

## Introduction

The Intersil HC-5560 digital line transcoder provides mode selectable, pseudo ternary line coding and decoding schemes for North American and European transmission lines. Coding schemes include Alternate Mark Inversion (AMI), Bipolar with N Zero Substitution (BNZS), and High Density Bipolar 3 (HDB3), used for transmission lines as follows:

AMI: North American T1 (1.544MHz) and T1C (3.152MHz) lines

B6ZS: North American T2 (6.3212MHz) lines

B8ZS: North American T1 (1.544MHz) lines

HDB3: European PCM30 (2.048 and 8.448MHz) CEPT lines. Recommended by CCITT

The transcoder is a single chip, single supply device fabricated with standard cell CMOS. Features include simultaneous coding and decoding, asynchronous operation, loop back mode, transmission error detection, an alarm indication signal, and a full chip reset.

This application note will describe why coding for digital transmission is necessary, the types of coding, which is best, and why, and the functionality and applications of the HC-5560 digital line transcoder.

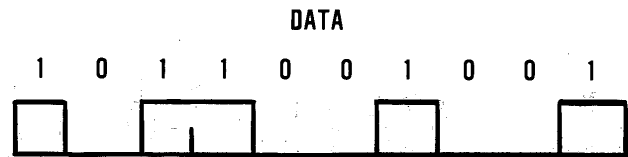
## Why Line Coding?

Transmission of serial data over any distance, be it a twisted pair, fiber optic link, coaxial cable, etc., requires "maintenance" of the data as it is transmitted (through repeaters, echo cancellors etc.). The data integrity must be maintained through data reconstruction, with proper timing, and retransmitted. Line codes were created to facilitate this "maintenance".

In selecting a particular line coding scheme some considerations must be made, as not all line codes adequately provide the all important synchronization between transmitter and receiver. Other considerations for line code selection are noise and interference levels, error detection/checking, implementation requirements, and the available bandwidth.

## Unipolar Coding

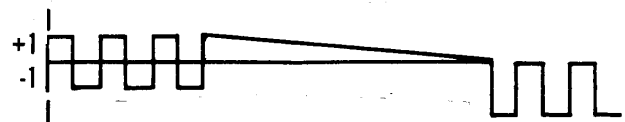
The most basic transmission code is unipolar or unbalanced coding whereby each discrete variable to be transmitted is assigned a different level, 0V and +3V, for example:



### UNIPOLAR (UNBALANCED) SIGNAL

There are, however, a number of disadvantages:

- The average power ( $A_0/2$ ) is two times other codes
- The coded signal contains DC and low frequency components. When long strings of zeros are present, a DC or baseline wander occurs. This results in loss of timing and data because a receiver/repeater cannot optimally discriminate ones and zeros.



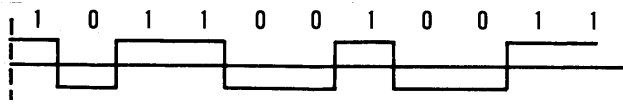
### DC WANDER

- Repeaters/receivers require a minimum pulse density for proper timing extraction. Long strings of ones or zeros contain no timing information and lead to timing jitter and possible loss of synchronization.
- There is no provision for line error rate monitoring.

## Bipolar Coding is Better

With bipolar, or balanced, coding, the same data may be transmitted more efficiently achieving the same error distance with half the power ( $A_0/4$ ). This coding is often referred to as Non-Return to Zero (NRZ) coding as the signal level is maintained for the duration of the signal interval.

Although bipolar coding is more efficient than unipolar, it still lacks provisions for line error monitoring, and is susceptible to DC wander and timing jitter.



**BIPOLAR (BALANCED) SIGNAL**

The HC-5560 digital line transcoder provides a number of augmented bipolar coding schemes which:

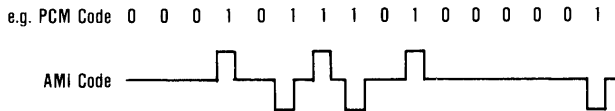
- Eliminate DC Wander
- Minimize Timing Jitter
- Provide for Line Error Monitoring

This is accomplished by introducing controlled redundancy in the code through extra coding levels.

### Line Code Descriptions

The HC-5560 transcoder allows a user to implement any of the four line coding schemes described below.

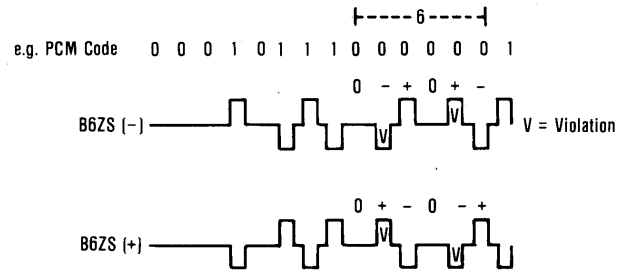
AMI, Alternate Mark Inversion, is used primarily in North American T1 (1.544MHz) and T1C (3.152MHz) carriers. Zeros are coded as the absence of a pulse and one's are coded alternately as positive or negative pulses. This type of coding reduces the average voltage level to zero to eliminate DC spectral components, thereby eliminating DC wander.



To facilitate timing maintenance at regenerative repeaters along a transmission path, a minimum pulse density of logic 1's is required. Using AMI, there is a possibility of long strings of zeros and the required density may not always exist, leading to timing jitter and therefore higher error rates.

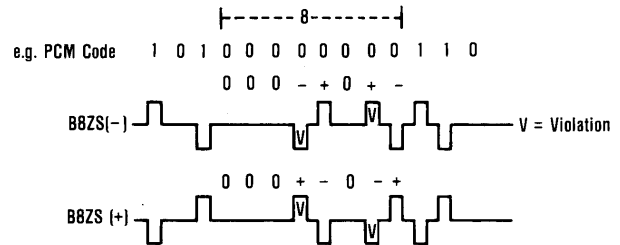
A method for insuring a minimum logic 1 density by substituting bipolar code in place of strings of 0's is called BNZS or Bipolar with N Zero Substitution. B6ZS is used commonly in North American T2 (6.3212MHz) carriers. For every string of 6 zeros, bipolar code is substituted according to the following rule:

If the immediate preceding pulse is of (-) polarity, then code each group of 6 zeros as 0+0+-, and if the immediate preceding pulse is of (+) polarity, code each group of 6 zeros as 0+-0+. One can see the consecutive logic 1 pulses of the same polarity violate the AMI coding scheme.



B6ZS is used commonly in North American T1(1.544MHz) and T1C(3.152MHz) carriers. For every string of 8 zeros, bipolar code is substituted according to the following rules:

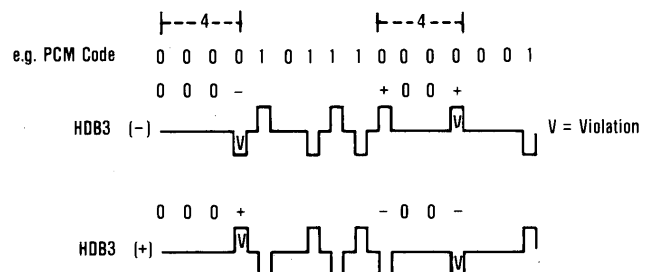
- 1) If the immediate preceding pulse is of (-) polarity, then code each group of 8 zeros as 000+0+.
- 2) If the immediate preceding pulse is of (+) polarity, then code each group of 8 zeros as 000+-0+.



The BNZS coding schemes, in addition to eliminating DC wander, minimize timing jitter and allow a line error monitoring capability.

Another coding scheme is HDB3, high density bipolar 3, used primarily in Europe for 2.048MHz carriers. This code is similar to BNZS in that it substitutes bipolar code for 4 consecutive zeros according to the following rules:

- 1) If the polarity of the immediate preceding pulse is (-) and there have been an odd (even) number of logic 1 pulses since the last substitution, each group of 4 consecutive zeros is coded as 000-(+00+).
- 2) If the polarity of the immediate preceding pulse is (+) then the substitution is 000+(-00-) for odd (even) number of logic 1 pulses since the last substitution.



The 3 in HDB3 refers to the coding format that precludes strings of zeros greater than 3. Note that violations are produced only in the fourth bit location of the substitution code and that successive substitutions produce alternate polarity violations.

A summary graph of all four substitution coding schemes is illustrated in Figure 1. To simplify timing recovery, logic 1's are encoded with 50% duty cycle pulses.

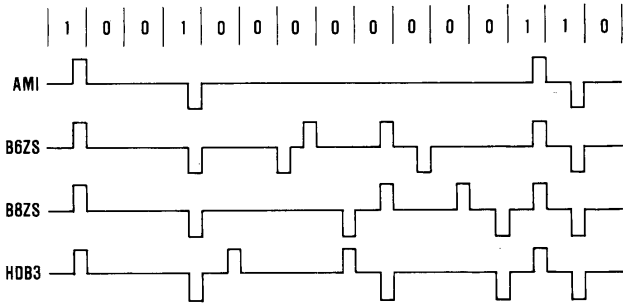


FIGURE 1. SUMMARY OF CODING SCHEMES PROVIDED BY THE HC-5560 TRANSCODER

### Functional Description

The HC-5560 transcoder can be divided into six sections: transmitter (coder), receiver (decoder), error detector, all ones detector, testing functions, and output controls. A block diagram is shown in Figure 2.

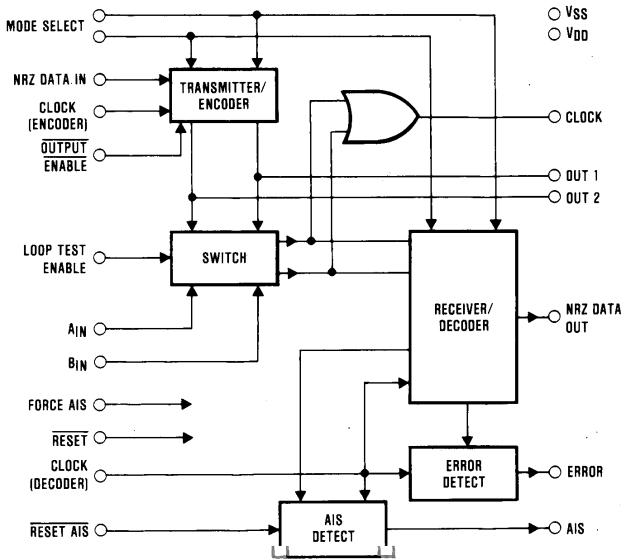


FIGURE 2. HC-5560 TRANSCODER FUNCTIONAL BLOCK DIAGRAM

### Transmitter (Coder)

The transmitter codes a non-return to zero (NRZ) binary unipolar input signal (NRZ IN) into two binary unipolar return to zero (RZ) output signals (OUT1, OUT2). These output signals represent the NRZ data stream modified according to the selected encoding scheme (i.e., AMI, B8ZS, B6ZS, HDB3) and are externally mixed together (usually via a transistor or transformer network) to create a ternary bipolar signal for driving transmission lines.

### Receiver (Decoder)

The receiver accepts as its input the ternary data from the transmission line that has been externally split into two binary unipolar return to zero signals (A<sub>IN</sub> and B<sub>IN</sub>). These signals are decoded, according to the rules of the selected line code into one binary unipolar NRZ output signal (NRZ OUT).

The encoder and decoder sections of the chip perform independently (excluding loopback condition) and may operate simultaneously.

### Error Detector

The Error output signal is active high for one cycle of CLK DEC upon the detection of any bipolar violation in the received A<sub>IN</sub> and B<sub>IN</sub> signals that is not part of the selected line coding scheme. The bipolar violation is not removed, however, and shows up as a pulse in the NRZ DATA OUT signal. In addition, the Error output signal monitors the received A<sub>IN</sub> and B<sub>IN</sub> signals for a string of zeros that violates the maximum consecutive zeros allowed for the selected line coding scheme (i.e., 8 for B8ZS, 6 for B6ZS, and 4 for HDB3). In the event that an excessive amount of zeros is detected, the Error output signal will be active high for one cycle of CLK DEC during the zero that exceeds the maximum number. In the case that a high level should simultaneously appear on both received input signals A<sub>IN</sub> and B<sub>IN</sub> a logical one is assumed and appears on the NRZ data out stream with the error signal active.

### All Ones Detector

An input signal received at inputs A<sub>IN</sub> and B<sub>IN</sub> that consists of all ones (or marks) is detected and signalled by a high level at the alarm indication signal (AIS) output is set to a high level when less than three zeros are received during one period of Reset AIS immediately followed by another period of Reset AIS containing less than three zeros. The AIS output is reset to a low level upon the first period of Reset AIS containing 3 or more zeros.

### **Testing Functions**

A logic high level on LTE enables a loopback condition where OUT1 is internally connected to input A<sub>IN</sub> and OUT2 is internally connected to B<sub>IN</sub> (this disables inputs A<sub>IN</sub> and B<sub>IN</sub> to external signals). In this condition, the input signal NRZ DATA IN appears at output NRZ DATA OUT (delayed by the amount of clock cycles it takes to encode and decode the selected line code). A decode clock must be supplied for this operation. The Reset input can be used to initialize this process.

### **Output Controls**

The output controls are Output Enable and Force AIS. These pins allow normal operation, force OUT1 and OUT2 to zero, or force OUT1 and OUT2 to output all ones (AIS condition).

### **Applications**

The HC-5560 transcoder is designed for use in North American and European PCM transmission lines where pseudo ternary line code substitution schemes are desired. Any equipment that interfaces to T1, T1C, T2 or PCM30 transmission lines may incorporate transcoders. Such equipment includes multiplexers, channel service units, echo cancelers, repeaters, etc. This section will illustrate and describe a basic circuit application, and various system level applications examples.

### **Basic Applications Circuit**

The basic applications circuit is shown in Figure 3. The encoder accepts serially clocked unipolar non-return to zero (NRZ/PCM) data at the NRZ IN pin and codes it into two unipolar return to zero (RZ) signals at pins OUT1 and OUT2. A coding scheme is chosen via mode select pins MS1 and MS2. Data is clocked in on the negative edge of ECLK and clocked out on the positive edge of ECLK. The outputs must be mixed externally, via a transistor/transformer network, to produce the ternary 'bipolar' code selected and to drive the transmission line. The length of OUT1 and OUT2 are set by the length of the positive ECLK pulse.

To decode ternary coded data, the signal must first be split into two unipolar signals and presented to the A<sub>IN</sub> and B<sub>IN</sub> pins. This may be accomplished by an amplifier with a differential output, and two comparators. Both inputs are sampled by the positive edge of DCLK. Decoded data is clocked out in NRZ form to the NRZ OUT pin on the positive edge of DCLK.

All the logic inputs and outputs are TTL compatible.

### **System Level Examples**

Examples of system level transcoder applications are illustrated in Figure 4 through 8.

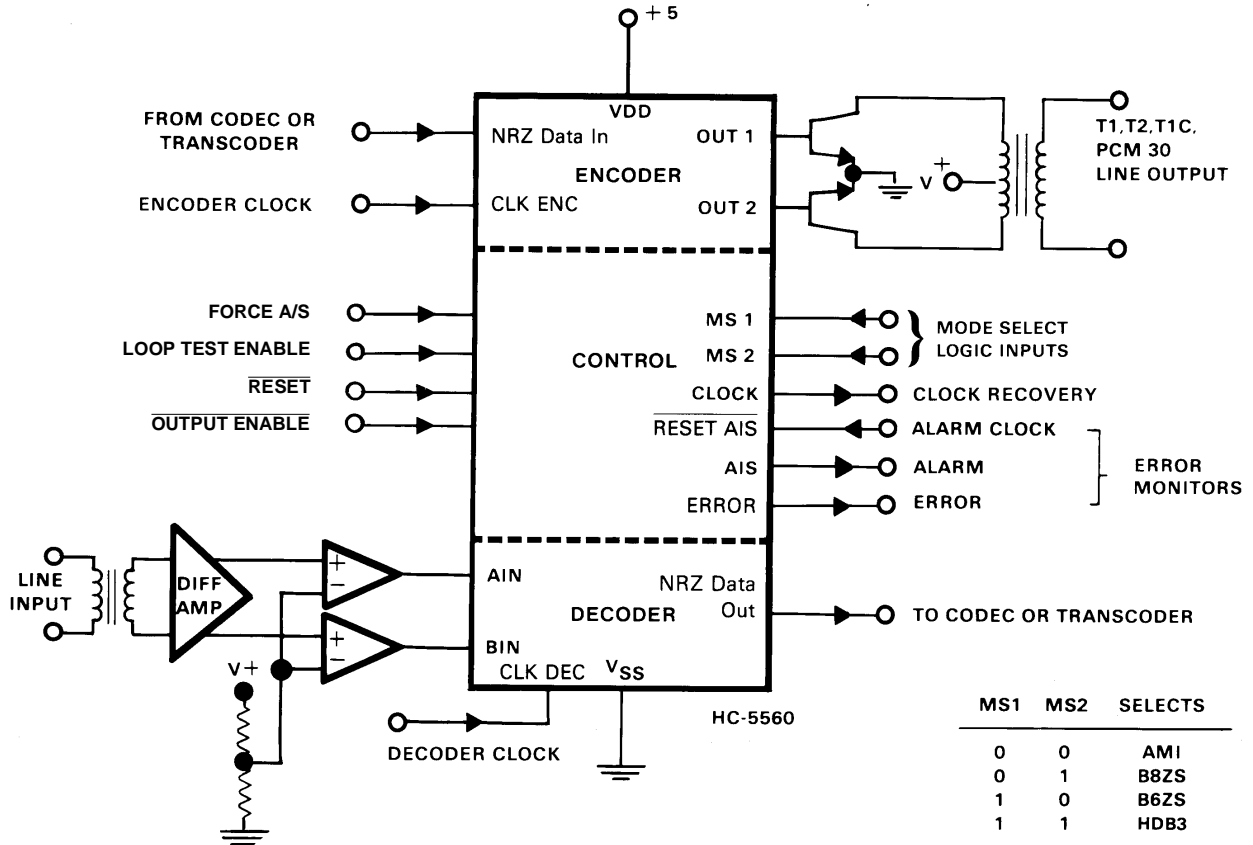


FIGURE 3. BASIC TRNASCODER APPLICATIONS CIRCUIT

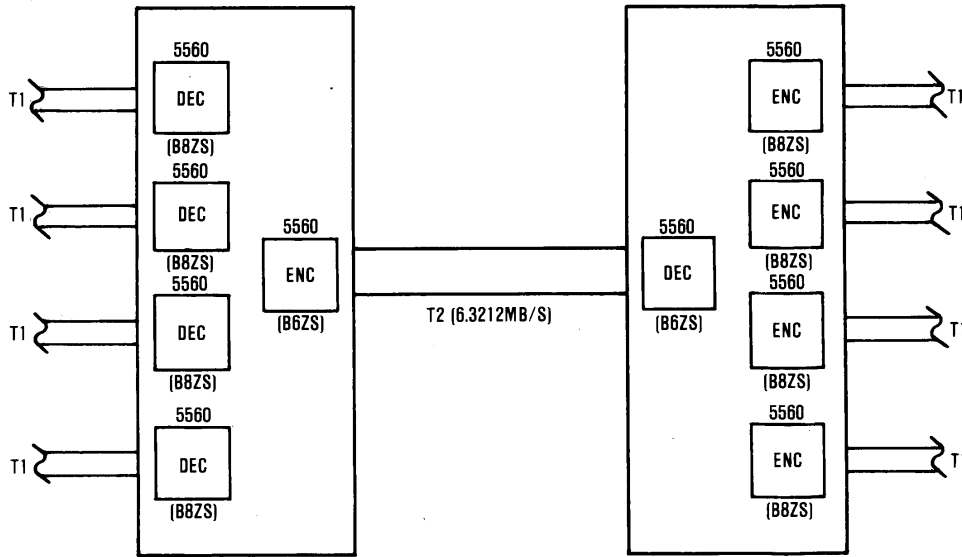


FIGURE 4. M12 MULTIPLIER

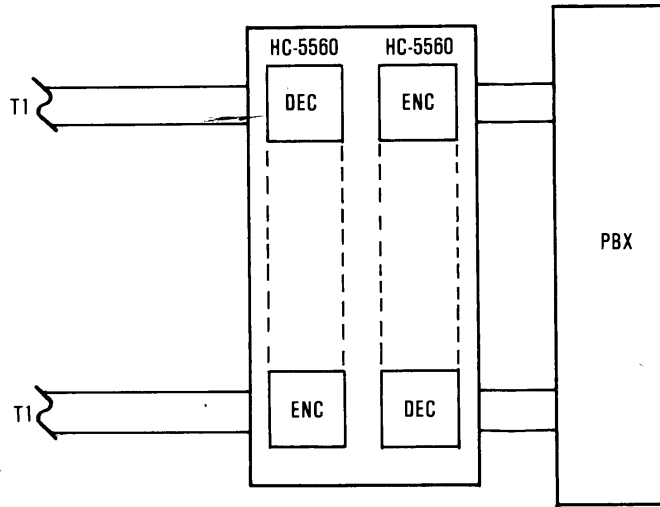


FIGURE 5. CHANNEL SERVICE UNIT (CSU)

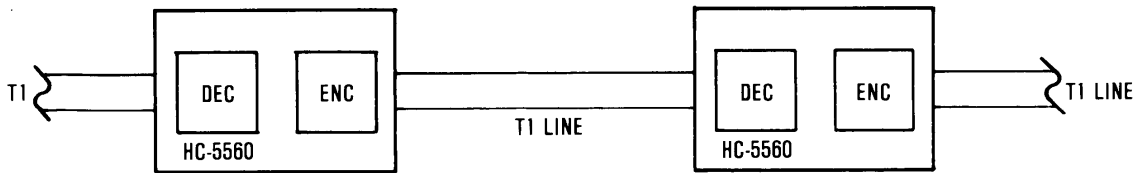


FIGURE 6. ECHO CANCELLOR

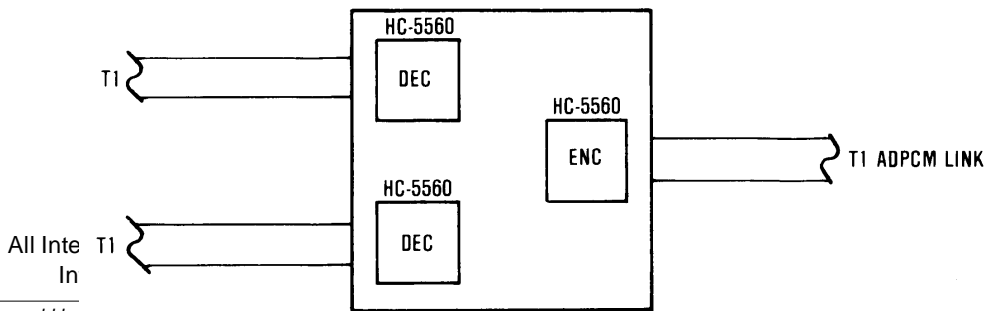


FIGURE 7. T1 COMPRESSION BY ADPCM

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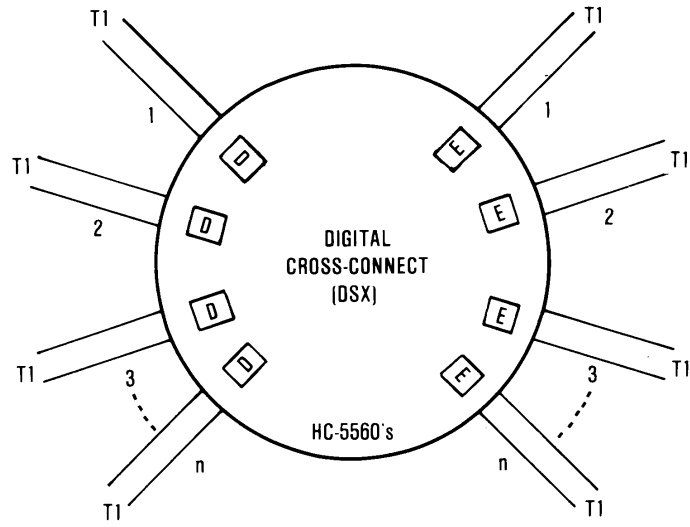


FIGURE 8. DIGITAL CROSS CONNECT (DCS)