Manchester Coding Basics

When beginning to work with communication systems, it is important to first understand a few basic terms that are used, Modulation and Coding. These are often used interchangeably which leads to many errors because they refer to completely different aspects of the communication. It is very important to observe and fully understand the application and implementation of these two aspects of communication theory. This application note will be focused on the Coding and Decoding. But, before we address this, we need to look at what must be done to send a message or data through our communication system.

1. Modulation

Modulation refers to the act of adding the message signal to some form of carrier. The carrier, by definition, is a higher frequency signal whose phase, frequency, amplitude, or some combination thereof, is varied proportionally to the message. This change can be detected and recovered (demodulated) at the other end of the communication channel. There are a number of ways this can be done but for simplicity we will only look at Amplitude Modulation (AM), On-Off Keying (a variation on AM), and Frequency Modulation (FM). Modulation is typically carried out in hardware, but that subject is beyond the scope of this document.

1.1 Amplitude Modulation

In amplitude modulation, the amplitude of the carrier is changed to follow the message signal. In this case we can see a "ripple" on the carrier, its envelope contains the message. This can be demodulated using an extremely simple envelope detector that captures this ripple as a low frequency response.

1.2 On-Off Keying

This form of modulation takes the amplitude modulation as described above to the extreme. In this instance, we have only two states: Carrier and No Carrier. This approach lends itself nicely to the transmission of digital data because the carrier can be simply switched "on" or "off" depending on the state of the data being sent. The demodulated output is either high or low depending on the presence of the carrier.

Manchester Coding Basics

Application Note

9164A–AUTO–09/09

1.3 Frequency Modulation

Frequency modulation is more complicated but provides the benefit of constant output power independent of the message being sent. With this approach, the frequency of the carrier is not constant but varies in relation to the message. This requires a much more complicated demodulation circuit typically implemented using a Phase Lock Loop (PLL).

1.4 Frequency Shift Keying

The relationship between Frequency Shift Keying and Frequency Modulation is analogous to the relationship between On-Off Keying and Amplitude Modulation in that only two carrier frequencies are used, each corresponding to a digital state. In this case, the benefits of Frequency Modulation are realized but with less complexity in the demodulation circuit.

2. Coding Techniques

Having reviewed the common modulation techniques in the previous sections, it should be noted that all of the techniques deal with how the message signal was impressed onto a carrier. Modulation did not address how the message signal was created from the data to be sent. Coding defines how we accurately, efficiently, and robustly construct a message signal from the data we desire to communicate. Just like modulation, there are a vast number of ways to code data, each having unique qualities and attributes and each can be chosen to optimize certain aspects in the desired system. We will briefly cover a few coding methods, NRZ and BiPhase, before looking at the primary topic of this article, Manchester. Also it should be mentioned that we are simply looking at coding digital (binary) information to create the message. Although coding can be implemented in hardware, we are going to look at how this is achieved through software. We will assume our encoded/decoded message signal will be present on an output/input pin of a microcontroller.

2.1 NRZ

NRZ is one of the most basic of coding schemes. In this method the message signal does Not Return to Zero after each bit frame. This means that the message exactly follows the digital data structure. For example, a long data string of “1”s will produce a long high period in the message signal. Transitions only occur in the message when there is a logical bit change (see Figure 2-1 on page 3).

This is a very easy method to implement on the encoding side but requires the data rate to be known exactly on the receiving side in order to be decoded. Any mismatch in data clock timings will result in erroneous data that is only detectable with some error detection such as a checksum or CRC. Also errors from the communication channel or interference will not be detected without some form of data integrity checks.

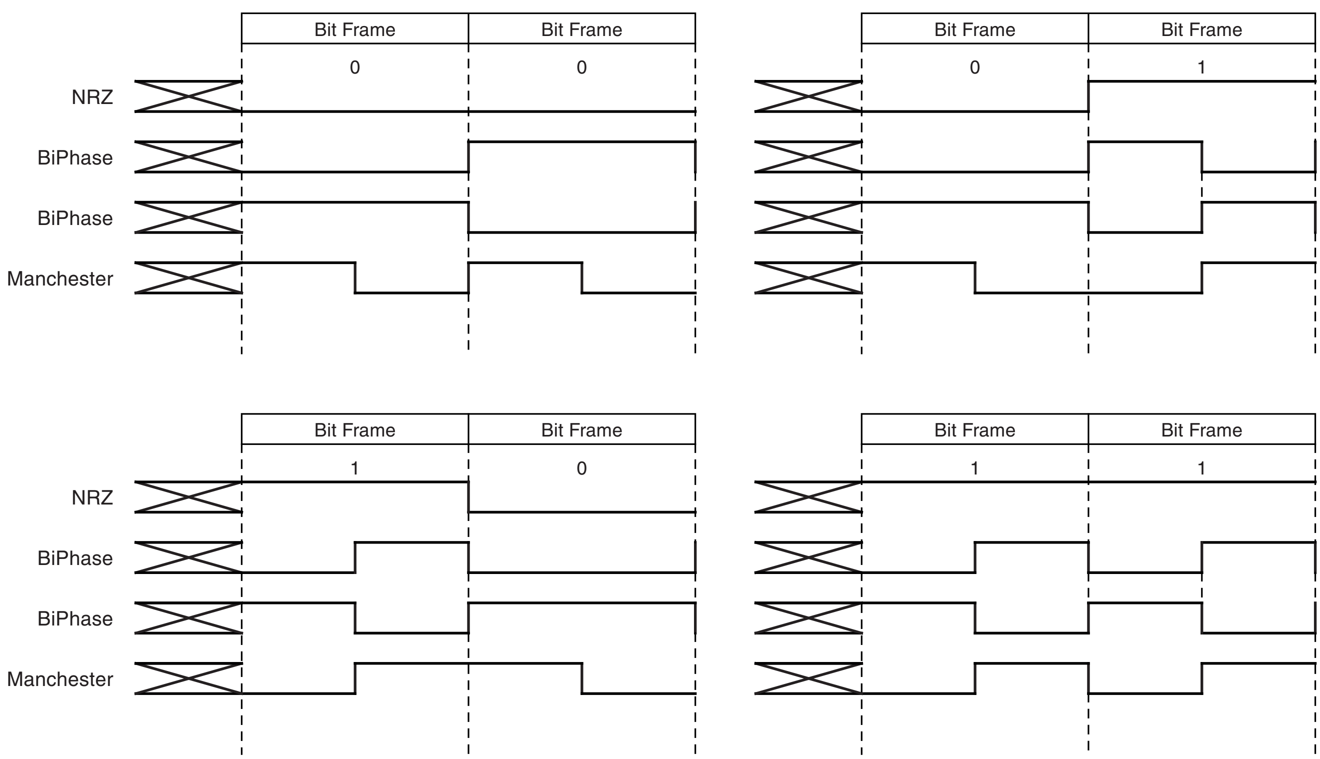
2.2 BiPhase

BiPhase adds a level of complexity to the coding process but in return includes a way to transfer the bit frame data clock that can be used in the decoding to increase accuracy. BiPhase coding says that there will be a state transition in the message signal at the end of every bit frame. In addition, a logical "1" will have an additional transition at the mid-bit (see Figure 2-1 on page 3). This allows the demodulation system to recover the data rate and also synchronize to the bit edge periods. With this clock information, the data stream can be recreated. This is similar to the method we will describe next.

2.3 Manchester

Manchester coding is one of the most common data coding methods used today. Similar to BiPhase, Manchester coding provides a means of adding the data rate clock to the message to be used on the receiving end. Also Manchester provides the added benefit of always yielding an average DC level of 50%. This has positive implications in the demodulator's circuit design as well as managing transmitted RF spectrum after modulation. This means that in modulation types where the power output is a function of the message such as AM, the average power is constant and independent of the data stream being encoded. Manchester coding states that there will always be a transition of the message signal at the mid-point of the data bit frame. What occurs at the bit edges depends on the state of the previous bit frame and does not always produce a transition. A logical "1" is defined as a mid-point transition from low to high and a "0" is a mid-point transition from high to low (see Figure 2-1). A more thorough look at methods to encode and decode data will be shown in detail in the next sections.

Figure 2-1. Encoding Signals



3. Manchester Encoding

Encoding is the process of adding the correct transitions to the message signal in relation to the data that is to be sent over the communication system. The first step is to establish the data rate that is going to be used. Once this is fixed, then the mid-bit time can be determined as ½ of the data rate period. In our example we are going to use a data rate of 4 kHz. This provides a bit period of 1/f = 1/4000 = 0.00025s or 250 µs. Dividing by two gives us the mid-bit time (which we will label "T") of 125 µs. Now let's look at how we use this to encode a data byte of 0xC5 (11000101b). The easiest method to do this is to use a timer set to expire or interrupt at the T interval. We also need to set up a method to track which ½ bit period we are currently sending. Once we do this, we can easily encode the data and output the message signal.

1. Begin with the output signal high.
2. Check if all bits have been sent, If yes, then go to step 7
3. Check the next logical bit to be coded
4. If the bit equals "1", then call ManchesterOne(T)
5. Else call ManchesterZero(T)
6. Return to step 2
7. Set output signal high and return

3.1 Implementation of ManchesterOne(T)

1. Set the output signal low
2. Wait for mid-bit time (T)
3. Set the output signal high
4. Wait for mid-bit time (T)
5. Return

3.2 Implementation of ManchesterZero(T)

6. Set the output signal high
7. Wait for mid-bit time (T)
8. Set the output signal low
9. Wait for mid-bit time (T)
10. Return

These easy routines will provide an output at the microcontroller pin that exactly encodes the data into a Manchester message signal at the desired data rate. The accuracy of the data rate and duty cycle depends on the accuracy of the clock source and the method used to create the wait times. It is recommended to use a timer/counter, and associated interrupts, as shown in the sample code provided in the appendix.

4. Manchester Decoding

Decoding is where most people attempting to work with Manchester have questions. There are several ways to approach this and each has unique benefits. This section will describe how to implement two different methods. To start we will look at the steps that are needed for either methodology.

1. The data rate clock must be either known or discovered (we will assume a known value)
2. We must synchronize to the clock (distinguish a bit edge from a mid-bit transition)
3. Process the incoming stream and recover the data using the previous two steps
4. Buffer or store this data for further processing.

This provides the basic outline for how we will perform Manchester decoding. All that remains is to implement this in software. As mentioned, we have two different options for consideration. One is based on timing while the other utilizes sampling.

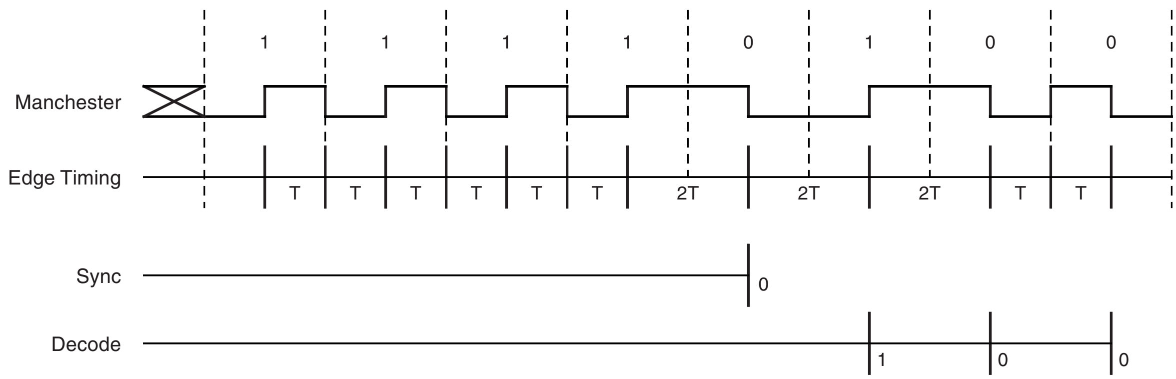
4.1 Timing Based Manchester Decode

In this approach we will capture the time between each transition coming from the demodulation circuit. The Input Capture function on a micro-controller is very useful for this because it will generate an interrupt, precise time measurements, and allow decision processing based on the elapsed counter value.

1. Set up timer to interrupt on every edge (may require changing edge trigger in the ISR)
2. ISR routine should flag the edge occurred and store count value
3. Start timer, capture first edge and discard this.
4. Capture next edge and check if stored count value equal 2T (T = ½ data rate)
5. Repeat step 4 until count value = 2T (This is now synchronized with the data clock)
6. Read current logic level of the incoming pin and save as current bit value (1 or 0)
7. Capture next edge
    a. Compare stored count value with T
    b. If value = T
        i. Capture next edge and make sure this value also = T (else error)
        ii. Next bit = current bit
        iii. Return next bit
    c. Else if value = 2T
        i. Next bit = opposite of current bit
        ii. Return next bit
    d. Else
        i. Return error
8. Store next bit in buffer
9. If desired number of bits are decoded; exit to continue further processing
10. Else set current bit to next bit and loop to step 7

It should be noted that in practice the value of the timer will not be exactly matched to the T and 2T times. To allow for this it is necessary to create a window of allowable values around the desired times. This allows for processing and distortion while still being able to recover the data correctly. See the software routines in the appendix for actual implementation. The window can be as large as ±50% of T, but no larger.

Figure 4-1. Timing Base Decode



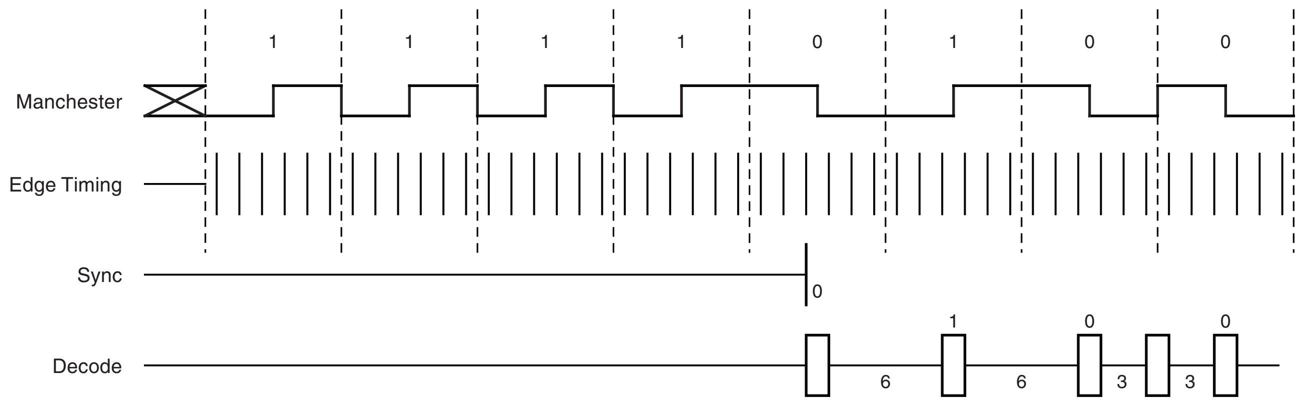
4.2 Sampling Based Manchester Decode

In this method we do not require the edge transitions to be captured or even acknowledged. Instead we will simply sample and buffer the state of the input pin at a rate (S) much higher than the data rate of the message. This requires more memory but also allows the processor intensive tasks to be undertaken at a less critical time where other interrupts can take precedence without corrupting the decoding. The sampling can be achieved by setting a timer to expire or interrupt and storing the state of the pin in a large buffer. No special timer features are required.

1. Set up timer to interrupt every 2T / S
2. SR routine should check and store the state of the microcontroller pin (1 or 0)
3. Repeat step 2 for desired number of bits * S occurrences
4. Process through the captured buffer counting the number of consecutive ones or zeros
5. When the next logic value changes
   a. Check if count >= (S/2); Then skip to step 6
   b. Else reset count and loop to step 4
6. Set current bit = logic value in buffer currently pointed too
7. Reset count and count to the next logic change
   a. Compare count with (S/2)
   b. If count < (S/2)
      i. Reset and count to next logic change
      ii. Make sure count also < (S/2)
      iii. Next bit = current bit
      iv. Store next bit in data buffer

   c. Else if count >= (S/2)
      i. Next bit = opposite of current bit
      ii. Store next bit in data buffer
   d. Else
      i. Return error
8. Loop to step 7 until completely through captured data
9. Exit for further data processing

Figure 4-2. Sampling Based Decode



5. Conclusion

Now that we have looked at two different approaches for Manchester decoding, the user must decide which approach is better suited to his end application. This decision must be made based on the support functions provided by the microcontroller and the level of priority this task has in the overall system. Each approach has benefits and drawbacks associated. The intent of this article is to provide real examples of Manchester decoding that can be applied. The appendix that follows contains code written for the Atmel® AVR® and is configurable to the inputs and outputs used in a real application. This should make working with Manchester coding very simple for the user.

6. Appendix: Code Samples

```
/*
Project : Configuration.h
Date    :
Author  : Toby Prescott
Company : Atmel
Comments:

Chip type            : ATmega128
Program type         : Application
Clock frecquency     : 8.000000 MHz
Memory model         : Small
External SRAM size   : 0
Data Stack size      : 1024

Revisions:
  v1.0 - Started WINAVR

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-------------------------------------------------------------------------
*/

//   List your includes
#include <avr/io.h>

//-----Hardware specific setup -----//
#define IOPORT          PORTD
#define IOPIN           PIND
#define IODDR           DDRD
#define DATAIN          PD4
#define DATAOUT         PD6

#define DEBUGPORT  PORTF
#define DEBUGDDR   DDRF
#define DEBUGPIN   PF1

#define CODINGTIMERCNT        TCNT1
#define CODINGTIMERCTRA       TCCR1A
#define CODINGTIMERCTRB       TCCR1B
#define CODINGTIMERCTRC       TCCR1C
#define CODINGTIMERMSK        TIMSK
#define CODINGTIMERFLR        TIFR

#define CODINGTIMER_OVF       TIMER1_OVF_vect
#define CODINGTIMER_IPC       TIMER1_CAPT_vect
#define CODINGTIMER_CMPA      TIMER1_COMPA_vect


//--------------------------------//
```

```
//------ Define Macros
#define sbi(port,bit)   (port |= (1<<bit))    // Set bit in port
#define cbi(port,bit)   (port &= ~(1<<bit))   // Clear bit in port
#define tgl(port,bit)   (port ^= (1<<bit))    // Toggle bit in port
#define tst(port,bit) (((port)&(1<<(bit)))>>(bit))// Test bit in port

#define DEBUG(state) if(state == CLEAR){cbi(DEBUGPORT,DEBUGPIN);}
else{sbi(DEBUGPORT,DEBUGPIN);}
#define TGLDEBUG() (tgl(DEBUGPORT,DEBUGPIN))

#define CLEAR          0
#define SET            1

#define WRITE     0
#define READ      1

// Error codes
#define SUCCESS0       0
#define SUCCESS1       1


/*
Project : Coding.h
Date    : 4/22/2009
Author  : Toby Prescott
Company : Atmel
Comments:
/*---------------------------------------------------------------------*/
#ifndef CODING_H__
#define CODING_H__
//   List your includes
#include <avr/io.h>
#include <avr/interrupt.h>
#include "Configuration.h"
//   Declare your global function prototypes here
unsigned char Coding_ClkSync(unsigned char numSamples);
void Coding_SetClk(unsigned int clk, unsigned int shortL,
unsigned int shortH, unsigned int longL, unsigned int longH);
unsigned char Coding_ManchesterSync(unsigned char maxSample);
unsigned char Coding_ManchesterEncode(unsigned char numBits);
unsigned char Coding_ManchesterDecode(unsigned char cBit);
unsigned char Coding_BiPhase1Decode(void);
unsigned char Coding_BiPhase2Decode(void);
void Coding_DSP(unsigned char Encoding);
unsigned char Coding_ReadData(unsigned char mode, unsigned int numBits,
unsigned char startBit, unsigned char Encoding);
```

```
void Coding_TimerInit(unsigned int countVal, unsigned char mode);
void Coding_Timer_Stop(void);
unsigned int Coding_Timer_Poll(void);
//   Declare your global sturctures here
struct DecodeTiming{
  unsigned int ShortL;
  unsigned int ShortH;
  unsigned int LongL;
  unsigned int LongH;
};
//   Declare your global definitions here
#define BUFFSIZE       128
#define UPPERTIMINGLMT  5000
#define SAMPLING       0
#define TIMING         1
#define MANCHESTER     0
#define BIPHASE1       1
#define BIPHASE2       2
#define INVERTED
//#define NONINVERTED
// Error codes
#define SyncErr        2
#define BitErr         3
#define TagErr         4
//   Declare your global variables (extern) here
extern struct DecodeTiming DecodeReadTime;
extern volatile unsigned char cDataBuff[BUFFSIZE];
/*--------------------------------------------------------------------*/
#endif // CODING_H__

/*
Project : Coding.c
Date    : 4/22/2009
Author  : Toby Prescott
Company : Atmel
Comments:

Chip type           : ATmega128
Program type        : Application
Clock frequency     : 8.000000 MHz
Memory model        : Small
External SRAM size  : 0
Data Stack size     : 1024

Revisions:
  v1.0 -   Started WINAVR
```

```
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----------------------------------------------------------------------*/

#include "Coding.h"

volatile unsigned char cDataBuff[BUFFSIZE] = {0};   // Read Data buffer
volatile unsigned char *cDataBuffPtr;

//  Runtime values for Reader Timings  //
unsigned int clk2T=0;
struct DecodeTiming DecodeReadTime = {0};

volatile unsigned char numSampleBits = 0;
volatile unsigned int RdTime = 0;          //Global var used for edgetiming
unsigned char directionFlag = READ;
```

```
// ********************************************************************
// Routine to recover clock and timings
// *******************************************************************/
unsigned char Coding_ClkSync(unsigned char numSamples)
{
  unsigned int clkT=0;
  unsigned int tmp=0, average=0, sample=0;

  directionFlag = READ;              // Set direction for timer interrupt
  Coding_TimerInit(0x00, TIMING);    // Initiate timer w/ edge2edge
                                        measurement
  Coding_Timer_Poll();               // Wait for edge
  clkT = Coding_Timer_Poll();        // Set initial measurment as T time
    do
    {
        tmp = Coding_Timer_Poll(); // Catch next edge time
    if(tmp < UPPERTIMINGLMT)         // Check if edge time is useable
      {
            if(tmp < (clkT*0.5)){clkT = tmp;}    // Time below limit
            else if((tmp >= (clkT*0.5)) && (tmp <= (clkT*1.5)))
            {
                    average += tmp;           // Accumulate
                    sample++;                 // Inc sample count
                    clkT = (average/sample); // Average
            }
            else if((tmp >= (clkT*1.5)) && (tmp <= (clkT*2.5)))
            {
                    average += (tmp/2);       // Accumulate but sample/2
                    sample++;                 // Inc sample count
                    clkT = (average/sample); // Average
            }
            else
            {
                    clk2T = 128;            // Force default to 2T = 256us
                    break;
            }
    }
    else
    {
            clkT = 128;                     // Force default to
                                                2T = 256us
            break;
    }
    }while(sample < numSamples);            // Repeat while < sample size
```

```
  Coding_Timer_Stop();                          // Stop timer
  clk2T = (clkT*2);                             // Compute 2T time
  DecodeReadTime.ShortL = (int)(clk2T*0.25);   // Compute low T limit
  DecodeReadTime.ShortH = (int)(clk2T*0.75);   // Compute high T limit
  DecodeReadTime.LongL = (int)(clk2T*0.75);    // Compute low 2T limit
  DecodeReadTime.LongH = (int)(clk2T*1.25);    // Compute high 2T limit
  if(sample == numSamples){return SUCCESS0;}
  else{return TagErr;}
}

// ***********************************************************************
// Routine to set clock and timings
// ***********************************************************************/
void Coding_SetClk(unsigned int clk, unsigned int shortL,
unsigned int shortH, unsigned int longL, unsigned int longH)
{
  clk2T = clk;                          // Force 2T time
  DecodeReadTime.ShortL = shortL;       // Force low T limit
  DecodeReadTime.ShortH = shortH;       // Force high T limit
  DecodeReadTime.LongL = longL;         // Force low 2T limit
  DecodeReadTime.LongH = longH;         // Force high 2T limit
}

// ***********************************************************************
// Routine to encode a Manchester data stream
// Pass in the number of bits to send
// Pulls from cDataBuff
// ***********************************************************************/
unsigned char Coding_ManchesterEncode(unsigned char numBits)
{
    volatile unsigned int cNumBits = 0,i;

    cDataBuffPtr = &cDataBuff[0];     // Place pointer at beginning of
                                         buffer
    directionFlag = WRITE;            // Set direction for timer interrupt
    Coding_TimerInit((clk2T/2), SAMPLING);  // Init timer w/ periodic
                                                interrupt
    for(i=0; i<numBits; i++)          // Repeat until all bits sent
     {
if(cNumBits == 8)                    // When full byte is read
        {
            cDataBuffPtr++;          // Increment pointer to next byte in
                                        buffer
            if(cDataBuffPtr == &cDataBuff[0]){i=numBits+1;}
            cNumBits = 0;            // Clear bit counter
        }
```

```
    if((*cDataBuffPtr & 0x80) == 0x80)   // Check bit value, process logic
                                            one
    {
      cbi(IOPORT,DATAOUT);                 // Set I/O low
      Coding_Timer_Poll();                 // Catch next interrupt
      sbi(IOPORT,DATAOUT);                 // Set I/O high
      Coding_Timer_Poll();                 // Catch next interrupt
    }
    else
    {
      sbi(IOPORT,DATAOUT);                 // Set I/O high
      Coding_Timer_Poll();                 // Catch next interrupt
      cbi(IOPORT,DATAOUT);                 // Set I/O low
      Coding_Timer_Poll();                 // Catch next interrupt
    }
    *cDataBuffPtr = *cDataBuffPtr<<1;      // Shift buffer to get next bit
    cNumBits++;                            // Increment number of bits sent
  }

  return 0;
}

// ***********************************************************************
// Routine to synchronize to manchester edge
// ***********************************************************************/
unsigned char Coding_ManchesterSync(unsigned char maxSample)
{
  unsigned char i=0;
  unsigned int tmp;
  unsigned char cOutput = SyncErr;

  directionFlag = READ;                 // Set direction for timer interrupt
  Coding_TimerInit(0x00, TIMING);       // Init timer w/ edge-2-edge
                                           measurement

  tmp = Coding_Timer_Poll();            // Wait for edge
  while(i++ < maxSample)                // Repeat until sample size is meet
  {
    tmp = Coding_Timer_Poll();          // Catch next edge time
    if(tmp > UPPERTIMINGLMT){break;}  // Check if edge time is useable
    else if((tmp >= DecodeReadTime.LongL) &&
            (tmp <= DecodeReadTime.LongH))
    {
      //2T time found, check starting logic value
      if(tst(IOPIN,DATAIN) == 0){cOutput = SUCCESS0;}
      else{cOutput = SUCCESS1;}
      break;
    }
```

```
  }
  return cOutput;
}

// **********************************************************************
// Routine to decode a Manchester bit
// Pass in the previous bit logic value
// *********************************************************************/
unsigned char Coding_ManchesterDecode(unsigned char cBit)
{
  unsigned char cOutput = BitErr;
  unsigned int tmp;

  tmp = Coding_Timer_Poll();              // Catch next edge time
  if(tmp < UPPERTIMINGLMT)                // Check if edge time is useable
  {
        //  Check edge time and determine next Logic value  //
       if((tmp > DecodeReadTime.LongL) && (tmp < DecodeReadTime.LongH))
       {cOutput = cBit ^ 0x01;}           // invert cBit for logical change
       else if(tmp > DecodeReadTime.ShortL && tmp < DecodeReadTime.ShortH)
      // Next edge time is short
       {
               tmp = Coding_Timer_Poll();
               if(tmp > DecodeReadTime.ShortL &&
               tmp < DecodeReadTime.ShortH)
               {cOutput = cBit;}          // bit stays the same
               else{cOutput = BitErr;}    // Un-paired short time
      }
     else {cOutput = BitErr;}             // Edge time outside limits
  }
  return cOutput;
}

// **********************************************************************
// Routine to decode a BiPhase1 bit
// *********************************************************************/
unsigned char Coding_BiPhase1Decode(void)
{
    unsigned char cOutput = BitErr;
    unsigned int tmp;

    tmp = Coding_Timer_Poll();            // Catch next edge time
    if(tmp < UPPERTIMINGLMT)              // Check if edge time is useable
    {
   //  Check edge time and determine next Logic value  //
   if(tmp > DecodeReadTime.LongL &&
   tmp < DecodeReadTime.LongH)
```

```
    {cOutput = 0;}
    else if(tmp > DecodeReadTime.ShortL && tmp < DecodeReadTime.ShortH)
    {
       tmp = Coding_Timer_Poll();
       if(tmp > DecodeReadTime.ShortL && tmp < DecodeReadTime.ShortH)
       {cOutput = 1;}
        else
      {
                    cOutput = BitErr;        // Un-paired short time between
      }
    }
    else {cOutput = BitErr;}                 // Edge time outside limits
  }
  return cOutput;
}

// *************************************************************************
// Read Routine Using the U2270
// *************************************************************************
void Coding_DSP(unsigned char Encoding)
{
  unsigned char count=0, cLong=0, cShort=0;
  unsigned char i, logicFlag, cNumBit=0, syncFlag=0;
  unsigned char tmpData,j, bitVal=0;
  volatile unsigned char *cDSPBuffPtr = &cDataBuff[0];

  cDataBuffPtr = &cDataBuff[0];               // Place pointer at beginning
                                                 of buffer
  if((*cDSPBuffPtr & 0x80) == 0x80){logicFlag = 1;}  // Initialize logic
                                                            flag
  else{logicFlag = 0;}

  for(j=0; j<BUFFSIZE; j++)                   // Process entire buffer
  {
    tmpData = *cDSPBuffPtr++;                 // Pull out working byte
    for(i=0; i<8; i++)                        // Process entire byte
    {
      if(!syncFlag)
      {
        if(logicFlag == 1 && (tmpData & 0x80) == 0x80){count++;}
        else if(logicFlag == 0 && (tmpData & 0x80) == 0x00){count++;}
        else
        {
          logicFlag = logicFlag^0x01;         // Current flag inverted
          if(count > 4)
```

```
        {
          syncFlag=1;                          // 2T sync found
          bitVal = logicFlag;
        }
        count=1;                               // Reset count
      }
    }
    else
    {
      if(logicFlag == 1 && (tmpData & 0x80) == 0x80){count++;}
      else if(logicFlag == 0 && (tmpData & 0x80) == 0x00){count++;}
      else
      {
        // Check if count below threshold, inc short
        if(count <=4){cShort++;}
        else{cLong++;}                         // else inc long
        count=1;                               // Reset count
        logicFlag = logicFlag^0x01;            // Current flag inverted

        if(cLong == 1)
        {
          cLong = 0;
          if(Encoding == MANCHESTER)           // Decode Manchester
          {bitVal = bitVal^0x01;}
          else if(Encoding == BIPHASE1)        // Decode BiPhase
          {bitVal = 0;}

          if(bitVal == 1)
          {
            *cDataBuffPtr = *cDataBuffPtr << 1;
            *cDataBuffPtr = *cDataBuffPtr | 0x01;
          }
          else if(bitVal == 0)
          {
            *cDataBuffPtr = *cDataBuffPtr << 1;
          }
          cNumBit++;
        }
        else if(cShort == 2)
        {
          cShort = 0;
          if(Encoding == MANCHESTER){;}
          else if(Encoding == BIPHASE1){bitVal = 1;}
          if(bitVal == 1)
```

```
          {
            *cDataBuffPtr = *cDataBuffPtr << 1;
            *cDataBuffPtr = *cDataBuffPtr | 0x01;
          }
          else if(bitVal == 0)
          {
            *cDataBuffPtr = *cDataBuffPtr << 1;
          }
          cNumBit++;
        }
        if(cNumBit == 8)                    // When full byte is read
        {
          cDataBuffPtr++;                   // Inc ptr to next byte
          cNumBit = 0;                      // Clear bit counter
        }
      }
    }
    tmpData = tmpData << 1;                 // Shift working byte to next
                                               bit
  }
 }
}

// *********************************************************************
// Read Routine Using
// Pass in the number of Tag Type, data encoding, and type of synch.
// Pass in the number of bits being sent and the data buffer
// *********************************************************************/
unsigned char Coding_ReadData(unsigned char mode, unsigned int numBits,
unsigned char startBit, unsigned char Encoding)
{
  unsigned char cBit = 2;
  volatile unsigned char cError = SUCCESS0;
  unsigned char cQuit = 0;
  unsigned int cNumBits = 0, cNumBytes = 0,i;

  cBit = startBit;

  if(mode == SAMPLING)
  {
        directionFlag = READ;               // Set direction for timer
                                               interrupt
        cDataBuff[BUFFSIZE-1] = 0x00;       // Clear buffer end byte
        Coding_TimerInit((clk2T/6), mode);  // Init timer w/ periodic
                                               interrupt
        do
```

```
        {
        }
        while(cDataBuff[BUFFSIZE-1] == 0x00);// Buffer end byte accessed
        Coding_Timer_Stop();                  // Stop Timer
        Coding_DSP(Encoding);             // Run DSP processing on samples.
}
else
{
   cBit = Coding_ManchesterSync(100);
   if(cBit == SUCCESS0 || cBit == SUCCESS1)
        {
           while(!cQuit)
           {
             for(i=0; i<(numBits*2)+10;i++)
              {
               if(cNumBits == 8)              // When full byte is read
                {
                cDataBuffPtr++;               // Increment pointer to next
                                                 byte in buffer
                cNumBits = 0;                 // Clear bit counter
                cNumBytes++;                  // Increment byte counter
                }
                if(Encoding == MANCHESTER)    // Decode the next bit
                                                 (Manchester)
                {cBit = Coding_ManchesterDecode(cBit);}
                else if(Encoding == BIPHASE1) // Decode the next bit
                                                  (BiPhase)
                {cBit = Coding_BiPhase1Decode();}
                if(cBit == 1)
                 {
                        *cDataBuffPtr = *cDataBuffPtr << 1;
                        *cDataBuffPtr = *cDataBuffPtr | 0x01;
                 }
                 else if(cBit == 0)
                 {
                       *cDataBuffPtr = *cDataBuffPtr << 1;
                 }
                 else{break;}
                 cNumBits++;                    // Increment number of
                                                   bits read
              }
              cQuit = 1;
           }
           if((cNumBits+(8*cNumBytes)) == (numBits*2)+10){cError = 0;}
           else{cError = BitErr;}
```

```
    }
    else{cError = SyncErr;}
    Coding_Timer_Stop();
  }
  if(cError != 0){for(i=0; i < BUFFSIZE; i++){cDataBuff[i]=0x00;}} //Reset
                                                                     Buffer

  return cError;                    // Return error code (zero = successfull)
}


// ***********************************************************************
// *   RFIDTimer Initialization of for Read Routine
// ***********************************************************************
void Coding_TimerInit(unsigned int countVal, unsigned char mode)
{
    CODINGTIMERMSK = 0x00;                  //Disable TC1 interrupts
    cDataBuffPtr = &cDataBuff[0];           // Place pointer at beginning of
                                               buffer

    OCR1A = countVal;
    CODINGTIMERCNT = 0x00;                  //Load TC1 count value

    if(mode == TIMING)
    {
       sbi(CODINGTIMERMSK,TICIE1);          // Timer1 Input Capture &
                                               Interrupt Enable
       sbi(CODINGTIMERMSK,TOIE1);
    }
    else{sbi(CODINGTIMERMSK,OCIE1A);}       // Timer/Counter1 Output
                                               Compare A
    CODINGTIMERFLR |= 0x27;                 //clear interrupt flags for TC1

    CODINGTIMERCTRA = 0x00;                 //Normal mode
    cbi(CODINGTIMERCTRB,ICES1);             //Look for Falling Edge on ICP1
    CODINGTIMERCTRB |= (1<<CS11);           //prescale=clocksource/8
                                            //exactly 1 us for every timer
                                              step
    CODINGTIMERCTRC = 0x00;                 //Normal mode
  }
```

```
// *********************************************************************
// *   Shutdown RFIDTimer
// *********************************************************************
void Coding_Timer_Stop(void)
{
   CODINGTIMERMSK &= ~0x27;            //Disable TC1 interrupts

   CODINGTIMERCTRA = 0x00;
   CODINGTIMERCTRB = 0x00;             //No clock source / Timer
                                        Stopped
   CODINGTIMERCTRC = 0x00;
   CODINGTIMERFLR |= 0x27;             //clear interrupt flags for TC1
}
// *********************************************************************
// *   Read Edge Time
// *********************************************************************
unsigned int Coding_Timer_Poll(void)
{
   asm("sei");                         // Turn on global Interrupts
   RdTime = 0;                         // Clear timing measurement
   while(RdTime == 0){}                // Wait for interrupt to
                                          generate measurement
   return RdTime;
}

// *********************************************************************
// *   RFIDTimer Output Compare Interrupt Routine
// *********************************************************************
ISR(CODINGTIMER_CMPA)
{
  CODINGTIMERCNT = 0x0000;              //Reset TC1 Count value
  RdTime = 1;                           //Set Read Time = 1 (Timer
                                          Match)
  if(directionFlag == READ)             //Only process level sampling
                                          on Read
  {
    if(numSampleBits == 8)              //Complete byte
    {
      numSampleBits = 0;                //Reset bit counter
      cDataBuffPtr++;                   //Inc buffer ptr
    }
    *cDataBuffPtr = *cDataBuffPtr<<1;   //Shift in new bit
    if(tst(IOPIN,DATAIN) == 1)          //Check logic level
    {
      *cDataBuffPtr = *cDataBuffPtr|0x01;   //Store one
    }
```

```
      numSampleBits++;                          //Inc bit count
    }
  }

  //
  **************************************************************************
  // *   RFIDTimer Overflow Interrupt Routine
  // ***********************************************************************
  ISR(CODINGTIMER_OVF)
  {
    CODINGTIMERCNT = 0x0000;                    //Reset TC1 Count value
    RdTime = 0xFFFF;                            //Set Read Time = 0xFFFF
                                                  (overflow)
  }
  // ***********************************************************************
  // *   RFIDTimer Input Capture Interrupt Routine
  // ***********************************************************************
  ISR(CODINGTIMER_IPC)
  {
    CODINGTIMERCNT = 0x0000;                    //Reset TC1 Count value
    tgl(CODINGTIMERCTRB,ICES1);                 //change edge on ICP1 (XOR)
    RdTime = ICR1;
  }
```

7. TESTBENCH Section

```
    asm("sei");                                 // Turn on global Interrupts

    // *** Manchester Encoding ***
    Coding_SetClk(256, 30, 210, 210, 350);
    cDataBuff[0] = 0xFF;
    cDataBuff[1] = 0xFE;
    cDataBuff[2] = 0x6A;
    tmp = Coding_ManchesterEncode(24);
    // ***************************

    // *** Manchester Decoding ***
    Coding_ClkSync(30);
    //tmp = Coding_ReadData(SAMPLING, 128, tmp, MANCHESTER);
    tmp = Coding_ReadData(TIMING, 128, tmp, MANCHESTER);
    if(tmp == SUCCESS0 || tmp == SUCCESS1)
    {
      // Process Data
    }
    // ***************************
```

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