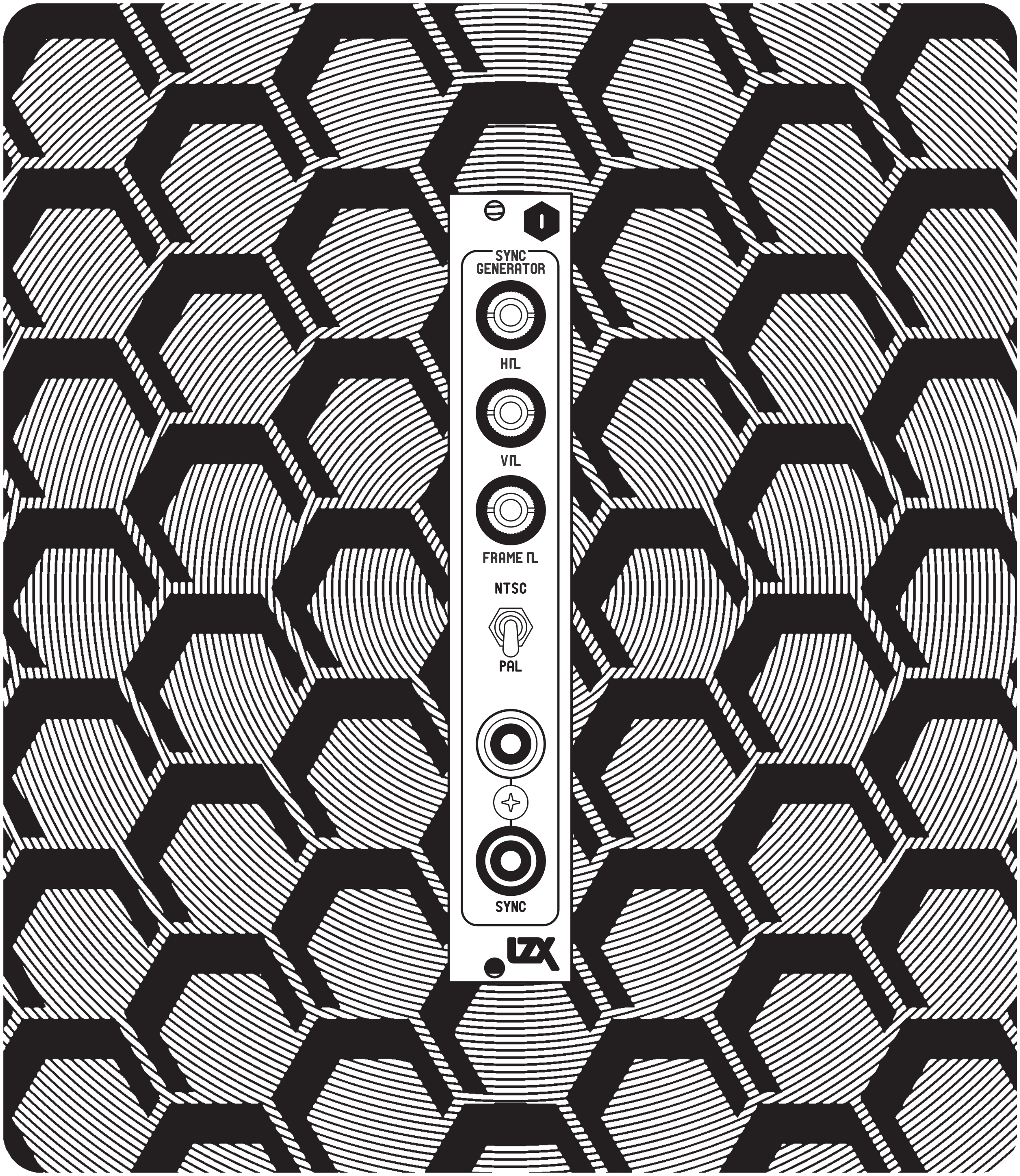
CADET I SYNC GENERATOR
OWNER'S MANUAL



LZX industries

ABOUT THE CADET SERIES

The practice of analog video synthesis has an inspiring legacy of innovators, sharers, and doers. In the early 70's, Dan Sandin released the hardware documentation of his Sandin Image Processor, a video instrument modeled after the Moog synthesizer. It contained several modules, an expandable architecture, and was an early example of what we now know as the open source movement.

In the mid 00's in Denton, Texas, I was diving deep into the tradition of synth DIY electronics when I stumbled across the documentation for the Sandin Image Processor and became enchanted. Teaming up with Ed Leckie in Sydney, Australia, we labored to adapt the circuits in ways that could be built with modern components. These efforts evolved into our own unique take on video synthesis, the LZX Industries format, and we began selling modules for the EuroRack synthesizer market in 2010.

With the Cadet series, we aim to take our work and give it back to the synth DIY and video hardware communities in a format we wished would have existed in the early days of our work. Each Cadet module performs a single function and is designed using through-hole parts where possible. Circuit schematics are published under the Creative Commons Attribution 4.0 International License. If our other product lines are recipes, Cadets are the ingredients. We encourage you to think outside the box, and to combine these circuits in new ways. Take the schematics, design your own modules and devices, and release them back into the world.

We salute you, Cadet! Go! Build!

Lars Larsen
September, 2016

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Firmware by Ed Leckie

Published September, 2016.

LZX-C1-PCB-V1.1
LZX-C1-FPN-V1.0
LZX-C1-BOM-V1.1
LZX-C1-SW-V1.1
LZX-C1-OM-V1.0

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Creative tools for video synthesis
and analog image processing.

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FEATURES

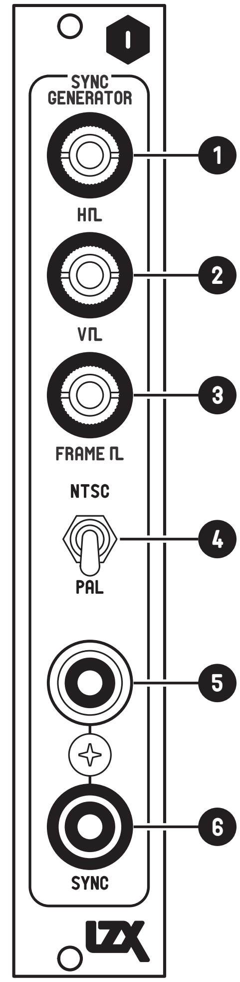
Cadet I Sync Generator (C1) generates the master timing signals required for your modular video synthesizer in both NTSC and PAL formats. C1 includes a 14-pin video sync output header which transmits timing information to other modules, such as Cadet II RGB Encoder, or Cadet IV Ramp Generator. It can also synchronize its timing, and consequently that of your entire video synthesizer, to an external video source.

- Horizontal Sync Pulse, Vertical Sync Pulse, and Frame Clock outputs accessible from frontpanel.
- NTSC/480i and PAL/576i timing modes.
- Synchronization to an external video source through Video/Sync In. Buffered pass-through of external video signal.
- 14-pin video sync distribution header output on rear, to transmit video sync to other modules in the system.
- Buffered distribution of Horizontal Sync Pulse and Vertical Sync Pulse outs to the EuroRack power header CV/Gate bus.

SPECIFICATIONS

Format	EuroRack Synthesizer Module
EuroRack Width	4HP
Mounting Depth	2.25 inches (57.15 mm)
Frontpanel Dimensions	0.788 inches (20.015 mm) * 5.059 inches (128.5 mm)
+12V Power Consumption	30mA
-12V Power Consumption	10mA
Series Output Resistance	499 ohms (3.5mm outputs) 75 ohms (RCA outputs)
Input Termination Resistance	100K ohms (3.5mm inputs) 75 ohms (RCA inputs)
Voltage Levels	0-1V DC (3.5mm outputs) 0-5V DC (14-pin video sync distribution header outputs) 2Vpk-pk (RCA input/output)
Video Formats	NTSC/480i & PAL/576i
Video Sync Distribution Header Outputs	Composite Sync Vertical Sync Horizontal Sync Odd/Even Field Composite Blanking

USER CONTROLS & CONNECTIONS



1 Horizontal Sync Pulse Out. Positive-going pulse, 0-1V DC. Pulses at the beginning of each video scanline. 15,734Hz for NTSC. 15,625Hz for PAL. Useful for synchronizing oscillators running above these frequencies.

2 Vertical Sync Pulse Out. Positive-going pulse, 0-1V DC. Pulses at the beginning of each video field. 59.97Hz for NTSC, 50Hz for PAL. Useful for synchronizing oscillators running at frequencies above these frequencies, but below the horizontal sync pulse frequencies.

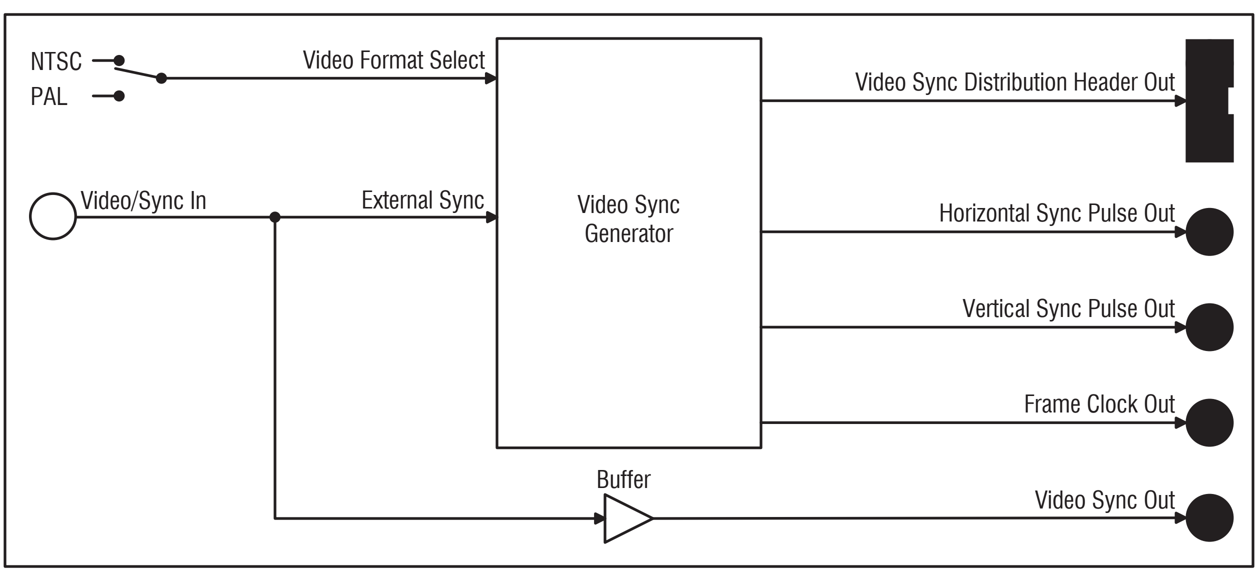
3 Frame Clock Out. Positive going pulse, 0-1V DC. Active high at the beginning of each video frame, and remains high during the odd numbered fields. Useful to drive sequencing at divisions of the video frame rate, or into clock dividers to create strobe sources.

4 Video Format Select Switch. Selects between NTSC (480i) and PAL (576i) sync timings. The desired setting must be selected prior to system power up.

5 Video/Sync In. Input an external video signal here to synchronize C1's timing to an external source.

6 Video/Sync Out. A buffered pass through of the Video/Sync Input. If you are synchronizing to an external camera, you could pass this signal to Cadet III Video Input (C3) to prepare that signal for patching throughout your system.

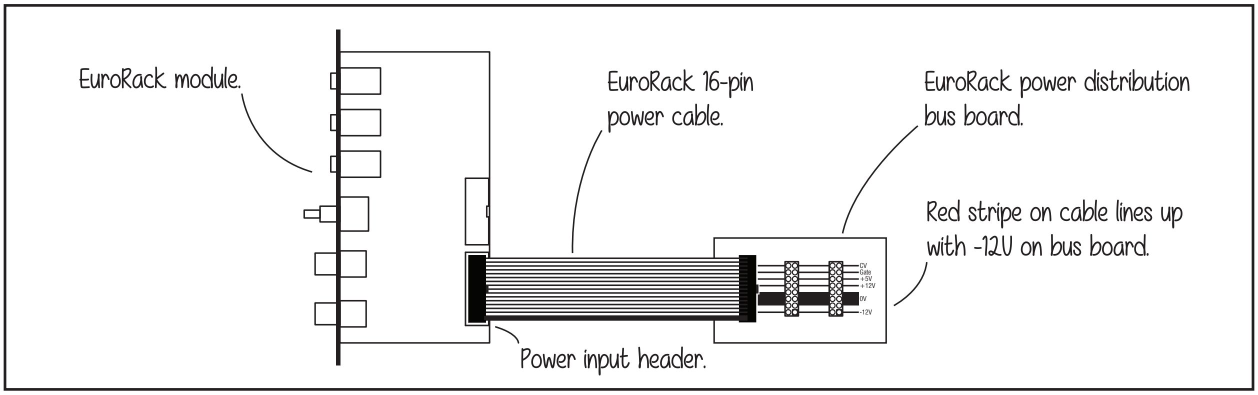
BLOCK DIAGRAM



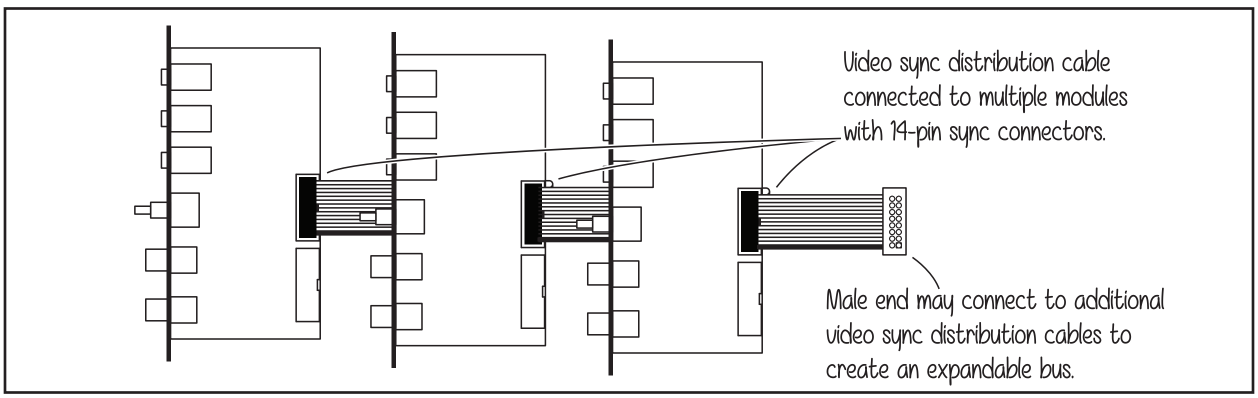
INSTALLATION

Power down your EuroRack case and disconnect it from AC power outlet while installing new modules.

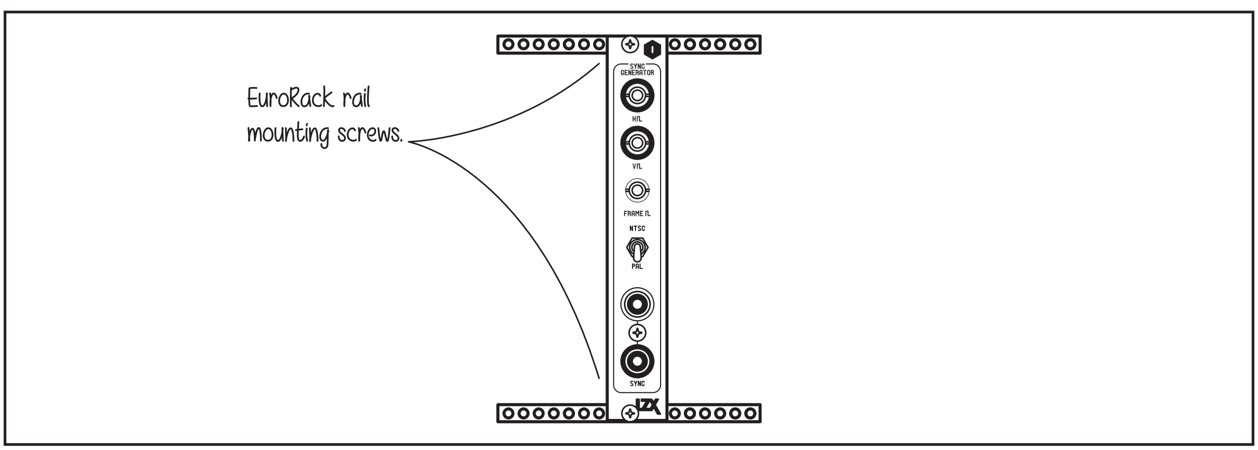
Remove the module from its packaging and connect the 16-pin power cable to the keyed power entry header on the rear of the module as shown. Connect the other end of the power cable to an empty connector on your EuroRack power distribution busboard. Ensure pin 1 (-12V, with the red stripe) is oriented as indicated on your power distribution busboard.



This module requires connection to other video modules through the 14-pin sync distribution header. This is done through the use of the Video Sync Distribution Cable (VSDC) available from LZX Industries. VSDC is an expandable bus cable allowing attachment to up to 5 different modules. Connect one of the female connectors on the VSDC to the rear of the module as shown. Each module in your system with a 14-pin sync header in your system must be connected to each other in this manner. Multiple VSDCs may be chained together to provide an expandable bus if more than five connections are required.



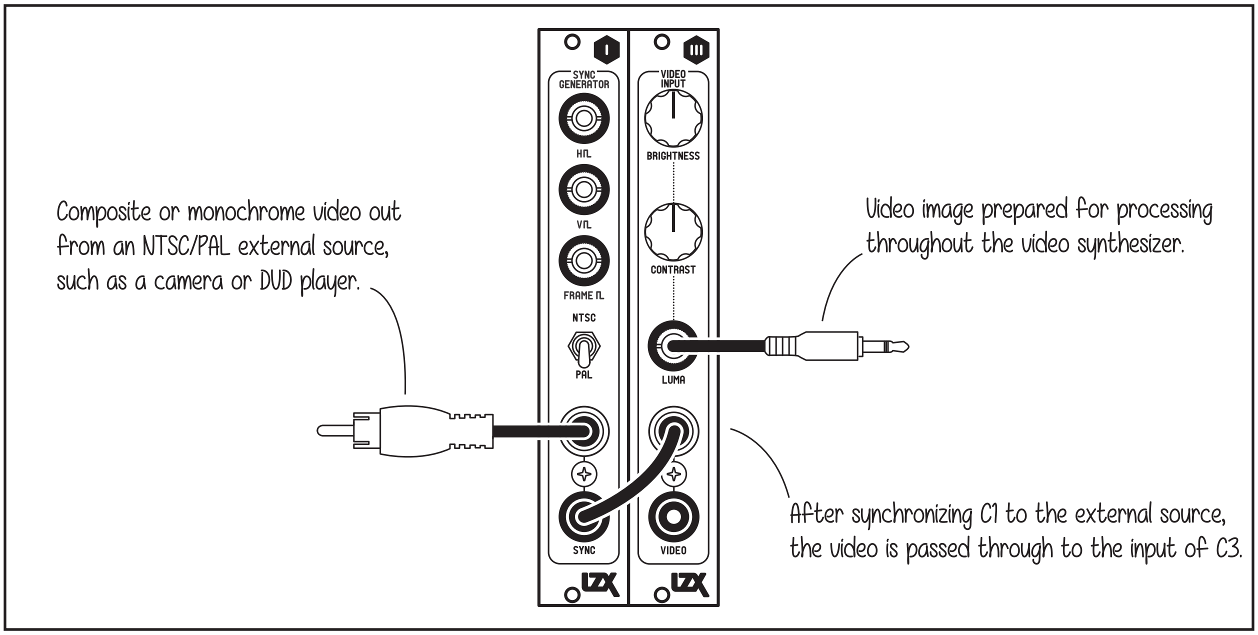
After connecting power and sync cables, mount the module frontpanel flush to your enclosure's EuroRack mounting rails and secure the module with the mounting screws provided by your enclosure's manufacturer.



EXAMPLE PATCHES

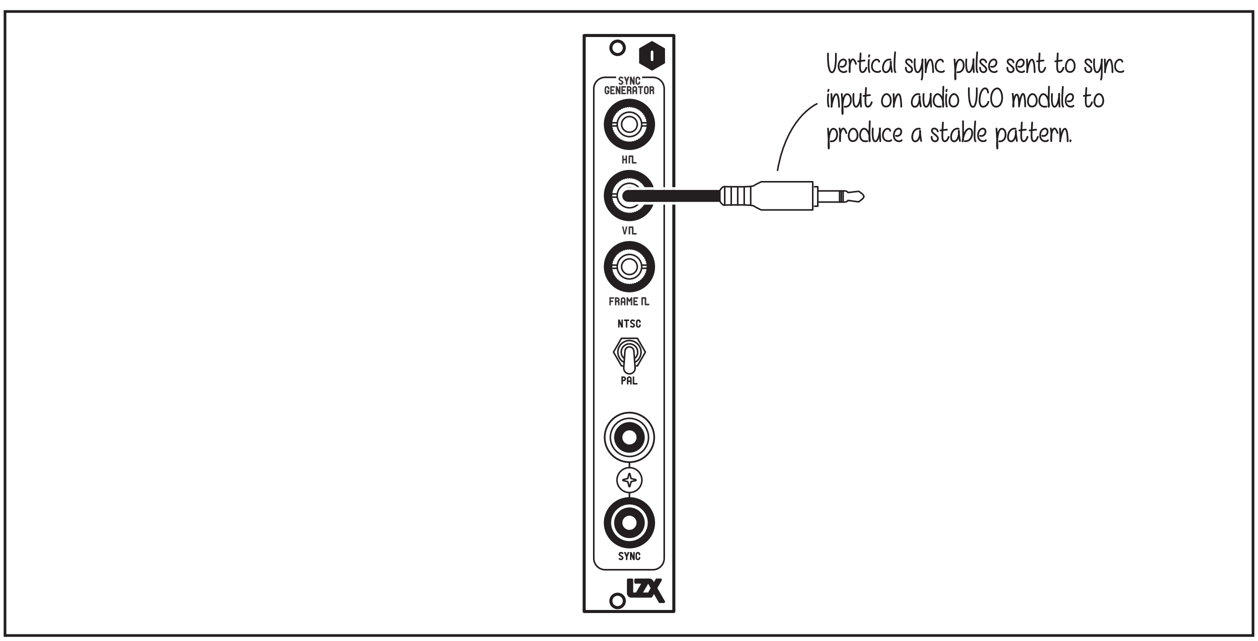
SYNCHRONIZING AND PROCESSING EXTERNAL VIDEO

While a sync generator is an essential module for a video synthesizer, it does most of its magic by simply being there and performing its job behind the scenes. The most commo patch you will make with C1 is to synchronize your system's timing to an external video source before patching that signal through to a video input amplifier, such as the Cadet III Video Input module.



SENDING VIDEO SYNC TO AUDIO OSCILLATORS

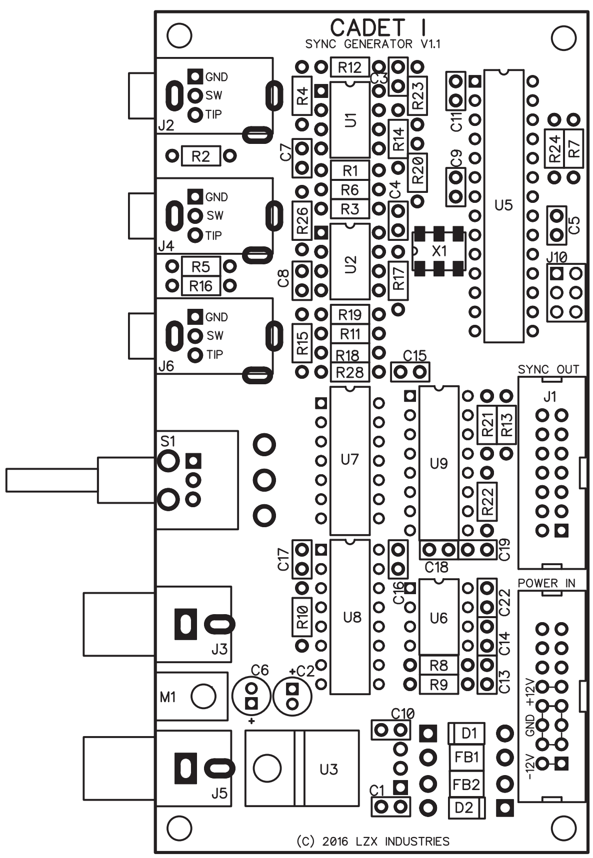
Most video pattern sources and oscillators designed by LZX will receive horizontal and vertical sync pulses through distribution behind the scenes, such as through the Video Sync Distribution output header or CV/Gate connectors on the power bus. However there may be cases in which you want to attempt synchronizing other sources, like EuroRack audio modules or laboratory test gear.



DIY BUILD NOTES

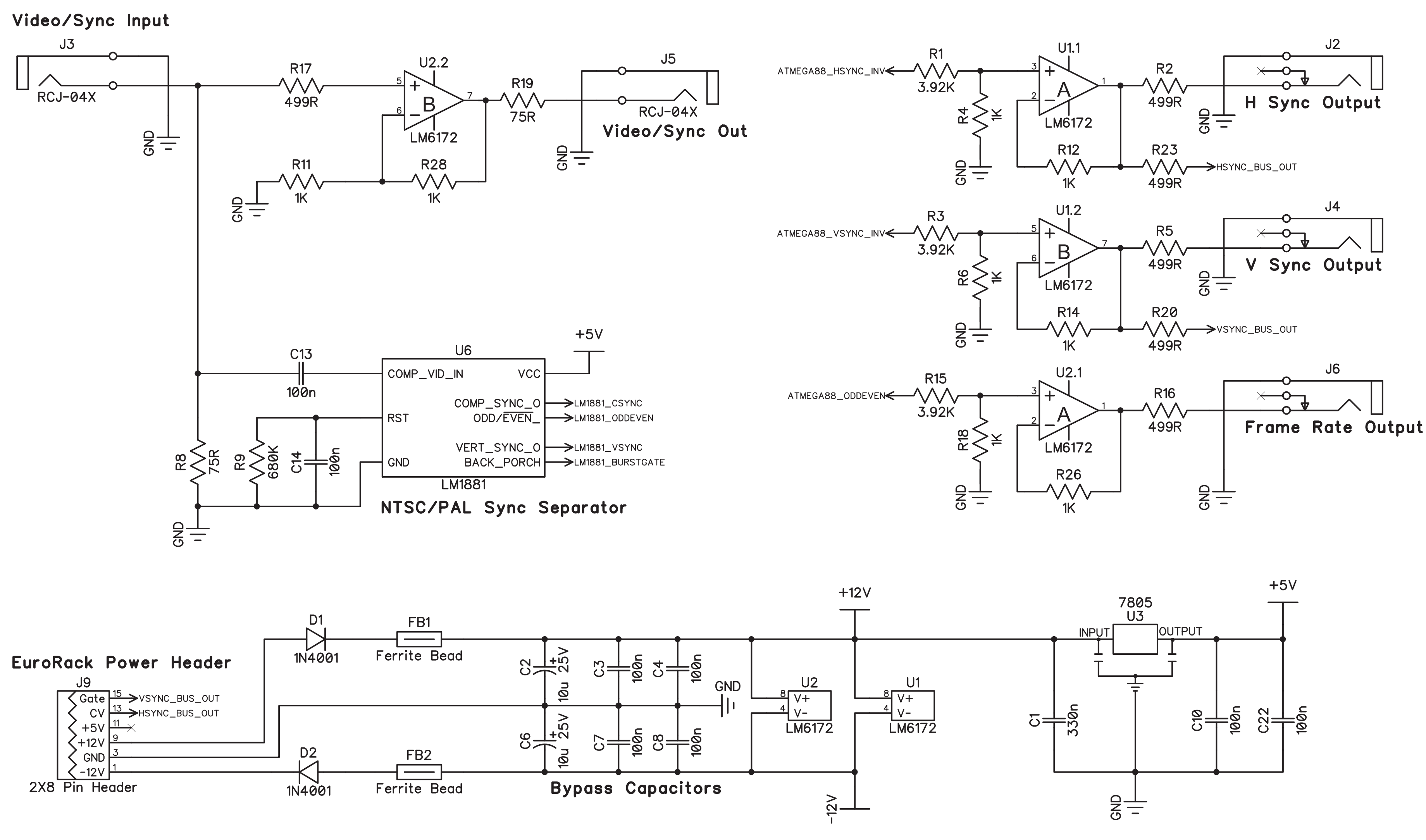
- Cadet DIY kits are intended for intermediate level builders. If this is your first DIY electronics kit, or the amount of assembly information provided is inadequate, you may need to seek instructional material outside of the context of this owner's manual.
- We recommend mounting and installing components in the order they appear in the Bill of Materials.
- If you can't find the 10TF230 PCB mounted toggle switch or find it too expensive, any miniature toggle with a 1/4 inch bushing will work. Just use hookup wire or resistor clippings to the switch to the PCB pads. We recommend you mount the switch to the frontpanel before doing this.
- If you don't want to purchase an assembled Video Sync Distribution bus cable from LZX Industries, you can make your own configuration using 2X7 IDC Connectors and 14-pin ribbon cable.
- We recommend securely attaching frontpanel mounted components to the frontpanel before soldering them to the PCB, if it can be managed. Keep the screws for the M1 mounting bracket slightly loose until the assembly is finalized.
- The surface mount VC Crystal Oscillator (X1) should come assembled with your PCB from LZX Industries. At the time of this writing, this is a hard part to source and we have a limited quantity available. If you didn't get your board with this part preassembled from us, the last source we used was DigiKey.
- We are assuming you purchased a pre-programmed ATMEGA88A microprocessor from us, with the C1 firmware already installed. If you didn't, you can easily install the firmware yourself via the 2X3 pin ISP header (J10) using an AVR programmer such as AVRISP-MKII and the Atmel Studio software available from Atmel. The firmware (ELF file) may be downloaded via our website.

COMPONENT PLACEMENT DIAGRAM

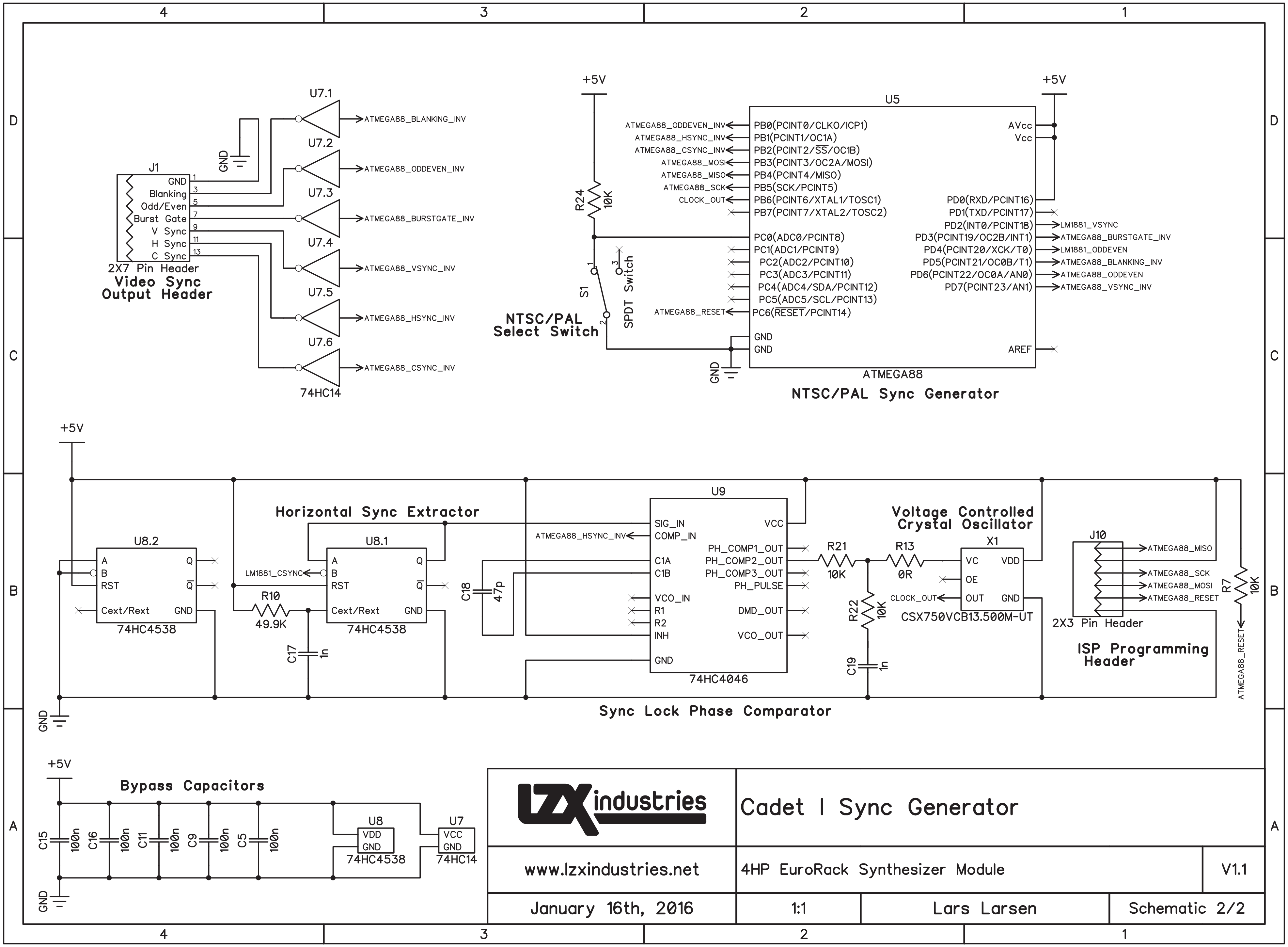


BILL OF MATERIALS

Qty	Description	Value / Partname	Reference Designators
2	1% Metal Film Resistor	75R	R8, R19
6	1% Metal Film Resistor	499R	R2, R5, R16, R17, R20, R23
8	1% Metal Film Resistor	1K	R4, R6, R11, R12, R14, R18, R26, R28
3	1% Metal Film Resistor	3.92K	R1, R3, R15
4	1% Metal Film Resistor	10K	R7, R21, R22, R24
1	1% Metal Film Resistor	49.9K	R10
1	1% Metal Film Resistor	680K	R9
1	Ceramic Capacitor	47p	C18
2	Ceramic Capacitor	1000p	C17, C19
13	Ceramic Capacitor	100n	C3, C4, C5, C7, C8, C9, C10, C11, C13, C14, C15, C16, C22
1	Ceramic Capacitor	330n	C1
2	Electrolytic Capacitor	10u	C5, C6
1	Bare Wire Jumper	-	R13
2	Diode	1N4001	D1, D2
2	Ferrite Bead	-	FB1, FB2
2	IC, High Speed Op Amp	LM6172	U1, U2
1	IC, 5V Regulator	7805	U3
1	IC, Microprocessor	ATMEGA88A	U5
1	IC, Video Sync Separator	LM1881	U6
1	IC, Hex Inverter	74HC14	U7
1	IC, Dual Monostable	74HC4538	U8
1	IC, Phase-Locked Loop	74HC4046	U9
1	IC, Surface Mount Crystal	CSX750VCB13.500M-UT	X1
1	0.1” Shrouded Pin Header	2X8	J9
1	0.1” Shrouded Pin Header	2X7	J1
1	0.1” Pin Header	2X3	J10
3	3.5mm Right Angle Jack w/Nut	PJ302M	J2, J4, J6
2	RCA Right Angle Jack	RCJ-044	J3, J5
1	SPDT Mini Toggle Switch	10TF230	S1
1	Right Angle Mounting Bracket	Keystone 621	M1
2	Pan Head Philips Screw	#4-40, ¼ inch	M1A/M1B



LZX industries	Cadet I Sync Generator		
www.lzxindustries.net	4HP EuroRack Synthesizer Module		V1.1
January 16th, 2016	1:1	Lars Larsen	Schematic 1/2



Video Sync Output Header
2X7 Pin Header
J1
GND
Blanking
Odd/Even
Burst Gate
V Sync
H Sync
C Sync
U7.1
U7.2
U7.3
U7.4
U7.5
U7.6
74HC14
ATMEGA88_BLANKING_INV
ATMEGA88_ODDEVEN_INV
ATMEGA88_BURSTGATE_INV
ATMEGA88_VSYNC_INV
ATMEGA88_HSYNC_INV
ATMEGA88_CSYNC_INV
NTSC/PAL Select Switch
S1
SPDT Switch
R24
10K
+5V
GND
NTSC/PAL Sync Generator
U5
ATMEGA88
PB0(PCINT0/CLKO/ICP1)
PB1(PCINT1/OC1A)
PB2(PCINT2/SS/OC1B)
PB3(PCINT3/OC2A/MOSI)
PB4(PCINT4/MISO)
PB5(SCK/PCINT5)
PB6(PCINT6/XTAL1/TOSC1)
PB7(PCINT7/XTAL2/TOSC2)
PC0(ADC0/PCINT8)
PC1(ADC1/PCINT9)
PC2(ADC2/PCINT10)
PC3(ADC3/PCINT11)
PC4(ADC4/SDA/PCINT12)
PC5(ADC5/SCL/PCINT13)
PC6(RESET/PCINT14)
AVcc
Vcc
AREF
PD0(RXD/PCINT16)
PD1(TXD/PCINT17)
PD2(INT0/PCINT18)
PD3(PCINT19/OC2B/INT1)
PD4(PCINT20/XCK/T0)
PD5(PCINT21/OC0B/T1)
PD6(PCINT22/OC0A/AN0)
PD7(PCINT23/AN1)
ATMEGA88_ODDEVEN_INV
ATMEGA88_HSYNC_INV
ATMEGA88_CSYNC_INV
ATMEGA88_MOSI
ATMEGA88_MISO
ATMEGA88_SCK
CLOCK_OUT
ATMEGA88_RESET
LM1881_VSYNC
ATMEGA88_BURSTGATE_INV
LM1881_ODDEVEN
ATMEGA88_BLANKING_INV
ATMEGA88_ODDEVEN
ATMEGA88_VSYNC_INV
Horizontal Sync Extractor
U8.2
U8.1
74HC4538
A
B
RST
Cext/Rext
Q
GND
LM1881_CSYNC
R10
49.9K
C17
1n
C18
47p
Sync Lock Phase Comparator
U9
74HC4046
SIG_IN
COMP_IN
C1A
C1B
VCO_IN
R1
R2
INH
VCC
PH_COMP1_OUT
PH_COMP2_OUT
PH_COMP3_OUT
PH_PULSE
DMD_OUT
VCO_OUT
ATMEGA88_HSYNC_INV
R21
10K
R13
0R
R22
10K
C19
1n
Voltage Controlled Crystal Oscillator
X1
VC
OE
OUT
VDD
CSX750VCB13.500M-UT
CLOCK_OUT
J10
2X3 Pin Header
ISP Programming Header
ATMEGA88_MISO
ATMEGA88_SCK
ATMEGA88_MOSI
ATMEGA88_RESET
R7
10K
Bypass Capacitors
C15 100n
C16 100n
C11 100n
C9 100n
C5 100n
U8
VDD
74HC4538
U7
74HC14
LZX industries
Cadet I Sync Generator
www.lzxindustries.net
4HP EuroRack Synthesizer Module
V1.1
January 16th, 2016
1:1
Lars Larsen
Schematic 2/2

CIRCUIT DESIGN NOTES

The sync generator is the heartbeat of an analog video system. In the time the average human's heart has beat once, the video system has displayed an image nearly thirty times. In each video image there are hundreds of scanlines. In each sweep of the cathode ray across the television display, there are hundreds of discernable shifts in color and brightness. Video is fast! So fast all you see is the streak left behind as it sprints. Analog video must keep moving, never missing a step, even when the images between your heartbeats appear motionless. Orchestrating this race of perfect visual rhythm is the function of your sync generator.

When we decided to build a video synthesizer, the sync generator was the first obstacle in our paths. There were no easy solutions, since most of the ICs in use as standalone video sync generators were long since out of production. We endeavored to find a solution which would not rely on any obsolete specialty ICs, and decided instead to use the ATMega88, a low-cost 8-bit microcontroller. We clocked the microcontroller with a 13.5MHz crystal resonator, a common clock speed for video systems, as it divides nicely down into intervals consistent with both NTSC and PAL timings. With my design partner's skill in Assembly programming and experience with Atmel microcontrollers, we soon had a working video sync generator.

Cadet I Sync Generator is a direct adaptation of our early work, and you can find the ATMega88 as U5 in the schematic diagram. The U7 hex inverter buffers 5V sync outputs to a 14-pin distribution header for transmission to other modules in the video system. U1 and U2.1 buffer attenuated signals from the microcontroller to drive the Horizontal Sync Pulse, Vertical Sync Pulse, and Frame Clock output jacks on the frontpanel. Video sync is usually an active low signal, which is the inverse of what most synthesizer modules respond to, so the frontpanel outputs are inversions of broadcast standard HSync and VSync signals.

Understanding synchronization between two video systems requires another metaphor, that of two runners on a track, one of whom must match stride in perfect timing with the other. Your sync generator is running perfectly in time with itself, when a newcomer appears. The newcomer might be a video camera, or a DVD player, or even another video synthesizer. The two are running at roughly the same speed, but not yet in perfect sync with each other's gait. Your sync generator observes the newcomer, perceptive and determined, making adjustments until its timing locks in perfect phase. Both devices now begin display of a video frame simultaneously, and each scanline also begins in tandem. This ability to synchronize with the timing of an external video device is known as genlock. It is what allows you to mix the output of your video synthesizer's oscillators and patterns with external sources. Genlock is essential for a modular video system, as a studio of devices with genlock can all run the same race together.

This external synchronization feature was the next obstacle to conquer in our circuit. It was essential if we wanted to process external video sources in our fledgling video synthesizer. The LM1881 Video Sync Separator (U6) is a specialty IC designed to extract the synchronization pulses from any NTSC/PAL standard video signal. The external video signal at J3 connects to U6, giving us several video sync outputs which we send to our ATMega88 as inputs. This allows our sync generator to perform some tasks in time with the external source, such as reset the field with Vertical Sync and start a new frame in time with the Odd/Even gate. Matching the gait of the horizontal scanline requires more delicate control through locking the frequency of the 13.5MHz crystal oscillator (X1) with the phase of the external signal's Horizontal Sync.

First, we need the external signal's Horizontal Sync pulse, and LM1881 only offers us Composite Sync (a combination of horizontal and vertical syncs.) This is the function of the 74HC4538 monostable (multivibrator), U8, which takes the Composite Sync pulse and extracts only the horizontal information from it. Now that we have the Horizontal Sync pulse from the external signal, and the Horizontal Sync pulse we are generating internally, we can compare the phase of the two using the phase comparator function of the 74HC4046 phase-locked loop IC (U9.) Our goal is to control the frequency of the crystal so that the rising edges of both the external signal and the internal one occur simultaneously. When the external signal's rising edge occurs after our internal signal's rising edge, the output of U9 goes high, causing our crystal's frequency to increase ever so slightly. When the opposite occurs, the output of U9 goes low, causing our crystal to slow down. When the phases match, the output floats -- causing no change in frequency. R21, R22 and C19 form a low pass filter so that these changes do not occur abruptly. Within milliseconds of observing the new runner, your sync generator's shoes are hitting the track at the exact same nanosecond.

U2.2 is used to buffer the external video signal so it may be passed on to other destinations. You might send the external video signal to the input of C3 next, so it may be prepared for image processing through the rest of your system through DC restoration and scaling.

There is much more to learn about video formats, timing, and the function of the various video synchronization pulse outputs. We haven't even touched on the color subcarrier -- something an LZX video synthesizer system typically generates only on output. I'll leave that up to the many good texts on video engineering. But now you have something most of those texts don't offer: a simple, practical example of how to generate NTSC/PAL sync and maintain genlock to an external source with commonly available ICs and at low cost.

We hope C1 will become the heartbeat of your own video device someday.

CREATIVE COMMONS LICENSE

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Read the full license and more at creativecommons.org.

MANUFACTURER'S WARRANTY

Fully assembled versions of this product are covered by our manufacturer warranty for one year following the date of manufacture. This warranty covers any defect in the manufacturing of this product., such as assembly errors or faulty components. This warranty does not cover any damage or malfunction caused by incorrect use – such as, but not limited to, power cables connected backwards, excessive voltage levels, or exposure to extreme temperature or moisture levels. The warranty covers replacement or repair, as decided by the manufacturer. Please contact customer service via our website at www.lzxindustries.net for instructions on returning the product. The cost of returning a product for repair or replacement is paid for by the customer.

DIY kits and bare printed circuit boards are not covered under any warranty and come with no guarantee of assembly troubleshooting or customer support. However, we are nice and will help you when possible. Please contact us if you have questions about or problems with your build.