Teaching with the

KRi Mixed Signal Test Unit

Model TU-100

Application Note Ref: MS-101
Date: January 11, 1999
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for KentRidge Instruments Pte Ltd

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Acknowledgements

Document File: MS-101.DOC

Printed in Singapore

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OVERVIEW

The Semiconductor Industry Association of the United States projects that together with dramatic increases in on-chip clock speed, chip gate and pin count, analog and mixed signal circuitry will be included on most high-end chips.

As a result there will be an increasing need for analog and mixed signal testing. This includes the need to establish correlation between system failures and physical causes such as process variations and defects, model faults at higher levels of abstraction, carry out on-chip parametric measurement, leading to possible Pass/Fail decisions and compute quality metrics (e.g. figure of merit).

The design and operation of automatic test equipment (ATE) will thus grow in sophistication. Technical personnel using such equipment will need a basic understanding of the fundamentals of mixed signal generation, measurement and analysis to maximise productivity.

The TU-100 is a test unit designed for laboratory teaching of automated device testing with emphasis on the testing of mixed signal units such as digital to analog converters or analog to digital converters.

This application note outlines a set of experiments, which uses the test unit.

OTHER *KRi* PRODUCTS

EXPERIMENT 1: SETTING UP THE TEST SYSTEM

Objectives

- To become familiar with the main components of the mixed signal test unit
- To learn about mixed signal sources and waveform generation

Synopsis

Figure 1 shows a schematic of the mixed signal test unit.

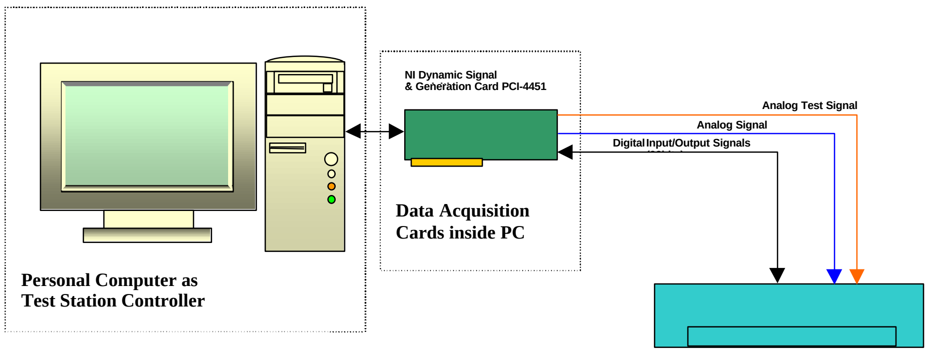

Figure 1 Diagram of mixed-signal test unit

Part One of this experiment is a familiarisation tour of the Test Setup.

Part Two focuses on the signal source component of the test setup. A representation of the analog information to be applied to the device is called a waveshape. The stimulus waveshape may be defined as numeric values or by graphical means. The Signal Source waveform synthesiser converts the desired waveshape into a repetitive waveform.

The Signal Source drives a digital to analogue converter to create an analog signal. In most test systems, the Source can be started and stopped through the user interface on the PC. Furthermore, mixed-signal testing frequently requires synchronisation of digital and analog test resources to determine whether a mixed-signal function is operating correctly.

Lessons Learned and Data Obtained

- Test Unit Signal Generation
- Typical test waveforms - sinusoidal signals, periodic signals, non-periodic signals, multi-tone signals

EXPERIMENT 2: USING A DIGITISER

Objective

- To learn about analog signal measurement

Synopsis

A digitiser converts an analog waveform such as a voltage signal into a numerical representation that can be analysed in a digital computer. The analog waveform may come from the device under test (DUT), usually as a result of a stimulus waveform applied to the DUT.

In mixed signal testing, the analog waveform may reveal that the DUT is faulty. The nature of the waveform may give clues to the origin of the fault. It is thus important that digitiser preserves measured signal accuracy and integrity, for both static and dynamic measurements of analog waveforms.

An important step in mixed signal testing is the ability to configure a digitiser intelligently. This experiment is an introduction to the limitations and constraints of signal digitising. In addition to showing how an analog waveform is captured, the effects of signal range and the resolution of the digitiser will be illustrated.

After a waveform has been measured, it must be characterised. For a pure sinusoidal signal, this may be no more that measuring amplitude, phase and frequency. For other waveforms, it be necessary to perform signal averaging and to remove signal offset. This experiment will also introduce some of these simple time domain characterisations and elementary signal processing techniques.

Lessons Learned and Data Obtained

- Obtaining periodic sample sets
- Time domain characteristics of an analog signal
- Impact of resolution - quantizing error
- Impact of data range
- Sample Size and Sample Rate
- Improving data - Signal Averaging

EXPERIMENT 3: ANALYSING A WAVEFORM

Objectives

- Understand the essential concepts of frequency domain analysis
- Understand frequency domain measurements.

Synopsis

In mixed signal testing, a common stimulus signal is the sinusoidal signal. The response of the device under test (DUT) to a sinusoidal signal is often an important source of information about the performance of the DUT.

For a periodic signal, one of the most useful characteristics is the frequency content of the signal. For every periodic signal, we can obtain a representation of the signal in the form of a spectrum. The spectrum may show for example the energy in each frequency component of the signal. A considerable amount of information about the DUT is often embedded in the spectrum.

For example, if we stimulate a linear amplifier with a sinusoidal signal of a single frequency, the amplifier output should contain a signal of the same frequency. If in fact it contains other frequency components, the signal strength of these other frequency components is a measure of the distortion introduced by the amplifier.

With a digitiser and appropriate digital signal processing tools such as the Fast Fourier Transform, it is possible to compute the frequency spectrum of a digitised waveform.

This experiment introduces measurements based on the Fast Fourier Transform. It illustrates how it common measures of analog signal quality can be computed.

Lessons Learned and Data Obtained

- Computing the frequency spectrum of an analog signal
- The relationship between time domain and frequency domain data.
- Measures of distortion
- Harmonic distortion testing
- Signal to Noise Testing
- The effects of time windows (Hanning, Blackman, etc.) on the frequency domain signal data.

EXPERIMENT 4: SAMPLING

Objectives

- To understand how many samples to take and choice of sampling frequency
- To understand the need for signal conditioning for removing measurement noise and aliasing

Synopsis

It is intuitively obvious that if a digitiser does not collect enough samples of an analog waveform, the digital sequence obtained will not be an accurate representation of the analog waveform. In 1949, Shannon formalised this notion. He demonstrated that to sample an analog signal having a maximum frequency of f_c requires sampling at greater than $2f_c$ to preserve and recover the waveform exactly. The consequence of sampling at a lower frequency is a phenomenon known as aliasing. In an aliased signal, a frequency component of the signal mistakenly takes on the identity of an entirely different frequency when recovered.

It may appear that this problem can be avoided by sampling at a rate greater than twice the maximum frequency found within the signal to be sampled. In the real world, however, most signals contain the entire spectrum of frequency components; from the desired to those present in white noise. To recover such information accurately the system would require an unrealisable (high) sample rate.

This difficulty can be overcome by pre-conditioning the input signal. This requires a band-limiting or frequency filtering function performed prior to the sample data input. The prefilter, typically called anti-aliasing filter guarantees, for example in the low pass filter case, that the sampled data system receives analog signals having a spectral content no greater than those frequencies allowed by the filter.

If an unnecessarily high sampling frequency is chosen, the computational load on the test unit will be large. Furthermore, it can be shown that given any finite resolution of the digitiser, an excessive sampling frequency will degrade the signal to noise ratio. There is thus a need to select appropriate sampling rates.

This experiment illustrates these basic ideas.

Lessons Learned and Data Obtained

- Effect of too low sampling frequency - Aliasing
- Determining sample size and sampling frequency
- Anti-Aliasing filters
- Oversampling and digital filtering

EXPERIMENT 5: MIXED SIGNAL TESTING

Objective

- To apply lessons learned on testing a specific device, for example, a digital to analog converter

Synopsis

The first 4 experiments introduce the student to signal generation, signal sampling and obtaining the characteristics of analog signals.

This experiment applies the techniques acquired to the testing of a mixed signal device.

A digital to analog converter is an example of a mixed signal device. This experiment demonstrates the requirements for testing DC and AC parameters of Digital to Analog Converters. This includes

- Techniques for testing
  - a. Differential Non-Linearity (DNL)
  - b. Integral Non-Linearity (INL).
  - c. Converter harmonic distortion
  - d. Signal to Noise Ratio.
- Techniques for testing AC characteristics such as
  - e. Glitch Impulse Area,
  - f. Settle Time,
  - g. Harmonic Distortion Tests,
  - h. Slew Rate,
  - i. Conversion Rate

Lessons Learned and Data Obtained

- AC and DC characteristics of Digital to Analog Converters
- Typical test techniques