Chapter 1

Line Code Encoder

1-1: Curriculum Objectives

1. To understand the theory and applications of line code encoder.
2. To understand the encode theory and circuit structure of NRZ.
3. To understand the encode theory and circuit structure of RZ.
4. To understand the encode theory and circuit structure of AMI.
5. To understand the encode theory and circuit structure of Manchester.

1-2: Curriculum Theory

Line coding is a part of source coding. Before PCM signal send to modulator, we use certain signal mode in certain application. The considerations of selecting the digital signal modes to carry the binary data are: 1. types of modulation, 2. types of demodulation, 3. the limitation of bandwidth, and 4. types of receiver.

Line coding can be divided into two types, which are return-to-zero (RZ) and nonreturn-to-zero (NRZ). RZ line coding denotes for a single bit time (normally is half of a single bit time), the waveform will return to 0 V between data pulses. The data stream is shown in figure 1-1(c). NRZ line coding denotes for a single bit time, the waveform will not return to 0 V. The data stream is shown in figure 1-1(a). As a result of the characteristics of signal, line coding also can be divided into two types, which are unipolar signal and bipolar signal. Unipolar signal denotes that the signal amplitude varies between a positive voltage level which are +V and 0 V. The only different between bipolar signal and unipolar signal is the signal amplitude varies between a positive and a negative voltage level which are +V and -V. Figure 1-1 shows different types of line code signals and we will discuss the encoding signals in next section.

1. Unipolar Nonreturn-to-zero Signal Encode

The data stream of unipolar nonreturn-to-zero (UNI-NRZ) is shown in figure 1-1(a). From figure 1-1(a), when the data bit is "1", the width and the gap between bits of UNI-NRZ are equal to each others; when the data bit is "0", then the pulse is represented as 0 V. The circuit diagram of UNI-NRZ encoder is shown in figure 1-2. As a result of the data signal and the NRZ encoder signal are similar, therefore, we only need to add a buffer in front of the circuit.

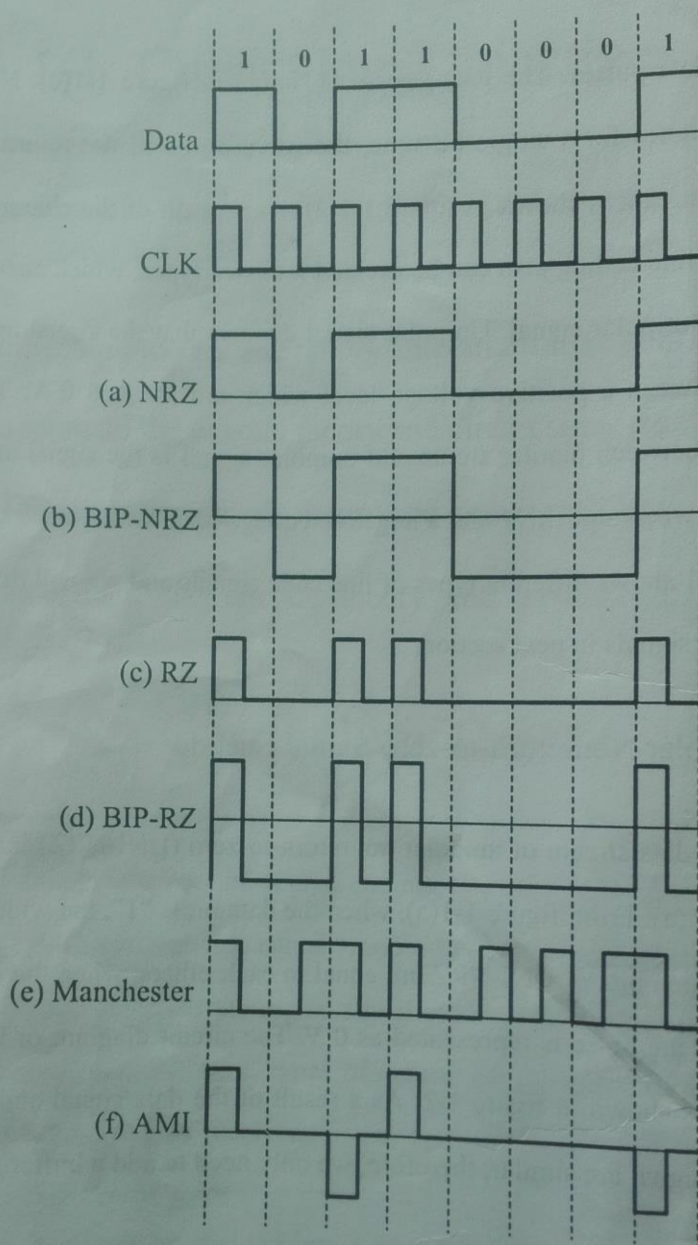

Figure 1-1 Different types of line code signal waveforms.

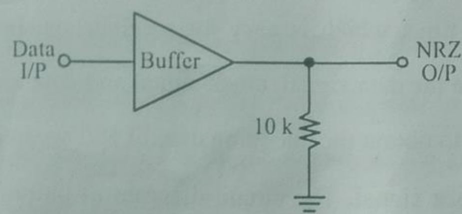

Figure 1-2 Circuit diagram of unipolar nonreturn-to-zero encoder.

2. Bipolar Nonreturn-to-zero Signal Encode

The data stream of bipolar nonreturn-to-zero (BIP-NRZ) is shown in figure 1-1(b). When the data bit of BIP-NRZ is "1" or "0", the signal amplitude will be a positive or a negative voltage level. As for bit time, no matter the data bit is "1" or "0", the voltage level remain same. Figure 1-3 is the circuit diagram of BIP-NRZ encoder. By comparing the data streams of UNI-NRZ and BIP-NRZ, the only difference is the signal amplitude is a negative voltage level when the data bit is "0", therefore, we may utilize a comparator to encode the data bit in the circuit.

3. Unipolar Return-to-zero Signal Encode

The data stream of unipolar return-to-zero (UNI-RZ) is shown in figure 1-1(c). When the data bit is "1", the signal amplitude at 1/2 bit time is positive voltage level and the rest of the bit time is represented as 0 V. When the data bit is "0", there is no pulse wave that means the signal amplitude is 0 V. The bit time of RZ is half of the bit time of NRZ, therefore, the required bandwidth of RZ is one time more than NRZ. However, RZ has two phase variations in a bit time, which is easy for receiver synchronization. From figure 1-1, compare the data signal, clock signal and data after encoding, we know that in order to obtain the encoding data of RZ, we need to "AND" the data signal and clock signal. The circuit diagram of unipolar return-to-zero encoder is shown in figure 1-4.

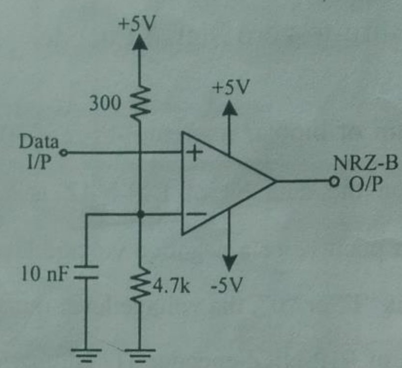

Figure 1-3 Circuit diagram of bipolar nonreturn-to-zero encoder.

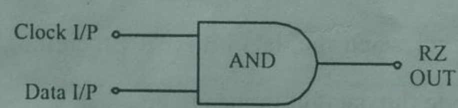

Figure 1-4 Circuit diagram of unipolar return-to-zero encoder.

4. Bipolar Return-to-zero Signal Encode

The data stream of bipolar return-to-zero (BIP-RZ) is shown in figure 1-1(d). When the data bit is "1", the signal amplitude at 1/2 bit time is positive voltage level and the other 1/2 bit time is negative voltage level. When the data bit is "0", the signal amplitude of the bit time is represented as negative voltage level. Figure 1-5 is the circuit diagram of BIP-RZ. By comparing the data streams of RZ and BIP-RZ in figure 1-1, we only need a converter to convert the encoding signal from unipolar to bipolar, therefore, we utilize a comparator to design the converter, which can convert the RZ signal to BIP-RZ signal.

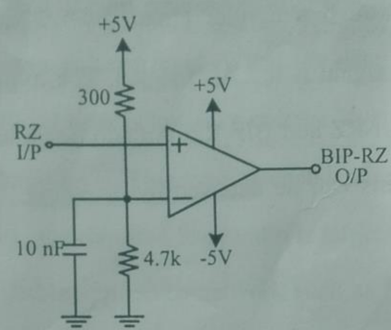

Figure 1-5 Circuit diagram of bipolar return-to-zero encoder.

5. Alternate Mark Inversion Signal Encode

Alternate mark inversion (AMI) signal is similar to RZ signal except the alternate "1" are inverted. The data stream of AMI signal is shown in figure 1-1(f). When the data bit is "1", the first signal amplitude at 1/2 bit time is positive voltage level and the other 1/2 bit time is 0 V; then the second signal amplitude at 1/2 bit time is negative voltage level and the other 1/2 bit time is 0 V, therefore, the only different between AMI and RZ is the alternate "1" are inverted. When the data bit is "0", the signal amplitude is 0 V. This type of encode is common used by telephone industry which is pulse coding modulation (PCM).

Figure 1-6 is the circuit diagram of AMI signal encode. In order to obtain the AMI encode signal, the data and clock signals need to pass through the buffer stage, which is comprised by a pair of transistors and NOT gates. After that we need to "AND" the output of data signal and clock signal, then pass through a divider circuit by utilizing clock as switch exchange. The final signal is the AMI signal. The minimum bandwidth of AMI is less than UNI-RZ and BIP-RZ. An additional advantage of AMI is the transmission errors can be detected by detecting the violations of the alternate-one rule.

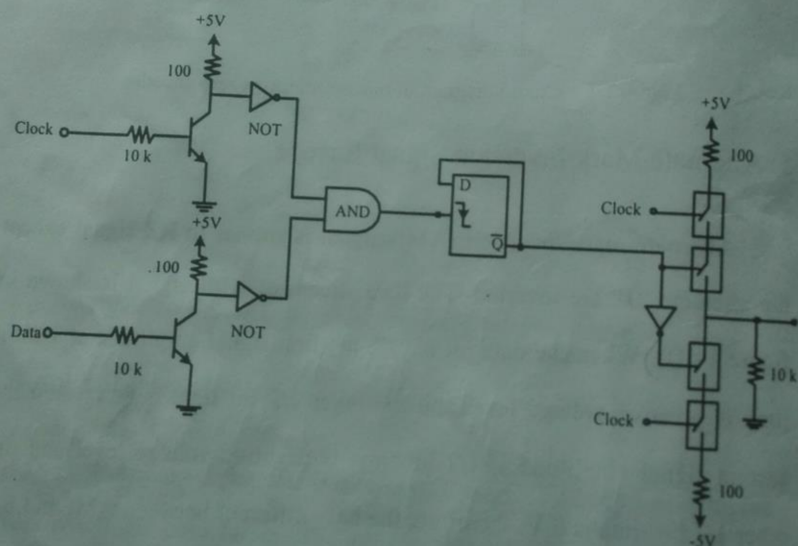

Figure 1-6 Circuit diagram of AMI signal encoder.

6. Manchester Signal Encode

Manchester signal is also known as split-phase signal. The data stream of Manchester signal is shown in figure 1-1(e). When the data bit is "1", the signal amplitude at first 1/2 bit time is positive voltage level and the other 1/2 bit time is negative voltage level. When the data bit is "0", the signal amplitude at first 1/2 bit time is negative voltage level and the other 1/2 bit time is positive voltage level. This type of encode signal has the advantage of memory, therefore, the required bandwidth is larger than the other encode signals. So, it is suitable applied to network such as Ethernet. From figure 1-1, compare the data signal, clock signal and data after encoding, we know that in order to obtain the encoding data of Manchester, we need to "XNOR" the data signal and clock signal. Figure 1-7 is the circuit diagram of Manchester signal encoder.

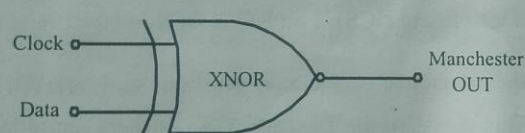

Figure 1-7 Circuit diagram of Manchester signal encoder.

1-3: Experiment Items

Experiment 1: Unipolar and bipolar NRZ signal encode

Experiment 1-1: Unipolar NRZ signal encode

1. To implement a unipolar NRZ encode circuit as shown in figure 1-2 or refer to figure DCS1-1 on ETEK DCS-6000-01 module.
2. Setting the frequency of function generator to 1 kHz TTL signal and connect this signal to the Data I/P. Then observe on the output waveform by using oscilloscope and record the measured results in table 1-1.
3. According to the input signals in table 1-1, repeat step 2 and record the measured results in table 1-1.

Experiment 1-2: Bipolar NRZ signal encode

1. To implement a bipolar NRZ signal encode circuit as shown in figure 1-3 or refer to figure DCS1-1 on ETEK DCS-6000-01 module.
2. Setting the frequency of function generator to 1 kHz TTL signal and connect this signal to the Data I/P. Then observe on the waveforms of TP1 and BIP-NRZ O/P by using oscilloscope and record the measured results in table 1-2.
3. According to the input signals in table 1-2, repeat step 2 and record the measured results in table 1-2.

Experiment 2: Unipolar and bipolar RZ signal encode

Experiment 2-1: Unipolar RZ signal encode

1. To implement a unipolar RZ signal encode circuit as shown in figure 1-4 or refer to figure DCS1-2 on ETEK DCS-6000-01 module.
2. Setting the frequency of function generator to 2 kHz TTL signal and connect this signal to the CLK I/P of figure DCS1-2 and CLK at the left bottom. After that connect the Data O/P at the left bottom to the Data I/P in figure DCS1-2. Then observe on the waveforms of CLK I/P, Data I/P and UNI-RZ O/P by using oscilloscope, and record the measured results in table 1-3.
3. According to the input signals in table 1-3, repeat step 2 and record the measured results in table 1-3.
4. Setting the frequency of function generator to 2 kHz TTL signal and connect this signal to the CLK I/P in figure DCS1-2. Then setting another frequency of function generator to 1 kHz TTL signal and connect this signal to the Data I/P in figure DCS1-2. Then observe on the waveforms of CLK I/P, Data I/P and UNI-RZ O/P by using oscilloscope, and record the measured results in table 1-4.
5. According to the input signals in table 1-4, repeat step 4 and record the measured results in table 1-4.

Experiment 2-2: Bipolar RZ signal encode

1. To implement a bipolar RZ signal encode circuit as shown in figure 5 or refer to figure DCS1-2 on ETEK DCS-6000-01 module.
2. Setting the frequency of function generator to 2 kHz TTL signal and connect this signal to the CLK I/P in figure DCS1-2 and CLK at the left bottom. After that connect the Data O/P at the left bottom to the Data I/P in figure DCS1-2. Then observe on the waveforms of CLK I/P, Data I/P, TP1 and BIP-RZ O/P by using oscilloscope, and record the measured results in table 1-5.
3. According to the input signals in table 1-5, repeat step 2 and record the measured results in table 1-5.
4. Setting the frequency of function generator to 2 kHz TTL signal and connect this signal to the CLK I/P in figure DCS1-2. Then setting another frequency of function generator to 1 kHz TTL signal and connect this signal to the Data I/P in figure DCS1-2. Then observe on the waveforms of CLK I/P, Data I/P, TP1 and BIP-RZ O/P by using oscilloscope, and record the measured results in table 1-6.
5. According to the input signals in table 1-6, repeat step 4 and record the measured results in table 1-6.

Experiment 3: AMI signal encode

1. To implement an AMI signal encode circuit as shown in figure 1-6 or refer to figure DCS1-3 on ETEK DCS-6000-01 module.

2. Setting the frequency of function generator to 2 kHz TTL signal and connect this signal to the CLK I/P in figure DCS1-3 and CLK at the left bottom. After that connect the Data O/P at the left bottom to the Data I/P in figure DCS1-3. Then observe on the waveforms of CLK I/P, Data I/P, TP1, TP2, TP3, TP4, TP5 and AMI O/P by using oscilloscope, and record the measured results in table 1-7.

3. According to the input signals in table 1-7, repeat step 2 and record the measured results in table 1-7.

4. Setting the frequency of function generator to 2 kHz TTL signal and connect this signal to the CLK I/P in figure DCS1-3. Then setting another frequency of function generator to 1 kHz TTL signal and connect this signal to the Data I/P in figure DCS1-3. Then observe on the waveforms of CLK I/P, Data I/P, TP1, TP2, TP3, TP4, TP5 and AMI O/P by using oscilloscope, and record the measured results in table 1-8.

5. According to the input signals in table 1-8, repeat step 4 and record the measured results in table 1-8.

Experiment 4: Manchester signal encode

1. To implement a Manchester signal encode circuit as shown in figure 1-7 or refer to figure DCS1-4 on ETEK DCS-6000-01 module.
2. Setting the frequency of function generator to 2 kHz TTL signal and connect this signal to the CLK I/P in figure DCS1-4 and CLK at the left bottom. After that connect the Data O/P at the left bottom to the Data I/P in figure DCS1-4. Then observe on the waveforms of CLK I/P, Data I/P and Manchester O/P by using oscilloscope, and record the measured results in table 1-9.
3. According to the input signals in table 1-9, repeat step 2 and record the measured results in table 1-9.
4. Setting the frequency of function generator to 2 kHz TTL signal and connect this signal to the CLK I/P in figure DCS1-4. Then setting another frequency of function generator to 1 kHz TTL signal and connect this signal to the Data I/P in figure DCS1-4. Then observe on the waveforms of CLK I/P, Data I/P and Manchester O/P by using oscilloscope, and record the measured results in table 1-10.
5. According to the input signals in table 1-10, repeat step 4 and record the measured results in table 1-10.

1-5: Problems Discussion

1. Explain what are the common types of line coding?
2. Explain how the unipolar and bipolar nonreturn-to-zero signals encode?
3. Explain how the unipolar and bipolar return-to-zero signals encode?
4. Explain how the AMI signal encodes?
5. Explain how the Manchester signal encodes?
6. Explain why do we need line coding?

Chapter 2

Line Code Decoder

2-1: Curriculum Objectives

1. To understand the theory and applications of line code decoder.
2. To understand the decode theory and circuit structure of NRZ.
3. To understand the decode theory and circuit structure of RZ.
4. To understand the decode theory and circuit structure of AMI.
5. To understand the decode theory and circuit structure of Manchester.

2-2: Curriculum Theory

For digital transmission system, the advantages of the applications of line code are as follow:

(1) Self-synchronization

Line code signal has the advantage of sufficient timing information, which can make the bit synchronizer catches the timing or pulse signal accurately to achieve self-synchronization.

(2) Low Bit Error Rate

Digital signal can be recovered by comparator, which can reduce the interference of noise and bit error rate. Besides we can also add a suitable device such as match filter at the receiver to reduce the affection of intersymbol interference (ISI).

(3) Error Detection Capability

The communication system has the ability of error detection or correction by adding the channel encoding and decoding to the line code signal.

(4) Transparency

By setting the line code signal and data protocol, we can receive any data sequence accurately.

Figure 2-1 shows different types of line code signal waveforms and we will discuss the decoding signals in next section.

1. Unipolar Nonreturn-to-zero Signal Decode

Figure 2-2 shows the circuit diagram of unipolar nonreturn-to-zero (UNI-NRZ) decoder. From figure 2-1, we notice that the waveforms between UNI-NRZ signal and data signal are similar to each other. Therefore, we only need to add a buffer in front of the decoder circuit, which can recover the original input data signal.

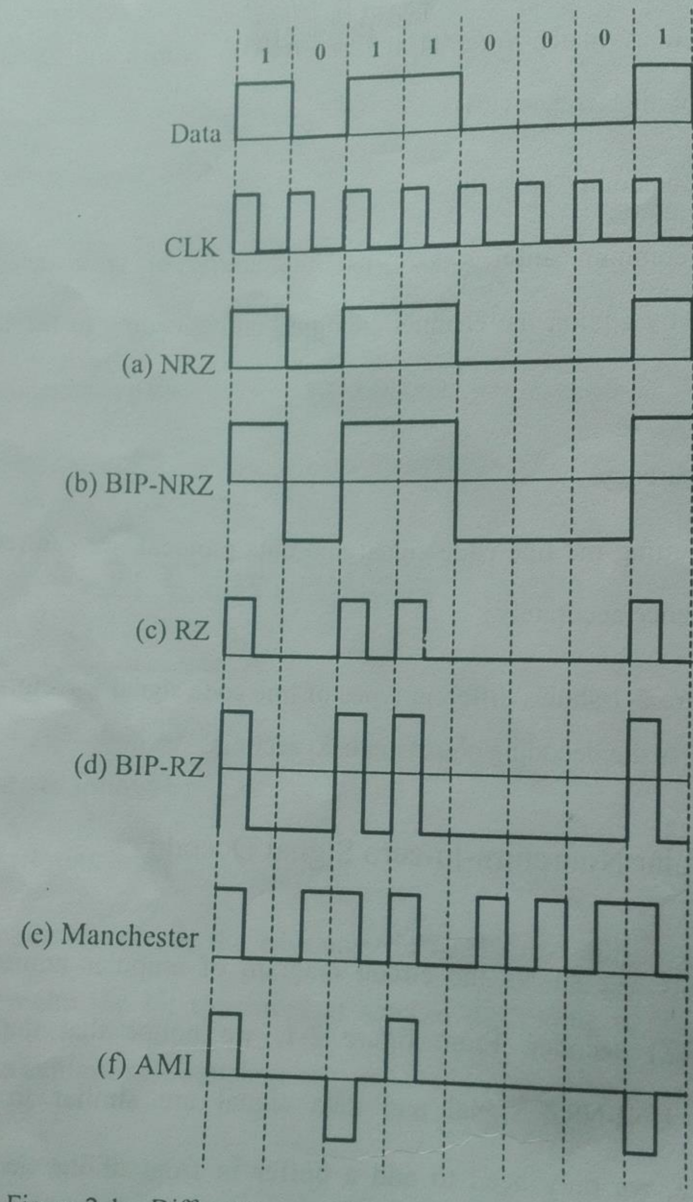

Figure 2-1 Different types of line code signal waveforms.

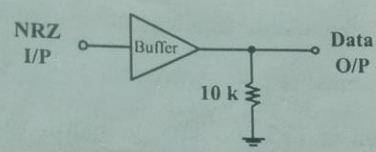

Figure 2-2 Circuit diagram of unipolar nonreturn-to-zero decoder.

2. Bipolar Nonreturn-to-zero Signal Decode

Figure 2-3 shows the circuit diagram of bipolar nonreturn-to-zero (BIP-NRZ) decoder. The signal amplitude of BIP-NRZ is either positive voltage level or negative voltage level. Therefore, for decoder, we can utilize a diode to change the negative voltage level to zero voltage level, and then we can recover the original input data signal.

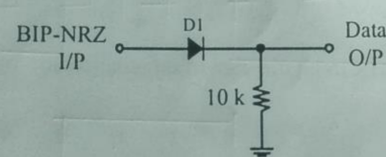

Figure 2-3 Circuit diagram of bipolar nonreturn-to-zero decoder.

3. Unipolar Return-to-zero Signal Decode

Figure 2-4 shows the circuit diagram of unipolar return-to-zero (UNI-RZ) decoder. The output of the UNI-RZ decoder is a NOR-RS flip-flop, which is comprised by R_3, R_4 and two NOR gates. TP2 is the "S" terminal and TP3 is the "R" terminal. The clock signal will be inverted by a NOT gate which is comprised by the NOR gate. After that by using XOR to operate the inverted clock signal and UNI-RZ signal; and then passing through a differentiator which is comprised by C_2 and R_2, the output will be transformed to pulse wave which is used for "R" terminal of RS flip-flop as shown in TP1 and TP3 of figure 2-5. UNI-RZ signal will pass through a capacitor to the "S" terminal of RS flip-flop, as shown in TP2 of figure 2-5. Finally by sending both UNI-RZ and clock signals into the RS flip-flop, we can recover the original input data signal.

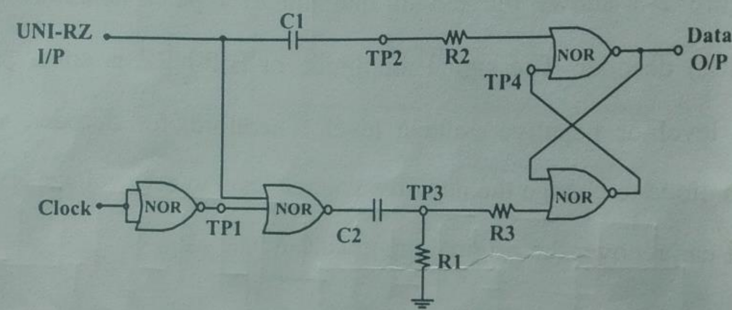

Figure 2-4 Circuit diagram of unipolar return-to-zero decoder.

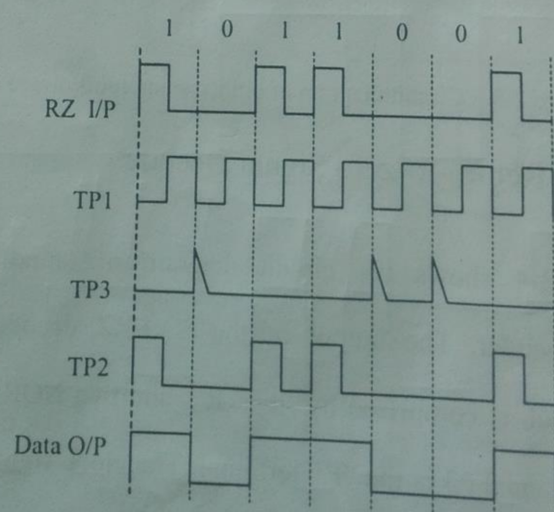

Figure 2-5 Output waveforms of unipolar return-to-zero decoder.

4. Bipolar Return-to-zero Signal Decode

As we know the difference between UNI-RZ and BIP-RZ is the UNI-RZ has only positive voltage level, nevertheless BIP-RZ has both positive and negative voltage level. Therefore, we utilize a diode to change the negative voltage level to zero voltage level as shown in figure 2-3, then we can obtain a UNI-RZ signal. After that, the UNI-RZ signal will pass through a UNI-RZ decoder circuit as shown in figure 2-4, then we can recover the original input data signal.

5. Alternate Mark Inversion Signal Decode

From figure 2-1, compare the RZ with AMI encode waveforms, we know that if the negative voltage level of AMI transforms to positive voltage level, the encode waveform is exactly similar to RZ encode waveform. Therefore, the AMI decoder can be divided into two parts, which are the circuit of AMI transform to RZ and the circuit of RZ decoder. The circuit diagrams of UNI-RZ decoder and AMI transform to RZ are shown in figures 2-4 and 2-6, respectively. From figure 2-6, when the AMI signal locates at positive voltage level, the signal will pass through D_2 to OUT; on the other hand, when the AMI signal locates at negative voltage level, the signal will pass through D_1, which is connected to the comparator, and then pass through D_3 to OUT. Therefore, we can obtain the RZ signal from AMI signal.

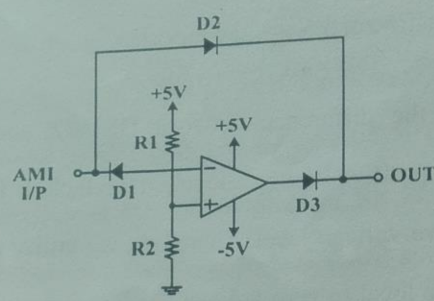

Figure 2-6 Circuit diagram of alternate mark inversion decoder.

6. Manchester Signal Decode

From figure 2-1, compare the data signal, clock signal and encode signal, we need to invert the clock signal, and then use an XOR to operate the inverted clock signal and Manchester signal. Finally, we can obtain the original data encode signal. Figure 2-7 shows the circuit diagram of Manchester decoder. From figure 2-7, the objective of the first XOR to operate the clock signal and +5 V signal is to invert the clock signal, then the second XOR to operate the inverted clock signal and Manchester signal is to recover the original input data signal.

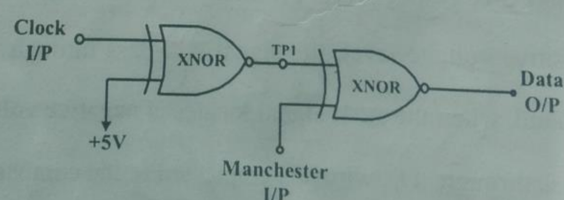

Figure 2-7 Circuit diagram of Manchester decoder.

2-3: Experiment Items

Experiment 1: Unipolar and bipolar NRZ signal decode

Experiment 1-1: Unipolar NRZ signal decode

1. Using the UNI-NRZ encode circuit as shown in figure 19-2 of chapter 19 or refer to figure DCS1-1 on ETEK DCS-6000-01 module to produce the UNI-NRZ signal.
2. To implement a UNI-NRZ decode circuit as shown in figure 2-2 or refer to figure DCS2-1 on ETEK DCS-6000-01 module.
3. Setting the frequency of function generator to 1 kHz TTL signal and connect this signal to the Data I/P of figure DCS1-1. Then connect the UNI-NRZ O/P of figure DCS1-1 to the UNI-NRZ I/P of figure DCS2-1. Next observe on the output waveform by using oscilloscope and record the measured results in table 2-1.
4. According to the input signals in table 2-1, repeat step 3 and record the measured results in table 2-1.

Experiment 1-2: Bipolar NRZ signal decode

1. Using the BIP-NRZ encode circuit as shown in figure 19-3 of chapter 19 or refer to figure DCS1-1 on ETEK DCS-6000-01 module to produce the BIP-NRZ signal.
2. To implement a BIP-NRZ decode circuit as shown in figure 2-3 or refer to figure DCS2-1 on ETEK DCS-6000-01 module.

3. Setting the frequency of function generator to 1 kHz TTL signal and connect this signal to the Data I/P of figure DCS1-1. Then connect the BIP-NRZ O/P of figure DAD1-1 to the BIP-NRZ I/P of figure DCS2-1. Next observe on the output waveform by using oscilloscope and record the measured results in table 2-2.

4. According to the input signals in table 2-2, repeat step 3 and record the measured results in table 2-2.

Experiment 2: Unipolar and bipolar RZ signal decode

Experiment 2-1: Unipolar RZ signal decode

1. Using the UNI-RZ encode circuit as shown in figure 19-4 of chapter 19 or refer to figure DCS1-2 on ETEK DCS-6000-01 module to produce the UNI-RZ signal.

2. To implement a UNI-RZ decode circuit as shown in figure 2-4 or refer to figure DCS2-2 on ETEK DCS-6000-01 module.

3. Setting the frequency of function generator to 1 kHz TTL signal, then connect this signal to the CLK I/P of figure DCS1-2, as well as CLK at the left bottom and CLK I/P of figure DCS2-2. After that connect the Data O/P at the left bottom to the Data I/P in figure DCS1-2. Then connect the UNI-RZ O/P of figure DCS1-2 to the UNI-RZ I/P of figure DCS2-2. Next observe on the waveforms of UNI-RZ I/P, TP1, TP2, TP3, TP4 and Data O/P by using oscilloscope. Finally record the measured results in table 2-3.

4. According to the input signals in table 2-3, repeat step 3 and record the measured results in table 2-3.

5. Setting the frequency of function generator to 2 kHz TTL signal and connect this signal to the CLK I/P in figure DCS1-2. Then setting another frequency of function generator to 1 kHz TTL signal and connect this signal to the Data I/P in figure DCS1-2. Next connect the UNI-RZ O/P of DCS1-2 to UNI-RZ I/P of DCS2-2. Then observe the waveforms of UNI-RZ O/P, TP1, TP2, TP3, TP4 and Data I/P by using oscilloscope, then record the measured results in table 2-4.

6. According to the input signals in table 2-4, repeat step 5 and record the measured results in table 2-4.

Experiment 2-2: Bipolar RZ signal decode

1. Using the BIP-RZ encode circuit as shown in figure 19-5 of chapter 19 or refer to figure DCS1-2 on ETEK DCS-6000-01 module to produce the BIP-RZ signal.

2. To implement a transformation circuit of BIP-RZ to UNI-RZ as shown in figure 2-3 and a BIP-RZ decode circuit as shown in figure 2-4 or refer to figure DCS2-2 on ETEK DCS-6000-01 module.

3. Setting the frequency of function generator to 2 kHz TTL signal, then connect this signal to the CLK I/P of figure DCS1-2, as well as CLK at the left bottom and CLK I/P of figure DCS2-2. After that connect the Data O/P at the left bottom to the Data I/P in figure DCS1-2. Then connect the BIP-RZ O/P of figure DCS1-2 to the BIP-RZ I/P of figure DCS2-2. Next observe on the waveforms of BIP-RZ I/P, TP1, TP2, TP3, TP4 and Data O/P by using oscilloscope. Finally record the measured results in table 2-5.

4. According to the input signals in table 2-5, repeat step 3 and record the measured results in table 2-5.
5. Setting the frequency of function generator to 2 kHz TTL signal and connect this signal to the CLK I/P in figure DCS1-2. Then setting another frequency of function generator to 1 kHz TTL signal and connect this signal to the Data I/P in figure DCS1-2. Next connect the BIP-RZ O/P of DCS1-2 to BIP-RZ I/P of DCS2-2. Then observe on the waveforms of BIP-RZ I/P, TP1, TP2, TP3, TP4 and Data O/P by using oscilloscope, then record the measured results in table 2-6.
6. According to the input signals in table 2-6, repeat step 5 and record the measured results in table 2-6.

Experiment 3: AMI signal decode

1. Using the AMI encode circuit as shown in figure 19-6 of chapter 19 or refer to figure DCS1-3 on ETEK DCS-6000-01 module to produce the AMI signal.
2. To implement a transformation circuit of AMI to RZ as shown in figure 2-6 or refer to figure DCS2-3 on ETEK DCS-6000-01 module.
3. Setting the frequency of function generator to 2 kHz TTL signal, then connect this signal to the CLK I/P of figure DCS1-3, as well as CLK at the left bottom and CLK I/P of figure DCS2-3. After that connect the Data O/P at the left bottom to the Data I/P in figure DCS1-3. Then connect the AMI O/P of figure DCS1-3 to the AMI I/P of figure DCS2-3. Next observe on the waveforms of AMI I/P, TP1, TP2, TP3, TP4, TP5, TP6 and Data O/P by using oscilloscope. Finally record the measured results in table 2-7.

4. According to the input signals in table 2-7, repeat step 3 and record the measured results in table 2-7.

5. Setting the frequency of function generator to 2 kHz TTL signal and connect this signal to the CLK I/P in figure DCS1-3. Then setting another frequency of function generator to 1 kHz TTL signal and connect this signal to the Data I/P in figure DCS1-3. Next connect the AMI O/P of DCS1-3 to AMI I/P of DCS2-3. Then observe on the waveforms of AMI I/P, TP1, TP2, TP3, TP4, TP5, TP6 and Data O/P by using oscilloscope, then record the measured results in table 2-8.

6. According to the input signals in table 2-8, repeat step 5 and record the measured results in table 2-8.

Experiment 4: Manchester signal decode

1. Using the Manchester encode circuit as shown in figure 19-7 of chapter 19 or refer to figure DCS1-4 on ETEK DCS-6000-01 module to produce the Manchester signal.
2. To implement a Manchester decode circuit as shown in figure 2-7 or refer to figure DCS2-4 on ETEK DCS-6000-01 module.
3. Setting the frequency of function generator to 2 kHz TTL signal, then connect this signal to the CLK I/P of figure DCS1-4, as well as CLK at the left bottom and CLK I/P of figure DCS2-4. After that connect the Data O/P at the left bottom to the Data I/P in figure DCS1-4. Then connect the Manchester O/P of figure DCS1-4 to the Manchester I/P of figure DCS2-4. Next observe on the waveforms of Manchester I/P, TP1 and Data O/P by using oscilloscope. Finally record the measured results in table 2-9.

4. According to the input signals in table 2-9, repeat step 3 and record the measured results in table 2-9.
5. Setting the frequency of function generator to 2 kHz TTL signal and connect this signal to the CLK I/P in figure DCS1-4. Then setting another frequency of function generator to 1 kHz TTL signal and connect this signal to the Data I/P in figure DCS1-4. Next connect the Manchester O/P of DCS1-4 to Manchester I/P of DCS2-4. Then observe the waveforms of Manchester I/P, TP1 and Data O/P by using oscilloscope, then record the measured results in table 2-10.
6. According to the input signals in table 2-10, repeat step 5 and record the measured results in table 2-10.

2-5: Problems Discussion

1. Explain what are the advantages of line code?

2. Explain how the unipolar and bipolar nonreturn-to-zero signals decode?

3. Explain how the unipolar and bipolar return-to-zero signals decode?

4. Explain how the AMI signal decodes?

5. Explain how the Manchester signal decodes?

6. Give an actual example of the application of line code.