

Leica Builder 503 Total Station

(Also refer to either the User Manual or How-To. The following is the most common setup.)

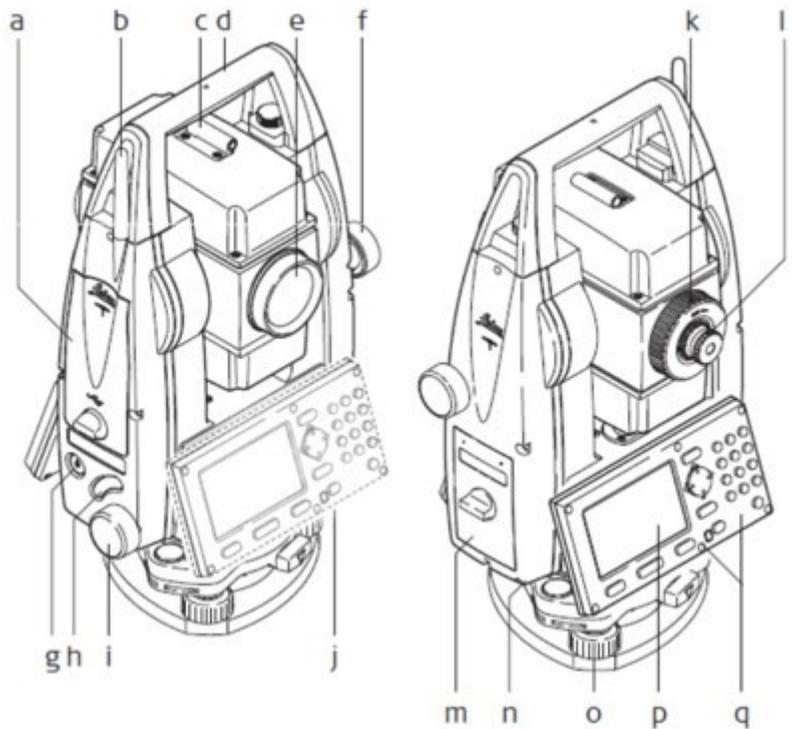
Before Going in the Field

Make sure the batteries are charged, one is installed in the door on the left side. The battery compartment will hold different size batteries, type GEB 211 Li Ion 7.4V. Probably should make sure a flash drive is on the right side.



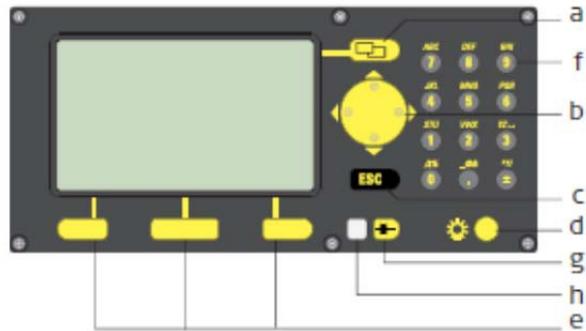
1. Tour of the Instrument

- a) Compartment for USB memory stick & USB cable ports
- b) Bluetooth antenna
- c) Alignment sight
- d) Detachable carrying handle
- e) Telescope with integrated EDM (electronic distance meter)
- f) Vertical control knob
- g) On/Off key
- h) Switch key – we probably don't need to use this:
 - Top: laser pointer toggle
 - Bottom: switch between Measure/record, All in 1, and Measure
- i) Horizontal control knob
- j) Optional second keyboard (not on our unit)
- k) Telescope focusing ring
- l) Eyepiece; focusing graticule
- m) Battery holder
- n) Serial interface
- o) Footscrew
- p) Display
- q) Keyboard



Interface and Settings

- a) Page key: Changes tab between CONFIG, TRANSIT, PROG and DATA
- b) Navigation key
 - Moves focus onscreen
 - Starts edit mode for fields
 - Control the input bar
- c) Escape key
 - Leaves the current menu
- d) Light
- e) Function keys (work with choices shown onscreen)
- f) Keypad
- g) EDM key
 - (short): access EDM settings
 - (long): toggle between red-dot (reflectorless shooting) and prism
- h) LED flashes once if EDM setting is changed, or when measurement is taken:
 - White: EDM prism mode
 - Red: EDM red dot mode (reflectorless)



Prism Settings

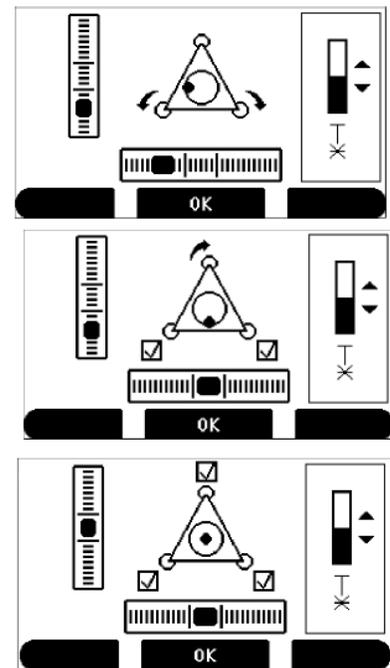
Press the EDM key  *short* to access this (not in TRANSIT, PROG or DATA mode)
When the instrument is turned on, it will blink either white for prism mode or red for red dot (reflect off anything) mode. These can be changed by pressing this key.

Using the Seco Prism with a -30 mm offset:

For an offset off -30 mm, what we need to do is to set the prism constant to -30 mm, by using the EDM button to go to EDM Settings, to get to the Prism Constant setting, and change that. There's another setting for Prism Type, but we set that to User, since non-Leica prisms are not shown on the list.

2. Initial Setup: Leveling

1. Set up the tripod, either over a known point, or anywhere.
 - a. If you are starting from scratch and don't care about getting things into standard coordinates, it doesn't matter.
 - b. If you want to tie to benchmarks, they will just need to be visible.
 - c. If you can set up on a benchmark, this is the most accurate method:
 - a. Setup the tripod itself over the point, getting it somewhat close to level.
 - b. Use the plummet (weight on a string) to position the tripod over the point. The plummet string can go through the 5/8" screw.
2. Carefully attach the total station on the 5/8" screw mount.
3. Close the case to keep out moisture and stuff.
4. Rotate the instrument so that two leveling screws are facing you and one at the back, with the control panel thus parallel to those two front screws, as shown in the picture.
5. Roughly level the instrument using the circular level.
 - a. For side-to-side leveling, turn both leveling screws on the parallel in opposite directions, by turning them both in or both out.
 - b. For front-to-back leveling, turn the single screw at the back.
6. Turn on the instrument with the red button on the right. *Note the color of the EDM light: for prism use it should be white.*
7. If you are mounting over a benchmark, you will need to make sure you are in the right place, by checking the downward-looking red laser pointer, *which turns on when you select Level in the interface.* You may be able to move the instrument around on the tripod surface by loosening the screw a bit and repositioning it over the benchmark. You may also have to move the tripod, and redo the rough leveling.
8. You'll get to a leveling window, and you can follow its directions with the leveling screws. When all three points are checked, it's leveled.



3. Create a New Job with Fixpoints

To use any total station, you need it to know **where it is** and **which direction it's looking**. Section 4 describes how we do this, but what it needs are known coordinates of benchmarks, stakes or other fixed points we can setup on or sight to. We need to get these *fixpoints* into the instrument in some way, which could be either by entering the data manually or importing them from a file we've created previously. This section will mainly assume you're entering these manually from at least 2 known points you've captured previously either with GPS or a previous survey. *Note: to use GPS, you should get these as accurate as possible, using a high-accuracy instrument with at least decimeter accuracy and post-processing or RTK, and get the points as far apart as possible. Ensure that your points are in a Cartesian coordinate system like UTM or state plane, not GCS.*

Why doesn't it know where it is or which direction it's looking?

A total station is far more accurate in determining vertical and horizontal angles than any other instrument (a compass has an accuracy of about 1° while this total station is accurate to 3" of arc, so 3/3600 or 1/1200 of a degree.) So it uses this *relative* angular direction accuracy combined with math to derive *absolute* angular directions. Similarly it uses known positions to determine where it is located with greater positional accuracy than a *global* positioning system (GPS).

Create a new job

First we'll need create a new job DATA|JOB|NEW. Or you can open an existing job with DATA|JOB then  toggle to select the job and OK.

Types of Points: Fixpoints and Measurements

Note that there two kinds of points stored in and used by the total station, *fixpoints* and *measurements*. They are stored with a particular job.

- **Fixpoints:** Data points entered in as coordinates or imported from a file, thus do not include measurements used to derive them.
- **Measurements:** These are the points you capture using the instrument by sighting to them, deriving horizontal angle, vertical angle, and distance as well as an id which you enter or let the instrument auto-increment numerically from the previous (e.g. pt01, pt02, etc.) You'll be able to export these from the instrument, including their derived position (x,y,z) and all measurements (angles and distance) used to create them. Normally we'll use an IDEX file for this, but if you also save them as a GSI file, you can later import them for a new job, where they will become fixpoints.

Create Fixpoints

In DATA, move toggle  to Fixpoint, then press POINTS to access point management. Choose NEW PT to create a new fixpoint. Enter id, easting, northing and height (elevation). **Important: Confirm the order of easting and northing – sometimes you'll see it displayed northing and easting.** Accept with OK, then continue with more points. *Be very careful entering the data – triple-check your entries; if these are wrong, your whole survey will be wrong!*

Import Fixpoints from GSI files

If you've previously exported a GSI from another job, you can import its fixpoints and measurements as fixpoints for your current job. Note that fixpoints and measurements are exported as separate GSI (or IDEX) files, with the file name prefaced with F_ or M_.

Note the GSI format can be edited in a text editor, but you have to be careful to keep the format consistent, since character position is important. Here's an example, from the field campus:

```
*11...+00000000000BR138 81...0+0000000707982501 82...0+0000004388995119 83...0+000000001678255
*11...+00000000000SWIMX 81...0+0000000707998720 82...0+0000004388913972 83...0+000000001681649
```

One thing to note is there are no field headers, but the code preceding the number tells you what each is:

- 11 point number
- 81 easting
- 82 northing
- 83 elevation

The order of our data is then point number, easting (x), northing (y), elevation, with coordinates in millimeters. So the first coordinate in meters is:

```
BR138, 707982.501, 4388995.119, 1678.255
SWIMX, 707998.720, 4388913.972, 1681.649
```

It's important to pay attention to what's x and y, and one clue is for UTM coordinates the northing (y) will have 7 digits to the left of the decimal place, while easting (x) will have 6. The total station can confuse you, because it seems to vary whether it orders coordinates as northing, easting or easting, northing, so watch for this.

4. Establishing Coordinates and Orientation

For most surveys, we will want to be in an absolute, projected coordinate system like UTM or State Plane. When you set up the instrument, it does not yet have its coordinate position, nor does it know its orientation. There are a few ways to establish this, using either permanent or temporary control points. You will need at least two, unless you also have a distant feature for which you know direction accurately. Permanent and monumented control points are called *benchmarks*, and may have been placed by geodesists as a brass plate, or as a surveying benchmark nail with an aluminum tag, or a rebar established by GPS or previous survey hammered into the ground, or maybe are a part of a concrete structure like a bridge or building; in any event, you need to know their position in the given coordinate system.

Option 1: Setting up over a Control Point and Sighting to One Point

This is the most accurate method, but is a bit tricky to set up, mainly in that it requires that you be able to set up directly over a benchmark. See: *User Manual* 9.3.2 “Establish Coordinates – Over Known Point”, or *How to Guide* 1.4 “Set Up over One Known Point with Second Known Point”.

1. Level the instrument over the fixed point/benchmark as described above.
2. Use the menu button to go to **PROG**, press **SETUP**, select **Coordinates...** and **Over Known Station...**
3. Enter Height of the Instrument (hi), after measuring this with a tape – there’s a mark on each side, on the door of each compartment; and the Height of the Rod (hr), which for the little rod in the case is 1.3 m and for the prism pole is 1.65 m if unextended, then press OK.
4. Either select a station if you have one stored, or use NEW PT to enter its id and coordinates.
5. Select Orientation Method, either as a Manual Angle Setting (maybe from a compass, though this is not very accurate) or a Known Backsight Point. We’ll assume we have the latter.
6. Select Backsight Point, OK, Measure. Message:

Station and Orientation
will be changed and set
NO – NEXT PT – YES

8. Alternatively, if you know an accurate azimuth to a distance point, use “Manual Angle Setting” for a backsight.
7. If you do another point and measure it, again only the angle will be measured, and an angular error will be displayed. If you’re not ok with it, you can REDO. Note that you can toggle between ANG and DIST errors. Once you OK this, you’ll again have the choice to add NEXT PT or YES to accept the setup. Then you’re ready to survey points.

Option 2: Setting up “Anywhere” by Sighting to Two or More Points

This is the easiest method, and lets you put the instrument where you want it, as long as you can sight to two or more control points. See: *User Manual* 9.3.3 “Establish Coordinates Anywhere”; *How to Guide* 1.3 “Set Up Anywhere with Given Coordinates”)

1. Set up within sight of benchmarks.
2. PROG, SETUP, Coordinates..., Anywhere...
3. Enter hi & hr, OK
4. Select First Point: Either enter data, or select from saved points, OK
5. Measure (and Record) First Point[do we really need to record?]
6. Select Second Point, Measure & Record
7. With 2 points, a plausibility check will be displayed, based on the distance. At this point, you can say Yes to be done with the setup, No to measure the point again, or NEXT PT to use another point to improve the accuracy.
8. If you three or more points, you’ll get an assessment of accuracy of each of the points. Once you OK, you’ll again have the option of OK to accept or REDO.
9. A message will be displayed that says

Station and Orientation
STANYAN005 (or some name)
will be changed and set.
NO -- NEXT PT -- YES

10. Once you’re done, you’re ready to start recording points: Use **APPL** to select **As Built...**

In either case:

Always shoot the backsight again as measurements!

This can save your butt later on if something goes wrong.

5. Surveying Points

The best program to measure XYZ points is **As Built**. In contrast, **Layout** would be for placing points at known locations, like you might do if you were building something from a plan. **Angle & Distance** would be used if you want to just use the readings of horizontal & vertical angles and distance.

To survey new measurements, you'll need to be in PROG mode with the As Built application, and have everything correctly set up (coordinates of the instrument and backsight direction set) to start surveying. You can either use All in one (measure & record) or set to Measure to first measure, then after comparing the id and such with your field notes, press Record to record the readings.

Prism vs. other points (like ground points):

While the prism readings are the most accurate, a handy way of adding a lot more points is to use the red-dot mode, which allows you to shoot off any reasonably reflective surface – it bumps up the laser power to do this. Note that in contrast to shooting off a prism, there's no rod so the rod height should be set to zero; this should be done automatically by the instrument, but check to confirm.

EDM Type: prism or red dot. I'm assuming that red dot refers to any non-prism points. Press the EDM

key  long to toggle between red dot and prism, or press it short and do the same with a menu selection. *The rod height should be set to 0 for red-dot points.*

Setting the prism (rod) height during a survey:

You may need to do this during any survey, such as when you need to extend the rod for visibility. You'll also want to use this if you go to red-dot. While surveying, go to **SETUP**, then **Height** to change any setting, including **hr** height of the rod. *Forgetting to change this is a common blunder, so make sure you're keeping this set correctly.*

Moving the instrument

To move the instrument, *you'll need to have a place to move it where you can determine its position and direction*. This could either be (a) over a known station, or (b) anywhere you can shoot to 2 known stations. This process is covered in the earlier section, **4. Establishing Coordinates and Direction**. You're just doing this again at a new location, requiring at least 2 monumented (at least staked) known points stored in the total station. So make sure you have these 2 points! (Don't let Tinkerbell die!)

1. First set up at least two control points. One could be where your instrument is currently to backsight to, and the other could be where you want to move the instrument. *Make sure you know the ID of both so you can accurately select them when you set up, and write this down in your field notebook; you should write down the coordinates of the instrument location to make the backsight accuracy check easier*. Also, make sure you will be able to sight back from the new location to the previous; sometimes sighting one direction works where the opposite direction does not. Alternatively you could create at least 2 points to sight to from the new instrument location using resection ("Set up anywhere"). Each point should be staked and probably flagged.
2. Turn off and unmount the instrument, and carefully store and move it in its backpack or case.
3. Move the tripod and instrument to the new instrument location, and set up the tripod over the new known point, using the plummet, etc. Then set up the instrument over the point and level it using the laser plummet. If too far off – maybe beyond a centimeter – you'll need to reposition the setup until it works.
4. Measure the instrument height (h_i) with a pocket rod or survey tape.
5. Use PROG|SETUP|Coordinates to set up over a known point, selecting the correct id, and entering the new h_i (height of the instrument) and h_r (height of the rod).
6. For Backsight, choose known backsight point, and focus on it and shoot. If you have multiple backsight points, choose a new one, but when you're done, select Yes and wait a few seconds to get back to the survey measurements screen.
7. At this point, you're ready to start surveying new measurements, but first we'll check the accuracy by shooting the backsight as a new point and comparing it with the coordinates already stored for the point:
 - a. Shoot the backsight point as a new measurement. Record it and also write the coordinates down in your notes.
 - b. Compare the new backsight point coordinates with what you previously had recorded for that instrument point. If you wrote down the coordinates of the previous instrument point, you can simply compare these. If not, you can look it up:
 - i. Go to DATA and toggle  the type to Measurements.
 - ii. Press POINTS to access point management.
 - iii. Scroll through points with the toggle to find the backsight point previously created.
 - c. If the points come within your survey tolerance (maybe 0.1 m under difficult conditions), proceed. Otherwise figure out what went wrong (wrong id? wrong rod or instrument height?).
8. To continue the survey, go to PROG.

6. Stream Survey

A total station is an excellent instrument for a survey under riparian cover where GPS is ineffective. We just need to get it oriented and into a coordinate system (which may be a challenge due to GPS benchmarking limitations). We can use a prism & pole to survey streambed points and control points, and then the reflectorless mode for many details. *Make sure to keep track of point ids, and record any data associated with the correct point is, also labeled on a sketch, which will later become your map.*

You'll probably need to move the instrument, and for stream surveys, this will probably require surveying to the next instrument location (carefully noting the id of both your current location and the new location), moving the instrument and backsighting. See the discussion on "Moving the instrument" on the previous page, in section 5.

The modes you may want to know about:

- *User Manual* 10.3 "As Built". PROG/APPL/As Built...
- Use Pt: for point id. Probably easiest to use just one prefix for the project, and let it increment a number. It's not very easy to change this for different feature types.
 - In your notebook: *Carefully* record info you'll need for each point, probably the type of point (thalweg, terrace, left bankfull, etc.), and include the point in your sketch.
- EDM key  long to toggle between prism for control points and streambed (e.g. thalweg) points, and red dot for reflectorless points. Go to SETTINGS ... Height to change the rod height. *Note that you can't shoot red-dot points through water because of refraction effects, so streambed points need to be prism shots.*
- Measure and Record Mode. Might initially set to Measure/Record, to make sure you have the id numbering system down. Then after you're comfortable with it, change to All in 1.
 - To measure a tree and get the center point, use a prism, with this set to Measure/Record: The distance is measured first at the right distance (on the side of the tree), then move to the middle of the trunk facing you to click Record – only then is the angle recorded.
 - Might also be used to measure the corner of a building.

7. Saving your data and reading into Excel

The instrument can save both its data in various formats to a USB flash drive you can use to transfer the data to your computer.

1. From the total station, export the data to the flash drive, using **DATA: IMP/EXP:**
 - Exchange Mode: **Export**
 - Data Type: **Meas.&Fixpoints**
 - Job: Select the job you want to export (*it won't necessarily be the recent one*)
 - Format **IDEX...** (to import later, you'll also want to save a GSI file)
2. Shut the total station down, and remove the flash drive.
3. Copy the .idx files from the flash drive to your computer.
Two comma-delimited files will be saved in the Data folder: F_name.IDX and M_name.IDX, where "name" is the job name, and they can be read into Excel as comma-delimited. Note that the file will include not only the xyz points (in the DATABASE section), but also the raw angle (Hz & Vz) and slope distance (SDist) readings in the THEODOLITE section.

Reading data into Excel

The IDEX format data is in text format, so can be edited with a text editor. However, it's going to be most useful after bringing it into Excel, and that's going to require a bit of text editing (or programming a script, but it's pretty easy to do the text editing), then there's some work in Excel to make it work:

1. Open the document named M_?????.IDX, where ????? is what you named the job, in a text editor like Notepad, Notepad++, TextPad. Not Word.
2. Delete the section called HEADER, and all the way up to the first field name, probably called PointNo. Then delete the closing parenthesis at the end of the first field name. Thus your first line should probably be:
`PointNo, PointID, East, North, Elevation, Code, Date, CLASS`
3. Delete all the stuff at the end of the file after your list of points. This might start with "THEMINFO" and include the sections "METEO" and "THEODOLITE". You basically want to end up with a single line of fields and x lines of coordinate data.
4. Save the file as ending with .csv.
5. Open the file in Excel.
6. The E, N and Z values won't work directly as numbers until you convert them from text. They will also have spaces and maybe hidden characters that prevent them being used, so the best solution is to create a new column of E, N, and Z values, using the function =VALUE(CLEAN(C2)) for E, =VALUE(CLEAN(D2)) for N, and =VALUE(CLEAN(E2)) for Z. The CLEAN function removes superfluous characters and VALUE converts text to numbers.
7. If you want these points to read into **Pix4D** as a CSV file, organize them as id, x, y, z, with the first line being the header line id, x, y, z.

8. Adjusting (calibrating) the instrument

Any instrument needs calibrating, and there is a way to calibrate the total station using a forward & reverse reading process. This is very easy to do, taking about 10 or 15 minutes if you have the right conditions, and should be done:

- Before the first use
- Before every high precision survey
- After rough or long transportations
- After long working periods
- After long storage periods
- If the temperature difference between current environment and the temperature at the last calibration is more than 20°C

The right conditions needed:

- Not too sunny conditions, with stable temperature. If it's sunny, use an umbrella to shade the instrument. 
- Two points 100 m apart, not more than 5° vertical angle apart. You might be able to measure this with the total station of course, or use a survey tape.

The process:

1. Set up the instrument and carefully level it; this will require turning it on for internal leveling as usual. Before starting to work, acclimate the instrument to the ambient temperature, at least 15 minutes from storage temperature.
2. Set the mode to TRANSIT
3. Press ESC for about 5 seconds until SYSTEM INFO is active.
4. Press CALIBR.
5. Press NEW.
6. Press MEASURE to measure to the target.
7. Rotate the target 180° vertically and horizontally to take a reverse reading.
8. (It'll be a bit awkward because the display is on the wrong side, but...) Press MEASURE to measure the same target again and calculate the instrument errors. The old and new adjustment results are shown.
9. Press SET to set new adjustment data, or ESC to quit without setting the adjustment data if you're not happy with it.

