Data Encoding – Chapter 5 (part 1)

CSE 3213
Fall 2011

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Signal Encoding Techniques

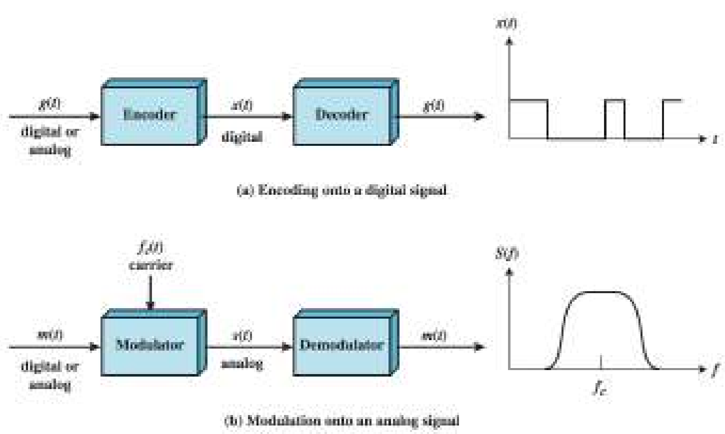

Figure 5.1 Encoding and Modulation Techniques

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Encoding Techniques

- Digital data, digital signals (5.1)
- Analog data, digital signals (5.3)
- Digital data, analog signals (5.2)
- Analog data, analog signals (5.4)

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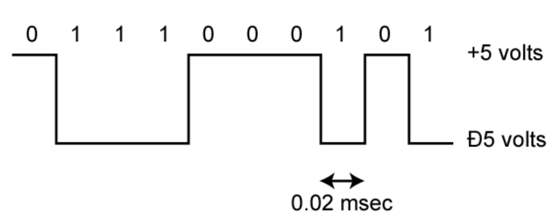
Digital Data, Digital Signals (5.1)

- Digital signal
  - —discrete, discontinuous voltage pulses
  - —each pulse is a signal element
  - —binary data encoded into signal elements



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Terminology (1)

- Unipolar
  - all signal elements have same sign
- Polar
  - one logic state represented by positive voltage the other by negative voltage
- Data rate
  - rate of data transmission R, in bits per second
- Duration or length of a bit
  - time taken for transmitter to emit the bit (1/R)

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Terminology (2)

- Modulation rate
  - rate at which the signal level changes
  - measured in baud = number of signal elements per second
- Mark and Space
  - binary 1 and binary 0 respectively

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Interpreting Signals

- Need to know
  - timing of bits - when they start and end
  - signal levels
- Factors affecting successful interpreting of signals
  - signal to noise ratio
  - data rate
  - bandwidth
  - encoding scheme

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Comparison of Encoding Schemes (1)

Factors to compare:

- Signal Spectrum
  - lack of high frequencies reduces required bandwidth
  - concentrate power in the middle of the bandwidth
- Clocking
  - synchronizing transmitter and receiver, using either
    - external clock, or
    - sync mechanism based on signal

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Comparison of Encoding Schemes (2)

- Error detection
  - responsibility of data link control
  - but can be built in to signal encoding for faster detection
- Signal interference and noise immunity
  - some codes are better than others
- Cost and complexity
  - higher signal rate (and thus data rate) lead to higher costs
  - some codes require signal rate greater than data rate

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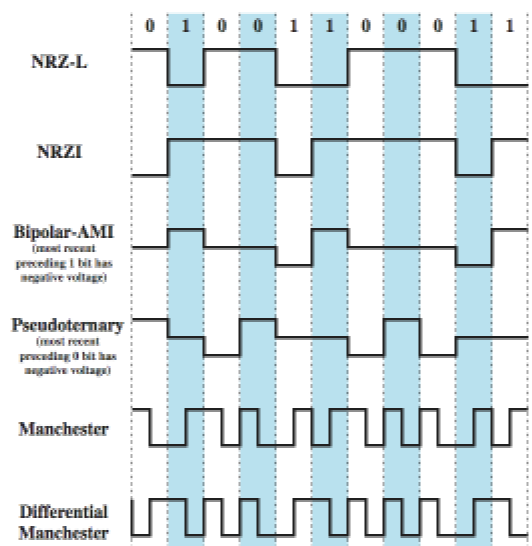
Encoding Schemes (1)



- **B8ZS**
- **HDB3**

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Encoding Schemes (2)

- Nonreturn to Zero-Level (NRZ-L)
- Nonreturn to Zero Inverted (NRZI)
- Bipolar -AMI
- Pseudoternary
- Manchester
- Differential Manchester
- B8ZS
- HDB3

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Nonreturn to Zero-Level (NRZ-L)

- Two different voltages for 0 and 1 bits
- Voltage constant during bit interval
  - no transition during a bit (no return to zero voltage)
  - absence of voltage for 0, constant positive voltage for 1
  - more often, negative voltage for 1, and positive voltage for 0 (NRZ-L)

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Nonreturn to Zero Inverted

- Non-return to zero, inverted on ones
- Constant voltage pulse for duration of bit
- Data encoded as presence or absence of signal transition at beginning of bit time
  - transition (low to high or high to low) denotes a binary 1
  - no transition denotes binary 0
- An example of differential encoding

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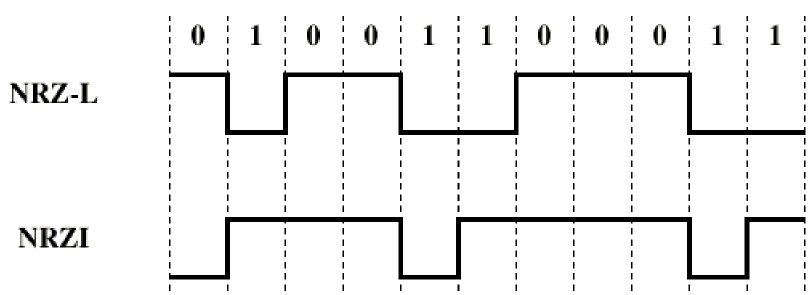
NRZ-L and NRZI Examples



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Differential Encoding

- NRZI is an example of differential encoding
- Data represented by changes rather than levels
- More reliable detection of transition rather than levels
- If the leads from an attached device to a twisted-pair lines are accidentally inverted, all 1s and 0s for NRZ-L will be inverted. This does not happen with differential encoding (NRZI).

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NRZ pros and cons

- Pros
  - easy to engineer
  - make good use of bandwidth
- Cons
  - presence of a DC component
  - lack of synchronization capability
- Used for magnetic recording
- Not often used for signal transmission

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Multilevel Binary

- Use more than two signal levels
  - Bipolar-AMI
  - Pseudoternary

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Bipolar-AMI

- binary 0 represented by no line signal
- binary 1 represented by positive or negative pulse
- binary 1 pulses alternate in polarity
- no loss of sync if a long string of 1s occurs (long strings of 0s still a problem)
- no net DC component
- lower bandwidth
- easy error detection

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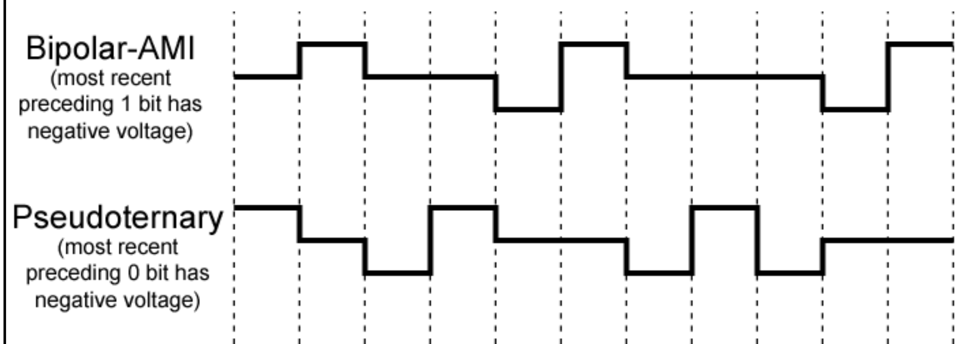
Bipolar-AMI and Pseudoternary



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Pseudoternary

- Same as bipolar-AMI, except that
  - binary 1 represented by absence of line signal
  - binary 0 represented by alternating positive and negative pulses
- No advantage or disadvantage over bipolar-AMI

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Multilevel Binary Issues

- Synchronization needed for long runs of 0s or 1s
  - can insert additional bits that force transitions (used in low-rate ISDN).
  - scramble data (later).
- Overcoming NRZ problems, but …
- Not as efficient as NRZ
  - each signal element represents only one bit instead $\log_2 3$ = 1.58 bits in a 3-level system.
  - receivers must distinguish between three levels (+A, -A, 0).
  - requires approx. 3dB more signal power for same probability of bit error.

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Theoretical Bit Error Rate

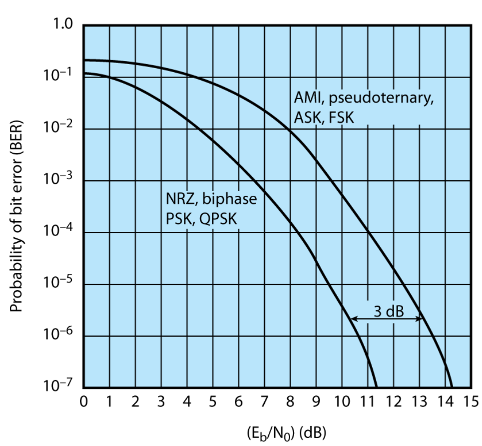

Figure 5.4 Theoretical Bit Error Rate for Various Encoding Schemes

Biphase Encoding

- Manchester
  - —Transition in middle of each bit period
  - —Transition serves as clock and data
  - —Low to high represents 1
  - —High to low represents 0
  - —Used by IEEE 802.3
- Differential Manchester
  - —Mid-bit transition is for clocking only
  - —Transition at start of a bit period represents 0
  - —No transition at start of a bit period represents 1
  - —Note: this is a differential encoding scheme
  - —Used by IEEE 802.5

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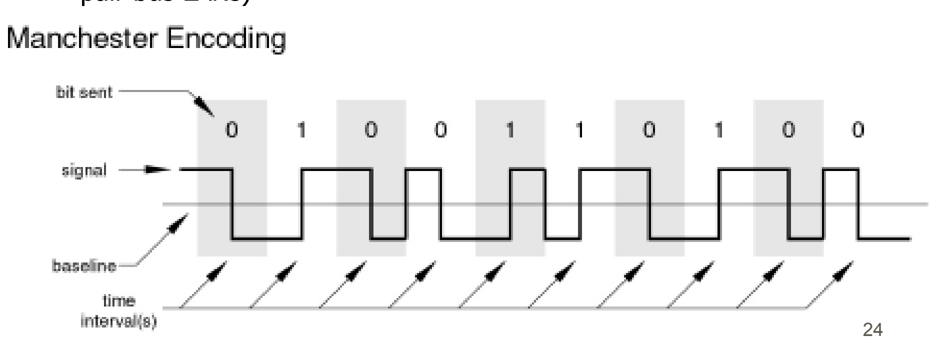
Manchester Encoding

- has transition in middle of each bit period
- transition serves as clock and data
- low to high represents 1
- high to low represents 0
- used by IEEE 802.3 (Ethernet, baseband coaxial cable and twisted – pair bus LANs)



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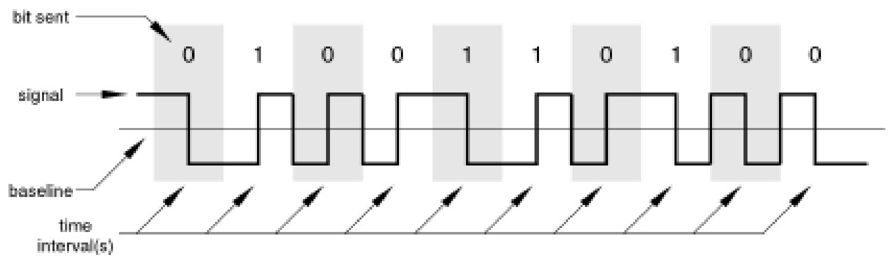
Differential Manchester Encoding

- mid-bit transition is for clocking only
- transition at start of bit period representing 0
- no transition at start of bit period representing 1
  - this is a differential encoding scheme
- used by IEEE 802.5 (token ring LANs using shielded twisted pair)

Differential Manchester Encoding



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Biphase Pros and Cons

- Pros
  - synchronization on mid bit transition (self clocking)
  - no dc component
  - has error detection
    - Absence of expected transition
- Cons
  - at least one transition per bit time and possibly two
  - maximum modulation rate is twice NRZ
  - requires more bandwidth

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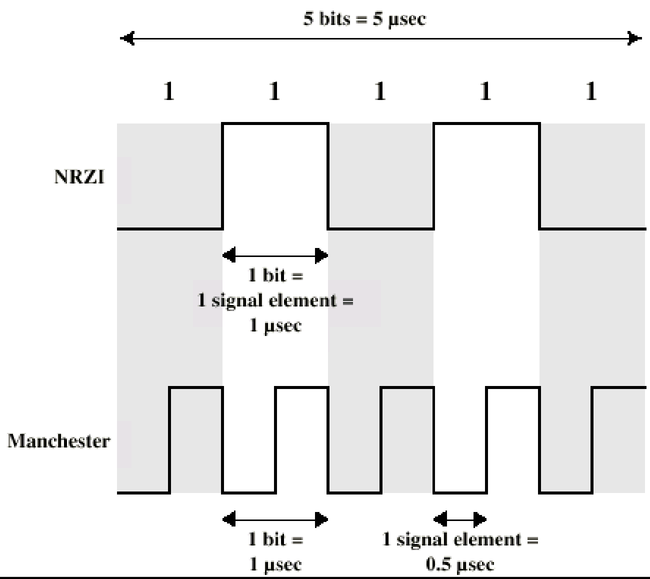
Modulation Rate (1)



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Modulation Rate (2)

- expressed in baud (Bd)
- named after Jean-Maurice-Émile Baudot, the French inventor of the Baudot code used in telegraphy
- 1 Bd = 1 signal/sec
- $D = R/L = R/(\log_2 M)$
  - D = modulation rate, baud
  - R = data rate, bps
  - L = number of bits per signal element
  - M = number of different signal elements = 2^L
- Example: R = 1 Mbps, L = 0.5 $\Rightarrow$ D = 2 MBd

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Normalized Signal Transition Rates

	Minimum	101010. . .	Maximum
NRZ-L	0 (all 0s or 1s)	1.0	1.0
NRZI	0 (all 0s)	0.5	1.0 (all 1s)
Bipolar-AMI	0 (all 0s)	1.0	1.0
Pseudoternary	0 (all 1s)	1.0	1.0
Manchester	1.0 (1010 . . .)	1.0	2.0 (all 0s or 1s)
Differential Manchester	1.0 (all 1s)	1.5	2.0 (all 0s)

Scrambling (1)

- Biphase encoding is widely used in LANs, at high data rates (up to 10Mbps).
- Biphase encoding not widely used in long distance communications:
  - high signaling rate relative to the data rate
  - more costly in long-distance applications
- Alternative: use other schemes in combination with scrambling
- Bipolar AMI + scrambling ⇒ B8ZS and HDB3

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Scrambling (2)

- Use scrambling to replace sequences that would produce constant voltage
- These filling sequences must
  - produce enough transitions to sync
  - be recognized by receiver and replaced with original
  - be same length as original
- Design goals
  - have no DC component
  - have no long sequences of zero level line signal
  - have no reduction in data rate
  - give error detection capability

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B8ZS

- Bipolar With 8 Zeros Substitution
- Based on bipolar-AMI
- If octet of all 0s and last voltage pulse preceding was positive encode as 000+-0-+
- If octet of all 0s and last voltage pulse preceding was negative encode as 000-+0+-
- Causes two violations of AMI code
- Unlikely to occur as a result of noise
- Receiver detects and interprets as octet of all zeros

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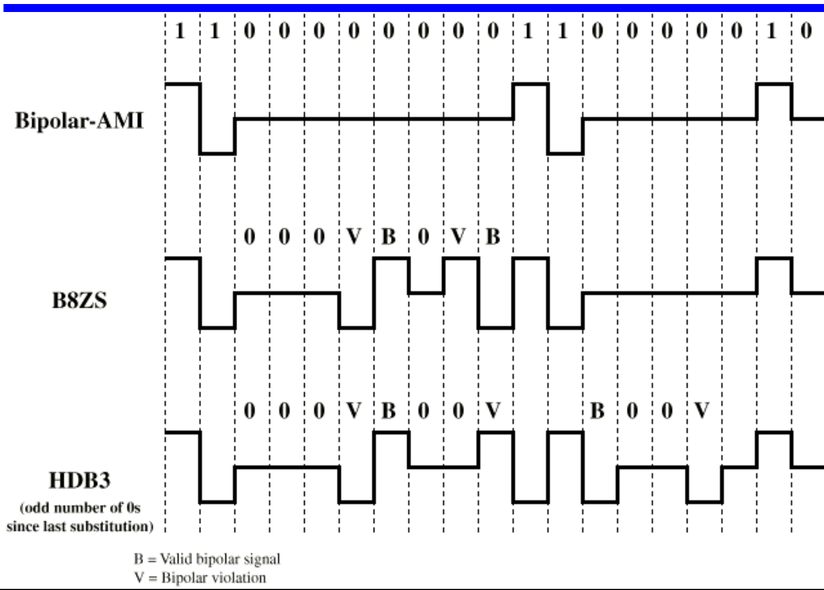
B8ZS and HDB3



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HDB3

- High Density Bipolar 3 Zeros
- Based on bipolar-AMI
- String of four 0s replaced with one or two pulses

Table 5.4 HDB3 Substitution Rules

	Number of Bipolar Pulses (ones) since Last Substitution	
Polarity of Preceding Pulse	Odd	Even
–	000–	+00+
+	000+	–00–

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Summary

Nonreturn to Zero-Level (NRZ-L)
0 = high level
1 = low level

Nonreturn to Zero Inverted (NRZI)
0 = no transition at beginning of interval (one bit time)
1 = transition at beginning of interval

Bipolar-AMI
0 = no line signal
1 = positive or negative level, alternating for successive ones

Pseudoternary
0 = positive or negative level, alternating for successive zeros
1 = no line signal

Manchester
0 = transition from high to low in middle of interval
1 = transition from low to high in middle of interval

Differential Manchester
Always a transition in middle of interval
0 = transition at beginning of interval
1 = no transition at beginning of interval

B8ZS
Same as bipolar AMI, except that any string of eight zeros is replaced by a string with two code violations

HDB3
Same as bipolar AMI, except that any string of four zeros is replaced by a string with one code violation

Reading

- Section 5.1, Stallings' book
- Homework: problems 5.6 to 5.9, Stallings' book

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