Application Note

Serial Line Coding Converters

AN-CM-264

Abstract

Because of its efficiency, serial communication is common in many industries. Usually, standard protocols like UART, I2C or SPI are used for serial interfaces. However, in many industrial applications, dedicated or customized serial protocols may be very desirable. Some customized serial protocols are based on standard line codes, and conversion to custom can be simplified. This app note details using the Dialog SLG46537 GreenPAK IC for several line code conversion examples. In this way, line code customization can be achieved in an inexpensive and easy way. This application note comes complete with design files which can be found in the References section.

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Table 1: Summarized Logic for Control Circuit Operation for Obtaining AMI Code 7

1 Terms and Definitions

AMI/BRZ	Alternate Mark Inversion / Bipolar Return to Zero
CAN	Controller Area Network
Clk	Clock Signal
DALI	Digital Addressable Lighting Interface
I2C	Inter-Integrated Circuit
LIN	Local Interconnect Network
MIPI	Mobile Industry Processor Interface
NRZ	Non Return to Zero
NRZ(L)	Non Return to Zero Level
PSI5	Peripheral Sensor Interface 5
RB	Return to Bias
RZ	Return to Zero
SENT	Single-Edge Nibble Transmission
SPI	Serial Peripheral Interface
UART	Universal Asynchronous Receiver/Transmitter

2 References

For related documents and software, please visit:

https://www.dialog-semiconductor.com/products/greenpak

Download our free GreenPAK Designer software [1] to open the .gp files [2] and view the proposed circuit design. Use the GreenPAK development tools [3] to freeze the design into your own customized IC in a matter of minutes. Dialog Semiconductor provides a complete library of application notes [4] featuring design examples as well as explanations of features and blocks within the Dialog IC.

[1] GreenPAK Designer Software, Software Download and User Guide, Dialog Semiconductor

[2] AN-CM-264 Serial Line Coding Converters.gp GreenPAK Design File, Dialog Semiconductor

[3] GreenPAK Development Tools, GreenPAK Development Tools Webpage, Dialog Semiconductor

[4] GreenPAK Application Notes, GreenPAK Application Notes Webpage, Dialog Semiconductor

[5] Configurable Protocol Decoding of Manchester and NRZ-Encoded Signals, Teledyne Lecroy Whitepaper.

[6] Petrova, Pesha D., and Boyan D. Karapenev. "Synthesis and simulation of binary code converters." Telecommunications in Modern Satellite, Cable and Broadcasting Service, 2003. TELSIKS 2003. 6th International Conference on. Vol. 2. IEEE, 2003

[7] Hd-6409 Renesas Datasheet.

[8] https://en.wikipedia.org/wiki/Manchester_code

3 Introduction

Serial data communication has become ubiquitous in many industrial applications, and several approaches exist to design any serial data communication interface. It is convenient to employ one of the standard protocols i.e. UART, I2C or SPI. In addition, several other protocols exist for more dedicated applications such as CAN, LIN, Mil-1553, Ethernet or MIPI. Another option to handle serial data is to use customized protocols. These protocols are usually based on line codes. The most common types of line encoding are NRZ, Manchester code, AMI etc. [5].

Examples of the specialized serial protocols include DALI for control of building lighting, and PSI5 which is used to connect sensors to controllers in automotive applications. Both of these examples are based on Manchester encoding. Similarly, the SENT protocol is used for automotive sensor-to-controller links, and the CAN bus commonly used to enable communication between microcontrollers and other devices in automotive applications are based on NRZ encoding. In addition, many other complex and specialized protocols have been and are being designed using Manchester and NRZ schemes.

Each of the line codes has its own merits. In the process of transmission of a binary signal along a cable, for example, distortion can arise that can be mitigated significantly by using the AMI code [6]. Besides, the bandwidth of an AMI signal is lower than the equivalent RZ format. Likewise, Manchester code does not have some of the deficiencies that are inherent in NRZ code. For example, use of the Manchester code on a serial line removes DC components, provides clock recovery, and provides a comparatively high level of noise immunity [7].

Therefore, the utility of the standard line codes conversion is obvious. In many applications where line codes are directly or indirectly used, the conversion of binary code is necessary.

In this app note, we present how to realize multiple line coding converters using a low-cost Dialog SLG46537 GreenPAK IC.

4 Conversion Designs

Design of the following line code converters are provided in this app note:

- NRZ(L) to RZ
- NRZ(L) to RB
- NRZ(L) to AMI
- AMI to RZ
- NRZ(L) to Split-phase Manchester
- Split-phase Manchester to Split-phase Mark code

4.1 NRZ(L) to RZ

The conversion from NRZ(L) to RZ is simple and can be achieved by use of a single AND gate. The following figure shows the design for this conversion.

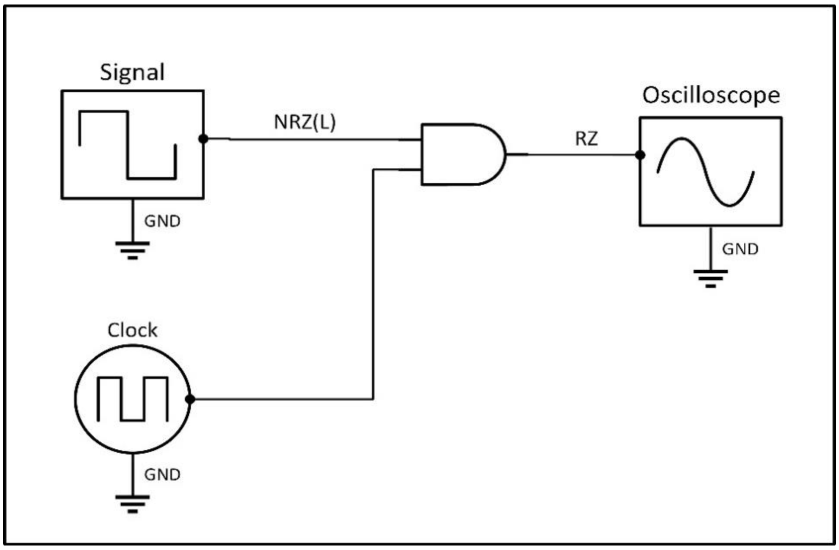

Figure 1: NRZ(L) to RZ Conversion

4.2 NRZ(L) to RB

For conversion of NRZ(L) to RB, we need to achieve three logic levels (-1, 0, +1). For this purpose, we employ a 4066 (quad-bilateral analog switch) to provide bipolar switching from 5 V, 0 V, and -5 V. Digital logic is used to control the switching of the three logic levels by selection of 4066 enable inputs 1E, 2E and 3E [6].

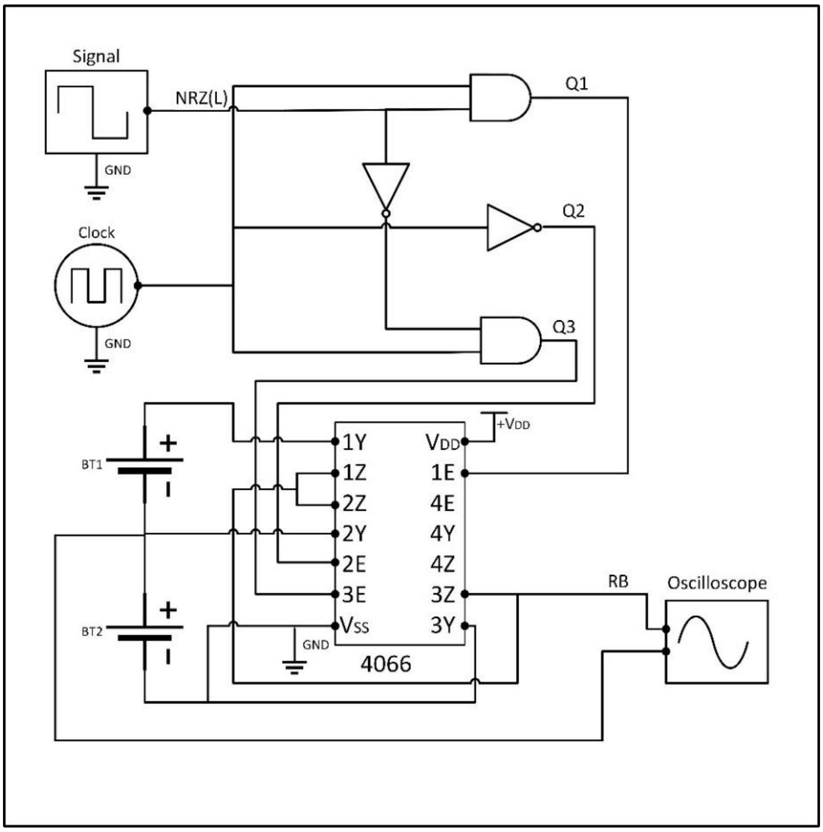

Figure 2: NRZ(L) to RB Conversion

The logic control is implemented as follows:

Q1= Signal & Clk

Q2= Clk'

Q3= Clk & Signal'

The overall conversion schematic is shown in Figure 2Figure 2.

4.3 NRZ(L) to AMI

The NRZ(L) to AMI conversion also employs the 4066 IC since AMI code has 3 logic levels. The logic control scheme is summarized in the following truth table corresponding to the overall conversion schematic shown in Figure 3 [6].

Table 1: Summarized Logic for Control Circuit Operation for Obtaining AMI Code

Signal	Clock	Q1	Q2	Q3
0	0	0	1	0
0	0	0	1	0
0	1	0	1	0
0	1	0	1	0
1	0	0	1	0
1	0	0	1	0
1	1	1	0	0
1	1	0	0	1

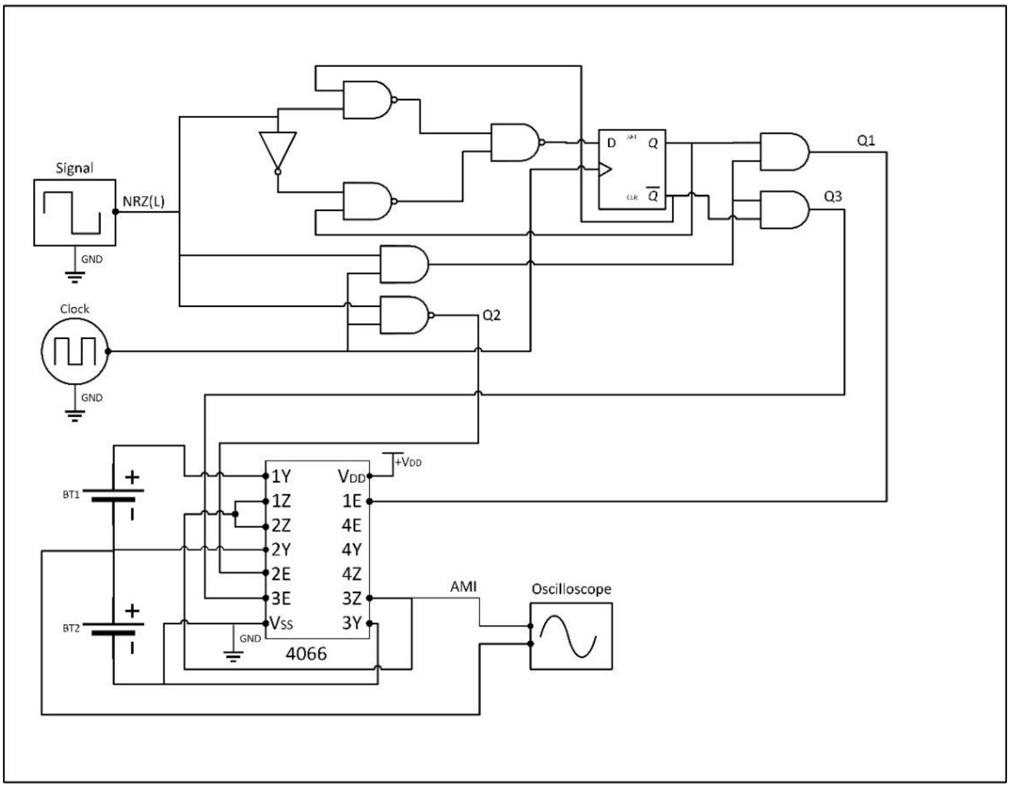

Figure 3: NRZ(L) to AMI Conversion

The logic scheme can be written in the following way:

Q1 = (Signal & Clk) & Q

Q2 = (Signal & Clk)'

Q3 = (Signal & Clk) & Q'

Where Q is the output of the D-Flip flop with the following transitional relationship:

Q_{next} = Signal & Q_{prev}' + Signal' & Q_{prev}

4.4 AMI to RZ

For AMI to RZ conversion two diodes are used to split the input signal into positive and negative parts. An inverting op-amp (or a transistor-based logic circuit) can be employed to invert the separated negative part of the signal. Finally, this inverted signal is passed to an OR gate along with the positive signal to obtain the desired output signal in the RZ format as shown in Figure 4 [6].

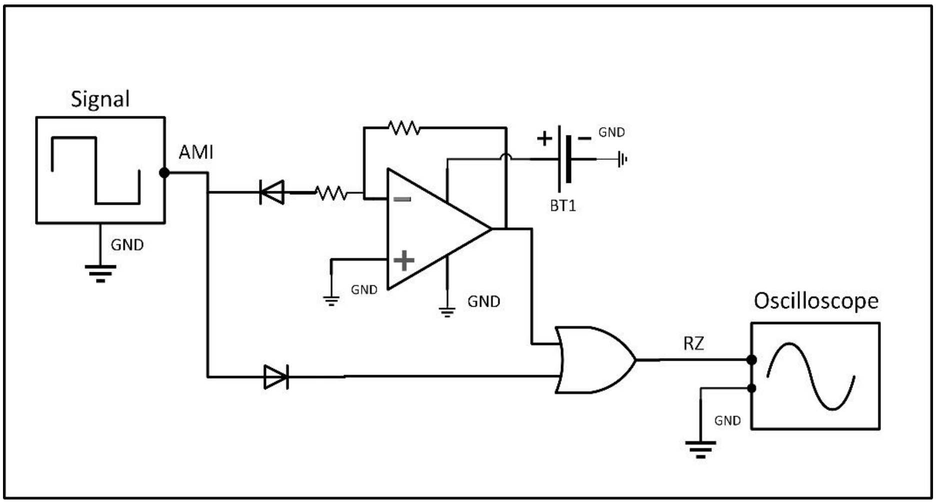

Figure 4: AMI to RZ Conversion

4.5 NRZ(L) to Split-phase Manchester

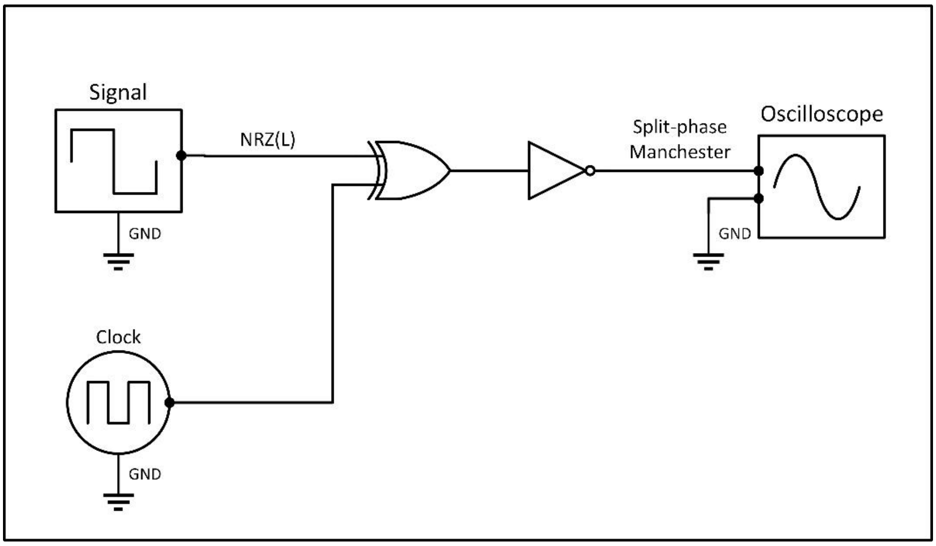

Figure 5: NRZ(L) to Split-phase Manchester Conversion

Conversion from NRZ(L) to Split-phase Manchester is straightforward as shown in Figure 5. The input signal along with the clock signal is passed to an NXOR gate to obtain the output signal (according to G. E. Thomas' convention). An XOR gate can also be used to obtain the Manchester code (according to IEEE 802.3 convention) [8].

4.6 Split-phase Manchester to Split-phase Mark

The conversion from Split-phase Manchester to Split-phase Mark code is shown in Figure 6. The input and the clock signal are passed through an AND gate to clock a D-flip flop [6].

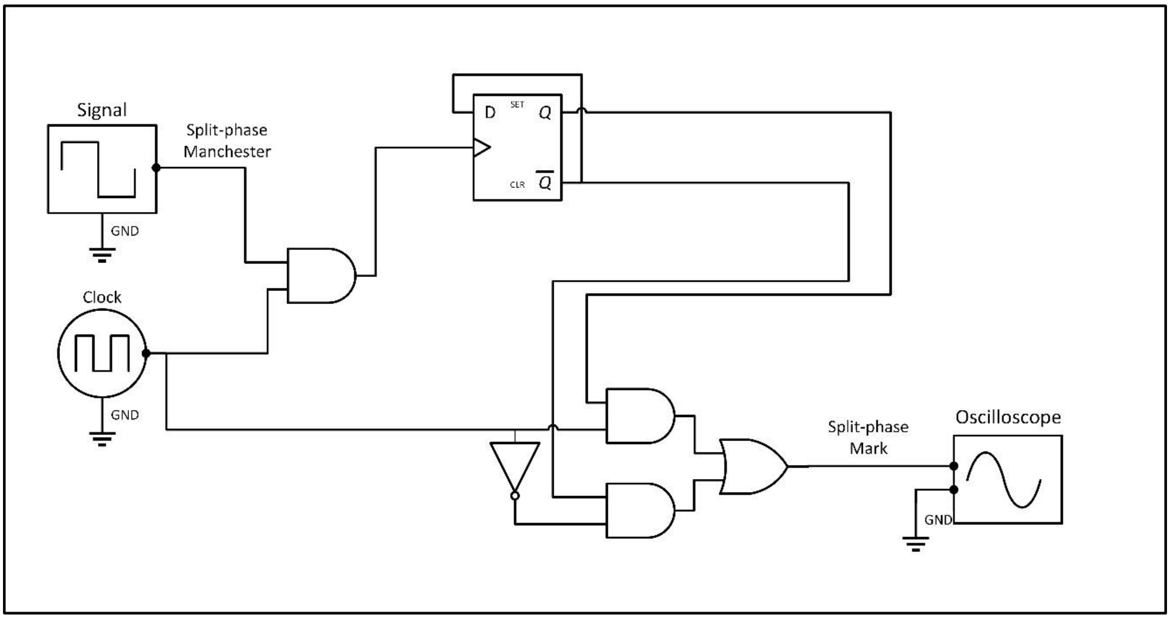

Figure 6: Split-phase Manchester to Split-phase Mark Code Conversion

The D-flip is governed by the following equation:

$Q_{next} = Q'$

The output signal is obtained as follows:

Output= Clk & Q + Clk' Q'

4.7 More Line Code Conversions

Using the above conversions one can easily obtain the designs for more line codes. For example, NRZ(L) to Split-phase Manchester code conversion given in section 4.5 and Split-phase Manchester Code to Split-phase Mark code conversion in section 4.6 can be combined to directly obtain NRZ(L) to Split-phase Mark code.

5 GreenPAK Designs

The conversion schemes shown above can be easily implemented in GreenPAK™ designer along with some ancillary external components. The SLG46537 provides ample resources to carry out the given designs. The GreenPAK conversion designs are provided in the same order as before.

5.1 NRZ(L) to RZ in GreenPAK

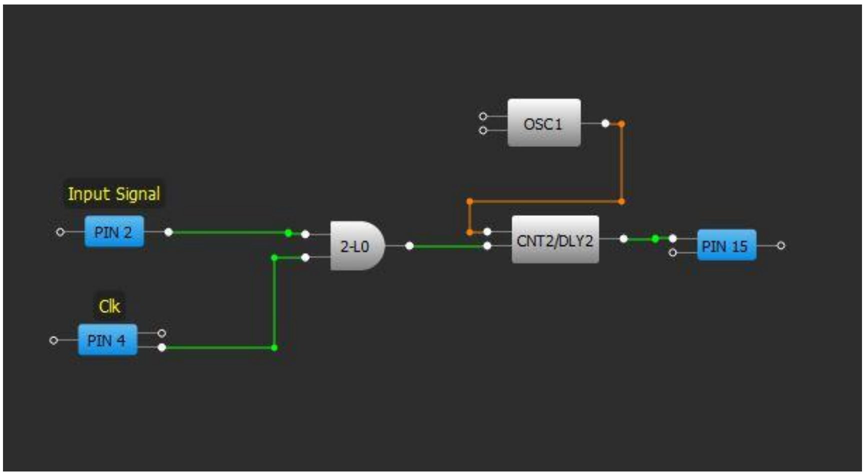

Figure 7: NRZ(L) to RZ GreenPAK Design

The GreenPAK Design for NRZ(L) to RZ in Figure 7 is similar to the one shown in section 4 except that there is one DLY block added. This block is optional but provides de-glitching for the synchronization errors between the clock and input signals.

5.2 NRZ(L) to RB in GreenPAK

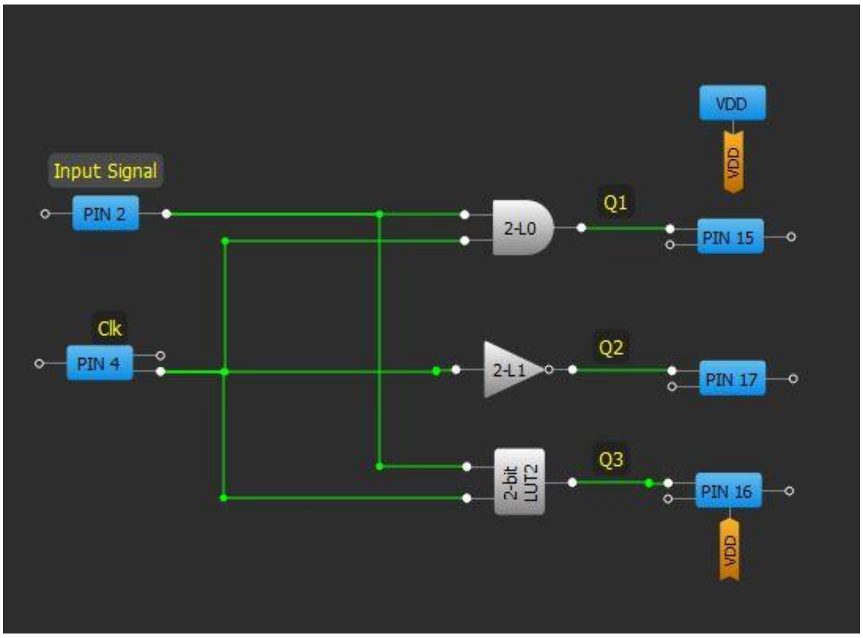

Figure 8: NRZ(L) to RB GreenPAK Design

The GreenPAK design for NRZ(L) to RB is shown in Figure 8. The figure shows how to connect the logic components in the GreenPAKIC to achieve the intended design given in section 4.

5.3 NRZ(L) to AMI in GreenPAK

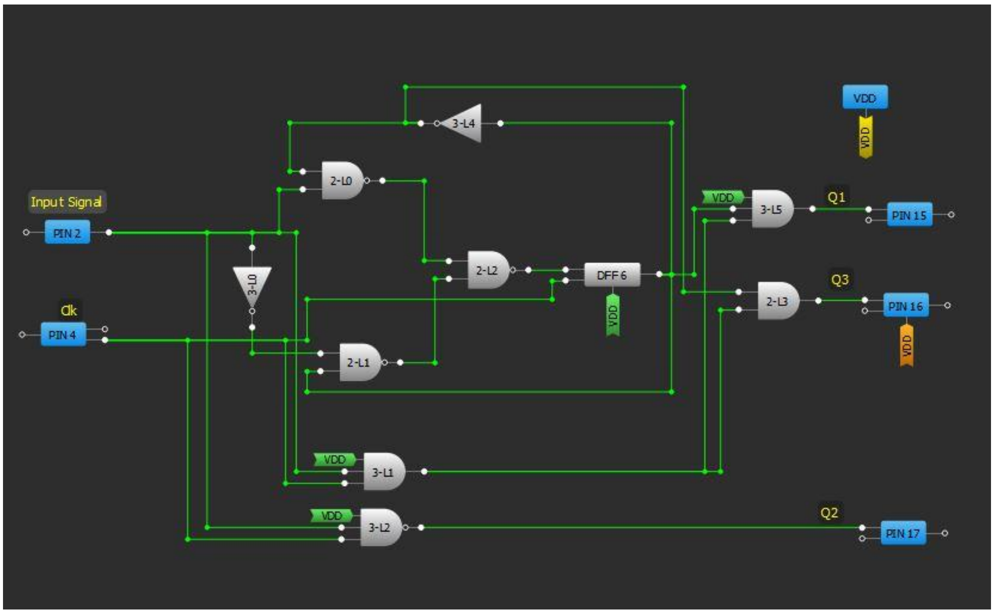

Figure 9: NRZ(L) to AMI GreenPAK Design

Figure 9 illustrates how to configure the GreenPAK IC for conversion from NRZ(L) to AMI. This schematic along with auxiliary external components given in section 4 can be used for the desired conversion.

5.4 AMI to RZ in GreenPAK

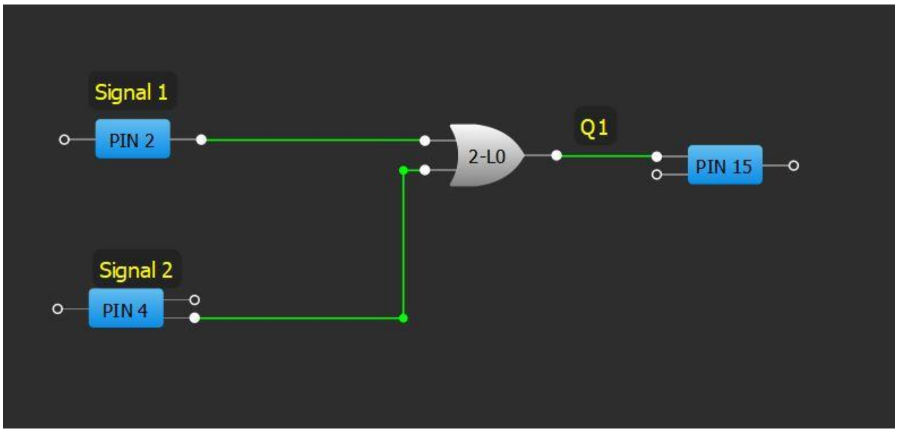

Figure 10: AMI to RZ GreenPAK Design

In Figure 10 the GreenPAK design for AMI to RZ conversion is shown. The GreenPAK IC configured in such a way along with op-amp and diodes can be used to obtain the required output.

5.5 NRZ(L) to Split-phase Manchester in GreenPAK

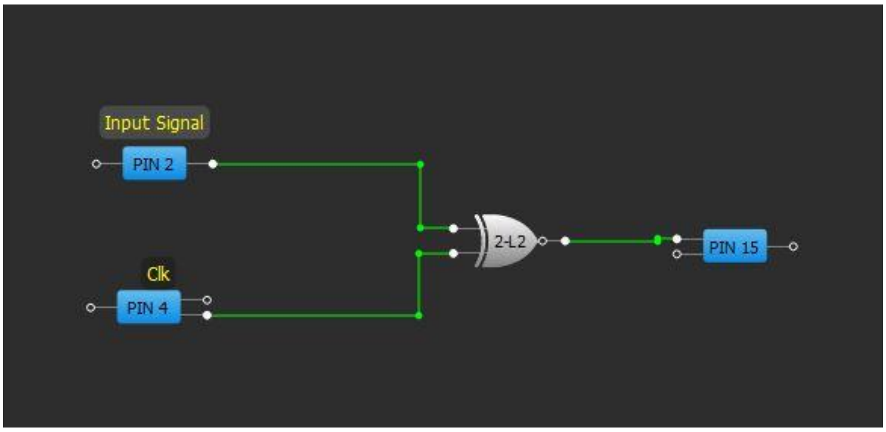

Figure 11: NRZ(L) to Split-phase Manchester GreenPAK Design

In Figure 11 an NXOR gate is employed in the GreenPAK design to obtain the NRZ(L) to Split-phase Manchester conversion.

5.6 Split-phase Manchester to Split-phase Mark code in GreenPAK

In Figure 12 the GreenPAK design for Split-phase Manchester to Split-phase Mark code is given. The design for the conversion is complete and no external component is needed for the conversion process. DLY blocks are optional for removing the glitches arising due to synchronization errors between the input and clock signals.

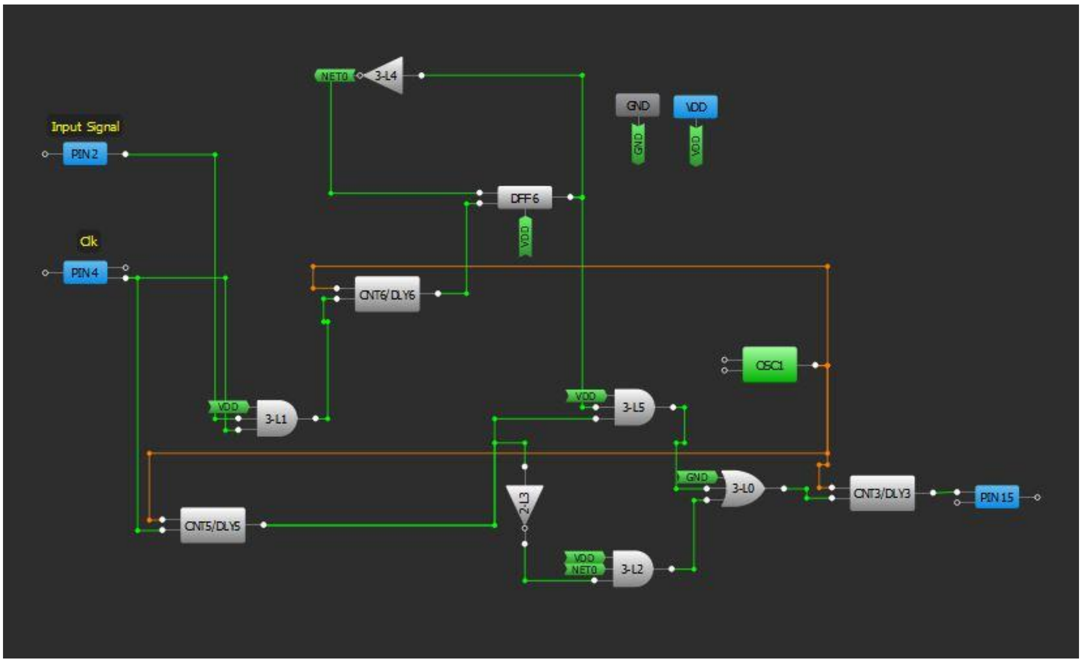

Figure 12: Split-phase Manchester to Split-phase Mark code GreenPAK Design

6 Experimental Results

All the designs presented were tested for verification. The results are provided in the same order as before.

6.1 NRZ(L) to RZ

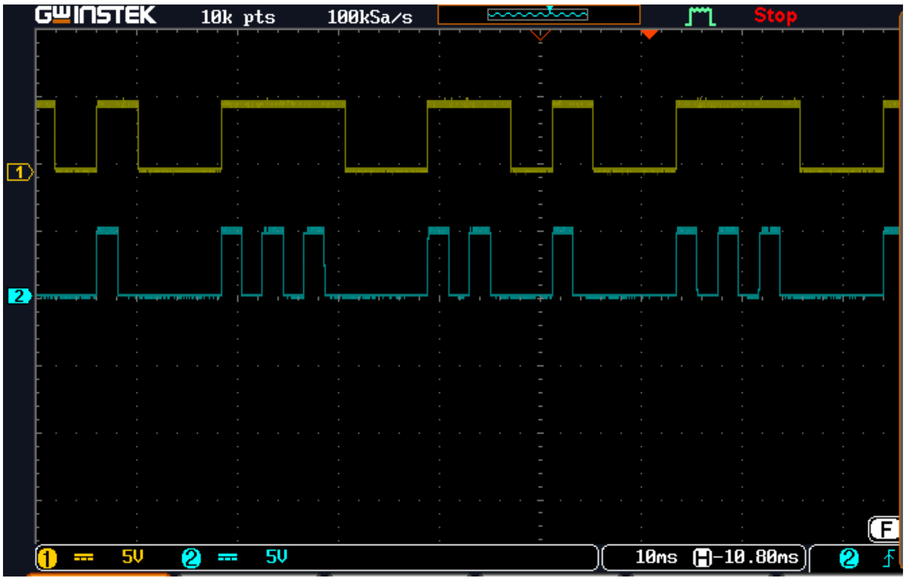

Figure 13: NRZ(L) to RZ Results

The experimental results for NRZ(L) to RZ conversion are shown in Figure 13. NRZ(L) is shown in yellow and RZ is shown in blue.

6.2 NRZ(L) to RB

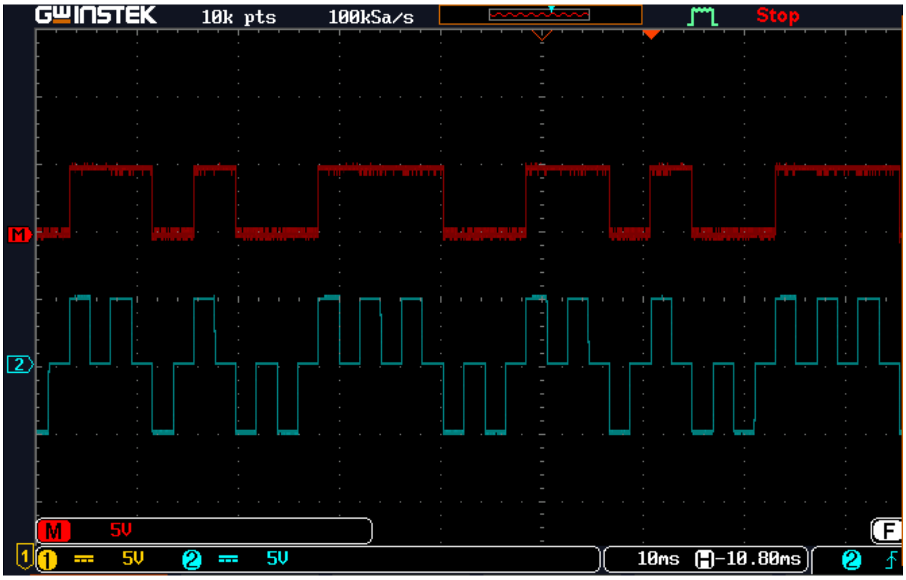

Figure 14: NRZ(L) to RB Results

The experimental results for NRZ(L) to RB conversion are given in Figure 14. NRZ(L) is shown in red and RB is shown in blue.

6.3 NRZ(L) to AMI

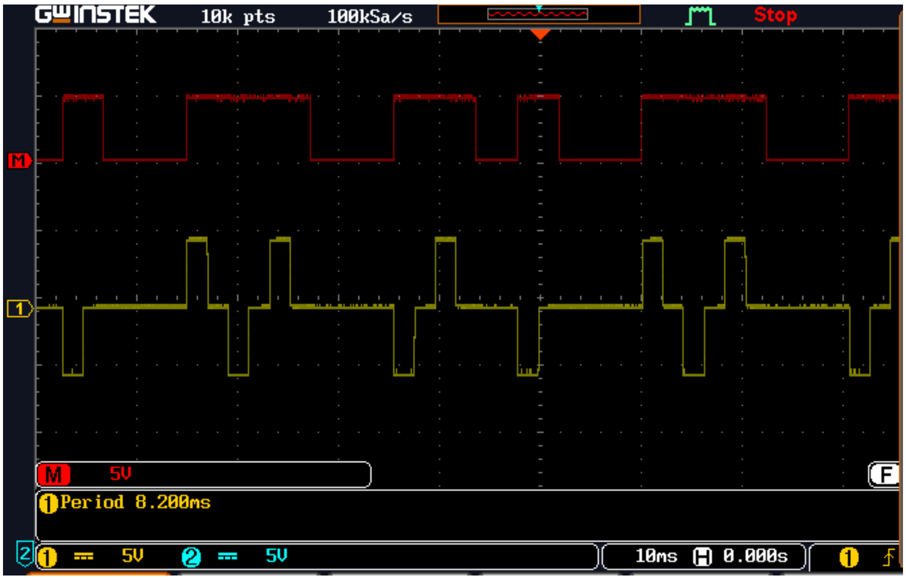

Figure 15: NRZ(L) to AMI Results

Figure 15 shows the experimental results for NRZ(L) to AMI conversion. NRZ(L) is shown in red and AMI is shown in yellow.

6.4 AMI to RZ

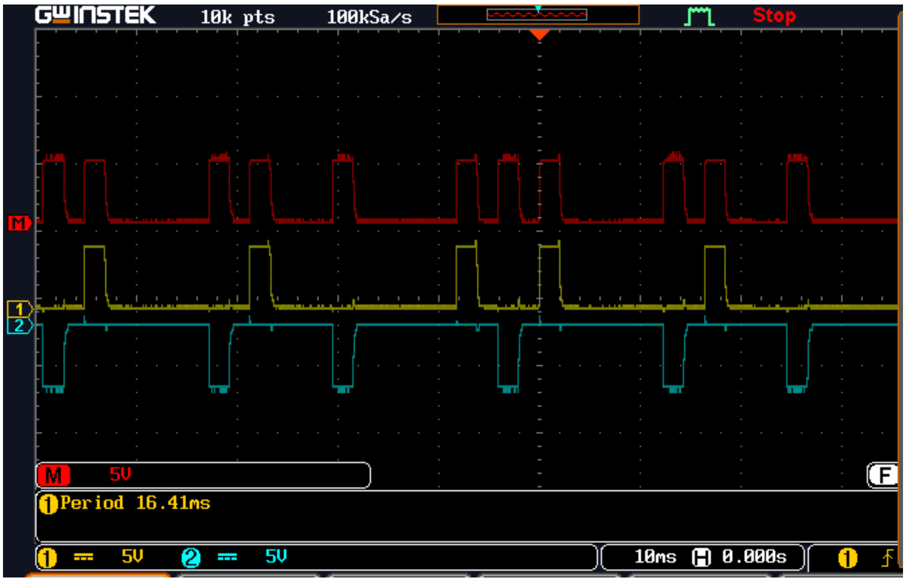

Figure 16: AMI to RZ Results

Figure 16 shows the experimental results for AMI to RZ conversion. AMI is split into positive and negative parts shown in yellow and blue. The converted output RZ signal is shown in red.

6.5 NRZ(L) to Split-phase Manchester

Figure 17 shows the experimental results for NRZ(L) to Split-phase Manchester conversion. NRZ(L) signal is shown in yellow and the converted output Split-phase Manchester signal is shown in blue.

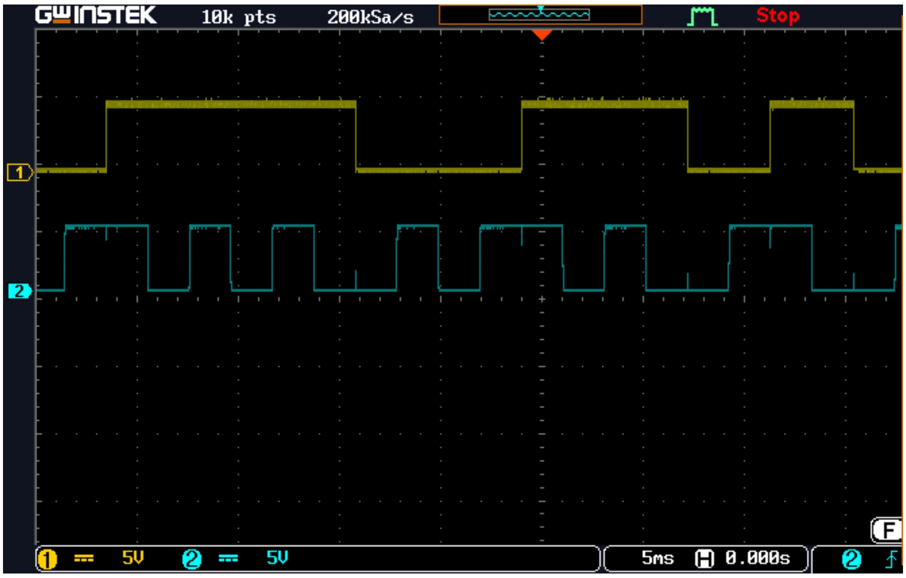

Figure 17: NRZ(L) to Split-phase Manchester Results

6.6 Split-phase Manchester to Split-phase Mark Code

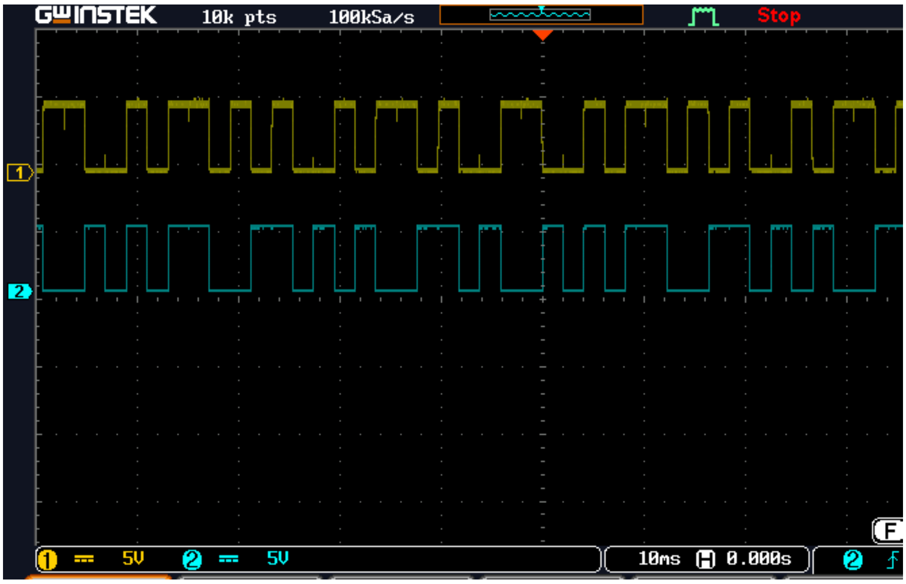

Figure 18: Split-phase Manchester to Split-phase Mark Code Results

Figure 18 shows the conversion from Split-phase Manchester to Split-phase Mark code. The Manchester code is shown in yellow while the Mark code is shown in blue.

7 Conclusion

Line codes form the basis of several serial communication protocols which are universally used in diverse industries. Conversion of line codes in an easy and low-cost way sought in many applications. In this app note details are provided for conversion of several line codes using Dialog's SLG46537 along with some ancillary external components. The presented designs have been verified, and it is concluded that conversion of line codes can be done easily using Dialog's GreenPAK ICs.

Revision History

Revision	Date	Description
1.0	04-Dec-2018	Initial Version

Status Definitions

Status	Definition
DRAFT	The content of this document is under review and subject to formal approval, which may result in modifications or additions.
APPROVED or unmarked	The content of this document has been approved for publication.

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