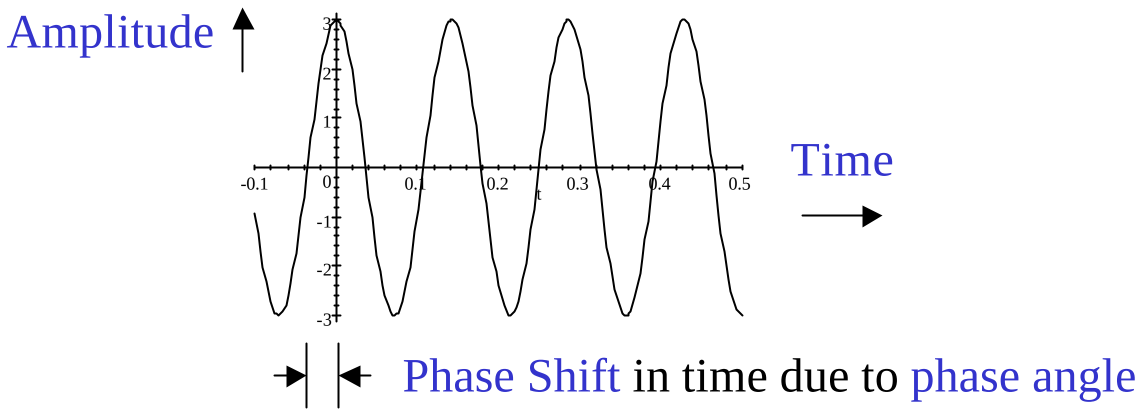
Baseband Digital Signals

- Kenneth Sherman, *Data Communications: A Users Guide*, Prentice-Hall (1981)
- J. R. Cogdell, *Foundation of Electrical Engineering*, 2nd Ed., Prentice-Hall (1990)

Sine Wave Examples

- A soprano's beautiful pure unwavering pitch
- A tuning fork
- A steady tone
- The sound of a bottle when you blow over it
- AC power

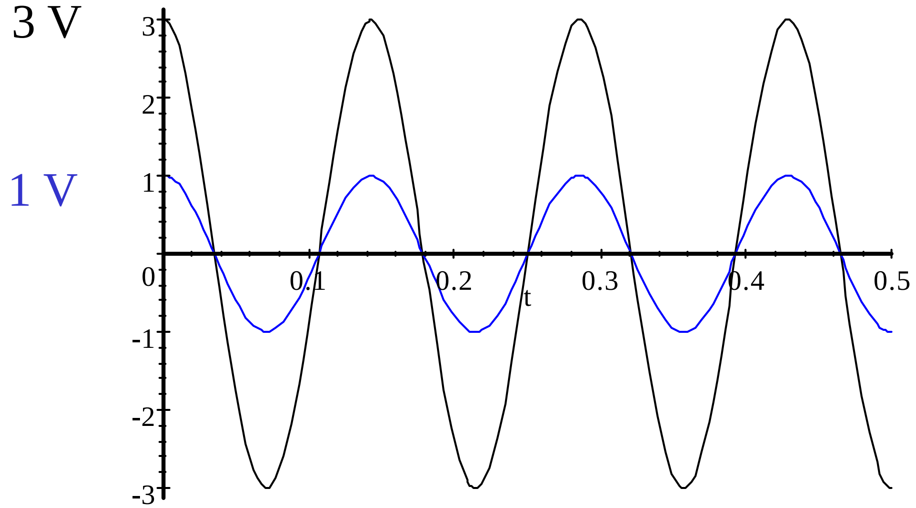
The Sine Wave



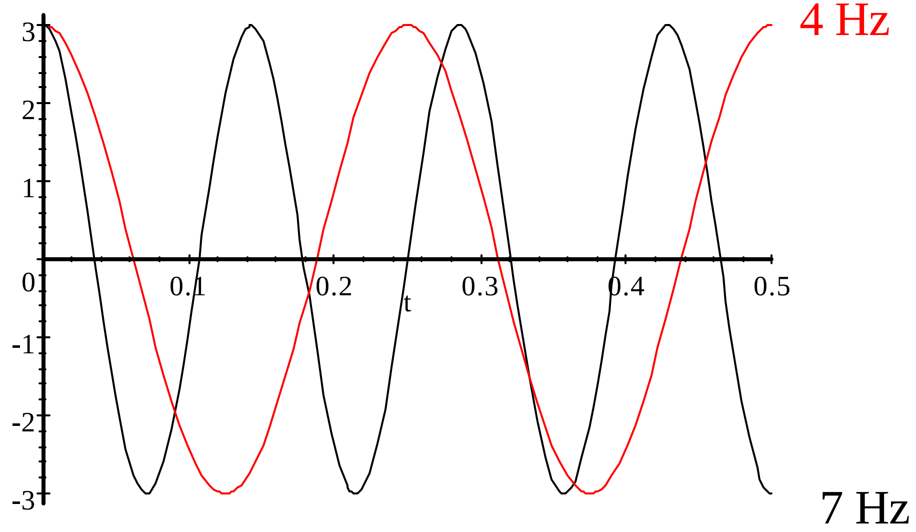
- x(t) = sin(2πf t + θ)
- t = time (seconds)
- f = frequency (Hertz)

  θ = phase angle (radians)
- sin = sine function in trigonometry

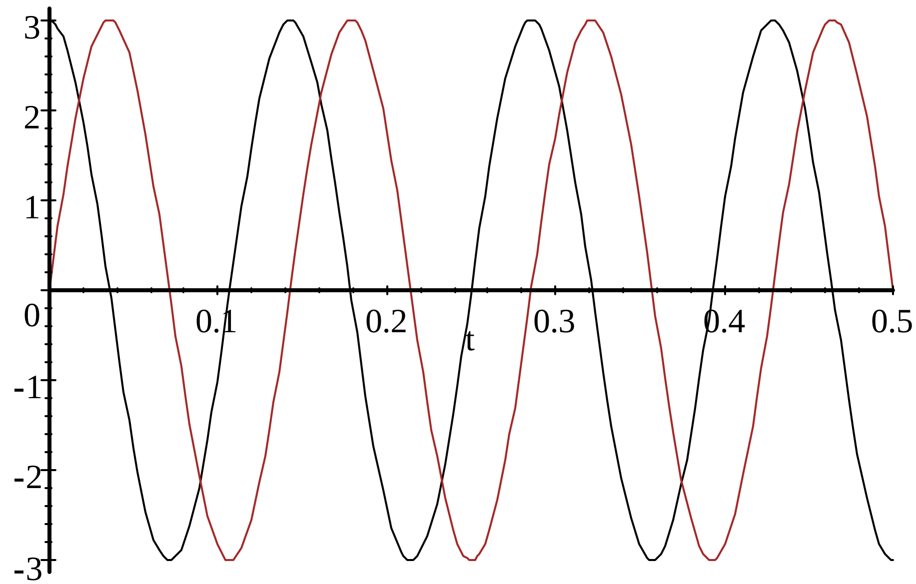
Amplitude



Frequency



Phase θ



Brown line: θ = 0 radians = 0 degrees

Black line: θ = π/2 radians = 90 degrees

Modulation

- $y(t) = x(t) * c(t)$
- $x(t)$ is the intelligence-carrying signal
  - "baseband signal"
  - "envelope" (in Amplitude Modulation: AM)
- $c(t)$ is a much higher frequency signal
  - Called the "carrier wave"
  - Selected for channel propagation characteristics
- $y(t)$ is the modulated carrier

Binary Formats

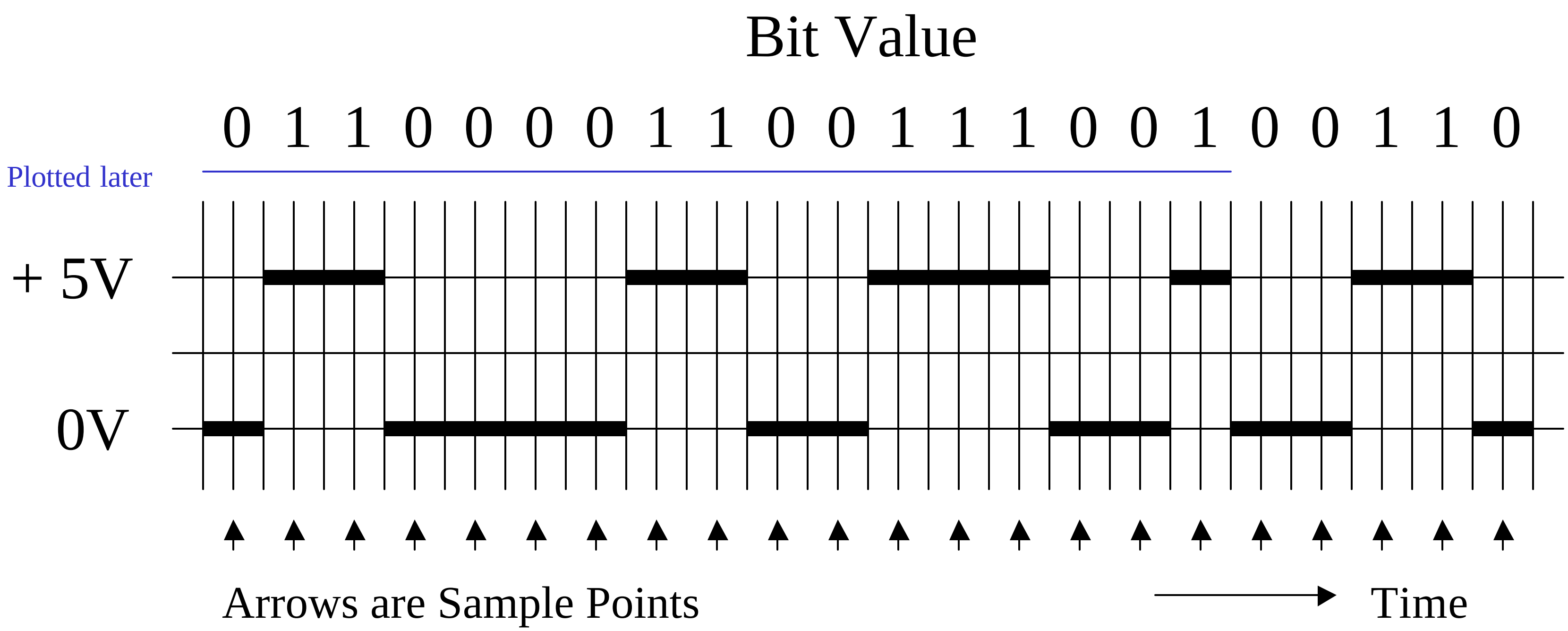
- Asynchronous
  - Binary state must be different than rest state
- Synchronous
  - Binary state or determined at predetermined time interval
  - Signal design can include encoded timing

Asynchronous Formats

- Return to Zero
  - The zero reference is the case of no signal
  - Most robust digital signal format
  - Allows for transmission channel path instability
  - Slowest transmission method

Synchronous Formats

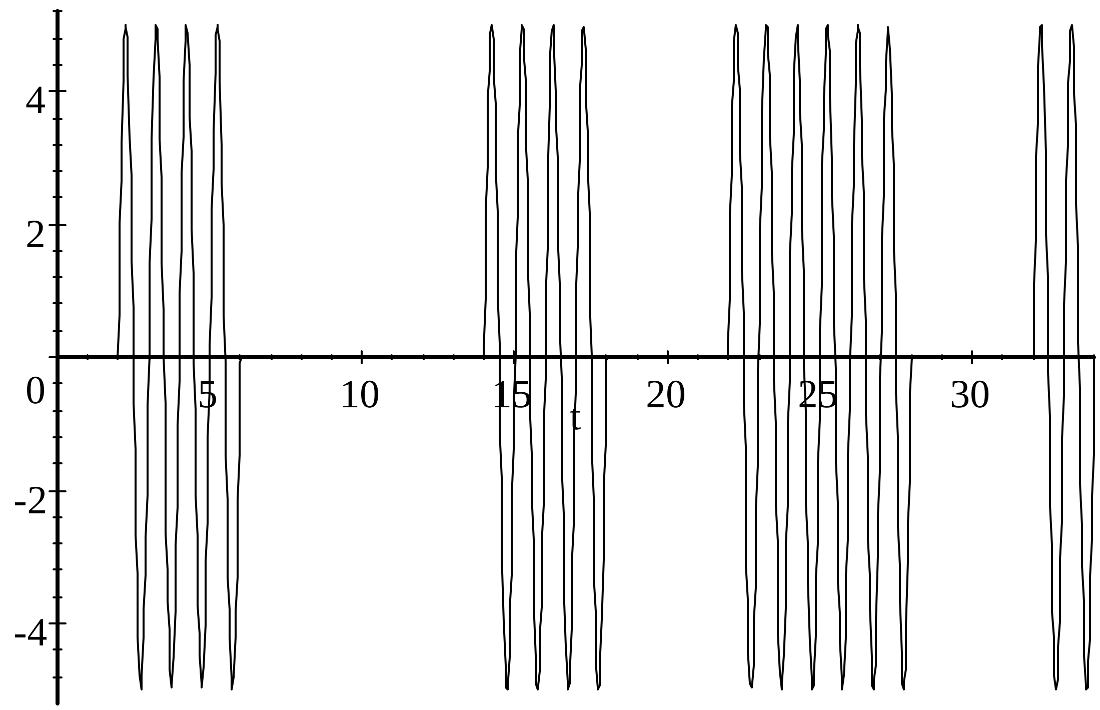
- Make/Break or Mark One/Zero Space, Unipolar Current Loop
- Polar Signals Bipolar Current Loop
- Bipolar Signal
- Non-Return to Zero Differentially Encoded



Make/Break or Mark One/Zero Space Unipolar Current Loop

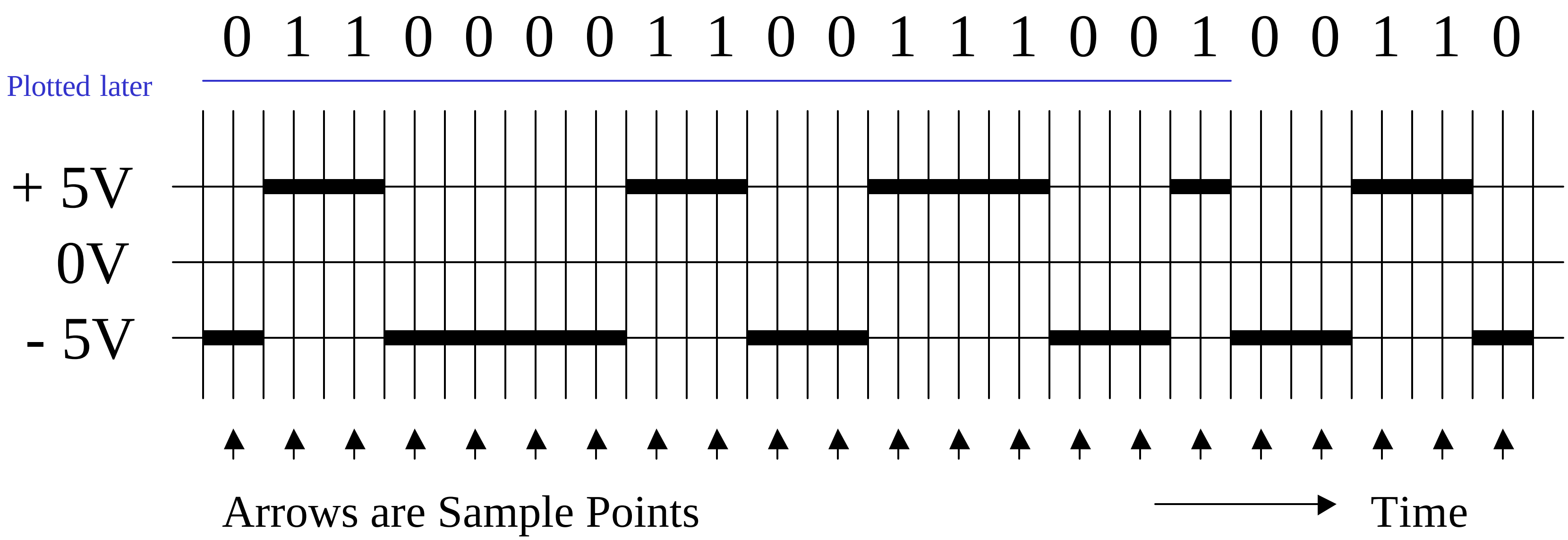
Binary zero (0) is the reference voltage (0V).

Make/Break on 1 Hz Wave



0 1 0 1 0 1 0 1

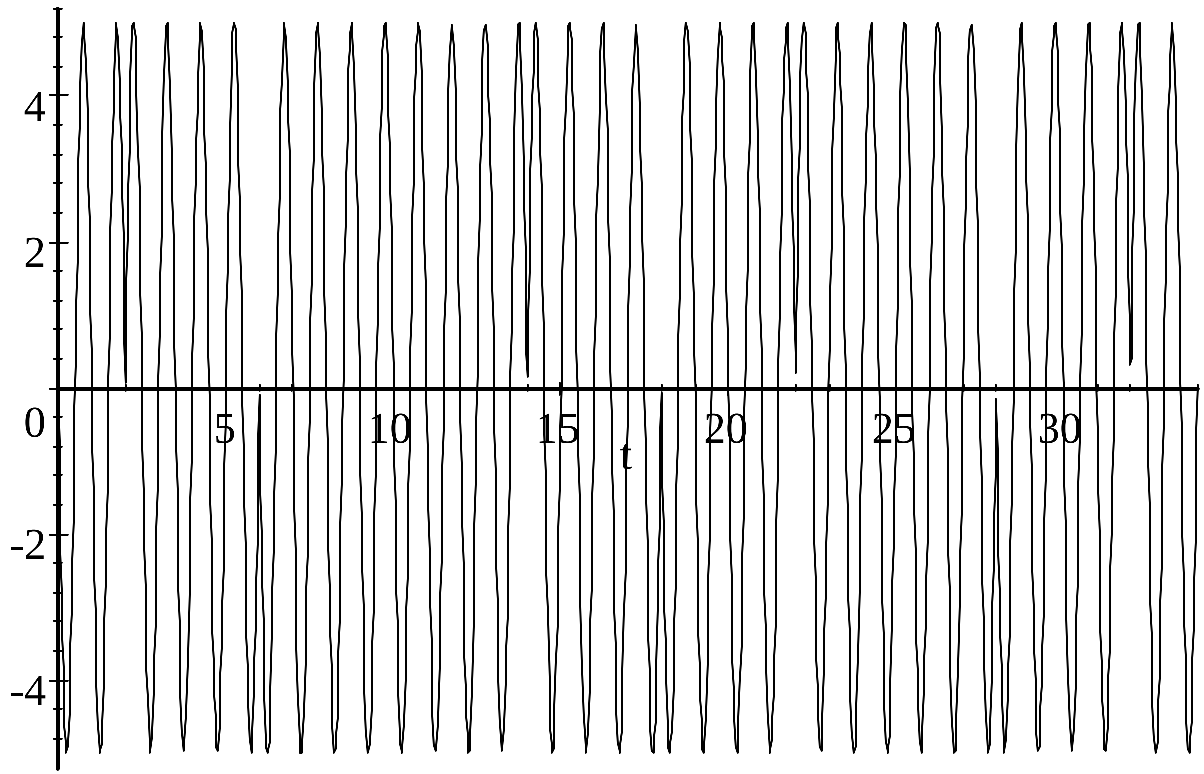
Bit Value



Polar Signals
Bipolar Current Loop

Notice that the reference voltage (0V) is between the signal levels.

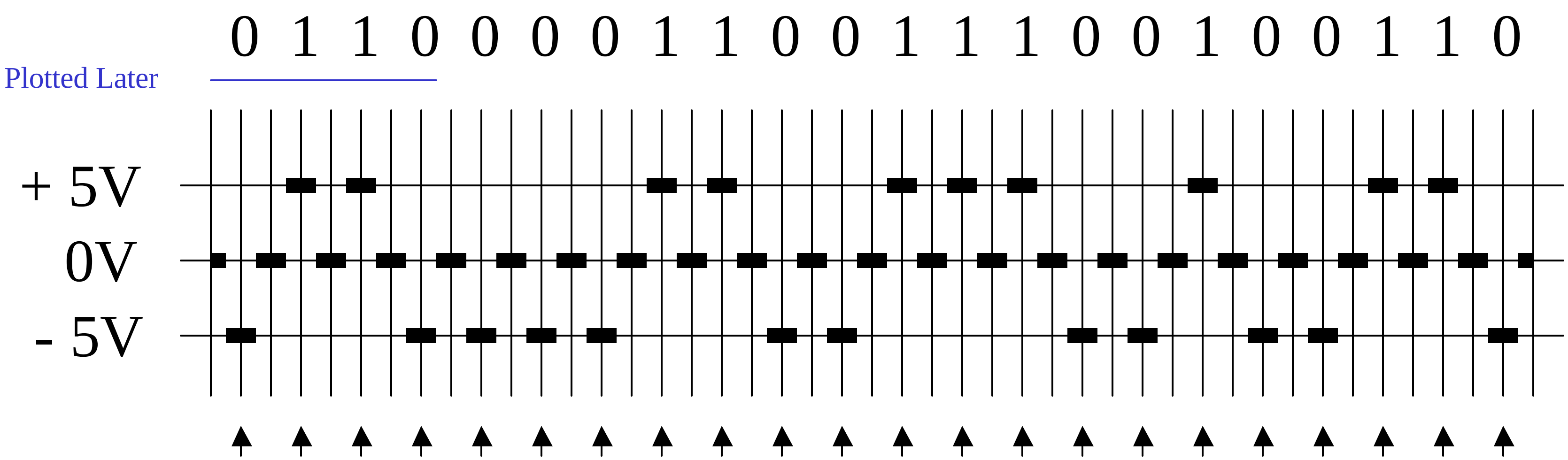
Bipolar Current Loop



0	1	0	1	0	1	0	1

The modulated signal changes phase by 180 degrees or π radians

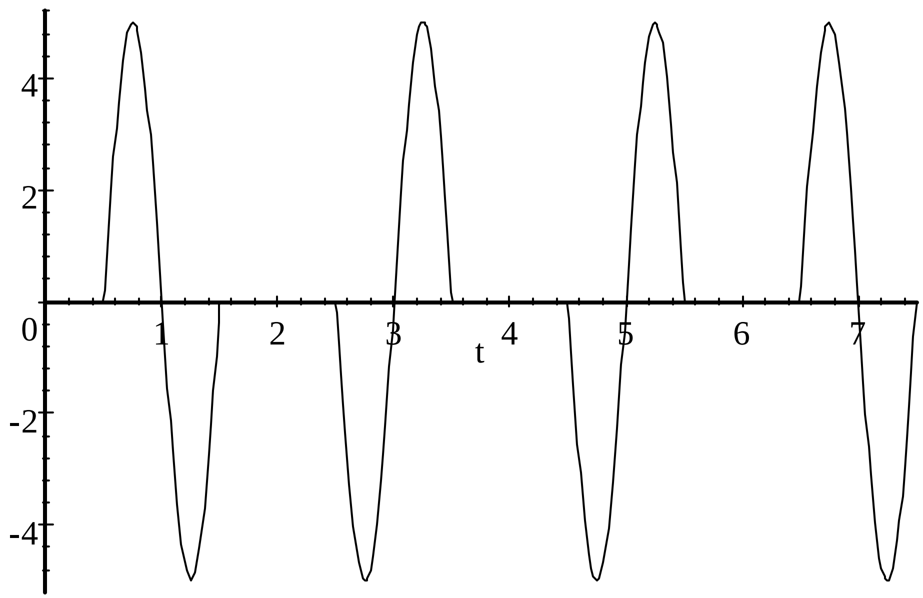
Bit Value



Return to Zero (RZ)

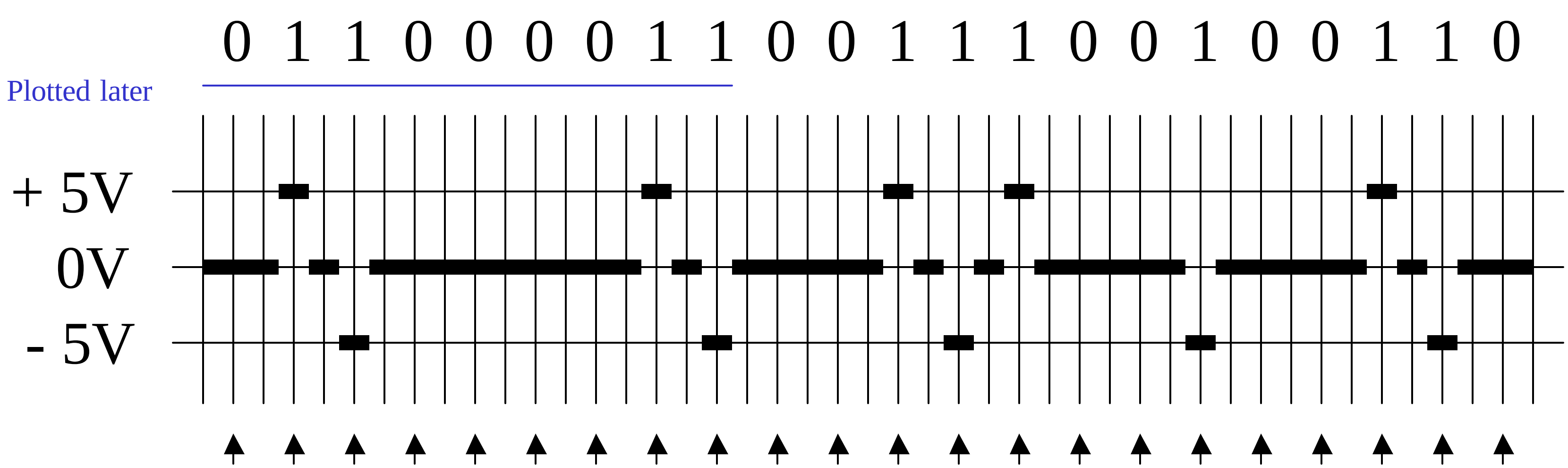
This is like a Polar Signal except that the signal always returns to the reference voltage between binary digits.

Return to Zero



0 1 1 0

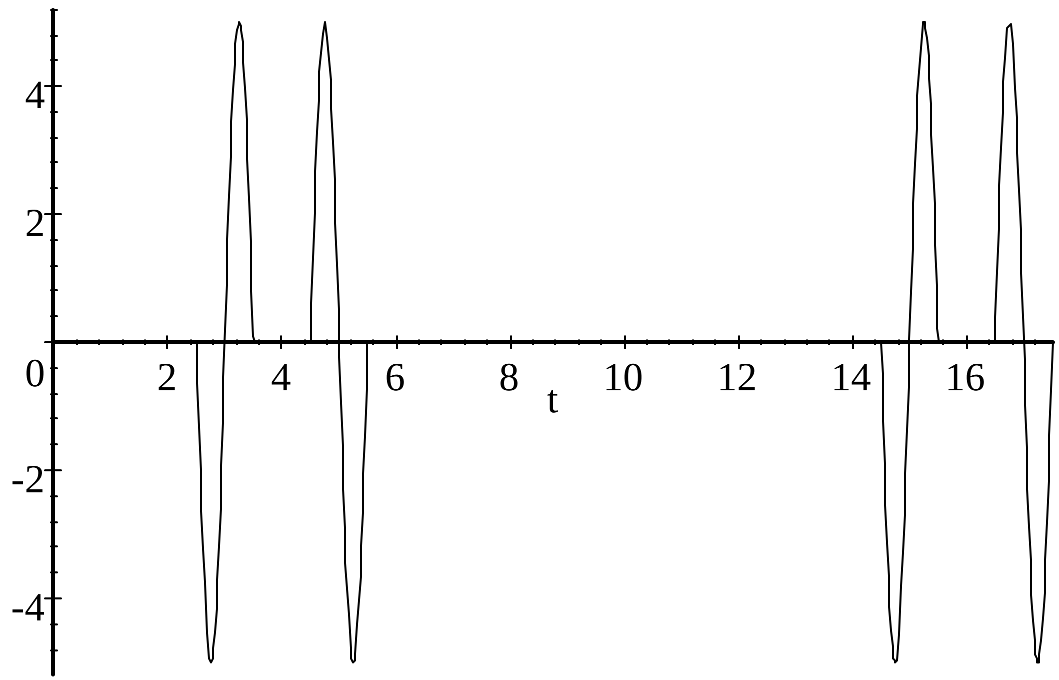
Bit Value



Bipolar Signal

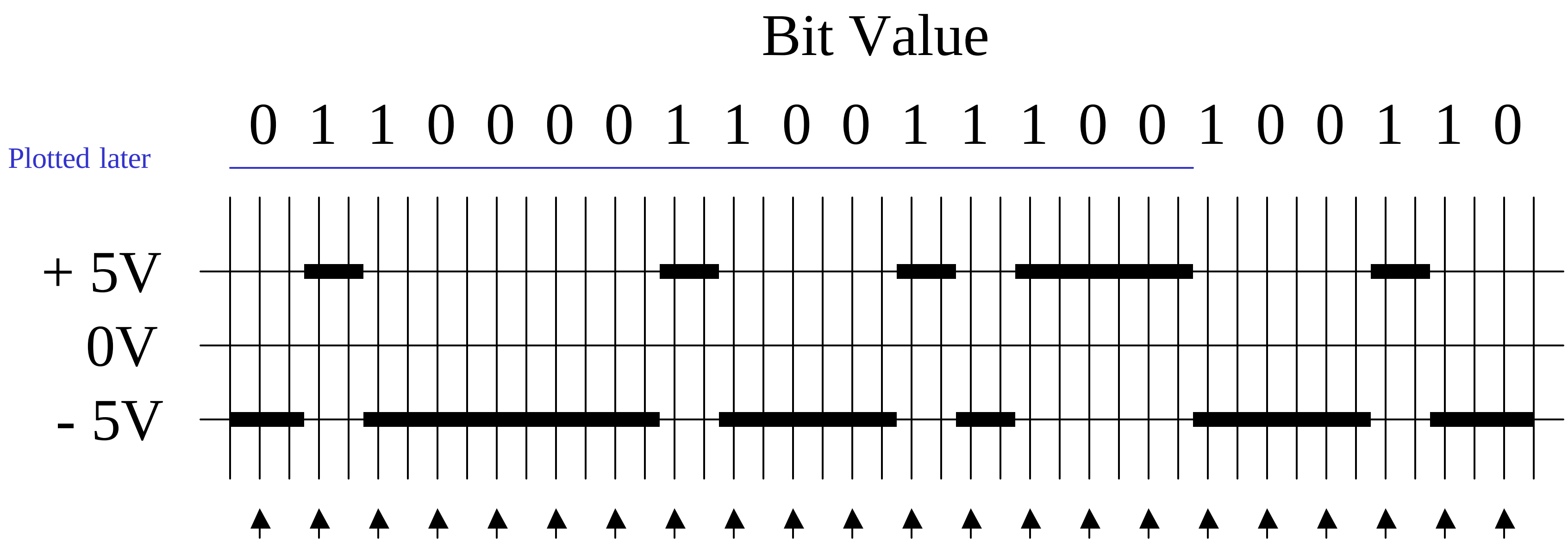
This variation on Return to Zero represents the binary digit 1 by a transition to a non-zero voltage. This reduces the overall number of voltage transitions, making higher speed transmission possible.

Bipolar Signal



0 1 1 0 0 0 0 1 1

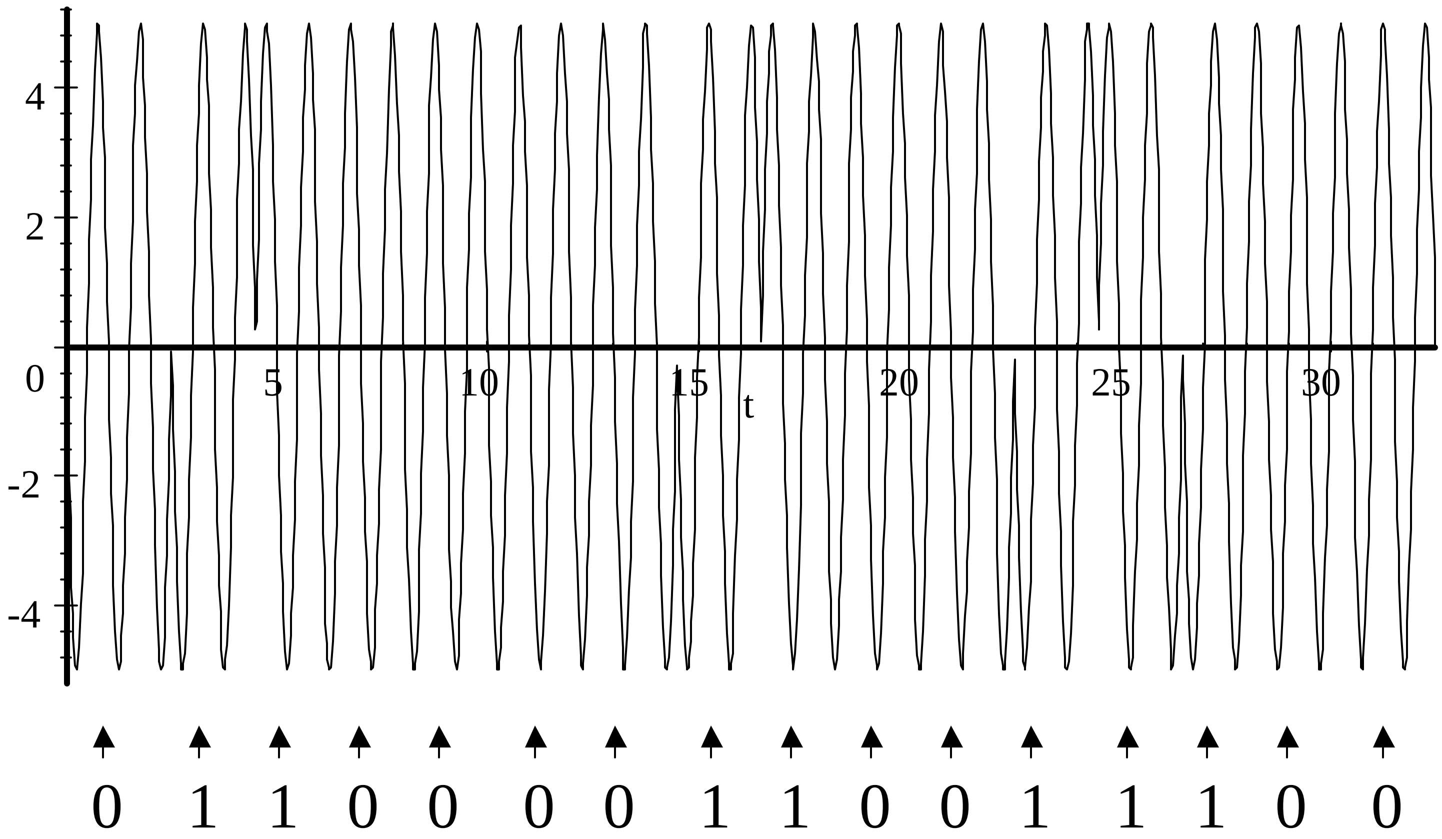
This is a variation of Return to Zero, with 0 V also representing binary 0.



Non-Return to Zero (NRZ)
Differentially Encoded

State transitions only occur for a binary digit 1. Voltage changes to the opposite voltage state, not to the reference (zero) voltage. This further reduces the number of state transitions, and makes higher transmission rates possible.

Differentially Encoded NRZ



Binary 1 corresponds to phase shifts since the last sample point.

State Change in Binary

- Ideal binary: instant changes of state
- Real binary:
  - State changes not instant
  - Gibb's Phenomena:
    - initial overshoot
    - Some possible damped oscillation about final value
  - Noise component