

# Manchester-NRZ Decoder, Documentation for Beta Testers

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# 1. Introduction

The Manchester-NRZ Decoder developed by Lahniss for LeCroy oscilloscopes is a tool aimed at decoding serial data that is not supported by main stream decoders, and whose structure is reasonably simple to be described with the 10-20 controls explained below. It was born out of recurring customers request for decoding fairly simple serial data, not belonging to the historical protocols such as I2C, UART and SPI, or the dedicated protocols such as CAN, LIN, MIL-1553, ARINC 429, MIPI, Ethernet, etc.... The diagram below exemplifies the situation.

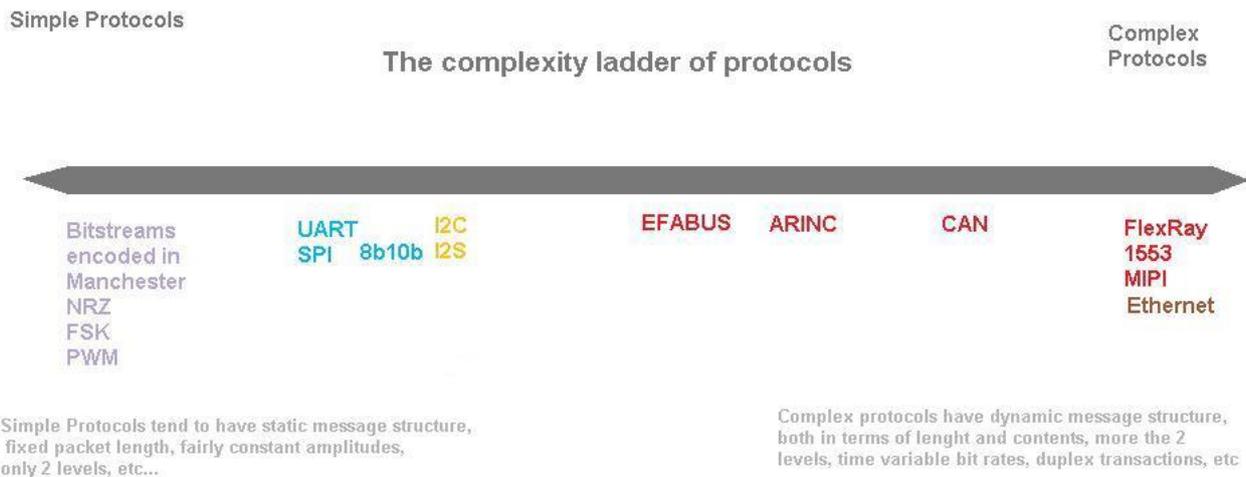


Figure 1: Complexity ladder of protocols

In that spirit, the user is required to configure a number of controls, making it possible for the general algorithms to execute on his particular signal. This process requires a little more knowledge of serial data encoding logic than previous decoders, but the explanations below should shed some light on the procedure. Once the settings have been determined for a given signal, they can be stored in normal panel files and recalled later, when analysis on the same signal are required. In its current form, the configurable Decoder operates on NRZ or Manchester streams.

- The product **will handle** digitally encoded data on a **single signal**, with **2 levels (High and Low)**, a **constant Bitrate** between 10 bit/sec to 60 Gb/sec at **any voltage levels** and a timeout(or Inter Frame Gap) allowing to separate bursts of data on the line.
- The product **will not handle** multi line signals, signals with more than 2 voltage levels, stuff bits and or complex synchronization pulses.

This product, whilst flexible, is **not suitable for complex protocol** streams such as i.e. CAN, CAN FD, MIL-STD-1553, FlexRay, MIPI or 2 or 3 signal transmissions such as I2C or SPI. For these protocols, the dedicated decoders are available.

So this software component is more of a **toolbox** aimed at supporting many different streams that have some basic characteristics in common, and a limited market that does not justify a dedicated decoder.

## 2. Fundamental mental model

Before we get started, we need to **emphasize the methodology** underlying the software described here. The fundamental model is a 3 step model. The signal needs to be decoded as:

- Burst(s) first with their constitutive **Transitions**, based on the Bitrate and the Timeout Definition. Bursts are separated by “Holes” or electrically speaking quiescent times on the transmission line.
- Then each Burst needs to be sliced into **Bits** using the **Transitions**, the Bitrate and Polarity and the Type either NRZ or Manchester.
- Finally the Bursts of **Bits** can be converted to **Words** using the **Bits** previously extracted, and based on grouping rules

The **Bit** conversion will not be functional before the Bursts are correctly separated with their **Transitions**, and the **Words** extraction will not function correctly until the **Bits** are properly decoded. The process is a 3 level stepwise method.

The tuning of the Decoder must therefore be conducted in this order:

**Transitions** → **Bits** → **Words**.

The following material will guide the operator through every step of the process, beginning at the **Transitions** level and ending at the **Words** level.

### 3. Getting started

In order to get started with the Manchester-NRZ Decoder, it is advisable to adjust the scope controls to acquire one Burst or Frame of relevant Data, and then **stop the acquisition**. The data Burst should be reasonably well centered on screen, in both directions, with generous idle segments on both sides.

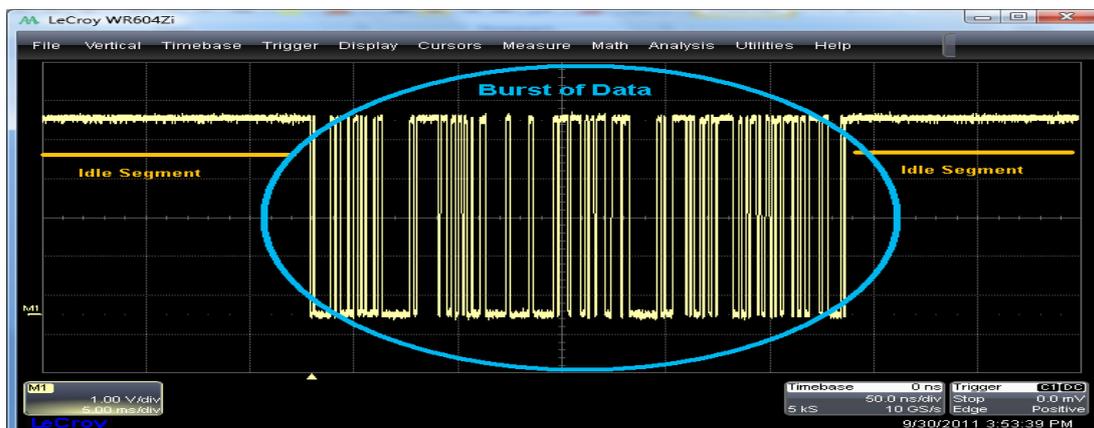


Figure 2: A Burst of Raw Data

Once the Burst of Data to be decoded is acquired, we will proceed to its interpretation using either the Manchester or the NRZ Decoder. We will proceed gradually; starting with the identification of the Burst controls, then extract the Bits and finally the Words, by grouping the Words. The words “Burst, “Frames” or “Packets” are used in interchangeable manner in this document, and in general literature.

Later we will address the decoding of many Packets into the same record, therefore allowing the observation of the encoded data values over a period of time. The decoder settings determined on a few packets will be reused when handling many packets.

In order to start the decoding we need to be familiarized with the User Interface of the Decoder.

Firstly, in the Serial Decode dialog, you need to select the signal source (here C1), and the Protocol, “Manchester” in this case.

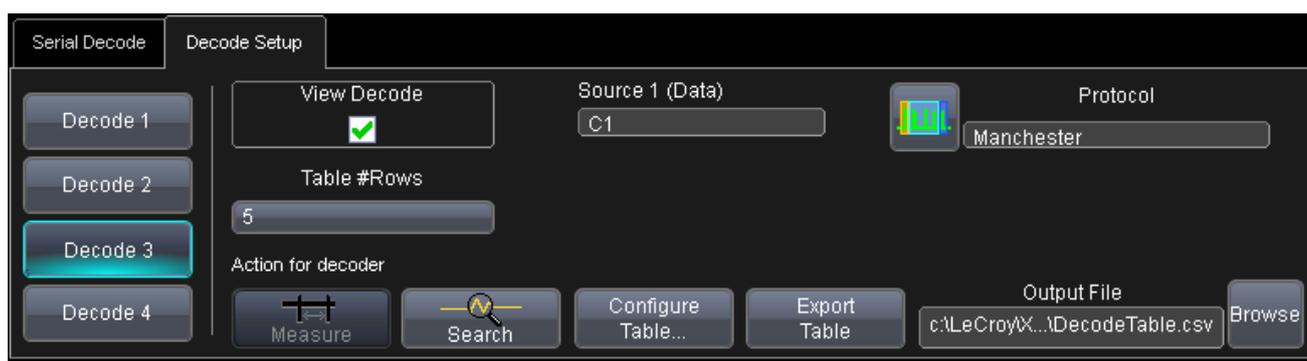


Figure 3: The Signal Source and Protocol Selection Dialog

Once the “Manchester” or “NRZ” Protocol has been selected 3 tabs will appear in the Right Hand Side Dialog. We will be setting various values in these 3 tabs (Basic, Decode, Level). When working on a given signal, some of the values in the tabs will not change anymore because they are strongly linked to the signal (i.e. Bit Rate or Polarity). Other values will have to be tuned to obtain optimal results. Some of the controls can be used to reverse engineer unknown signals



Figure 4: The 3 tabs (Basic, Decode, Levels) driving Manchester and NRZ decode.

The “Use Timeout” selection allows decoding of continuous streams when unchecked.

## 4. The Basic Tab, Bit Level Decoding

The Basic tab presents all the fundamental controls necessary to allow proper bit level decoding. We will look at each control individually.



Figure 5: The Basic Tab

### Bit Rate



Introduce the Bit Rate of your signal here, as precisely as you know it. Hardware engineers working on a design often know the Bit Rate. If you are not sure about the value, use the cursor read outs, on one single bit or a sequence of bits to determine the exact Bit Rate of your signal. The value should be correct within about 5%. Note that a mismatched Bit Rate will cause various confusing side effects on the decoding, so it is best to take time to correctly adjust this fundamental value. Bit Rates can be selected from 10 bits/s to 10 Gb/s.

### Idle State



The idle State complements the Timeout value set previously. In order to declare that a new Burst has to be started, the algorithm looks at the time elapsed between 2 consecutive Transitions, as well as the state of the idle level between these transitions. This mechanism allows a precise definition of what the separation gap between 2 Bursts should be. In most cases, the idle state is specified, and therefore provides an additional condition to the timeout to define the Burst start. If this distinction is not desired, select “Don’t care” in the popup box.

### Encoding



The encoding control (Manchester only) allows the selection of several Manchester flavors. When Standard is selected the Polarity control is visible, when any other encoding is chosen, the Polarity disappears. The differences will be explained below, with examples.

## Timeout Units



The Timeout, or Gap, separating Burst can be selected either in Bits or Seconds. Both methods are perfectly equivalent in terms of their results, but depending on the context, the protocol specifications or the user preference, one or the other representations might be chosen. Note that regardless of the Timeout Units selected, the allowed Timeout range will be from 1 bit to 100 bits.

## Timeout in Bits

When a Timeout in bits is selected, as in our example above, the system will use the Bit Rate to determine the Bit Length, and multiply it by the number of bits selected to obtain a Timeout in seconds.

## Timeout in Seconds

As an alternative to the Timeout in Bits, the value can be expressed directly in seconds. This is useful in protocols with a timeout spec expressed in time units. The following image provides an example of the controls and their effect on the annotation.

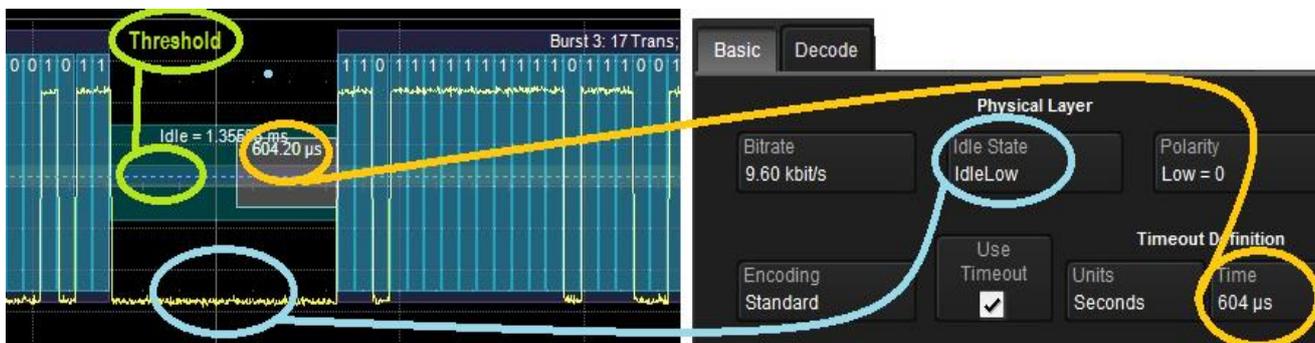
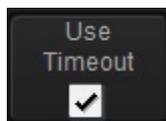


Figure 6: Example of a Timeout Definition (Use Timeout assumed)

In the Figure above, a Timeout of 604 micro-seconds has been selected. The grey rectangle on the trace shows this timeout, as well as the value selected by the user, rounded to the next bit time. Note that the value of 604 us is adequate to separate the 2 Bursts of transmission. Furthermore, this protocol requires the timeout span to be “Idle low” which is set in the “Idle State” control. “Idle low” refers to the Threshold level marked as a blue dotted line. Note that the idle state is only used by the algorithm for the packet separation mechanism. The polarity control is used by the bit level decoder. The “Idle State” and the “Polarity” are independent controls.



## Use Timeout

When this control is unchecked, the stream will no longer be packetized. This is useful on high speed protocols, which usually have continuous bit streaming. The following images exemplify the behavior of the bit level slicer.

**Note:** This example is not using a continuous bit-stream in order to demonstrate the behavior, however it is not very realistic in the sense that not using a timeout is primarily useful on continuous protocols, but it allows the comparison.

The opposite proof of behavior is not possible since on a streaming signal(no packets), a timeout will never occur, and hence no decoding either.

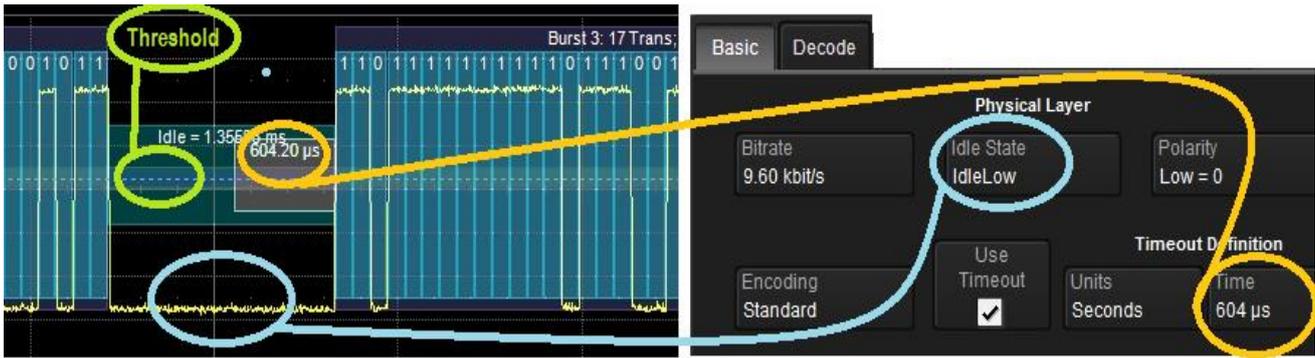


Figure 7: Bit level slicing with Timeout used on a packetized protocol

As visible in the image the timeout mechanism fragments the signal into distinct packets, which will then be decoded individually on separate lines of the decode table.

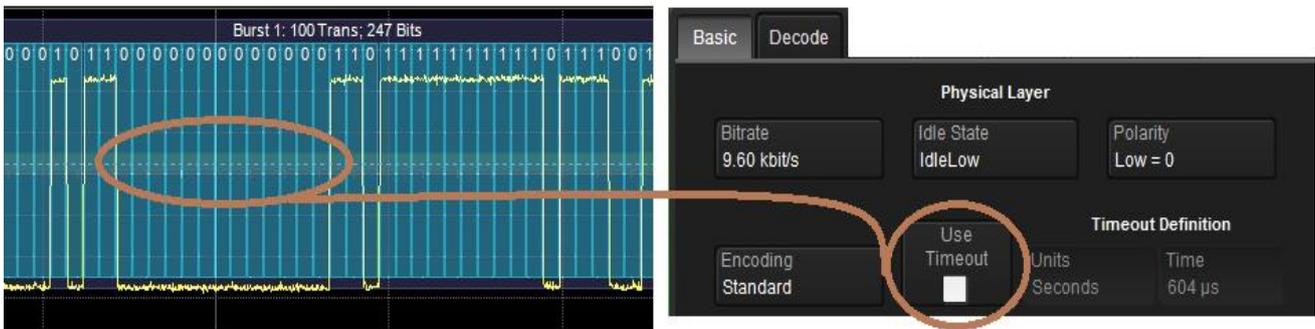


Figure 8: Bit level slicing without Timeout used on the same signal as previous image

As opposed to the previous image, the idle time between the packets is also sliced into bits, and the timeout values are greyed out, meaning they are ignored.

## Polarity (Manchester Standard and NRZ)



The Manchester “Polarity” governs the conversion of the physical signal transition into a logical bit state. In Manchester When Falling=0 is chosen, a falling edge through the threshold level, will be decoded as a logical Zero, whereas a rising edge through the threshold level, will be decoded as a logical One.



The NRZ “Polarity” governs the conversion of the physical signal transition into a logical bit state. When Low=0 is chosen, a low level signal state (below threshold) will translate as a logical zero whereas a high level (above threshold) signal will translate as a logical 1. The opposite logic will apply when Low=1 is selected.

The image below shows a Manchester example



Figure 9: Manchester Physical to Logical mapping, case Falling = 0

When Falling=1, the opposite logic will be applied, leading to the following image of the low level decode annotation:

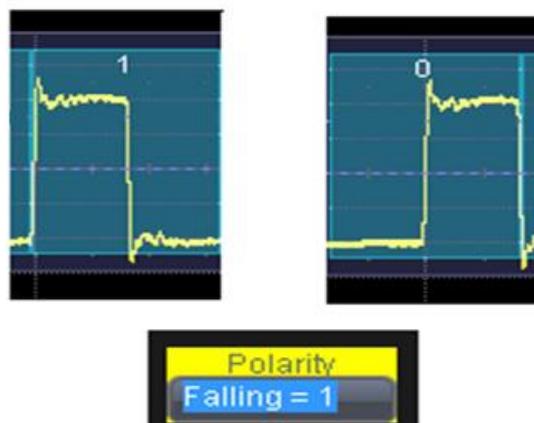


Figure 10: Manchester Physical to Logical mapping, case Falling = 1

## The different Manchester Encoding Types

There exists a great variety of Manchester encoding. The current implementation supports the 4 versions, documented on this page. A stream of about 40 bits is shown in every case, and allows the association of the physical signal with the logical signal according to the encoding at hand.

Manchester Standard, Falling = 0

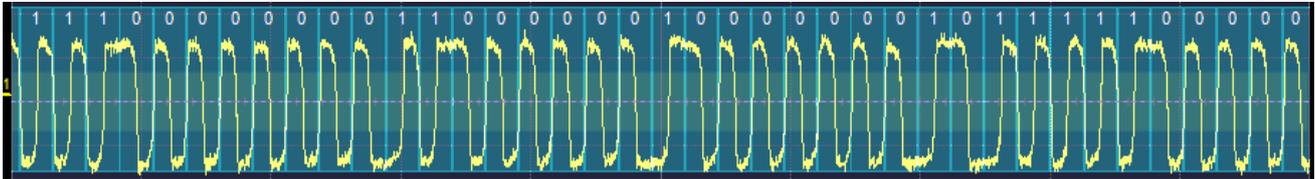


Figure 11: Manchester Standard, Falling=0, Rising=1

Manchester Standard, Falling = 1

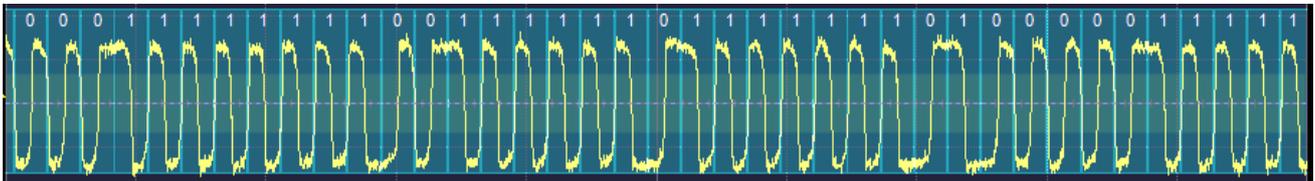


Figure 12: Manchester Standard, Falling=1, Rising=0

Differential Bi-Phase Mark

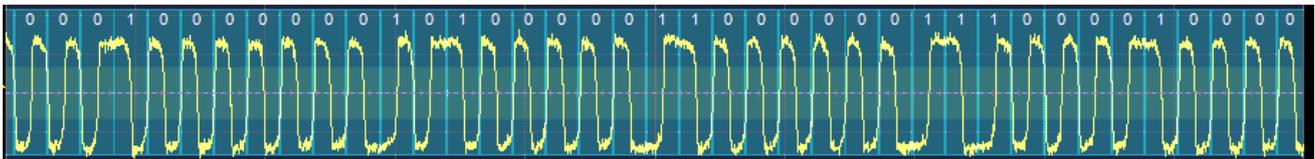


Figure 13: Differential Bi-Phase Mark, always Midbit change, "1" no change at bit start and "0" changes

Differential Bi-Phase Space

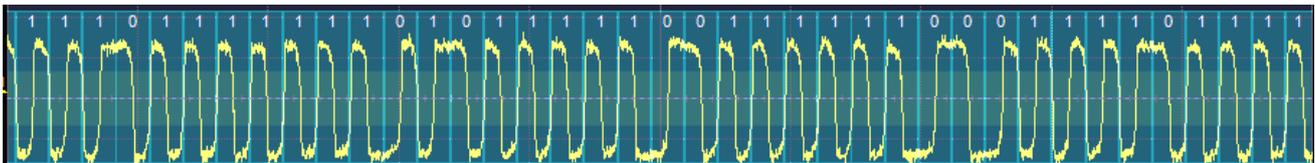


Figure 14: Differential Bi-Phase Space, always Midbit change, "0" no change at bit start and "1" changes



## 5. The Decode Tab

The bit level decode reached in the previous section can be taken further, so that some transitions are skipped, and subsequent bits are grouped into words, and the words interpreted lsb first or msb first.

We will not explain the classical encoding schemes here but refer to selected Internet contributions i.e. as in:

<http://ckp.made-it.com/encodingschemes.html>  
<http://www.rhysshaden.com/encoding.htm>

The following image shows the decode tab, when Data Mode is “Bits”. In this Mode, most of the controls are grayed out indicating that they have no action. As soon as we select “Data Mode” as Words, the grayed out fields will become active.



Figure 19: Decode Tab in Bit Mode

### The Data Mode

This control drives the level of decoding desired. Initially make sure you select “Bits”. “Bits” is also the default value when starting the decoder.

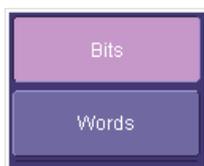


Figure 20: The Table Mode selection popup

### Decoding into Bits

We have already looked at the low level decoding in bits in the previous section. There are a few more items to look at as part of the Bit Level decoding. Then we will address the Word level decoding.

#### First Transition Used (FTO)

Many Manchester or NRZ encoding schemes utilize a preamble, a synchronization sequence, or a voluntary Manchester violation. The FTO can be used to start the decoding after the violation, where the real data payload starts. It avoids the intricacies of dedicated protocols in the initial segment of each packet.

#### Bit Stretch Tolerance

The Manchester bit slicer hops from midbit to midbit. However, due to hardware or signal propagation issues, the midbits might not be perfectly equidistant. In this case the tolerance can be manually increased to attempt to decode jittery signals. Conversely, it can be decreased until the decoding starts showing anomalies, to assess the stability of the midbit distribution.

### Interpretation of the Manchester bits, tuning of Bit Slicer.

When decoding a serial stream as a Manchester, it is normally expected to see Ones and Zeroes as explained above. It is however possible that 2's and 3's appear in the decoded stream. These values correspond to violations for the Manchester rules, stating there must be a transition at midbit.

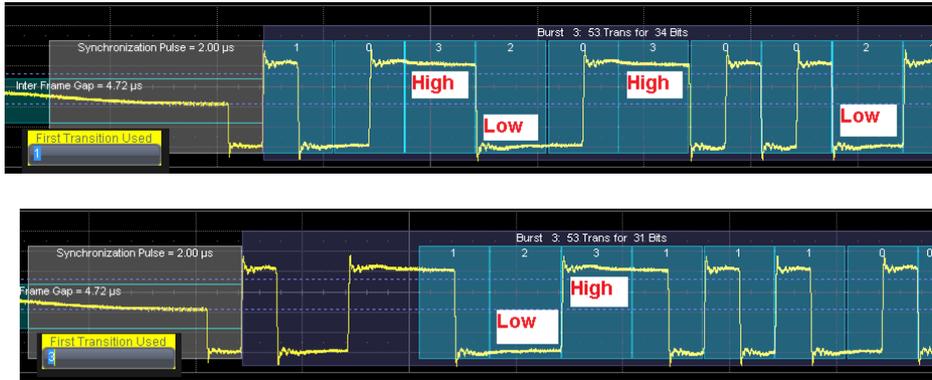


Figure 21: Examples of Interaction between FTO and decoding

These violations can be voluntary, as in the MVB (Multiple Vehicle Bus) example above. They often correspond to synchronization patterns used by the hardware to start the decoding. In other cases the Highs and Lows carry information and allow the detection of different Frame types. There is a nearly endless set of combinations used in various protocols. The initial part of the Manchester packet is called different names in different protocols: Preamble, Start Of Frame, Packet Header, Packet Start, etc.

In order to obtain a correct decoded stream, the user needs to set the FTO in a way that the bits are correctly synchronized throughout the packet. Usually this can be achieved by setting the Bitrate first as in the previous section. Then The Transition Tolerance might have to be enlarged from its default of 20% (see above). When the signal is stable it might be decreased to less than 5 % without changing the output of the Decoder observed in the table. In the example below, the many 2s and 3s in the Data indicate an incorrect phasing of the bit decoder with the signal. More tuning is required before the Word Level can be used.

| MAN | Time     | Sync   | Data                                       | NonData | IFG     | Status                        |
|-----|----------|--------|--|---------|---------|-------------------------------|
| 1   | 4 ns     | 2.0 µs | 1 2 3 1 1 1 0 0 0 0 1 1 1 1 1 1 0 0 1 0... |         | 29.2 µs | Burst 1: 53 Trans for 31 Bits |
| 2   | 25.8 µs  | 2.0 µs | 1 1 3 1 2 3 1 0 2 3 2 1 3 2 1 3 0 0 0 0... |         | 3.5 µs  | Burst 2: 51 Trans for 33 Bits |
| 3   | 52.8 µs  | 2.0 µs | 1 2 3 1 1 1 0 0 0 0 1 1 1 1 1 1 0 0 1 0... |         | 4.7 µs  | Burst 3: 53 Trans for 31 Bits |
| 4   | 78.6 µs  | 2.0 µs | 1 1 3 1 2 3 1 0 2 3 2 1 3 2 1 3 0 0 0 0... |         | 3.5 µs  | Burst 4: 51 Trans for 33 Bits |
| 5   | 105.7 µs | 2.0 µs | 1 2 3 1 1 1 0 1 1 0 1 1 1 0 1 1 1 0 1 1... |         | 4.7 µs  | Burst 5: 50 Trans for 31 Bits |

Figure 22: Table view, with too many 2s and 3s in Data

Note that the Word decoder will silently process bits with values of 2 and 3, but the results will be incorrect.

### Decoding into Words

We have now achieved a correct bit level decoding, and we can look at higher level concepts.

#### Converting Burst Bits into Words

This is achieved by selecting the Data Mode “Words”. When this mode is selected, all of the fields become accessible. Unlike decoding into bits, the conglomeration of bits into words does no longer depend upon the physical layer. In other words, the bits can be grouped to form words, regardless of their origin (NRZ, Manchester or else). As a consequence the mechanisms described below apply to both the NRZ and the Manchester Decoders.

The tools offered by the Decoders allow a grouping of bits into PrePad, Data Bits, and PostPad. The next image shows an example, with the corresponding annotations.

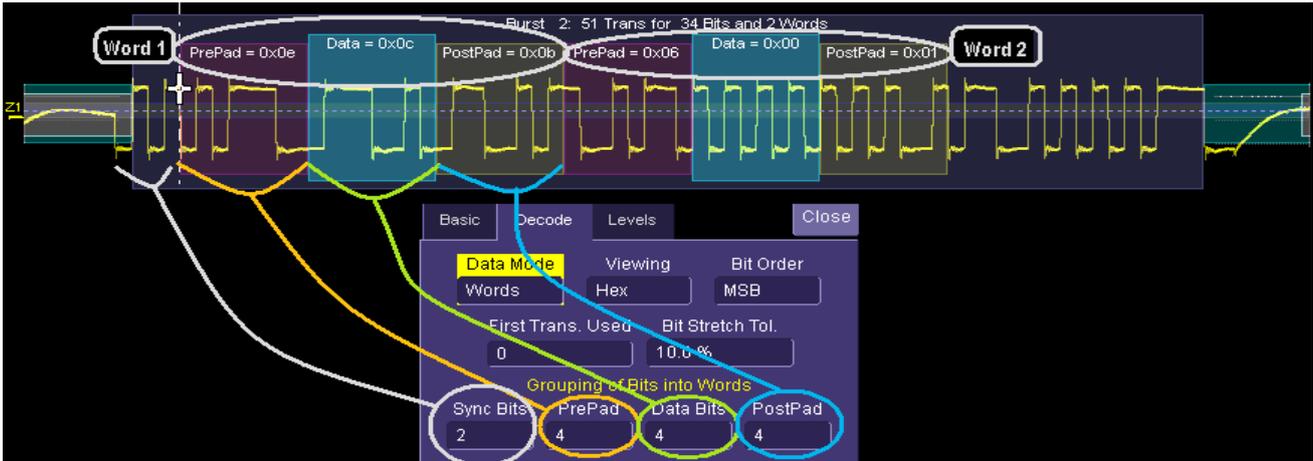


Figure 23: Decoding a Burst into 2 Words, Decode Tab in Word Mode (no Nx field in this image, pre 7.9)

### The Viewing



This control will be used to choose how we want to view the PrePad, Data Bits, and PostPad, both in the table and the annotations on the trace. This parameter has no impact when “Data Mode” is “Bits” and is therefore grayed out.

### Bit Order



When decoding in “Words” this control selects a conversion of the Word with the Most Significant Bit first or the Least Significant Bit first. This parameter has no impact when “Data Mode” is “Bits” and is therefore grayed out.

### Sync Bits

The “Sync Bits” lets the user choose at which bit the packetizing should start. The algorithm will start at “Sync Bits” and group bits into the 3 fields “PrePad”, “Data Bits” and “PostPad”. Then it will restart with the “PrePad” of the next sequence. There might be 0 to 100 Sync Bits.

### PrePad Bits

The “PrePad Bits” are used to group information preceding the Data Bits. There might be 0 to 32 PrePad Bits. PrePad bits might be used to group Address bits, Preambles, Subaddress, etc...

### The Nx Factor

This value allows the replication of several Data Words defined by the Data bits. Its default is 1, meaning that there is only one Data word with the defined number of Data bits. When the value is set to one, the grouping of bits into words occurs as a repeated sequence of <Prepad|Data|PostPad> blocks. When the value is greater than 1, for example 3, the grouping of bits will occur as a repeated sequence of <Prepad|Data|Data|Data|PostPad> blocks. Examples are shown below.



## Comparison of Signal Decoded with varying Nx

This section shows the same signal decoded using 3 common variations.



Figure 25: Payload bits grouped as repeated  $\langle 1 | 1x8 | 2 \rangle$  blocks

This structure is frequently found in UART type protocols, when consecutive characters are being transmitted over the line. Each character is made up of a start bit(s), data bits and stop bit(s).

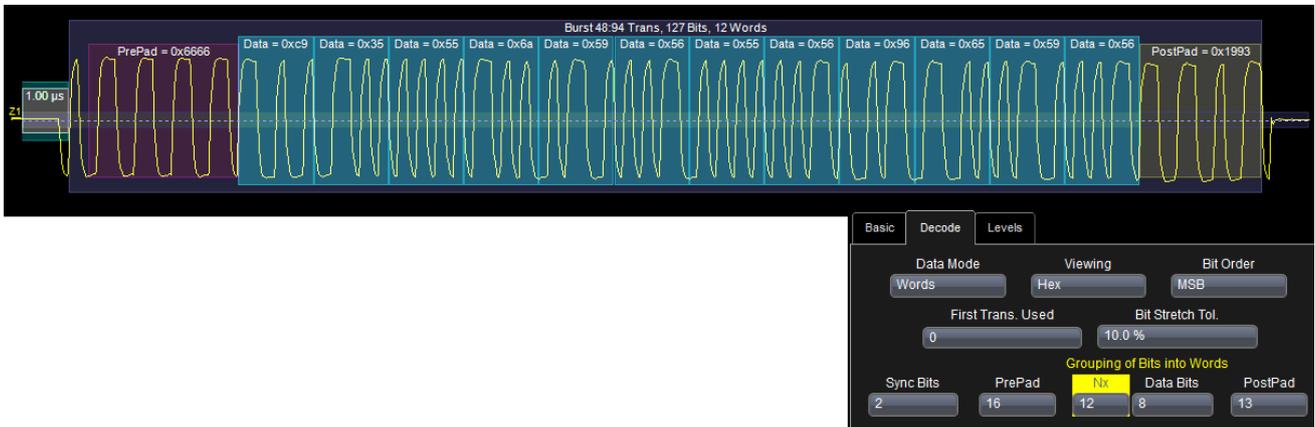


Figure 26: Payload bits grouped as single  $\langle 16 | 12x8 | 13 \rangle$  blocks

Another frequently found structure with an initial ID, or Destination, several adjacent Data bytes and a trailing field.



Figure 27: Payload bits grouped as repeated  $\langle 4 | 2x8 | 5 \rangle$  blocks

This structure is less frequent, but possible, and combines above examples into blocks. The use of the above set of controls allows a flexible and rich decomposition of the payload data bits. For even more flexibility,

several decoders can be switched on to decode the same trace, whilst using the hidden variable MaxWords (accessible via xStreamBrowser) to limit their individual action span.

## 6 The Level Tab

### The contents and actions of the controls in the Level Tab

The last tab to be discussed is the level tab. The image below shows its contents

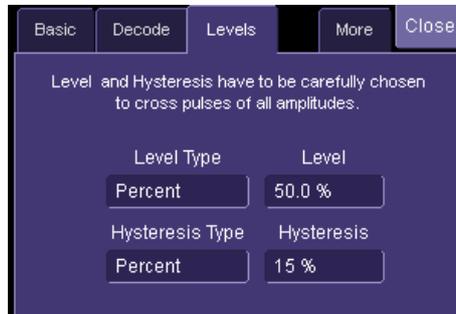


Figure 28: The Level Tab, with default settings

The next image will show the effect of the controls when using the percent mode.

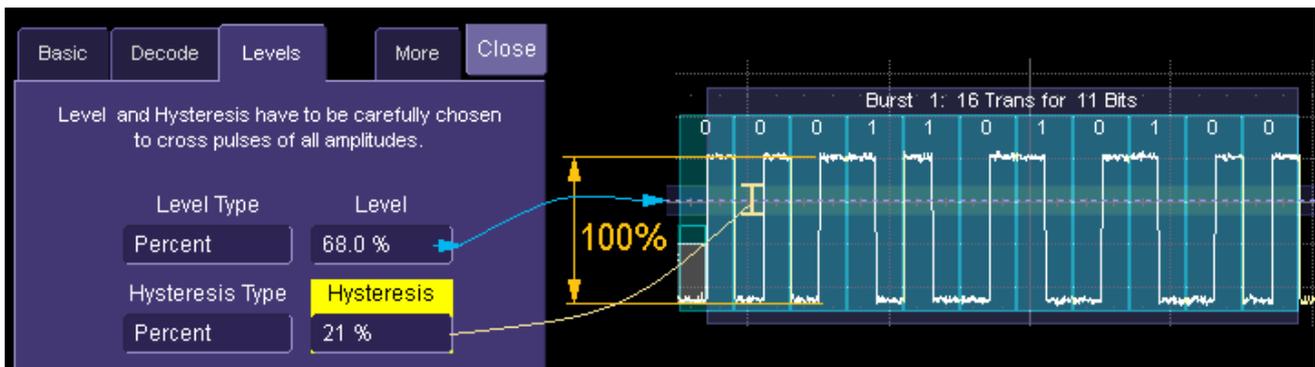


Figure 29: Effect of the Level and Hysterisis values on the decoding

When working in percent, all the values are proportional to the 100% signal amplitude. In the example, the level of 68% refers to the 100% amplitude shown. The same applies to the Hysterisis. Both Level and Hysterisis can be switched to "Type=Absolute". In this case the values need to be set in Volts. Both methods have their merits.

It is also possible to use the Level in one Mode (i.e. Absolute) whereas Hysterisis is in the other Mode (i.e. Percent). In general, the Percent Mode is more convenient and faster to setup because it immediately determines the optimal threshold. However, on poor signals the Percent Mode can fail and lead to bad decodes. Then it might help to use the Absolute Mode.

On very long signals, the Percent Mode adds computational load. If performance is an issue, it might be beneficial to switch to Absolute mode.

Before we continue, let's emphasize the visual rendering of Level and Hysterisis again. The Hysterisis color is fairly subtle as it should not dominate the rendering of the decoded information, but nevertheless important as the hysteresis plays an important role in the determination of the crossing times.

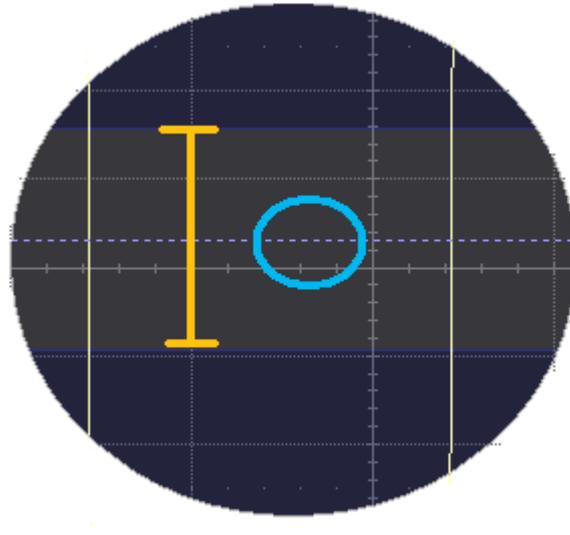


Figure 30: Heavily zoomed image of the Level and Hysteresis rendering.

In this Figure the level appears as a blue dotted line (highlighted with a blue circle) while the Hysteresis is annotated as a dark grey band (yellow line)

The next section will discuss an example of a bad signal decoded by tuning the Level and hysteresis settings.

## How to tune Level and hysteresis when working on noisy signals

We will now look at an example of a noisy signal that will not decode correctly with the default Level and Hysteresis values. The first image shows the reference decoding of a clean Manchester signal, with 16 transitions, 11 bits of values 000-1101-0100

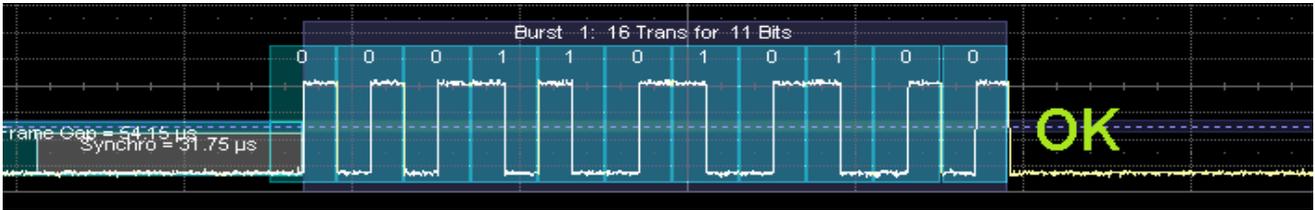


Figure 31: Correct decode of a clean Signal, Level 50%, Hysteresis 15%

When noise is added to the signal, various wrong decoding symptoms appear, such as 2's and 3's, non contiguous bits, too many transitions (here 37) and fake bits on the idle portion. The reason is that the signal spikes create fake transitions where it crosses the Level Threshold with insufficient hysteresis. (Red markers). Note that if we were decoding in Word Mode, other errors would appear, but with the same root cause.

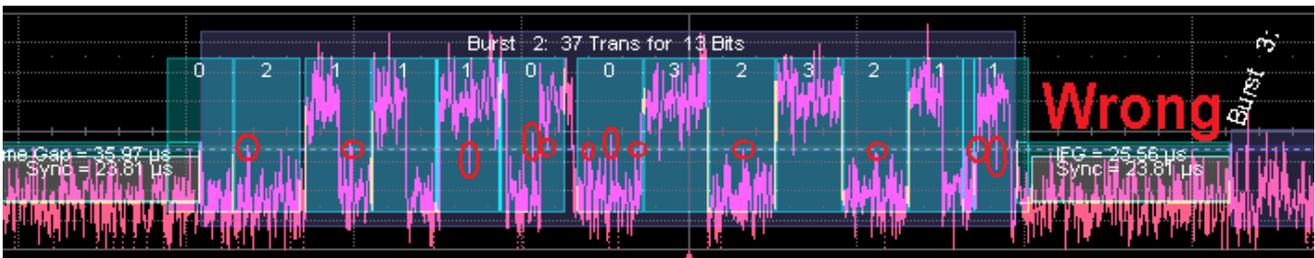


Figure 32: Wrong decode of the same signal, heavily perturbed, Level 50% and Hysteresis 15%

As soon as we increase the hysteresis, the spikes no longer cross the hysteresis band and the decoding converges back to correct values. In this image note the expanded Hysteresis annotation band around the blue dotted level marker line.

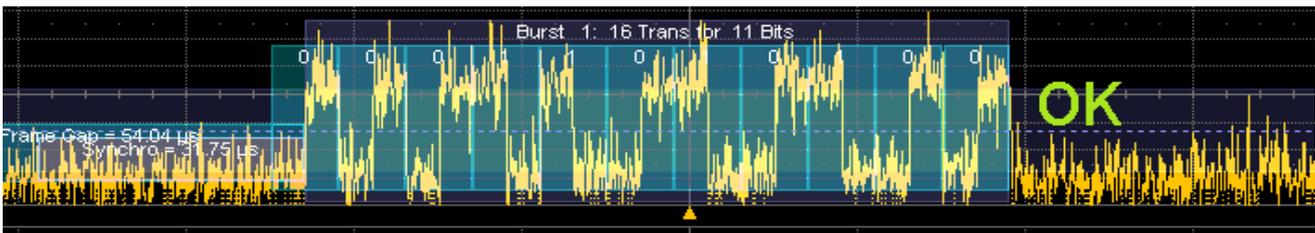


Figure 33: Correct decoding on Noisy Signal, with Level at 50% but Hysteresis at 3 Divisions

Finally another method using a numerical Filter (Median Filter) to smoothen the noise and still decode with default Level and Hysteresis.



Figure 34 Correct decoding on Filtered Signal, with Default level and Hysteresis

## A philosophical comment and a word of caution

Although the above numerical tricks have shown that it is possible to decode a noisy or corrupted signal, these techniques do not replace the fundamental healthy signal hygiene. Having good signal is the best way to avoid system failures or performance degradation. The decoding techniques are meant to help **until the signal is fixed**. There are many reasons for having poor signals: bad lines, poor components at every level in the circuitry, EMC issues and many more, and last but not least wrong probing techniques or even faulty oscilloscope. The discussion of those is outside the realm of this manual, but should be taken seriously.

## Technical information

A burst might contain at most 100000 transitions, or 32000 bits or 1000 words, whichever occurs first. This is merely a safety limit for software engineering reasons then a limit based on any protocol.

The Bit rate limit is not an algorithmic limitation, but rather is based on the availability of test signals for the extreme cases. As for other decoders, the limit might be expanded if and when signals at those speed are available to validate the algorithm.