DATA Multifunction Eurorack Module

MX-E101

User Guide

SYS V. 01.02.02
BOOT V. 01.00.00

Updated: 171002

Contents

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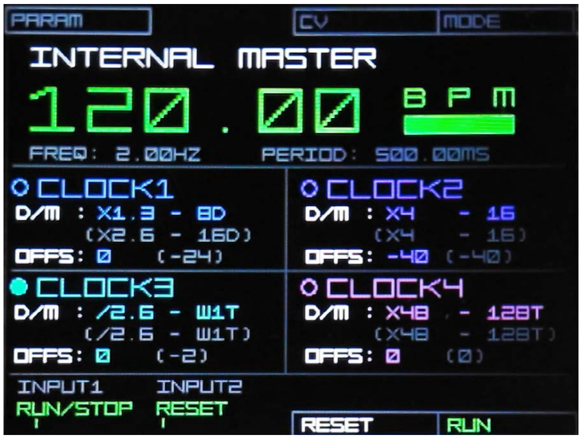
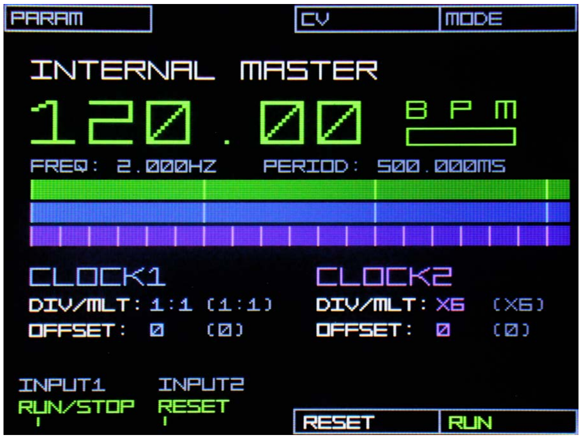
https://www.youtube.com/c/mordaxnet

What's New in DATA Firmware SYS V. 01.02.02

With the latest DATA firmware SYS V. 01.02.02 we have a major update to the CLOCK OUTPUT program. The new CLOCK core has been completely redesigned, **now with 4 channels of independent clock output** (upgraded from 2 ch), all with full CV input control over their divide/multiply value and offset.



NEW 4ch CLOCK



OLD 2ch CLOCK

Many **new CLOCK divide/multiply values have been added, including fractional div/mults allowing for dotted and triplet note values** (e.g., x1.3 = dotted 8th note), and an increased overall range from /48 (12 measures) to x48 (128th note triplets). The selected div/mult now also displays the corresponding note value beside the numerical value where applicable.

We had to drop the old CLOCK's "tick display" bars to fit all the extra channels on the screen, which we quite liked, but we think it's a fair trade. Also, note that patches saved with the old CLOCK firmware are not compatible with the new CLOCK; it's not going to crash or anything, just know if you load a system patch from the old firmware the CLOCK will be skipped, so whatever settings you currently have on the CLOCK will remain as they are.

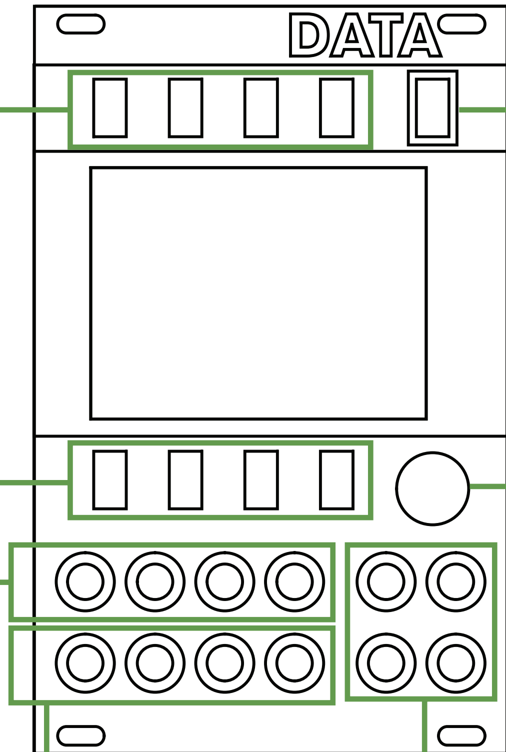
Check out the updated User Guide section on [Program: Clock Output]for more new CLOCK info.

The Wave Output program also got some "under-the-hood" work on this update. The **oscillators have been improved, they are now higher resolution and have less aliasing noise**, and the CV input processing has been further optimized allowing for **faster and more precise CV modulation** of the oscillator's frequency and amplitude

DATA Overview

Soft Buttons, top row: Referred to in this guide, left to right, as 2-1, 2-2, 2-3, 2-4

Menu Button: Pressing this at any time will return you to the main menu.



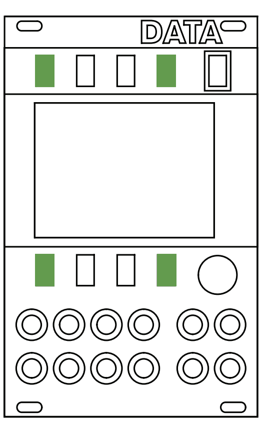
Soft Buttons, bottom row: Referred to in this guide, left to right, as 1-1, 1-2, 1-3, 1-4

Push Encoder Knob: Turn the encoder to scroll through parameters and change values. Pushing the encoder often selects and deselects items. In some functions, pushing the encoder while turning allows for coarse/fine changing of values.

Input Jacks: All inputs can accept +/-10V signals, though depending on the program running, the expected voltage range and hardware signal path may vary. Similarly, all, none, or a subset of the inputs may be utilized per program (see program-specific instructions).

Buffered Through Jacks: Regardless of the program running, a signal present at an Input Jack is buffered and sent back out of its corresponding Through Jack for use elsewhere in your patch.

Output Jacks: All outputs can produce +10V to -5V Audio, CV, Trigger, or Gate signals. Depending on the program running, all, none, or a subset of the outputs may be utilized. Similarly, the effective voltage ranges are program dependent (see program-specific instructions).

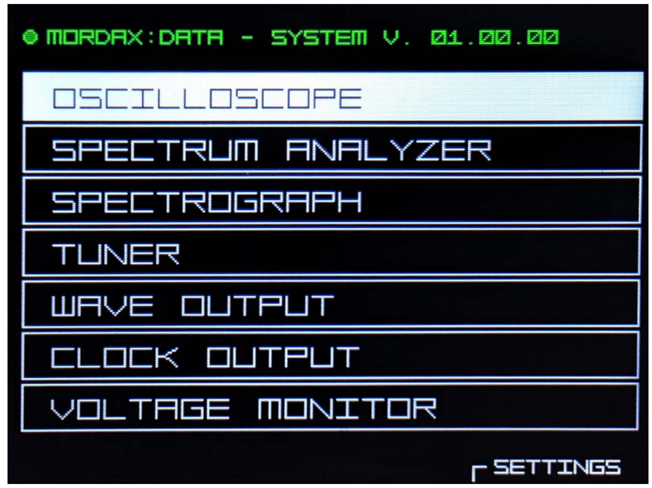


Front Panel Reset

Typically you wouldn't need to reset the DATA during operation, but it's good to know you can do so easily without interrupting power to the rest of your Eurorack system. You can reset the DATA system at any time by simultaneously pressing the buttons 1-1, 1-4, 2-1, and 2-4 (the four corner soft-buttons). This produces the same affect as power cycling the DATA by turning your Eurorack system on and off, but effects only the DATA.

Getting Around the DATA System

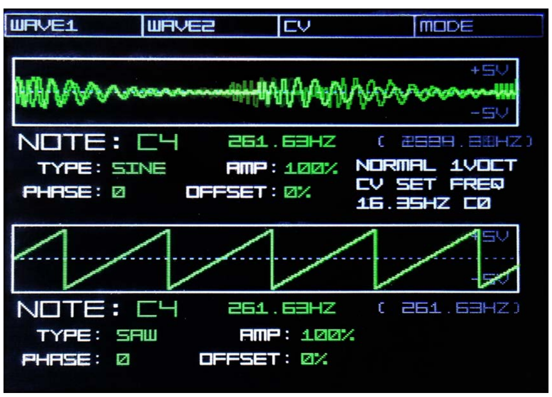
When the DATA starts up you are brought to the Main Menu. Use the encoder knob to scroll through the menu; when you have highlighted the program you wish to use, push in on the encoder to launch the program. You can also access the system's Settings page from the Main Menu by pushing soft-button 1-4, located under the screen text 'SETTINGS'.



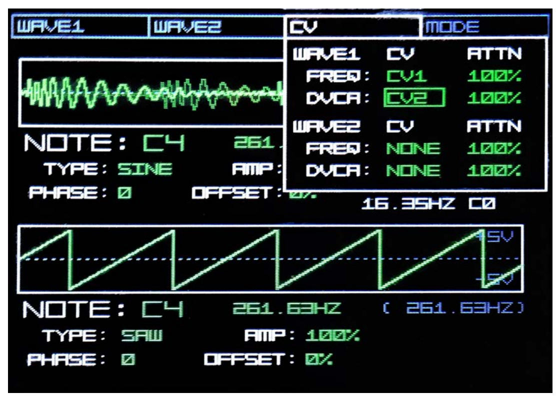
The function of the DATA's buttons and encoder, as well as the DATA's input and output jacks, are specific to each program, and are covered in each program's section of this manual. Generally though, the user input controls have the following common behaviors throughout the system:

- Boxes with text along the display top and bottom correspond to the soft-buttons along that edge. These boxes can allow the ability to select pages in a program (e.g., Settings), activate a pop-up menu (e.g., Scope cursor sub-menu), or engage a control (e.g., Volt Monitor CV control).
- The encoder is used to scroll available items in a list or menu. Often in pop-up menus pushing the encoder will select that item, then turning the encoder will act on that variable. Pushing the encoder again will return it to scrolling the list.

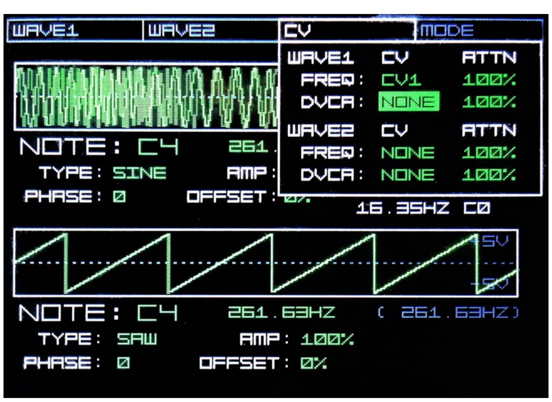
Navigation Example: Change WAVE1 CV DVCA Assignment



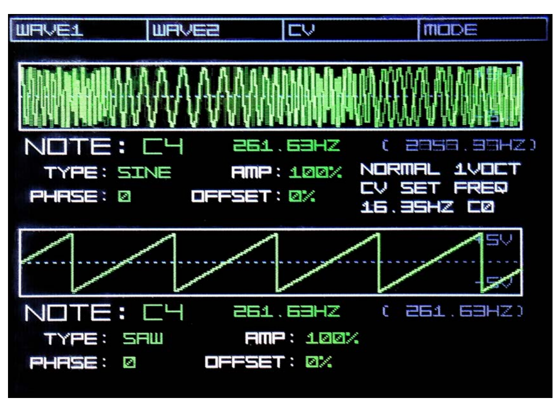
1. In Wave Output, push soft-button 2-3, corresponding to the CV item at the top of the display, to engage the CV pop-up menu.



2. Turn the encoder to select WAVE1 CV source for DVCA, as indicated by the hollow green box. Currently CV INPUT 2 is the active source.



3. Push the encoder to act on this parameter. Turn the encoder so the parameter is NONE. Push the encoder again and scroll to move to a different parameter.



4. When you're done with the CV assignments, hit soft-button 2-3 again to leave the pop-up menu.

Power

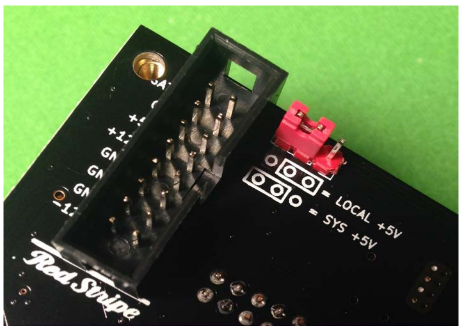
Power to the DATA module is provided by a standard 16 pin Eurorack power connector, supplied with the module. A +5V source header is located on the back of the DATA by the 16 pin power header (pictured below). This allows for +5V to be provided directly by your Eurorack system's power bus, or for +5V to be produce locally inside the DATA from your system's +12V rail. The choice of +5V source allows for balancing your system's power as you see fit, as well as providing an option to power the DATA if your system does not have a +5V rail available (via a user-provided 16 pin to 10 pin cable power cable).

**Note: Using the Local +5V Option generates more heat. Regardless of power option, always be sure your Eurorack system has sufficient case ventilation!*

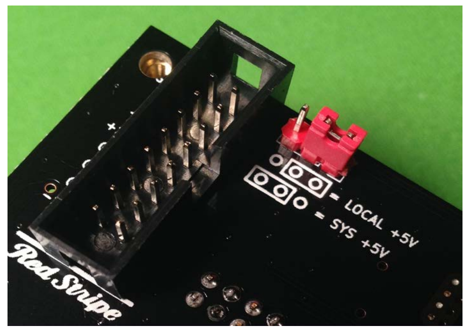
Typical Current Consumption

Using Option - System +5V
+12V ~ 100 mA
-12V ~ 60 mA
+5V ~ 150 mA

Using Option - Local +5V
+12V ~ 250 mA
-12V ~ 60 mA



SYSTEM +5V Option: The +5V power is provided directly by your Eurorack system's +5V power rail.

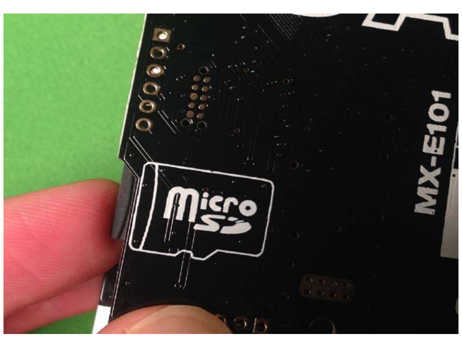


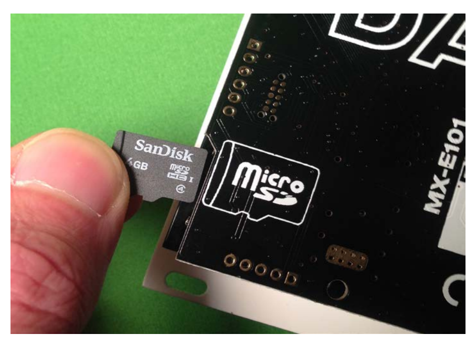
LOCAL +5V Option: The +5V power is converted from your Eurorack system's +12V power rail via a voltage regulator inside the DATA module.

microSD Card

The DATA is equipped with a standard FAT32 formatted 4GB microSD Card, which ***must be inserted in the DATA's SD card slot at all times during operation***. Currently, the SD Card's primary functions are to transfer firmware update files to the DATA and for the storage and recall of user system state patch memory and calibration variables.

To remove the SD Card for firmware update or replacement, first turn the DATA off. The DATA's SD Card reader slot is located in the bottom left corner of the back PCB, as indicated by the microSD guide image. The SD Card reader is a "push-push" type mechanism, meaning that to remove the card, simply push gently in on the card and the card will partially eject, after which the card can be fully removed. When re-insterting the card, line it up with the microSD guide image on the PCB and push it into the slot until you feel the "push-push" mechanism engage, after which the card should be flush with the edge of the PCB and firmly held by the card reader.





Firmware

The DATA's software is comprised of two parts: the bootloader firmware and the system firmware. The bootloader is a small program that runs every time the DATA is started; it checks for system firmware updates on the SD Card. If the there is no system firmware file present on the card, then the bootloader will start the system normally. The system firmware is the main software and contains all of the DATA's functions (e.g., oscilloscope, spectral analyzer, etc.). You are able to update the bootloader firmware from the settings menu of the main system. All this may sound confusing, but the process of updating both the system and the bootloader firmware is really quite simple, as explained below.

To get the most of out your DATA, be sure to keep the firmware up-to-date! It is through this process we provide new and improved features, as well as fix bugs, for optimal DATA performance. *Both the DATA's system and bootloader firmware update files can be found on the Mordax website as they become available (major updates will also be announced via the email newsletter and social media channels). Also, note that system and bootloader updates are independent, for example we've had multiple system updates in a row and no bootloader updates since the DATA was first launched.*

Updating the System Firmware

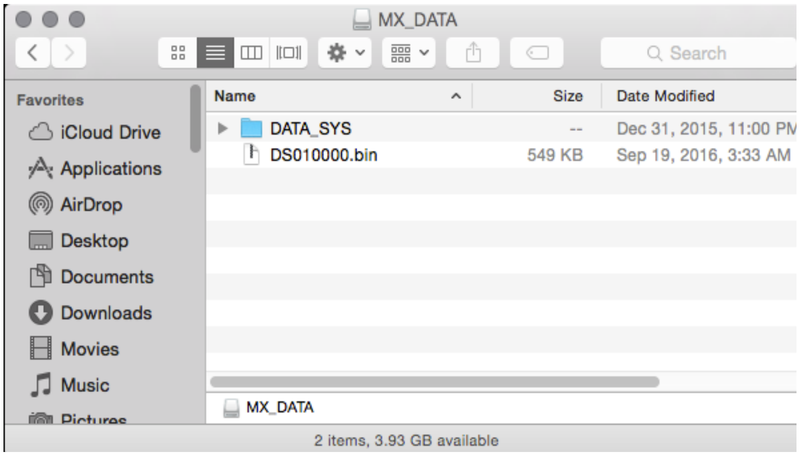
1. Go to www.mordax.net and download the latest DATA system firmware file to your computer. All DATA system firmware .bin files start with DS followed by 6 numbers, which indicate the version number (e.g., DS010000.bin is DATA System Version 01.00.00).

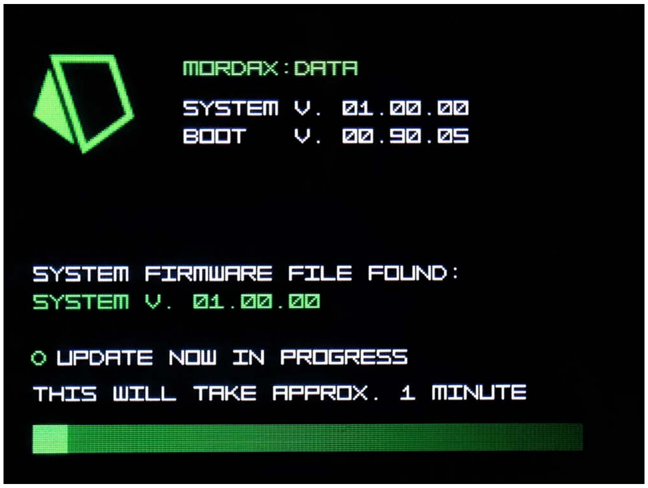
2. Turn off the DATA, remove its microSD card and put the microSD card in your computer (or if your computer doesn't have a microSD card reader, use a USB based reader, available at any electronics retailer). You'll see the card is named 'MX_DATA'.

3. Take the downloaded DATA firmware .bin file and place it in the mircoSD card's root directory– a fancy way of saying the place that you see when you first open the card on your computer (see top image).

4. Eject the card and put it back into the DATA.

5. Power on the DATA. The firmware file will be automatically detected and loaded into the DATA's memory. Once the firmware update is complete, the .bin source file will be deleted from the card.

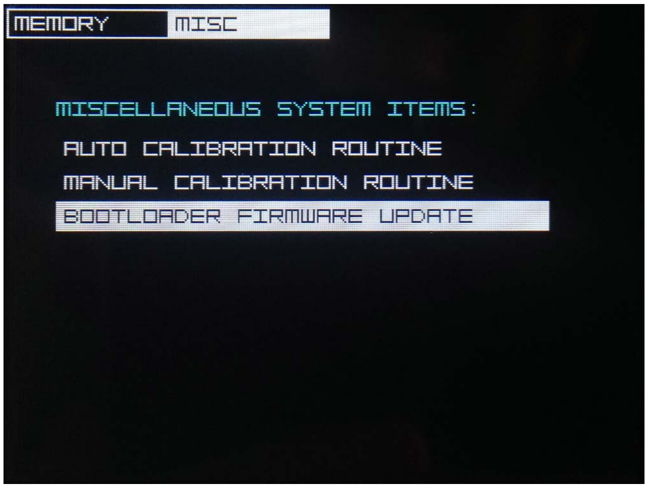




Updating the Bootloader Firmware

This is a similar process to updating the system firmware, except that you will download a file which starts with DB (compared to system firmware files, which start with DS) and you will go into the DATA's Settings program to execute the update.

NOTE: System firmware is different from the boot loader firmware - Bootloader firmware is rarely updated, and typically you will only be dealing with the system firmware when updating your DATA, as described in the previous section.



To update the bootloader firmware:

1. Got to www.mordax.net and download the latest DATA bootloader firmware file to your computer. All DATA bootloader firmware .bin files start with DB followed by 6 numbers, which indicate the version number (e.g., DB010000.bin is DATA Bootloader Version 01.00.00).

2. Turn off the DATA, remove its microSD card and put the microSD card in your computer (or if your computer doesn't have a microSD card reader, use a USB based reader, available at any electronics retailer). You'll see the card is named 'MX_DATA'.

3. Take the downloaded DATA firmware .bin file and place it in the mircoSD card's root directory.

4. Eject the card and put it back into the DATA.

5. Power on the DATA. From the DATA's main menu, hit button 1-4 to access the Settings program.

6. The Settings program opens in the 'Memory' page. Hit button 2-2 to navigate to the 'Miscellaneous Systems Items' page. Then scroll with the rotary encoder knob to select 'Bootloader Firmware Update' from the sub-menu. With this item highlighted, push in on the encoder to access the Bootloader Update routine.

7. The Bootloader Update program will recognize the new firmware and display the version number on the screen. Push button 1-1 to start the update. Heed the notice on the screen; while this update process is rather fast, if the bootloader update is interrupted before completing, it may brick your DATA and would have to be returned to Mordax HQ for service.

8. Once the firmware update is complete, the .bin source file will be deleted from the card.

Calibration

Like all measurement equipment, the voltage accuracy of the DATA's inputs and outputs are reliant on many factors, such as the system's calibration scheme, the initial accuracy of the performed calibration, and changes in the physical environment (i.e.., temperature). To best mediate environmental effects, it is recommended to perform calibrations after the DATA has been powered on for a period of 30 minutes or longer. The DATA's voltage calibration is composed of two interlinked routines, Manual Calibration and Automatic Calibration. Let's take a look at each of these.

Manual Calibration

Manual Calibration is used to calibrate the DATA's digital-to-analog converters (DACs); these are the DATA's voltage outputs. ***Unlike the Automatic Calibration covered next, Manual Calibration is not intended to be performed often, as it requires the use of a Digital Multimeter (DMM) or other voltage measurement device with sub-millivolt precision.*** At the factory, each DATA is put through a "burn-in" period, where the unit is powered for ~1 hour, after which manual calibration is performed using a 5.5 digit DMM, in addition to other tests. Despite calibration at the factory, the Manual Calibration routine may need to be performed on your DATA from time to time. As long as you have access to a reliable DMM or similar device, the process is simple:

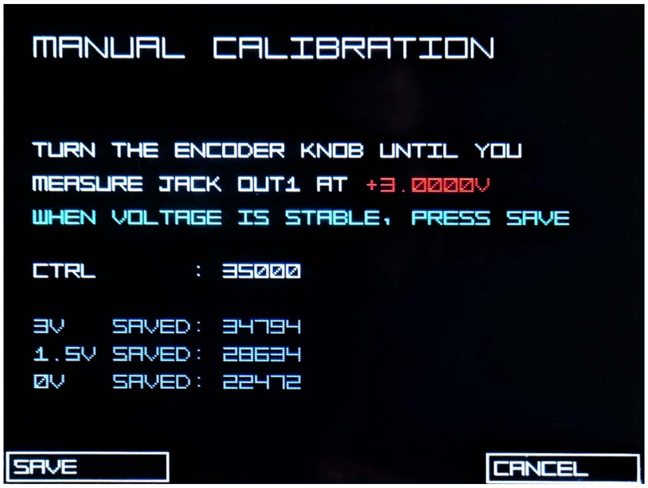
1. Power on the DATA for at least 30 minutes. From the DATA's main menu, hit button 1-4 to access the Settings program.

2. The Settings program opens in the 'Memory' page. Hit button 2-2 to navigate to the 'Miscellaneous Systems Items' page (top box MISC), then scroll with the rotary encoder knob to select 'Manual Calibration Routine' from the sub-menu. With this item highlighted, push in on the encoder to access the Manual Calibration Routine. This takes you to the entry screen for the routine; press START to begin.

3. Follow the on-screen instructions, first measuring the OUT1 jack for a range of voltages, then the OUT2, OUT3, and OUT4 jacks.

4. Once Manual Calibration is complete, the calibration information is stored in the DATA's on-board non-volatile memory. Neither Manual Calibration information nor Automatic Calibration information are stored on the microSD Card, so if your card is ever replaced for any reason, you won't need to perform a Manual Calibration again (unless you want to).

5. Immediately after the Manual Calibration finishes, the DATA will start the Automatic Calibration routine to calibrate the DATA's analog to digital converters (ADCs), applying the new Manual Calibration values.



Automatic Calibration

Automatic Calibration is used to calibrate the DATA's analog to digital converters (ADCs); these are the DATA's voltage input sensors. Automatic Calibration relies on the DATA's internal signal routing matrix to send known voltage levels into the ADCs and record their values. This process should be done whenever using the DATA in a new environment, after the unit has warmed up, preferably for > 30 minutes.

To perform Automatic Calibration, enter the Settings program, navigate to the 'Miscellaneous Systems Items' page, then scroll with the rotary encoder knob to select 'Auto Calibration Routine' from the sub-menu and follow the on-screen instructions.

Saving & Loading System State

Basic patch memory is available for saving and loading the DATA's system-wide settings. There are 8 memory slots used to take a "snap-shot" of the DATA as it is currently configured. The Oscilloscope program's channel positions and time value, the Wave Output program's waveform type and frequency, and the Clock Output program's BPM can all be saved for later recall. This is useful for recalling specific configurations for performances or moving between different test and measurement routines.

To save or load a system state:

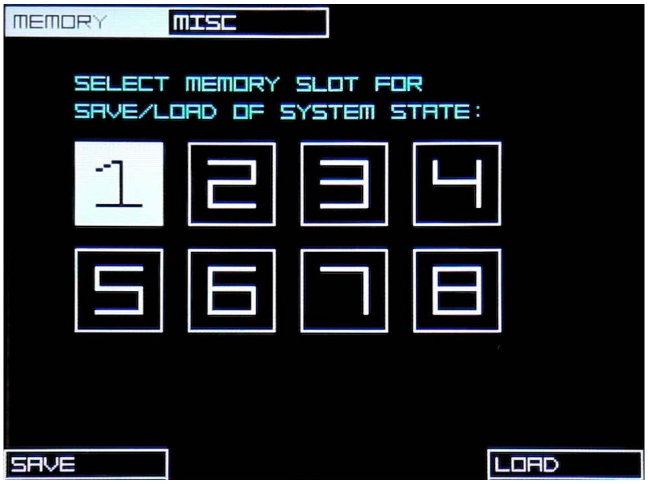
1. From the DATA's main menu, hit button 1-4 to access the Settings program.

2. The Settings program opens in the 'Memory' page. Scroll with the rotary encoder knob to select one of the eight available memory slots to save or load.

3. To save the current system state to the highlighted slot, press button 1-1, under the display text 'SAVE'. Saving to the memory slot will automatically overwrite any previously saved state in that slot. The display will show a message indicating that the save was successful.

4. To load a saved state from the highlighted slot, press button 1-2, under the display text 'LOAD'. This will change all values in all programs to those set at the time the system was originally saved.

5. To copy a saved state from one slot to another, simply load the saved state from its memory slot, scroll to highlight the slot you want to copy to, then save it there.



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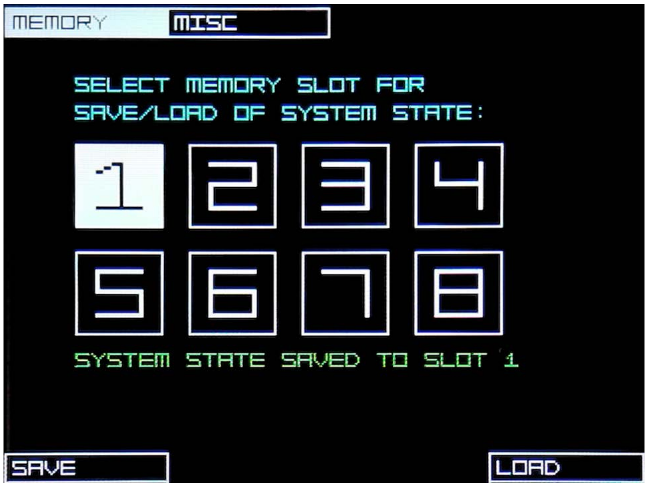
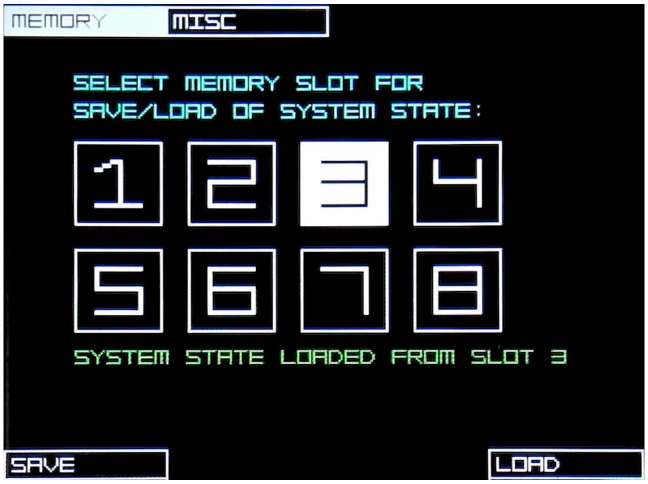




Program : Oscilloscope

An oscilloscope is to an electrical engineer as a telescope is to an astronomer; it allows the investigator to see, with their own eyes, a representation of what they are studying. And as a eurorack user, you're going to become an electrical engineer on some level, like it or not! (Why? Because, you're powering and wiring together different circuits [modules] to build a complex system [your rack] for signal generation, and so EE concepts like voltage, resistance, PCBs, oscilloscopes, etc. will seep into your vocabulary eventually).

The primary function of an oscilloscope, the DATA's or any other, is to display a 2D graph of voltage amplitude over time, with amplitude on the Y-axis and time on the X-axis. With this simple display a multitude of information can be extracted and questions answered – from getting a basic understanding of a module's behavior (what shape is my envelope really?), to exploring interesting topics like frequency modulation and phase cancellation.

Scopes can be deceptively simple though, especially digital storage oscilloscopes (DSOs); in fact, when I got my first DSO and started messing around with it, I thought it was broken! In reality, the scope was fine; I just needed to take some time to properly learn how the DSO works. Just like positioning and focusing a telescope, you have to adjust the settings of an oscilloscope to get the clear and accurate image you're after.

We'll be covering the operation of the DATA's scope in the following pages, and we'll visit a few specific oscilloscope "gotchas" like triggering and aliasing. If you're brand new to using scopes, I highly recommend checking out the excellent primer guide from Tektronix "XYZs of Oscilloscopes" (Google it) as well as watching some YouTube videos (AdaFruit and EEVBlog have some good ones) on general scope concepts. And of course, don't forget to check out the Mordax YouTube channel for video tutorials on the DATA's scope and other programs!

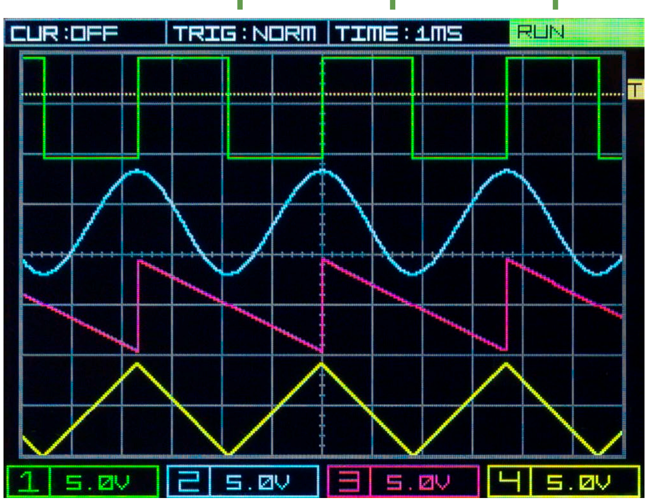
Oscilloscope - Display Overview

Trigger button: Shows current trigger mode - automatic or normal. Push to access the trigger pop-up menu.

Time Scale button: Shows the scope's current horizontal resolution - microseconds, milliseconds, or seconds per division, the X-axis. Push the button and turn the encoder to change the time scale.

RUN/STOP button: Push to switch between RUN and STOP.

Cursor button: Shows current cursor scale channel reference. Push to access the cursor pop-up menu.



Trigger Line: Indicates the trigger level for the associated trigger source channel (for use in trigger mode "NORM").

Channel buttons: Shows channel input jack number and the channel's current vertical resolution - volts per division, the Y-axis. Push to access the channel's pop-up menu.

Triggering

Triggering is one of the most important concepts to understand when using an oscilloscope. The trigger controls the oscilloscope's "horizontal sweep"; in other words, it controls the display window of the incoming signal. The trigger can be used to synchronize the oscilloscope's display with an incoming repeating signal (e.g., an oscillator's waveform), allowing for clear viewing and measurement.

The DATA's oscilloscope currently has two trigger modes available: AUTO (automatic trigger) and NORM (normal trigger). The AUTO mode continuously samples the incoming signal and triggers at a fixed rate, based on the currently selected time scale. The NORM mode continuously samples the incoming signal, but will only generate a trigger event when the signal crosses the trigger level. **In NORM mode, if the signal does not cross the trigger level, the screen will not change.**

When to use trigger mode NORM - Viewing repeating, high frequency signals, such as audio-rate waveforms (typical oscillator output). The oscilloscope time scale would be set at 10ms or less.

When to use trigger mode AUTO - Viewing slower signals like slower envelopes, low frequency oscillators (LFOS). Also useful for viewing non-repeating higher frequency signals, like your main audio outputs (mix of many oscillators and FX). The oscilloscope time scale would typically be set at 10ms or more.

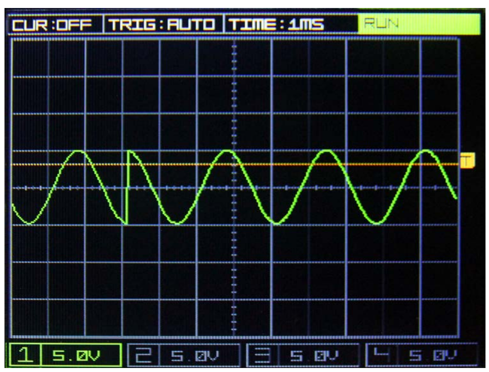
****Always use trigger mode AUTO when your time scale is set to large values (e.g., 100's of milliseconds or seconds)***

Trigger Example - AUTO vs NORM

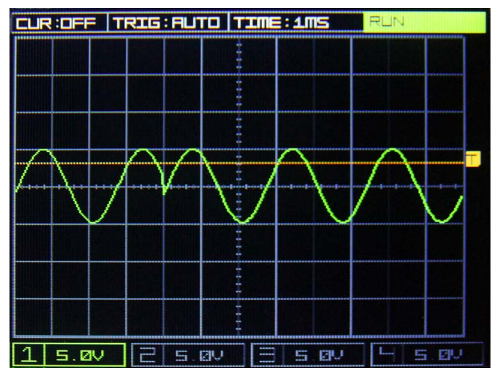
The images 1, 2, and 3 show an audio-rate sinewave coming in on channel 1, with the TRIG mode set to AUTO and a TIME scale of 1ms. Note the distortion of the sinewave in each image, this is due to the triggering of the waveform being out of sync with the AUTO mode trigger rate.

Pressing button 2-2 displays the TRIG pop-up menu (image 3). Switching the mode to NORM synchronizes the display with the waveform, producing a trigger event every time the waveform crosses the trigger level (currently set at 3.14V).

Now that the oscilloscope is triggering off of channel 1 the distortion is gone (image 4). You can even change the frequency of the incoming sinewave and its relative position will remain centered on the screen.



1



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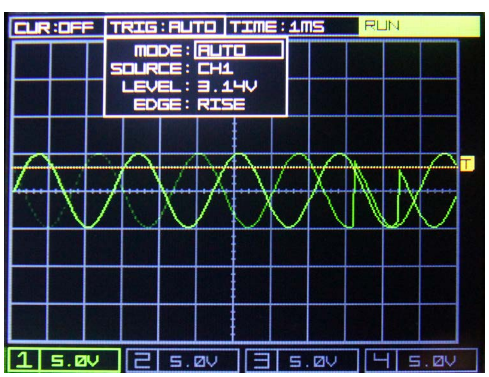

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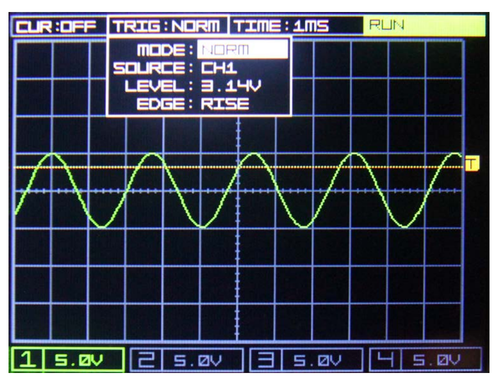


4

****Note that if the incoming signal changes so that it never reaches the trigger level (3.14V in this case), the displayed waveform <u>will not update</u>. For this reason, it's advisable to start viewing a signal of unknown amplitude or shape in AUTO mode, adjust parameters such as the trigger level and time scale, and then switch to NORM mode.***

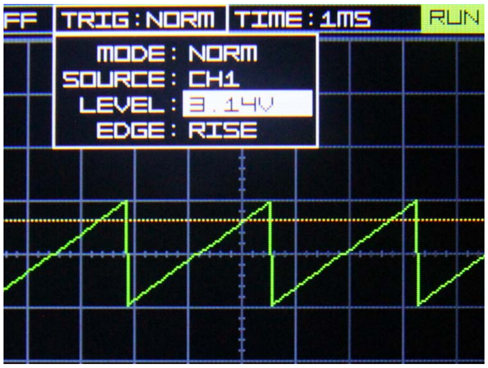
Trigger Level & Edge

When triggering from a signal in NORM mode, the trigger event occurs when the incoming signal crosses the trigger threshold, or LEVEL (orange dotted line). When a trigger occurs **the signal display is centered at the trigger point** - the intersection of the orange trigger line, the grey center grid Y-axis, and the incoming signal.

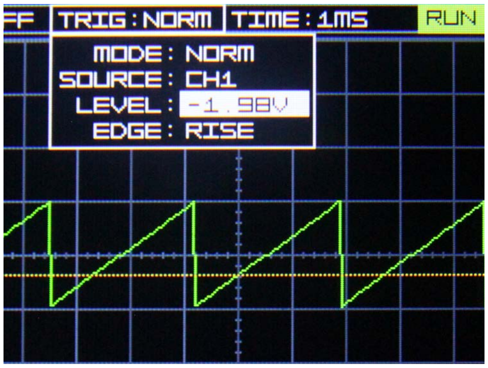
Images 1 and 2 to the right show the trigger LEVEL changed from 3.14V to -1.98V. This results in the trigger point moving down; in image 1 the trigger is towards the top of the saw wave, while in image 2 it's towards the bottom, and the wave appears to have shifted to the right.

The Trigger EDGE parameter selects whether a trigger event occurs when the signal crosses the LEVEL from below, low to high (RISE), or from above, high to low (FALL).

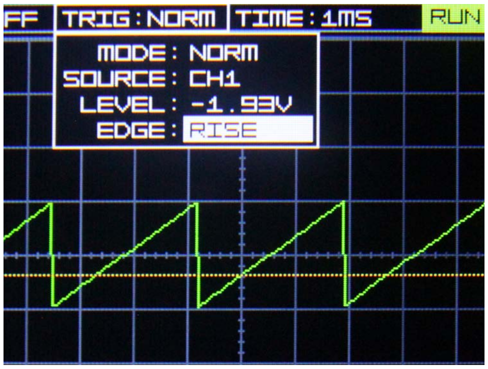
Images 3 and 4 to the right show the trigger EDGE changing from RISE to FALL. With RISE, the signal display is centered around the left slope of the saw wave, while with FALL the signal is centered at the right edge of the saw wave. Similar to changing the LEVEL previously, the wave appears to have shifted, this time to the left.



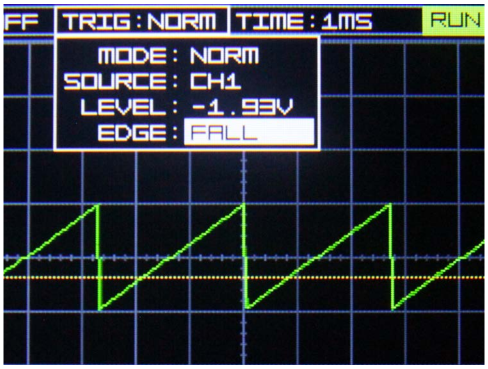
1



2



3



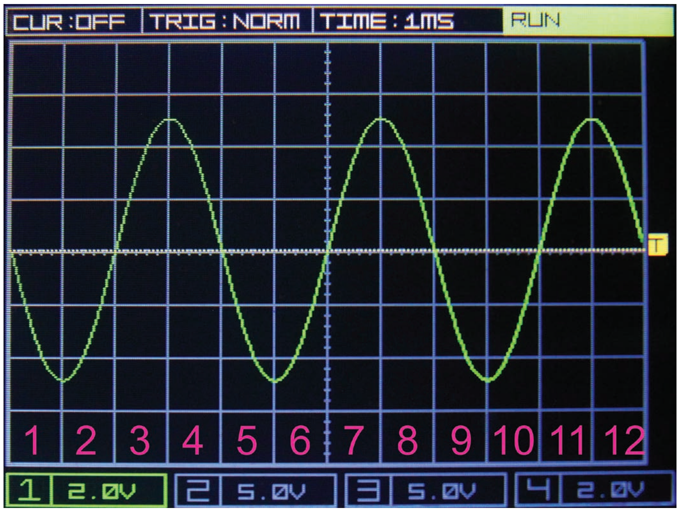
4

Pro-tip: *if your oscillator's waveform is complex and contains non-repeating elements (e.g., wavefolding modulation or scanning wavetables with lots of jagged edges), it might cross the trigger LEVEL many times per cycle, causing the display to center the wave at different places, seeming to shift the wave left and right as it modulates. Try setting the trigger source to another channel that's monitoring a squarewave oscillator set to the same frequency as your complex waveform (or use the SYNC output of your complex oscillator if it has one). This will keep a stable sync window for viewing your complex oscillator's waveform, even while it's changing shape.*

Time - Horizontal Scale (X-axis)

The TIME parameter (top of the screen, accessed via button 2-4) shows the scope's current horizontal resolution in microseconds, milliseconds, or seconds per division. On the grid there are 12 divisions on the X-axis (the grid is 12 boxes wide). For example, if the TIME parameter is set to 1MS (one millisecond), then the scope is showing a total of 12 milliseconds of signal across the display.

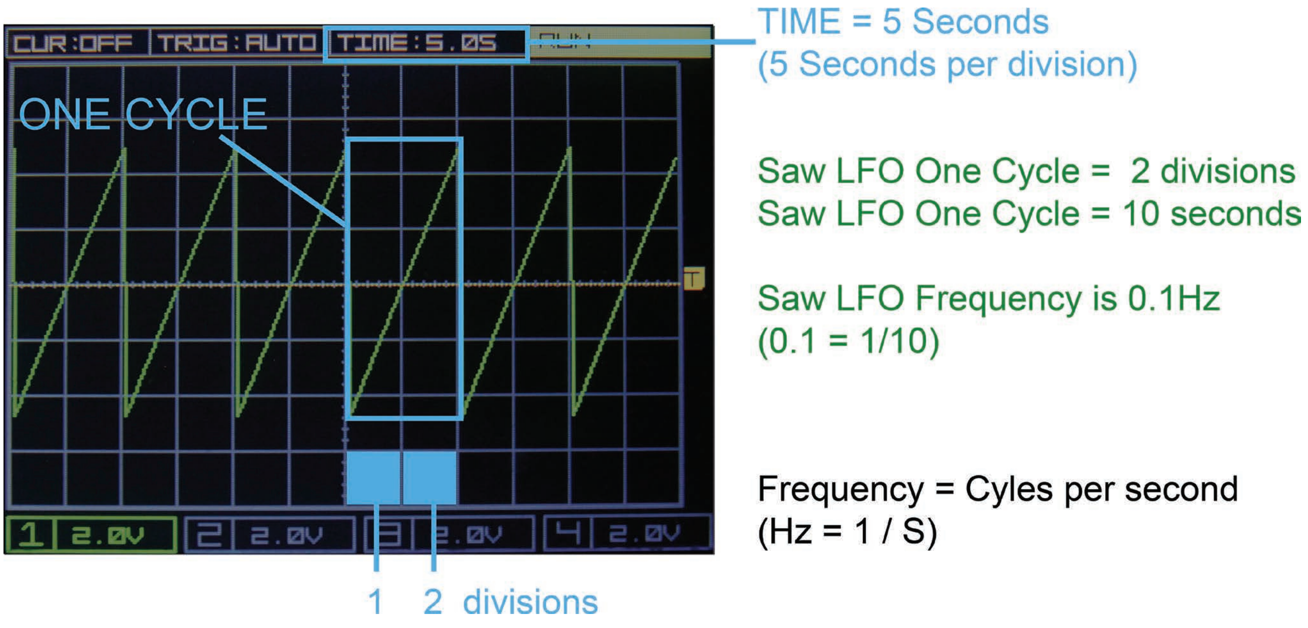
The TIME parameter ranges from 50uS (50 microseconds) to 5.0S (five seconds), allowing for a minimum total display of 600 microseconds and a maximum total display of 60 seconds.



Let's look at an example of viewing a LFO waveform. The incoming LFO signal is a sawtooth wave with a frequency of 0.1Hz, which is equal to a period of 10 seconds (1Hz frequency = 1 second period); it's a fairly slow LFO. But let's say we didn't know the LFO's frequency or period; we can use the scope's horizontal scale to measure it (or alternately, the scope's cursor, covered in the following pages).

The TIME parameter is set to 5.0S (five seconds), so each vertical grey line is equal to 5 seconds of time. You can see on the scope's grid that the waveform crosses two of the vertical grey lines before repeating, so from this we can tell that the LFO's period is 10 seconds.

Also, there are 6 full cycles of the saw wave across the scope's display. With 10 seconds per cycle this demonstrates that there are 60 seconds of time displayed when the TIME parameter is set to 5.0S.



Aliasing - Sampling Distortion

In any digital sampling system, such as a digital oscilloscope, aliasing distortion of the sampled signal can occur. In the image right there are two sine waves signals shown in yellow, each with the same number of X-axis divisions. In this graphic the X-axis divisions are sample points; both sine waves are being sampled at the same rate, though they are different frequencies. The circles show where the incoming sinewave signal is sampled; if you draw a line connecting the points of the top sine wave they would meet up and trace the actual sine wave input signal. However on the bottom, higher frequency signal, connecting the sample points draws a sine wave but doesn't match the input signal. The distorted signal produced is an example of aliasing distortion; the incoming signal is too fast to be properly sampled at the current sample rate.

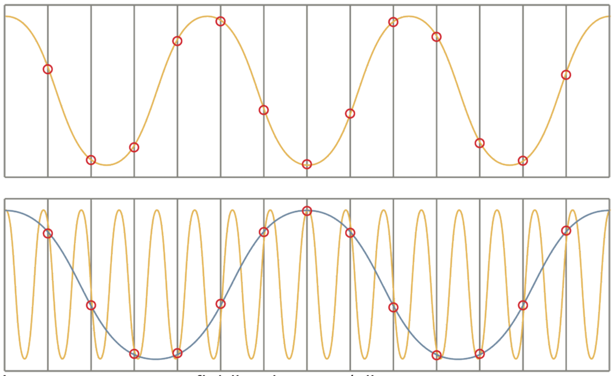
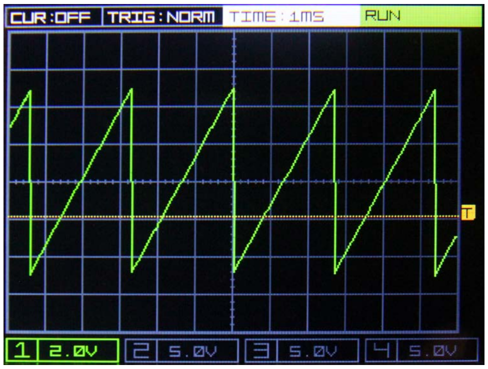
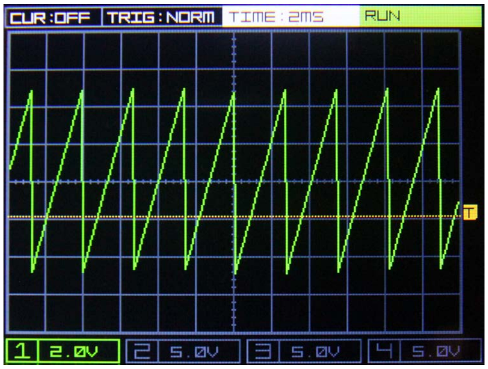


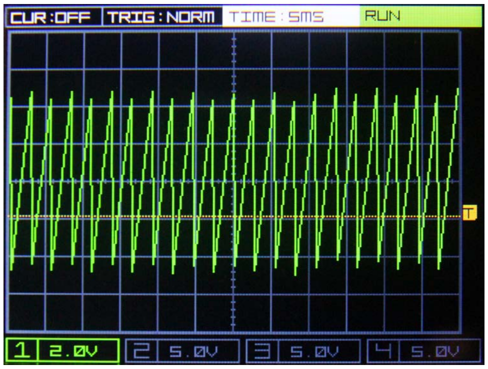
Image source: www.fieldingdsp.com/alias

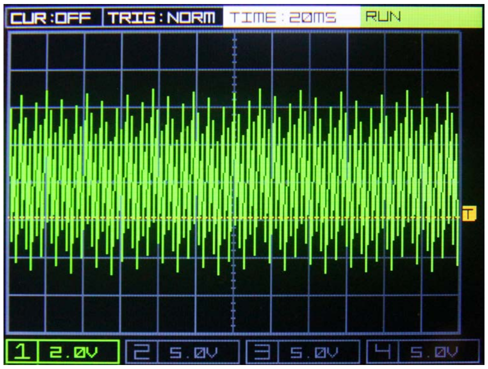
Below is an example of this aliasing distortion on the DATA's scope display. The saw wave signal's frequency is a little less than 350Hz (F4 note); with TIME: 1MS the signal is displayed appropriately, but as the TIME value is increased, there is more time between samples and similarly each pixel on the screen spans more time. At TIME 2MS and 5MS the signal is still reasonably displayed, while the bottom three images show TIME 20MS, 100MS, and 500MS, neither of which are appropriate for displaying this frequency of signal. As the time per division is increased to larger and larger values, this relatively high frequency signal experiences aliasing distortion resulting in interesting, but incorrect representations.

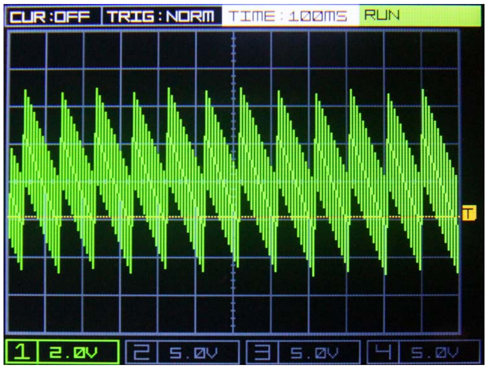
To avoid aliasing distortion, first start with a smaller TIME value and increase it until the signal is displayed to your liking, rather than starting with a large TIME value and decreasing it.

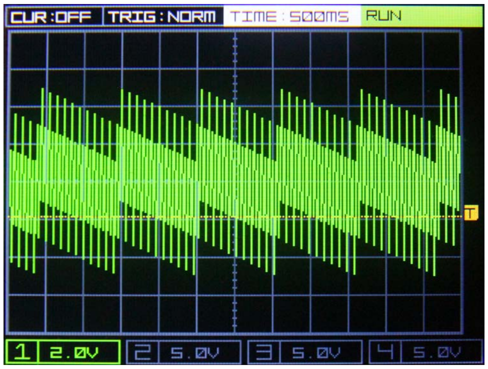












Voltage - Vertical Scale (Y-axis)

Each channel's SCALE parameter shows the volts-per-division of the vertical scale. On the grid there are 8 divisions on the Y-axis (the grid is 8 boxes tall). The vertical scale's resolution can be controlled independently for each channel, accessed via the channel's pop-up menu at the bottom of the display.

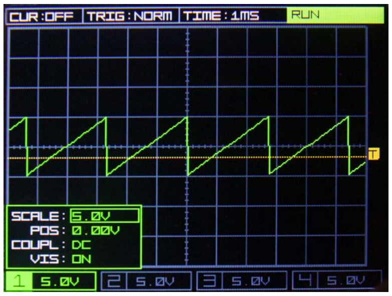
For example, in image 1 right, the SCALE parameter for channel 1 is set to 5.0V per division. That means each square on the grid is now 5.0V tall, and with 8 vertical divisions on the grid, the entire display is showing a range of 40V. You can see that the incoming saw wave is 2 boxes high, so 2 X 5.0V gives 10V; at a glance you now know the waveform spans 10V peak-to-peak.

Also in the first image, note that the position of channel 1 (parameter POS) is set to 0.00V; this means the center of the grid is displaying 0.00V. The saw wave spans one box above the center grid line, and it spans one box below; we now know the saw wave's actual voltage amplitude, +5V to -5V peak-to-peak

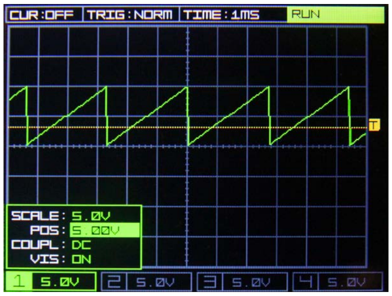
If we set the position to 5.00V (image 2) the saw wave is moved up, offset by vertical division (one box) at this scale.

Changing the SCALE parameter has the effect of zooming in or out on the signal. Images 3 and 4 show the same +/-5V saw wave, but the vertical scale is changed, making the signal larger on the display. Recall that at SCALE:5.0V the display can show a full 40V (8 vertical divisions, 8 x 5 = 40). Similarly, at a scale setting of 2.0V the screen can display 16V from top to bottom, and at a scale of 1.0V it displays a range of 8V.

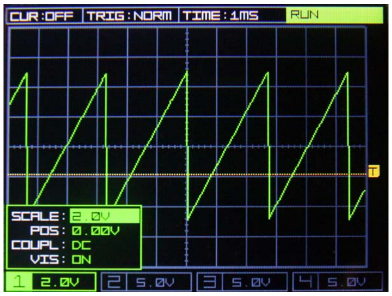
In image 4 you can see that our 10V peak-to-peak saw wave is clipped at it's top and bottom, because it spans a voltage range wider than what can be shown at SCALE:1.0V (8V full display range).



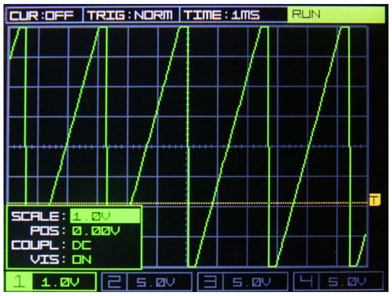
1



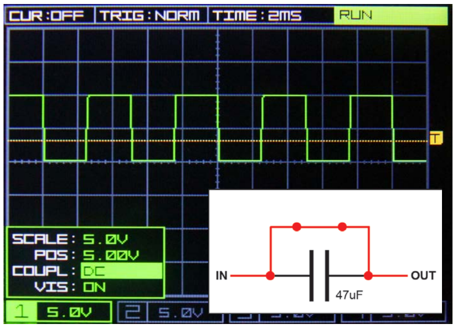
2

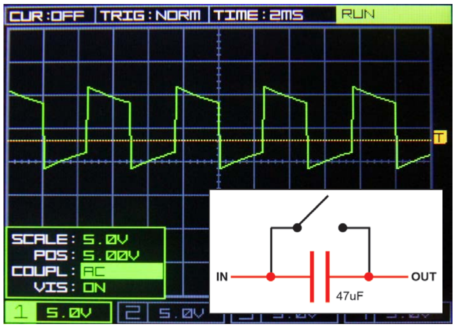


3



4





Coupling - AC / DC

Also available in the channel pop-up menus is the parameter COUPL, which selects AC (alternating current) or DC (direct current) coupling on the channel's input. AC coupling places a 0.47uF capacitor in series with the channel input, which blocks DC signals, only allowing AC signals to pass. For example, if you have AC coupling selected and you put a constant 5V CV signal into the input, it will show 0V on the scope, as that 5V DC has been blocked. Similarly, the flat components of a square wave will appear distorted when AC coupling is selected, as these are periods of DC (see images above). This distortion becomes more pronounced the lower the sqaurewave frequency becomes (longer periods of DC). ***Typically, you will want to view signals as COUPL: DC.***

Fun fact: The squarewaves you hear coming out of a speaker are generally distorted as shown in the AC coupled image, as the signal lines to speakers most always have these series DC blocking caps.

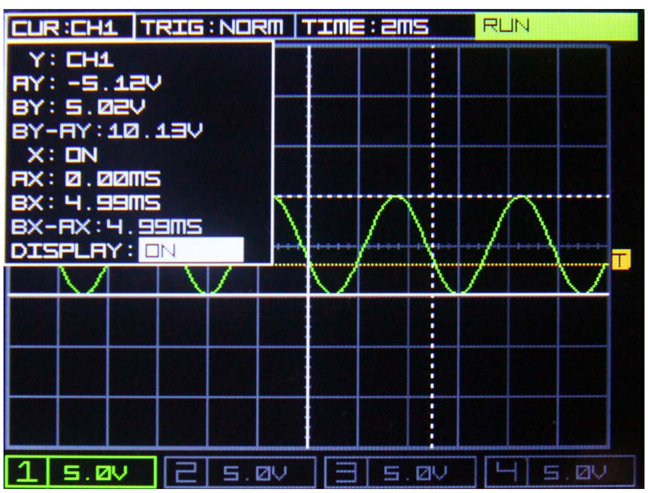
Cursor

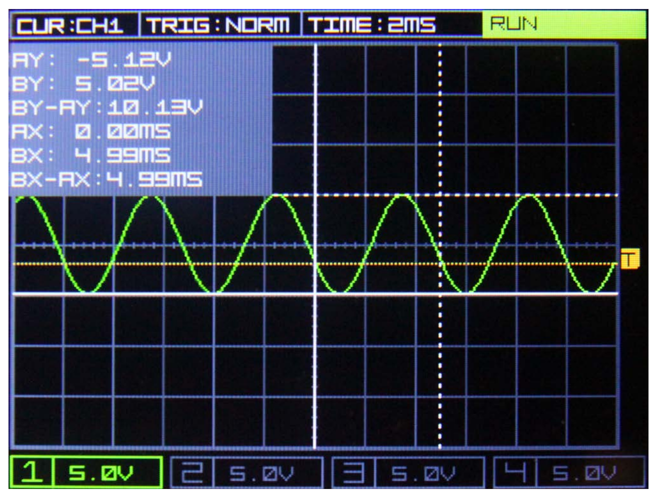
As we saw in the sections on the DATA scope's horizontal (X-axis) and vertical (Y-axis) scales, the scope's grid can be used to take quick measurements of an incoming signal's voltage as well as its period and frequency. The scope's cursors allow for more precise measurements, in addition to creating custom visual windows or thresholds.

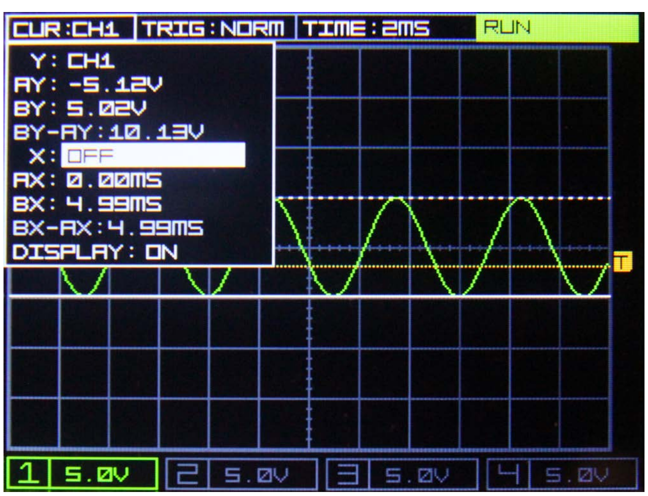
The cursor pop-up menu is accessed via the top left button (2-1), labeled CUR, with the current Y-axis scale reference shown. The Y-axis scale can reference any of the four input channel's scales; there's no need to readjust the cursor if a channel's voltage scale or position is changed, as the cursor's scale and relative position change along with it on the fly. Similarly, the cursor's X-axis scale is automatically updated to reference the display's current TIME setting.

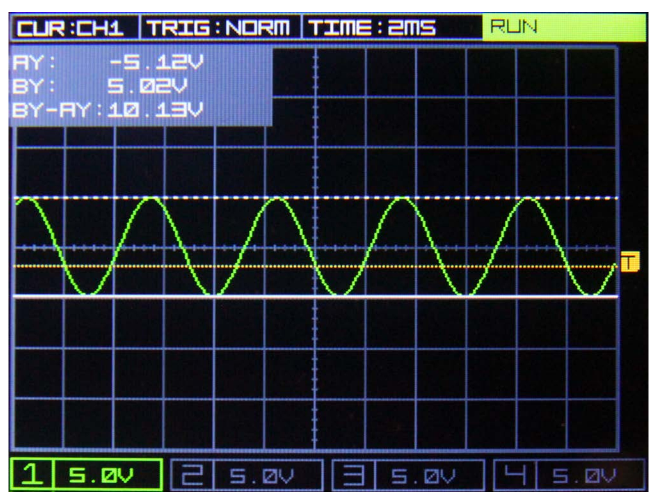
There are two cursors available per axis, with cursors AY and AX displayed as a solid white lines and cursors BY and BX displayed as dotted white lines. Difference (delta) between each axes' cursors are shown under each set of controls, calculating the span in voltage or span in time between their A and B cursors.

The DISPLAY parameter of the cursor pop-up menu turns on and off the cursor display. This allows you to continue viewing the cursor's position and delta values while the pop-up menu is not engaged. Only the active cursors are present in the display window, saving display space when only one cursor axis is being used.



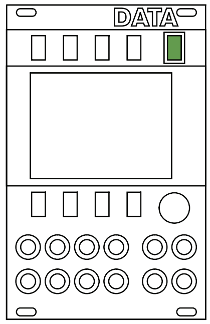






Secondary Top Menu Functions

To access the Oscilloscope program's secondary top menu functions, press and hold for ~1.5 seconds the DATA's Menu Button, the top right most button on the unit. To return to the primary oscilloscope top menu functions, press and hold the button again. To access the system main menu, simply press and release the Menu Button quickly.



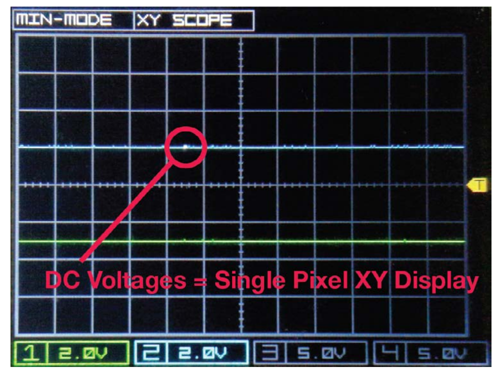
Primary Top Menu

Secondary Top Menu

XY Scope

The Oscilloscope program's XY Scope takes a pair of inputs and plots both of their amplitudes, one on the X axis and one on the Y. The pairs are either CH1(X) & CH2(Y) or CH3(X) & CH4(Y).

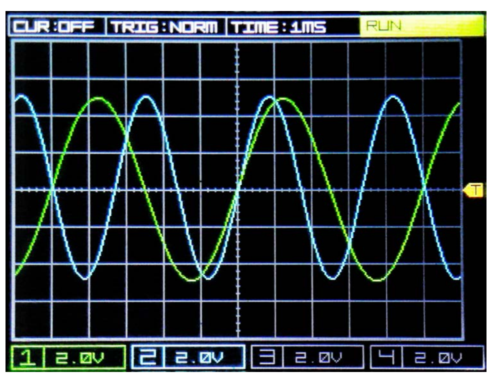
This is just like how you'd draw on an Etch-a-Sketch, one control for left to right (X) and one for up and down (Y). If you send the XY Scope a pair of DC voltages (a constant voltage, a straight line on the scope) then you'll see only a single white pixel drawn. To make cool shapes you need to input waveforms.

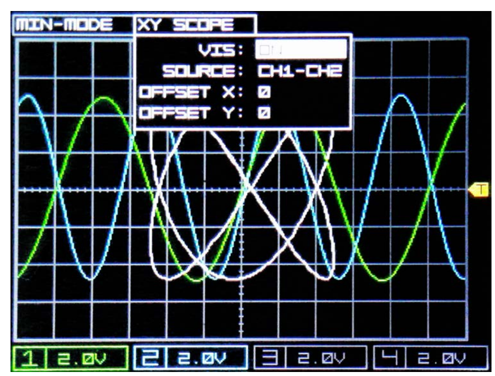


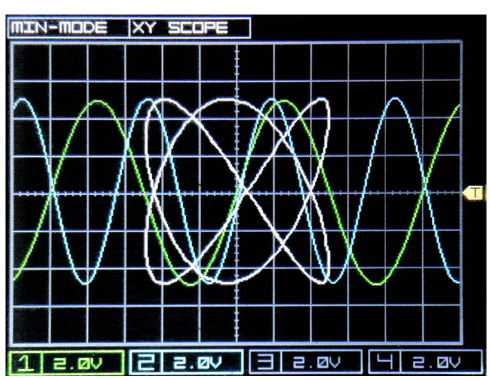
In this example we have two sine waves on the scope, CH1 is 200Hz and CH2 is 300Hz. The scope is triggering off of CH1 and the time scale is set to 1ms (note: it is important to TRIGGER off of one of the source channels to get a crisp XY display).

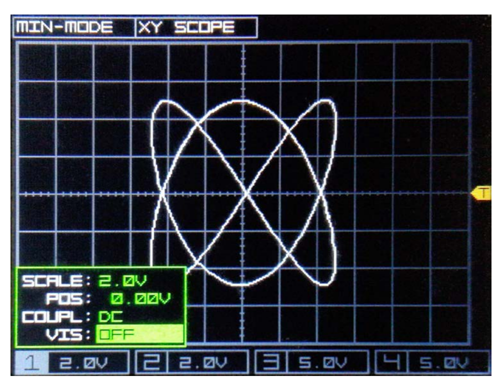
Enter the secondary top menu functions by pressing and holding the top right button as described above. Access the XY Scope pop-up menu by clicking the XY SCOPE button. Here the XY Scope's visibility can be turned on and off, channel pairs can be selected (SOURCE), and the position of the XY Scope can be offset.

If you want to view only the XY Scope and not the source channels, you simply turn off both of the source channel's visibility, via the channel pop-up menus.









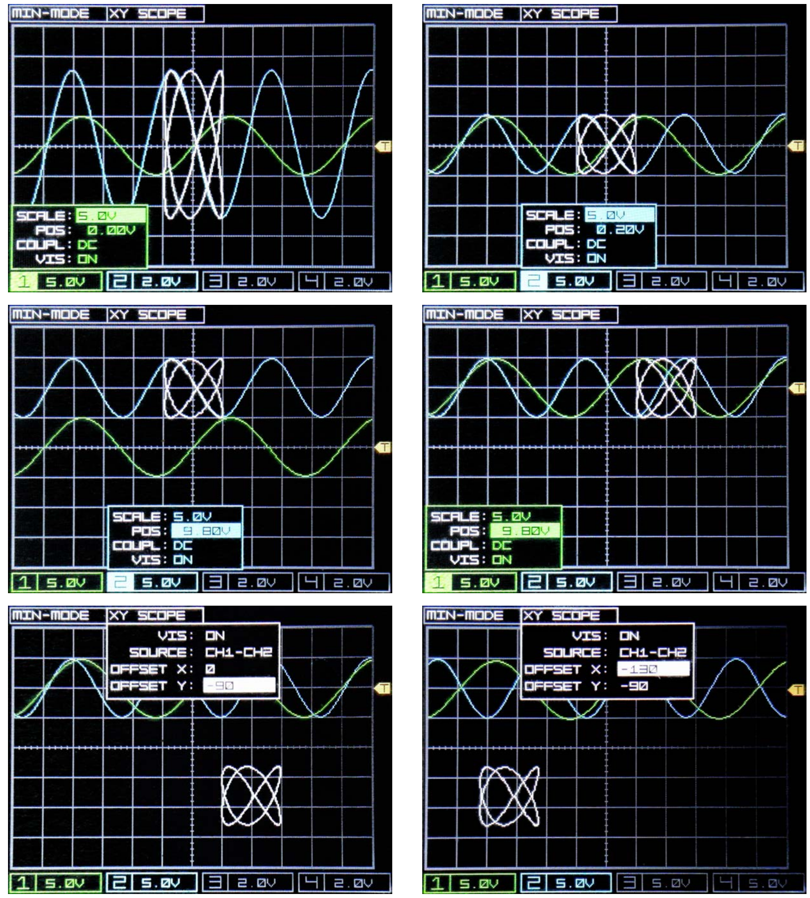
XY Scope - Positioning Basics

While the XY Scope's visibility is independent from the source channels, the scale and position are linked.

In the example right, first changing the CH1(X) scale value to 5.0V appears to compress the XY Scope horizontally. Then changing the CH2(Y) scale to 5.0V compresses it vertically. Now the XY Scope is a smaller version of what we started with above.

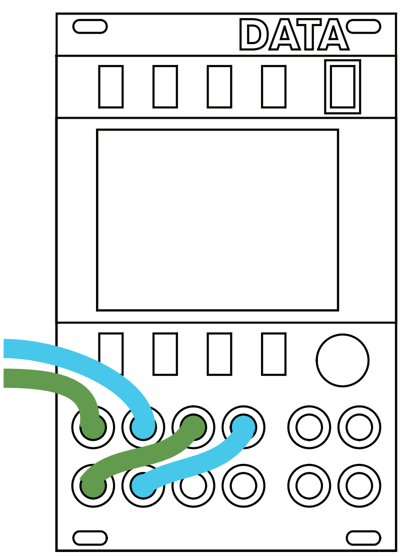
Next, you can see changing the channel position of CH2(Y) moves the XY Scope up along with the waveform, while increasing the CH1(X) position shifts the XY Scope towards the right.

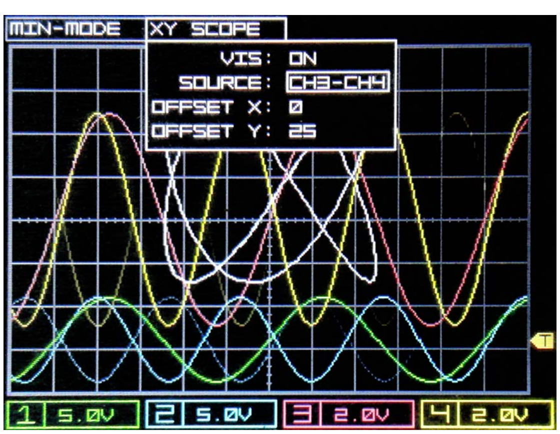
The OFFSET controls in the XY SCOPE pop-menu allow for further controlling the XY Scope position, shifting it from the channel positions.

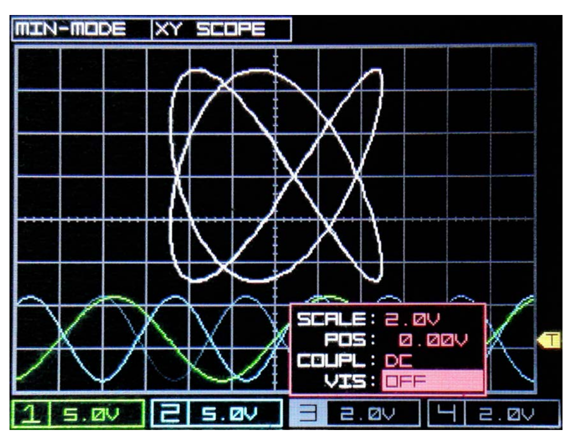


XY Scope - Decoupled Scale & Positioning

Since the XY Scope is linked to the source channel's position and scale, you can really dial in monitoring of two channels on the waveform oscilloscope and XY by connecting the buffered output jacks of channel 1 & 2 into the input jacks of 3 & 4. Then set the XY source to CH3-CH4 but in the waveform scope turn off those channel's visibility, only monitoring the waveform scope channels 1 & 2. This way you can have a **larger or smaller scale** for the XY than the waveform scope channels. This is the technique used in the images below, where the visible waveform scope channels 1 & 2 are at scale 5.0V and position -14.0V, and the not visible waveform scope channels used for the XY, 3 & 4, are set to 2.0V scale, making the XY display larger than the channel 1 & 2 waveforms.





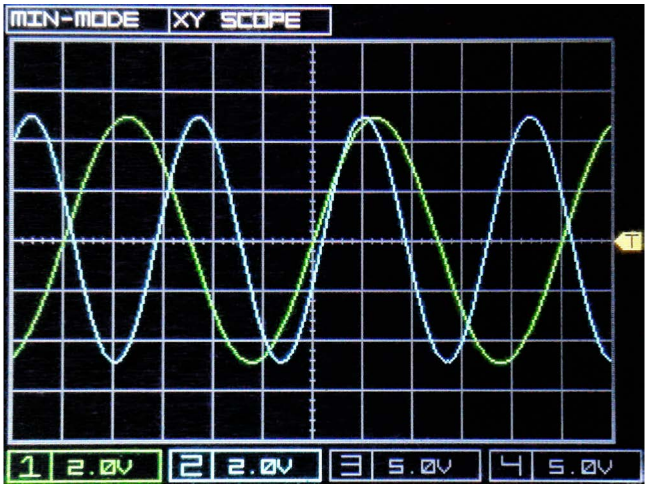


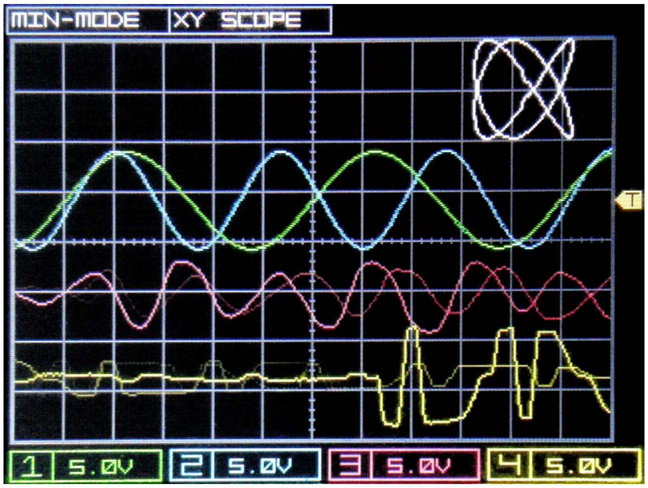
MINIMAL DISPLAY MODE

Sometimes you just want to see some pretty waves! By popular demand, the DATA's Oscilloscope program now includes a Minimal Display Mode, which allows you to turn off the scope's grid and control buttons and just view the channel waveforms and XY display.

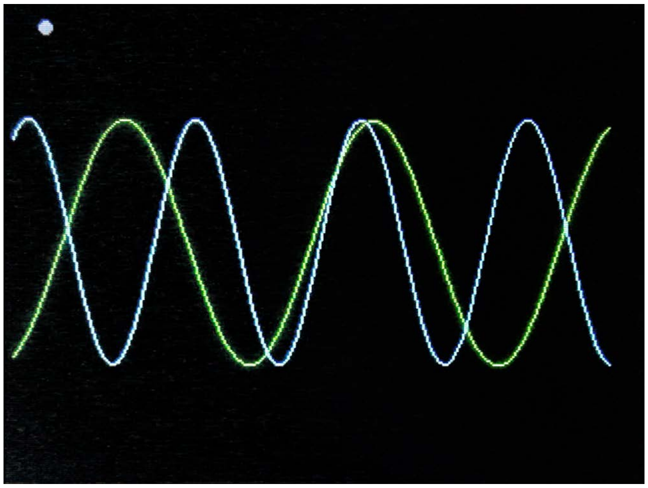
To toggle Minimal Display Mode, first enter the secondary top menu functions by pressing and holding the top right button, as previously described. Click the MIN-MODE button in the top left to turn Minimal Display Mode on. Once in MIN-MODE all of the soft button cease to function except the MIN-MODE button, which is indicated by the small grey circle in the top left of the screen; click it again to exit MIN-MODE.

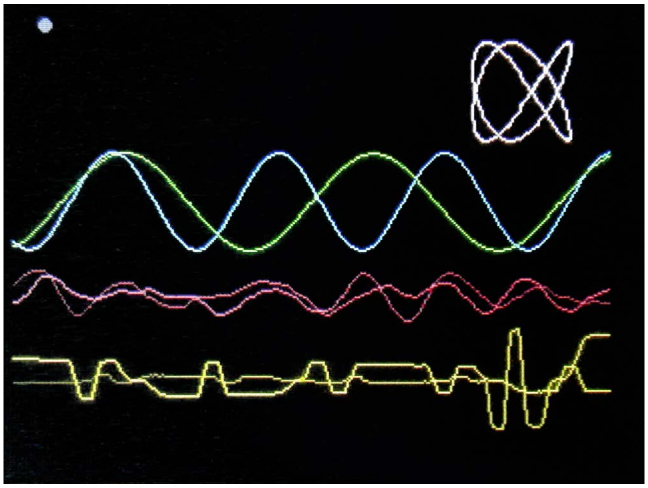
NORMAL





MIN-MODE

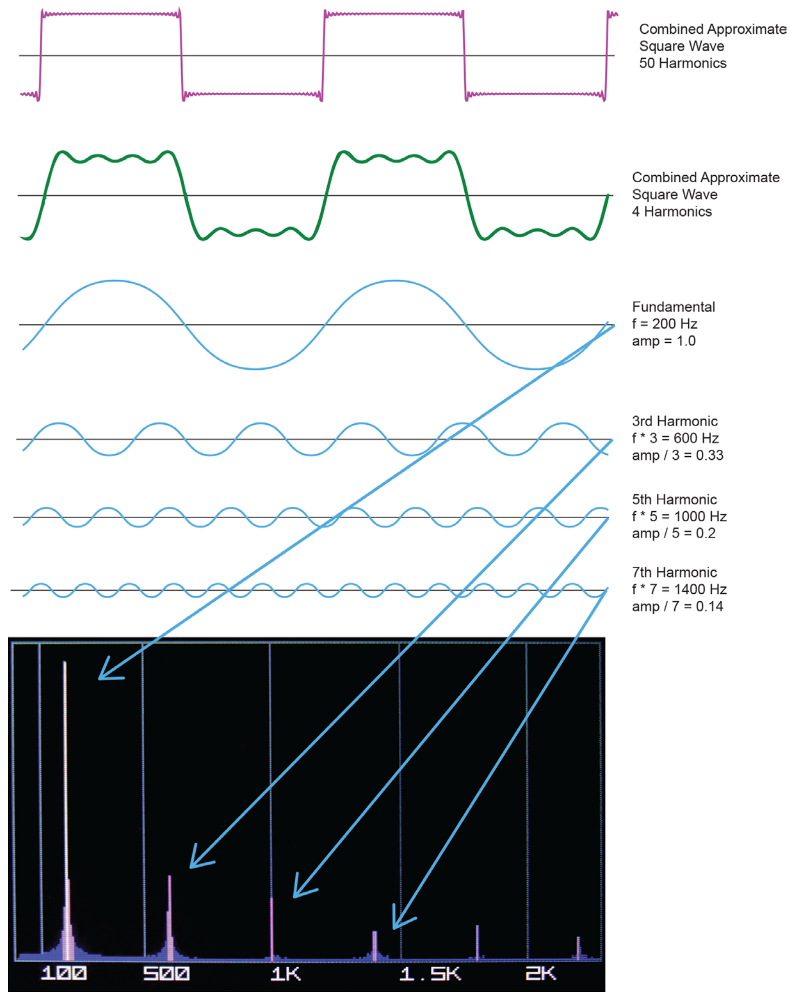




Program : Spectrum Analyzer & Spectrograph

One of the most interesting things about sounds (and periodic signals in general) is that they can be described as the sum of an infinite set of sine waves at various frequencies and amplitudes. This collection of sine waves that make up a signal is the signal's frequency spectrum, and the individual sine waves in the spectrum are its harmonics (also called partials).

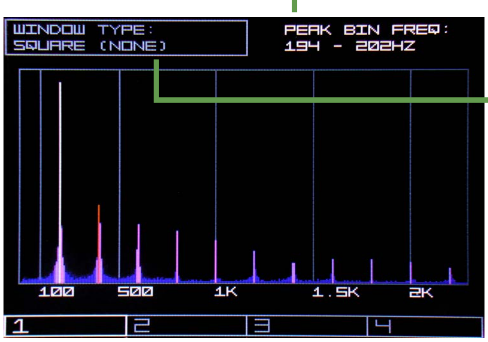
For example, a square wave can be created by starting with a sine wave of a given frequency (the fundamental or first harmonic), then adding subsequent sine waves at odd multiples of the fundamental frequency and decreasing amplitudes (odd harmonics). The green waveform right shows the additive synthesis of a fundamental and three additional odd harmonics (blue sine waves). It's not a perfect square wave, but it's starting to take shape. If you continued adding subsequent odd harmonics in this fashion the combined wave to become increasingly more square, as seen with the magenta wave, which is the result of 50 sine waves combined.



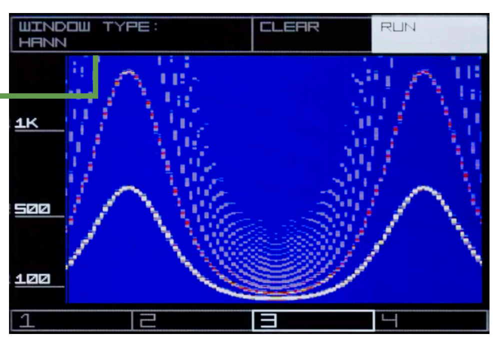
The DATA's spectral programs allow you to view these frequency components, taking a time domain signal and displaying it in frequency domain, showing it's harmonic content (the various sinewaves that make up the signal). This is accomplished by Fourier analysis, specifically fast Fourier transform (FFT). Both the DATA's Spectrum Analyzer and Spectrograph display the incoming signal's frequency spectrum, with the Spectrum Analyzer showing the output of one FFT analysis at a time, and the Spectrograph showing multiple FFT's. The Spectrum Analyzer provides the frequency components of a signal as a bar graph, with each bar representing a small frequency range (also called a bin); the higher the bar, and the lighter it's color, the greater the magnitude of the frequency band in the signal. The Spectrograph shows the same information as the Spectrum Analyzer, but only displays magnitude as a function of color.

Peak Bin: The tallest bar in the bar graph is the frequency bin with the greatest magnitude. This is the signal's first harmonic (fundamental frequency).

RUN/STOP button: Push to switch between RUN and STOP of the display.



Window Type: Shows the current windowing function (filter) applied to the incoming signal. Push button 2-1 and scroll with the encoder to apply different window types.



Channel buttons:
The currently active input channel is highlighted. Push the soft buttons below each channel number to change inputs.

Program : Tuner

The DATA's Tuner program measures an incoming signal's frequency and automatically displays the nearest note in the chromatic scale, as well as calculates the difference in hertz from the nearest note. Any of the four input channels can be selected for measurement, allowing for quick tuning of multiple signals (e.g., tuning four oscillators to make a chord).

Typical accuracy:	+/- 0.01 Hz
Frequency range:	27.50 Hz - 2,960 Hz (spans notes A0 to ~F#7)

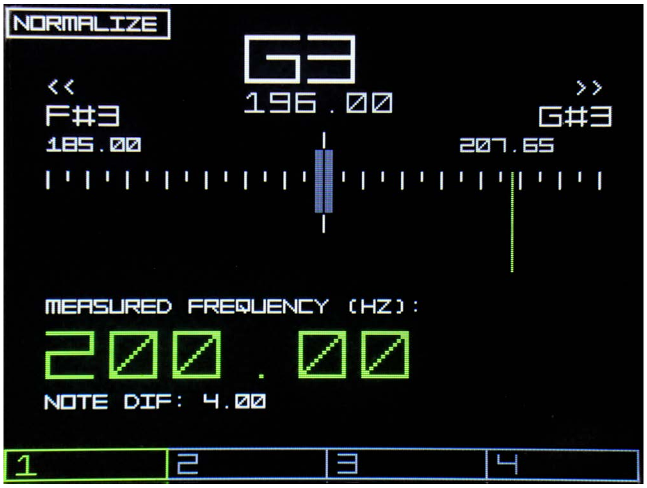
Normalization - Small Signals

Eurorack audio oscillators generally produce a 10V peak-to-peak (+/-5V) signal. If the input signal is significantly less than this (e.g., less than 6V peak-to-peak), engage the Tuner's normalization function (button 2-1, top left) to maintain analysis of the lesser signal. Note that normalization can effect measurement accuracy and is not recommended for use on signals > 2,200 Hz. For measurement of high frequency, low amplitude signals, disengage the normalization function and boost the target signal prior to input via an external gain amplifier, buffered adder, or similar.

Tuner - Display Overview

Normalize: Push button 2-1 to turn ON/OFF normalization processing of the input signal. Used when the incoming signal is significantly less than 10V peak-to-peak (e.g., +/-5V typical oscillator signal).

Nearest Note: The nearest note name and frequency compared to the incoming signal's measured frequency.



Next Note: The nearest note in the chromatic scale to the incoming signal's measured frequency.

Measured Frequency: The fundamental frequency of the incoming signal.

Note Dif: Difference in Hz between the incoming measured frequency and its nearest note frequency.

Channel buttons: The currently active input channel is highlighted. Push the soft buttons below each channel number to change inputs.

Program : Wave Output

The DATA's Wave Output program provides two precision waveform generators. Each unit can act as either LFO modulation sources or audio rate oscillators, with 1V per octave CV pitch tracking over 8 octaves. CV control over each oscillator's pitch and amplitude (digital VCA) can be assigned on the fly to any of the 4 input jacks, with independent attenuators per modulation destination.

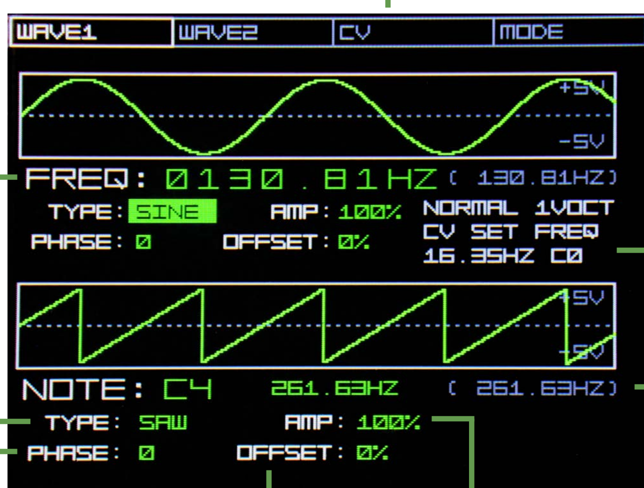
Frequency - Manual Control:	0.01 Hz - 9,999.99 Hz
Frequency - CV Input:	0.01 Hz - 4,200.00 Hz C0 to C8 / 0V to +8V is the normal functional CV input range *Will accept CV input up to +10V, producing glitchy, weird signals up to around 15,800 Hz
Amplitude (VCA) - CV Input:	0V to +5V, linear response

Waveform Generator - Display Overview

WAVE1/2: Push to scroll and act on available parameters for either waveform generator (e.g., scroll frequency, type, phase, etc.)

CV: Push to bring up the CV pop-up menu and assign the CV source and attenuation amount for either waveform generator's pitch or amplitude

MODE: Push to bring up the Mode pop-up menu. TUNE for choosing either decimal frequency or note value for setting the waveform generator's base frequency. SHAPE for selecting different waveshaping modes



FREQ/NOTE: The waveform generator's base frequency (frequency before CV pitch control) is displayed as either decimal Hz or note name.

CV Message: Not a control, but a reminder message to set the oscillator base frequency to note C0 (16.35Hz) for normal 1V per octave CV tracking.

TYPE: The initial waveform shape, which can be SINE, SQR, SAW, or TRI.

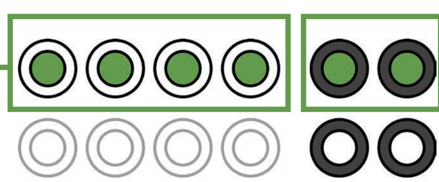
Final Frequency: The waveform generator's current output frequency, which is a combination of the set base frequency and the incoming CV pitch information (if pitch CV is active)

PHASE: The starting point of the waveform's cycle

OFFSET: Percent gain or reduction in the waveform's center voltage value (e.g., 0% = 0V center, 25% = 2.5V center). This can be used in combination with the AMP control to clip and shape the waveform.

AMP: The waveform's amplitude as a percentage of 10V peak-to-peak (e.g., 100% = 10Vpp, +/-5V). Max value is 200% and will clip the waveform over +5V and under -5V for wave shaping. Min values is -200%; negative amp values invert the wave (e.g., saw to ramp). This gain stage is prior to the VCA, so that clipping waves will maintain their shape under VCA control.

CV Control: Input channels 1-4 can be assigned as CV source for control of the frequency or VCA amplitude of either oscillator



Wave Out: Oscillator 1 and 2 output, 10V peak-to-peak (+/-5V)

Input/Output Jacks

Oscillator Waveshaping

Using the internal amplification and offset controls allow for waveshaping the basic oscillator waveforms, providing a range of non-standard forms for use as LFOs or audio sources.

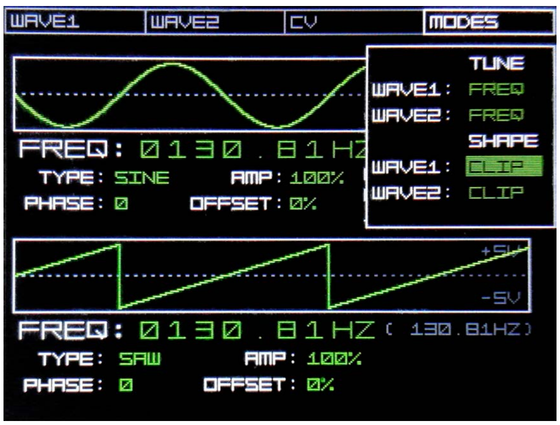
Click the MODE button and choose the waveshaping type via the SHAPE section in the MODE pop-up menu.

Note that you can't clip or fold a square wave. It's kind of like trying to low pass filter a sine wave - nothing happens.

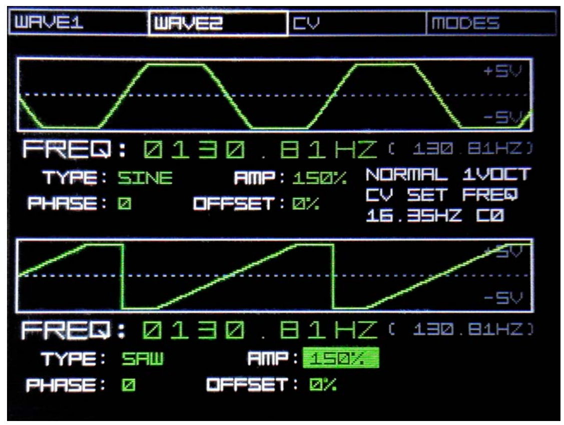
SHAPE : CLIP

CLIP waveshaping will cause the waveform to clip (register a flat voltage) when shifted past the +5V or -5V limit on the wave display window.

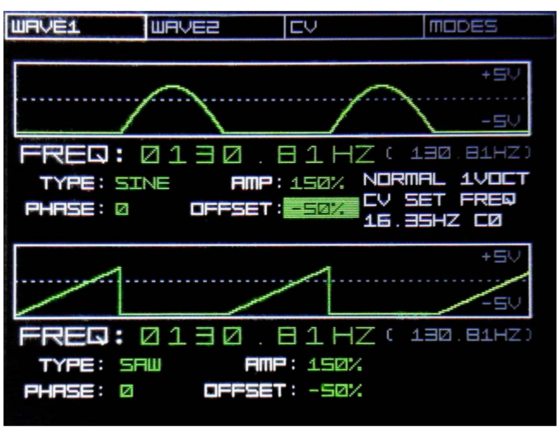
In the examples below the same AMP and OFFSET control values are applied to both a sine wave and a saw wave.



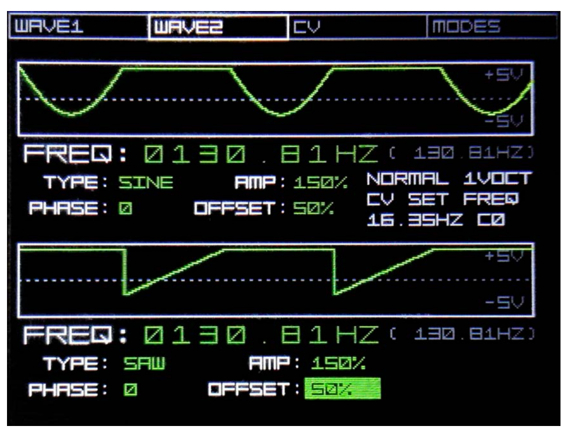
AMP: 100% OFFSET: 0%
(no waveshaping)



AMP: 150% OFFSET: 0%



AMP: 150% OFFSET: -50%



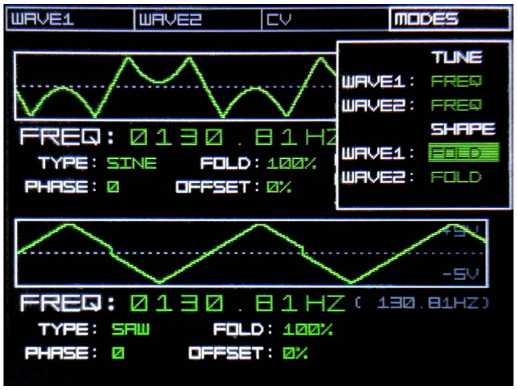
AMP: 150% OFFSET: 50%

SHAPE : FOLD

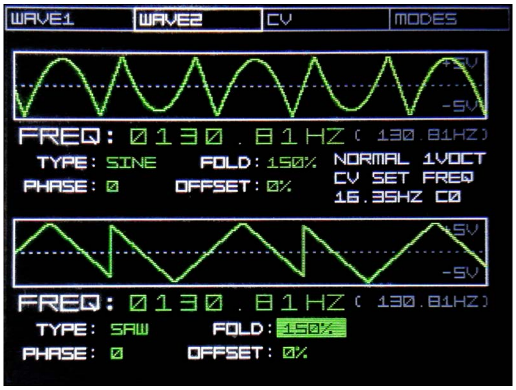
FOLD waveshaping will cause the waveform to reflect negatively when shifted past the +5V or -5V limit on the wave display window.

Note that when the FOLD waveshape mode is selected, the waveform control AMP becomes FOLD. When OFFSET is 0%, a 100% FOLD value generates a first reflection, while a 50% FOLD value generates an unaltered waveform.

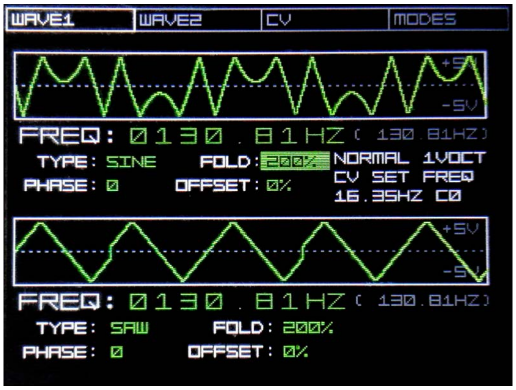
In the examples below the same AMP and OFFSET control values are applied to both a sine wave and a saw wave.



AMP: 100% OFFSET: 0%



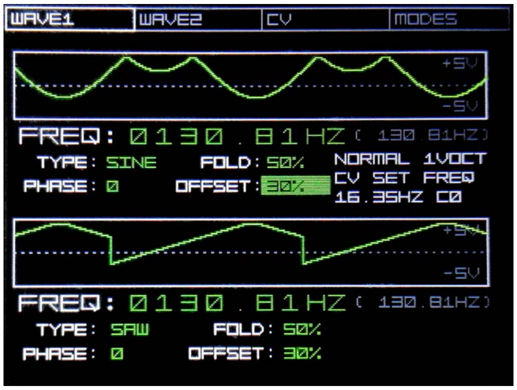
AMP: 150% OFFSET: 0%



AMP: 200% OFFSET: 0%

AMP: 50% OFFSET: 0%
(no waveshaping)

AMP: 50% OFFSET: -70%



AMP: 50% OFFSET: 30%

Program : Clock Output

The DATA's Clock program provides four CV controlled Clock trigger outputs, which can be driven by either the highly stable, BPM defined Internal Master clock, or can be synced to an external clock source (External Sync Mode). Each Clock output rate is a multiple (DIV/MULT parameter) of the Internal Master or External Sync clock and can be offset in time from the source clock up to one quarter note forward or backwards (+/-96 ticks).

The DATA's Clock outputs can be used to trigger external sound generators directly (e.g., drum voices), acting as trigger sequencers, or they can be used as variable clock sources to drive step sequencers or other time-based modules in your system. With the use of CV modulation over the output clock parameters, very complex rhythms are possible, from mechanical ratcheting to African-style drumming.

Clock - Internal Master Mode - Display Overview

BPM: Decimal quarter note beats per minute of the base clock generator.

FREQ & PERIOD Display: The frequency (Hz) and period (ms) of the base clock generator (quarter notes)

DIV/MLT: Division or multiplication of the base clock frequency to be output. Setting to 1:1 produces quarter notes, x4 gives 16th notes (PPQN 4), x5.3 dotted 32nds, etc. The final DIV/MTL value, adding CV influence, is below in grey in parentheses.

OFFSET: Output clock's shift +/- 96 ticks (one quarter note) from the base clock. Final OFFSET value, adding CV influence, is shown to the right in grey in parentheses.

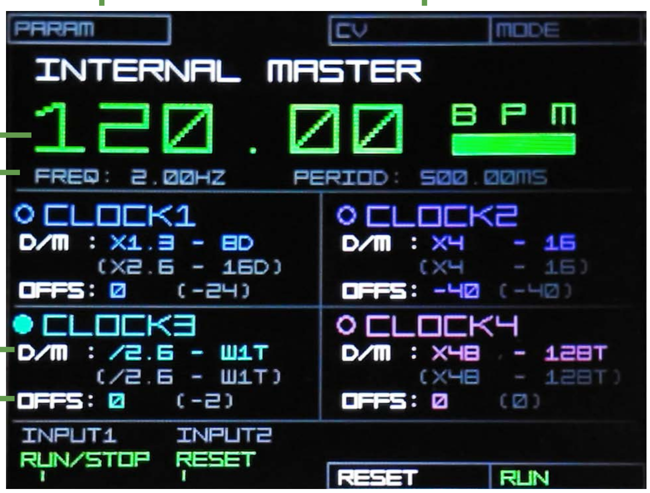
PARAM: Push to scroll and act on available main screen parameters (e.g., Master BPM, Clock div/mult, offset)

CV: Push for the CV pop-up menu and assign the CV source and attenuation amount for any clock's div/mult and offset modulation.

MODE: Push for the Mode pop-up menu, choosing either INTERNAL MASTER mode or EXTERNAL SYNC mode.

RUN/STOP: Push soft button 1-4 to toggle RUN/STOP of the clock generator.

RESET: Push soft button 1-3 to reset the clock generator's measure position (applies to longer division settings). *This button is active on release for precise performance timing.

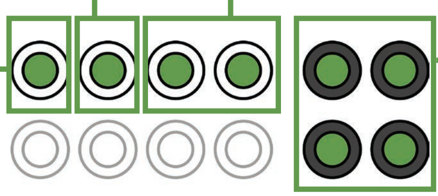


INPUT2 - RESET: Indicates the function of INPUT2. Send a gate signal to reset the clock generator's measure position (applies to longer division settings). This has the same effect as pushing soft button 1-3 RESET.

INPUT1 - RUN/STOP: Indicates the function of INPUT1. Send a gate signal to toggle RUN/STOP of the clock generator (same as pushing soft button 1-4).

CV Control: Input channels 3 & 4 can be assigned control over any clock's div/mult or offset parameters. Input range +/-5V (10Vpp)

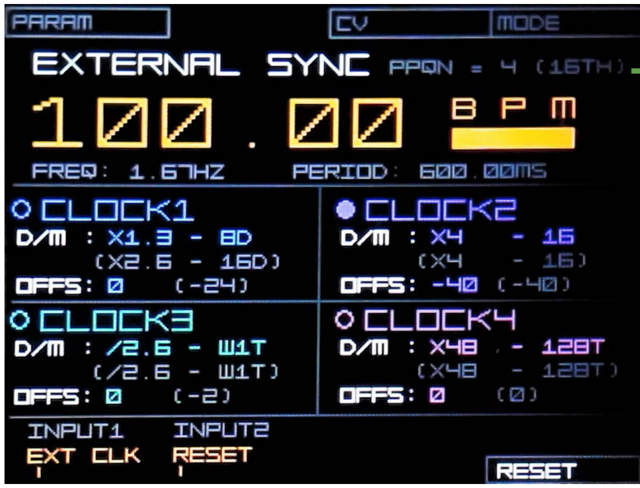
Clock Out: Clock 1, 2, 3, 4 output, 5V peak-to-peak (0V to +5V)



Input/Output Jacks

Clock - External Sync Mode - Display Overview

Most elements are the same as INTERNAL MASTER MODE referenced previously; only those unique to EXTERNAL SYNC MODE are highlighted below.



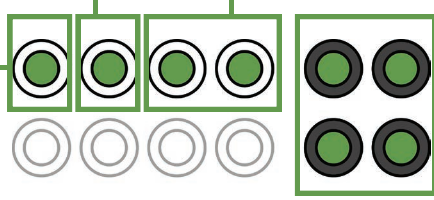
EXT PPQN: The expected pulses per quarter note (PPQN) of the incoming external clock signal (INPUT1 jack). This is currently fixed at PPQN = 4, or 16th notes, which is the typical resolution of eurorack sequencer clock out jacks

INPUT2 - RESET: Indicates the function of INPUT2. Send a gate signal to reset the clock generator's measure position (applies to longer division settings). Some sequencers have a RESET out jack; connect it here.

INPUT1 - EXT CLK: Indicates the function of INPUT1. This is the input for incoming external clock signal. Send in 16th note pulses 0-5V. Typically connected to a sequencer's CLOCK output jack (but you could also use a square wave LFO)

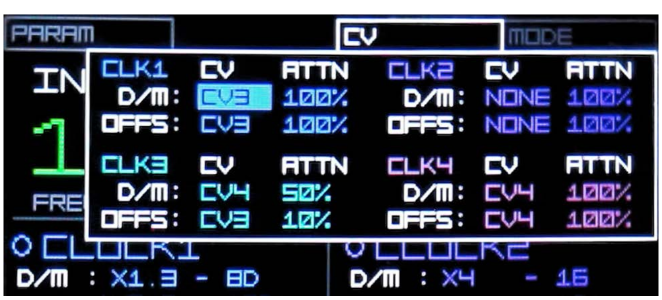
CV Control: Input channels 3 & 4 can be assigned control over any clock's div/mult or offset parameters. Input range +/-5V (10Vpp)

Clock Out: Clock 1, 2, 3, 4 output, 5V peak-to-peak (0V to +5V)



Input/Output Jacks

Clock - CV Input Pop-up Menu



Available in both INTERNAL MASTER and EXTERNAL SYNC modes. All four CLOCK OUTPUT channels can be assigned a CV modulation source, either input jack 3 or 4, for both their div/mult and offset parameters. The ATTN column provides independent attenuation of the incoming CV signal per modulation destination, allowing for the same CV source to impact a number of destinations differently.

Program : Voltage Monitor

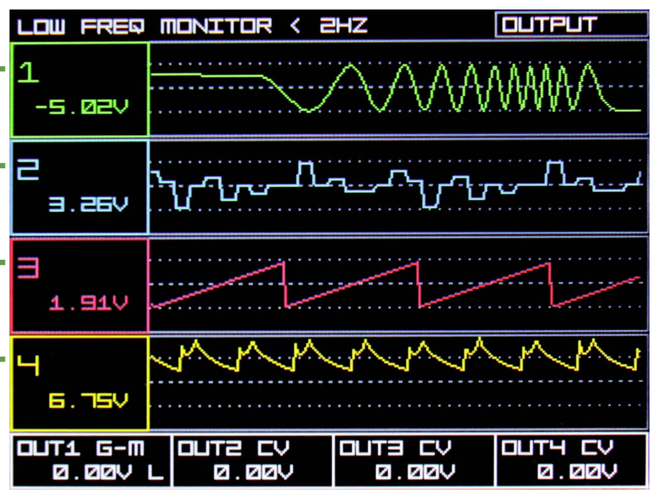
The DATA's Voltage Monitor program provides a four-channel voltage meter with time display, as well as four output channels of continuous DC voltage (CV), momentary gate (GATE-MO), or latched gate (GATE-LA).

The voltage monitor display shows approximately 12 seconds of incoming information. For each channel display the thick dotted center line represents 0V and the two fine dotted lines +/-5V. The display is designed to monitor constant or slowly changing signals (LFOs, sequencers, manual CV or gate controls, etc.). Repeating signals at a frequency greater than 2 Hz will experience display aliasing, as described in the DATA's Oscilloscope Program section on aliasing distortion.

Output channels are configured via the OUTPUT pop-up menu in the top right corner. TYPE: CV configuration will output a constant voltage from the channel's output jack. To change this voltage, push the corresponding channel button at the bottom of the display. The channel will then be highlighted in white and you can change the voltage via the encoder knob; scroll for fine adjustment or push in while scrolling for coarse adjustment (1V per increment).

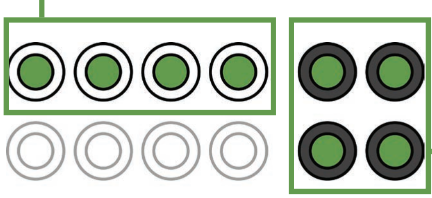
Output TYPE: GATE-MO configures the output as a momentary gate, where the voltage level set as G-HI is output only while you press the associated channel button, otherwise the channel will output the G-LOW voltage. Output TYPE: GATE-LA configures the output as a latched gate, meaning that the output voltage toggles between the high and low voltages with each button press.

Voltage Monitor - Display Overview



OUTPUT: Push for the OUTPUT pop-up menu, to assign output functions (CV, Gate-Momentary, Gate-Latch) and Gate high and low voltage values.

Monitor Inputs: Inputs for the four monitor channels. Voltage range is +/-10V.



Input/Output Jacks

CV/Gate Outs: Outputs for the four CV/Gate channels. Each can be either a constant DC voltage (CV), momentary gate (G-M), or latched gate (G-L). Push the channel buttons to either access the CV voltage value (and scroll with the encoder knob to change) or engage the channel gate. Output range is -5V to +10V.

Pro-tip: *Most of the DATA programs with outputs will reset to 0V upon exit, but not the Voltage Monitor, which allows for fixed voltage outputs while using the Tuner, Oscilloscope, and Spectral programs. Simply go to the Voltage Monitor, dial in your CV voltage level, then go directly into the Tuner, Oscilloscope, or Spectral program and the outputs will stay where you set them in the Voltage Monitor.*

Change Logs

SYSTEM FIRMWARE

DATE	Revision	Changes
171002	SYS V 01.02.02	Clock Output • Complete program re-design, improving stability and range • Increased output channels from 2 to 4 • Increased available number of div/mult factors from 20 to 32 Wave Output: • Increased waveform resolution and reduced aliasing noise • Optimized CV input processing for increased modulation rate Moved LOAD button to opposite side of the display from the SAVE button in the Settings SAVE/LOAD program (per user request). Bug fix - Rare OSX Apple Double SD Card file read error. System wide optimizations in UI and memory buses.
170420	SYS V 01.01.00	Oscilloscope: • Added XY Display (Lissajous curves) • Added Minimal Display Mode • Improved waveform drawing Wave Output: • Wave Folding Mode Improved encoder knob handling and added encoder velocity system wide. Made various little improvements, system optimizations, and bug fixes.
161229	SYS V 01.00.00	Initial Release

BOOTLOADER FIRMWARE

DATE	Revision	Changes
161229	BOOT V 01.00.00	Initial Release

USER GUIDE

DATE	Revision	Changes
171002	171002	Added “What’s New” section to beginning of the User Guide. Updated Clock Output section to reflect new design. Updated SAVE/LOAD images Updated TUNER freq maximum - was B7, should be F#7 Added note on Voltage Monitor CV output persistence Added note on System vs. Bootloader firmware Various small formating, wording, spelling changes
170531	170531	Added sections: • Oscilloscope - Secondary Top Menu Functions • Oscilloscope - XY Scope • Oscilloscope - Minimal Display Mode • Wave Out - Oscillator Waveshaping (CLIP & FOLD)
161229	161229	Initial Release