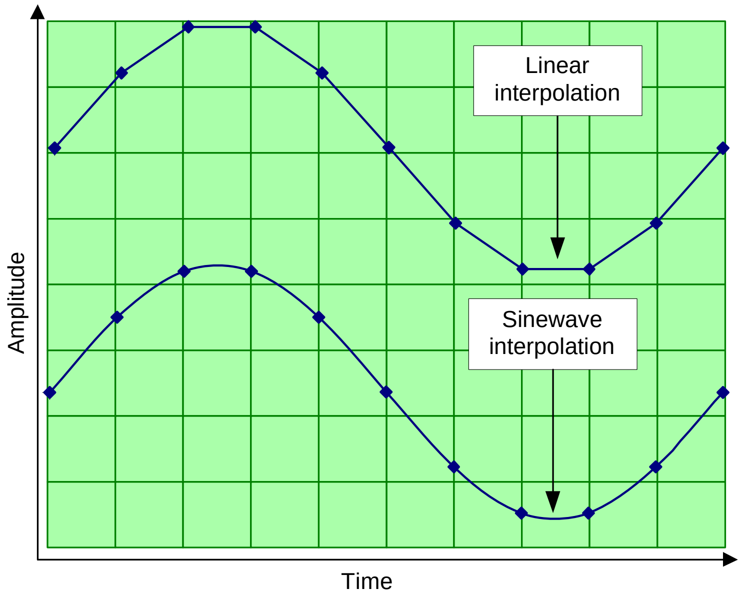

Figure 6 Linear and sinewave interpolation

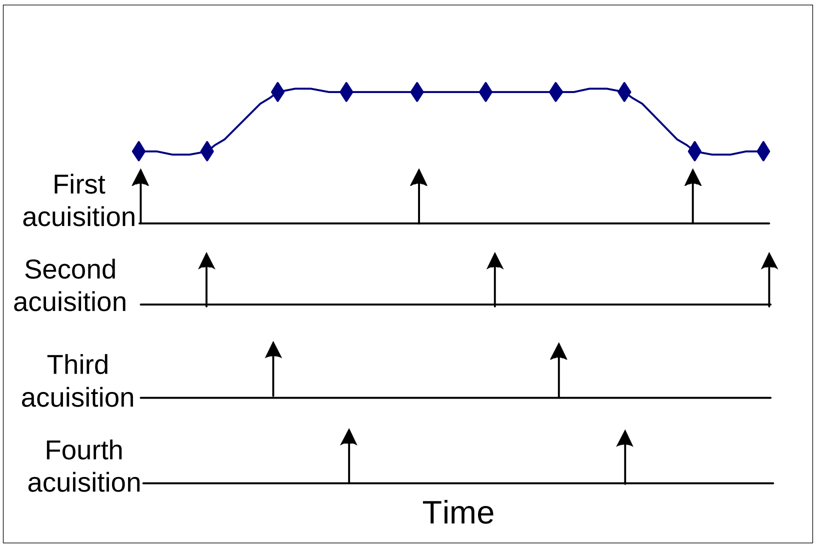

Figure 7 Equivalent time sampling

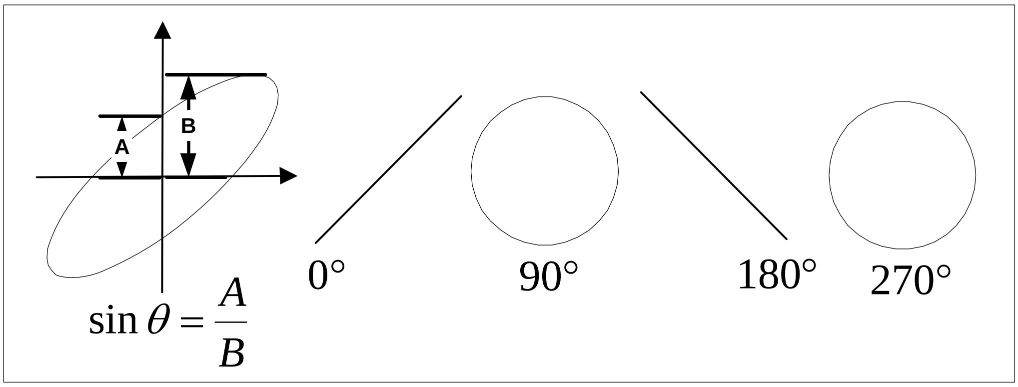

Figure 8 XY display of two sinewave, with equal frequency, and different phase difference

1.9 Advanced Measurement-Timing Jitter

What Is Jitter? one definition of jitter is "The slight movement of a transmission signal in time or phase that can introduce errors and loss of synchronization. More jitter will be encountered with longer cables, cables with higher attenuation, and signals at higher data rates. Jitter lead to, timing distortion, or intersymbol interference. other definition of timing jitter is“Jitter is defined as the short-term variations (instability) of a digital signal’s significant instants from their ideal positions in time.”

This captures the essence of jitter, but some of the individual terms (short-term, significant instants, ideal positions) need to be

clarified before this definition can be unambiguously used. In all real applications, jitter has a random component, so it must be specified using statistical terms. Metrics such as mean value, standard deviation, and other qualifiers such as confidence interval, must be used to establish meaningful, repeatable measurements.

1.10 Defining Short-Term: Jitter vs. Wander

By convention, timing variations are split into two categories, called jitter and wander, based on a Fourier analysis of the variations

vs. time. Timing variations that occur slowly (typically minutes or hours) are called wander. Jitter describes timing variations that occur more rapidly (scale of seconds). The threshold between wander and jitter is defined to be 10 Hz according to the ITU2 but other definitions may be encountered. In

many cases wander is of little or no consequence on serial communications links, where a clock recovery circuit effectively eliminates it.

1.11 THD- Total Harmonic Distortion and Distortion Analyzer

Distortion analyzers measure the distortion produced in the Device Under Test (DUT). Basically, the distortion analyzer applies a very pure sine wave (with very low harmonics) to the input of a circuit and measures the resulting output. If the circuit is distortion free, the output will also be a pure sine wave. However, in real circuits, some distortion may be produced (typically harmonics). The distortion Analyzer determines the amount of distortion in the output by filtering out the original sine wave and measuring the RMS voltage of all residual signals , including harmonics, spurious responses and noise at defined bandwidth.

Figure 9 shows the simplified block diagram of a distortion analyzer. The sine wave output is connected to the circuit under test. This sine wave must be very pure, its distortion will limit the accuracy of the instrument. The output of the circuit under test is connected to the input of the distortion analyzer. The analyzer uses a narrow sharp notch filter to remove the original sine wave from the input signal. Anything left over is assumed to be distortion in the signal caused by the DUT. The distortion is then compared to the waveform, including the fundamental sine wave, and the distortion is read out on the analyzer as a percentage of the original signal. It is important to note that noise and spurious responses present in the circuit will also contribute to the distortion reading, since they will not be removed by the notch filter. Most distortion analyzers include selectable low-pass and high-pass filtering to help eliminate these unwanted signals.

Advanced distortion analyzers provide the capability of selecting the test frequency. These instruments have a tunable notch filter over the measured bandwidth which automatically tracks the frequency of the internal oscillator. The purity of the measured signal may be expressed in several different ways. For audio system, distortion (either in percent or dB relative to the fundamental) is defined as

$$distortion\,(\%) = 100\frac{V_{RMS}\ of\ all\ signal\ without\ fundametal}{V_{RMS}\ of\ all\ \ signal}$$

alternative expression for distortion is

$$distortion\,(\%) = 100\frac{V_{RMS}\ of\ all\ signal\ without\ fundametal}{V_{RMS}\ of\ fundamental\ \ signal}$$

Another alternative is expressing the imperfections in terms of either SINAD

$$SINAD\,(dB) = 20\log_{10}\frac{V_{RMS}\ of\ \ (signal + noise + distortion)}{V_{RMS}\ of\ \ (noise + distortion)}$$

SINAD measurements are often used to measure the sensitivity of a radio receiver. A signal generator with a 1-kHz modulating tone is connected to the antenna connection of the receiver. The signal generator's frequency is set to match the receiver frequency. A distortion meter is connected to the audio output of the receiver where it measures the SINAD of the recovered audio. The amplitude of the signal generator is reduced until a particular SINAD value is reached, typically 12dB. The signal generator amplitude at this point defines the sensitivity of the receiver.

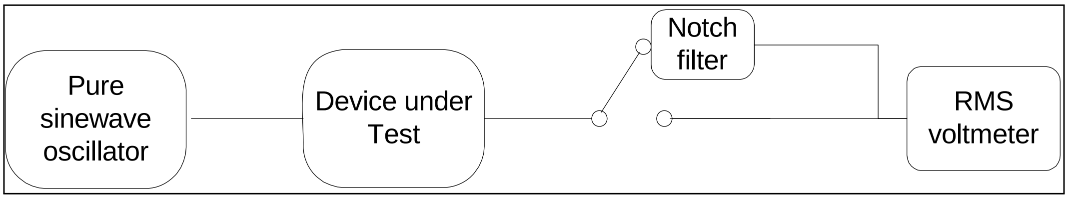

Figure 9 Major blocks of Distortion Analyzer

Chapter 2

EXPERIMENT PROCEDURE

2.1 Required Equipment

1. Oscilloscope -Agilent 54621A
2. Function generator- Agilent 33120A
3. Signal generator -Agilent 8647B or equivalent.
4. 50 Ohm feedthrough .
5. 100kHz notch filter.

2.2 Bandwidth

In this part of the experiment you will understand the meaning of the oscilloscope Bandwidth, (60 MHz or 100 MHz depend on your oscilloscope) by measuring the oscilloscope bandwidth using signal generator which have constant amplitude across all the frequency range, and 50Ω feedthrough termination to achieve correct termination.

1. Connect the signal generator using 50Ω feedthrough termination to the oscilloscope, as indicated in Figure-1.

2. Set the frequency of the signal generator to 250 kHz, amplitude 800mV.

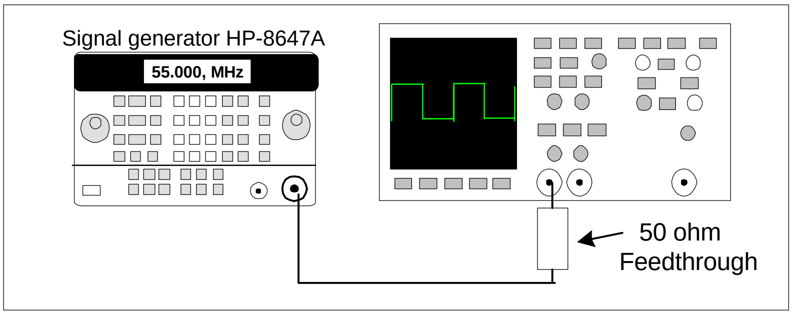

Figure 1 Bandwidth measuring system

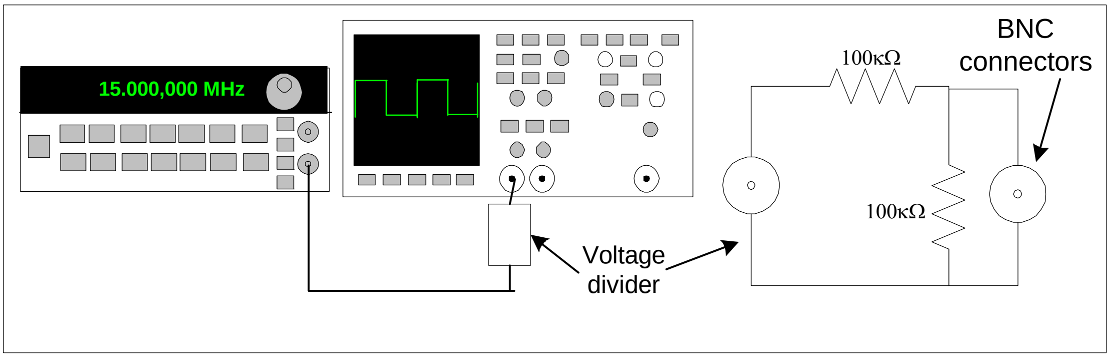

Figure 2 Input impedance affects on measurement

3. Press **Autoscale** bottom on the oscilloscope, adjust the output of the signal generator to exceed exactly 8 vertical division (record the value O. dB).

4. Observe the display of the oscilloscope, while changing the frequency of the signal generator, and the time base by steps to 60 MHz (100 MHz), and 5 ns/div respectively.

5. Verify that the amplitude of the signal is within ±3dB at 60 MHz (100 MHz). (record the value).

6. Continue to change the frequency according to the table below, up to the one that you got a noisy waveform (record the value), explain those three records.

Frequency→	250kHz	20MHz	40MHz		80MHz	110MHz	140MHz
V_m							
dB	0			-3			

2.3 Input Impedance

The input impedance of the oscilloscope is $1M\Omega$, parallel with $13pf$. In some cases such impedance could load the DUT and cause a measurement error.

1. Connect the function generator directly to the oscilloscope.

2. Set the function generator to sinewave 1 kHz, amplitude $1V_{pp}$.

3. Compare the amplitude reading of the oscilloscope and function generator? what is the ratio and why?

4. Change the signal to squarewave and triangle wave and measure V_{pp} and V_{RMS} of each signal, compare the results to prelab exercise. **Store the data on magnetic media.**

5. Connect the divider to the function generator, as indicated in Figure-2

6. Set the function generator to sinewave 1kHz, amplitude $1V_{pp}$.

7. Verify that the Voltage across each resistor is about $1V_{pp}$(why the voltage remain $1V_{pp}$ after the division).

8. Change the frequency of the function generator to 1MHz, measure the voltage on each resistor, and the source, why the sum of the two voltage is less then the displayed voltage source, **store the voltage of the resistor and the source on magnetic media.**

9. Change the frequency to 3MHz and explain why the signal change to triangle wave, what happen to the amplitude of the signal? **Store the voltage of one resistor on magnetic media.**

2.4 Bandwidth and Impedance Limitation

Sometime you asked to measure the rise time of a single or repetitive pulse. Such measurement could be meaningless if you don't pay attention to the oscilloscope bandwidth and the rise time of the oscilloscope.

1. Connect the function generator using 50Ω feedthrough to the oscilloscope, as indicated in Figure-1

2. Set the function generator to squarewave frequency 15 MHz, amplitude 1V$_{pp}$.

3. Watch the signal at the oscilloscope, try to explain why the signal looks like a sinewave, reduce the frequency by step to 1MHz and verify your answer.

4. change the signal to squarewave 1MHz and measure the rise time of the square wave signal. According to the specification the rise time is 20 ns. **Store the data on magnetic media.**

5. Disconnect the 50Ω feedthrough termination, measure again the rise time, what happen to the rise time of the signal, explain. **Store the data on magnetic media.**

2.5 Input coupling

Sometimes you have to measure small AC signal in a presence of a large DC signal e.g. power supply ripple and noise measurement. In such a case using AC coupling enable the measurement. In our case we have to measure 20 mV$_{pp}$ sinewave in the presence of a 5 VDC.

1. Connect the function generators to the oscilloscope, as indicated in Figure-3
2. Set one of the function generator to 5VDC.
3. Set the second function generator to sinewave 1 kHz, amplitude 40mV.
4. Press **Autoscale** (DC coupling) explain why the AC signal 'disappears'.
5. Measure V$_{RMS}$ of the signal, record your measurement, replace the oscilloscope with digital multimeter, set the multimeter to VAC, why the two results are so different? if you set the multimeter to VDC the results will be approximately the same explain?

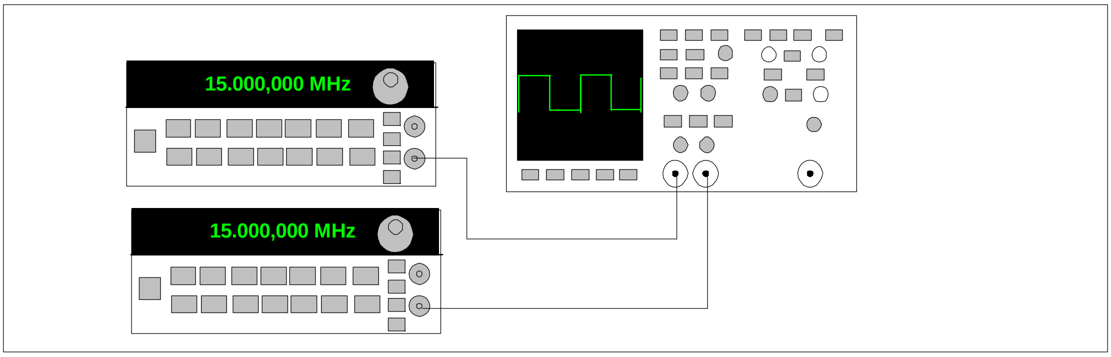

Figure 3

6. Reconnect the oscilloscope and change the coupling of the oscilloscope to AC and measure the amplitude (V_{pp}) of the sinewave signal.

2.6 Instantaneous and average Power.

In this section you multiply two sinusoid signal e.g. voltage and current, and the multiply signal is the power of the system.

1. Connect two function generators to the oscilloscope, as indicated in Fig-3
2. Set the two function generators to sinewave $1V_{pp}$, frequency 10kHz.
3. Lock the two function generators to the same phase according to the procedure of Appendix-1.
4. Multiply the two channels, by pressing **Math** button. Operate the average function if necessary to stabilize the multiplication signal (instantaneous power).
5. Turn off the **Math** button and measure the amplitude of each signal.(two function generators).
6. Turn on the **Math** button and measure the amplitude peak to peak, and the frequency of the third signal (use cursors)compare the result to the theory.
7. Set the Y cursor at the minimum point of the signal (assume that is the point of the ground). Change the phase of one signal continuously, what happen to the signal? explain.

2.7 Distortion Measurement

In this part of the experiment, we measure the Total Harmonic Distortion (THD) of 100kHz triangle wave signal. (assume that the triangle wave is the distorted output of a system, where the input is a pure sinewave)

1. Connect function generators to the oscilloscope, as indicated in Fig-4
2. Set the function generators to trianglewave $1V_{pp}$, frequency 100kHz.
3. Measure the RMS value of the harmonics.

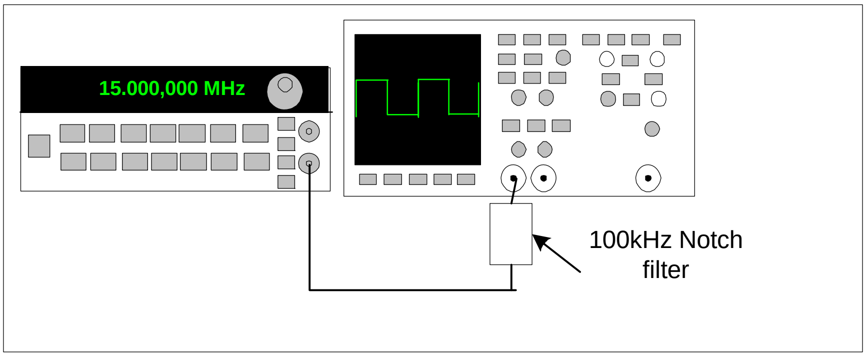

Figure 4

4. Disconnect the notch filter and measure the RMS value of the signal+noise +distortion..

5. Calculate the THD and SINAD(dB) of the trianglewave signal, compare your result to the prelab results.

2.8 Jitter

In this part of the experiment, we measure the jitter (time domain instability) of 1kHz squarewave signal.

1. connect the function generator directly to the oscilloscope.

2. Set the function generator to squarewave, frequency 1kHz, amplitude 100mv.

3. Set the oscilloscope to infinite persistence by pressing **Display Persist** ∞,and set the trigger to **Slope Falling**, by pressing the proper keys of the trigger.

4. Set the rising edge of the signal at the center of the oscilloscope, and change the time base to 50 ns/div, the jitter of the squarewave will be displayed.

5. Measure peak to peak jitter using proper cursor (see Fig.-5) **Save the data on magnetic media.**

2.9 Final Report

1. Explain why you need to add 50Ω feedthrough termination, when you measured the bandwidth of the oscilloscope, what will happen if you connect the signal without the feedthrough termination.

2. Using Matlab or other mathematics software:

a. Expand 10 MHz squarewave to Fourier series.

b. Choose the first four odd harmonics, add them and draw a graph (voltage versus time), and compare the graph to the graph of your result (time domain and rise time).

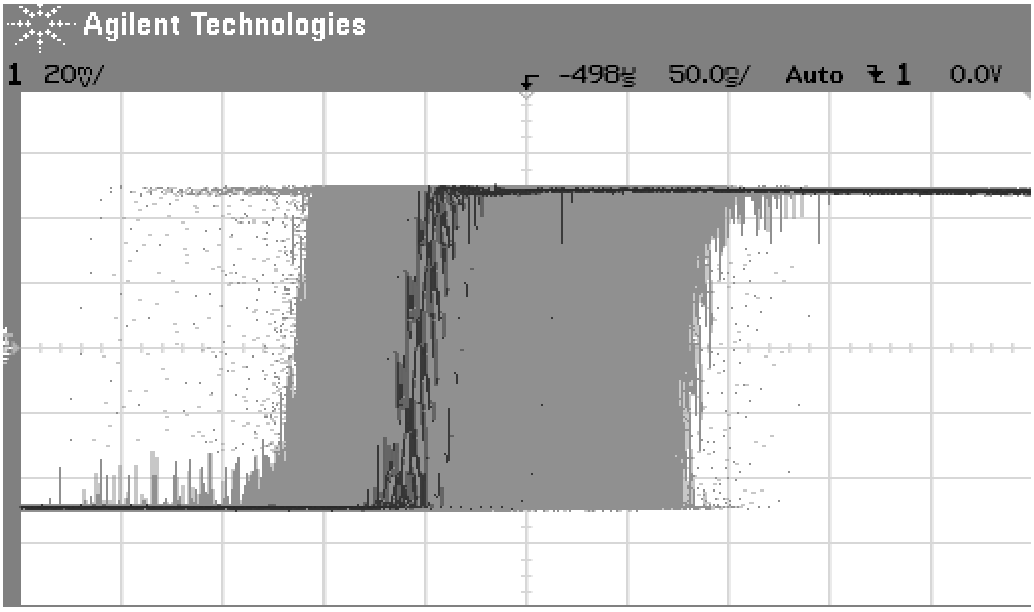

Figure 5 A jitter 1kHz squarewave signal, time base set to 50ns/div

3. Explain why the rise time measurement change, when you disconnect the feedthrough termination, prove your answer using graphs.

4. Explain why Kirchof voltage law 'fail' when you use the voltage divider? Prove your answer using the stored graphs.

2.10 Appendix-1

2.10.1 To phase lock two function generator.

1. Connect rear-pane Ref Out 10MHz output terminal of the master Arbitrary Waveform Generator HP-33120A to Ext Ref in on the rear panel of the slave HP-33120A as indicated in Figure-6

2. Connect the two AWG's to the oscilloscope as shown in Figure-6

3. set the oscilloscope to standard display-arbitrary phase between the two channel, by pressing **AUTOSCALE.**

4. Turn on the menu of the AWG by pressing **shift menu on/off** the display then looks like **A:MOD MENU.**

5. Move across to **G:PHASE MENU** by pressing the $<$ button.

6. Move down one level to the **ADJUST** command, by pressing $\vee$, the display looks like **1:ADJUST**

7. press $\vee$ one level and set the phase offset, change the phase continuously between the two AWG's until one trace cover completely the other trace (zero phase). You see then a display like $\wedge$**120.000DEG.**

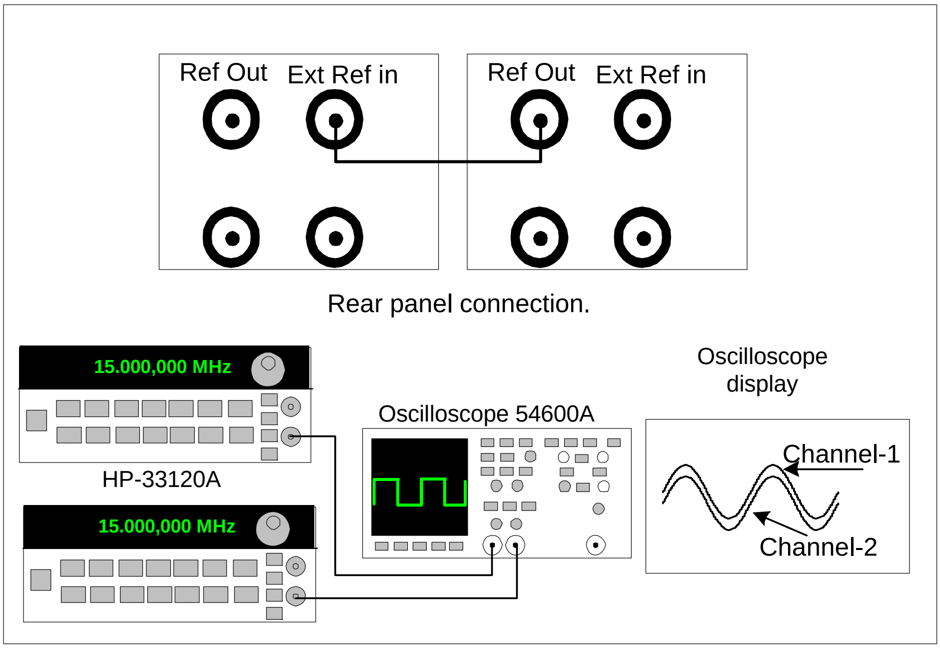

Figure 6

8. Turn off the menu by pressing **ENTER.** You have the exited the menu.

2.10.2 Setting a Zero phase reference at the end of the cable.

1. Turn on the menu by pressing **shift menu On/off** the display looks like **A:MOD MENU.**

2. Move across to the PHASE MENU choice on this level, by pressing <, the display looks like **G:PHASE MENU.**

3. Move down one level and then across to the **SET ZERO** by pressing ∨ and > bottoms, the display shows the message **2:SET ZERO.**

4. Move down a level to set the zero phase reference, by pressing ∨ the displayed message indicates **PHASE=0.**

5. Press **ENTER**, save the phase reference and turn off the menu.

IMPORTANT : At this point; the function generator HP-33120A is phase locked to another HP-33120A or external clock signal with the specified phase relationship. The two signals remain locked unless you change the output frequency.