

Lab Manual:  
Communications Principles  
  
Using the EMONA Communications board for NI ELVIS III



Lab 3: FFT and spectra

List of Updates

|  |  |
| --- | --- |
| **Date** | **Details** |
| 7/9/2018 | Completed final document |
| 19/10/18 | Revisions and fixes |
|  |  |

**© 2018 EMONA Instruments Pty Ltd**

All Emona TIMS/ETT-Series/DxIQ user manuals, experiment manuals and supplied software   
are (C) Copyright to Emona Instruments Pty Ltd and its related entities. All rights reserved.

LIMITED AUTHORITY TO COPY TIMS MANUALS

This License Agreement grants a limited authority only to those educational institutions who have purchased the Emona TIMS/ETT/DxIQ laboratory learning equipment, to reproduce (in whole or in part,), and/or to give away copies of any of Emona Instrument’s published TIMS/ETT/DxIQ User Manuals and Experiment Manuals for the exclusive use of their own enrolled students.

No licensing fees are payable to Emona under this limited Authority.

Emona Instruments Pty Ltd retains the copyright of any edited and/or derivative documents.

**SOFTWARE**

EMONA Instruments Pty Ltd respects the intellectual property of others, and we ask our readers to do the same. This resource is protected by copyright and other intellectual property laws.

LabVIEW and National Instruments are trademarks of National Instruments.

All other trademarks or product names are the property of their respective owners.

**ADDITIONAL DISCLAIMERS**

The reader assumes all risk of use of this resource and of all information, theories, and programs contained or described in it. This resource may contain technical inaccuracies, typographical errors, other errors and omissions, and out-of-date information. Neither the author nor the publisher assumes any responsibility or liability for any errors or omissions of any kind, to update any information, or for any infringement of any patent or other intellectual property right.

Neither the author nor the publisher makes any warranties of any kind, including without limitation any warranty as to the sufficiency of the resource or of any information, theories, or programs contained or described in it, and any warranty that use of any information, theories, or programs contained or described in the resource will not infringe any patent or other intellectual property right. THIS RESOURCE IS PROVIDED “AS IS.” ALL WARRANTIES, EITHER EXPRESS OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, ANY AND ALL IMPLIED WARRANTIES OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, AND NON-INFRINGEMENT OF INTELLECTUAL PROPERTY RIGHTS, ARE DISCLAIMED.

No right or license is granted by publisher or author under any patent or other intellectual property right, expressly, or by implication or estoppel.

IN NO EVENT SHALL THE PUBLISHER OR THE AUTHOR BE LIABLE FOR ANY DIRECT, INDIRECT, SPECIAL, INCIDENTAL, COVER, ECONOMIC, OR CONSEQUENTIAL DAMAGES ARISING OUT OF THIS RESOURCE OR ANY INFORMATION, THEORIES, OR PROGRAMS CONTAINED OR DESCRIBED IN IT, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGES, AND EVEN IF CAUSED OR CONTRIBUTED TO BY THE NEGLIGENCE OF THE PUBLISHER, THE AUTHOR, OR OTHERS. Applicable law may not allow the exclusion or limitation of incidental or consequential damages, so the above limitation or exclusion may not apply to you.

Table of Contents

[Lab 3: FFT and spectra 5](#_Toc528915592)

[Learning Objectives 5](#_Toc528915593)

[Prerequisites 5](#_Toc528915594)

[Required Tools and Technology 6](#_Toc528915595)

[Expected Deliverables 7](#_Toc528915596)

[Section 1: FFT and spectra of impulses 8](#_Toc528915597)

[1.1 Theory and Background 8](#_Toc528915598)

[1.2 Implement: Spectrum of the impulse train 8](#_Toc528915599)

[1.3 Implement: Spectrum of the filtered impulse train 13](#_Toc528915600)

[Section 2: Duty cycle and sampling 16](#_Toc528915601)

[Section 3: “Sinc pulse” trains 16](#_Toc528915602)

[Section 4: Spectrum of pseudorandom sequence 20](#_Toc528915603)

[4.1 Analog noise generation (AWGN) 23](#_Toc528915604)

[Section 5:Non-linear processes: clipping, rectification and harmonic multiplication 26](#_Toc528915605)

[Figure 1: Pulse source to System Under Investigation. 10](#_Toc528915606)

[Figure2 (a): Spectrum of single width (10% duty cycle) impulse (b) Spectrum of double width (20% duty cycle) impulse 11](#_Toc528915607)

[Figure 3(a) impulse after filtering (b)post–filter spectrum 14](#_Toc528915608)

[Figure4: Sinc pulse and its bandlimited spectrum of the unfiltered sinc pulse 18](#_Toc528915609)

[Figure 5: TUNEABLE LPF time & frequency response to the sinc pulse train 20](#_Toc528915610)

[Figure 6: Block diagram for the of DxIQ-45GSEQUENCE GENERATOR 1 21](#_Toc528915611)

[Figure7: Patching diagram for PN sequence from SEQUENCE GENERATOR 1 21](#_Toc528915612)

[Figure 8:Block diagram for PRBS generated analog noise 23](#_Toc528915613)

[Figure 9:Patching diagram for PRBS analog noise 24](#_Toc528915614)

[Figure 10: Clipping a signal 26](#_Toc528915615)

[Figure 11: Patching for signal clipping 27](#_Toc528915616)

# Lab 3: FFT and spectra

## Learning Objectives

After completing this lab, you should be able to complete the following activities.

1. Understand the spectrum of an impulse train.
2. Understand the spectrum of a filtered impulse train.
3. Understand the relationship between the duty cycle of a periodic pulse train and its spectrum.
4. Understand the finite spectrum of a sinc pulse train.
5. Understand the spectrum of variable-length pseudorandom sequence and how such sequences can be used for analog noise generation.
6. Understand the effects of clipping and half-wave rectification on a signal’s spectrum.

## Prerequisites

You should have completed Lab 1 and Lab 2 and be familiar with the equipment, its use and the handling precautions for the equipment.

## Required Tools and Technology

|  |  |
| --- | --- |
| Platform: NI ELVIS III Instruments used in this lab:   * Oscilloscope-Time * Oscilloscope-FFT * Function and Arbitrary Waveform Generator | * Install Instruments: [http://www.ni.com/documentation/en/ni-elvis-iii/latest/getting-started/installing-the-soft-front-panel/](http://www-preview.ni.com/documentation/en/ni-elvis-iii/1.0/getting-started/installing-the-soft-front-panel/) * Access instruments   <https://measurementslive.ni.com>   * View User Manual   <http://www.ni.com/en-us/support/model.ni-elvis-iii.html>   * View tutorials <https://www.youtube.com/playlist?list=PLvcPIuVaUMIWm8ziaSxv0gwtshBA2dh_M> |
| Hardware: Emona Communications Board Components used in this lab:   * Four BNC to 2mm banana-plug leads * Assorted 2mm banana-plug patch leads * Set of headphones or earbuds | * View User Manual   <http://www.ni.com/en-us/support/model.emona-communications-board-for-ni-elvis-iii.html> |
| Software: NI ELVIS III Function Generator File used in this lab:  Sinc 10k 2ms.csv | * Access instrument <https://measurementslive.ni.com> |

## 

## Expected Deliverables

In this lab, you will collect the following deliverables:

* Calculations
* Data from measurements
* Observations

Your instructor may expect you complete a lab report. Refer to your instructor for specific requirements or templates.

## Section 1: FFT and spectra of impulses

## Theory and Background

We are well familiar with the virtues of the scope as our eyes for observing signals and waveforms in the time domain. In this Lab we discover the reality of the frequency domain through the eyes of the spectrum analyser.

Various experiments introduced in earlier labs are extended through the use of the spectrum analyser. An important theme is the observation of special properties, such as those relating to periodic waveforms, and to discrete-time signals.

By understanding the frequency domain characteristics of various signal types, we can further develop our ability to think in both the time AND frequency domain when considering signals. The two go hand in hand and it is essential for the engineer to be well versed in both.

Having hands-on experience with signals and their spectrums will consolidate the theory, particularly of broad-spectrum signals, in a way that supports the learning of telecommunications principles in other coursework.

Signals and their spectrum are the foundation for several other fields of study.

## Implement: Spectrum of the impulse train

For this experiment you’ll use the EMONA Communications board to generate a BPSK signal with the Multiplier module to implement its mathematical model. Digital data for the message is modelled by the Sequence Generator module. You’ll then recover the data using another Multiplier module and observe its distortion. Finally, you’ll use a comparator to restore the data.

It should take you about 40 minutes to complete this experiment.

**Powering up the ELVIS III + EMONA Communications Board**

|  |  |
| --- | --- |
| 1. | Ensure that the NI ELVIS III Application Board power button at the top left corner of the unit is OFF (not illuminated). |

|  |  |
| --- | --- |
| 2. | Carefully plug the Emona Communications board (ECB) into the NI ELVIS III ensuring that it is fully engaged both front and back. |

|  |  |
| --- | --- |
| 3. | Ensure that you have connected the NI ELVIS III to the PC using the USB cable and that the PC is turned on. |

|  |  |
| --- | --- |
| 4. | Turn on the Application Board *Power* button by pressing it once and confirm that it is illuminated. The LEDs on the ECB should also be illuminated. If they are not, then switch the unit off immediately and check for connection or insertion errors. |

|  |  |
| --- | --- |
| 5. | Open the Instrument Launcher software in your browser and select the required instruments. |

Scope Configuration

|  |  |
| --- | --- |
| Channel Voltage range | 1 V/div |
| Horizontal Timebase | 500*µ*s/div |
| Coupling | Chan 1: DC, Chan 2: DC |
| Trigger | Analog Edge, Chan 1, Rising |
| Probe Attenuation | 1x |
| Additional Channels | FFT On, Source Channel: Channel 1, Start Frequency: 0Hz, Stop Frequency 50kHz, Window: Hamming |

Function and Arbitrary Waveform Generator Configuration

|  |  |
| --- | --- |
| Channel 1 | Square |
| Frequency | 500Hz |
| Amplitude | 2Vpp |
| Duty Cycle | 10% |

We will generate a train of impulse responses, and pass these through a Tunable LPF channel and display the spectrum both before and after filtering.

|  |  |
| --- | --- |
| CH9-a1 |  |

Figure 1: Pulse source to System Under Investigation.

1. Patch together the experiment as shown in Figure 1 above.
2. Observe the pulse train on the scope. Use the Scope Cursors to measure the pulse width and repetition interval and confirm that these are as you would expect for the settings on the Function Generator.

NB: It’s always a good idea to measure and confirm that signals set up on equipment are as expected, to avoid errors and wasted time.

1. Observe the FFT spectrum of this pulse train on Scope Channel 1. Vary the Scope timebase, which in return varies the resolution of the frequency scale, to provide a convenient balance between range and resolution in the frequency display.
2. Note that the envelope of the spectrum consists of discrete components. Confirm that the interval between components is determined by the pulse frequency.

|  |  |
| --- | --- |
|  |  |

Figure2 (a): Spectrum of single width (10% duty cycle) impulse   
(b) Spectrum of double width (20% duty cycle) impulse

1-1 At what frequencies do the nulls occur at?

|  |
| --- |
|  |
|  |
|  |

1. Increase the width of the pulse to double, but not the frequency, by varying the duty cycle of the pulse train. Set the Function Generator duty cycle to 0.2 (20%)
2. Confirm that the frequency interval between nulls is determined by the pulse width and duty cycle.

1-2 What is the mathematical relationship between null spacing and the pulse width?

|  |
| --- |
|  |
|  |
|  |

1. Confirm that the spacing of the individual components of the spectrum, i.e.: its harmonics, have not changed with the double width pulse.
2. Make suitable measurements of the spectrum amplitude to show that the shape of the envelope is of the form sin(x)/x for both impulse widths. Confirming the ratio of envelope peaks would be one important characteristic to check.
3. Verify that the general form of the spectrum is not affected by the pulse frequency i.e.: that it still maintains the sin(x)/x shape.

1-3 What are the characteristics of the sin(x)/x form that you are looking for?

|  |
| --- |
|  |
|  |
|  |

1. Now, reduce the width of the pulse, but not the frequency, by again varying the duty cycle of the pulse train. Set the Function Generator duty cycle to 0.02 (2%)
2. Confirm that the frequency interval between nulls is determined by the pulse width. You may need to vary the scope timebase to alter the FFT frequency display range.
3. Try a final reading with a duty cycle of 1%. Set the Function Generator duty cycle to 0.01 (1%)

1-4 What is the general trend that you are observing as the duty cycle tends towards 0?

|  |
| --- |
|  |
|  |
|  |

1-5 Using the various findings so far, what shape you expect the spectrum of a single pulse, that is, a pulse train with very large separation between pulses, to have?

|  |
| --- |
|  |
|  |
|  |

## Implement: Spectrum of the filtered impulse train

1. Return to the original single width pulse settings.

Scope Configuration

|  |  |
| --- | --- |
| Channel Voltage range | 1 V/div |
| Horizontal Timebase | 500*µ*s/div |
| Coupling | Chan 1: DC, Chan 2: DC |
| Trigger | Analog Edge, Chan 1, Rising |
| Probe Attenuation | 1x |
| Additional Channels | FFT On, Source Channel: Channel 2, Start Frequency: 0Hz, Stop Frequency 50kHz, Window: Hamming |

Function and Arbitrary Waveform Generator Configuration

|  |  |
| --- | --- |
| Channel 1 | Square |
| Frequency | 500Hz |
| Amplitude | 2Vpp |
| Duty Cycle | 5% |

1. Observe the scope display of the pulse response at the Tunable LPF channel output. Set the *Gain* and *Tune* knobs on the Tunable LPF to positions so that the observed waveform and spectrum resemble those shown on the Figure 3.

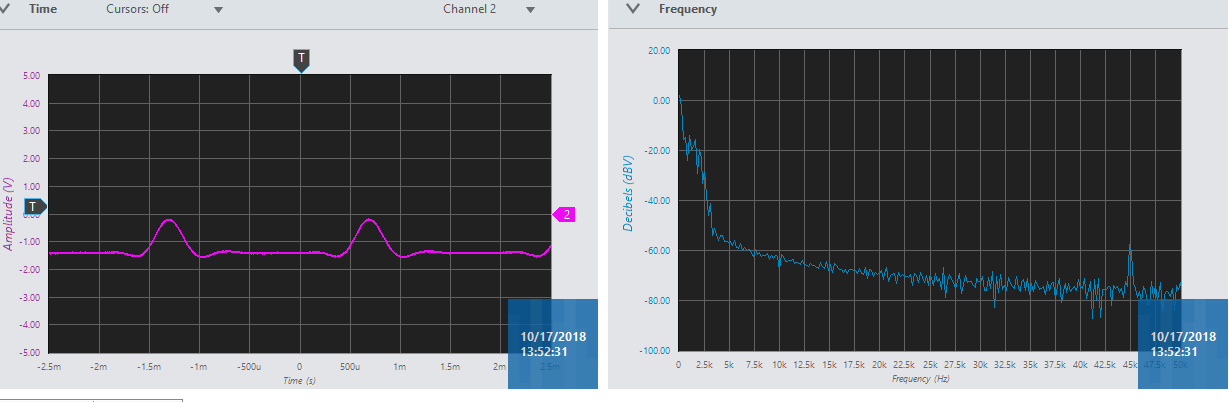


Figure 3(a) impulse after filtering (b)post–filter spectrum

1. Ensure that the pulse width is narrow enough such that the filtered pulse output is the impulse response of the channel.
2. Observe the frequency response of this output and compare with the frequency response of the unfiltered input train. Sketch these responses below:

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |

Graph 1: impulse train responses

1. Determine and plot the response characteristic of the Tunable LPF. This will be the ratio of the output to the input. Because the frequency responses are shown using a log/dBscale on the vertical axis, the process is a straightforward subtraction of input from the output.

## Section 2: Duty cycle and sampling

In the section above you have determined the frequency response of a periodic pulse train with variable duty cycle. This is the typical signal used as a sampling pulse train. Sampling will be covered in a later experiment (X16 – Sampling) in this manual.

It suffices at this point to emphasize that the spectrum of the sampling signal will be interacting with the message to be sampled, hence it is imperative to be familiar with it and its characteristics.

Start with a square wave from the Function Generator, frequency = 500Hz, set to duty cycle = 50%. Using the Scope, examine the FFT Spectrum of the square wave and slowly reduce the duty cycle from 50, to 40, 30, 20,10, and finally 5%, and observe the occurrence of even harmonics. You should realise that at 5% you have the same spectrum studied above and you should have an insight into the origin of the harmonics present.

## Section 3: “Sinc pulse” trains

In previous experiments we have encountered spectrums of rectangular pulse trains which are shaped by the sin(x)/x form. This sin(x)/x characteristic is known as the “sinc function”.

A rectangular shaped signal in the time domain results in “sinc function” shaped frequency response spectrum. In this part of the experiment we investigate the spectrum of pulse with sin(x)/x shaping in the time domain i.e. a sinc function in time. For convenience we will use a repetitive train of sinc pulses.

1. Set up the Scope and the Function Generator software as follows:

Scope Configuration

|  |  |
| --- | --- |
| Channel Voltage range | 500mV/div |
| Horizontal Timebase | 1ms/div |
| Coupling | Chan 1: DC, Chan 2: DC |
| Trigger | Analog Edge, Chan 1, Rising, Level: 500mV |
| Probe Attenuation | 1x |
| Additional Channels | FFT On, Source Channel: Channel 1, Start Frequency: 0Hz, Stop Frequency 50kHz |

Function and Arbitrary Waveform Generator Configuration

|  |  |
| --- | --- |
| Channel 1 | Custom |
| Frequency | 100kS/s |
| Gain | 1 |
| Waveform File | Sinc 10k 2ms.csv |

With this signal we have a unique situation where the spectrum is finite. In order for this to occur this sinc pulse must itself be infinite in the time domain, and in fact a true single sinc pulse is only asymptotically limited in time. That is, it tends to zero in both positive and negative time directions. In this experiment we have made approximation by repeating the pulse in a train and terminating the oscillations after about 20 cycles.

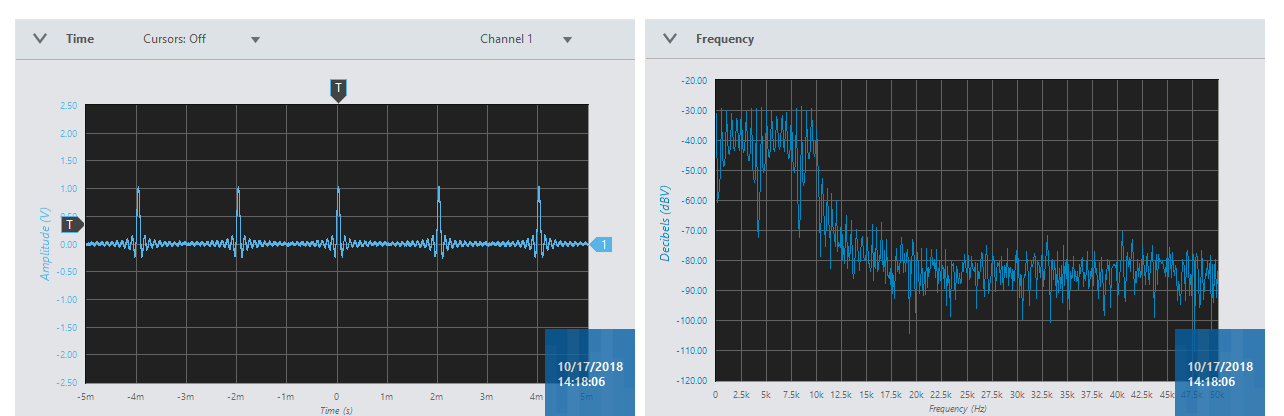


Figure4: Sinc pulse and its bandlimited spectrum of the unfiltered sinc pulse

3-1 What is the time difference between the zero crossings of the sinc pulse?

|  |
| --- |
|  |
|  |
|  |

1. Sketch both the sinc pulse and its spectrum in a graph below, and annotate the diagrams of all the relevant measurements.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |

Graph 2: sync pulse train time and frequency responses

1. As per the steps taken above in the impulse section, apply this sinc pulse train to the Tunable LPF module and observe its input and output in both the time and frequency domain. Plot the output frequency response on the graph above.

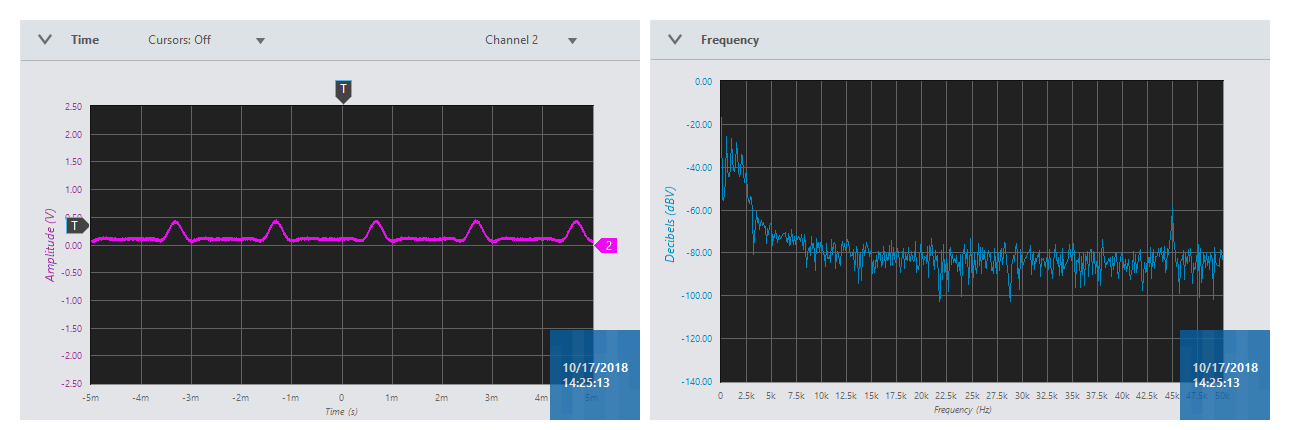


Figure 5: TUNEABLE LPF time & frequency response to the sinc pulse train

1. It is also interesting to see the difference in response between the RRC FILTER and the TUNEABLE LPF. Pass the sync pulse train through the RRC FILTER and slowly turn the *TUNE* knob to reduce the -3dB cutoff frequency to the same as that of the TUNABLE LPF as found above. Notice the difference in the roll off rate.

Applying an impulse train and sync pulse to a system is equivalent to applying many simultaneous sinusoids.

## Section 4: Spectrum of pseudorandom sequence

In this set of exercises, we examine and compare the spectra of various forms of pseudorandom sequences. Usually known as PRBS (Pseudo random bit sequences). We will begin with short clocked Maximal Length sequences, i.e. the kind of sequence available at the SEQUENCE GENERATOR 1 module. Next, we will examine longer length clocked Maximal Length sequences.

It is interesting to consider how pseudorandom sequences are generated. Firstly, it has to be said that they are named “pseudo” random as they are not truly random sequences. They are actually periodic and completely deterministic. However, they have numerous qualities which make them useful as signals.

PN sequences are created by structures such as shown in Figure 6. These structures can either be implemented in hardware via shift registers, or in software. They are usually called LFSR (Linear feedback shift registers).

.

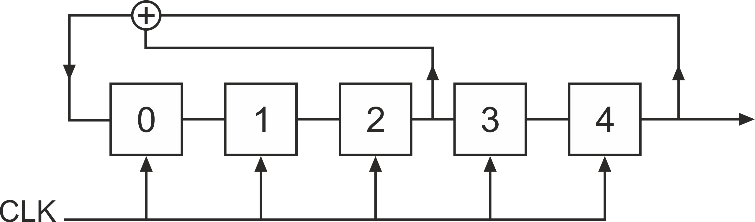


Figure 6: Block diagram for the of DxIQ-45GSEQUENCE GENERATOR 1

In this example, 5 registers are used, resulting in a sequence of period 25 – 1 = 31 bits. There is one less than the maximum number possible as state [00000] is considered illegal.

4-1 Why do you suppose state [00000] is illegal?

|  |
| --- |
|  |
|  |
|  |

1. Patch together the experiment in Figure 7 and view the output X from SEQUENCE GENERATOR 1.

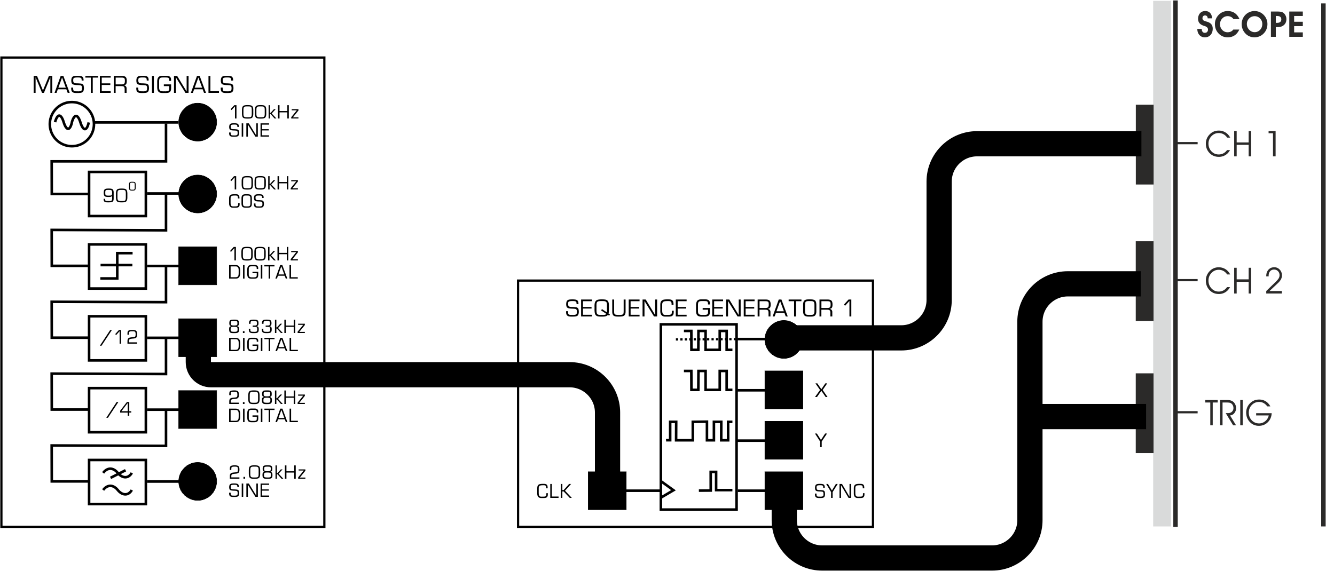


Figure7: Patching diagram for PN sequence from SEQUENCE GENERATOR 1

Settings are as follows:

Scope Configuration

|  |  |
| --- | --- |
| Channel Voltage range | 1V/div |
| Horizontal Timebase | 5ms/div |
| Coupling | Chan 1: DC |
| Trigger | Digital, Source: TRIG, Rising |
| Probe Attenuation | 1x |
| Additional Channels | FFT On, Source Channel: Channel 1, Start Frequency: 0Hz, Stop Frequency 50kHz |

The top X output from SEQUENCE GENERATOR 1 is a zero DC version of the X output, and is more convenient for viewing due to no DC component.

1. View the spectrum of this signal. Can you see where the nulls of the envelope of the spectrum occur. Vary the scope timebase so that you can see the separation between the individual harmonics of the PN sequence. Notice the sin(x)/x form of the envelope of the spectrum.

4-2 Where do the nulls occur? What is the separation between harmonics? What do these values relate to?

|  |
| --- |
|  |
|  |
|  |

1. Switch to the Y output of Sequence Generator 1. The Y output generates an11-bit sequence with length of 211 – 1 = 2047bits.
2. Confirm that the nulls and harmonic separation are in accordance with the relationships we uncovered in the previous part of the experiment.

When considering a PN sequence such as this example, it is easy to see the repetition of such short sequences, and hence to understand that it is not truly random. You can even count the one and zeros, and runs of ones and zeros and prove to yourself some of the characteristics of these maximal length sequences. Try this for yourself.

You can also see that if such a sequence is correlated against itself i.e.: autocorrelated, then it will only have one position in which there is strong correlation. Hence these sequences are useful for coding in spread spectrum type systems.

## 4.1 Analog noise generation (AWGN)

As we have just seen with the PN sequences, the spectrum of composed of many evenly spaced harmonics with a rolloff to repetitive nulls. If we wish to create a signal composed of many evenly spaced harmonics of equal amplitude, we can isolate a small region of the PN sequence spectrum and use that as our signal. Using a low pass filter, we can attenuate all harmonics above say 10% PN CLOCK frequency and then we are left with a signal with White Gaussian Noise characteristics which is useful in various experiments as a noise source. AWGN stands for “additive white Gaussian noise” meaning the type of noise which is imposed on a signal travelling through a particular noisy channel.

1. Patch together Figure 9 and view the output of the TUNEABLE LPF. Set the TUNEABLE LPF controls both to fully clockwise at this stage. View the input and output signals to the filter in the time domain and the frequency domain.

CH9-e

Figure 8:Block diagram for PRBS generated analog noise

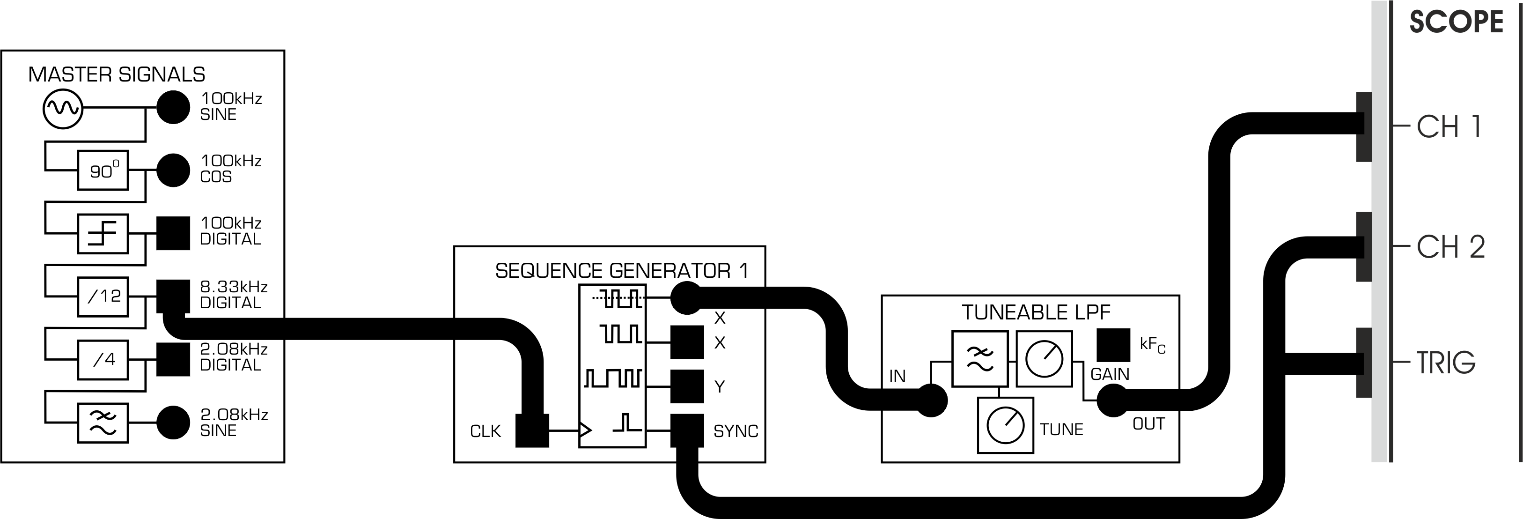


Figure 9:Patching diagram for PRBS analog noise

Scope Configuration

|  |  |
| --- | --- |
| Channel Voltage range | 1V/div |
| Horizontal Timebase | 5ms/div |
| Coupling | Chan 1: DC |
| Trigger | Digital, Source: TRIG, Rising |
| Probe Attenuation | 1x |
| Additional Channels | FFT On, Source Channel: Channel 1, Start Frequency: 0Hz, Stop Frequency 50kHz, Window: Hamming |

1. With the cutoff frequency of the TUNEABLE LPF above 12kHz, you can view the unfiltered PN sequence as a bipolar sequence. We are using the bipolar output from SEQUENCE GENERATOR 1 as we want a bipolar analog output with no DC component.
2. Slowly reduce the cutoff frequency until you have reached approximately 500-600 Hz. You can see this from the spectrum display. Consider the output of the filter in the time domain. Is it a satisfactory noise signal?

4-3 How many harmonics are prominent in the filter output?

|  |
| --- |
|  |
|  |
|  |

1. Switch the input of the TUNEABLE LPF to the SEQUENCE GENERATOR 1 Y output. This will select the longer 11-bit sequence. Now take a look at the output from the filter. Would you describe this as a satisfactory noise signal? It certainly looks like “noise” with no visible repetition.

4-4 How many harmonics are visible in the filter output? Calculate this.

|  |
| --- |
|  |
|  |
|  |

4-5 Is this analog noise signal periodic? What is its period? Calculate this.

|  |
| --- |
|  |
|  |
|  |

When analysing the frequency response of systems, rather than sweeping a single frequency across the band, it is convenient to input a multi-frequency signal such as this PN noise, and then view the system response spectrum all in one display.

This approach is used is several later experiments in this DxIQ-45G Lab Manual and is particularly useful when used with an averaging display.

## Section 5:Non-linear processes: clipping, rectification and harmonic multiplication

Clipping or amplitude limiting a sinusoid can often occur in a system due to overload conditions. It may even be done on purpose in cases where the amplitude does not carry any information and class C amplifiers are to be used. Class C amplifiers are not linear and the maintenance of amplitude of the signal is not critical. These are typically used with FM signals, which are signals which do not carry any information in their amplitude but depend solely on the frequency and phase of the signal.

Although slight clipping of a sinusoid does not appear to be drastic when viewed in the time domain it will be interesting to see what effect it has on the frequency domain. To simulate clipping, we will input a sinusoidal waveform of varying peak-to-peak voltages to a +/- 1V Limiter.

1. Patch together Figure 11 and view the output of the LIMITER block. View the input and output signals to the LIMITER in the time domain and the frequency domain.

CH9-g

Figure 10: Clipping a signal

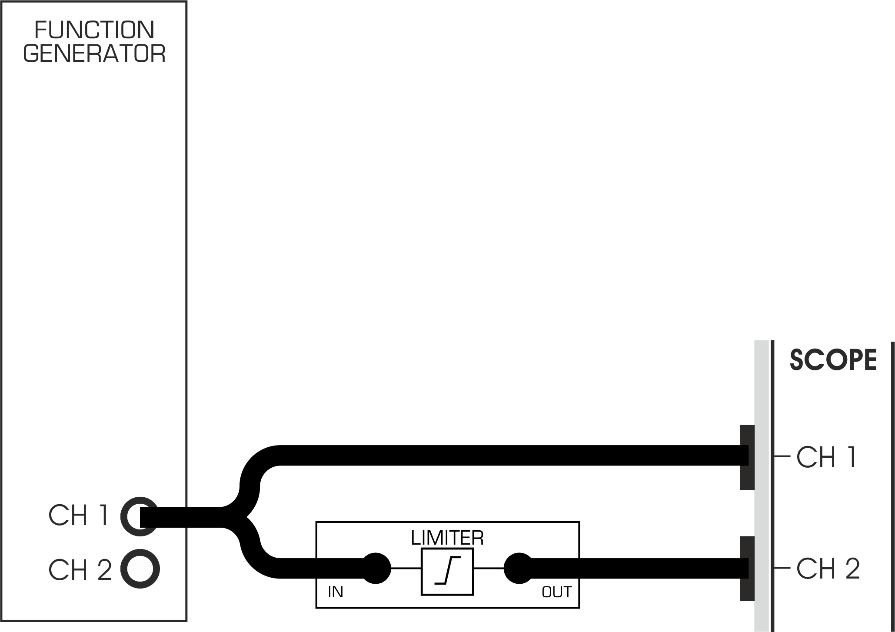


Figure 11: Patching for signal clipping

Scope Configuration

|  |  |
| --- | --- |
| Channel Voltage range | Ch1: 1V/div, Ch2: 1V/div |
| Horizontal Timebase | 1ms/div |
| Coupling | Chan 1: DC, Chan 2: DC |
| Trigger | Analog Edge, Chan 1, Rising, Level: 0V |
| Probe Attenuation | 1x |
| Additional Channels | FFT On, Source Channel: Channel 1, Start Frequency: 0Hz, Stop Frequency 50kHz, Window: Hamming |

Function and Arbitrary Waveform Generator Configuration

|  |  |
| --- | --- |
| Channel 1 | Sine |
| Frequency | 1kHz |
| Amplitude | 10Vpp |

1. Patch together the figure above and view both the input and output of the LIMITER block for Function Generator input signal settings of 10Vpp, 6Vpp, 4Vpp, and 2Vpp.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |
|  |  |  |  |  |  |  |  |  |  |

Graph 3: clipped signals and spectra

You can see that different levels of clipping are applied to the input sinusoid depending on the input voltage. Label your sketch with these levels, you may wish to use terms such as low, medium, high.

5-1 What effect does a higher level of clipping have on the spectrum of the clipped signal?

|  |
| --- |
|  |
|  |
|  |

1. Vary the frequency of the input sinusoid and observe the change in the harmonics of the clipped output.

5-2 What is the relationship between the input frequency and the output harmonic frequencies?

|  |
| --- |
|  |
|  |
|  |

1. Switch from the LIMITER block to the DIODEblock, and observe the spectrum of the half-wave rectified sine wave. Plot the responses on the previous graph.

5-3 What can you say about the spectrum of the half-wave rectified sine wave? Is this what you would have expected? Refer back to your pre-lab preparation questions.

|  |
| --- |
|  |
|  |
|  |

5-4 Is the clipping process a linear or non-linear process? Explain.

|  |
| --- |
|  |
|  |
|  |