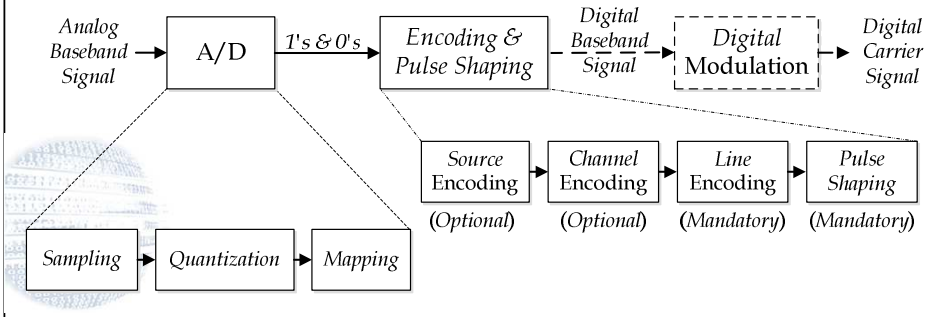
Lecture 5*b*: Line Codes

Dr. Mohammed Hawa
Electrical Engineering Department
University of Jordan

Digitization

- **Sampling** (discrete analog signal).
- **Quantization** (quantized discrete signal)
- **Mapping** (stream of 1's and 0's).
- **Encoding** and **Pulse Shaping** (digital baseband signal).



Copyright © Dr. Mohammed Hawa

Line Coding

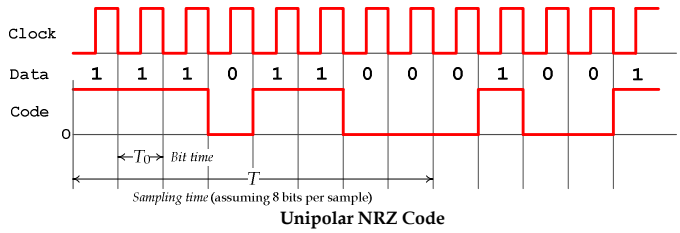
Advantages of a good ***Line Code***:

- *Clock recovery* at the receiver (enough transitions in the received bit sequence).
- No *DC component* nor *low-frequency* power content (important for long-distance communication channels).
- Smaller transmission bandwidth.
- Maximum power in the signal to improve Signal-to-Noise Ratio (SNR).

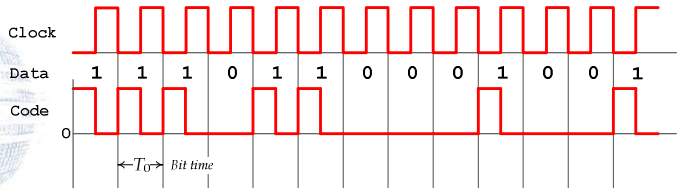
Copyright © Dr. Mohammed Hawa

Unipolar NRZ and Unipolar RZ

Uses a positive rectangular pulse p(t) to represent binary 1, and the absence of a pulse (i.e., zero voltage) to represent a binary 0.



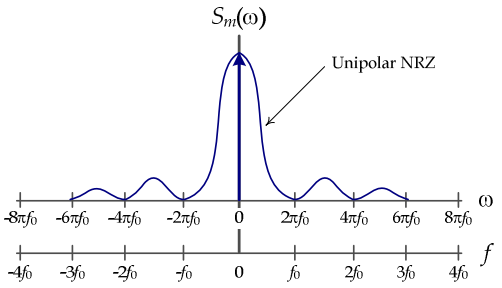
Unipolar NRZ Code

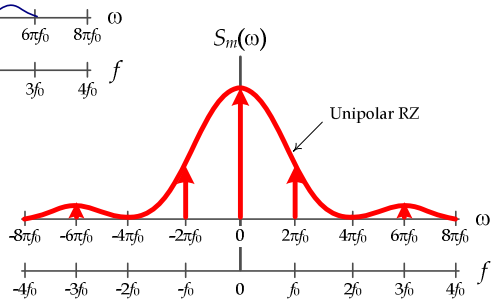


Unipolar RZ Code

Copyright © Dr. Mohammed Hawa

Unipolar PSD

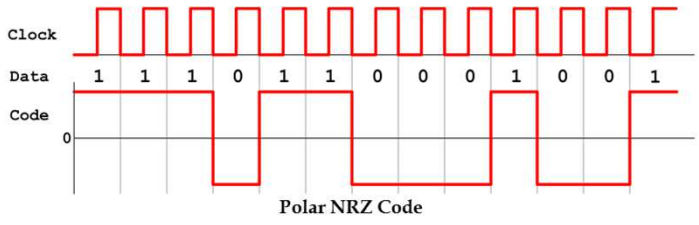




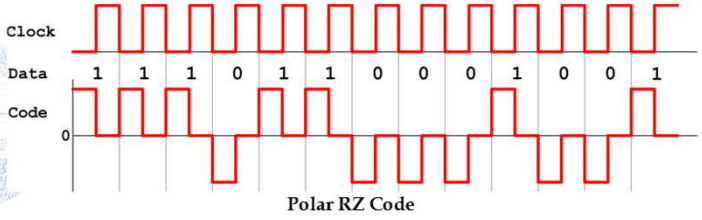
Copyright © Dr. Mohammed Hawa

Polar NRZ and Polar RZ

Binary 1's are represented by a pulse p(t) and binary 0's are represented by the negative of this pulse -p(t).



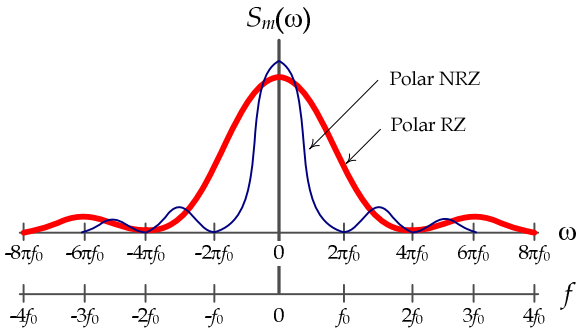
Polar NRZ Code



Polar RZ Code

Copyright © Dr. Mohammed Hawa

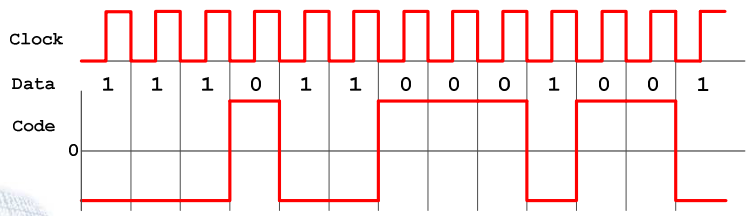
Polar PSD



Copyright © Dr. Mohammed Hawa

Non-Return-to-Zero-Level (NRZ-L)

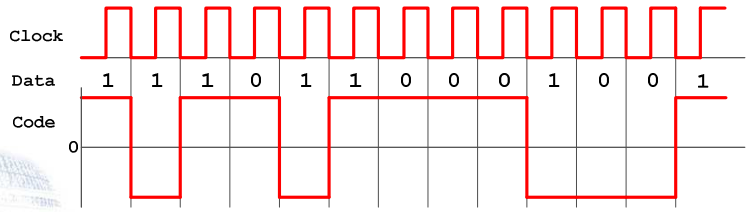
A variant of Polar NRZ is NRZ-L in which the 1's and 0's are represented by -p(t) and p(t), respectively.



Copyright © Dr. Mohammed Hawa

Non-Return-to-Zero, Inverted (NRZI)

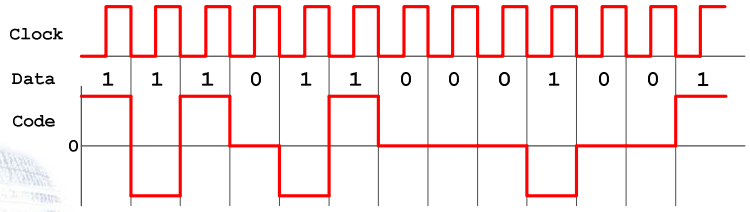
In NRZI there are two possible pulses, p(t) and -p(t). A transition from one pulse to the other happens if the bit being transmitted is a logic 1, and no transition happens if the bit being transmitted is a logic 0.



Copyright © Dr. Mohammed Hawa

Bipolar (AMI)

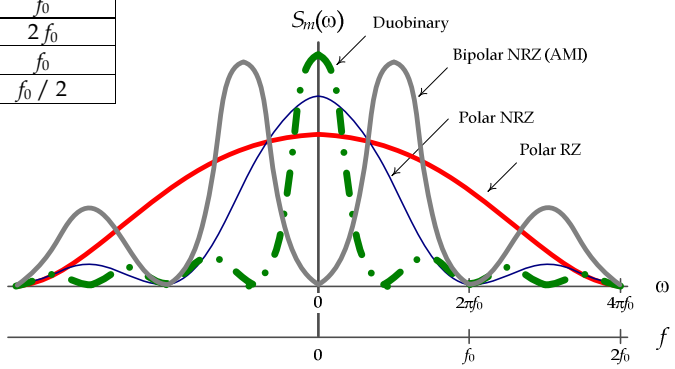
A logic 0 is represented with a grounded or absent pulse, and a logic 1 by either a positive pulse p(t) or negative pulse -p(t). The direction of the pulse is opposite of the pulse sent for the previous logic 1 (mark).



Copyright © Dr. Mohammed Hawa

Power Spectral Density

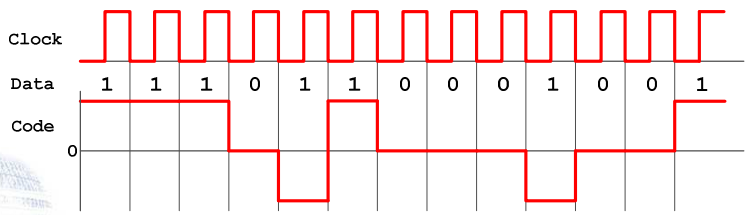
Line Code	Bandwidth
Unipolar NRZ	f_0
Unipolar RZ	$2 f_0$
Polar NRZ	f_0
Polar RZ	$2 f_0$
Bipolar NRZ	f_0
Duobinary	$f_0 / 2$



Copyright © Dr. Mohammed Hawa

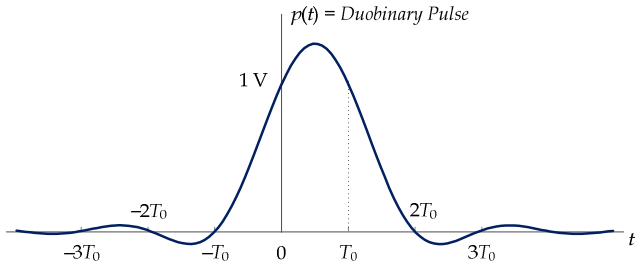
Duobinary

A **0** bit is represented by a zero-level electric voltage; a **1** bit is represented by a p(t) if the quantity of 0 bits since the last 1 bit is even, and by -p(t) if the quantity of 0 bits since the last 1 bit is odd.



Copyright © Dr. Mohammed Hawa

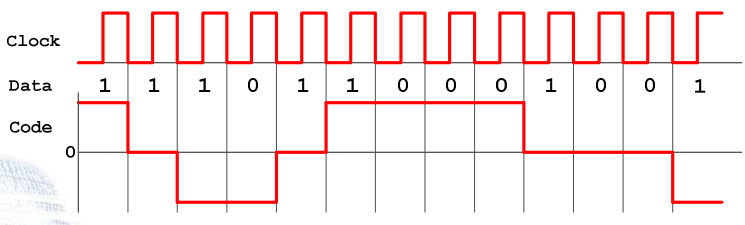
Be ware: Duobinary Pulse



Copyright © Dr. Mohammed Hawa

MLT-3

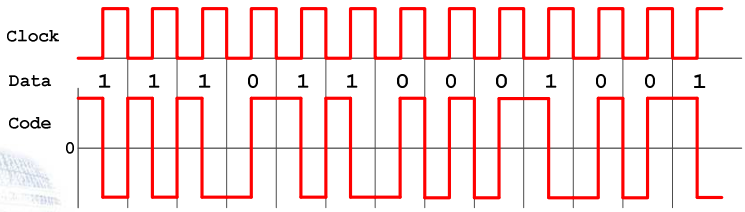
MLT-3 cycles through the states -p(t), 0, p(t), 0, -p(t), 0, p(t), 0, ... etc. It moves to the next state to transmit a **1** bit, and stays in the same state to transmit a **0** bit.



Copyright © Dr. Mohammed Hawa

Manchester

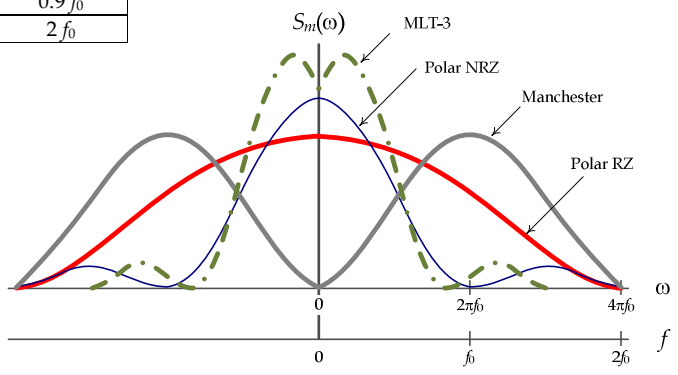
Manchester states that a logic **0** is represented by a **High-Low signal** sequence and a logic **1** is represented by a **Low-High signal** sequence.



Copyright © Dr. Mohammed Hawa

Power Spectral Density

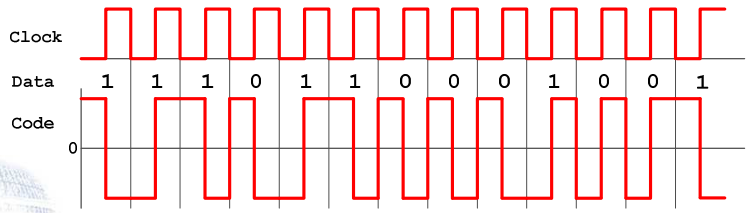
Line Code	Bandwidth
Polar NRZ	f_0
Polar RZ	$2\,f_0$
MLT-3	$0.9\,f_0$
Manchester	$2\,f_0$



Copyright © Dr. Mohammed Hawa

Differential Manchester

A **1** bit is indicated by the absence of a transition at the start of the bit-time. A **0** bit is indicated by a transition at the beginning of the bit-time.

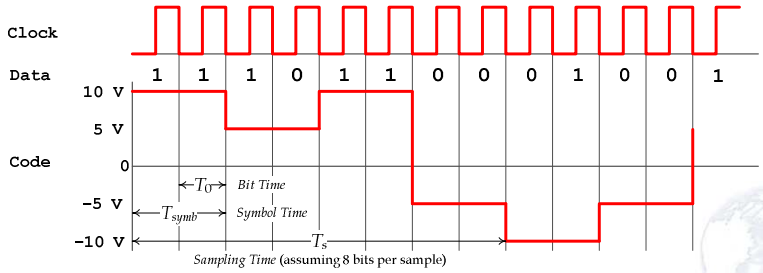


Copyright © Dr. Mohammed Hawa

M-ary Coding

Bits	Symbol
00	–5 V
01	–10 V
10	5 V
11	10 V

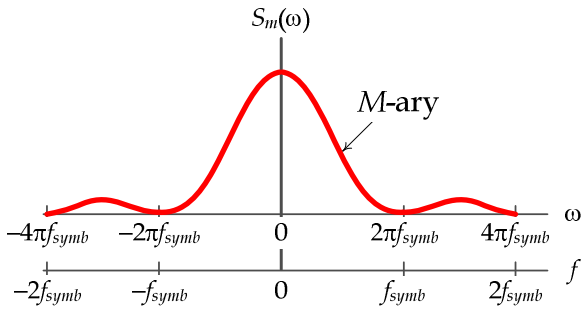
M=4 levels



Quaternary Code

Copyright © Dr. Mohammed Hawa

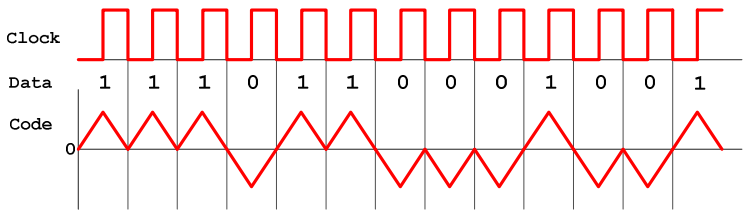
M-ary PSD and Bandwidth



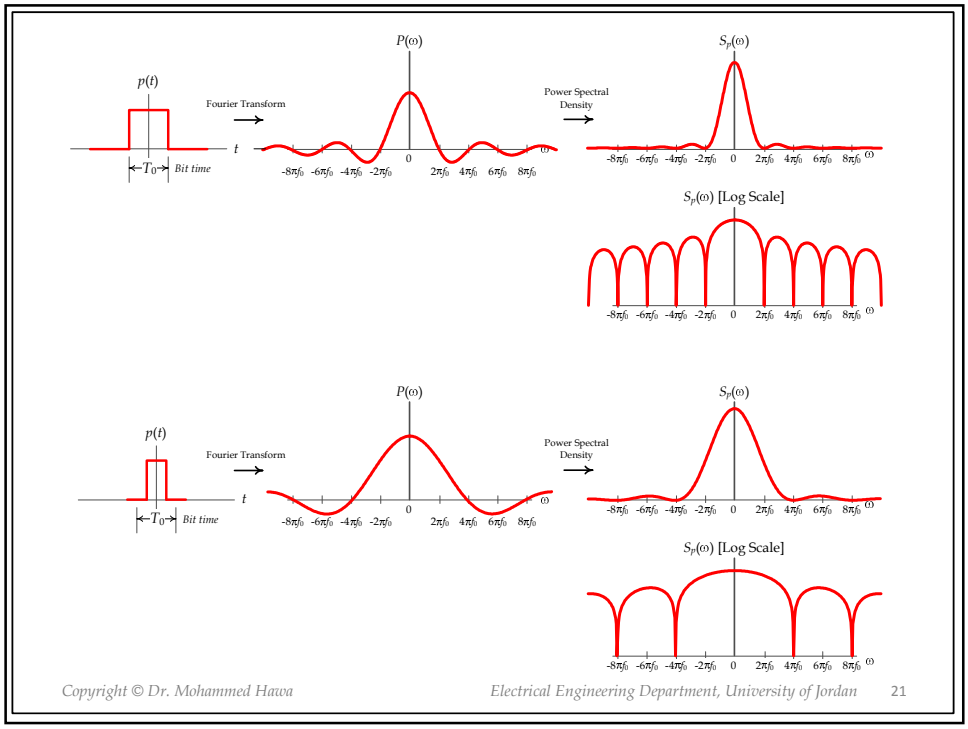
symbol rate [*in units of* baud] = $(1/\log_2(M))$ × data bit rate [*in units of* bit/s]

Copyright © Dr. Mohammed Hawa

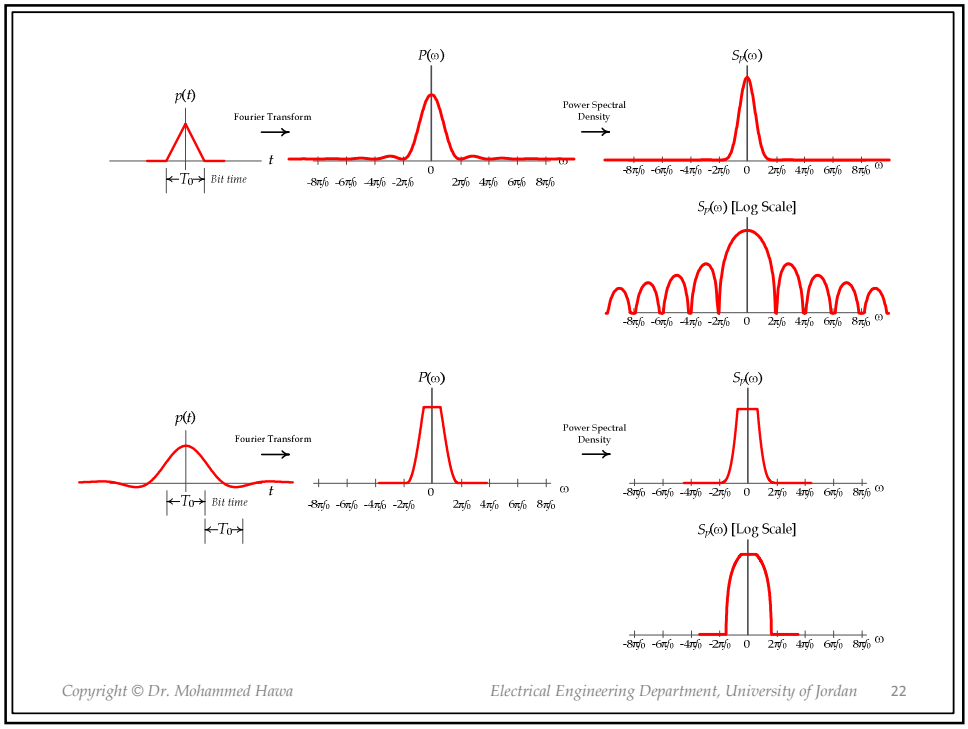
Pulse Shaping



Copyright © Dr. Mohammed Hawa

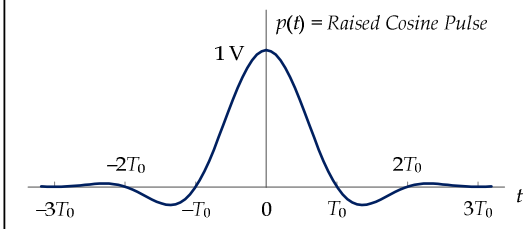


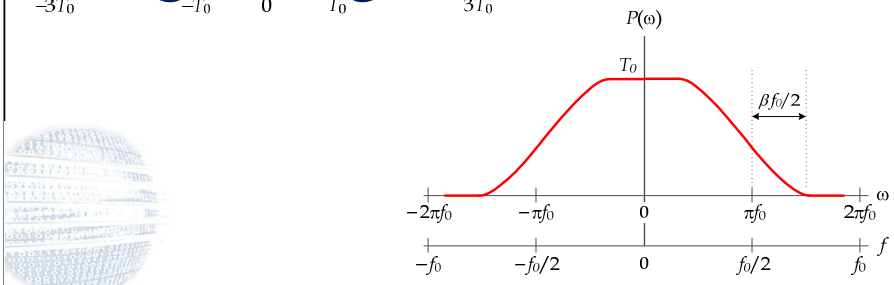
Copyright © Dr. Mohammed Hawa



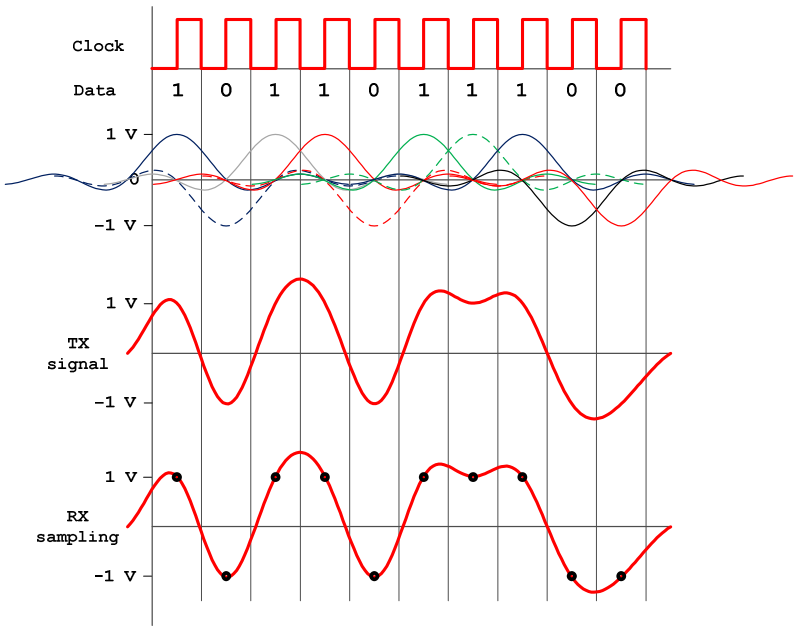
Copyright © Dr. Mohammed Hawa

Pulse Shaping: Polar *Raised-Cosine*





Copyright © Dr. Mohammed Hawa



Copyright © Dr. Mohammed Hawa