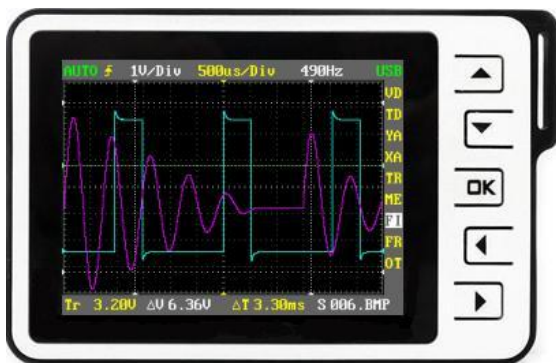
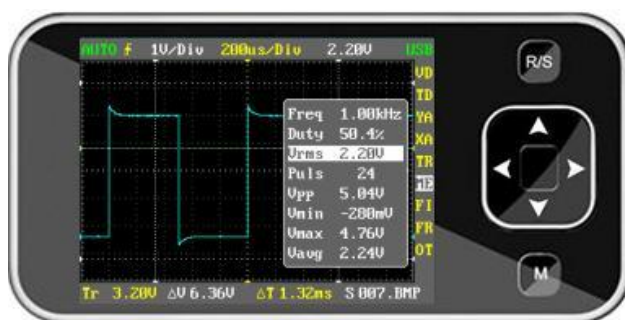


## BenF V3 firmware users guide

### DSO Nano V1



### DSO Nano V2

## Introduction

The BenF V3 firmware has been developed to overcome some of the limitations and issues with the official firmware releases. In particular this applies to improved SD card support, a more advanced no loss sampling algorithm and a more intuitive user interface. The firmware is designed to run on Saeed Studio DSO Nano V1 and V2 hardware. It may or may not work with hardware supplied by other manufacturers.

The firmware is free of charge to individuals in its binary format and is put into the public domain in the hope that it will be useful for others and not only the author. Any use of this firmware is at your own risk. No express or implied warranty is granted for the firmware or related documentation and under no circumstance can the author be held responsible for any direct or consequential damage that may arise from using it.



## Background

The DSO Nano first appeared in the market fall 2009 with a compact attractive design and a very competitive price. Despite its limited bandwidth, the Nano is nonetheless an excellent tool for a range of practical measuring tasks such as basic electronics design/repair and auto/marine diagnostics. The stock firmware however is very basic and despite a few updates along the way, much is still left to be desired. Even with the most recent official 2.5e release, we're not much further than a pretty enclosure with potential. To realize this potential, a complete rewrite of the firmware was needed.

A key feature of any digital oscilloscope is its data acquisition capability and to get this right we need a three phase approach to sampling. That is pre-fetch, trigger-fetch and post-fetch. An acquisition must run uninterrupted until a trigger is found (forever if need be) while the sampling buffer is continually reused in a round-robin fashion. No samples must be lost or disregarded during the entire acquisition cycle. When a trigger is found, its position in the

buffer is marked and acquisition continues until the entire sampling buffer is filled with data. The data from this acquisition cycle is then displayed with the trigger point centered on the screen.

The official DSO Nano firmware is using the simplistic single phase acquisition model. That is start acquisition, stop acquisition and then search for a trigger. An issue with this approach is that the trigger (the data of interest) may arrive while we're not acquiring data and so will be lost. This makes it more or less unfit for digital analysis (e.g. SPI, I2C, RS-232, RS-485) and also of limited use for signals like electronic ignition (narrow, infrequent pulses) and many (if not most) other real life measuring and fault finding challenges.

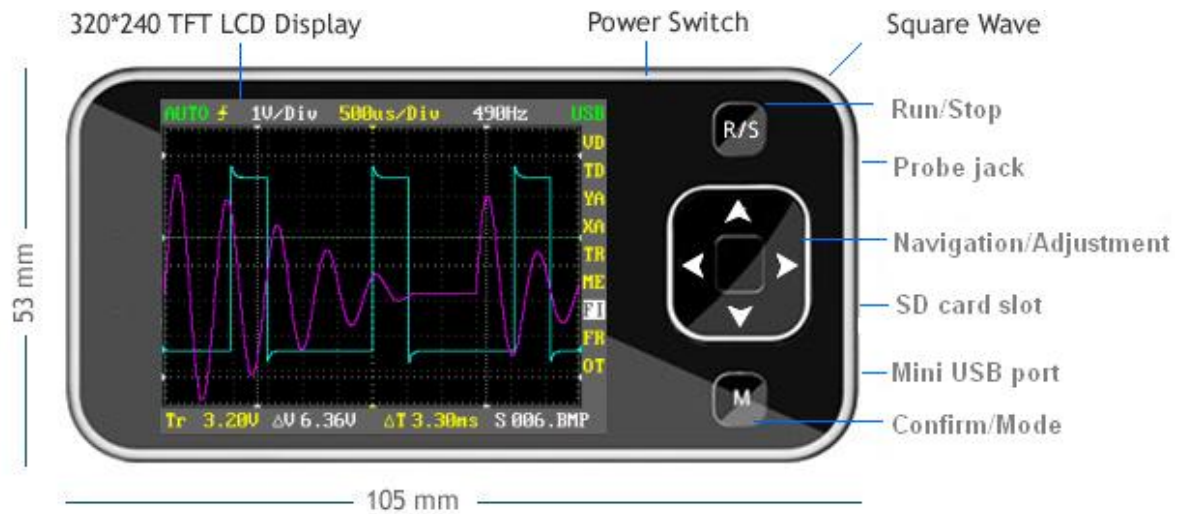
## Feature Summary

Thanks to Sseed Studio and its DSO forum, sufficient information has been provided to allow the stock firmware to be replaced with a custom version. Based in part on the official 2.5e source release, V3 has been developed as a complete new firmware replacement. Fixes and new features include the following:

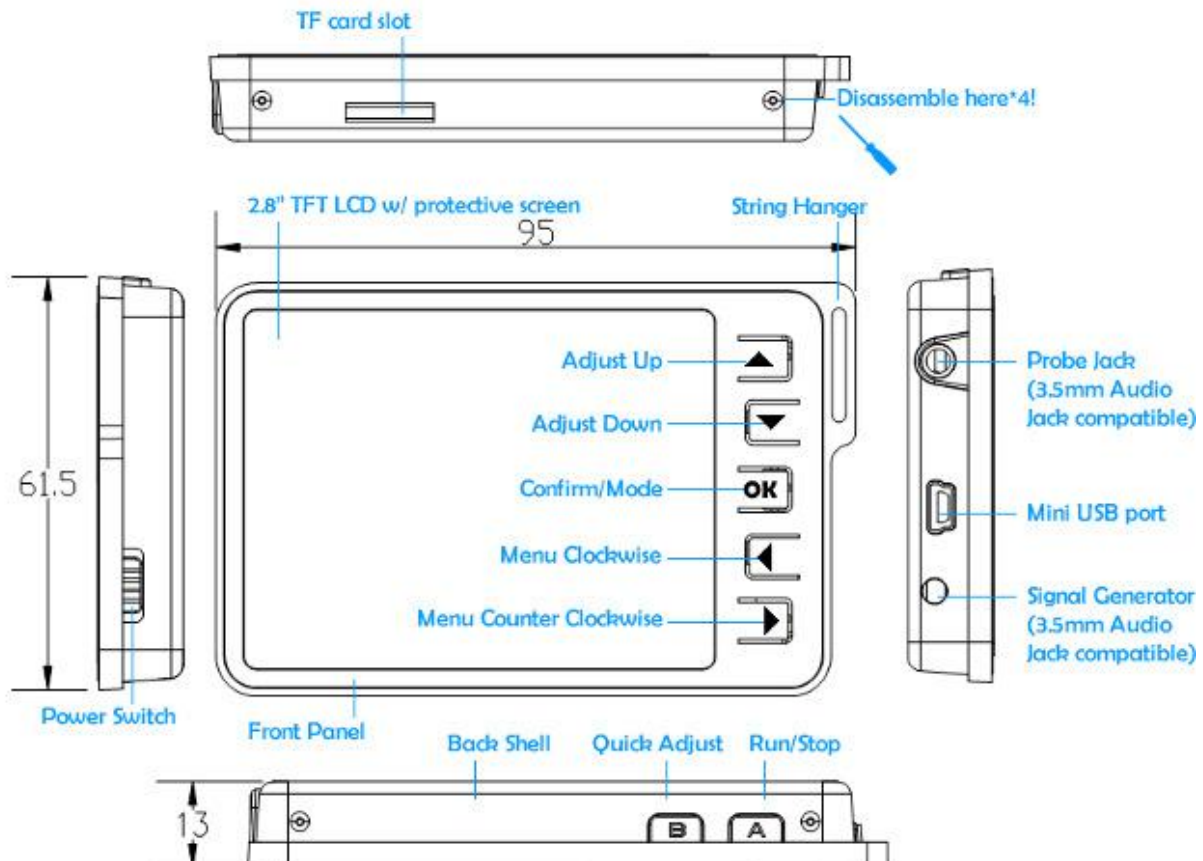
- ✓ Three phase sampling (pre-fetch, trigger-fetch, post-fetch) guaranteed never to miss infrequent events
- ✓ More efficient screen update (10-100 times faster than version 2.5e)
- ✓ Eliminate all flickering and stuck pixels
- ✓ Code is re-written to allow full compile time optimization (much faster and compact code all over)
- ✓ A number of overflow bugs have been fixed (calculations for large time/div settings)
- ✓ Scan has been replaced with a proper continuous real-time scan mode
- ✓ Configuration profiles can be saved to and restored from SD card or flash memory (default power on settings).
- ✓ Wave data (reference waveforms) can be saved to and restored from SD cards
- ✓ Screen capture can be saved to bitmap files on SD cards
- ✓ Snapshots of the full DSO sampling buffer can be exported to XML formatted files for further processing and analysis
- ✓ A number of issues with incorrect SD card support and file handling in 2.5e have been fixed
- ✓ Files and directories will be created by the DSO Nano as needed without having to preload template files
- ✓ Automatic waveform tuning (FIT mode) can be selected with a dedicated key combination
- ✓ The full sampling buffer can be panned left right on the Nano display
- ✓ Waveform resizing and vertical scroll capability (zoom in on area of interest)
- ✓ A more relevant collection of information fields is selected for on screen display
- ✓ A more relevant selection of measurements
- ✓ Simultaneous view of all measurements
- ✓ Use common abbreviations and terminology
- ✓ A completely redesigned user interface (no annoying blinking or color abuse)
- ✓ Automatic ground level calibration and manual gain calibration for all input ranges
- ✓ User selectable grid light intensity level
- ✓ Fine tuning of output frequency to three digits
- ✓ Set duty cycle (PWM) of output frequency from fully-off to fully-on in 1% increments
- ✓ Single button quick select for frequently used functions

## DSO Nano Operation

The following shows the DSO Nano V1. Note the location of keys (buttons) as they are referred to frequently throughout this document.



DSO Nano V2 has a different layout and one additional quick adjust key (B).



V3 firmware is designed to fully support both V1 and V2 hardware. The same feature set is available on both models and operation is identical except for the differences in layout and the additional quick select key found on V2 hardware. Key to function mapping for the two DSO Nano models is as outlined in the following table:

| V1                | V2                | Function   |
|-------------------|-------------------|--|
| <b>M</b>          | <b>OK</b>         | These keys have dual functions. Push and release to open/close popup menus. Push and hold to activate or quick select. |
|                   | <b>B</b>          | Activate or quick select. This key is identical in function to a push and hold of M or OK.                             |
| <b>R/S</b>        | <b>A</b>          | Start or stop data acquisition.  |
| <b>Arrow keys</b> | <b>Arrow keys</b> | Navigate in menus, move markers and select options.  |

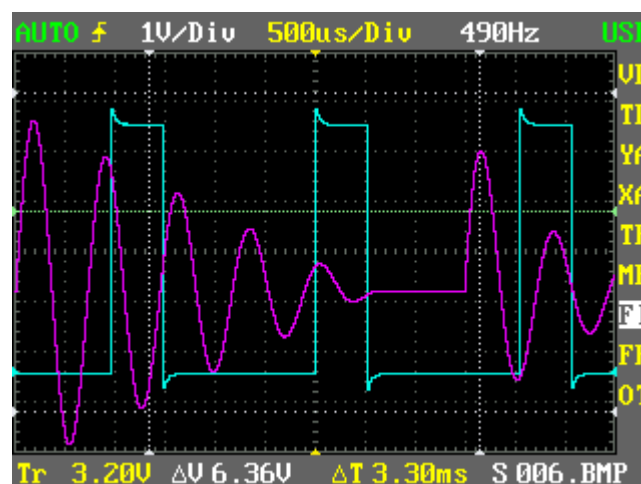
The B key is only available on V2 hardware. DSO Nano V1 users should push and hold the M key to activate functions mapped to this key. V2 users have the option to either press the B key or push and hold the OK key. In the remainder of this document, any reference to the B key can be substituted with a push and hold of the M (V1) or OK (V2) keys.

## User Interface

All menu items are available from the right hand side of the display. These are organized in the following main groups:


| Main group                | Available options  |
|---------------------------|--|
| <b>VD</b> Voltage/Div     | Select voltage (y-axis) scale  |
| <b>TD</b> Time/Div        | Select time (x-axis) scale   |
| <b>YA</b> Y-axis          | Set horizontal cursors, ground position and vertical offset                            |
| <b>XA</b> X-Axis          | Set vertical cursors, trigger position and buffer usage priority                       |
| <b>TR</b> Trigger options | Choose trigger mode, level, sensitivity and kind                                       |
| <b>ME</b> Measurements    | Select or display measurements   |
| <b>FI</b> File options    | Options for reading and writing from/to SD cards and Flash memory, show/hide reference |
| <b>FR</b> Frequency       | Select output frequency and duty cycle (PWM)   |
| <b>OT</b> Other           | Select probe attenuation, options for calibration and grid intensity level adjustment  |

The following image is an example screen capture showing how the above menu categories appear on the DSO display.



The cyan square wave is a trace of the live input signal and the magenta waveform is a static reference waveform.

Information fields on the top and bottom bars include the following:

| Field   | Information   |  |
|---|---------------|--|
| AUTO  | Trigger Mode  | NORM, AUTO, SING, SCAN or FIT (red when paused)      |
|  | Trigger Kind  | Edge rising or edge falling (red if loss of trigger) |
| 1V/Div  | Voltage Div   | Y-axis scaling (red if over/under voltage detected)  |
| 500us/Div   | Time Div      | X-axis scaling                                       |
| 490Hz   | Measure       | Measure value  |
| USB   | Power         | USB or battery level indicator                       |
| Tr 3.20V  | Trigger Level | Active trigger level                                 |
| $\Delta V$ 6.36V  | Delta V1/V2   | Voltage between horizontal cursors V1 and V2         |
| $\Delta T$ 3.30ms   | Delta T1/T2   | Time between vertical cursors T1 and T2              |
| S 006 .BMP  | Info field    | Context sensitive information field                  |

Use arrow up/down keys to move between menu groups. Moving past upper/lower wraps around to the opposite side. Within each group there are one or several sub-commands. As an example YA (Y-axis) have sub commands for V1 Cursor, V2 Cursor, Gnd Pos and Vert Pos. Use the M/OK key to display a popup window with supported sub-commands, up-down to change selection and M/OK to close the popup.

Use left/right keys to change the setting of the selected sub command within the active main group. Use the B key to show/hide cursors, save/load files or reset to a default value.

When input voltage exceeds the range (too high or too low) for the active V/Div, the V/Div information field will display with a red color.

## Trigger modes

In NORM trigger mode, the Nano will continuously search for a trigger and not update the display unless a trigger is found. In AUTO mode, the Nano will search for a trigger as for NORM, but force a trigger after 100ms if none was found. SING works as NORM, but will not initiate a new acquisition cycle after a successful trigger. Use the A key (R/S on V1) to start a new SING cycle.

Choose “Tr. Mode” (Trigger Mode) and press B to activate (or deactivate) FIT mode. In FIT trigger mode, the Nano will automatically identify the type of waveform and adjust the settings to produce a usable display of the input signal. This is similar in function to the Auto push button found on most scopes. The function will track the input signal and continuously adjust trigger level, V/Div and T/Div in small steps until a stable waveform can be displayed. Manually adjusting trigger level, V/Div or T/Div when in FIT trigger mode will revert to AUTO mode. A stable repeating input signal must be present for this function to work well.

Choose AUTO trigger mode and T/Div greater or equal to 100ms to activate real-time scan. In SCAN mode, data acquisition runs continuously and the input signal is progressively

displayed from left to right in real-time disregarding other trigger options. This mode is useful for observing or trending a slow changing signal such as temperature variations.

No trigger found is indicated with the trigger kind (rising/falling) symbol displayed in the color red.

When acquisitions are stopped, trigger mode is displayed with the color red.

Use menu option “Tr.Kind” (Trigger Kind) to select rising or falling edge trigger, “Tr. Level” to set trigger level and “Tr. Sens” to set trigger sensitivity.

## **Panning the full sampling buffer**

Panning left/right is possible through menu item XA (X axis) and sub option “Trig Pos” (Trigger Position). With the left/right keys, you offset the trigger position in steps of 1 horizontal div. When using this technique, you can pan left/right to view the full sampling buffer (more than 13 full screens). When panning left/right, pressing B will reset trigger point back to center. When at center, this key will alternately show/hide the trigger position axis. To stop capture, you can use either SING trigger mode or use NORM/AUTO in combination with the A key (R/S on V1).

Empty areas far left and far right, represent time before and after the acquisition period. The size of these areas will vary between acquisition cycles subject to the position where the trigger was found. Irrespective of empty areas, acquired data will always span the full capacity of the sampling buffer.

Use sub option “Buff Pri” to switch between equal buffer priority mode and post trigger priority mode. In equal priority mode, an even split is used for waveform data before and after the trigger. In post trigger priority mode, maximum buffer capacity will be used for data after the trigger.

Changing buffer priority mode will reset trigger position back to center.

## **Resizing and zooming**

A captured (stopped) waveform can be resized (zoomed in/out) through altering V/Div and/or T/Div. V/Div will either stretch or compress a waveform in the vertical dimension whereas T/Div will allow you to stretch/compress a waveform in the horizontal dimension. This feature applies to data currently in the sampling buffer (static data). Once acquisitions are restarted (using the A key), new data will be sampled using the currently active V/Div and T/Div selections.

Use menu item YA and sub option “Vert Pos” to scroll a waveform vertically. The left/right keys will offset vertical position of the displayed waveform in steps of 1 vertical div. This feature can be used with acquisitions running (live data) or stopped (static data). Pressing B with “Vert Pos” selected, will reset vertical offset back to zero.

Note that sampling an input signal with a high gain (low V/Div selection) may lead to distorted waveforms (flattened top and/or bottom) and inaccurate measurements. This is the case when the input voltage level exceeds the min/max levels for the selected V/Div. The



Nano will check for this condition and display the V/div selection with a red color as a voltage out of range warning. Color will revert to normal (white), when V/Div is increased and/or the input voltage drops to within min/max for the selected V/Div.

## **Profiles and power on defaults**

Preferences can be saved to a micro-SD card for recall or to flash memory to act as power on defaults. First, use the various menu options to configure DSO Nano any way you prefer. Then choose menu FI and sub-option "Save Pro". Choose profile zero (S Flash) and press the B key. This will save all active settings to DSO internal flash memory for use as power on defaults. Profiles other than zero (e.g. S 001.CFG ) will be saved to your SD card and can be recalled with sub-option "Load Pro".



## Measurements

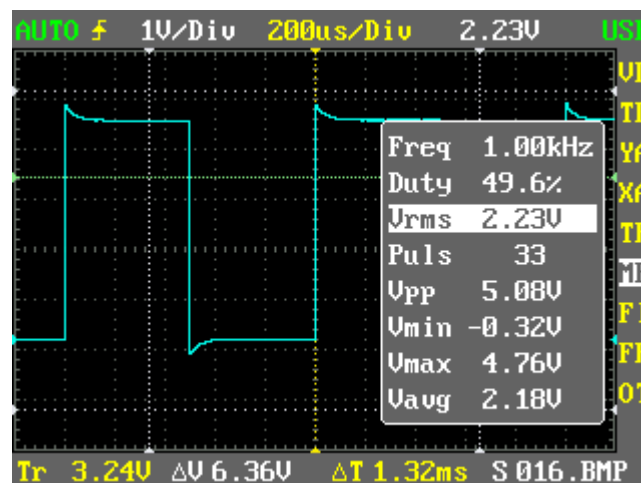
The following is a list of the measurements you can obtain directly from your Nano:

| Name        | AC/DC | Description  |
|-------------|-------|--|
| <b>Freq</b> | AC    | Input frequency measured in Hz   |
| <b>Duty</b> | AC    | Duty cycle as a percentage of high vs. full period relative to <b>Vavg</b> |
| <b>Vrms</b> | AC    | Root-mean-square voltage relative to <b>Vavg</b>                           |
| <b>Puls</b> | AC    | Pulse count (count of low to high transitions, below/above trigger)        |
| <b>Vpp</b>  | AC+DC | Voltage difference (peek-to-peek) between <b>Vmax</b> and <b>Vmin</b>      |
| <b>Vmin</b> | AC+DC | The minimum input voltage relative to ground                               |
| <b>Vmax</b> | AC+DC | The maximum (peek) input voltage relative to ground                        |
| <b>Vavg</b> | AC+DC | Average voltage (DC voltage)   |

Measurement calculations start with identifying the AC part of the input signal. If at least one full cycle is detected, calculations will be restricted to the AC part of the input signal (data between the first and last rising edge). That is, partial cycles at the beginning and end of the acquired waveform will be omitted from calculations. For signals with multiple cycles, calculations will be averaged across all cycles.

If no cycles are detected, calculations will be from all points inclusive, but limited to DC measurements.

Below is an example screen image of a 1.00 kHz square wave input signal with its associated measurements:



The highlighted/selected measurement (**Vrms**) is duplicated on the top bar for reference when the popup is closed.

Select menu ME and press the B key to save a screen capture to your micro-SD card with overlaid measurements.

## Frequency Generator

Output frequency can be set to three digits of precision in the range from 10Hz to 1MHz using menu FR and sub option “Freq Out”. Press the B key to cycle between 1, 2 and 3 digits of precision. Press left or right to alter the highlighted digit.

Duty cycle (pulse width modulation) can be set with sub option “Freq Duty” in steps of 1% from fully off to fully on. Press the B key to reset duty cycle back to the default 50%.

## Calibration

Ground level calibration is automatically handled by the firmware and requires no manual intervention. Gain can be calibrated for each of the DSO Nano’s 6 hardware input ranges as follows:

| Range   | Probe | V/Div from to scale |        | Max voltage |
|---------|-------|---------------------|--------|-------------|
| Range 1 | X1    | 10 mV               | 100 mV | 800mV       |
| Range 2 | X1    | 200 mV              | 1 V    | 8V          |
| Range 3 | X1    | 2 V                 | 10 V   | 80V         |
| Range 4 | X10   | 0.2 V               | 1 V    | 8V          |
| Range 5 | X10   | 2 V                 | 10 V   | 80V         |
| Range 6 | X10   | 20 V                | 100 V  | 800V        |

First step is to configure the DSO Nano for voltage measurement. Select trigger mode AUTO, T/Div 100us and **Vavg** as active measurement. Then choose a V/Div from the range you want to calibrate. Connect the probe to a known DC voltage reference and select sub option “Cal Gain” to start calibration. Then use left/right arrow to adjust gain until you have a **Vavg** reading that match your reference. Calibration data is automatically applied to all V/Div’s within the same range. Repeat the steps for a V/Div within each range to cover all 6 ranges.

Gain is applied as a percentage of full scale (see max voltage above). Pressing the B key will reset calibration data to factory defaults across V/Div’s in the same range.

Use “Save Cal” to save calibration data to FLASH. Calibration data saved to FLASH will automatically be restored when you power on your Nano.

## Files on SD cards

Configuration profiles (preferences), reference waveforms, screen capture bitmaps and snapshots of the full DSO sampling buffer can be saved to files on micro-SD cards. Profiles and reference waveforms can be read back. The files are laid out on the card as follows:

| Directory | File         | Content                                   |
|-----------|--------------|---|
| IMAGE     | IMAGExxx.BMP | Screen capture (write only)               |
| PROFILE   | FILExxx.CFG  | Configuration files (read and write)      |
| REFWAV    | FILExxx.DAT  | Reference waveforms (read and write)      |
| BUFFER    | FILExxx.XML  | Sampling buffer export files (write only) |

The x characters represent sequential numbers in the range 001 to 999 within each category.

When powering on the Nano, naming of new files will start with the first available number (highest file number on the card plus one) within each category. If you select and then write to an existing file, the file will be overwritten without warning. A successful write is followed by an automatic file sequence number increment.

When using left/right keys to select a save to file name, existing files will display with a red color. When selecting a load from file name, choice of name is limited to existing files.

In order to read files back, they must be placed in their designated directory with the proper file extension. It is possible however to change the base name of files from a PC when the DSO is connected via USB (e.g. FILE0001.CFG could be renamed to IGNITION.CFG). When selecting files to load, they will be listed in alphabetical order. Even though your PC's operating system may support long filenames, DSO Nano will only display 8 uppercase characters for the base name.

Writing of files to micro-SD cards is immediate (whatever is displayed when activating write) except for XML files. Writes to XML files will be pending until the active acquisition cycle is complete. When in NORM or SING mode, this implies waiting for a successful trigger and subsequent post-fetch. You can also use the A key (R/S on V1) to stop acquisitions prior to saving. This allows full control of what gets written to the XML file. In SCAN mode however, writes will be immediate also for XML files, but limited to data between the leftmost point displayed and the current insertion point (just before the moving gap). Acquisitions will continue to run in real-time and the display will catch up once the write is complete.

Data written to XML files is fetched directly from the DSO Nano sampling buffer and will generally have a higher precision than what can be obtained from the waveform display. That is, exported XML data points are neither constrained by nor scaled to fit the DSO Nano LCD display.

## **Voltage range and sensitivity**

Through use of the V/Div setting, we can configure the Nano to measure voltage levels in the range from 10mV/Div to 10V/Div with an x1 probe and 0.2V/Div to 100V/Div with an x10 probe. Note that the higher voltage range supported with x10 attenuation is a property of the probe, not of the Nano. That is, the x10 probe will reduce the voltage input to the Nano with a factor of 10 and thus protect it from excessive levels. Choice of attenuation (x1 or x10) should always match that of the probe.

Absolute limits for voltages that can be measured are as follows:

| Probe | V/Div from to scale |        | Sensitivity | Max differential voltage (see text) | DC Input Resistance |
|-------|---------------------|--------|-------------|-------------------------------------|---------------------|
| X1    | 10 mV               | 100 mV | 288 uV      | 800mV                               | 1.02MΩ              |
| X1    | 200 mV              | 1 V    | 2.2 mV      | 8V                                  | 546kΩ               |
| X1    | 2 V                 | 10 V   | 23 mV       | 80V                                 | 546kΩ               |
| X10   | 0.2 V               | 1 V    | 2.8 mV      | 8V                                  | 1.02MΩ              |
| X10   | 2 V                 | 10 V   | 22 mV       | 80V                                 | 575kΩ               |
| X10   | 20 V                | 100 V  | 205 mV      | 800V                                | 517kΩ               |

Sensitivity is the minimum change in voltage that can be detected with the associated range of V/Div's.

Max input voltage is subject to choice of V/Div and ground position on the Nano display. With ground positioned at vertical center (use menu YA and sub option "Gnd Pos"), max range with an x1 probe and 10V/Div is from minus 40V to plus 40V. If we move ground position down, positive max voltage extends towards range max (see above table) while min voltage gets reduced towards zero. Moving ground position upwards will reverse the ratio of min to max levels. Exposure to voltages outside these limits may permanently damage your Nano.

When excessive voltage levels are detected, the V/Div info field will be displayed with a red color. Start new measurements with a high V/Div, trigger mode AUTO and observe the color of the V/Div info field when connecting test leads. Disconnect the leads if the field turns red and/or increase V/Div to a safe level. Note that excessive levels will be reported for triggered data only. Test leads should always remain disconnected whenever the Nano is powered off.

DC input resistance is calculated from the Nano V1 and V2 datasheet's. Probe resistance is not included in the specifications (a passive x10 probe should add a 9MΩ resistor in series with the Nano input).

## Installation

The procedure to upgrade firmware is described in the manual that came with your DSO Nano. A copy of this manual (PDF file) can also be downloaded from the Seeed Studio product pages. You need to follow the steps in this procedure carefully and upload both the **DSO BenF APP v3.xx.dfu** and **DSO BenF LIB v3.xx.dfu** files. The order of upload (LIB or APP) is not significant.

Micro-SD cards must be formatted to use either the FAT16 or the FAT32 file system (NTFS and exFAT are not supported). The newer model high capacity SD cards (SDHC) are not supported. SD cards must support the SPI access protocol. The 2GB SanDisk card supplied by Seeed Studio has been confirmed to work well with the new V3 firmware. The FAT16 file system appears to be more responsive on Windows XP (e.g. when doing a directory refresh from the PC after writing a new image file to the card). This may or may not be the case on other platforms.

SD cards that have previously been formatted with the original Seeed Studio firmware must be reformatted prior to use. A utility program called “sdformatter” (Google for a download site) can be used to fully initialize a card to a known compatible format (sdformatter V2.9.0.5 was used for testing during development).

## XML export files

Below is a condensed copy of an exported XML file showing 5 sample points around the trigger position. The **Profile** section includes information items documenting the active configuration at the time of export. There are also three numeric items in this section, namely **triggerIndex**, **sampleCount** and **timeRange**. The **sampleCount** item is the total number of sample points included in the file (currently 4098 in the V3 firmware), **timeRange** is the time interval in seconds between the first (0) and last (4097) sample, **triggerIndex** is the index of the trigger sample point. Time between individual samples can be calculated as **timeRange** / **sampleCount**.

```
<?xml version="1.0" encoding="UTF-8"?>
<Document>
<Profile>
  <triggerMode>NORM</triggerMode>
  <triggerKind>EdgeRising</triggerKind>
  <triggerLevel>3.76V</triggerLevel>
  <triggerSensitivity>200mV</triggerSensitivity>
  <attenuation>x1</attenuation>
  <voltageDiv>1V</voltageDiv>
  <timeDiv>200us</timeDiv>
  <firmware>V3.40</firmware>
  <fileNumber>S003</fileNumber>
  <triggerIndex>1420</triggerIndex>
  <sampleCount>4098</sampleCount>
  <timeRange>32.784e-3</timeRange>
</Profile>
<Point>
  <seq>1418</seq>
  <val>-40.000e-3</val>
</Point>
<Point>
  <seq>1419</seq>
  <val>-40.000e-3</val>
</Point>
<Point>
  <seq>1420</seq>
  <val>5.280</val>
</Point>
<Point>
  <seq>1421</seq>
  <val>5.200</val>
</Point>
<Point>
  <seq>1422</seq>
  <val>5.160</val>
</Point>
</Document>
```

Each individual sample point is placed in a **Point** section. The **seq** item is the sequential number of the sample point in the range from 0 (first point in time) to **sampleCount** – 1, **val** is the measured voltage of the sample point.

## Reference waveform files

Reference waveform files (FILExxx.DAT) have a size of 302 bytes with the following layout:

```
typedef struct _ReferenceType {  
    unsigned char  Signature[2];    // 2 byte signature field  
    unsigned char  Ref_Buffer[300]; // 300 byte waveform  
} ReferenceType;
```

The full DSO Nano screen is 320x240 pixels and the area used for waveform display is 300x200 pixels (grid size is 25x25). Values in “Ref\_Buffer” represent y-axis absolute screen coordinates with a valid range from 20 to 219 (20 being bottom). Index within the buffer represents waveform relative x-axis coordinates with a range from 0 to 299 (zero being left).

A value of 255 in Ref\_Buffer is interpreted as “no value”. Values 0 to 19 and 220 to 254 are reserved.

The Signature field is currently unused. Values in this field will be zero on output from the DSO Nano (V3 firmware) and should be set to zero in files created for import to the Nano.