

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



Lab 10: Frequency Shift Keying (FSK)

List of Updates

|  |  |
| --- | --- |
| **Date** | **Details** |
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# Lab 11: Frequency Shift Keying (FSK)

## Learning Objectives

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

1. Generate a real FSK signal
2. Describe the concepts of mark and space in the signal
3. Recover the data from an FSK signal using envelope detection
4. Explain the use of a comparator with bandlimited data signals in FSK

## 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**

|  |  |
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| Platform: NI ELVIS III  Instruments used in this lab:   * Oscilloscope-Time * 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:  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: Frequency Shift Keying

## Theory and Background

Frequency division multiplexing (FDM) allows a channel to be shared among a set of users. Recall that this is achieved by superimposing the message onto a carrier signal inside the user’s allocated portion of the radio-frequency spectrum. Recall also that any of the analog modulation schemes can be used to transmit digital data in this way. When frequency modulation (FM) is used it is known as *binary frequency shift keying* (BFSK or more commonly just FSK).

One of the reasons for using FSK is to take advantage of the relative noise immunity that FM enjoys over AM. Recall that noise manifests itself as variations in the transmitted signal’s amplitude. These variations can be removed by FM/FSK receivers (by a circuit called a *limiter*) without adversely affecting the recovered message.

Figure 1 shows what an FSK signal looks like time-coincident with the digital signal that has been used to generate it.



Figure 1: Typical FSK signal

Notice that the FSK signal switches between two frequencies. The frequency of the signal that corresponds with logic-0s in the digital data (called the *space frequency*) is usually lower than the modulator’s nominal carrier frequency. The frequency of the signal that corresponds with logic-1s in the digital data (called the *mark frequency*) is usually higher than the modulator’s nominal carrier frequency. The modulator doesn’t output a signal at the carrier frequency, hence the reference here to it as being the “nominal” carrier frequency.

Figure 2 shows the time and frequency domain views of a portion of a live FSK signal with a 100kHz mark frequency and a 130kHz space frequency. You can see the shift in frequency as the digital signal transitions from logic-1 to logic-0 in the time-domain view on the left. The peaks in the frequency domain view correspond to the two frequencies.

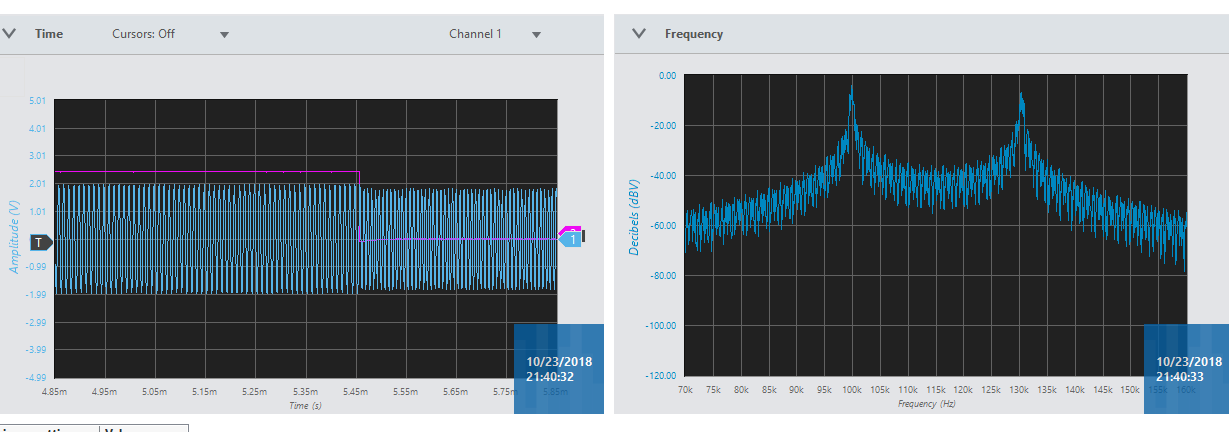


Figure 2: A live FSK signal shown in the time (left) and frequency domain.

FSK generation can be handled by conventional FM modulator circuits and the *voltage-controlled oscillator* (VCO) is commonly used. Similarly, FSK demodulation can be handled by conventional FM demodulators such as the *zero-crossing detector* (refer to the preliminary discussion of Experiment 9 for an explanation of this circuit’s operation) and the *phase-locked loop*. Alternatively, if the FSK signal is passed through a sufficiently selective filter, the two sinewaves that make it up can be individually picked out. Considered on their own, each signal is an ASK signal and so the data can be recovered by passing either one of them through an envelope detector (refer to the preliminary discussion of Experiment 5 for an explanation of the envelope detector’s operation).

## Implement: Generating an FSK signal

For this experiment you’ll use the Emona Communication Board to implement the VCO method of generating an FSK signal. Digital data for the message is modelled by the Sequence Generator module. You’ll then recover the data by using a filter to pick-out one of the sinewaves in the FSK signal and demodulate it using an envelope detector. Finally, you’ll observe the demodulated FSK signal’s distortion and 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**

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

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

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| 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 and the Function and Arbitrary Waveform Generator instruments. |

## Implement: Setting up the mark and space frequencies

For this experiment you’ll use the Emona Communication Board to implement the VCO method of generating an FSK signal. Digital data for the message is modelled by the Sequence Generator 1 module, however this data is used to generate the respective DC levels for both the mark and space portions of the signal as needed by the VCO.

The “1” level of the data creates the “mark” frequency portion of the FSK signal, whilst the”0” level of the data creates the “space” frequency portion of the FSK signal.

The multiplexer module “MUX” is used to convert the digital data stream to a two DC level stream which then drives the VCO to output two specific frequencies as determined by the DC level. One of the DC levels will be 0V supplied by a ground point (GND). The other DC level will be supplied by a custom waveform supplied by the Function and Arbitrary Waveform Generator.

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| 6. | Configure the Oscilloscope and the Function and Arbitrary Waveform Generator instruments using the parameters in the following tables. |

Scope Configuration

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| --- | --- |
| Channel Voltage range | 1V/div |
| Horizontal Timebase | 100*µ*s/div |
| Trigger | Type: Analog Edge, Source: Channel 1, Rising |
| Probe Attenuation | 1x |

Function Generator Configuration

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| --- | --- |
| Channel 1 | Custom |
| Update rate | 10kS/s |
| Gain | 1 |
| Waveform file | ECB\_positive1V\_DC.csv |

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| 7. | Turn the VCO GAIN control knob fully clockwise (maximum). |

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| 8. | Connect a GND point to the VCO module Vin input. |

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| 9. | Connect Scope CH1 to the SINE output of the VCO. Click the Scope Run button to start acquiring and measuring waveforms. On the Scope instrument, open the Measurements display found just below the Scope Time waveform display to see the Channel 1 Frequency measurement. |

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| 10. | Watching the Scope Channel 1 Frequency measurement, turn the VCO module FREQ control knob to adjust the VCO output frequency to approximately 100kHz. This will serve as our MARK frequency. |

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| 11. | Disconnect the GND point from the VCO module Vin input. Connect the Function Generator CH1 output to the VCO module Vin input. Click the Run button on the Function Generator to start generating a signal. |

In this experiment, we have set Function Generator Channel 1 to generate a Custom waveform with the ECB\_positive1V\_DC.csv file and a Gain value setting of 1. Doing so configures the Function Generator to output a DC waveform that we will use as a control voltage for a VCO. By changing the Gain value on the Function Generator, we can set the DC voltage level so as to specify a VCO output frequency.

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| 12. | Watching the Scope Channel 1 Frequency measurement, change the Function Generator Gain value until the VCO output frequency is approximately 130kHz. This will serve as our SPACE frequency. |

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| 13. | With the Gain value that you just set, use the Scope to measure the output voltage of Function Generator CH1. To do so, connect Scope CH1 to Function Generator CH1 using a test lead. Open the Scope Measurements display and read the value in the Channel 1 RMS column. |

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| 14. | Connect the set-up shown on Figure 3. Make sure that the micro-switch found under the EX-OR GATE module is set to MUX. Doing so sets the PARALLEL SERIAL/MUX module to MUX mode. |

This set-up can be represented by the block diagram in Figure 4. It uses an electronically controlled switch (the MUX) to connect the VCO Vin input to either a 0V (GND) or the DC value that you determined in step 13. The choice between the two levels is set by the value of the MUX CLK/DATA input.

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| 15. | Set up the Scope to the values on the following table: |

Scope Configuration

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| --- | --- |
| Channel Voltage range | CH1: 2V/div, CH2: 2V/div |
| Horizontal Timebase | 100*µ*s/div |
| Trigger | Type: Digital Edge, Source: Trig, Rising |
| Probe Attenuation | 1x |

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| 16. | Connect Scope CH1 to the MUX module output and connect Scope CH2 to the MUX module CLK/DATA input. Confirm that when the CLK/DATA input is at logic-1, the MUX module output is 0V and when the CLK/DATA input is at logic-0, the MUX module output is the DC value that you determined in step 13. |

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| 17. | Connect Scope CH1 to the VCO SINE output. Confirm that Scope CH1 shows an FSK waveform with 130kHz periods when the MUX CLK/DATA input is at logic-0 and 100kHz periods when the MUX CLK/DATA input is at logic-1. |

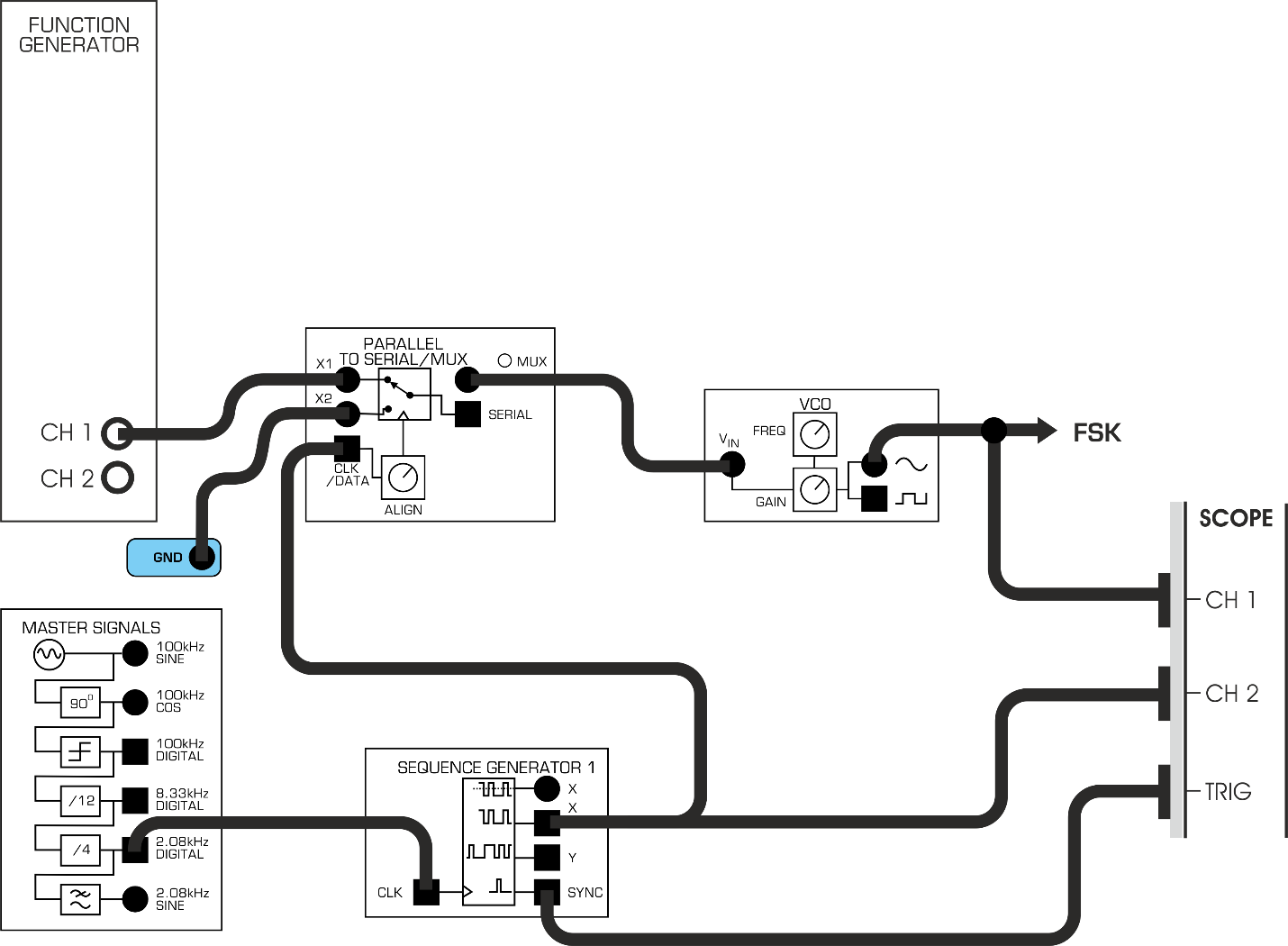


Figure 3: Patching diagram for dual-tone FSK generation

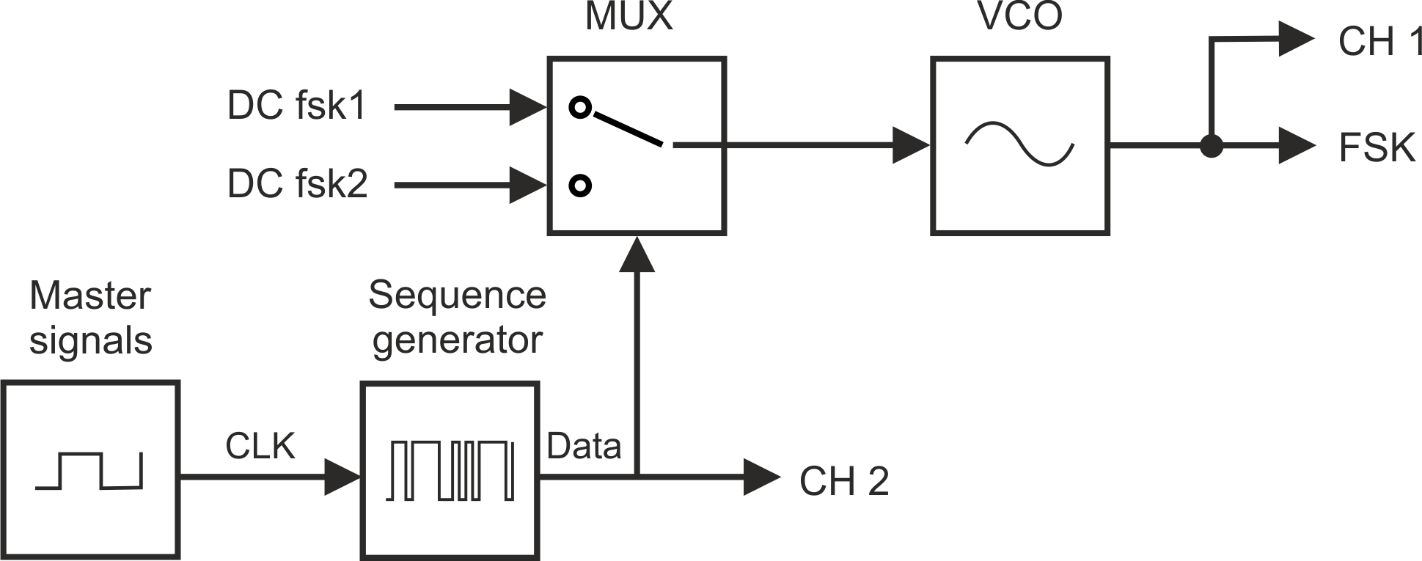


Figure 4: Block diagram for dual-tone FSK generation

* 1. What’s the name for the VCO output frequency that corresponds with logic-1s in the digital data? **Tip:** If you’re not sure, see the preliminary discussion.

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* 1. What’s the name for the VCO output frequency that corresponds with logic-0s in the digital data?

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* 1. Based on your observations of the FSK signal, which of the two is the higher frequency? Explain your answer.

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## Section 2: Demodulating an FSK signal using bandpass filtering and an envelope detector

As FSK is really just FM (with a digital message instead of speech or music), it can be recovered using any of the FM demodulation schemes. However, as the FSK signal switches back and forth between just two frequencies, we can use a method of demodulating that cannot be used to demodulate speech-encoded FM signals. The next part of the experiment lets you do this.

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| 1. | Connect the VCO SINE output to the input of the 100kHz BPF module. Connect Scope CH1 to the 100kHz BPF module output. Connect Scope CH2 to the SEQUENCE GENERATOR 1 Unipolar X output. Examine the Scope CH1 and CH2 waveforms. |

* 1. Which of the FSK signal’s two sinewaves is the filter letting through?

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* 1. What does the filtered FSK signal now look like?

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| 2. | Following the patch diagram shown on Figure 5, extend the setup to add an envelope detector to the output of the 100kHz BPF module. |

This set-up can be represented by the block diagram in Figure 6. It extends the block diagram of Figure 3 to add an envelope detector the FSK signal generator. The envelope detector includes a 100kHz band-pass filter to let the 100kHz portion of the signal through and block the 130kHz portion. It also includes a diode rectifier to convert the filtered signal from bipolar to unipolar. Finally, it includes a RRC low-pass filter to attenuate the high frequency components of the signal.

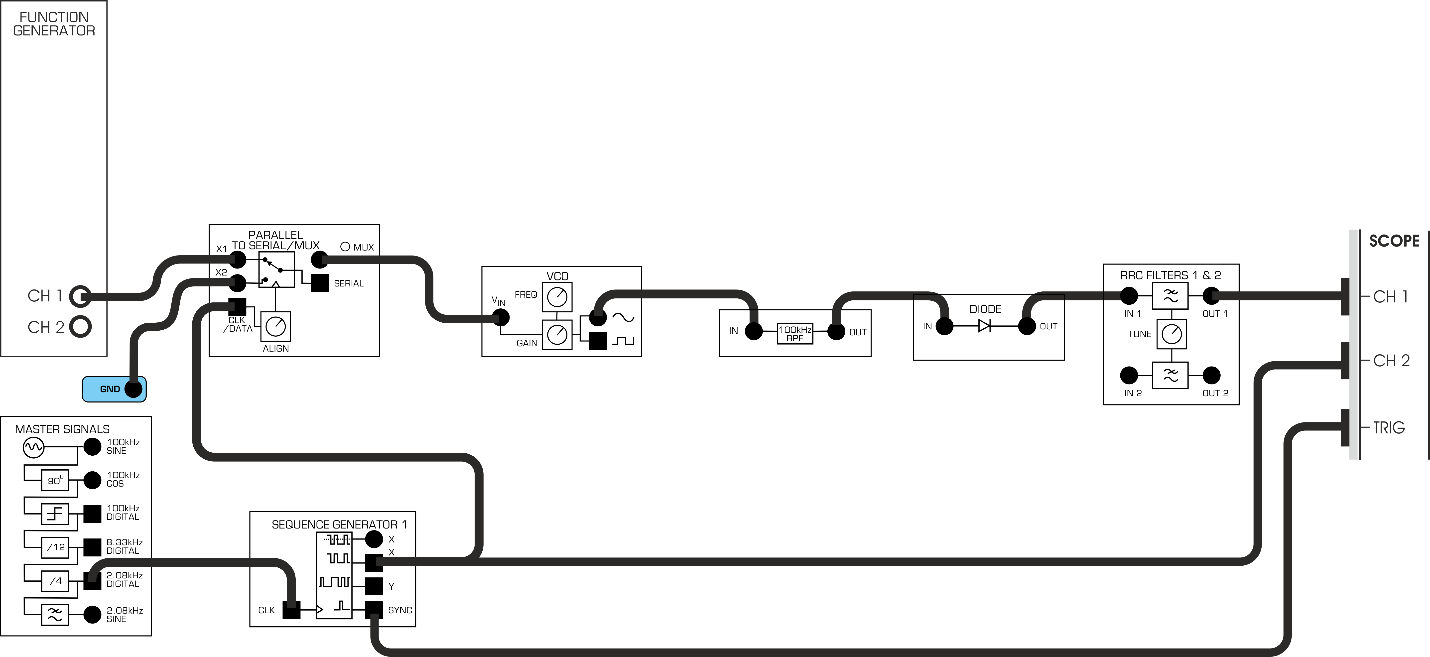


Figure 5: Patching diagram for FSK generation with envelope detection

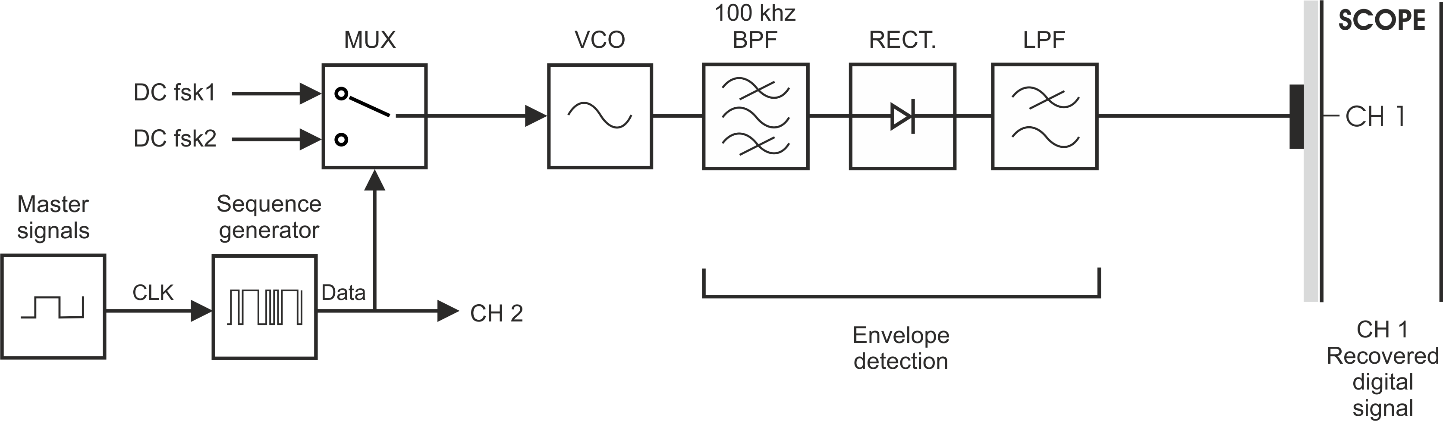


Figure 6: Block diagram for FSK generation with envelope detection

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| 3. | Turn the RRC FILTER 1 module TUNE knob fully clockwise. Doing so sets the RRC FILTER 1 module low-pass cut-off frequency to approximately 15kHz. |

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| 4. | Compare the original digital signal on Scope CH2 with the recovered digital signal on Scope CH1. |

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* 1. What can be used to “clean-up” the recovered digital signal?

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## Implement: Restoring the recovered data using a comparator

It is helpful to know that the 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 FSK signal.

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| 5. | Following the patch diagram shown on Figure 7, extend the setup to add a COMPARATOR module to the output of the envelope detector. |

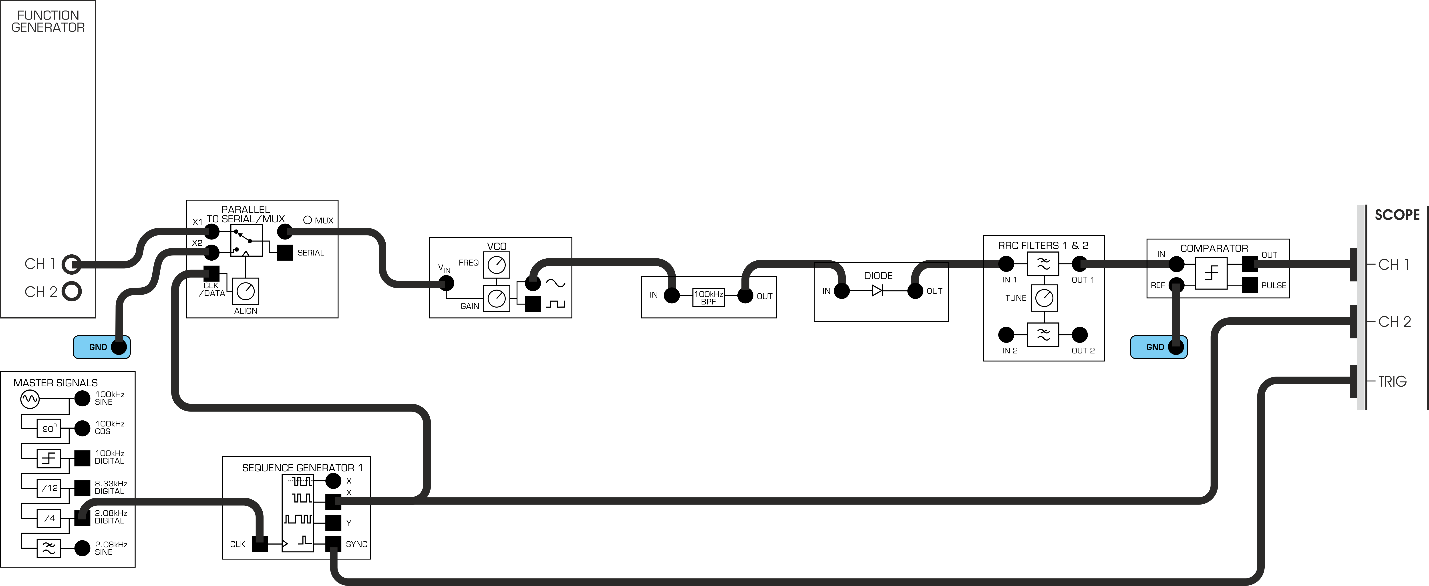


Figure 7: Patching diagram for FSK generation with envelope detection and digital reconstruction

The FSK generation, demodulation and digital signal restoration parts of the set-up can be represented by the block diagram shown on Figure 8.

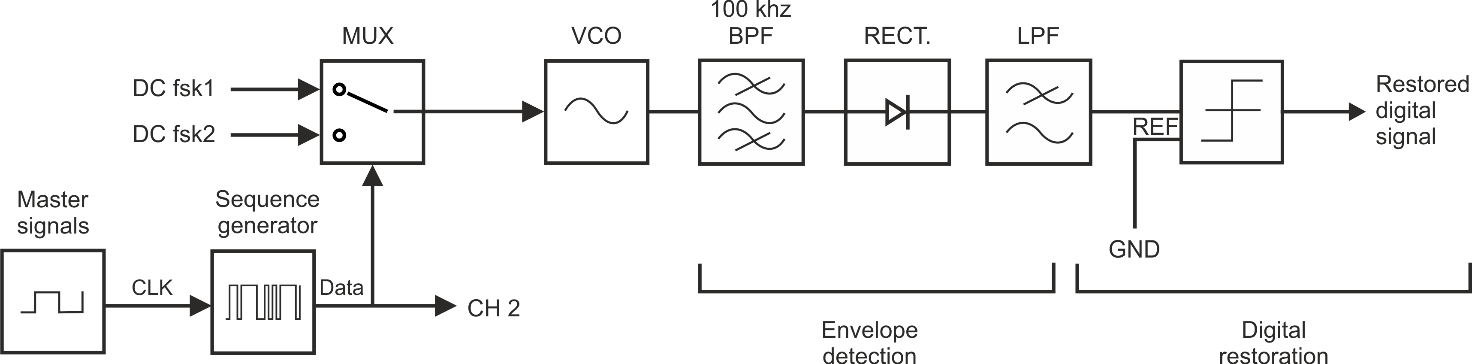


Figure 8: Block diagram for FSK generation with envelope detection and digital reconstruction

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| 6. | Compare Scope CH1 and CH2 to see differences between the input digital message signal and the recovered digital signal. |

* 1. How does the original digital message from the sequence generator compare to the recovered output of the comparator?

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

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