Name: ______________________

Class: ______________________

15 - Amplitude shift keying

Experiment 15 – Amplitude Shift Keying

Preliminary discussion

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 fibre 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 fibres 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 which can't afford to be delayed (like digitally encoded speech) then, as the number of users increases, so must the data's bit-rate. Experiment 14 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*.

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

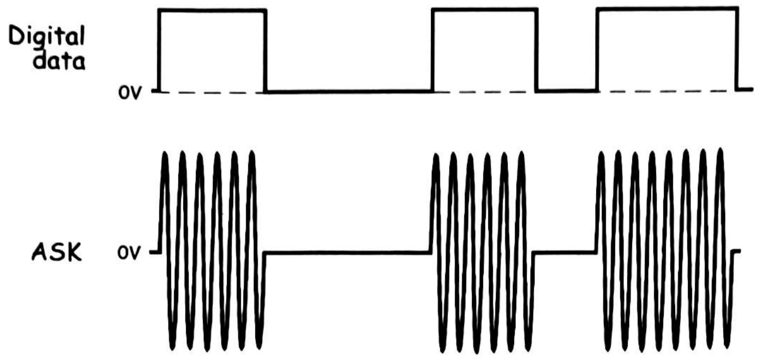

Figure 1

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 6 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).

ASK can be generated by conventional means like the one modelled in Experiment 4. Here you'll examine the operation of an alternative method that involves using the digital signal to switch the carrier's connection to the channel on and off.

The experiment

In this experiment you'll use the Emona Telecoms-Trainer 101 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.

Equipment

- Emona Telecoms-Trainer 101 (plus power-pack)
- Dual channel 20MHz oscilloscope
- three Emona Telecoms-Trainer 101 oscilloscope leads
- assorted Emona Telecoms-Trainer 101 patch leads

Procedure

Part A - Generating an ASK signal

1. Gather a set of the equipment listed above.

2. Set up the scope per the instructions in Experiment 1.

3. Set the scope's *Trigger Source* control to the *EXT* position.

4. Set the scope's *Trigger Source Coupling* control to the *HF REJ* position.

5. Set the scope's Channel 1 and Channel 2 *Input Coupling* controls to the *DC* position.

6. Set the scope's *Timebase* control to the *1ms/div* position.

7. Connect the set-up shown in Figure 2 below.

   Note: Insert the black plugs of the oscilloscope leads into a ground (*GND*) socket.

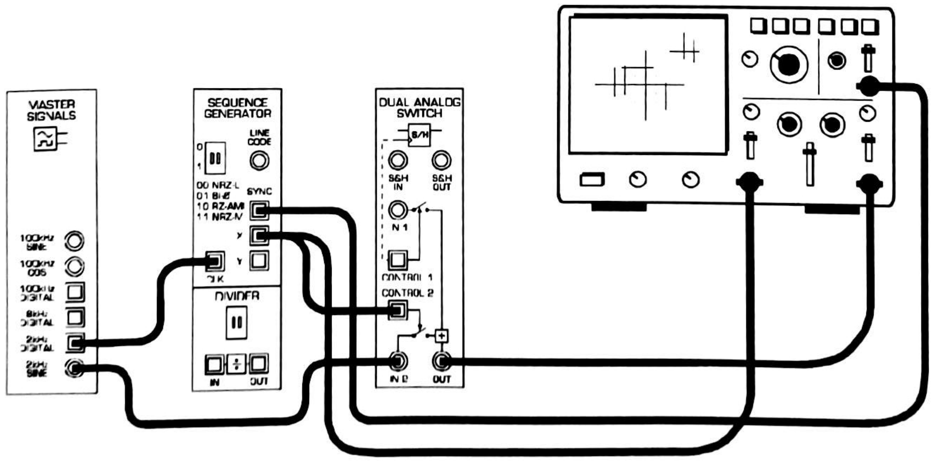

Figure 2

The set-up in Figure 2 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 Dual Analog Switch module is used to generate the ASK signal.

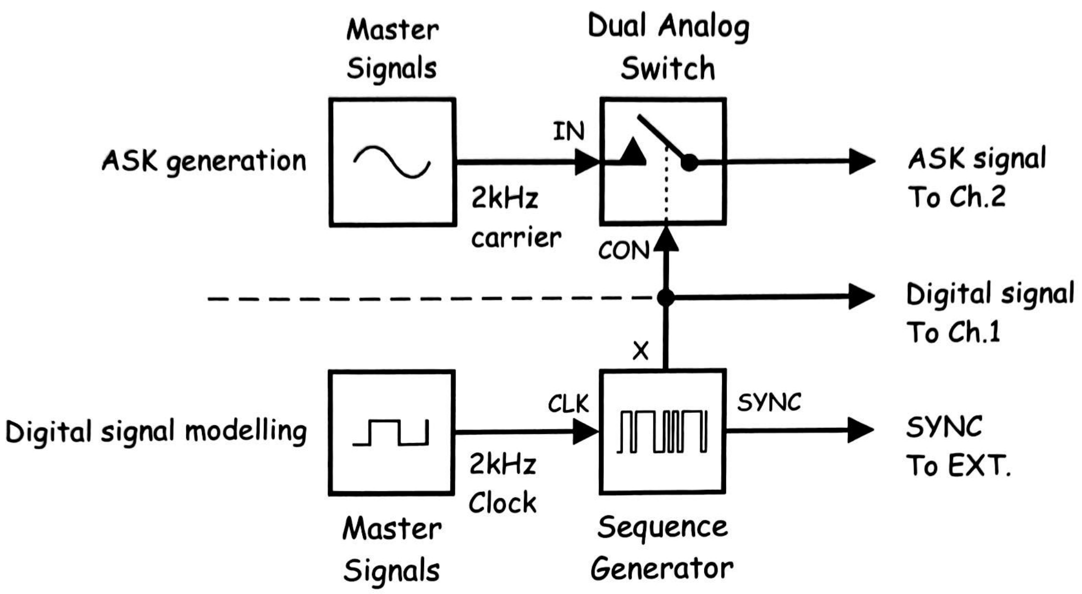

Figure 3

8. Set the scope's *Mode* control to the *DUAL* position to view the Sequence Generator module's output and the ASK signal out of the Dual Analog Switch module.

9. Compare the signals.

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

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Question 2
What is the ASK signal's voltage when the digital signal is logic-0? **Tip:** If you're not sure, briefly set the Channel 2 *Input Coupling* control to the *GND* position.

Ask the instructor to check your work before continuing.

Notice that the ASK signal's carrier and the Sequence Generator module's clock are the same frequency (2kHz). 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. 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. For reasons explained in Experiment 6 (see pages 6-10 and 6-11), this makes 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 (about 100kHz). In the process, the Dual Analog Switch module's output will look more like a conventional ASK signal.

10. Locate the VCO module and set its *Frequency Adjust* control to about the middle of its travel.

11. Set the VCO module's *Range* control to the *HI* position.

12. Modify the set-up as shown in Figure 4 on the next page.

    Remember: Dotted lines show leads already in place.

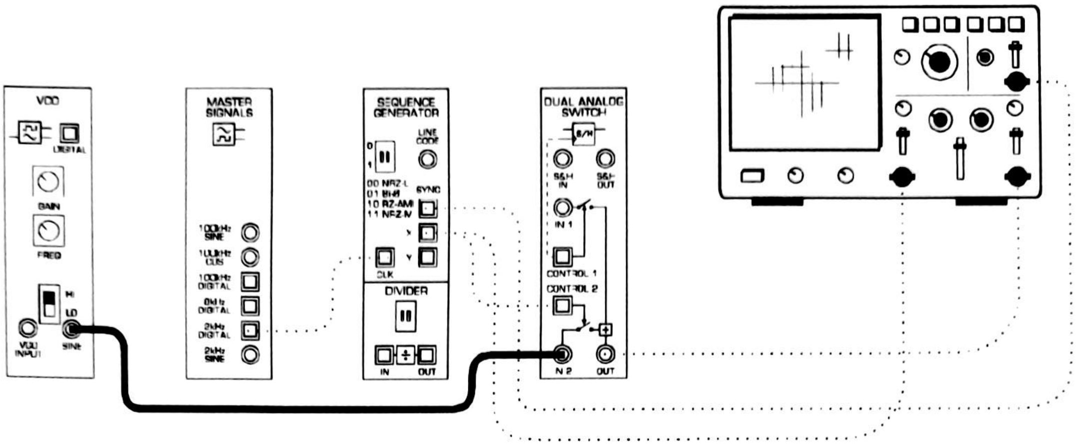

Figure 4

This set-up can be represented by the block diagram in Figure 5 below.

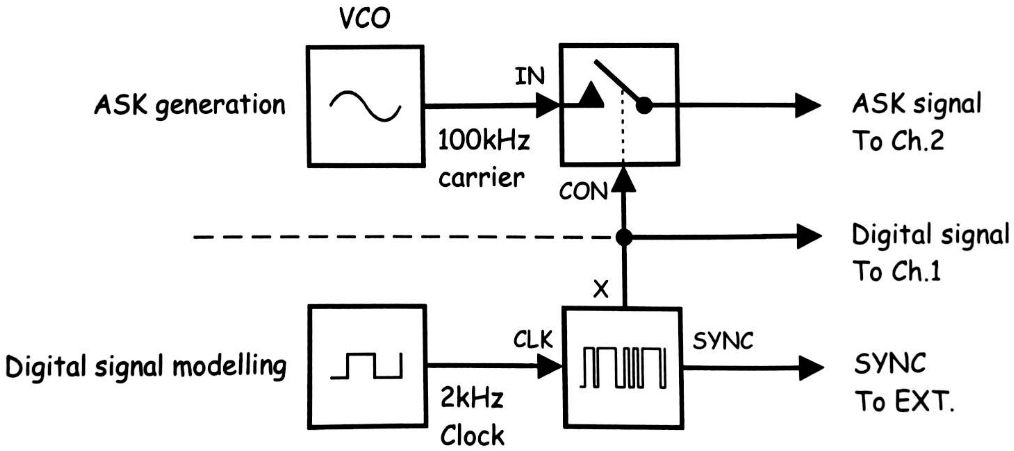

Figure 5

13. Compare the signals.

14. Use the scope's Channel 1 *Vertical Position* control to overlay the digital signal with the ASK signal's envelopes and compare them.

Question 3

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

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☑ Ask the instructor to check your work before continuing.

Part B - 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 AM demodulation schemes. The next part of the experiment lets you do so using an envelope detector.

15. Locate the Tuneable Low-pass Filter module and turn its *Gain* control fully clockwise.

16. Turn the Tuneable Low-pass Filter module's *Cut-off Frequency Adjust* control fully clockwise.

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

    Note: The left most modules have been left off to fit the drawing on the page.

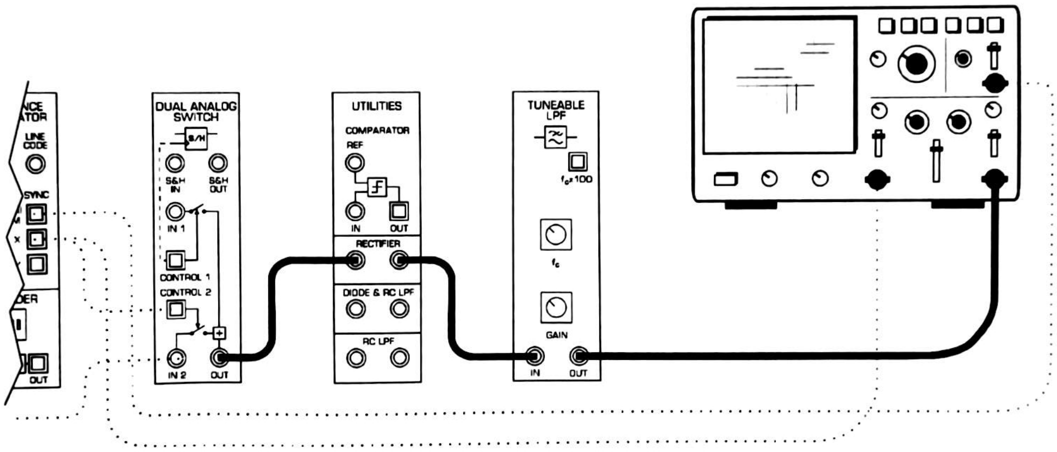

Figure 6

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 Utilities module and the Tuneable Low-pass filter module are used to implement an envelope detector to recover the digital data from the ASK signal.

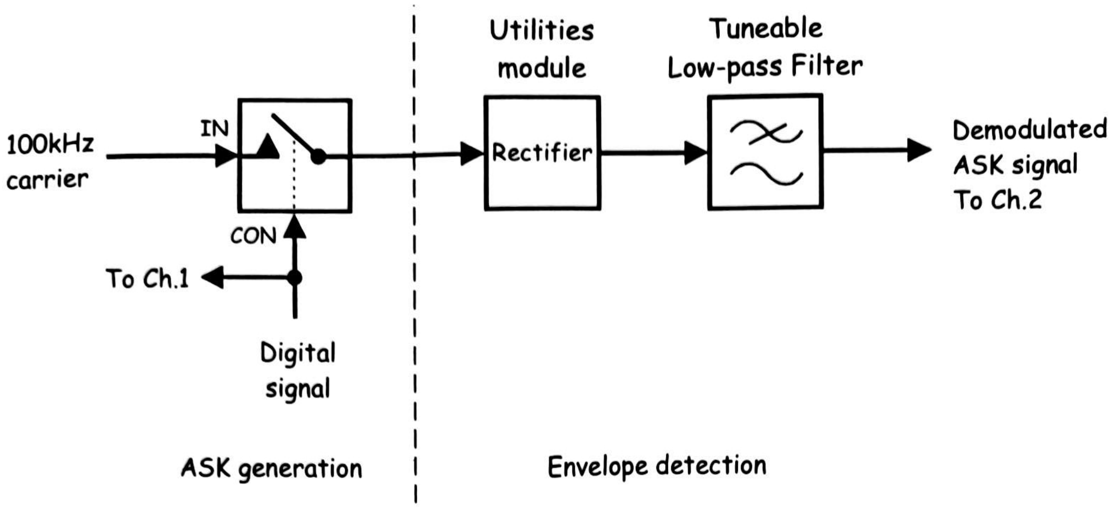

Figure 7

18. Compare the original and recovered digital signals.

Question 4
Why is the recovered digital signal not a perfect copy of the original?

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Question 5
What can be used to "clean-up" the recovered digital signal?

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Ask the instructor to check your work before continuing.

Part C - Restoring the recovered digital signal using a comparator

Experiment 14 shows 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 ASK signal.

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

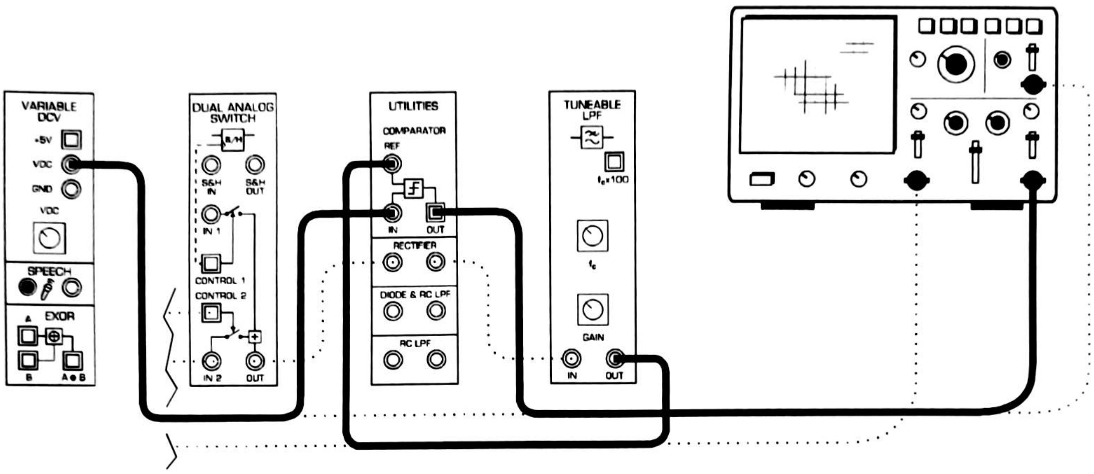

Figure 8

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

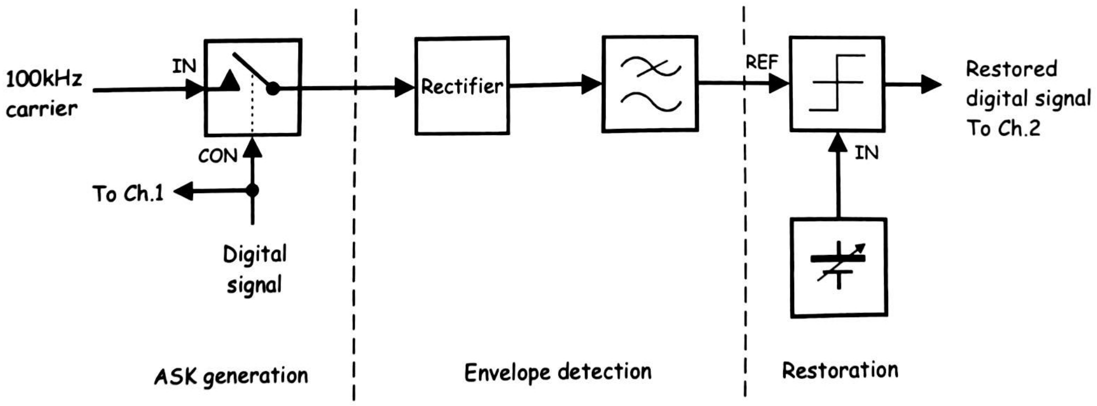

Figure 9

20. Set the Variable DCV module's *Variable DC* control to about the middle of its travel.

21. Compare the signals. If they're not the same, vary the Variable DCV module's *Variable DC* control until they are.

Question 6
How does the comparator turn the slow rising voltages of the recovered digital signal into sharp transitions?

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Ask the instructor to check your work before finishing.

Noise

It's common for radio frequency communications systems to be upset by unwanted electromagnetic radiation called *noise*. Some of this radiation occurs naturally and is generated by the Sun and atmospheric activity such as lightning. Much of the radiation is also human-made - either unintentionally (the electromagnetic radiation given off by electrical machines and electronics equipment) or intentionally (other peoples' communication transmissions that we don't want to receive).

Most noise gets added to signals while they're in the channel. This changes the signals' shape which in turn changes how the signal sounds when demodulated by the receiver. If the noise is sufficiently big (relative to the size of the signal) the signal can be changed so much that it cannot be demodulated.

It's possible to model noise being added to a signal in the channel of a communications system using the Emona Telecoms-Trainer 101. If the instructor allows, this activity gets you to do so.

1. Connect the set-up shown in Figure 1 below but **don't** disconnect any of your existing wiring.

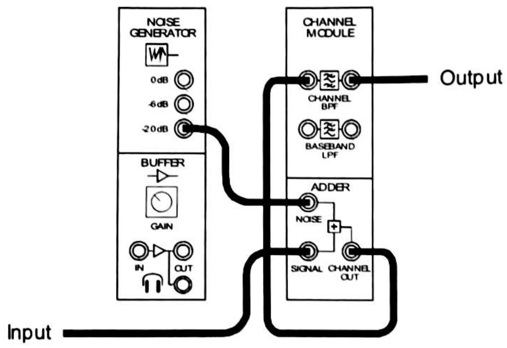

Figure 1

This set-up can be represented by the block diagram in Figure 2 on the next page. It models the behaviour of a real channel by adding noise to communications signals such as ASK.

Usefully, the amount of noise can be varied by selecting either the *-20dB* output (noise is about one-tenth the size of the signal), the *-6dB* output (noise is about half the size of the signal) or the *0dB* output (noise is about the same size as the signal).

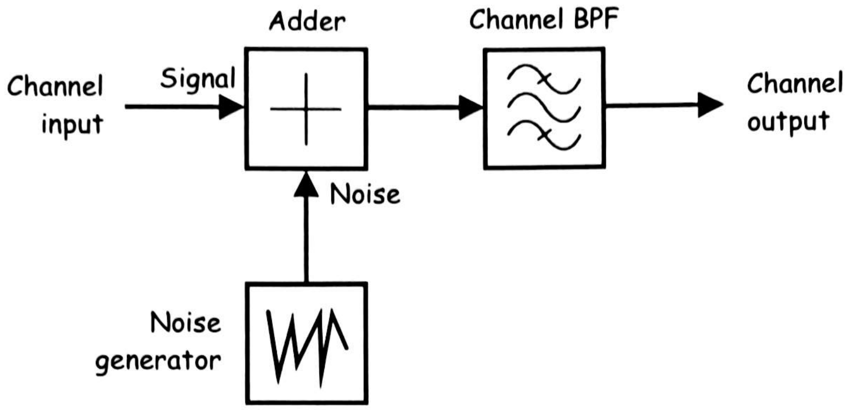

Figure 2

2. Unplug the patch lead to the Dual Analog Switch module's output and connect the noisy channel's input to it.

3. Unplug the patch lead to the rectifier's input and connect the noisy channel's output to it.

   Note: Once done, the transmitter's signal (the Dual Analog Switch module's output) travels to the receiver's input (the rectifier's input) via the model of a noisy channel.

4. Compare the original and recovered data. If they're not the same, vary the Variable DCV module's *Variable DC* control until they are.

5. Unplug the scope's Channel-2 input from the comparator's output and connect it to the Adder module's output to observe the noisy ASK signal.

6. Connect the Adder module's *Noise* input to the Noise Generator module's -6dB output to increase the noise in the channel.

7. Observe the effect that this has on the ASK signal.

8. Reconnect the scope's Channel-2 input to the comparator's output.

9. Compare the original and recovered data. If they're not the same, vary the Variable DCV module's Variable DC control until they are.

   Note: It may be impossible to recover the data.