

# SHDSL Time Domain Reflectometry Application Note

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## Revision History

Revision	Date	Author	Notes
1	9/26/2017	Stephen Ochs	Initial

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## Abbreviations

The following abbreviations are used in this document:

CSV	Comma separated values
SELT	Single ended line testing
SHDSL	Single-pair high-speed digital subscriber line
TDR	Time domain reflectometry
VF	Velocity factor

## **1 Introduction**

Trinity OS makes the TDR functionality provided by the SHDSL chipset used in many Patton Electronics devices available for use. TDR can be used for SELT tests to determine cable properties such as length, type, opens, shorts, and bridge taps. See the Trinity OS release notes for details on which releases and which products this feature is available.

This document explains how to use the TDR functionality.

## 2 Theory

The SHDSL chipset performs the TDR by transmitting a pseudo-random noise sequence and training its echo canceller to measure the echo impulse response. The echo canceller coefficients, representing the impulse response at various points in the time domain, are displayed as the results.

The signal transmitted by the SHDSL chipset will be reflected by the hybrid circuit contained within the device and will appear as near end echo. All other discontinuities of the cable such as bridge taps, wire gauge changes, and loop termination will appear as far end echo. If the loop is terminated with the characteristic impedance, then there will be no reflection from the loop termination. This means that to estimate the cable length, the cable needs to be either terminated with high impedance or left open.

To evaluate the results, the near end echo must be separated from the far end echoes. Then the delay between the near end and far end echo indicate the distance to the discontinuity. The sign and magnitude of the reflection indicate the type of discontinuity.

### 2.1 Determining the distance to a discontinuity

The distance represented between each echo canceller coefficient is determined by the VF of the cable, i.e. how fast an electrical signal propagates along the cable in proportion to the speed of light, and the time represented between each echo canceller coefficient:

$$\Delta distance = VF \times c \times \frac{\Delta T}{2}$$

Notice that we divide by 2. That is because the transmitted signal must travel to the discontinuity, and the reflected signal must travel back the same distance.

The time represented between each echo canceller coefficient is determined by the baud rate of the transmitted signal:

$$\Delta T = \frac{1}{4 \times \text{baud\_rate}}$$

The baud rate is determined by the bits per symbol, i.e. the TCPAM, and the payload rate:

$$\text{baud\_rate} = \frac{8000 \text{ bps} + \text{payload\_rate}}{\text{bits\_per\_symbol}}$$

There is 1 bit per symbol for TCPAM-4, 2 for TCPAM-8, 3 for TCPAM-16, 4 for TCPAM-32, 5 for TCPAM-64, and 6 for TCPAM-128.

There are 256 echo canceller coefficients, so the length of cable tested is:

$$\text{length} = (256 - 1) \times \Delta \text{distance}$$

A higher baud rate, i.e. a lower TCPAM or higher payload rate, will provide a finer grained test. That is, the distance represented by each echo canceller coefficient will be shorter, allowing the test to pinpoint

discontinuities more precisely. A lower baud rate, i.e. a higher TCPAM or lower payload rate, will provide a test that covers a longer length of cable. In general, you should select the highest baud rate that covers the length of cable you want to test.

Selecting TCPAM-128 and payload rate 15296 kbps results in a granularity of 9.4 m between each coefficient, but only tests a total of 2397 m of cable. Selecting TCPAM-16 and payload rate 1984 kbps results in a granularity of 36 m, but tests a total of 9210 m of cable.

Note that the longer the distance to the discontinuity, the more the reflected signal is attenuated, so for very long cable lengths, the reflections can be hard to see.

### 3 Execution

In order to use the TDR functionality, follow these steps:

**Mode:** port dsl

Step	Command	Purpose
1	<code>node(prt-dsl)[0/0]#shutdown</code>	The port must be disabled in order to execute the TDR.
2	<code>node(prt-dsl)[0/0]#firmware <i>idc sdfe</i></code>	Load firmware that supports TDR onto the SHDSL chip. The default firmware does not support TDR. We suggest that you use <code>IDC_Online_v1_1_2_1_0</code> and <code>shdsl_soc4e_cot_rt_210__001</code> for this test, and that you reset the firmware back to the default when the test is done. Note that this will cause all ports on this slot to drop.
3	<code>node(prt-dsl)[0/0]#test time-domain-reflectometry payload-rate &lt;64..15296&gt; tcpam {4 8 16 32 64 128} annex-type {a-f b-g} power-backoff &lt;0..31&gt;</code>	Execute the TDR. The payload rate and the TCPAM determine the baud rate. See section 2.1 for details. The annex type and power backoff determine the transmitted signal power.

The “test time-domain-reflectometry” command will perform TDR on all ports specified by the “service-mode” mode command. For example, if the port is configured for “service-mode 2-wire” the TDR will be performed on one port, whereas if the port is configured for “service-mode 8-wire” the TDR will be performed on all four ports.

Patton Electronics provides a Microsoft Excel worksheet, `SHDSL_TDR_Worksheet.xlsx`, to help analyze the results of the “test time-domain-reflectometry” command. See section 4 of this document for an example of how to use the worksheet.



## 4 Example

This section shows how we might estimate the length of cable connected to the SHDSL port.

Log into the device's CLI and execute the test.

```
node(prt-dsl) [0/0]#shutdown
node(prt-dsl) [0/0]#firmware IDC_Online_v1_1_2_1_0 shdsl_soc4e_cot_rt_210__001
node(prt-dsl) [0/0]#test time-domain-reflectometry payload-rate 15296 tcpam
128 annex-type a-f power-backoff 0
Test takes about 60 seconds to complete...
0/0,3224,3431,2692,2336,-488,-1412,-1450,-1642,-2570,-1655,-
1489,220,1699,2738,3370,2912,8352,12338,43695,166221,535135,1429105,3304432,6
714742,12199938,19485069,27551611,33977915,34993005,26174056,3915332,-
33181132,-83705259,-138767080,-187651919,-216019166,-208995053,-156272554,-
55575694,84588845,246963991,396119979,501924202,535574365,477886572,330787340
,112830704,-140796927,-389104613,-577083356,-673154476,-658954802,-
535340619,-332499857,-
90093298,145162063,334211290,441928461,462616974,405123944,290229406,15295543
2,22013982,-79137584,-138717299,-154069013,-135699089,-97899874,-54686627,-
19030729,3899451,13511103,12973201,7317452,1204967,-2399632,-2552556,-
78439,3280033,5795806,6404101,4933129,2086812,-1097840,-3669351,-4938170,-
4896149,-3874084,-2369873,-
932080,160998,820055,1122423,1191345,1149483,1053262,902660,698694,442596,181
148,-27487,-102746,-
11233,251466,641736,1068533,1443610,1681870,1722655,1540730,1149912,591687,-
68066,-721649,-1296038,-1710986,-1918683,-1893804,-1662679,-1268391,-769595,-
266281,190881,540852,762144,835854,789803,647851,443611,222115,18795,-
144348,-245970,-266176,-215384,-
98404,64257,241919,408017,524865,578121,550912,443502,279473,79538,-118436,-
274965,-350914,-326651,-
157918,164940,668196,1352446,2180080,3098255,4005726,4752879,5096258,4822523,
3694871,1514315,-1688716,-5800997,-10490636,-15311057,-19408764,-22148766,-
22878211,-21093387,-16699008,-9921609,-
1366869,8220324,17403236,25229712,30759724,33375171,32759209,29181052,2322945
2,15607203,7542569,-168111,-6778623,-11876554,-15070146,-16518397,-16482513,-
15305065,-13429306,-11210911,-8944644,-6788051,-4922414,-3344170,-2041062,-
965961,-
123010,543285,1058701,1443672,1702559,1860674,1930813,1923359,1862439,1756983
,1620170,1463908,1302153,1142896,992325,851028,732700,632302,551336,484621,42
9230,380418,332875,287948,241953,201083,160190,119989,89741,63637,43709,33296
,29075,32844,39019,43102,49760,52297,49054,40545,24061,2774,-21559,-43772,-
68076,-87829,-102548,-112749,-112729,-112834,-108322,-97855,-82690,-72370,-
62760,-51999,-47329,-37721,-31048
node(prt-dsl) [0/0]#
```

Patton Electronics provides a Microsoft Excel worksheet, SHDSL\_TDR\_Worksheet.xlsx, to help analyze the results. Open this worksheet.

[SHDSL\\_TDR\\_Worksheet.xlsx](#)

Enter the cable properties and test parameters.

The screenshot shows the Microsoft Excel interface with the following data and callouts:

Section	Parameter	Value	Unit
Cable Properties	VF:	0.64	Velocity factor. 0.64 is typical for Cat 5e.
	$v_p$ :	191867173	Propagation velocity (m/s)
	<b>Test Parameters</b>		
Test Parameters	TCPAM:	128	
	Payload Rate:	15296	(kb)
	Bits per Symbol:	6	
	Baud Rate:	2550666.7	(Hz)
Test Results	1		
	2		
	3		
	4		
Graph	Tap 1:	1	
	Tap 2:	256	
	Cable length between each tap:	9.402795	(m)
	Distance between tap 1 and tap 2:	2397.713	(m)

**Callout 1:** We are using Cat 5e cable, which has a nominal VF of 0.64, meaning that the electrical signal propagates at 0.64 the speed of light.

**Callout 2:** We specified TCPAM-128 and 15296 kbps when we executed the test on the CLI above.

**Callout 3:** TCPAM-128 and 15296 kbps result in a baud rate of 2550666.7 Hz.

**Callout 4:** A baud rate of 2550666.7 Hz results in each tap receiving reflections from about 9.4 m (30.8 ft.) further away than the previous tap. There are 256 taps, so that allows us to test about 2397 m (7866 ft.) of the cable. If the cable is longer than that, we won't see the reflection from the end, and we will need to re-run the test with a lower baud rate.

Copy the test results from the device's CLI and paste them into the worksheet.

The screenshot shows the following data in the worksheet:

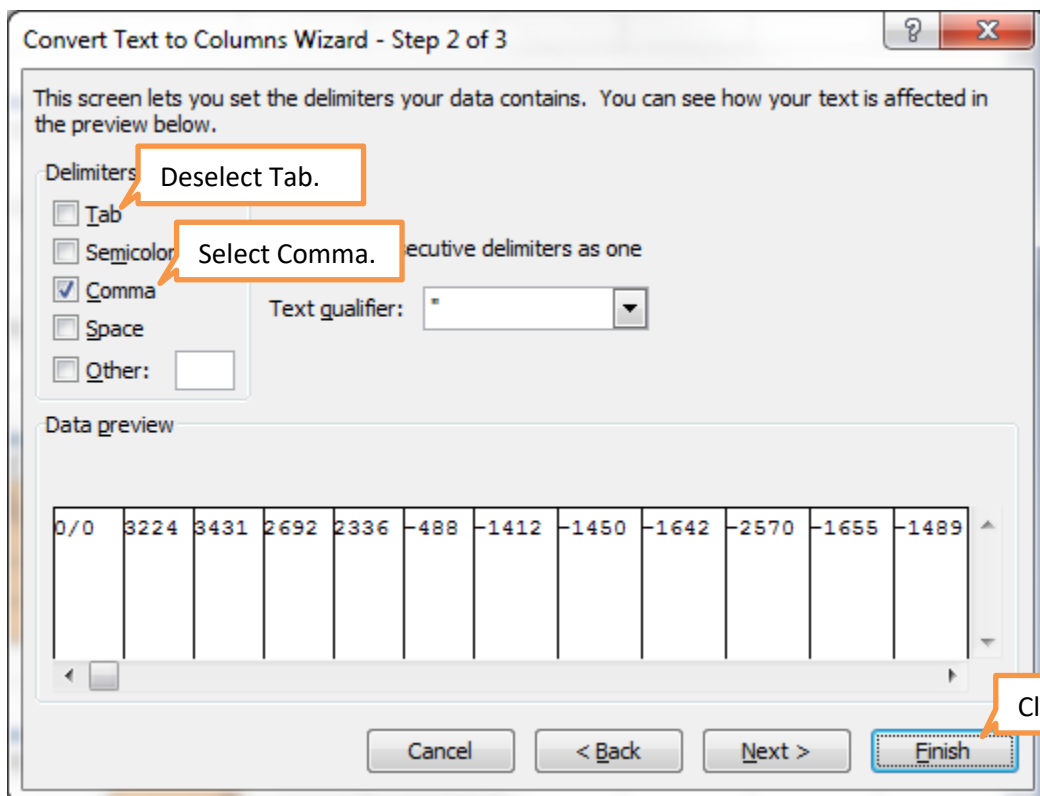
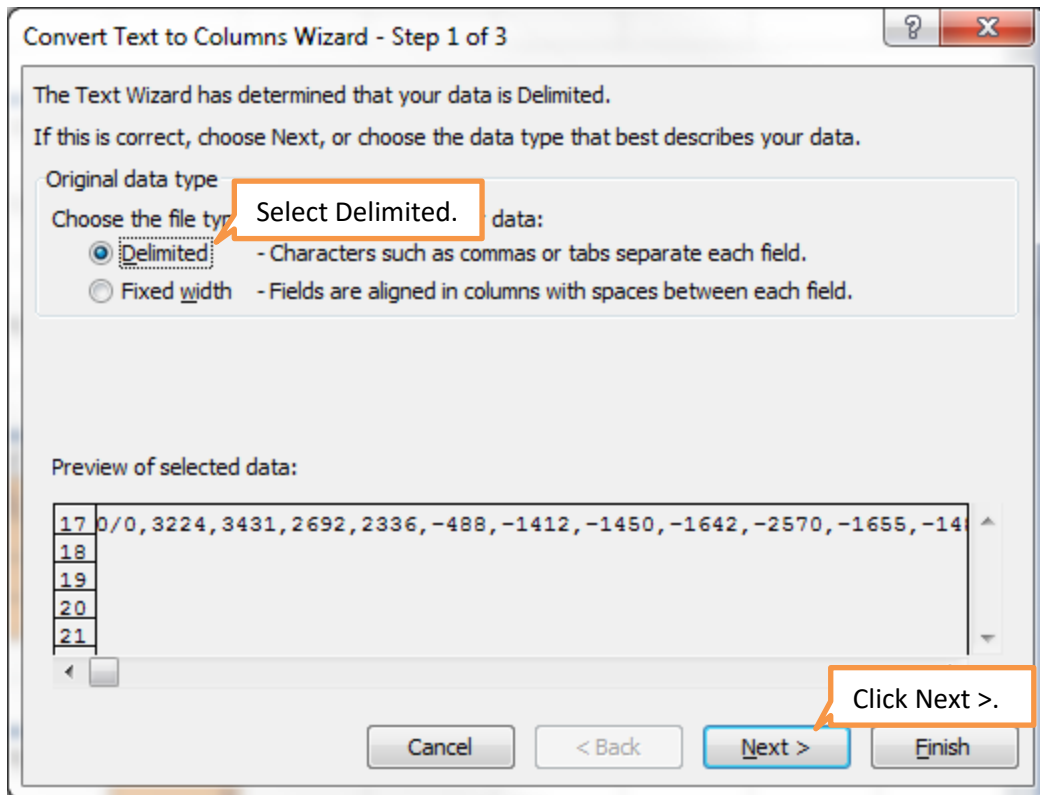
Section	Parameter	Value	Notes
Cable Properties	VF:	0.64	Velocity factor. 0.64 is typical for Cat 5e.
	v <sub>p</sub> :	191867173	Propagation velocity (m/s)
Test Parameters	TCPAM:	128	
	Payload Rate:	15296	(kbps)
Test Results	Test Results	0/0,3224,3431,2692,2336,-488,-1412,-1450,-1642,-2570,-1655,-1489,220,1699,2738,3370,2912,8352,12338,43695,166221,	
	Graph	Tap 1:	1
	Tap 2:	256	
	Cable length between each tap:	9.402795 (m)	30.84907 (ft.)
	Distance between tap 1 and tap 2:	2397.713 (m)	7866.512 (ft.)

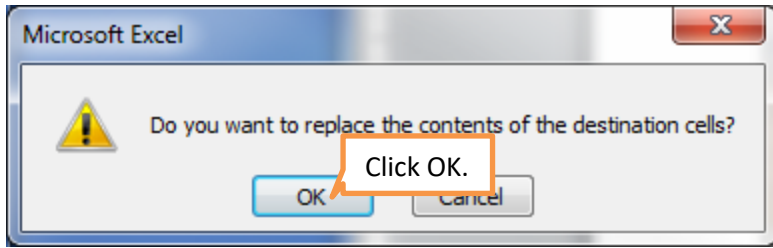
The callout box contains the following text: "The port was configured for 'service-mode 2-wire' so there are only results for one port. If we configured the port for 'service-mode 8-wire' we would see results for all four ports. The results are CSVs. Excel does not automatically delimit them, so they are all in a single cell."

Split the test results into columns.

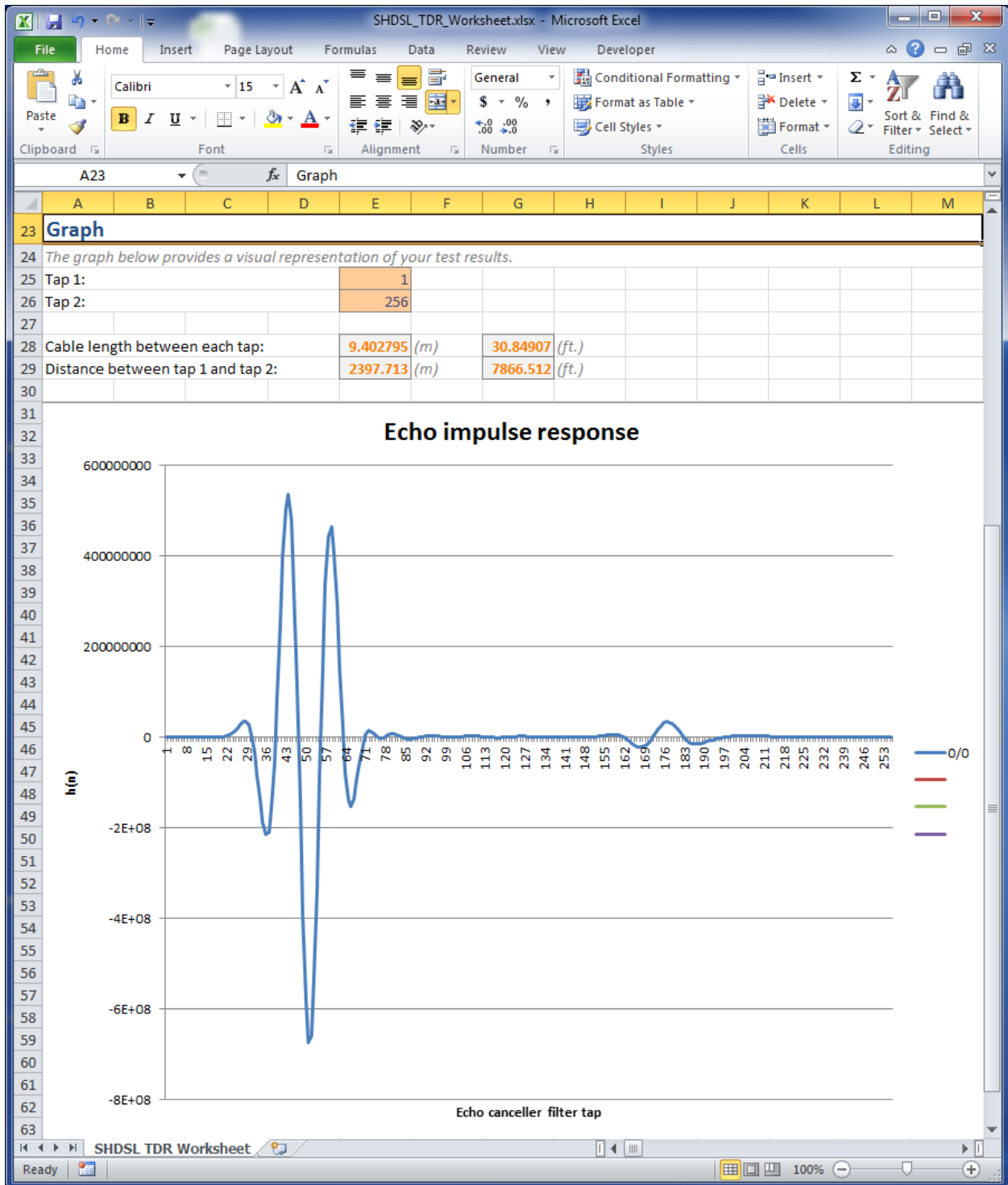
The screenshot shows the Microsoft Excel interface with the 'Data' tab selected. The 'Text to Columns' button in the 'Data Tools' group is highlighted with an orange callout box containing the text 'Click Data | Text to Columns.' The spreadsheet content is as follows:

Row	Column A	Column B	Column C	Column D	Column E	Column F	Column G	Column H	Column I	Column J	Column K
1	<b>Cable Properties</b>										
2	<i>Please provide the properties of your cable.</i>										
3	VF:	0.64	Velocity factor. 0.64 is typical for Cat 5e.								
4											
5	v <sub>p</sub> :	191867173	Propagation velocity (m/s)								
6											
7	<b>Test Parameters</b>										
8	<i>Please provide the parameters you used for your test.</i>										
9	TCPAM:	128									
10	Payload Rate:	15296	(kbps)								
11											
12	Bits per Symbol:	6									
13	Baud Rate:	2550666.7	(Hz)								
14											
15	<b>Test Results</b>										
16	<i>Please copy and paste the output of your test at cell A18. Then select Data   Text to Columns to split it on commas.</i>										
17		1	2	3	4	5	6	7	8	9	10
18	0/0,3224,3431,2692,2336,-488,-1412,-1450,-1642,-2570,-1655,-1489,220,1699,2738,3370,2912,8352,12338,43695,166221,										
19											
20											
21											
22											
23	<b>Graph</b>										
24	<i>The graph below provides a visual representation of your test results.</i>										
25	Tap 1:	1									
26	Tap 2:	256									
27											
28	Cable length between each tap:	9.402795	(m)	30.84907	(ft.)						
29	Distance between tap 1 and tap 2:	2397.713	(m)	7866.512	(ft.)						

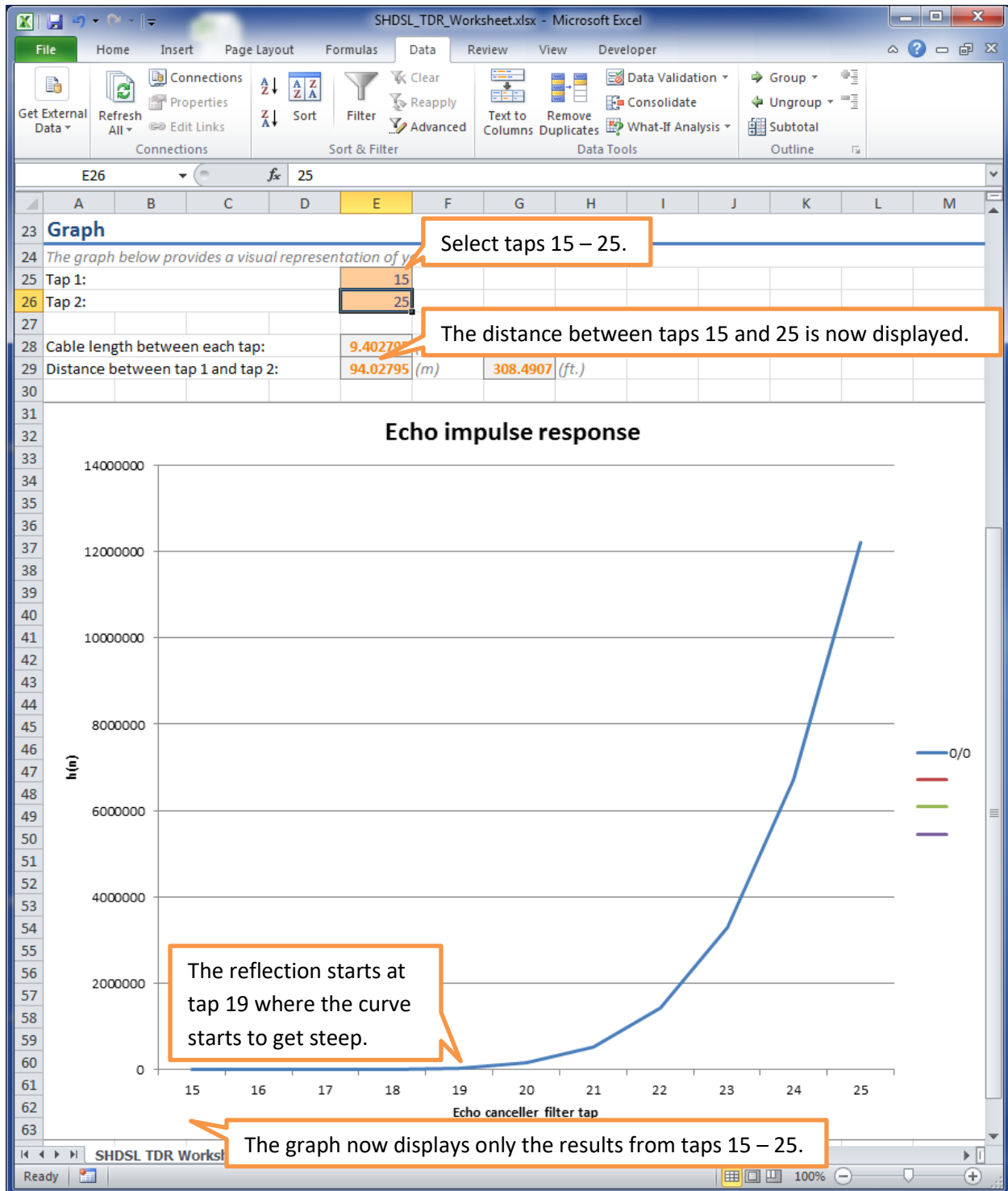




The results are now split into columns. Scroll down in the worksheet to see a graph of the results.

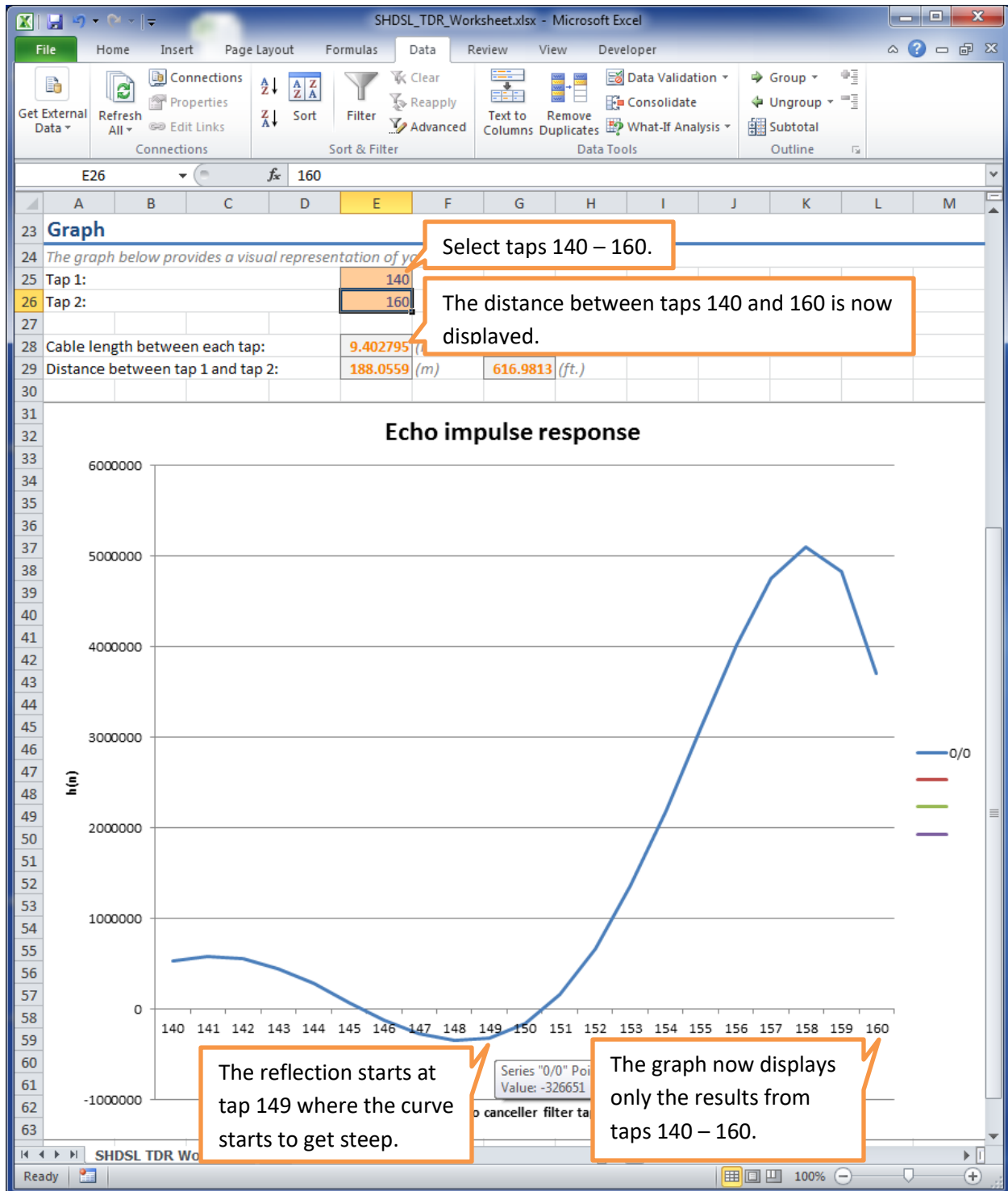


Find the near end echo. This represents the reflections of the test signal produced by the hybrid circuit included in the device, i.e. the start of the cable. It is not at tap 0 because there is some delay built into the chip. It appears to start close to tap 20. We will zoom in to taps 15 – 25 to see it better. Tap 19 is where the near end echo starts.

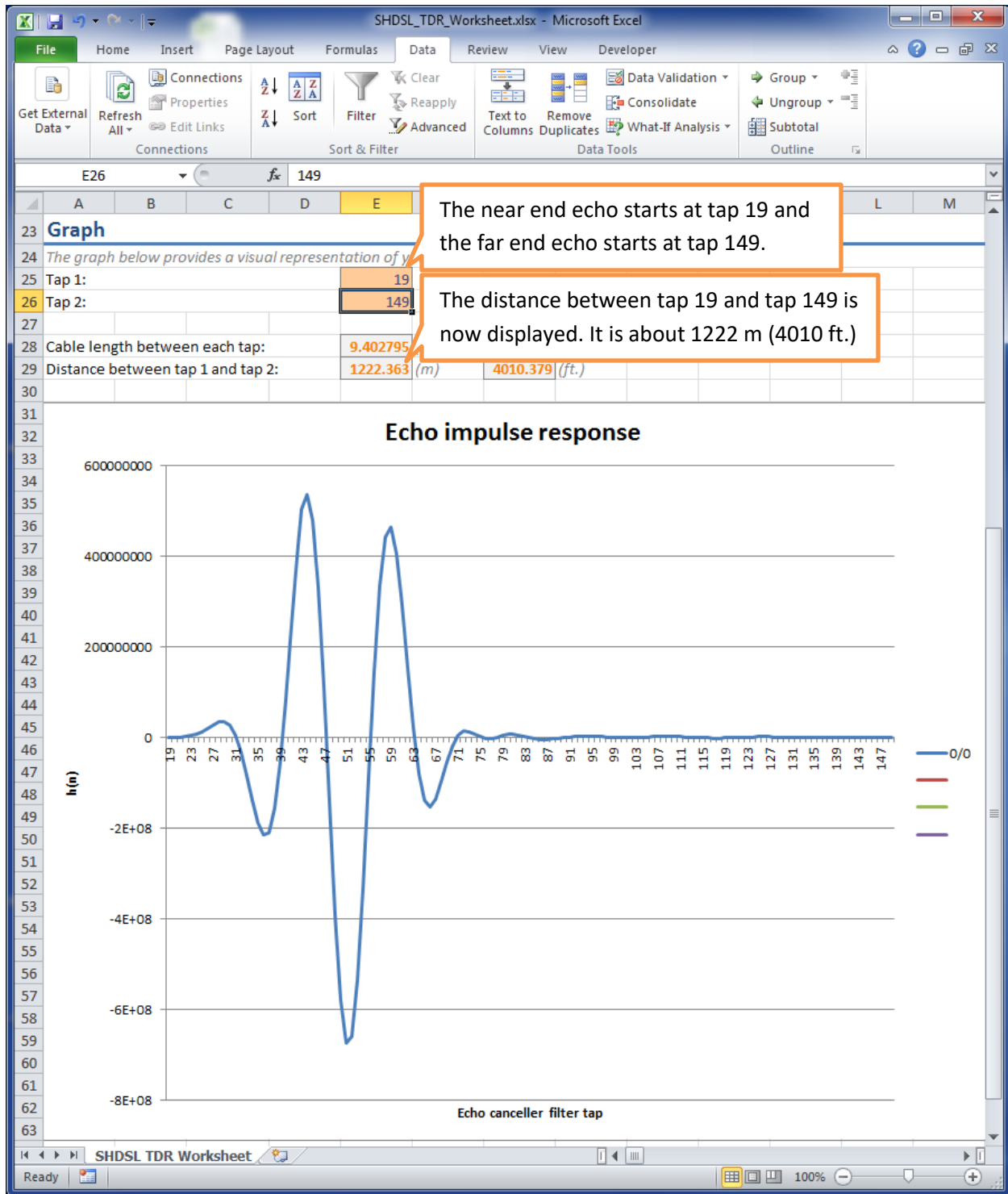




Find the far end echo. This represents the reflections of the test signal produced by the open cable end which is not plugged into anything. It has a lower amplitude than the near end echo because the cable attenuates the signal. It appears to start close to tap 150. We will zoom in to taps 140 – 160 to see it better. Tap 149 is where the far end echo starts.



Enter the taps where the near end echo and the far end echo start to get an estimate of the cable length.



As seen above, we estimate the cable to be 4010.379 feet. We were actually connected to a 4000 foot cable, so this is a good estimate.