

## CT00B-AN-1011: Advanced Scanning Concepts – Understanding Resolution

This application note will walk you through some of the choices you should consciously make when scanning a cable. There are many options when using the CT100B that will affect the quality of your saved scans.

This note assumes that you are familiar with the basic operation of the CT100B and CT Viewer 2, and also that you are familiar with our earlier application notes.

Several factors affect the data points that make up a scanned trace. These include the choice of Screen or Fixed resolution, exactly how much cable (horizontal scale) is visible on the screen, the smoothing setting, the Vp setting, and, finally, the use of the Snapshot or Cursor options for the scan itself.

### Screen Mode

Screen mode is a setting which allows very fast updating of the trace being drawn on the display. There is one reading taken for each pixel in the display and a complete scan happens hundreds of times per second. Older CT100 models always worked in what is now called Screen mode.

The downside of using Screen mode is that the resolution of the data points is very coarse when displaying long cables. There are 480 points drawn on the display, so a scan of a 48 inch cable would have a resolution of about a tenth of an inch per pixel. However, displaying the scan of an entire 960 foot long cable would only show one measurement every two feet. This can be a quick way to find the end of a cable, but most of the detail will be missed. To see details in a long cable requires zooming in until only a small section of cable is displayed and then using the HORIZONTAL POSITION knob to scroll along the length of the cable. Fixed mode was created to solve this problem.

What the CT100B calls “Screen” mode is how almost all competing portable TDRs work all of the time. The ability to specify a Fixed high resolution mode that is independent of the display resolution is one of the features that makes the CT100B special.

### Fixed Mode

Fixed mode allows the user to specify a desired resolution. Use the M-FUNCTION knob to adjust the step size to as small as 0.76 picoseconds. This resolution is then used no matter how long a section of cable is displayed on the screen. Long traces at high resolution can consist of over a million data points. Each pixel on the display will have multiple points drawn in it so variations in the cable’s impedance, such as caused by a connector or defects, can be identified at a glance. Once the initial scan has been taken (and

saved if desired), the display can be zoomed in around points of interest to view the interesting details at a larger scale. The drawback to using an extremely fine step size is that the sampling of all those data points takes longer.

## Normal Mode

Normal mode is where the CT100B sets the step size to factory defined values for each of the three cable length settings. It is just like Fixed, but with the settings hard-coded. It is a convenient default to use for many common situations.

## Step Size

The step size is the delay time in picoseconds between successive data points in a trace. At the top-left of the display appears a short description of the current setting (see Figures 1 and 2 for examples.) This shows the current cable length setting and the current resolution setting. The “S” is for short cables (up to about 100 meters in length).<sup>1</sup> The number is the picosecond value currently being used by the CT100B. A small number gives more details in the trace.<sup>2</sup>

The figures below show examples of two settings when the horizontal scale displays about 20 feet of cable on the screen:

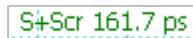


Fig. 1. Short Cable, Screen Mode

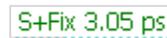


Fig. 2. Short Cable, Fixed Mode

Figure 1 shows that this example of the Screen resolution mode has a much larger step size than the Fixed mode shown in Figure 2. Because the points are farther apart, there will be fewer of them in a scan. A scan will be taken faster, but details in the cable and connectors may be missed.

## How Does Step Size Compare to Physical Distances?

So far we’ve talked about step size in picoseconds. But how does that compare to physical distances in the cable being scanned? The CT100B keeps track of everything in terms of time, and then converts time to distance when displaying the results. It uses the Vp (Velocity of propagation of electricity in the wire) for this conversion.

The electrical pulse from the CT100B has to travel to a point in the cable and then the reflection has to travel back to the CT100B to be measured. As a rule of thumb, in the CT100B at a Vp of 1.0 (the speed of light in a vacuum), it takes about 166 picoseconds per inch (counting the round trip time). At a Vp of 1.0,

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<sup>1</sup> The possible abbreviations include **S**, **M**, and **L** for **Short**, **Medium**, and **Long** cable lengths and **Scr**, **Fix**, and **Nor** for **Screen**, **Fixed**, and **Normal** modes.

<sup>2</sup> The CT100B can make measurements as close as 0.76 ps between successive data points. This ultra-high resolution setting allows very precise distance measurements to be made, around 1/10<sup>th</sup> of a millimeter.

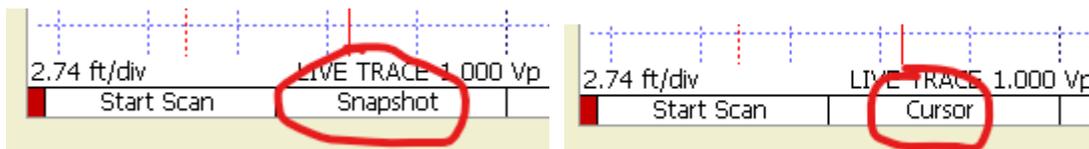
this is about 6 ps per millimeter. Real Vp values in cables are less than 1.0, so it takes more picoseconds to travel a given distance. At a common Vp value of 0.66, it takes about 9 ps per millimeter.

Some examples:

- Using a Vp value of 0.85 and Fixed resolution mode with a setting of 5.34 ps allows the CT100B to measure a physical resolution of less than a millimeter.
- A resolution of 17.5 ps results in a physical resolution of about three millimeters.
- A resolution of 50 ps results in a physical resolution of just under a centimeter.

## Snapshot vs Cursor Scans

The CT100B has two ways to record a cable scan: Snapshot and Cursor. The Scan button loads a menu which contains a command to toggle between the two modes:



The Snapshot Scan just saves the Live Trace that is currently being displayed. It uses the resolution in picoseconds that is currently displayed at the top of the screen. If the resolution that is specified is a small enough value, the resulting scan will be a good one. But, if the current resolution is quite coarse, the resulting scan will be of low quality. A Cursor Scan allows more control over the result, but requires more setup. We'll show examples of using each scan type below.

## Snapshot Scan Examples

Our sample setup is a short 50 ohm cable connected to the CT100B and then a 1000 foot long 75 ohm cable connected to that. The following Figure 3 shows two Snapshot scans loaded into the CT Viewer 2 program. One Snapshot scan was made using a Fixed resolution (the red trace labeled "normal") and the second scan was using Screen resolution (the black trace). On the screen of the CT100B and when loaded into the CT Viewer 2 program, they appear nearly identical at first glance.

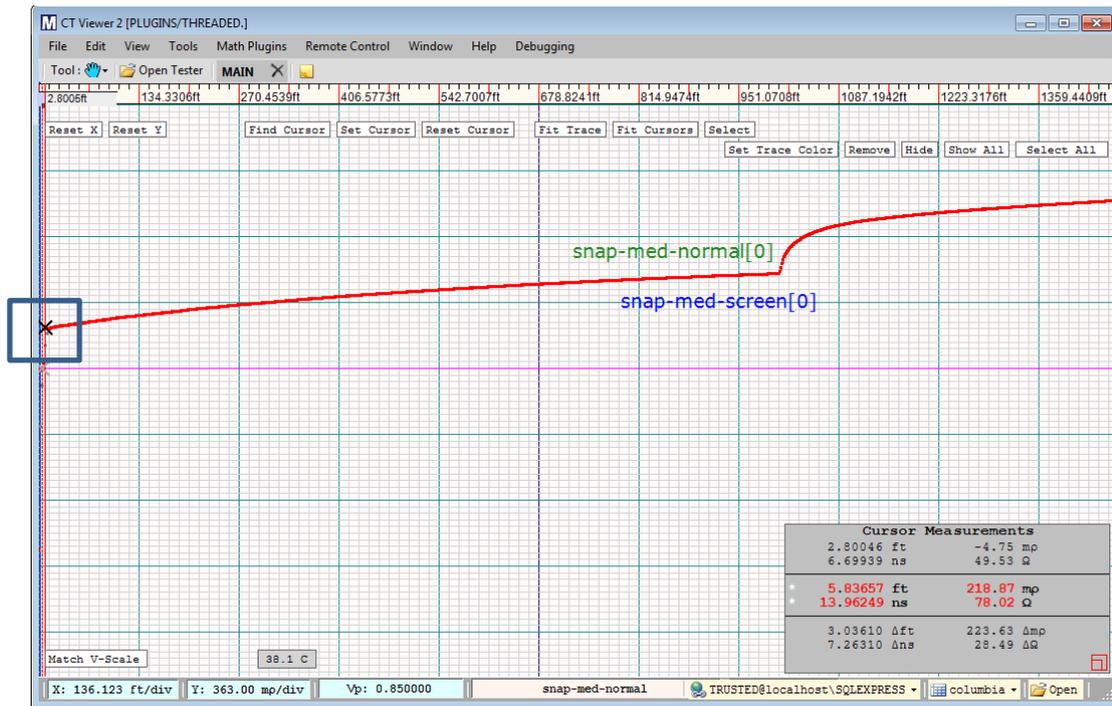


Fig. 3. Two snapshot scans of a 1000+ ft cable loaded into CT Viewer 2.

However, when we zoom in to see details in the outlined box (Figure 4) at the beginning of the trace, the difference in resolution becomes obvious.

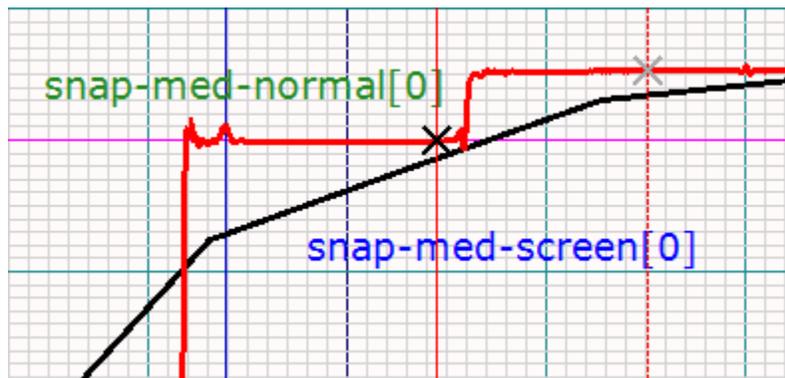


Fig. 4. Zoom in to see details of the two scans.

Figure 4 is zoomed in to display only the first few feet of the scan, showing the internal cable to the connector on the front of the CT100B, then the short 50 ohm cable, and finally the first few feet of the longer 75 ohm cable. The red trace was taken with the CT100B using a Fixed 17.5 ps step size. It is a high quality trace; the “stair-step” shows clearly where the 50 ohm cable is connected to the 75 ohm cable.

The black trace was taken using Screen resolution and had a step size of 7284 ps. Figure 3 shows ~1400 feet of trace (several hundred feet past the end of the actual cable) so the 480 data points for the Screen scan means the data points are almost three feet apart. It misses many interesting details. The short 50 ohm cable is almost missed completely.

Figure 5 shows the same region of cable, but with CT Viewer 2 displaying the individual data points instead of connecting the points with lines. Note that the black Screen mode trace has *only four plotted points* in this view vs. hundreds of red points for the higher resolution Fixed mode scan.

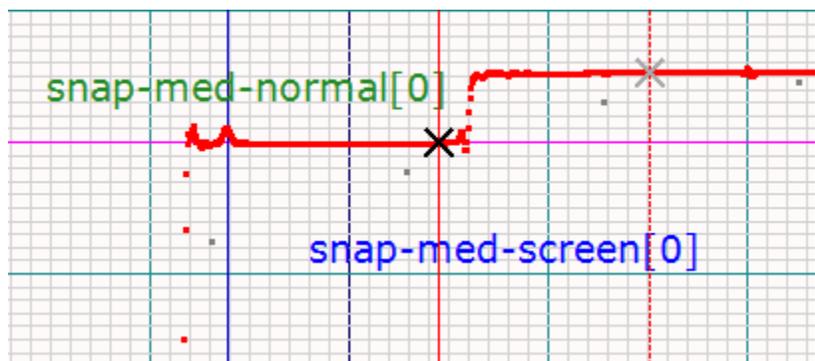


Fig. 5. Individual data points drawn in red and black.

The Fixed scan has sufficient detail that we can zoom in even more on the connector at the end of the short cable and still see lots of details. The Screen mode trace is basically useless at this scale. The data points are more than two feet apart and completely miss the connection between the two cables.

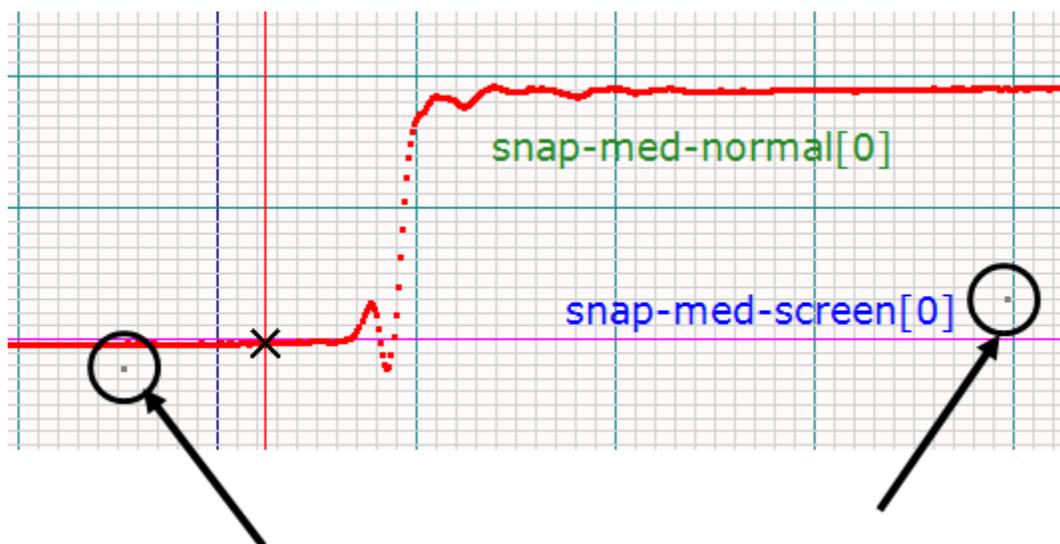


Fig. 6. Zoom in even more to show details of the connection between two cables.

The moral of the story is to always check the resolution before doing a Snapshot scan. And, only use Screen mode for very short sections of cable.

## Cursor Scan Examples

Now let's scan the same cable using a Cursor scan. The Cursor scan takes a scan from cursor position to cursor position using the resolution displayed on the screen. Place one cursor at or before the beginning of the cable and one cursor at or after the end of the portion of the cable to be scanned. It doesn't matter if the cursors are visible on the screen or not. The Cursor scan will always record the portion of the trace between the cursors. If the cursors are both visible on the screen, the scanned area will be

shorter than the screen. If one or both of the cursors are off-screen, the resulting scan will still go from cursor to cursor.

A Cursor scan can be used with any of the resolution modes. For Fixed, specify the desired resolution (this example used 17.5 ps), then select Cursor mode in the SCAN menu and press Start Scan. A little dialog box pops up with a countdown timer showing the progress of the scan. Save the resulting scan.

For Screen mode, position the cursors and select Cursor mode in the SCAN menu, *but before pressing Start Scan*, use the HORIZONTAL SCALE knob to zoom in until the picosecond value displayed on the top of the screen is at the resolution you desire. For our example, we set it to approximately the same as the 17.5 ps used in the Fixed scan. Basically this forces the Screen mode to act the same as Fixed mode for purposes of taking a scan. Then press the Start Scan menu button.

The resulting scans this time are nearly identical, even when zoomed in to display just a few inches of our 1000 feet of cable.

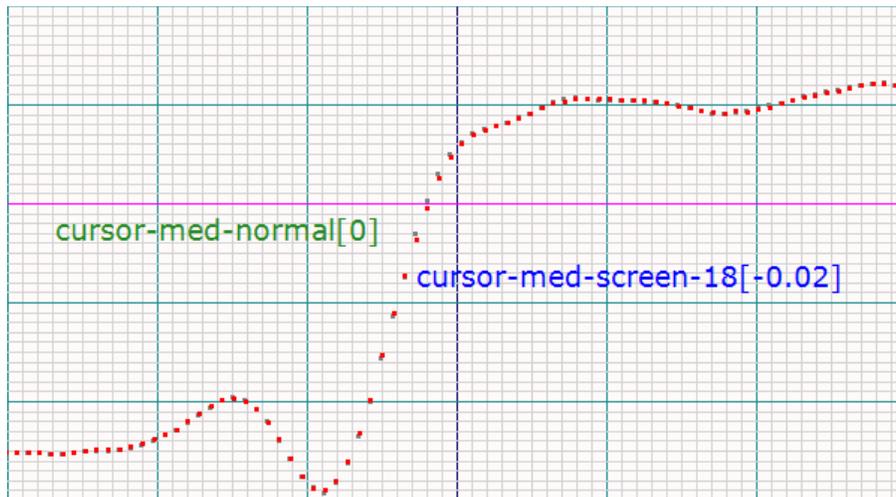


Fig. 7. Two high resolution cursor scans showing the connector between the 50 and 75 ohm cables.

Doing a Cursor scan was the technique that older CT100s used to get a high resolution scan of a longer cable. The Fixed mode was developed to provide an easier and less error prone way to do high quality scans, as well as always showing connectors, cable defects, etc. on the screen even when displaying long sections of cable.

## Impact of Smoothing on Screen Scan Mode vs Cursor Scan Mode

When the Scan mode is Snapshot, the system basically takes an immediate copy of the current trace. This is convenient for many cases, but may not always result in the best scan. As discussed in the previous section, Screen vs Fixed resolution can have a large impact. But in addition, even if the resolution is adequate, if Smoothing is turned up to a high value, it can take some time for the drawn

trace to “settle” down to a final value.<sup>3</sup> Taking a Screen scan too soon after the last display change results in the scan not including all of the smoothing that was intended.

If the Scan mode is Cursor, the scan is taken “fresh”; i.e., if smoothing is on, that many traces will be scanned and averaged. The trace that is currently displayed on the screen when the Start Scan button is pressed is ignored.

Cursor scan was the only way to make a high resolution scan in previous versions of the CT100 since resolution was always Screen mode. This method still works correctly when using the CT100B, but using Fixed mode or Normal mode is easier to teach new users. The most important thing to remember is that whether using Cursor scan or Snapshot scan, the picosecond resolution displayed at the top of the screen is the resolution used by the Start Scan command.

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<sup>3</sup> For example, if a cable is being scanned at a high resolution, it can take many seconds for a single scan. If smoothing is set to a value of 64, then 64 complete scans will have to be taken before the trace is stable. Each time that settings are changed in the CT100B, the smoothing resets.