Terminology

The word *mark* (and its converse *space*) often appears in a description of a binary waveform. This is an historical reference to the mark and space of the telegraphist. In modern day digital terminology these have become HI and LO, or '1' and '0', as appropriate.

Unipolar Signaling: where a '1' is represented with a finite voltage V volts, and a '0' with zero voltage. This seems to be a generally agreed-to definition.

Those who treat *polar* and *bipolar* as identical define these as signaling where a

'1' is sent as +V, and '0' as -V. They append AMI when referring to three- level signals which use +V and -V alternately for a '1', and zero for '0' (an alternative name is pseudo-ternary).

You will see the above usage in the *TIMS Advanced Modules User Manual*, as well as in this text.

However, others make a distinction. Thus:

> *Polar Signaling*: where a '1' is represented with a finite voltage +V volts, and a '0' with -V volts.
>
> *Bipolar Signaling*: where a '1' is represented alternately by +V and -V, and a '0' by zero voltage.

The term 'RZ' is an abbreviation of 'return to zero'. This implies that the particular waveform will return to zero for a finite part of each data '1' (typically half the interval). The term 'NRZ' is an abbreviation for 'non-return to zero', and this waveform will not return to zero during the bit interval representing a data '1'.

The use of 'L' and 'M' would seem to be somewhat illogical (or inconsistent) with each other. For example, see how your text book justifies the use of the 'L' and the 'M' in NRZ-L and NRZ-M.

Two sinusoids are said to be antipodal if they are 180^0 out of phase.

Available Line Codes

For a TTL input signal the following output formats are available from the LINE- CODE ENCODER.

NRZ-L

Non-return to zero - level (bipolar):

This is a simple scale and level shift of the input TTL waveform.

NRZ-M

Non-return to zero - mark (bipolar):

There is a transition at the beginning of each ‘1’, and no transition for a ‘0’. The ‘M’ refers to ‘inversion on mark’. This is a differential code. The decoder will give the correct output independently of the polarity of the input.

UNI-RZ

Uni-polar - return to zero (uni-polar):

There is a half-width output pulse if the input is a ‘1’; no output if the input is a ‘0’. This waveform has a significant DC component.

BIP-RZ

Bipolar return to zero (3-level):

There is a half-width +ve output pulse if the input is a ‘1’; or a half-width -ve output pulse if the input is a ‘0’. There is a return-to- zero for the second half of each bit period.

RZ-AMI

Return to zero - alternate mark inversion (3-level):

There is a half-width output pulse if the input is a ‘1’; no output if the input is a ‘0’. This would be the same as UNI-RZ. But, in addition, there is a polarity inversion of every alternate output pulse.

Bi -L

Biphase - level (Manchester):

Bipolar ±V volts. For each input ‘1’ there is a transition from +V to -V in the middle of the bit-period. For each input ‘0’ there is a transition from -V to +V in the middle of the bit period.

DICODE-NRZ

Di-code non-return to zero (3-level):

For each transition of the input there is an output pulse, of opposite polarity from the preceding pulse. For no transition between input pulses there is no output.

The codes offered by the line-code encoder are illustrated in Figure 2 below. These have been copied from the Advanced Module User’s Manual, where more detail is provided.

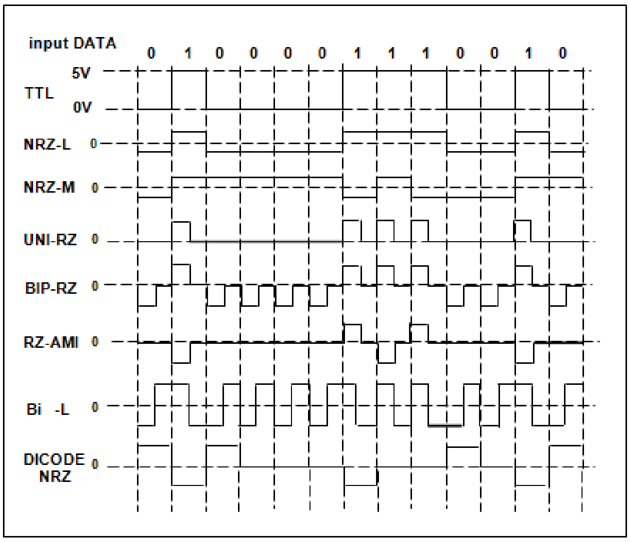

Figure 2: TIMS line codes

The output waveforms, apart from being encoded, have all had their amplitudes adjusted to suit a TIMS analog channel (not explicitly shown in Figure 2).

When connected to the input of the LINE-CODE DECODER these waveforms are de-coded back to the original TTL sequence.

Band Limiting

No matter what the line code in use, it is not uncommon to band limit these waveforms before they are sent to line, or used to modulate a carrier.

As soon as band limiting is invoked individual pulses will spread out (in the time domain) and interfere with adjacent pulses. This raises the issue if inter-symbol interference (ISI).

A study of ISI is outside the intended scope of this text, but it cannot be ignored in practice. Band limiting (by pulse shaping) can be effected and ISI controlled by appropriate filter design.

An alternative approach, duobinary encoding, was invented by Lender 1.

Duobinary Encoding

A duobinary encoder (and decoder) is included in the line code modules.

Duobinary encoding is also called correlative coding, or partial response signaling.

The precoded duobinary encoding model implemented in the LINE-CODE ENCODER module is described in the *TIMS Advanced Modules User Manual*.

[1] Lender, A. "The Duobinary Technique for High Speed Data Transmission", IEEE Trans. Comm. Electron, vol 82, pp. 214-218, May 1963