

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



Lab 18: ASK modulation & demodulation

List of Updates

|  |  |
| --- | --- |
| **Date** | **Details** |
| 7/9/2018 | Completed final document |
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|  |  |

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# Lab 18: ASK modulation & demodulation

## Learning Objectives

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

1. Generate a real ASK signal at both baseband and bandpass
2. Describe the concept of amplitude modulation with digital data
3. Recover the data from an ASK signal using envelope detection
4. Explain the use of a comparator with bandlimited data signals in ASK
5. Recognise the frequency spectrum of ASK signals

## 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 * Function and Arbitrary Waveform Generator | * 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:  ECB\_positive1V\_DC.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: Amplitude Shift Keying

## Theory and Background

An essential part of electronic communications and telecommunications is the ability to share the channel. This is true regardless of whether the channel is copper wire, optical fiber or free-space. If it’s not shared then there can only ever be one person transmitting on it at a time. Think about the implications of this for a moment. Without the ability to share, there could only be one radio or TV station in each area. Only one mobile phone owner could use their phone in each cell at any one time. And there would only be the same number of phone calls between any two cities as the number of copper wires or optical fibers that connected them.

So sharing the channel is essential and there are several methods of doing so. One is called *time division multiplexing* (TDM) and involves giving the users exclusive access to the channel for short periods of time. On the face of it, this type of sharing might seem impractical. Imagine giving all mobile phone users in a cell just a minute or so to make their call then having to wait until their turn comes around again. However, TDM works well when the access time is extremely short (less than a second) and the rate of the sharing is fast. This allows multiple users to appear to have access all at the same time.

TDM is used for digital communications and is achieved by interleaving the users’ data. That is, a portion of one user’s data is transmitted followed by a portion of the next user’s data and so on. Unfortunately, there’s a catch. If the message is real-time information that cannot afford to be delayed (like digitally encoded speech) then, as the number of users increases, so must the data’s bit-rate. However, Experiment 16 has shown that doing so increases the likelihood of the channel’s bandwidth distorting the signal causing errors at the receiver.

Another method of sharing the channel is called *frequency division multiplexing* (FDM) and involves giving the users exclusive and uninterrupted access to a portion of the channel’s radio frequency spectrum. To transmit their message the user must superimpose it onto a carrier that sits inside their allocated band of frequencies. This method is used by broadcast radio and television to share free-space.

FDM is also used for digital communications and uses the same modulation schemes available to analog communications including: AM, DSBSC and FM. When AM is used for multiplexing digital data, it is known as *amplitude shift keying* (ASK). Other names include: *on-off keying*, *continuous wave* and *interrupted continuous wave*.

Fig%2015-1

Figure 1: Digital data and ASK signal

Notice that the ASK signal’s upper and lower limits (the *envelopes*) are the same shape as the data stream (though the lower envelope is inverted). This is simultaneously an advantage and a disadvantage of ASK. Recovery of the data stream can be implemented using a simple envelope detector (refer to the preliminary discussion of Experiment 8 for an explanation of the envelope detector’s operation). However, noise on the channel can change the envelopes’ shape enough for the receiver to interpret the logic levels incorrectly causing errors (analog AM communications have the same problem and the errors are heard as a hiss, crackles and pops).

Here you’ll examine the operation of a method that involves using the digital signal to switch the carrier’s connection to the channel on and off.

## Implement: Generating an ASK signal

For this experiment you’ll use the Emona Communications board to generate an ASK signal using the switching method. Digital data for the message is modelled by the SEQUENCE GENERATOR module. You’ll then recover the data using a simple envelope detector 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). |

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| --- | --- |
| 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. |

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| --- | --- |
| 5. | Open the Instrument Launcher software in your browser and open the Oscilloscope. |

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| --- | --- |
| 6. | Configure the Oscilloscope instruments using the parameters in the following tables. |

Scope Configuration

|  |  |
| --- | --- |
| Channel Voltage range | 1V/div |
| Horizontal Timebase | 1ms/div |
| Trigger | Type: Digital Edge, Source: TRIG input, Rising |
| Probe Attenuation | 1x |

## Implement: Setting up the data signal

|  |  |
| --- | --- |
| 1. | Connect the set-up shown in Figure 2 below.  **Note:** Insert the black plugs of the oscilloscope leads into a ground (*GND*) socket. |

This set-up can be represented by the block diagram in Figure 3 below. The SEQUENCE GENERATOR module is used to model a digital signal and its SYNC output is used to trigger the scope to provide a stable display. The MUX module is used to generate the ASK signal.

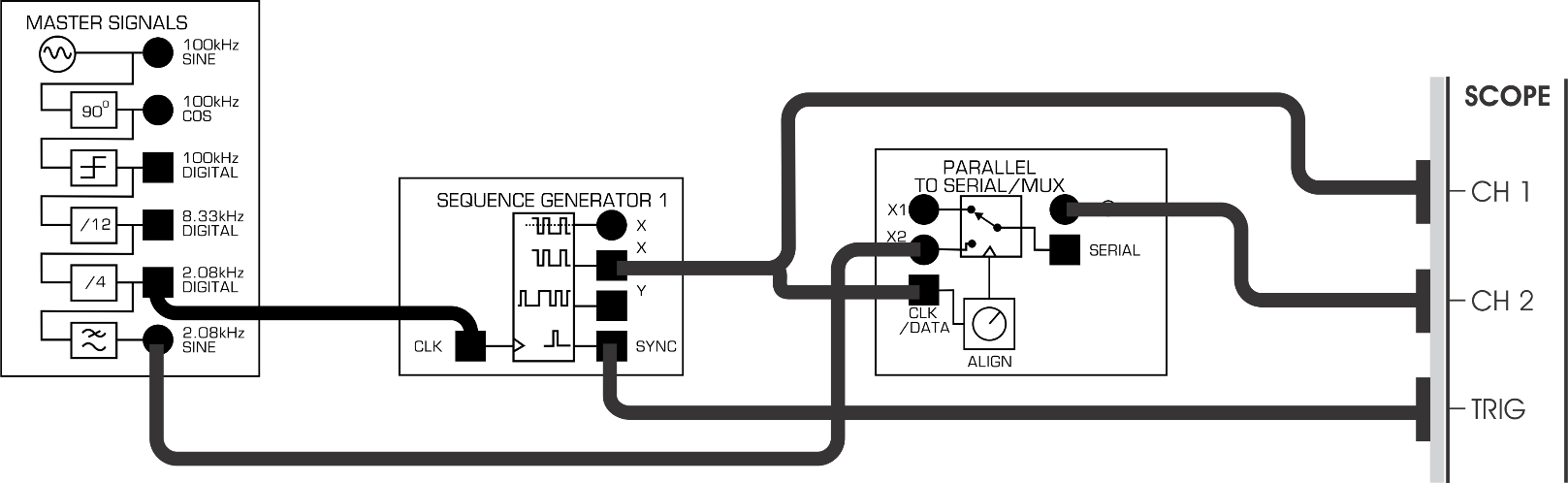


Figure 2: Patching for baseband ASK signal generation

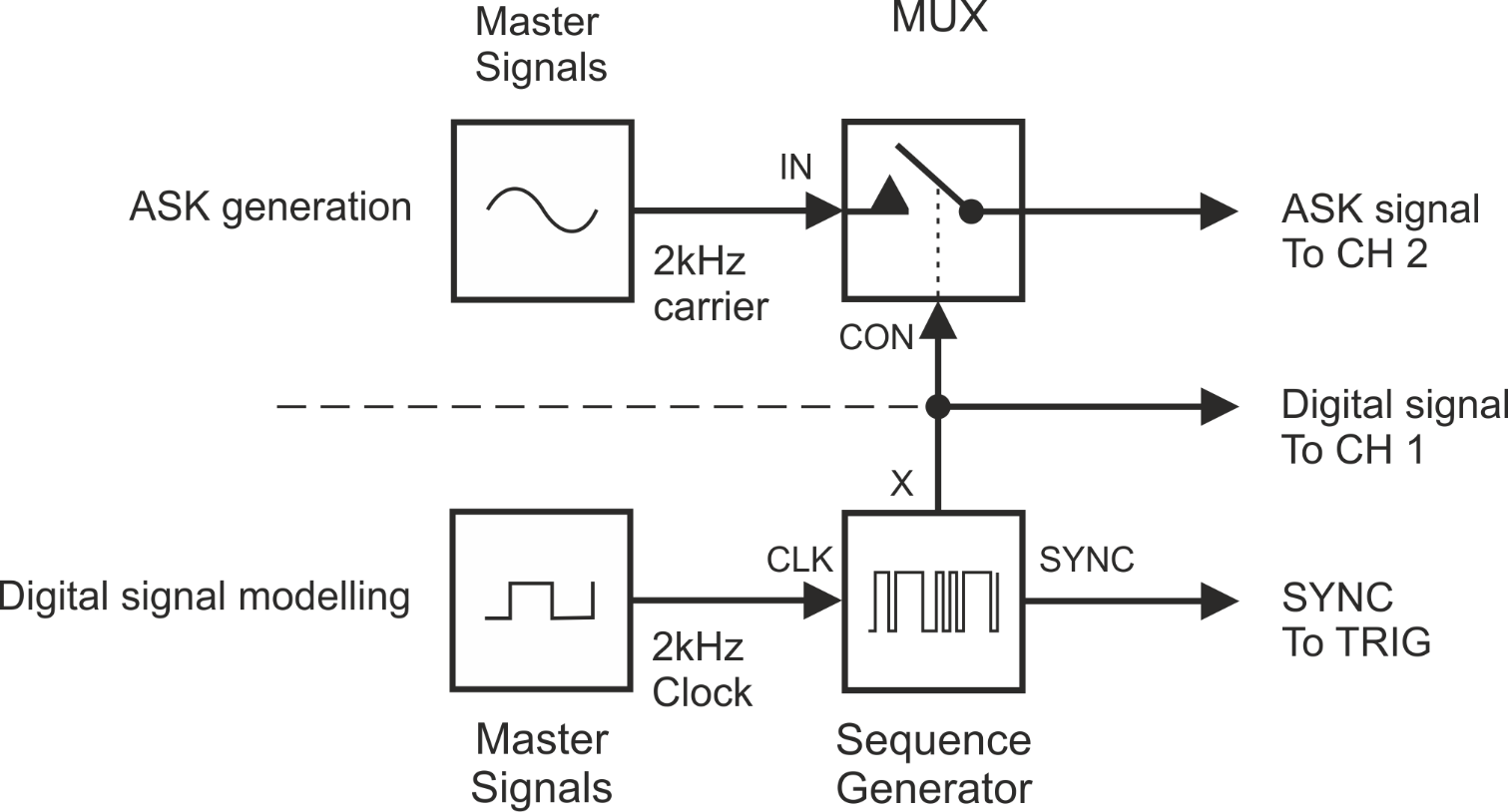


Figure 3: Block diagram for baseband ASK signal generation

|  |  |  |
| --- | --- | --- |
| 2. | To select the MUX function in the PARALLEL TO SERIAL/MUX module, ensure to set the top DIP switch on the board to the left; to the MUX position. | |
| 3. | | Activate the scope’s Channel 2 input to observe the SEQUENCE GENERATOR module’s output and the ASK signal out of the MUX module. | |

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| --- | --- |
| 4. | Compare the signals. |

|  |
| --- |
| 1-1 What is the relationship between the digital signal and the presence of the carrier in the ASK signal? |
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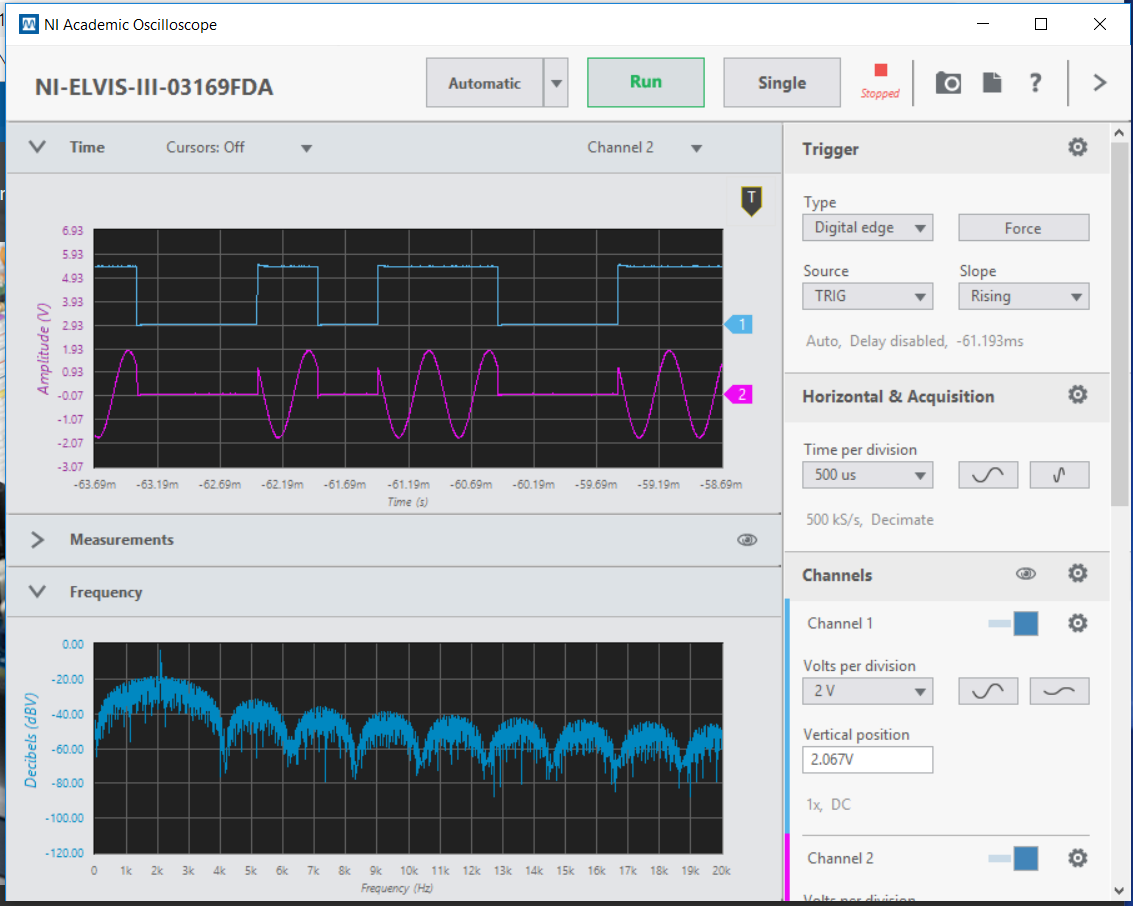


Figure 4: time and frequency domain signals for baseband ASK

|  |
| --- |
| 1-2 What happens if you switch the 2.08kHz sine signal to the X1 input of the MUX temporarily? |
|  |
|  |

Notice that the ASK signal’s carrier and the Sequence Generator module’s clock are the same frequency (2.08kHz). Moreover, notice that they’re from the same source – the MASTER SIGNALS module.

This has been done to make the ASK signal easy to look at on the scope and somewhat “textbook-like”. However, it makes the set-up impractical as a real ASK communications system because the carrier and the data signal’s fundamental are too close together in frequency. This would make recovering the digital data at the receiver difficult if not impossible.

Ideally, the carrier frequency should be much higher than the bit-rate of the digital signal (which is determined by the SEQUENCE GENERATOR module’s clock frequency in this set-up). The next part of the experiment gets you to set the carrier to a more appropriate frequency. In the process, the MUX module’s output will look more like a conventional ASK signal.

|  |  |
| --- | --- |
| 5. | Modify the set-up as shown in Figure 4 below.  **Remember:** Dotted lines show leads already in place. |

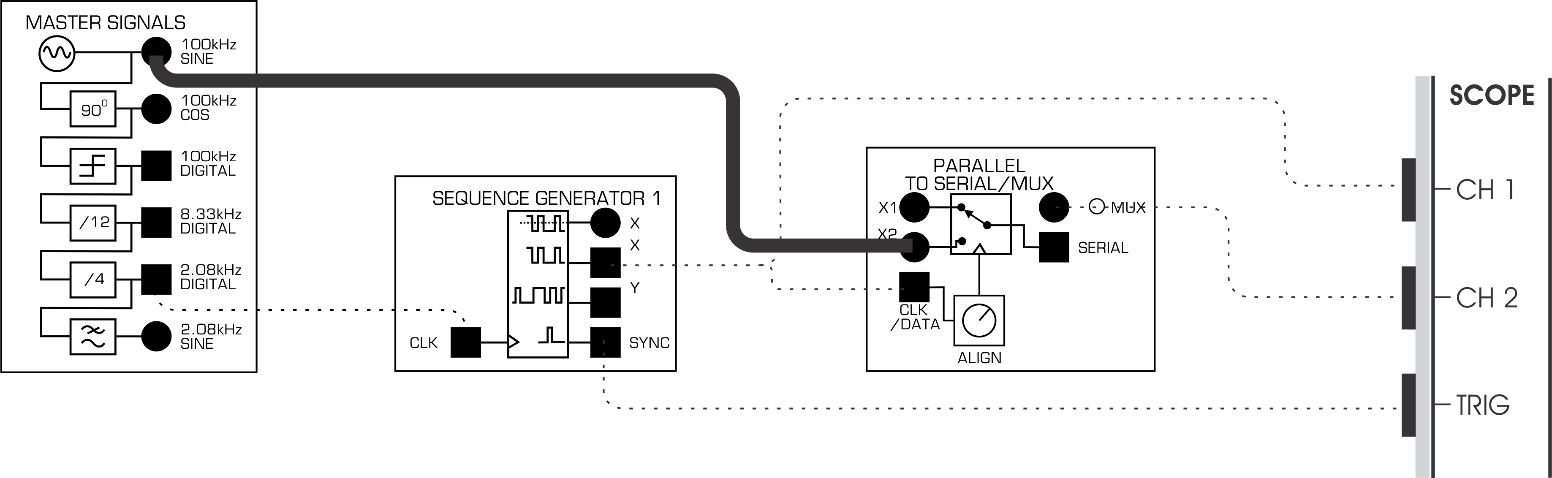


Figure 5: Patching for ASK with 100kHz carrier

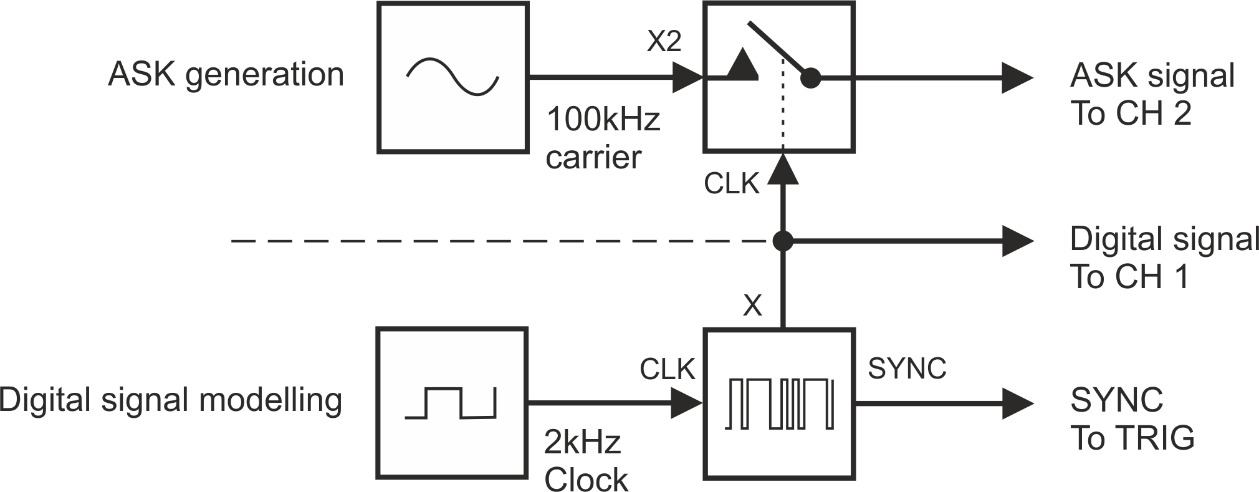


Figure 6: Block diagram for ASK with 100kHz carrier

|  |  |
| --- | --- |
| 6. | Compare the signals. |

|  |
| --- |
| 1-3 What feature of the ASK signal suggests that it’s an AM signal? **Tip:** If you’re not sure, see the preliminary discussion. |
|  |
|  |

## Section 2: Demodulating an ASK signal using an envelope detector

As ASK is really just AM (with a digital message instead of speech or music), it can be recovered using any of the AM demodulation schemes. The next part of the experiment lets you do so using an envelope detector.

|  |  |
| --- | --- |
| 1. | Locate the TUNEABLE LOW-PASS FILTER module on the ECB and turn its *Gain* control fully clockwise. |

|  |  |
| --- | --- |
| 2. | Turn the TUNEABLE LOW-PASS FILTER module’s TUNE control fully clockwise. |

|  |  |
| --- | --- |
| 3. | Modify the set-up as shown in Figure 6 below. |

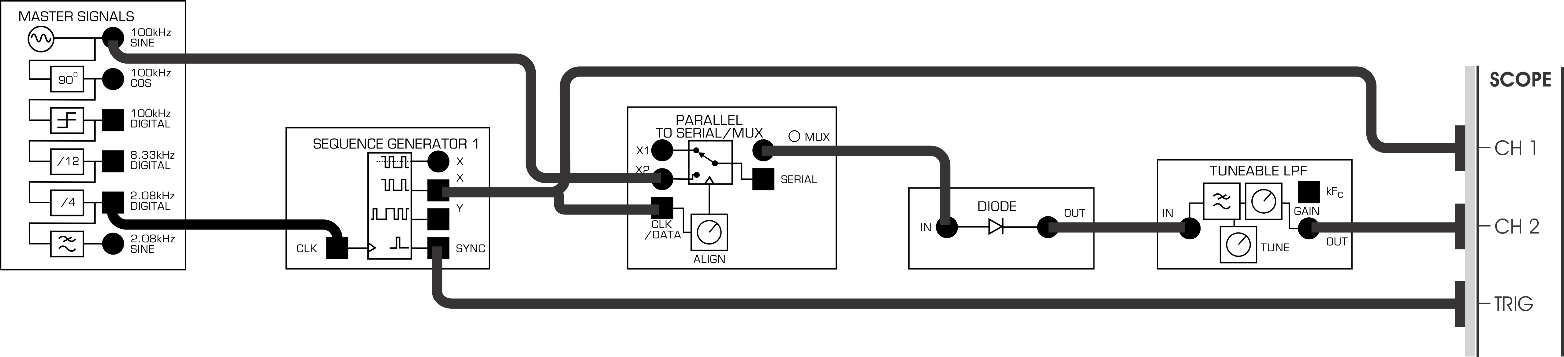


Figure 7: Patching with envelope detection

1. The ASK generation and demodulation parts of the set-up can be represented by the block diagram in Figure 7 on the next page. The rectifier on the DIODE module and the TUNEABLE LOW-PASS FILTER module are used to implement an envelope detector to recover the digital data from the ASK signal.

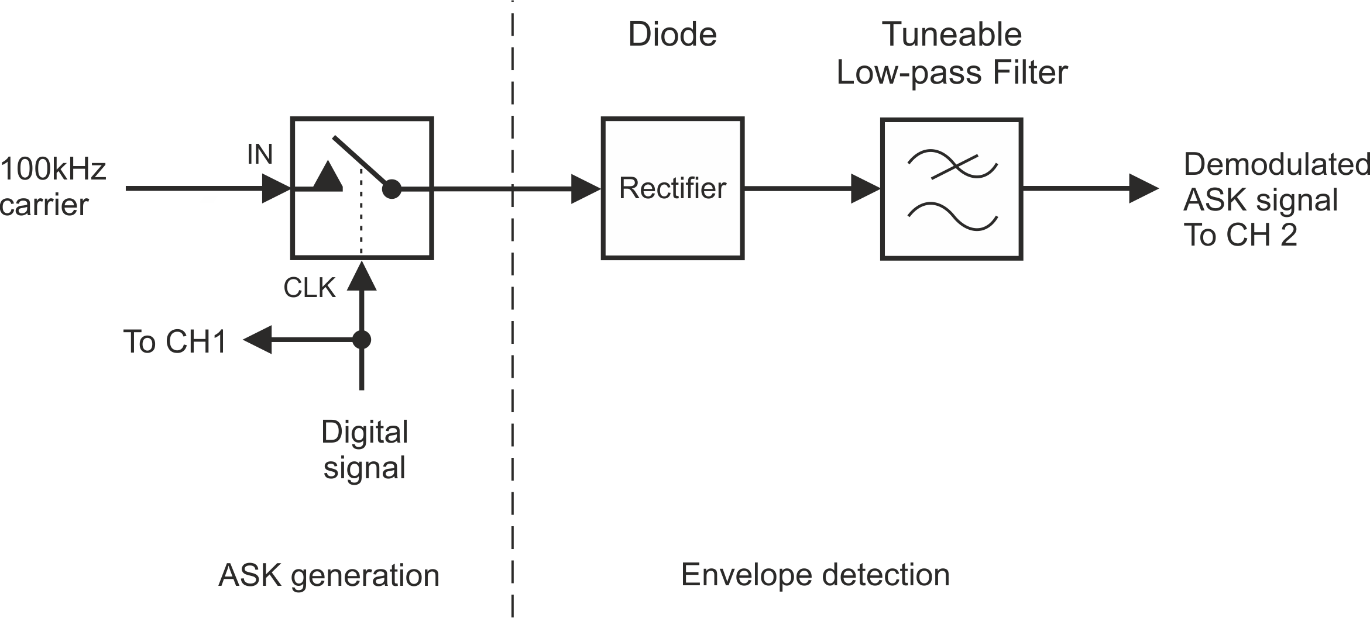


Figure 8: Block diagram with envelope detection

|  |  |
| --- | --- |
| 5. | Compare the original and recovered digital signals.  **Tip:** If necessary, adjust the scope’s Channel 2*Scale* control for a better comparison between the signals. |

|  |
| --- |
| 2-1 Why is the recovered digital signal not a perfect copy of the original? |
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|  |
|  |

|  |
| --- |
| 2-2 What happens to the recovered signal if you swap the 100kHz carrier for the 2.08kHz carrier briefly? |
|  |
|  |
|  |

|  |
| --- |
| 2-3 What can be used to “clean-up” the recovered digital signal? |
|  |

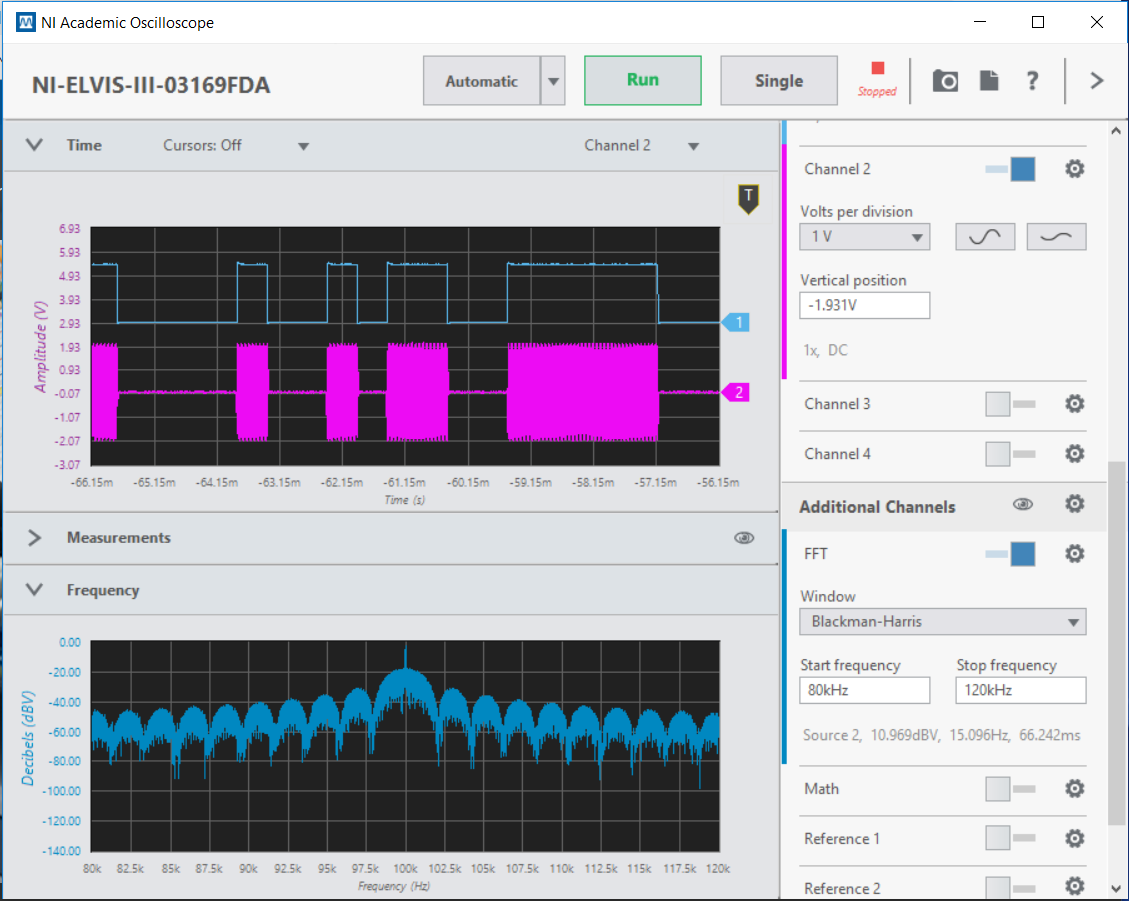


Figure 9: Time and frequency domain signals for 100kHz carrier ASK

## Section 3: Restoring the recovered digital signal using a comparator

A comparator is a useful circuit for restoring distorted digital signals. The next part of the experiment lets you use a comparator to clean-up the demodulated ASK signal.

|  |  |
| --- | --- |
| 1. | Launch and run the NI ELVIS IIIFUNCTION GENERATOR and configure as follows: |

Function Generator Configuration

|  |  |
| --- | --- |
| Channel 1 | Custom |
| Update rate | 1kS/s |
| Gain | 1 |
| Waveform file | ECB\_positive1V\_DC.csv |

|  |  |
| --- | --- |
| 2. | Modify the set-up as shown in Figure 8 below. |

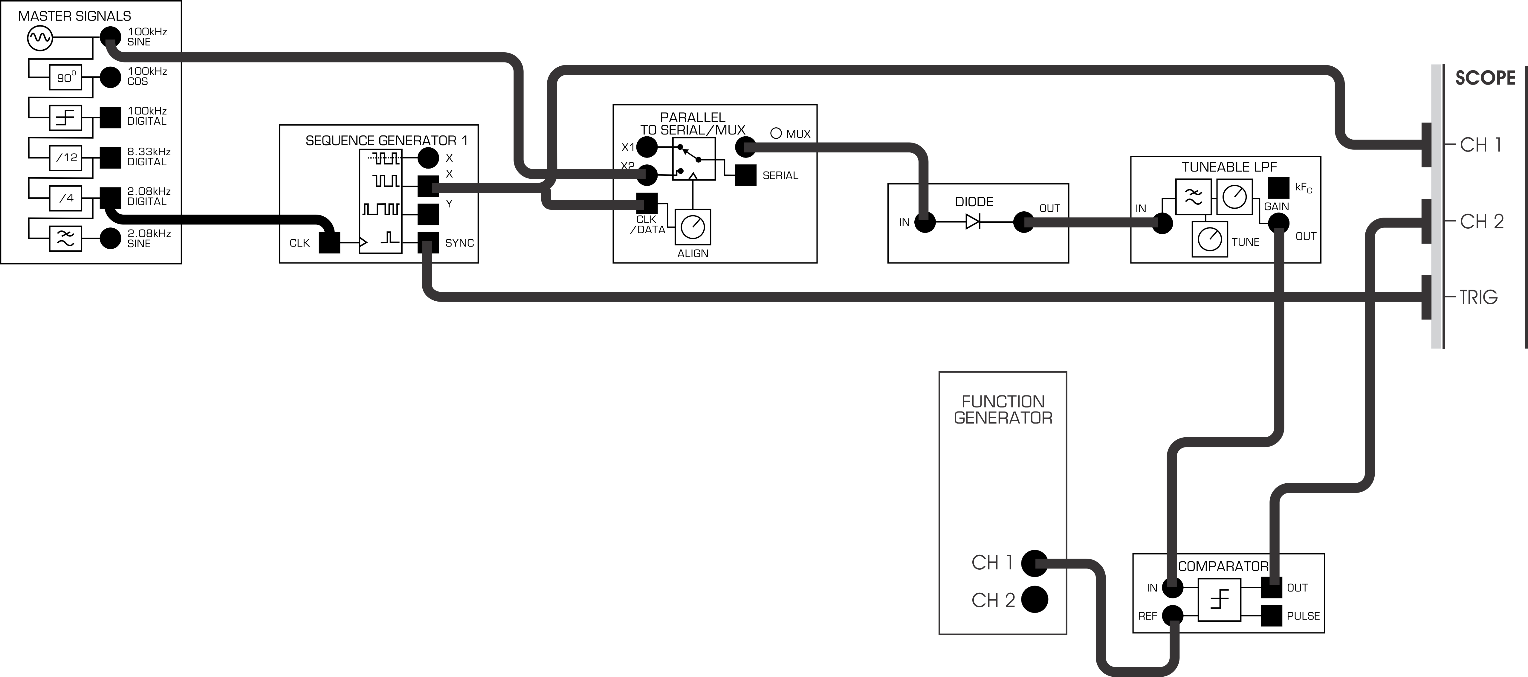


Figure 10: Patching to add comparator

The ASK generation, demodulation and digital signal restoration parts of the set-up can be represented by the block diagram in Figure 9 below.

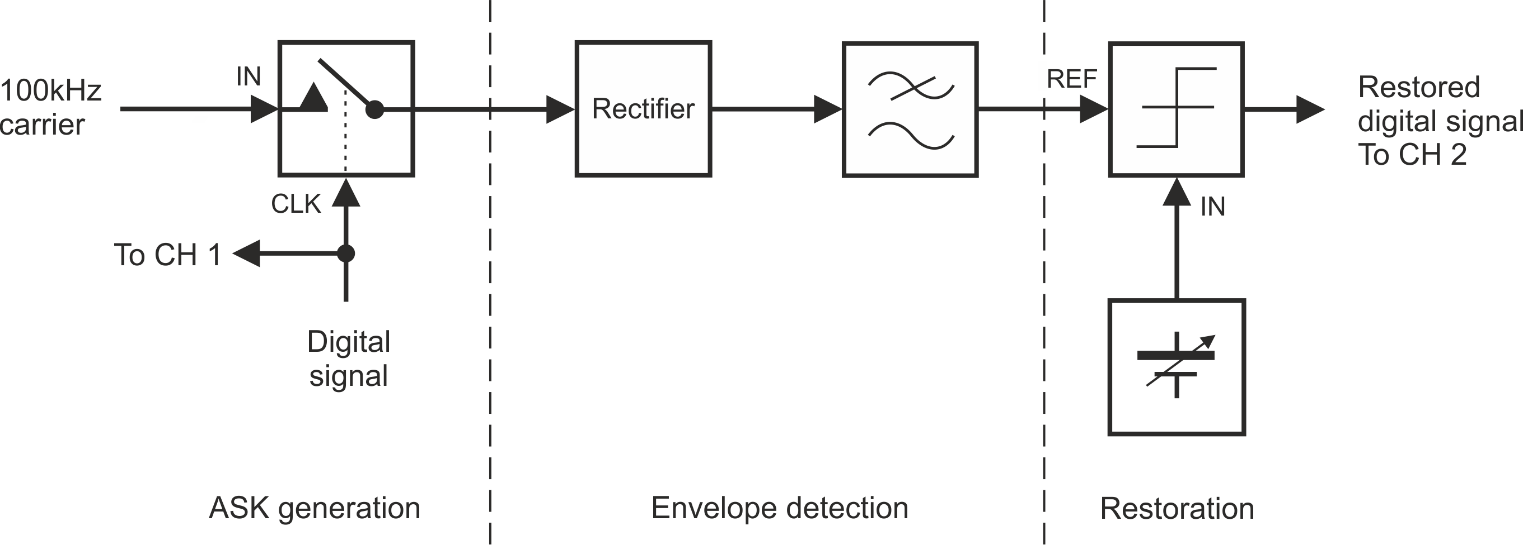


Figure 11: Block diagram with digital restoration

|  |  |
| --- | --- |
| 3. | Compare the original data and the output from the COMPARATOR module. If they’re not the same, view both inputs to the COMPARATOR and adjust the Gain of the 1V signal out of the FUNCTION GENERATOR until this reference voltage is at a level half the amplitude of the Incoming ASK signal. |

|  |
| --- |
| 3-1 How does the comparator turn the slow rising voltages of the recovered digital signal into sharp transitions? |
|  |
|  |