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**Electronic Digital Levels**

# **The new Leica Digital Levels DNA03 and DNA10**

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## **Key words:**

Levelling, Digital level, Sensor, Data formats, Software

## **ABSTRACT**

Leica Geosystems AG Switzerland presents its new digital levels, the DNA03 and DNA10; successors of the NA3003 and NA2002. The instruments are equipped with a new sensor system, which processes the signal of the existing bar code staff pattern based on proven correlation methods. This document describes the user interface, measurement system, on-board applications, data format and storing concept, LevelPak-Pro post-processing software and performance of the completely redesigned instrument.

## **ZUSAMMENFASSUNG**

Leica Geosystems AG, Schweiz, präsentiert die neuen Digitalnivelliere DNA03 und DNA10 als Nachfolgergeräte der NA3003 und NA2002. Die Instrumente sind mit einem neuen Sensor ausgerüstet und verarbeiten das Signal des bestehenden Strichcodemusters mittels der bewährten Korrelationsmethode. Der Bericht beschreibt die Bedienelemente, das Mess-System, die Applikationsprogramme, das Datenspeicher- und Datenformatkonzept und die Leistungsmerkmale des völlig neu gestalteten Instrumentes wie auch LevelPak-Pro, die neue Datenverarbeitungs-Software.

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# **The new Leica Digital Levels DNA03 and DNA10**

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## **1. INTRODUCTION**

In 1990 Leica Geosystems AG released the world's first digital level: the NA2000 engineer's level. The NA2000 represented a breakthrough in levelling techniques, using the innovative concept of reading a bar-coded staff. Due to its ease of use and high performance the digital level was quickly adopted by the market, which soon demanded a high accuracy instrument. As a result of this demand the NA3000 was released in 1991. In spite of GPS and other alternative height determination techniques, classical levelling has maintained its importance, especially in the domain of 1<sup>st</sup> and 2<sup>nd</sup> order levelling, accurate height determinations and height determinations in tunnels. Due to the permanent demand for digital levels Leica Geosystems AG is proud to launch the 2<sup>nd</sup> generation of digital levels. The following paper gives an overview of the new DNA03 and DNA10.

## **2. THE INSTRUMENT DESIGN**

### **2.1 Design conditions**

The hardware and software for the new generation of digital levels was completely redesigned while continuing to use the existing bar-code pattern. The new generation's optical and mechanical design and the correlation method of signal processing uses the same fundamental principles as the NA3003.

A further design strategy was to utilise design concepts proven successful in the TPS instruments. The digital level design intergrated the Camcorder battery concept (including charger), display and keyboard layout of the TPS700 and a data storage and format structure based on the TPS700.

The design considerations provide benefits for the user. The current digital level staff range can be used in combination with the new Leica state-of-the-art products. Users who are familiar with the TPS700 instruments also benefit from a reduced learning curve.

## 2.2 The instrument from outside



Figure 1 The Leica DNA03.

The most conspicuous element of the DNA03/DNA10 is the front panel, which accommodates an 8-line LCD display and a keyboard with full alphanumerical capabilities.

On the left hand side is the compartment for the PCMCIA card, used as a data saving device. Horizontal drives are positioned on both sides of the instrument.

The position of the measure button on the right hand side of the instrument was moved to the centre of the instrument body in order to minimise the impact on the instrument when pressing the button.

## 2.3 The instrument from inside

The DNA03 and DNA10 use a magnetically damped compensator based on the model used in the NA3003. Due to the none-magnetic characteristics of all parts of the pendulum system the magnetic field of the earth does not influence the compensator.

Improvements made in regard to the circular level were incorporated in the DNA03/DNA10. Its platform was shifted closer to the telescope and close to the bottom of the telescope housing. The location guarantees a higher stability of the bubble under the influences of temperature changes.

The staff image is captured by a new high sensitivity CCD linear sensor that is sensitive in the visible light spectrum. The incoming light is split into a portion for the visual measurement (visual path) and a portion for the electronic measurement (CCD). The electronic measurement uses the spectral range, which is partly within the visible light spectrum. The light from incandescent or halogen lamps is suitable for the staff illumination when measuring in dark conditions.

### **3. THE MEASUREMENT SYSTEM**

#### **3.1 The events of a single measurement**

The process of the single measurement consists of three events: 1) waiting, 2) exposure, 3) coarse and fine correlation.

- 1) The waiting time of 1sec is necessary to allow the compensator to set properly.
- 2) The total exposure time lasts from 0.5sec (normal conditions) to 1sec (worst case). Within that period up to 36 scans ("single shots") depending on the scan exposure time are performed.
- 3) The typical time for the coarse and fine correlation is about 1.5sec.

The resulting typical time for a single measurement is 3sec. In the repeat mode the measurement time for the measurements performed after the first measurement lasts one second less as the waiting time for the compensator is skipped.

#### **3.2 The field of view of the electronic measurement**

There is a different field of view for coarse and fine correlation. For the coarse correlation the full field of view of  $2^\circ$  is required in the distance range up to 50m. The field of view is reduced in two further steps to a final angle of  $1.4^\circ$  at the maximum distance of 110m. For the fine correlation a typical field of view angle of  $1.1^\circ$  is used. When measuring at the staff end then that window is shifted into the visible code section.

As a consequence, any coverage in the fine correlation window should be avoided.

#### **3.3 The measure modes**

The measure modes implemented in the NA3003 were well accepted by the users. These modes are also found in the DNA03 and DNA10. They consist of the single measurement, the mean mode, the median, and the mean mode with predefined standard deviation. A new mode has been added, the "repeated single mode" which can be compared with a tracking mode but with each measurement being a full single measurement. This mode allows the user to investigate the tendency of a measurement situation and to stop and accept the last measurement when the conditions have stabilised.

### **4. DISPLAY AND KEYBOARD CONCEPT**

#### **4.1 The display**

The DNA03 and DNA10 are the first digital levels that are equipped with a display with the dimensions of 8 lines at 24 characters. The display is identical to the one of the TPS700 instruments. In order to have similar user guidances through all the Leica product ranges it was

attempted to get the user guidance as close as possible to the TPS700 instruments but still leaving room for improvements and applying typical levelling features. Like the TPS instruments, the DNA03/DNA10 display text is offered in different languages.

The advantages and the strength of the display is demonstrated on the example of the measurement display which is the display that comes up during a running measurement:

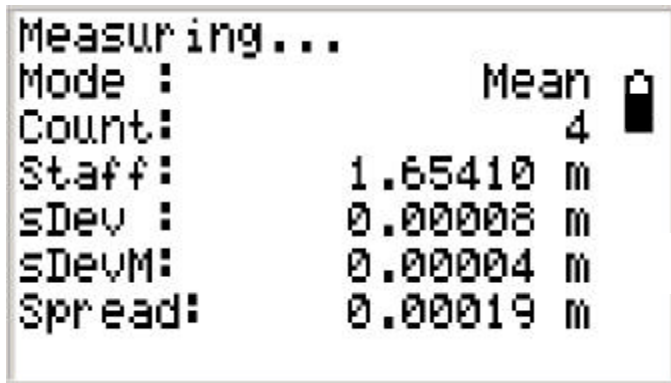


Figure 3  
The measurement display.

All the relevant information such as count of measurements, actual staff reading, standard deviation of the single measurement as well as of the mean, including the spread of all repeated measurements, are summarised in one display view.

## 4.2 The keyboard

The keyboard structure is similar to the TPS700 series.



Figure 4 Keyboard of the DNA03 and DNA10.

Entry and navigation keys form the main block. The function keys are located on the left side of the keypad. The PROG (MENU) and USER (FNC) keys have the same functionality as in TPS700.

Differences from TPS700 include: ESC is on a single key for fast exiting of the displays and DATA is on a single key for immediate access to the data manager.

## 5. DATA STORAGE CONCEPT

The data storage concept is based on the TPS700. The measurement data is automatically stored in a binary format in an internal memory with a capacity of appr. 6000 measurements or 1650 stations (Backsight - Foresight). In addition the data that is stored in the internal memory can be copied on a PCMCIA card. The data that is copied to the card is converted into a read-

able XML or ASCII-type format that the user can select from a choice of customisable data formats. Direct storing of measurements to the card is not possible. Storing the data on the card is useful for saving the data on a personal storing device or for easy transportation of the data to the office environment.

Users who prefer to work without card can download the data from the internal memory via the serial interface RS232 to the PC by using the Leica Survey Office program. Again the user has the choice to select in which format the data is to be converted into. The Leica Survey Office program also allows the user to download or upload files from and to the PCMCIA card when the card is inserted in the instrument.

The PCMCIA card is also useful for storing the coordinates of fixed or setting-out points and of code lists. The content of such files can be downloaded to the instrument when needed in the field. The system is compatible with Flash and SRAM cards with a capacity not exceeding 32MB.

## 6. ON-BOARD APPLICATIONS

### 6.1 The "Measure & Record" measure program

Like the TPS instruments, the "Measure & Record" program is also implemented in the new digital levels. When the DNA03 and DNA10 are turned on the instruments will immediately be ready for measuring a backsight or simply measuring a staff reading repeatedly. Due to the large display all the necessary information of the measurement can be shown on one screen, which is very comfortable as toggling to other displays is not necessary anymore.

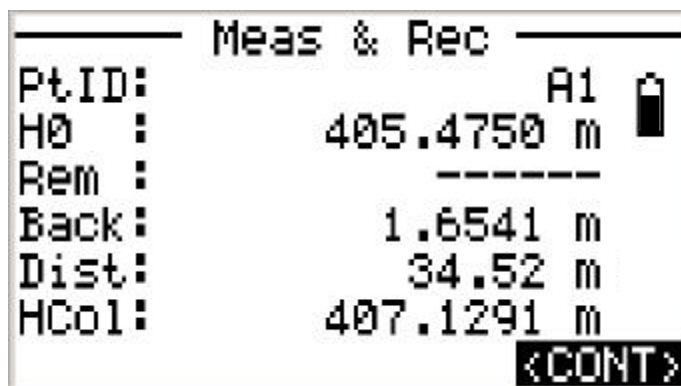


Figure 5

The "Measure & Record" display.

Information that refers to a staff reading type (here the Backsight) is immediately updated. Here it is the height of collimation (HCol).

The user has time to look at the data until he or she decides to continue.

### 6.2 The line levelling applications

Both the DNA03 and the DNA10 have the four established line levelling applications BF, aBF, BFFB and aBFFB built in. These measure programs are, to a large extent, automated. In the normal case hardly any keys have to be pressed more on the keyboard as the displays are automatically updated.

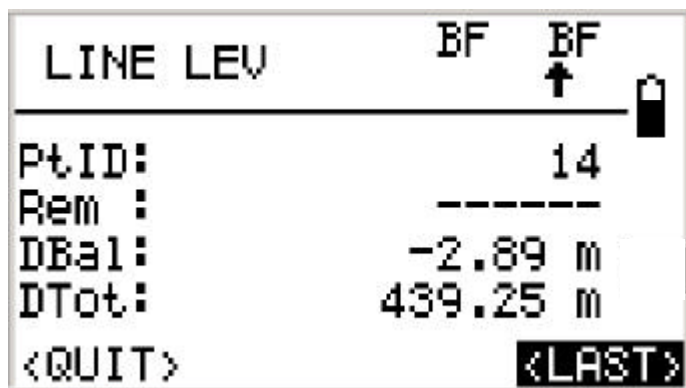


Figure 6  
The "BF" line levelling display.

The marking of the line levelling method in the top line symbolizes the pair of stations. The arrow indicates the actual station order (odd or even number) and the observation to be measured as next one (B or F). The station indication is useful in order to end the line levelling with an even

station number.

The distances balance value informs the user about the total distance difference between Back-sight and Foresight distances.

### 6.3 The coding

The DNA03 and DNA10 offer three possibilities for storing codes. There is the free code, which can be stored at any time before or after measurements. The Quick code function as a second option is based on a code list, which is stored in the instrument. That code is stored either before or after each measurement depending on the setting but always together with the measurement in a one step operation. For launching the measurement the user has to press a two-digit number on the keyboard. A third option is to store a point code as a remark before the measurement is started (see the "Rem" field in figure 6).

## 7. PERFORMANCE

### 7.1 Measurement accuracy

An essential question is how accurate the measurements are over the total staff reading range 0m to 4.05m and combined over the total distance range 1.8m to 110m. With modern simulation software tools it is possible to simulate a mass of random measurements in the whole measure area for example in order to test the performance of the coarse and fine correlation algorithms. The results of such a simulation are shown in the figure 7.

The upper graphs show the spread of the absolute height and distance errors of 1000 measurements randomly distributed in the whole measure area. The lower graphs show the running mean deviations from the true value, each of them with 100 measurements per point.



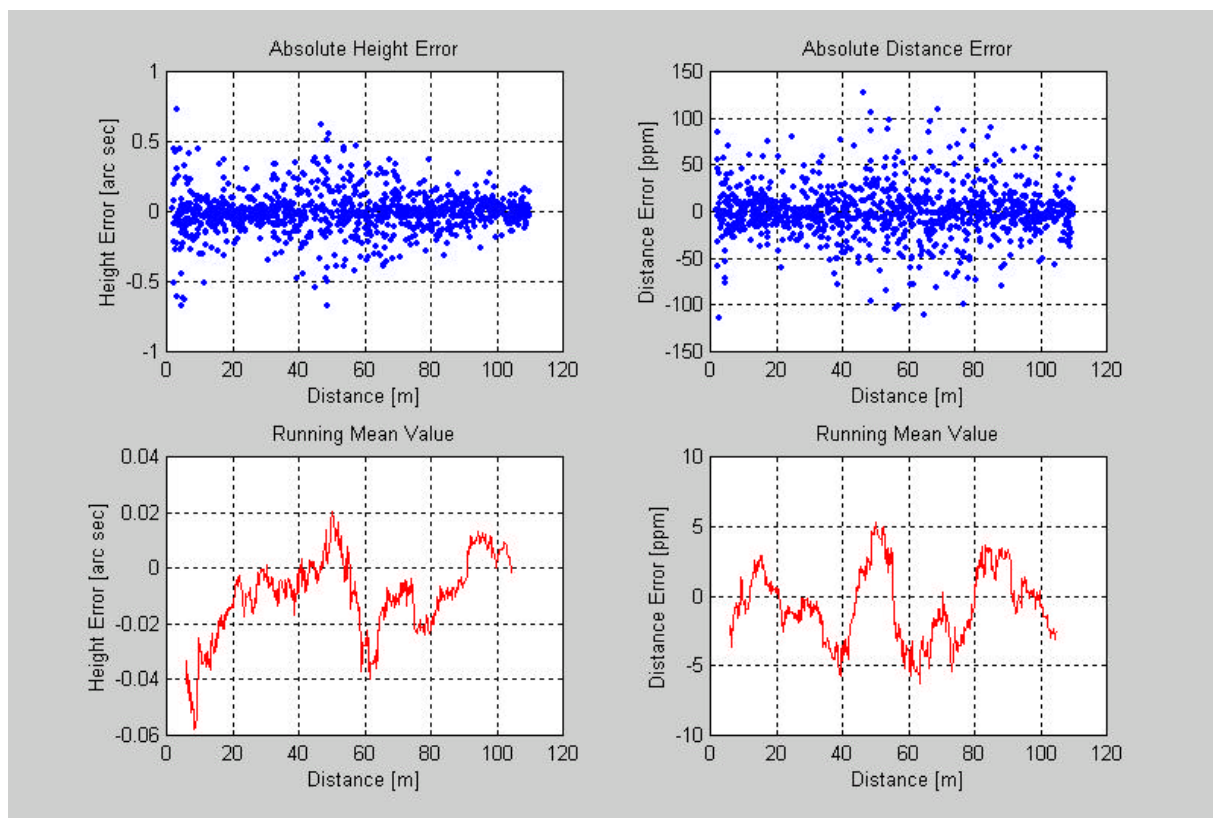


Figure 7 Performance of the correlations with simulated measurements.

The running mean values show the good performance of the correlations. For example the mean deviation of the height reading at 50m distance is +0.005mm (+0.02") or -0.003mm at 10m distance (-0.06"). The mean deviations of the distance measurements are in the range of less than 1mm, for example -0.3mm at 60m (-5ppm).

## 7.2 Performance under poor light conditions

The distance range compared to the NA3003 is significantly improved when measuring to illuminated staffs in the dark.

The high sensitivity of the sensor is also responsible for the stable measurements of the DNA03 and DNA10 when measuring in poor light conditions, for example at dusk. A comparison test with NA3003 done by Gasser and Moser (2001) is shown in figure 8 and 9.

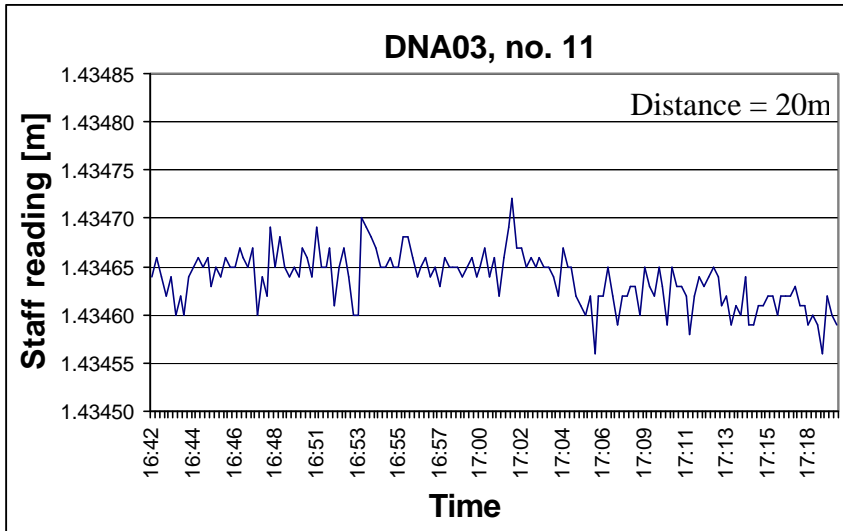


Figure 8  
DNA03 single measurements at dusk.

The DNA03 measures over a long time interval; the spread remains stable even under extremely poor light conditions.

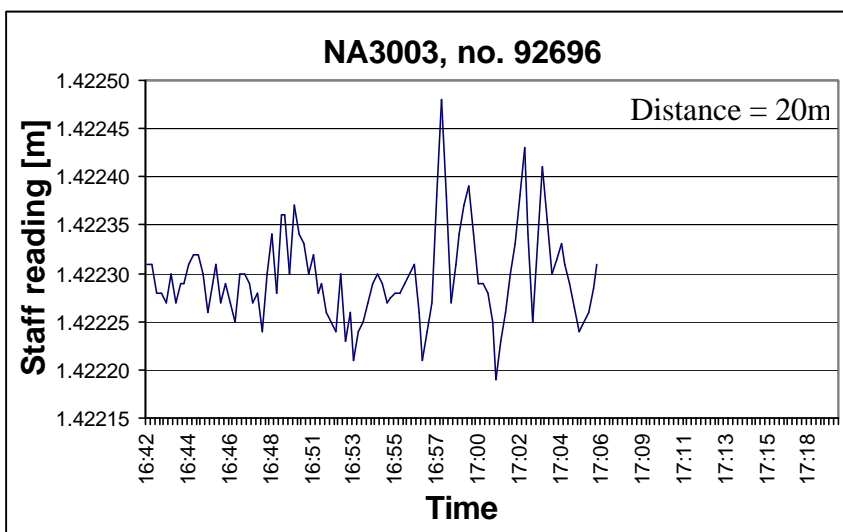


Figure 9  
NA3003 single measurements at dusk.

The NA3003 stops earlier; the spread increases while light conditions get poorer, however remains within a tolerance of appr. +/-0.1mm.

## 8. DATA FORMAT CONCEPT

The DNA03 and DNA10 store information like: job, line, measure mode, corrections, start point, measurement, target point, station results and more. A measurement block consists of up to 16 values; among them is also the correlation coefficient of the fine correlation to provide a quality indication of the measurement.

The instrument can convert the data into different formats. The XML, GSI-8 and GSI-16 are implemented as standard formats. In addition up to three user-definable formats can be loaded into the instrument. The user formats offer great flexibility for outputting data. Even fieldbook-like outputs can be produced directly from the instrument (see the following samples for the BF method in figures 10 to 12).

```

Line: 1          / BF
=====
Date: 05.12.2001 / Time: 10:03:22
Staff1: ----- / Staff2: -----
=====
| PointID | Backsight | Intmdt | Foresight | delta H | Distance | Point Hgt. |
-----|-----|-----|-----|-----|-----|-----|
| Start PtID | | | | | | |
| 1 | | | | | | 0.000 |
| | | | | | | |
| 1 | 1.61076 | | | | 28.77 | |
| 1 | | | 1.51306 | +0.09770 | 30.61 | 0.098 |
| 1 | 1.55976 | | | | 13.49 | |
| 2 | | | 1.57026 | -0.01050 | 11.57 | 0.087 |
| 2 | 1.64827 | | | | 18.89 | |
| 3 | | | 1.59179 | +0.05648 | 18.76 | 0.144 |

```

Figure 10 User format: Basic style

```

Line: 1          / BF
=====
Date: 05.12.2001 / Time: 10:03:22
Staff1: ----- / Staff2: -----
=====
| PointID | Backsight | Fore/Intm. | Rise | Fall | Distance | Pt.Height |
-----|-----|-----|-----|-----|-----|-----|
| Start Point | | | | | | |
| 1 | | | | | | 0.000 |
| | | | | | | |
| 1 | 1.61076 | | | | 28.77 | |
| 1 | | 1.51306 | +0.09770 | + | 30.61 | 0.098 |
| 1 | 1.55976 | | | | 13.49 | |
| 2 | | 1.57026 | + | -0.01050 | 11.57 | 0.087 |
| 2 | 1.64827 | | | | 18.89 | |
| 3 | | 1.59179 | +0.05648 | + | 18.76 | 0.144 |

```

Figure 11 User format: Rise-and-Fall style

```

Line: 1          / BF
=====
Date: 05.12.2001 / Time: 10:03:22
Staff1: ----- / Staff2: -----
=====
| PointID | Type | Staff | Distance | Pt.Height | Remarks |
-----|-----|-----|-----|-----|-----|
| 1 | Back | 1.61076 | 28.77 | | ----- |
| 1 | Fore | 1.51306 | 30.61 | 0.098 | ----- |
| 1 | Back | 1.55976 | 13.49 | | ----- |
| 2 | Fore | 1.57026 | 11.57 | 0.087 | ----- |
| 2 | Back | 1.64827 | 18.89 | | ----- |
| 3 | Fore | 1.59179 | 18.76 | 0.144 | ----- |
| 3 | Back | 1.62498 | 19.53 | | ----- |

```

Figure 12 User format: List style

## 9. DATA POST-PROCESSING

LevelPak-Pro is the latest generation of software for importing, processing, reporting and exporting Leica digital level data. LevelPak-Pro can import level data from DNA03 and DNA10 in the new XML format. It can also support GSI formats, making it compatible with the previous generation of Leica digital levels. This data is then stored in a powerful data base. Once

imported the user can view and edit level observations and job details. Level lines can be easily processed using the "by station" or "by distance" techniques with just a click of a button.

In LevelPak-Pro the user can create reports from, or export, the processed data. Customisable reports are generated of Level Lines and Point details. In addition a "Summary" report containing the all the processing parameters and processed heights is produced. Using the PCMCIA card, the user can then export the processed points to the DNA03/ DNA10 and assign these points to a specific job.

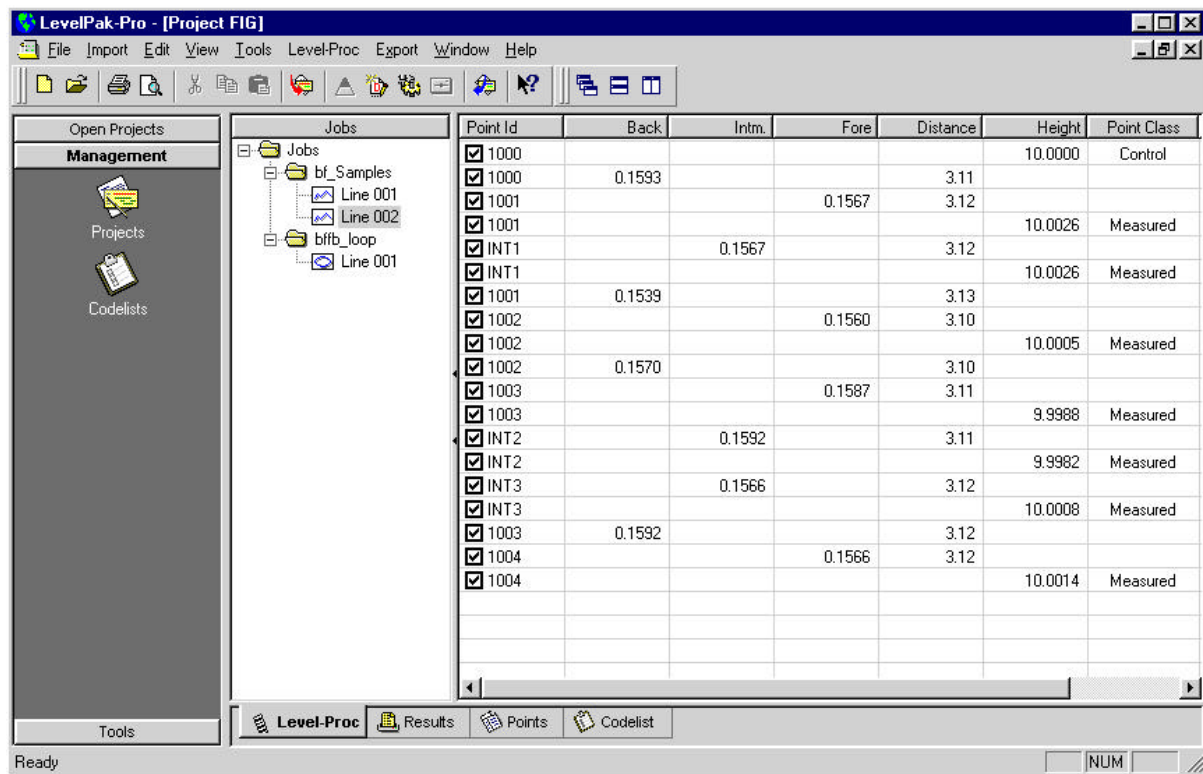


Figure 13 LevelPak-Pro, View of a level line.

## 10. CONCLUSION

The new Leica digital levels DNA03 and DNA10 open new possibilities, particularly in regard to the performance of the measurements. Due to the large display, which is unique for digital levels, and the integrated on-board applications operating of the instrument is very comfortable. With the flexible data formats there are many possibilities for different data structures. The new post-processing software LevelPak-Pro ensures a fluent data flow from the field data to final heights.

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## BIOGRAPHICAL NOTES

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